Web-based Visualisation Techniques for Reporting Zoonotic Outbreaks

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Abstract

Zoonotic diseases are diseases that are transmitted from animals or vectors to humans and vice versa. The public together with veterinarian authorities should readily access disease information as it is vital in rapidly controlling resultant zoonotic outbreak threats through improved awareness. Currently, the reporting of disease information in South Africa is predominantly limited to traditional methods of Information Communication Technologies (ICTs) like faxes, monthly newspaper reports, radios, phones and televisions. Although these are effective ways of communication, their disadvantage is that the information that most of them offer can only be accessed at specific times during a crisis. New technologies like the internet have become the most efficient way of distributing information in near-real-time. Many developed countries have used web-based reporting platforms to deliver timely information through temporal and geographic visualisation techniques. There has been an attempt in the use of web-based reporting in South Africa but most of these sites are characterised by heavy text which makes them time consuming to use or maintain. As a result most sites have not been updated or have ceased to exist because of the work load involved. The success of web reporting mechanisms in developed countries offers evidence that web-based reporting systems when appropriately visualised can improve the easy understanding of information and efficiency in the analysis of that data. In this thesis, a web-based reporting prototype was proposed after gathering information from different sources: literature related to disease reporting and the visualisation of infectious diseases; the exploration of the currently deployed web systems; and the investigation of user requirements from relevant parties. The proposed prototype system was then developed using Adobe Flash tools, Java and MySQL languages. A focus group then reviewed the developed system to ascertain that the relevant requirements had been incorporated and to obtain additional ideas about the system. This led to the proposal of a new prototype system that can be used by the authorities concerned as a plan to develop a fully functional disease reporting system for South Africa.

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Glossary of Abbreviations

2D	2 Dimensional
3D	3 Dimensional
ASP	Active Server Pages
DSN	Database Source Name
GIS	Geographical Information Systems
GLEWS	Global Early Warning and Response System
FAO	Food and Agriculture Organisation
ICT	Information Communication Technology
IIS	Information Internet Services
IOE	Office International des Epizooties
MS	Microsoft
NAHIS	National Animal Health information System
ODBC	Open Database Connections
OECD	Organisation for Economic Co-operation and Development
PAHO	Pan American Health Organisation
SARS	Severe Acute Respiratory Syndrome
USAID	United States Agency for International Development
USGS	United States Geological Survey
WHO	World Health Organisation
XML	Extensible Mark-up Language

1 Introduction

1.1 Introduction

Zoonoses are diseases that can be transmitted from animals and vectors (living organisms that carry a disease-causing organism to new hosts) to humans or vice versa (Figure 1.1) [49]. They are caused by infectious agents like bacteria, viruses and fungi. Examples of zoonoses include avian influenza, rabies, anthrax and foot and mouth disease. One of the ways in which zoonoses are transmitted is when a person comes into direct contact with secretions or excretions such as saliva or faeces from an infected agent [49]. Alternatively they may be transmitted through contact with water or food that has been contaminated by an infected agent. Since interaction between animals and humans is unavoidable, humans are continually at risk of being infected by zoonotic diseases [73]. It has been estimated that “approximately 75% of recently emerging infectious diseases are diseases of animal origin and approximately 60% of all human pathogens are found to be zoonotic in nature” [78]. The main concern with the high numbers of zoonotic diseases is due to the negative effects that resultant zoonotic outbreaks bring about. For example, the loss of livestock especially for subsistence farmers can leave individuals poverty-stricken and in extreme cases it can affect the economy of a country because of the significant decline in the exportation of the nation’s livestock.

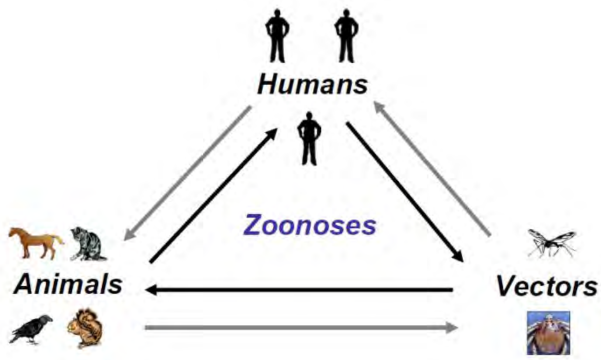


Figure 1.1 Cross species transmission of zoonoses [7].

Due to the high prevalence of zoonotic disease outbreaks, they are problematic for the following reasons [17]:

- They are very expensive to treat especially in developing countries with poor resources and great dependence on livestock for a living.
- Many of these diseases have the potential to spread through various means over long distances thereby becoming global problems.

- They are very difficult to eliminate or manage especially when the diseases are continually being transmitted.
- They are known to cause disastrous outbreaks that affect millions of people and cause large numbers of deaths every year.
- They cause fear amongst the public especially during large outbreaks and people do not have information about how to prevent themselves from being infected.
- Worldwide, zoonotic diseases are known to have a negative impact on commerce, travel, and economies.
- In times of large outbreaks, zoonotic diseases are of particular concern for high-risk groups, such as, elderly people, pregnant women and children.
- The risk of zoonotic infection is expected to continue to increase.

As a result, the need for knowledge about the spread of any zoonotic disease from onset is necessary in preventing and controlling the negative effects of zoonoses on the public [28]. The rapid identification of infectious disease outbreaks is critical for alerting first government agencies, and then the general public in order to carry out preventative health measures expeditiously [28]. However, rapidly identifying these diseases has proved to be a major challenge for the public veterinary health sector especially when the public is unaware of circulating diseases since these diseases are not easily detected [7]. During outbreaks, readily available information can provide knowledge to improve the rapid identification of zoonoses [45]. Knowledge only comes as a result of processed data which is then efficiently and effectively distributed to its users as information.

Information is thus vital in dealing with infectious disease outbreaks. Data needs to be collected, scrutinised, shared and visualised for it to be functional [5]. Various measures such as proper data management and use of efficient tools in manipulating data can be a good start in ensuring that data is processed, made available promptly and delivered efficiently to its users. This highlights the need for surveillance measures that can be implemented in obtaining and processing data for use by concerned parties like veterinarians, farmers and the general public [57].

Ivanov and Blue [44] have stated that health surveillance is the "Ongoing systematic collection, analysis, and interpretation of outcome specific data, which are closely integrated with the timely dissemination of these data to those responsible for health policies and interventions". Disease surveillance is specifically for monitoring the occurrence and spread of diseases. It comprises eight critical factors that are essential in promoting good disease surveillance systems. Because each of the factors is a broad subject of surveillance, this research focuses on only two of these critical factors, namely, web-based disease reporting pathways and information visualisation [7]. Surveillance is of little use if the data obtained is not acted upon, hence the need for processing the acquired data into useful information. In order to achieve the best surveillance results, new technologies like internet use are being adopted to hasten the distribution of the processed information to the relevant parties [80].

1.2 Motivation

As already stated zoonoses are diseases that spread rapidly since they are infectious. The fact that they have no boundaries and can be transmitted around the world easily, and that they affect not only animals but humans too makes them important diseases to control at all times. There is no possibility of separating humans to animals hence mechanisms have to be placed to ensure health living primarily for humans. Literature also shows that these diseases are less emphasized in developing countries and as a result should a huge outbreak occur it could lead to a national disaster. Historically, zoonotic disease outbreaks have been known to affect the economy severely and result in the death of millions of people. This expresses the importance of exploring specifically zoonotic diseases.

Through other projects conducted with veterinarian personnel, one of the key points that arose was the need for better communication mediums for delivering detailed information rapidly. Due to this, the project seeks the use of modern technologies in rapidly delivering information to the relevant entities especially in crisis times. To ascertain this, the swine flu outbreak that reached SA in the beginning of 2009, even though it did not raise alarm, it brought about the need for preparedness should there be cases of fatal outbreaks. Because of this, an opportunity to improve the communication and information delivery mechanisms in the veterinary field arose.

When looking at the current web systems that deliver zoonotic information, the common characteristic on all of them is the use of a lot of text and the absence of modern visualisations like interactive maps. And because of this, this project seeks to find reasons for this trend and also promote the application of visualisations on South African websites that deliver disease information. Since they are hardly used, visualisations are therefore studied extensively to ensure that their use is supported for quick adoption when the developed prototype system is suggested. Various systems have been created for the purpose of combating zoonotic disease outbreaks, e.g. a visualisation based criminality outbreak was used for successfully dealing with a bird flu outbreak. Due to this, the application of visualisation to improve the magnitude of disasters brought by disease outbreaks is apparent and this project seeks to improve the delivery systems of South Africa through the use of efficient visualisations.

To begin this project, the current disease reporting systems of South Africa were observed to identify problematic areas in the various ways of reporting zoonotic disease information. The findings obtained after observing the web-based reporting systems of South Africa, indicated that modern visualisation techniques are not being used optimally when representing zoonotic disease surveillance data especially on the web [39]. Currently the disease information that is available to the public is from a large database with over 20 000 records which only provides query facilities with resultant reports in table form. In addition the veterinarians only have access to static maps that cannot be manipulated. This makes it difficult to compare, analyse and observe data easily. There is a need for reporting disease information during outbreaks and in order for the concerned parties to access, manipulate and understand that information easily, it should be visualised properly.

Substantial under-reporting of suspected disease cases and the time interval between suspected and confirmed diseases seem to be two of the major challenges faced during outbreaks [102]. The cases reported by the public together with the laboratory-confirmed cases are known to be highly effective ways of complementing official reporting systems [79]. The disease status information is very important largely because laboratory-confirmed cases are usually an understatement of the actual number of disease cases in the area where they are discovered [79]. This explains why reporting of disease cases is essential especially in identifying the root and extent of the disease before it spreads widely in order to contain the outbreak.

The internet has become a common medium for presenting and distributing information to the public [35, 85]. Several countries have websites for reporting disease outbreaks on the internet [69, 107]. Various forms of web-based data streams are being used to supply near real-time information about infectious disease outbreaks [34, 106]. Web-based sources of information are thought to detect disease outbreaks early and cost effectively [14, 106]. They are also known to provide high reporting transparency which is vital for distributing important facts that are essential in protecting communities [106]. Despite the existence of secure and effective tools for dealing with zoonoses during outbreaks, many individuals in countries like South Africa still lack access to preventive information or disease status reports.

For reported information to be beneficial to the parties concerned the information should be expressed through appropriate visualisations, be effectively organised and it should answer precisely what the user wants to know [11, 71, 76]. The data displayed by the visualisations is mainly targeted at veterinarians and the public (citizens or patients). When a veterinarian or user wants to know about the diseases that are in the areas where they live they can easily search the system and view the information displayed by the visualisations. Due to the fact that the entities involved have various needs, one system cannot totally meet the needs for all of the entities. Therefore the visualisation can be created to allow restriction considerations through credentials that mask certain information such that it is only available to a specific group. The analysis later conducted in this projects build a guide that leads to the favourable decisions on who can access different types of information and how that information should be delivered for use.

When graphically represented, the infectious disease information can be analysed more effectively to deal with immediate problems [85, 95]. Spatial visualisation techniques like maps have been used extensively in tracking infectious diseases. The way in which maps are used for visualising spatial data has improved since maps have become digitised and so can easily be manipulated. Spatial visualisation techniques are known to be an essential tool in visualising infectious disease areas because of their ability to depict spatial relations and identify disease flows [85].

South Africa is not fully exploring recent reporting mechanisms in its distribution of information during disease outbreaks [39]. Reporting is clearly an important aspect of disease surveillance because it gives knowledge to those who need it [96]. It promotes transparency and the prompt availability of information that can be useful during outbreaks. The reporting of information has originally been recorded on paper, however nowadays, reporting systems have been developed and improved to digitised forms due to the rise in computer usage [96]. The current system in South Africa provides tabular data that was adequate previously but is now avoided because it is difficult to search through the many rows and columns of information [39]. A system that highlights the important information that one can view easily at a glance would remove these challenges. Questions arise about how one can continue to improve the current disease reporting systems especially in developing countries that have limited resources for incorporating new technologies. Hence, the purpose of this project focuses on two points that are critical for successful disease surveillance, (a) web-based disease information reporting and (b) appropriate visualisation of the information to be reported.

1.3 Problem Statement

The aim of this project is to investigate web-based systems that report zoonotic disease information during outbreaks and to find the appropriate visualisation techniques that can effectively present the spatial and temporal characteristics of disease information in South Africa. In order to achieve this, five sub-problems are identified:

1. Determine what the literature states about disease reporting and disease information visualisation especially on the web. This includes finding the information that is considered important to report during outbreaks and determine the visualisation techniques that could be suitable in representing that data.
2. Observe the visualisation techniques used in currently deployed websites. This is to verify if the appropriate visualisation techniques that best represent the spatial and temporal characteristics of disease surveillance data are being used. This also leads to determining if the observed websites match up to the requirements and characteristics of successful web-based disease reporting systems.
3. Discover what veterinarians want to view when using web-based systems to acquire information during disease outbreaks. This assists in ensuring that developed systems meet the user requirements as opposed to developing systems based on assumptions made about what needs to be viewed.
4. Determine how the gathered requirements of disease reporting systems can be integrated to build a system that incorporates each of them. This provides information for the proposal and development of a prototype system that can report zoonotic disease information.

5. Determine if the developed system meets the needs of its users and discover more favourable features that the system should include.

1.4 Scope

Although there are many infectious diseases that can affect humans, this research is limited to reporting zoonotic diseases since they are considered to be the highly infectious diseases between animals and humans. This research concentrates on zoonoses because of the continuous growth of human and livestock populations thereby increasing the risk of close contact between humans and animals [66]. Transportation mediums have also advanced such that it is now possible to travel around the world in less than the incubation period of most infectious zoonotic agents; hence the diseases can spread rapidly and so need to be controlled [66].

Even though the provinces of South Africa all face the disease reporting problem, due to proximity limitations, the performance analysis of this project is conducted from one province of South Africa, the Eastern Cape and so only veterinarians that work in that area are used. However, the assumption is that the findings of this project can constitute a beginning in extending development to other provinces of South Africa. This project does not consider different development environments that can be used when developing the proposed system. It therefore does not seek to determine the latest or best programming languages and visualisation software tools to create the proposed system. This means that the visualisation software tool used is selected because of its ability to effectively render the requirements of the proposed system. This project builds a web-based prototype system but is not responsible for designing a website to deploy the developed system. This project only evaluates the use of the created prototype by the veterinarians; however, the public and other health practitioners are considerable for future evaluation work to help strengthen the outcome results.

1.5 Methodology

The first step involves briefly studying and understanding what veterinary informatics is and how it developed from medical informatics. This includes understanding why medical informatics is a more developed field and determining how veterinary informatics can draw from advances in medical informatics. Subsequently, veterinary service delivery is discussed and the tools that can be used to improve the delivery of veterinary services are identified. Disease surveillance is studied extensively and the critical success factors of disease surveillance systems are determined. From the critical factors, the reporting pathways and visualisation of information in disease surveillance are investigated further. The various visualisation techniques used in the delivery of information that is related to the spread of zoonotic disease outbreaks are explored. This provides insight into what is expected and identifies what to include before embarking on the system development.

Subsequently, the existing websites are evaluated to observe what is currently being done. This includes discovering the current visualisation techniques used for the effective visualisation of information. The information about these websites will then be compared and contrasted to gain more insight on how surveillance data is rendered.

Another essential task is to obtain user requirements from veterinarian authorities that can relate to the South African veterinary service needs especially for preventing outbreaks. In order to achieve this, the participatory design approach is chosen. This approach attempts to involve stakeholders that can yield important information for drawing effective conclusions. The stakeholders participate during the initial exploration and problem definition both to help define the problem from their own perspective and to focus ideas for solution, and during development, they help evaluate proposed solutions. User requirements analysis will help identify more about people's needs to help find ways to support them in the system. This is important in the development of a system that can improve the reporting of disease information by ensuring that the project's solutions meet the demands and needs of its potential users extensively.

From the information gathered, a prototype system that suits the South African needs will be proposed and implemented. This prototype will then be evaluated by a mini focus group (further illustrating the use of the chosen participatory design approach) to obtain views on how the system can be improved. After the evaluation, the prototype system is re-evaluated to propose a better prototype that can then be declared as a possible functional system for reporting zoonotic diseases.

1.6 Thesis Organisation

Chapter 1 introduces the research and identifies those key points that led to the research topic. It provides a summary of what is expected and the steps that need to be followed in obtaining the results. This chapter elaborates more on why it was considered necessary to do the project. It also gives an outline of how the project was conducted.

Chapter 2 provides an overview of the literature related to the research topic. It explains more on each of the topics that need to be studied for the benefit of this research. This involves the sub topics like veterinary informatics, surveillance, ICTs, reporting of diseases with the main focus being on web-based disease reporting mechanisms. This chapter focuses on web-based reporting pathways and introduces visualisation which is then discussed in detail in the next chapter.

Chapter 3 consists of background information that primarily focuses on visualisation and the techniques used in visualising health related data on web-based platforms. It highlights the important points to be followed in developing systems that use graphics in explaining data. This chapter also discusses the importance of choosing the right technique in visualising health data especially for outbreak information purposes. The chapter explores temporal and spatial visualisation in detail since some of the characteristics of disease data include spatial and time matters.

Chapter 4 provides detail on the websites that are found for the purpose of providing information about diseases like zoonoses especially during outbreaks. It explores all the finer details of each website and gives a conclusion on which visualisation technique is commonly used and why some systems are successful whilst others are not.

Chapter 5 considers the user requirements and gives a summary of what users want to view from a disease reporting system. The chapter also obtains user preferences on how disease surveillance information could be represented. These requirements are then compared and contrasted with what the literature says about the needs of users when creating disease reporting systems.

Chapter 6 integrates the points obtained from chapters 2, 3, 4 and 5 and proposes a prototype system that incorporates those points. It elaborates more on how the proposed system is built. It also involves an extensive description of Flash as a software development tool for the proposed system.

An evaluation of the developed prototype is given in Chapter 7. The prototype system is analysed by a mini focus group to draw conclusions on the prototype's positive and negative points. Any possible changes to the developed prototype are also discussed here. Finally a better prototype is proposed.

Lastly Chapter 8 discusses the final result of the project research, states limitations and draws final conclusions about the research. It also provides a discussion on possible research extensions from this research.

2 Related Work

2.1 Introduction

The way in which health information is being dealt with has evolved with time because of the evolution of ICTs [8]. The health industry involves large amounts of information which changes regularly. Because of this, efficient ways of manipulating information have to be pursued to help manage the information. Informatics is the study of how people transform technology, and how technology transforms people [79]. Within health, information technology has been incorporated into the health disciplines to help manage the increasing amounts of information more efficiently.

Veterinary services assist in the control of zoonotic diseases in order to ensure a healthy environment. One example of a veterinary service is the task of providing the public with information about diseases and how one can follow precautionary measures during outbreaks [2]. This information can only result from surveillance activities that include monitoring the occurrence of new and existing diseases. After the data has been obtained, it is processed and distributed to the public for use in ways that can easily be understood. The speed with which disease-related information is distributed is crucial because disease information is time-limited. Time is critical since zoonotic diseases are highly infectious and can spread rapidly if not controlled in time. Because of this, methods of distributing information rapidly are identified and adopted to improve the delivery of veterinary services. These methods include the use of computer based systems which are classified as modern technologies that are used in disseminating information rapidly.

2.2 Veterinary Informatics

Veterinary informatics is a discipline that developed from medical informatics since both fields are concerned with health. According to Murphy A. Frederick, medical informatics is defined as “the organisation, processing, retrieval, and communication of information in medical practice, education, research and the science and technology needed to support those tasks” [37, 74]. Veterinary informatics is a similar discipline that focuses on combining veterinary data with information technology [4]. The incorporation of informatics into the veterinary discipline is to offer efficient workflow of information. Investments that are directed to support information systems in health care have been increasing over the past years [82]. New information system technologies that facilitate the efficient workflow of information are continually evolving and hence the need for regular evaluation and updating of veterinary information systems [4].

Information technology transforms data into valuable information that can contribute to disease knowledge needed in problem solving and decision making [26]. Many medical informatics concepts and techniques have been incorporated into all aspects of veterinary informatics [86]. This is because medical health has improved over the years due to the incorporation of informatics into the field [86]. This is seen from medical health websites that promote the distribution of information about diseases so that people can be aware of the health status. The health systems are connected to large databases that can be queried by users. However even though information technology has been accepted in the medical field it is still struggling to be accepted into the veterinary field. The veterinary fields can adopt the same structure of having databases that can be queried by users to obtain information around infectious diseases especially during outbreaks. Literature research indicates that strategies for incorporating information technologies have only partially succeeded because of limited resources [13]. Many countries lack fundamental strategies that can help incorporate health and veterinary informatics to assist in the handling of information for use in times of disease outbreaks [18].

2.3 Veterinary Service Delivery

One of the key roles of veterinarians is to work with governments to provide the public with veterinary services [2]. The information used and distributed in the veterinary practice forms part of the veterinary services that the government delivers to the public [25]. Veterinary service delivery is the study of how disease information or services are distributed to users. The national government's primary animal health emergency response organization is concerned with the delivery of veterinary services to the public [56]. The duties included in veterinary services are investigating suspected cases of animal diseases, as well as ensuring national emergency preparedness and management [103].

Figure 2.1 shows the different fields that veterinary services promote and alleviate. Veterinary services are mainly to promote first human health and then animal health [30]. Because many people depend on livestock for a living in most developing countries, veterinary services support the alleviation of poverty through reduced animal losses [101].

Livestock plays an important role as a source of income for poor people because a large number of livestock keepers are not fully market oriented but are subsistence farmers, therefore the elimination of many of these animals can leave households at a disadvantage [32]. Veterinary services also ensure that animal products are safe to consume since during disease outbreaks affected animals are slaughtered and declared unfit for human consumption. Most developing countries depend on animal trade for boosting their economic resources therefore the death of livestock is a hindrance in maintaining the import and export exchanges amongst countries [104].

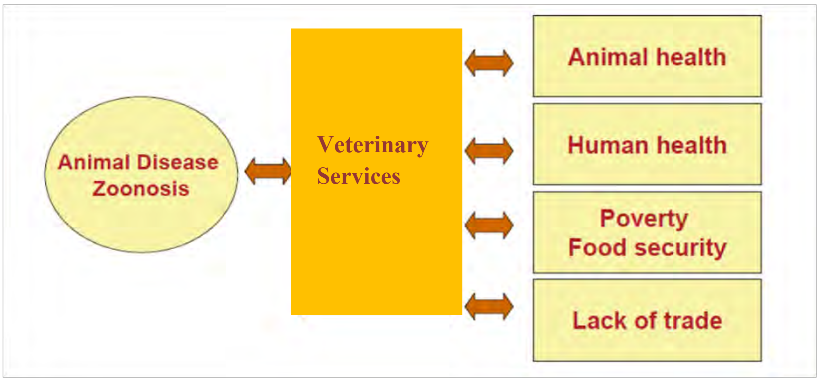


Figure 2.1 Veterinary service delivery [15].

Besides promoting the four factors in Figure 2.1, veterinary services also include the control of zoonotic diseases. The control of zoonotic diseases is directly linked to the services that the veterinary field is supplying. This means that if there is any decrease in animal or human health, it can lead to the emerging of zoonoses and if the zoonoses cannot be controlled, they lead to a decrease in the state of animal and human health thereby bringing poverty and reducing trade opportunities [15, 67]. The veterinary services act as a mediator in ensuring that zoonoses are kept at the minimum whilst human and animal health are maximised to alleviate poverty and improve both food security and animal trade. The following sub-sections describe the delivery of veterinary services in developing countries and elaborate on the veterinary services needed for controlling zoonotic diseases.

2.3.1 Delivery of Veterinary Services in Developing Countries

There has been resistance or reluctance in the incorporation of tools that support the effective delivery of health related services throughout the world, but increasingly so in developing countries [13]. This is because developing and developed countries have different economic and institutional frameworks in the animal industry [25]. These differences affect the way that veterinary services are delivered. For example, most developed countries have resources that promote technological innovations, whilst developing countries are vulnerable since they are struggling to adopt the new technologies [25]. The veterinary services of developing countries are therefore in urgent need of the necessary resources and capacities used to improve the disease information management. This will enable countries to provide greater protection for animal health, animal welfare and public health and reduce the risks linked to zoonoses.

The technological innovations required to improve veterinary services include improved mechanisms of manipulating information. The information has to be captured correctly and regularly updated to ensure that correct actions are taken at the right time, and that progress is monitored. In South Africa today, health information systems are increasingly becoming web-based [39]. Although this is greatly increasing South Africa's capacity to deliver health services, there are still some areas that are not functioning as they should especially in the veterinary field. Inefficient systems impede the effective management of health systems and can eventually pose a threat to the health of our nation due to lack of awareness. The main purpose of these systems include epidemiological surveillance, disease control, import controls, animal disease reporting systems, animal identification systems, traceability systems, animal movement control systems, communication of epidemiological information, inspection and certification [84]. All these points are to be incorporated into accessible systems that can easily be used.

2.3.2 Control of Zoonoses

Control measures are often implemented as a crisis response when the level of disease is considered unmanageable, e.g. when the number of confirmed disease cases reaches a certain threshold. The control of zoonoses requires combined action between the veterinary and the human health sectors, because zoonoses affect both people and animals [27]. The need to control zoonotic diseases arises because zoonoses are highly infectious, they cause outbreaks and have been increasing significantly over the years [104]. Zoonoses have no boundaries and because of this, the co-existence of highly prevalent animal diseases and the freedom to exchange animals across borders increases the global spread of zoonotic diseases that sometimes spreads unnoticed [81]. Humans and animals are carriers, it is therefore necessary to keep people informed about what is happening around them especially when they live in close proximity to animals.

There are a number of areas that have been discovered to be important when controlling zoonoses (Figure 2.2). One of the areas promotes an integrated veterinary and medical health information system to improve health, epidemiological searches and the use of new tools, availability of information and the surveillance and diagnosis of diseases.

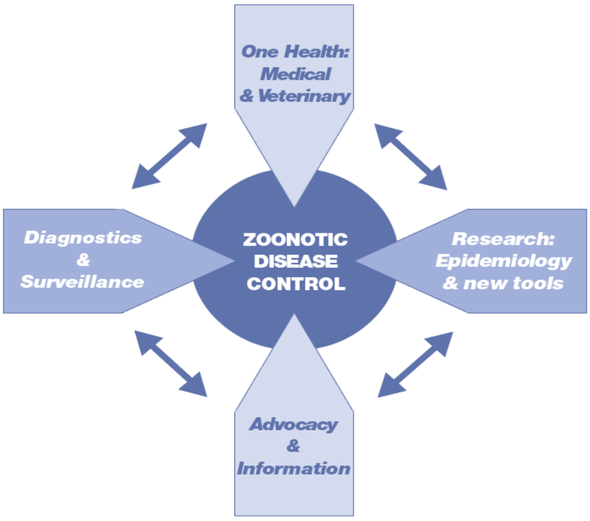


Figure 2.2 Important areas for controlling zoonotic diseases [38].

Because zoonoses affect both humans and animals, there should be an increase in the communication between the medical and veterinary fields. These two fields should work together since they both promote good health. Information that has been discussed is an important source of knowledge to users and it is crucial when dealing with zoonoses. Diagnosis is important because at the first sign of an existing disease, the magnitude of the problem should be identified through various laboratory tests. The numbers of diseases that are reported are only a small proportion of the actual number of infected animals that are not reported [70]. For example in African countries, for every death reported of a rabies infection ten more similar cases are never reported [5]. This emphasises the importance of reporting confirmed cases at an early stage. Surveillance is therefore significant because it helps to monitor emerging and re-emerging zoonotic diseases, thereby ensuring that cases are identified and reported in time [66]. Because the surveillance of diseases is complex and it is the first step in reducing the presence of zoonoses, it is an important aspect of eradicating zoonotic disease effects.

2.4 Surveillance Systems

Zoonoses are one of the problems that veterinary services are working to combat. This therefore means that by controlling their existence there could be less need for concern about human health, animal health, poverty and trade. This highlights the need for systems that support the early discovery and elimination of zoonotic diseases. The rapid identification of potential zoonotic disease outbreaks is however a problem for many health sectors [72]. This brings about the introduction of disease surveillance systems that help monitor diseases.

There are many types of surveillance systems, and a zoonotic disease surveillance system is one of them. Zoonotic disease surveillance is a system for monitoring infected animals that can transfer the disease to other animal species or to human beings. It involves all the activities that are needed to ensure that outbreaks are traceable when they occur. Various surveillance methods have been used to inform the public and health professionals about the presence or trends of a disease. The purpose of surveillance tools in the health sector is to identify infectious disease outbreaks that have the potential to cause high morbidity and mortality rates primarily in human beings [40, 99]. The need for better tools for monitoring disease trends is revealed through the reasons that have already been stated in the introduction of this thesis about why zoonoses remain problematic. Disease surveillance comprises factors that are critical for its success. The following subsection describes the critical success factors of infectious disease surveillance systems.

2.4.1 Critical Factors for Infectious Disease Surveillance Systems

Disease surveillance as already stated is used in monitoring emerging and re-emerging diseases. For surveillance systems to be successful, certain critical factors need to be considered so as to make good decisions during outbreaks (Figure 2.3) [7]. These factors are processes that are vital in the monitoring of diseases from the time they are reported to the time they are controlled or prevented. They also ensure that diseases are monitored efficiently to help minimise their existence. The two factors (6 and 7) that are shown in bold on Figure 2.3 are the subject matter of this thesis. As the Figure 2.3 illustrates, these two factors, which this research centres on, are not the only major problems in the delivery of disease information.

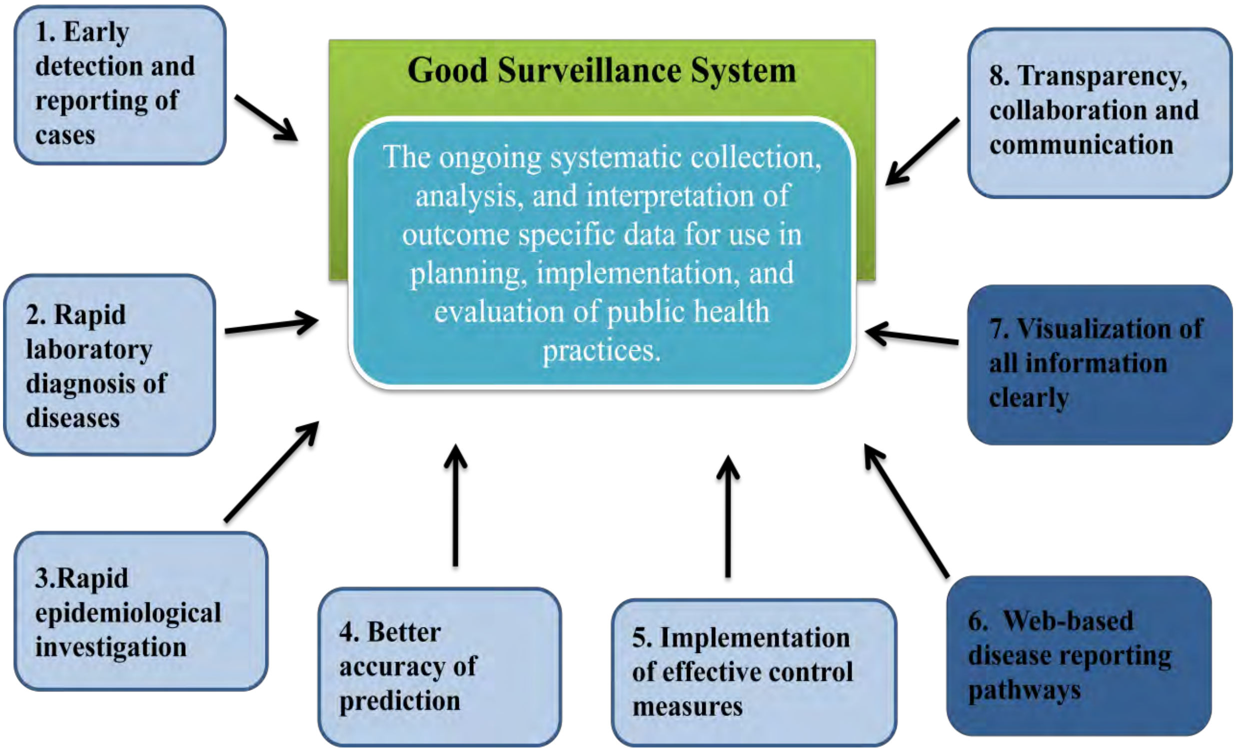


Figure 2.3 Critical success factors of disease surveillance systems (bold represents the subject matter of this thesis).

- **Early detection and reporting of cases**
  One of the critical tasks of surveillance systems is the strengthening of early warning systems through infectious disease case reporting [25]. Information on suspected cases can be useful as part of early warning systems [50]. As soon as a disease is suspected it must be reported so that rapid investigations can be made to confirm the disease. The success of protecting the public health depends on the prompt delivery of information about an existing disease. This is crucial in making decisions that can assist in preventing further spread.

- **Rapid laboratory diagnosis of diseases**
  Rapid confirmation of positive or negative results from samples taken to the labs for experiments is essential in speedily identifying the area of concern for the purpose of beginning preventative measures. Time is important when dealing with zoonoses. Timely prevention and control measures depend highly on laboratory diagnostics [70]. It is highly likely that when a disease is confirmed there are more unreported cases in the area where the sample was obtained. This means that swift procedures should be implemented to prevent further spread of disease in affected areas.

- **Rapid epidemiological investigation**
  Health information needs to be handled and kept for future use since epidemiological data is important especially in times of outbreaks. Epidemiology is the study of disease distribution in populations and it takes a historical perspective to the disease outbreaks [60]. One of the important goals of this task includes rapidly searching through a mass of data and observing the historical occurrences within a short space of time. This can be achieved through improved data mining and transmission techniques [4, 26]. During suspected or confirmed outbreaks it is important to have a background of how a similar disease has been dealt with before [12]. This is helpful in ensuring that previous mistakes are avoided and precedent preventative strategies are strengthened [29]. This is however only useful if that information is readily available and can rapidly be analysed.

  The epidemiological data gathered should be reliable information that is up to date. Because of this, a system that stores all the information gathered from various trustworthy sources which include the results of the laboratory data obtained from reported cases should be created and maintained. To improve reliability, the data stored should be recorded as events occur. This task should be constant and repeatedly reviewed to improve its validity during outbreaks. This is crucial in promoting the immediate use of information and so prevents any lagging in the delivery of information needed during crisis.

- **Better accuracy of prediction**
  Surveillance systems must be built in a way that promotes analysis. The analysis includes being able to observe the direction in which the disease is spreading. This is important in knowing how or where to begin when treating and controlling outbreaks [68]. Proper calculations of data are obligatory to ensure that errors and false alarms do not arise which might cause public panic.

- **Implementation of effective control measures**
  Various control measures may be available to deal with an outbreak, however only the most effective measure should be taken [101]. The appropriate control measure needs to be followed during an outbreak to prevent prolonging the outbreak. If animals have to be slaughtered in a certain region to prevent the disease from spreading to other regions then that action should be strictly followed with no exceptions.

- **Web-based disease reporting systems**
  Nowadays the internet is a platform for reporting any information in near real-time [30] [72]. It is known as a modern means of providing fast and up to date information to users [6]. This makes information available whenever it is needed. Users are able to login to a site in order to view more information regarding possible threats to their areas and the surrounding ones. This topic is discussed in detail later in this chapter.

- **Visualisation of information**
  For information to be understood it has to be presented in ways that are simple and clear to the user [75]. Heavy text has become an ancient way of displaying data that can easily be viewed at a glance. This is because heavy text is time and energy consuming and can be frustrating to the user if the information being searched for is difficult to find. The data gathered to support the visualisations should be Disease case visualisation is important in its effectiveness in alerting interested parties about possible threats through effortless techniques. This topic will be discussed further in Chapter 3.

- **Transparency, collaboration and communication**
  The main purpose of surveillance systems is to use the information obtained more effectively. Communication is very important especially where infectious diseases are concerned and systems that hasten this collaboration are necessary in the exercise of timeous precautions [25]. Reliable risk communication systems that offer free information to users and encourages them to ask questions deepens public understanding and trust of preventative measures that should be followed during severe disease outbreaks [105, 106].

Most of the critical points stated above are intertwined. They work to benefit each other. For example, the development of a reporting system can use different visualisations to explain the information in easier terms. It can also promote transparency, communication of information and improve collaboration between the public and veterinarians. This thesis focuses on ways that are used in reporting diseases especially concentrating on web pages and how the ideal visualisation of information can be achieved [11]. Visualisation is to improve the understanding of information by users of different intellectual levels. The efficient delivery of information to concerned parties is supported by the continual development of ICTs and their incorporation into various fields like health.

2.5 Information Reporting

Information, as already explained, is required in understanding the risk that zoonoses could possibly pose. The importance of information is that it allows the rapid detection of changes and consequently the building of strategies to follow in reacting to disease outbreaks on time [26, 106]. In order for this information to be understandable, procedures need to be followed in extracting data that can be transformed into useful information that can be read and understood easily. For the information to be evenly distributed it has to be delivered through technologies that widen and hasten the reporting procedures [80].

Communication can be used strategically to improve health services [5]. Appropriate communications can make information available for use in making complex decisions on how to react during disease outbreaks [105]. It can improve awareness of disease risks and it has the ability to inform and influence individual and community decisions that improve health [5]. Health communication can contribute to all aspects of disease prevention and health promotion [105]. It is important in disseminating individual and population health risk information to various interested parties [5]. However, the information being communicated must be disseminated rapidly for it to be useful.

Information technologies that promote the communication of information need to be utilised to ensure that data is easily available at all times. The USAID proposes that ICTs can be divided into two; namely modern or new ICTs and traditional or old ICTs [80]. Traditional ICTs include print material (e.g. newspapers), fixed telephones, radios, televisions, drums, fliers and tree gatherings, whilst modern ICTs are the recently developed computer systems which are known to be more efficient [80]. Modern ICTs include communication systems between computers like the internet, PDAs, cell phones and video enabled systems.

Most countries in Africa are under-developed and are still in the process of adopting new technologies compared to developed countries where new technologies are already in place [72]. This makes developing countries more vulnerable to the adverse effects of zoonotic disease outbreaks since they do not use ICT tools that promote data manipulation and make information constantly accessible worldwide [25]. Basically this shows that there is an urgent need to use necessary resources and capacities for decreasing the number of reported diseases in developing countries. Some developed countries, like Germany, have equipped veterinary authorities with computers and communication software platforms as a prerequisite for promoting governmental veterinary services [50]. These procedures were taken to embrace and promote the use of reporting information systems that improve disease crisis management procedures. Developing countries can follow suit in order to improve the management of disease outbreaks.

The reason why much emphasis is placed on developing countries is because there are four major driving forces that require attention to increase the significance of ICTs in the health sector of developing countries [25]:

- The need to reduce costs
- Dealing with infectious disease e.g. zoonoses
- Focusing on precautionary care
- Promoting change in the health care systems

In this new era of simultaneously disseminating large amounts of information, rapid adoption of modern ICT developments is important because they hasten the distribution process. The continual development of newer technologies aims at providing superior means of efficient information delivery. Developed countries are characterised by economic globalisation and modern ICTs since new technologies are discovered and exploited often in those areas [18]. Modern technologies therefore rapidly evolve in developed countries whereas developing countries are struggling to keep up [80].

The importance of controlling infectious diseases is in using communication mediums that can reach out to large masses of people in order to supply them with preventative mechanisms. Usually the information given is questionable and users may need answers that are specific to their individual needs. Because of this, a platform that allows one to query the information given can be a powerful tool in assisting with the outbreak control or prevention. Newer technologies like the internet provide a two-way communication from system to user and vice versa. This will enable the user to request information and have the results displayed for analysis. Although radios and televisions are effective forms of communication, they provide one-way information flow. Users can only rely on what they are told and cannot query the information to understand it better [23]. The report from radios or televisions is specifically timed and if one misses a report one has to wait for the next report. The internet has the ability to be an informative data source that complements traditional methods of information dissemination because it is available at all times and users can access for information whenever they desire [107]. Because of the detailed information that web pages provide, when users search for information on the web, they are empowered and alerted to take measures that protect their health and that of the animals around them. However, webpages are not a replacement of traditional communication measures, they can be the primary source of delivering outbreak news to the public, and then for detailed information viewers or listeners can be directed to the web. The veterinarians on the other hand need to be aware of the disease outbreaks before they can even be reported and the web could be a platform to manage this distribution of information rapidly amongst the veterinarians to prevent false alarms.

Despite the disadvantages that modern ICTs have, e.g. poor internet connectivity resources, they present a better approach of communicating near-real-time information [34, 80]. Even though this is clear, distinct ICT strategies for communicating zoonotic disease information across the globe are still not being established in African countries. This includes South Africa which is considered the most developed African country [87]. For example, literature research indicates that in South Africa 16% of the sites found on the web have interactive features [39]. Veterinary websites are also included in the 16%. The technology is present but it is gradually being applied to the veterinary field. 70% of South African sites use the web for health purposes [39]. This indicates that the medical health systems are ahead of the veterinary health systems. Although this is so, the slow adoption of modern tools makes the information less customisable. This makes it difficult to offer maximum transparency and quick investigation of epidemiological data during zoonotic outbreaks.

2.5.1 Web-based Reporting Pathways

The internet is a computer driven communication medium comprising of web pages that display information [72]. The internet has brought about opportunities for the innovative delivery of information that makes it accessible to concerned parties worldwide at all times [11, 23]. In the past, information has been mediated using paper, books and other traditional techniques but nowadays the internet has become an easier way to rapidly gather, transform and distribute information [96]. The following subsections describe the use of web-based reporting pathways in delivering disease information. They also describe how the web can be used as a medium for reporting information about zoonoses.

2.5.1.1 *Using the Internet for Reporting Health Information*

Generally, the internet is an information resource and statistics indicate that about 60-80% of the internet users around the world, have used the web for obtaining health information [72]. In America, 80% of Americans use the internet to seek health information [23, 96]. These high percentage levels indicate that health related information is successfully being disseminated using the internet. The information is convenient to the users and it is advantageous in that it supports self-help and privacy [72]. The web allows users to self-manage their infections and health needs. This makes reporting of sensitive symptoms or diseases easier because users can communicate with health authorities privately e.g. currently chronic diseases are managed online [41]. This is said to improve the success results of dealing with diseases since users are free to report diseases and their symptoms privately [96].

The use of the internet for managing health services has been growing successfully and this has inspired its use in communicating information about zoonotic diseases especially during outbreaks [72, 96]. The internet increases the chances of detecting diseases early when compared to traditional reporting systems. This is because near-real-time information is accessible to a wide range of users thereby improving transparency. Users can also interact with the systems by asking questions that can give them more insight about solving the problem. Since users can log on to the system using accounts with passwords, privacy of sensitive information is taken into account. However, unless the information is properly visualised, information is unstructured and difficult to understand [97]. Sometimes the public can panic over suspected cases which can promote the circulation of false positive reports that could result in huge workload issues. Since the internet has the ability to provide quick and up to date information to the veterinary authorities and the public, it must be fully explored to improve the distribution of important information about occurring outbreaks [50, 107].

The advantages of web-based platforms support the goals of dealing with zoonoses. Real-time delivery of information and interactivity are amongst the major characteristics that are desirable in a disease reporting system because it promotes the early identification of disease cases since as soon as the diseases are discovered, they are reported. Some of the disadvantages of internet systems are points that need careful consideration when systems are built. Strictness to ensure that only authorised personnel can flag positive cases is mandatory in minimising false alarms; the systems should therefore demonstrate accountability for all the disease reports that are made [23]. Proper visualisations are also required to ensure that the public do not interpret results inappropriately. Clear and understandable information must be offered to cater for all intellectual levels so as to prevent miscommunication.

There are major challenges that are faced when ensuring that the web-based systems are used [106]. This is because people are usually reluctant to use new mediums of communication until they are convinced that it is advantageous to them [72]. The surveillance activities for rapidly identifying diseases at an early stage can be expensive and some countries, especially developing ones, still need to develop public health infrastructures to identify diseases whilst there is time to prevent their spread [106]. The internet has the ability to minimise some of these challenges. Web-based reporting can provide a basis to share information that can allow transparency and early disease detection at low costs [106]. Attention should therefore be focused on developing suitable web interfaces that can alert the public and the health authorities timeously so that proper preventative measures can be followed.

2.5.1.2 *Web-based Reporting Systems for Zoonoses*

In order for disease outbreak information to be utilised, the government has to distribute all the information into all areas that are at risk and the surrounding areas. During outbreaks, investigations are taken to gain more understanding about the problem and to obtain results that can be used in decision making [76]. However those results need to be reported to parties that are interested or affected as soon as the information is available or they will be of no use. Results improve timely investigations of the infectiousness of a disease and alertness to the appearance of disease symptoms. Transparency in the delivery of information improves disease awareness amongst all people worldwide and the web-based systems are currently the best means of ensuring quick communication and transparency [11].

Any delays when notifying the public about possible threats could result in more damage. Timeliness and completeness of disease reporting makes people aware of risks whilst there is time to prevent any calamities [70]. It is therefore critical to ensure that the public are forewarned of suspected disease cases. Web pages allow the reporting of disease outbreak information in near-real-time [106]. This is very important because outbreaks are time-limited and the more time is wasted, the more severe an outbreak becomes.

The information to be reported usually includes knowing [37]:

- where the disease originated
- the areas at risk
- which species are most at risk
- the symptoms of the diseases
- the transmission methods
- who to ask for more information
- status of disease outbreak in an area
- what measures to follow in preventing spread
- similar cases of previously reported information

This information is necessary to discover the origin of the diseases, watch out for threats in areas surrounding the detected areas, observe how fast the outbreak is spreading and inform the public on preventative mechanisms they should follow and to inform the veterinarians on how they could prevent further spread. The reporting of disease cases has been known to improve completeness and timeliness of surveillance systems and so systems to ensure this need to be strengthened [70].

2.5.1.3 *Current Web-based Reporting Sites for Zoonoses*

Nowadays the internet is being used for the delivery of disease outbreak information through creatively visualised web pages [58]. The web is increasingly becoming the most effective medium for dealing with health related problems [23, 96]. In 2003, 12.5 million of worldwide daily web searches were found to be health related [6]. Research conducted in 2005 indicated that 58% of web users search for personal health information [6]. The given statistics indicate the continual rise in the use of Web pages when disseminating health related information. Literature research indicates that these statistics keep increasing with technological advances.

The significance of webpage development for health reporting is in the content of the Web pages. If the websites are developed properly they become successful and can achieve the main aims of their development. Web pages create a platform to visualise information in ways that promote the detection of the first evidence of an outbreak [106]. They also ease the access of a variety of disease information to the public, yet this was not easily achievable in the past [13].

International organisations manage sites for reporting disease outbreaks on the web. These organisations include WHO, NAHIS, IOE, PAHO and many more. The governments have authorised these organisations to supply this information to the public because freely available data from Web pages may rapidly identify disease trends thereby promoting the detection of disease outbreaks at an early stage which is our primary goal in building web systems for disease reporting. Web systems each have their strengths and weaknesses. Lessons from the current web reporting systems need to be evaluated to develop even better systems. This involves evaluating their success factors and discovering the reasons why they are successfully recognised as reporting systems during outbreaks.

The first web-based surveillance platforms were created by Canadians who used the Global Public Health Intelligence Network to retrieve articles that could be relevant in determining possible disease threats [106]. This system gathers information from news feeds that are found using search queries every fifteen minutes [106]. This information can also be sent to experts from various health agencies like WHO for further analysis and for presenting formal reports. The information gathered through the surveillance of the Listeriosis outbreak in Canada that resulted from contaminated deli meat, provides further evidence of the potential power that web-based surveillance systems bring about [106].

Since then, similar online resources that disseminate real time information have been created [22, 107]. An example is the HealthMap (Figure 2.4), which can monitor, organise, integrate, filter, visualise and disseminate information about emerging diseases [106]. The information is extracted from approximately 20 000 news sources every hour. The various approaches taken in gathering data make it easy to view diseases from different angles. Another example is the Google Flu trends that provide a near-real-time spatial view of influenza activities around the world.

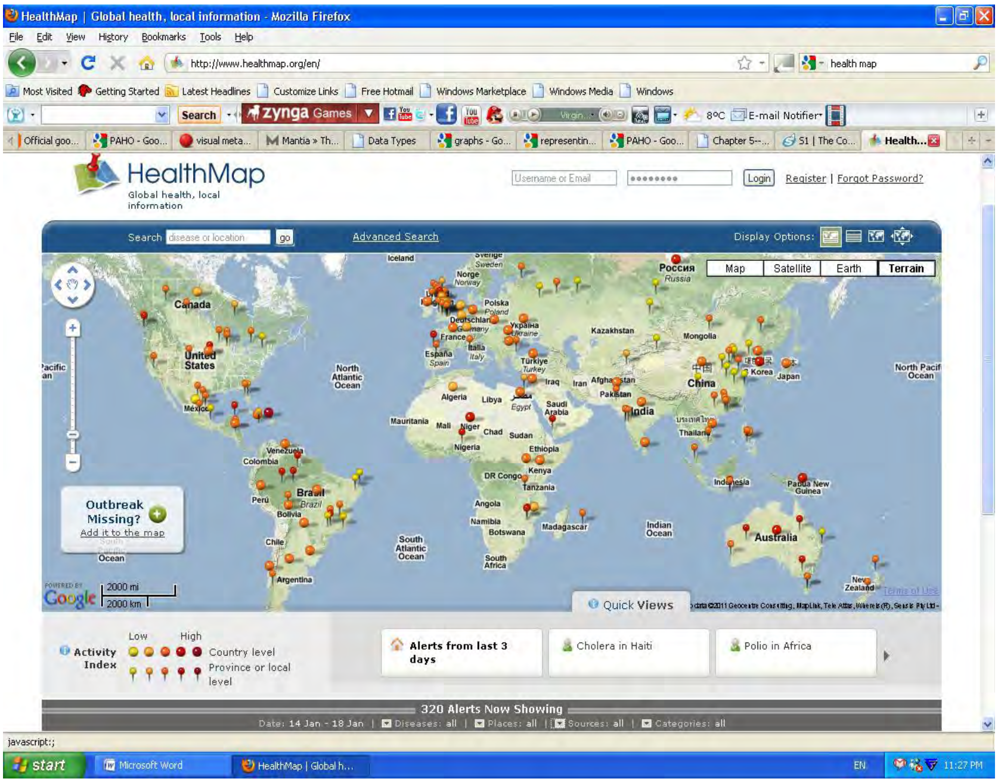


Figure 2.4 HealthMap website
(http://healthmap.org/en/).

Most of these organisations are specific for internationally problematic diseases, e.g. the SARS and the influenza strains are reported worldwide. Other organisations are specifically for identifying regional disease problems, e.g. the USGS (Figure 2.5) which provides a spatial view of diseases that are categorised into bird, veterinary, mosquito, human and sentinel search sections for the different parts of the USA. This is to avoid having information reports from specific countries about the status of a disease in neighbouring countries. Although international collaboration in eradicating diseases affecting the world is important, regional reporting is also important. This is because it is easier and more thorough to report data from its origin than from far away areas since from its origin the proximity to the disease occurrences makes the reports more reliable and yet information reports from afar could be hearsay. Because of this, similar systems can be created specifically for South African based disease surveillance information delivery. For example, the concepts behind Google Flu trends can be used on a regional basis to support the South African information systems. This is to achieve the same results of rapidly identifying and reporting disease outbreaks within the country.

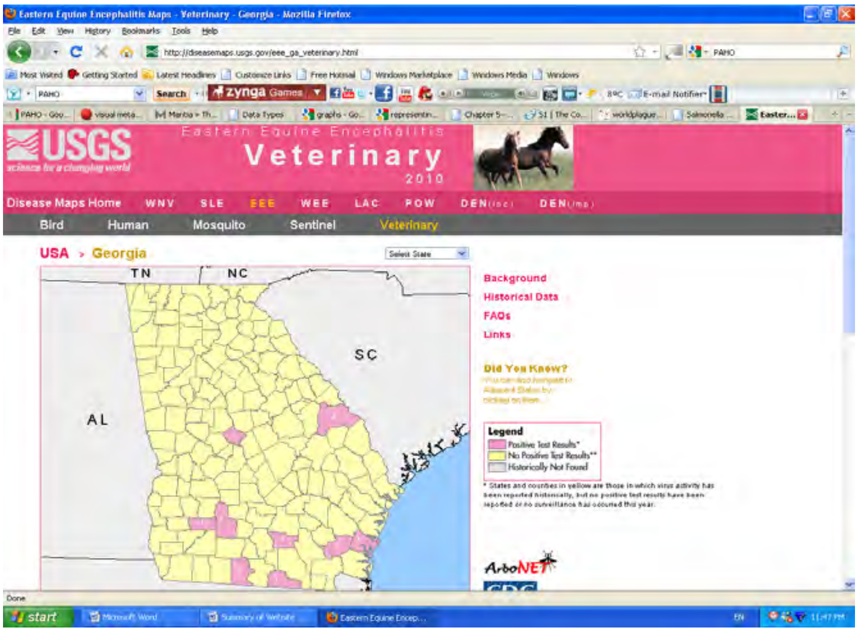


Figure 2.5 USGS website used for reporting diseases (http://diseasemaps.usgs.gov/eee_nc_veterinary.html).

Literature research has shown that web-based reporting pathways can improve the dissemination of zoonotic disease information during outbreaks. Several authors have looked at the websites that are used for disease reporting, identifying the key factors of using them for reporting [59, 69, 82, 96]. This is because the web is a very good medium for distributing information and ways of improving the dissemination of information are constantly being sought. This has helped to identify the advantages and disadvantages together with strengths and limitations faced when using the web as a source of information during outbreaks [3, 41, 96]. Studies have also been conducted to understand some of the visualisations that can support disease-related data [91]. These have been seen to be successful in displaying information that uses less text and can easily be understood. The properly visualised disease reports are created to observe increasing or decreasing trends in disease occurrence and to perform rapid analysis of data [24]. Because of this knowledge, more focus is given to visualisation to better understand how it can be used on the web to support the discovery of disease trends in the reporting of zoonotic diseases during outbreaks.

2.6 Conclusion

This chapter has reviewed literature around veterinary information and veterinary service delivery. It has demonstrated the need to develop systems that can improve the delivery of veterinary services in combating zoonotic diseases. The critical points of monitoring infectious zoonotic diseases through surveillance have been highlighted and explained as important in the design of disease surveillance systems. Web-based systems and visualisation are important points to explore for the efficient reporting of zoonoses. There is no doubt that nowadays, the internet is an effective platform for displaying spatially related problems on a large scale to ensure rapid communication. The importance of web-based platforms is described in detail to ascertain their role in the delivery of information for the eradication of zoonotic outbreak threats. However it is highlighted that the design of such platforms contributes to the success of communicating a lot of information to interested parties. The next chapter will focus on understanding how information can be displayed to facilitate better understanding.

3 Information Visualisation

3.1 Introduction

Information visualisation is generally defined as the process of presenting an abstract concept in a form that can easily be understood [71, 91]. Lau and Vande Moere state that "visualisation aims to amplify cognition by developing effective visual metaphors for mapping abstract data" [53]. It has been concluded that visual presentations of data are much easier to use than textual descriptions or spoken reports. This is because the brain analyses visual information from given displays to obtain patterns to support cognitive activities [85]. Information visualisation thus plays a huge role in displaying large amounts of information that makes sense and can efficiently be utilised to gain knowledge [77].

Information visualisation involves the common use of three terms namely data, information and knowledge [75]. These indicate different levels of understanding. Figure 3.1 is a common model of classifying human understanding in the perceptual and cognitive space. Since as humans we can read data and transfer it to information to gain knowledge, we therefore try to understand these terms in the perceptual and cognitive space [75]. Since nowadays data is computerised, use of these terms in the computational environment is explored.

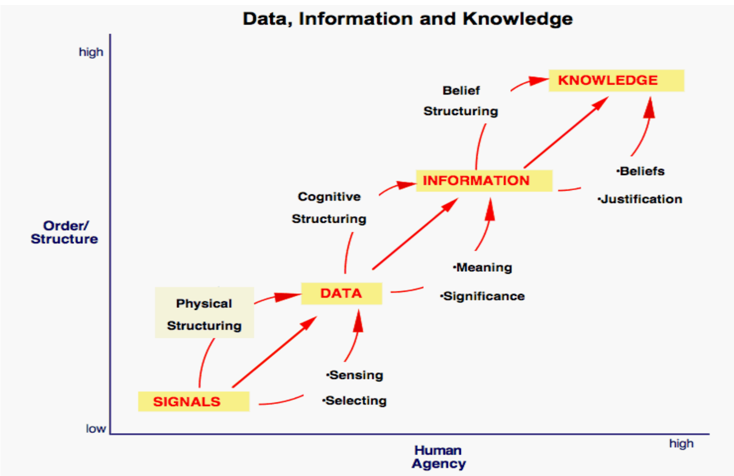


Figure 3.1 Hierarchy of data processing [38].

As illustrated in Figure 3.1, data includes the raw material used to explain situations. Through data, one decides on the visualisation tools and techniques that they can use to explore the data [91]. This involves the selection, organisation and sensing of data that can result in meaningful images that promote the cognitive abilities of a user thereby improving the way that the data is understood. Information is data that has been processed to be useful using different visualisation techniques [91]. The techniques are able to change complex data into easily understandable forms e.g. time changing data is visualised using techniques like line graphs or timelines. Knowledge is the application of data and information in providing answers to questions related to the data used [75]. These terms indicate different levels of abstraction, understanding and truthfulness [75]. They also need to be studied and understood so that data can be read easily, information can be developed and grasped and knowledge can be acquired by the user for utilisation.

Visualisations can represent different types of abstract data with differing numbers of attributes such as single and multidimensional data types, tree data and network data [85]. Each of these data types has to be represented in appropriate visual forms that complement their type [77]. Regardless of the dataset, there are tasks that characterise the levels of data abstraction. The visualisation tasks followed provide a summary of what a visualisation application should demonstrate to ensure its success. These tasks include [85]:

a) Overview: This summarises and clearly follows strategies that can tell the user what the entire system is about.
b) Zoom: Enables users to focus on features that they find interesting.
c) Filter: This is one of the important points of information visualisation because it allows the user to view only those items that they are interested in and mask those that are of no interest to them.
d) Details on demand: This task enables the user to group data and gets more details about that group or item chosen. This makes it easy for users to search data about that group.
e) Relate: This brings out relationships amongst items.
f) History: Steps like *undo replay* and *next* give users a way to retrace their steps.
g) Extract: Users are able to save extracted data from queries performed on the data.

Due to the expansion of information research and development, exploring and analysing large amounts of abstract data has always been unavoidable. Visualisation has been used to help understand increasing amounts of data across varying fields such as the environment and business fields. Traditional ways of information retrieval like using paper based tools for data management are being overtaken by newer or modernised ways like databases which allow data mining and filtering [80]. Upgrading and improving these ways becomes very critical and important because data handling is increasing day by day due to the increase in information and the need for knowledge. Modern information visualisation technologies have been discovered to ensure that the manipulation and use of large amounts of complex data is made feasible within a limited amount of time [85, 96]. They remove display challenges and help design interfaces that promote the user's ability to recognise patterns and relationships that are not readily evident from large amounts of raw data [63]. Visualisations also promote the generation of information hypothesis in order to enhance problem solving skills [62].

Successful visualisation systems require extensive work. One has to be aware of what makes a good visualisation. There are some visualisation problems that can be faced when designing systems and in order to build a proper visualisation interface, a designer should be aware of them to avoid them. A good design involves being aware of the available visualisation principles and properties, recognising when they are not being used, and applying them in systems used for reporting information. In this chapter visualisation is studied in detail to understand what is required to make it successful. Afterwards visualisation is studied to determine how it can be used in representing disease surveillance data to improve disease identification and risk analysis. Disease surveillance is characterised by features that are geographic in nature with time limits [60]. Visualisations that support disease information characteristics have to be studied in detail so as to visualise the information effectively. These visualisations include spatial and temporal visualisations. The combination of these two visualisation techniques results in systems that can effectively display disease information.

3.2 Properties of Visualisations

For any application or process to be successful it has to follow certain procedures, rules or properties [61]. There are numerous rules and properties followed in the visualisation of data [83]. These properties are stated to have been derived through informal discussions with data visualisation experts and the exploration of existing literature on graphics, data visualisation, visual observations, investigative data analysis on existing tools used for visualisation, and human-computer interaction [77]. They have been discovered for strengthening developed visualisation interfaces and for making information relationships stand out and be immediately visible to read and interpret [85].

Figure 3.2 shows the five properties of visualisation. The segments of the circle indicate that all the slices must work together in order to give one desirable result that incorporates all the properties of a good visualisation system. When designing a visualisation interface these properties must be carefully considered and used to ensure a good visualisation. Disregarding any one of the properties could make the visualisation partially successful and at times a failure since one property can have a large effect on the overall visualisation interface result. The following subsections describe each of these properties in detail.

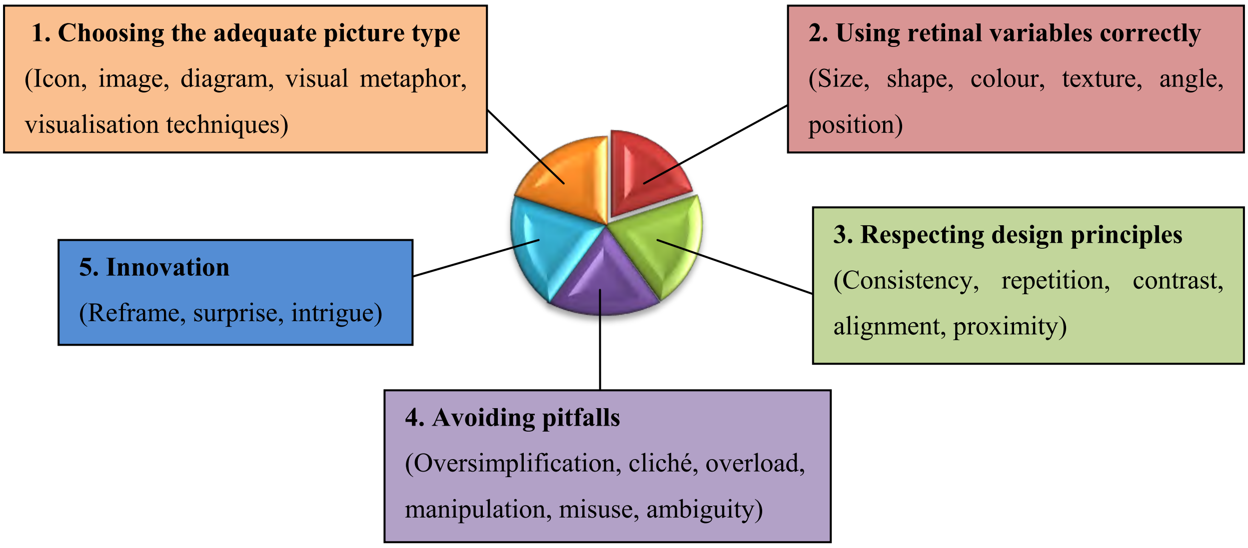


Figure 3.2 Properties of visualisations [38].

3.2.1 Choosing the Adequate Picture Type

The selection of picture type for data representation is very important in depicting the appropriate message. Data can be presented graphically in the form of icons, images, diagrams, visual metaphors and visualisation techniques [61, 93]. Graphics can express spatial, colour or textural relations better than words. Because the graphic is what the user first sees, it should provide a systematic overview of what the information or message being conveyed is. Figure 3.3 describes some of the graphical elements used to express data in detail.

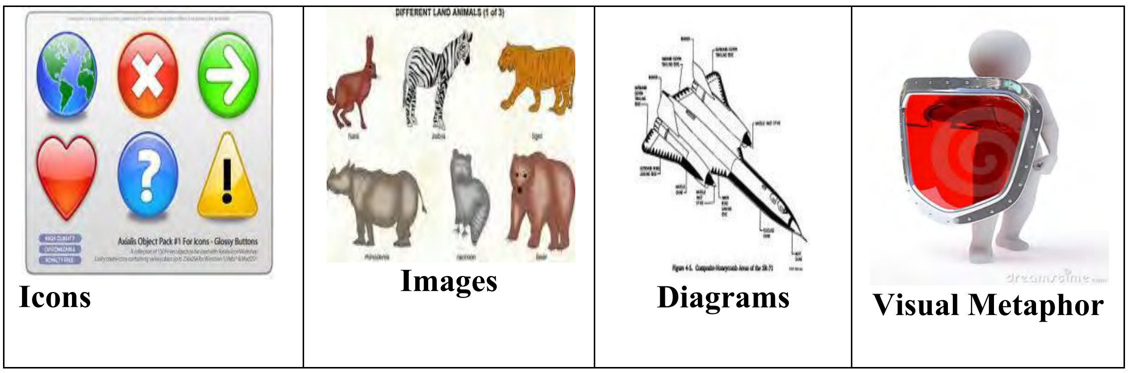


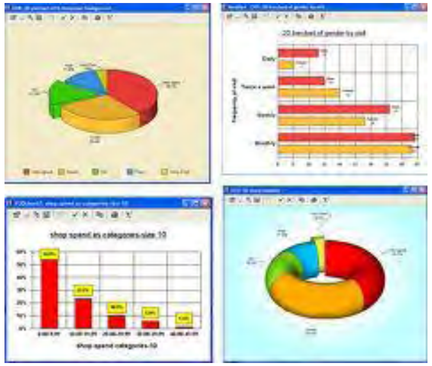
Figure 3.3 Graphical representations of data [38].

Icons are symbolic signs that represent objects discretely. Instead of using plain text to describe data about an object, activity, situation, place or event, icons describe that data visually [43]. For example, from Figure 3.3, the last icon represented is a warning or caution sign [93]. Icons sometimes yield results from specific commands e.g. toolbar icons represent commands such as “save” or “undo”. Images are photographs taken of objects. They are used to give a visual of the object being described e.g. from the images in Figure 3.3, the first image is a rabbit. A diagram is a drawn visualisation of an object usually to indicate the different parts of the object. The diagram in Figure 3.3 represents an aeroplane to show the many parts that make an aeroplane.

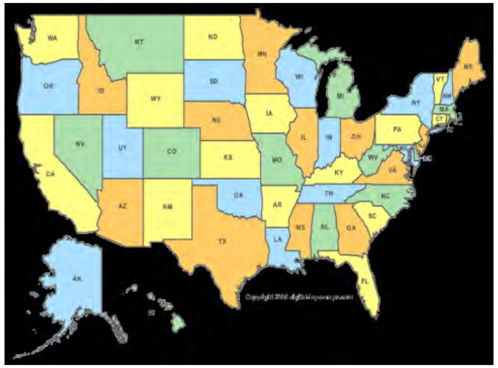
A visual metaphor is a sign that uses comparison of one object to another to demonstrate similar features of both objects [61]. They do not only refer to objects as icon or image signs do; instead they transfer qualities from one domain to another [93]. For example, a shield is known to be an object to protect and can be used to advertise an antivirus program thereby informing users that they can shield themselves from viruses using the antivirus program. Icons can also be metaphors that represent a subject [94]. They are commonly used on the web, e.g. an envelope icon represents the contact page.

Apart from icons, images, diagrams and visual metaphors, there are visualisation techniques that are used to represent data. These include maps, charts, tables, Venn, network and tree diagrams and timelines (

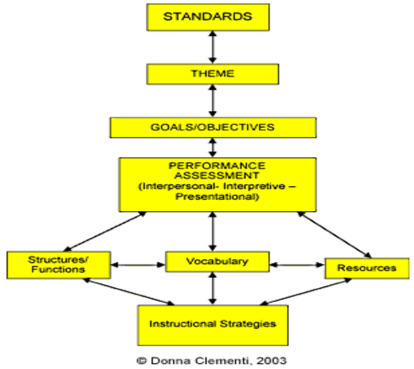
Figure 3.4). Charts are mainly for analysing statistical data. They include pie charts, bar and line charts and scatter plots. Maps usually represent spatially or geographically defined datasets. Flow charts visualise steps to follow in a process. Network diagrams are used to show how networks are organised, tree diagrams are aimed at visualising hierarchical data and Venn diagrams are for visualising concrete concepts for easy comparisons of relationships. Timelines are techniques used for visualising temporal data. Tables are a set of data elements stored in an organised way, with columns as the basis of the storage. The application of some of these visualisation techniques will be discussed in detail later in this chapter.



Charts

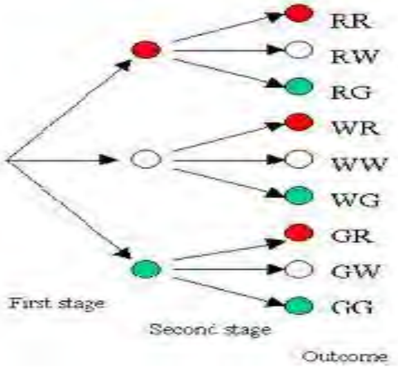


Map



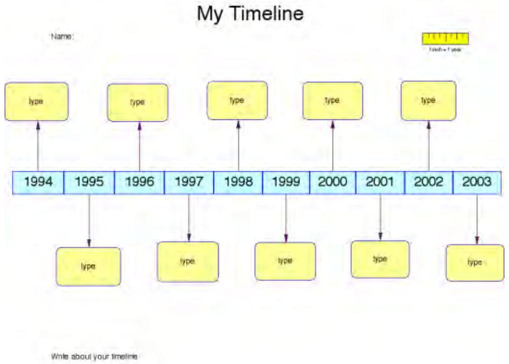
Flow Chart

Network diagram

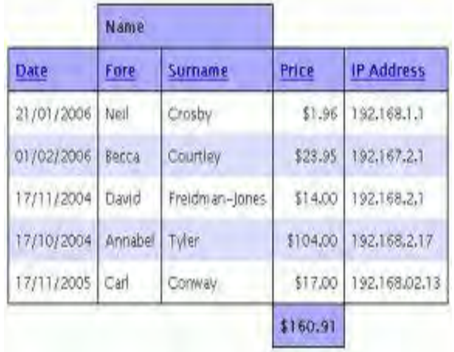


Tree diagram

Venn diagram



Timeline



	Name			
Date	Fore	Surname	Price	IP Address
21/01/2006	Neil	Crosby	$1.96	192.168.1.1
01/02/2006	Becca	Courtley	$23.95	192.167.2.1
17/11/2004	David	Freidman-Jones	$14.00	192.168.2.1
17/10/2004	Annabel	Tyler	$104.00	192.168.2.17
17/11/2005	Carl	Conway	$17.00	192.168.02.13
			$160.91	

Table

Figure 3.4 Examples of visualisation techniques [38].

Each type of technique chosen has to appropriately suit the purposes of the message being interpreted because one technique may be suitable for representing data in one field and yet the same technique in another field will be unsuitable [31]. Different techniques have their own strengths for displaying specific types of data and those strengths have to be capitalized on to bring clarity in the presentation of the data. The potential of using each technique in certain fields should therefore be recognised.

The purpose of selecting the most appropriate visualisation technique is to make data easier to interpret and to make it more informative. The goal is to improve the understanding of complex forms of data to suit all kinds of users who have varied intellectual levels. Different visualisation techniques can be used to deliver different messages about data, like the distribution of the data, trends and correlations in the data and summary of statistics. The distribution of data is how the data values are organised when compared to each other. It is important to find the proper visualisation technique for distribution data so that the true distribution of the dataset demonstrated thereby promoting accurate analysis of data. Correlation is the measure of how random data variables are dispersed. It reveals the strength of dependence between data values. The trend on the other hand depicts the general direction in which values tend to flow. The summary of data shows the derived summary of a given dataset. It is usually used to show measures of location, spread and number of observations.

Different visualisations are also suitable for displaying different types of data, like categorical or continuous and bivariate or multivariate data [31, 98]. Categorical data is data that has been grouped into different categories that are mutually exclusive [10]. Continuous data is usually associated with accurate physical measurements; they can take an infinite number of values in between whole numbers. Bivariate data is data that shows the relationship between two variables whilst multivariate data is data that shows the relationship between more than two variables [10]. Figure 3.5 gives an example of the questions, about the type of data that one can answer before selecting the appropriate technique to use. The diagram helps depict visualisation techniques that are good to use based on what message one is trying to display and the type of data being visualised.

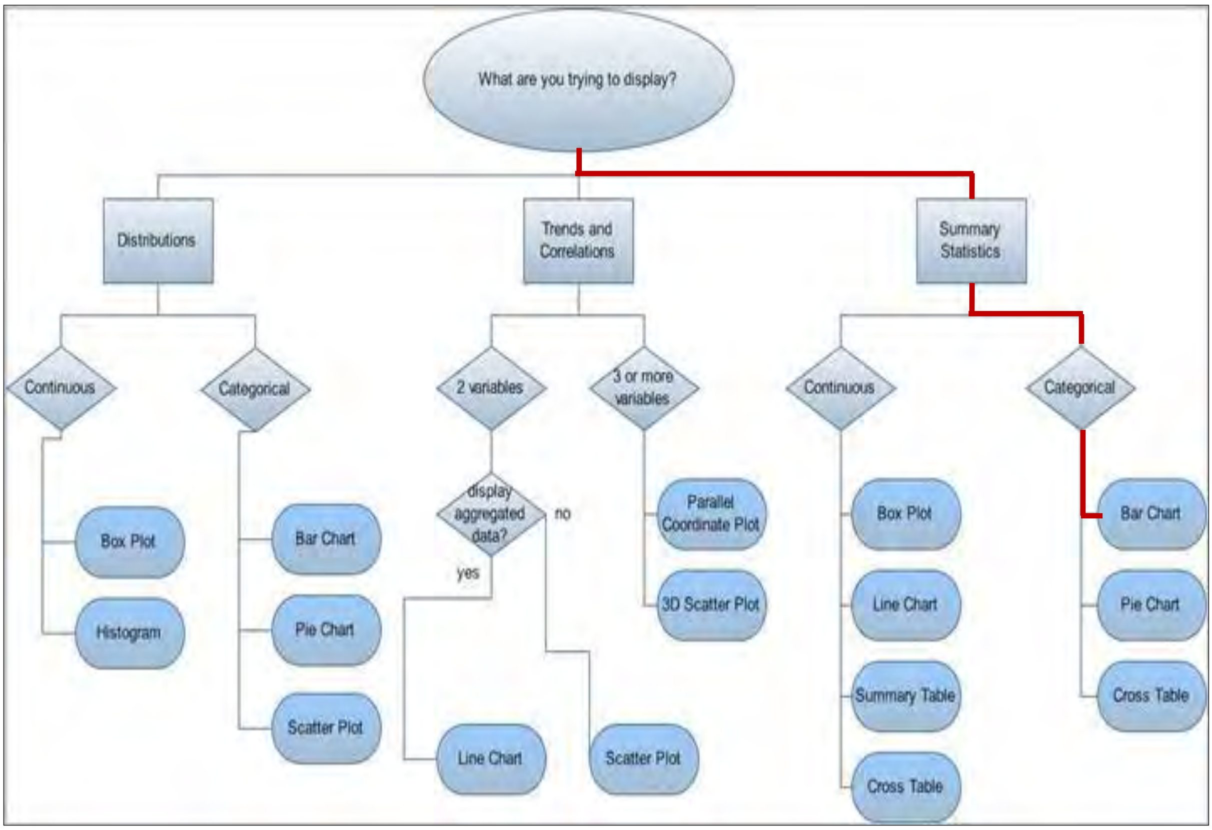


Figure 3.5 Choosing a visualisation technique (http://spotfire.tibco.com/community/blogs/tips/default.aspx?PageIndex=6).

An example indicated by a thick red line on Figure 3.5 is when one is trying to display a summary of different disease case statistics (for comparison purposes) in the months of a given year e.g. number of animal death cases, number of reported cases and number of confirmed cases. Then one looks at visualisation techniques that are used to demonstrate statistical data. The data to be displayed is observed to determine if the data is continuous or categorical and to confirm the number of variables to be visualised. Variables generally represent measurements on a continuous scale like size or time series data or they may represent information with discrete characteristics like gender and height of students. In this case the statistics of the type of cases per month is categorical since the information is discrete. From the list of techniques available for representing summary statistics of categorical data, any of the three suitable visualisation techniques is then chosen for that type of data, i.e. a bar chart, pie chart or a cross table.

3.2.2 Using Retinal Variables Correctly

Besides choosing the adequate picture type to represent data, there are other symbols that can be used together with visualisation techniques. However, due to the different effects to visualise from large amounts of data, different symbols can be used to represent different classes of data. The characteristics of the chosen symbols are very important. Metaphors make it easier to visualize data because they have the ability to trigger deeper thoughts without saying a word [93]. Retinal variables, which are considered as examples of metaphors, are used to represent data on an information display, examples include colour and shape. Visual metaphors representing a certain object are easier to understand than a block of text explaining the same thing [93]. In order to remember things easily the brain seeks to correlate any two objects that are close together making it easier to understand things.

Qualitative data is descriptive data that is subjected to user opinions. It can be divided into different classes according to differences in data values. Quantitative data is definitive data that has numerical values attached to it. Qualitative data is represented by different variables when compared to quantitative data. The symbol properties more appropriate for qualitative data include shape, pattern and hue. The symbolization of quantitative data is more complex because it usually depicts a logical progression of data. Quantitative symbols usually involve using visual variables of size and colour value. It is important to use the correct variable because viewers have to be able to depict differences between values that are represented by standard variables. Figure 3.6 shows a visual description of the retinal variables used in the representation of data.

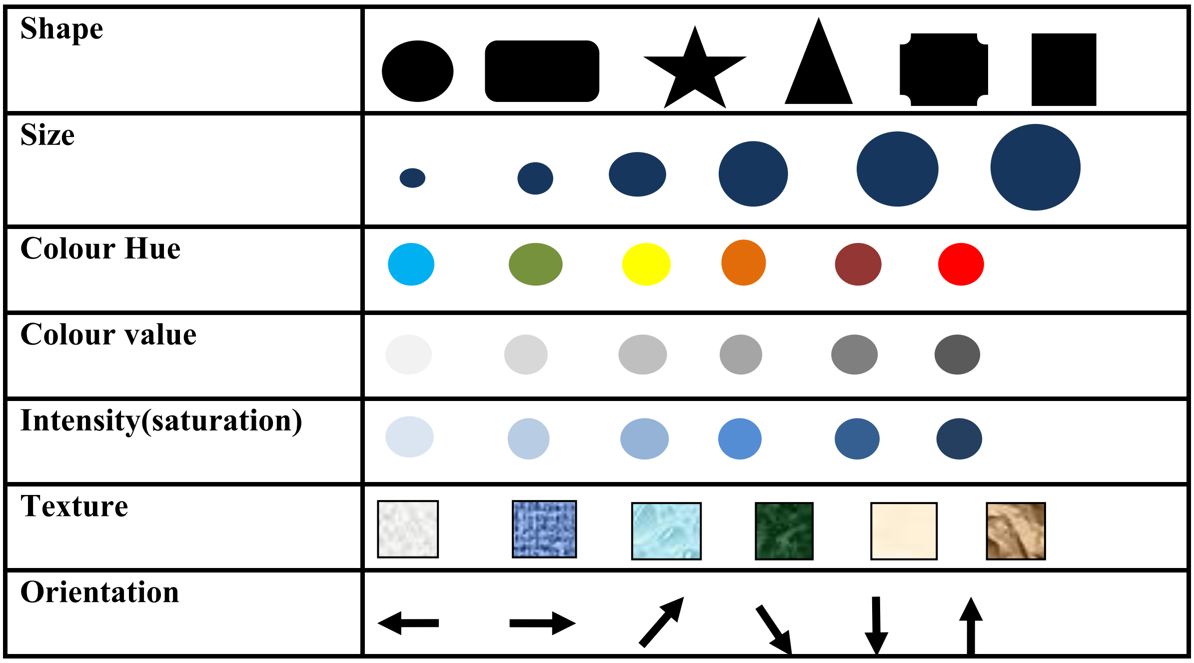


Figure 3.6 Retinal variables

(Adapted from http://understandinggraphics.com/visualizations/information-display-tips/).

Different shapes provide visual interest and gain attention from users. The size usually symbolizes quantity or a category of data and it is usually used when dealing with quantitative data like counts, ranks, calculated rates and percentages [10]. Colour hue can be used to highlight exceptional events or objects. It adds life to an interface and can make complex structures easily readable especially if coloured appropriately [88]. The colour value variable represents the lightness or darkness of a colour [88]. Adding white to a colour hue produces a tint which is a high-value colour and adding black to a colour hue produces a shade which is a low-value colour. For example, when black is added to a red colour it produces a dark value of red known as maroon colour. Colour intensity represents the brightness of a colour at given saturation levels. Colour hue, value and intensity are usually used for classifying data that is quantitative in nature. The colour hue, saturation and value model used in this case (Figure3.6) was chosen out of many other available models to appropriately suit the needs of this research. Texture variables show variation in density of the graphic elements of the same value, i.e. with the same overall colour impression. Orientation is a variable which shows the direction in which symbols are positioned.

3.2.3 Design Principles

Design principles describe the essential values of good visual designs. These values recommend effective ways of graphically arranging text, picture types and variables used in an interface. There are certain principles that have to be respected when arranging graphical components. Failure to do this can lead to confusion about the message being conveyed. The proper application of these design principles usually determines the success of the overall display. A properly designed interface conveys the required message effectively. Design principles include consistency, repetition, contrast, alignment and proximity.

Readers often expect to find elements in the same place or in the same way always [61]. For example, the colour of a stop traffic sign is consistently red all over the world. This prevents chaos and confusion of having to remember the colours used in each country since people often travel to different places of the world. Red can also be used to alert or describe something that has to be noted without fail [88]. Repetition focuses on how often elements of a design are used. Users often recognise and remember repeated elements easily from given layouts [61]. This allows them to navigate through the interface easily and safely. Repetition can come in many forms, e.g. in the form of repeated colours, shapes, fonts, themes, or even the overall style of the design.

Contrast addresses the degree of conflict that exists within a given design between the visual elements in the layout [16]. This guides the users around the design and it emphasizes the differences between elements so that users can easily identify them. If the elements in a design are too similar it makes the interface boring and monotonous. On the other hand too much contrast between objects can be confusing to the user. Figure 3.7 illustrates how the three concepts, contrast, repetition and consistency, have been used together to build one visualisation. The contrast is indicated by different colours to distinguish between the header and navigation bar. The navigation bar elements are repeated and are presented in the same font and colour for consistency

Figure 3.7 Contrasting, repetition and consistent properties of visualisation [38].

The brain easily groups similar objects together to form a semantic relationship between the objects so that they can easily be remembered [16]. It is therefore important to put similar objects together. Objects that are close together or aligned to one another also tend to be grouped together by users to form a relationship because objects that are close together tend to suggest a relationship as compared to those that are far apart [16]. The arrangement of the objects is also important because it brings order where there could be confusion [16]. Aligning different types of objects in relation to others determines if the layout will be readable and familiar to the user or not [16]. Figure 3.8 shows an example of how the two concepts, proximity and alignment, can be used together. The first picture of Figure 3.8 is not arranged in an orderly way and the second picture demonstrates order of object proximity to form a group that can be understood. The arrangement of the circles into a circle demonstrates how the objects are aligned together.

Figure 3.8 Demonstration of the proximity and alignment concepts [38].

3.2.4 Avoiding Pitfalls

There are some factors that interfere or limit the effectiveness of a visual design. Avoiding these factors is especially important because it prevents designs that are difficult to understand since most unfavourable elements are avoided to improve understanding of the used graphical components. Following is a description of some common pitfalls like over-simplification, cliché, over manipulation, overload, misuse and ambiguity.

Oversimplification can impede the understanding of a message due to lack of coherence. Although a design has to be simple to ensure understanding it need not be too simplified because it can end up confusing the user. This is because over simplification removes useful visual cues that can aid understanding or navigation. A cliché is an expression, idea, or element of any design which has lost its original meaning or effect because it has been overused. It is what is predictable or expected and it should be avoided if the designed interface is to have an impact on its users.

The degree to which a user can control a system must be restricted. Over manipulation can interfere with the purpose of the system and should be avoided. For example, in some areas of a system, certain individuals can have restricted manipulation rights. The design should reuse internal and external components and behaviours, maintaining consistency with purpose rather than using arbitrary consistencies, thus reducing the need for users to rethink and remember [61]. However if an object is misused, it distracts the design purpose and makes information difficult to understand. When a visual expression has more than one interpretation it makes the whole system ambiguous and this should be avoided.

It is tempting to use many graphical images especially on web interfaces; however an overload of these can have negative effects [48]. Too many pictures cause some websites to load very slowly and not to be easily readable. This is problematic because users have no patience for sites that take longer to download or that take time to offer what the users want [48]. Figure 3.9 shows how system overload is unsuitable when creating a visualisation system.

Figure 3.9 Social network overload

(http://gregverdino.typepad.com/greg_verdinos_blog/2007/07/social-media-ho.html).

3.2.5 Innovation

Overall, a design must be attractive to the user. The user should be encouraged to use a design from its appearance. Innovation includes using new ideas to satisfy the needs of our users [99]. To achieve this, there are points that need to be kept in mind when designing such visual interfaces. Examples of innovative points to look out for include reframe, surprise and intrigue.

Reframe is a principle that alters the meaning or value of something, by altering its context or description. The visualisation system should be able to change our perceptions, and this may then affect our actions. There should also be minimal surprise. The user must not be surprised by the behaviour of the interface by expecting a certain object to perform differently to what it is doing. Overall, a visualisation system ought to be captivating and it should arouse the curiosity or interest of users. It should have compelling qualities that are new, unusual and fascinating.

3.3 Application of Visualisation Techniques

Visualisation techniques have been used in these various fields of research to assist in understanding various concepts, e.g. in geographic problems they are used to understand spatially related problems. These techniques support characteristics like space, time and comparisons of data. For the purpose of this research, spatial (geographic or map based), temporal (time based) visualisations and spatio-temporal visualisations are studied in detail. This is because some of the important characteristics of zoonotic disease outbreaks are spatially and temporally related. For example, as stated in Chapter 2, infectious diseases can rapidly spread to various areas and they are time-limited. The visualisation of where the disease is occurring and to which areas it is spreading can assist in controlling the outbreak. Previous information about when a disease outbreak occurred and how long it lasted can assist in elementary preparation of control measures.

3.3.1 Tabulated Data

Tabular data is data that comprises of rows and columns. These contain various forms of data, mostly descriptive information, which is usually alphanumeric in nature. They can be linked to spatial data by containing attributes that define the parameters of the map features. Tools have been developed to extract tabular data from a database to display on various other techniques. This is the visualisation technique that promotes interactivity of other visualisation techniques. The importance of tables as a visualisation technique when used on its own is that it organises information for easy analysis so that decisions can be made. However, when the dataset being large, it becomes difficult to analyse the data and hence other visualisation techniques that can handle large data are then used. Nowadays tabular data is interactive such that small tables pull data from large tables. The user is able to select what they want to view by submitting queries to a database which then results in information being displayed on a smaller table.

3.3.2 Temporal Visualisation Techniques

Temporal or time series data visualisation is generally performed to identify changes with time e.g. observe values that have exceeded or decreased certain thresholds from one step of time to another like observing crime rates. Visualisation takes away the burden of knowing when certain data occurred and how one can compare previous datasets to current ones. It makes information readily available to users for making rapid decisions [85]. The main purpose of visualising temporal data is to easily analyse events that have evolved with time to identify hidden patterns [33].

The analysis of temporal data has been discovered to be problematic in the science, business and engineering fields [98]. Statistics shows that 70% of business graphical data display change through time [85]. Temporal analysis is therefore an important task in many fields because the manipulation of large amounts of multivariate time dependant data stored in modern databases can aid in the understanding of natural phenomena e.g. temperatures observed in a month and business dealings [92, 98]. The analysis of temporal data by visualisation techniques has been demonstrated as successful, highly effective and necessary to discover trends of a dataset [92, 98]. Temporal visualisation techniques are those that are concerned with the change in time and each is suitable and applicable to different backgrounds [33].

The techniques used to visualise temporal data are numerous. Line graphs have been demonstrated to be exceedingly successful in visualising temporal data [98]. Line graph visualisation can answer questions like how many road accidents have been reported in a year and it can combine the visualisation of one dataset with another to compare the deaths brought by road accidents and that caused by other means (
Figure 3.10). The line graph is suitable here because the shape of the line clearly shows the decreases and increases of the dataset through time [33]. However, line graphs cannot visualise other types of data such as the cities showing the death statistics since they are mostly for quantitative analysis [33]. Gapminder, a tool used for statistics animation, gives a good example of line graphs that depict change through time for given datasets (see Figure 3.22). It will be discussed in detail later in this chapter. By using line graphs, the increase and decrease in disease case levels can easily be viewed.

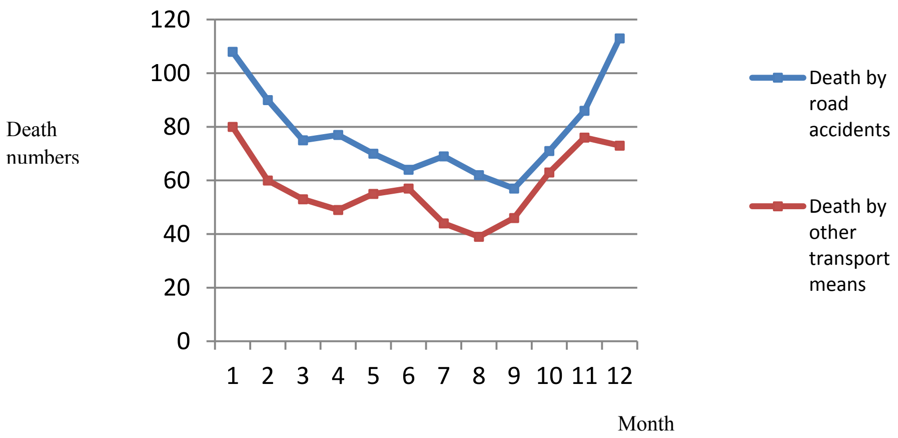
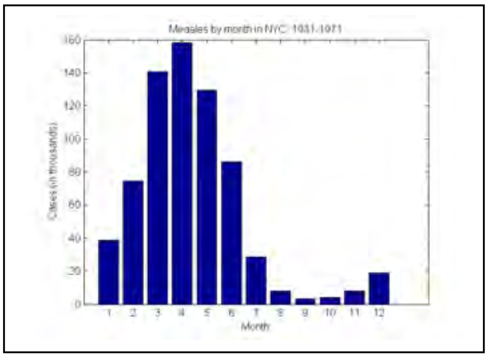


Figure 3.10 Line graphs for temporal visualisations.

Bar charts have also been used to visualise data [98]. Bar charts distinctively show individual values of a dataset making them easily comparable [33]. However as the dataset enlarges, it becomes difficult to distinguish one value from another. From Figure 3.11, the first bar chart can easily be analysed but the second bar chart is difficult to analyse because the density of the bars means the axis labelling becomes overcrowded and hence bars cannot be easily distinguished from one another. Bar charts can therefore be used in visualising disease information, e.g. if one wants to compare different types of cases during an outbreak. One can compare the number of dead animals, the number of killed animals, the number of suspected animals and the number of outbreaks. Because these are distinct values, one can draw conclusions by looking at a bar chart with these values.



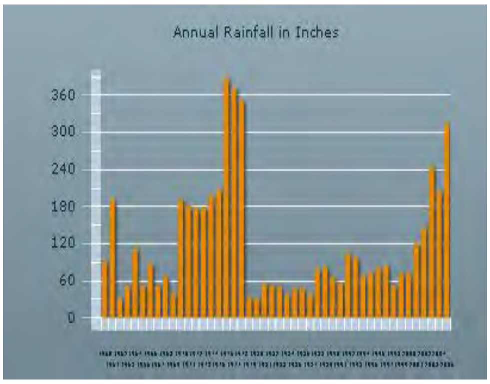


Figure 3.11 Clear and crowded bar chart

http://www.cs.utsa.edu/~cs1173/lessons/Lesson3PiesAndBarsQuestions/Lesson3PiesAndBarsQuestions.html,

http://www.connectedpixel.com/blog/scrollingcharts

Cyclic temporal time dependencies are visualised by spirals. Although all the given techniques can visualise temporal data, some can be inadequate for visualising large temporal datasets as they cannot bring out fundamental structures of datasets clearly [98]. The spiral graph is a new technique that is known to be highly suitable for representing large datasets and they can promote the recognition of fundamental structures of a given dataset [98]. This is an option to use when visualising the temporal features of disease specific data.

The time being visualised is vital in the visualisation of temporal data. There are two ways in which time can be described, e.g. linear time and cyclic time with time as the temporal primitives. Linear time is time that is identified by points on a linear time axis e.g. time in seconds (Figure 3.12). Sequence charts represent temporal data on a single time axis usually in the form of a straight line; these are known as timelines [98]. This is how time is commonly visualised for nominal or linear time series data [98]. The data values are marked and aligned with the time axis in a chronological order to display periodic behaviours [98]. The shape of the time axis varies for many developers. The straight line is suitable for representing linear temporal time dependencies. Besides using cyclic timelines, a designer can also choose to use this timeline to represent an interactive temporal visualisation of easily obtaining epidemiological data.

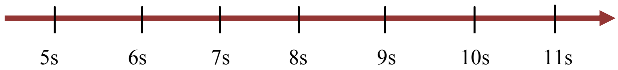


Figure 3.12 Example of a timeline for visualising linear time.

One problem brought about by line charts, is that of continuity, however this has been resolved by using circular charts. Circular time chart visualisations are used to represent cyclical data, so as to observe the most interesting trends that always reoccur at a particular time, e.g. over the year. Conclusions can then be drawn from similar trends that frequently occur at that particular time of the year (Figure 3.13). A combination of cyclic time and the number of cyclic passes, e.g. weeks and the year, is usually considered to be linear [98]. This aids the technique in emphasising the type of time for the features of a given dataset.

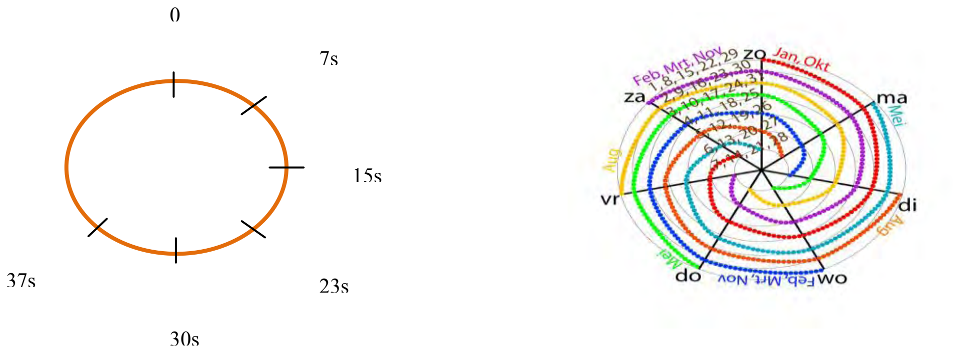


Figure 3.13 Circular time visualisations.

Besides the type of time considered in the visualisation of temporal data, the type of data is also important. The data can be nominal, ordinal, quantitative and a combination of all these for multivariate data [98]. Point charts represent two dimensional data with one of the dimensions being the axis to represent quantitative properties of the data in relation to the time series represented on the single time axis as the other dimension [98]. The data values are represented by points on the linear axis. Bar charts are similar to point charts except that the data is represented as bars instead of points (Figure 3.14). The use of bars instead of points clarifies the differences in adjacent values, especially for uneven values, and so the data values can easily be compared [98]. Line graphs are an extension of point charts. They differ in that the points of the point charts in this case, are linked by lines to clearly show the relationships and the decrease or increases in the data values [98].

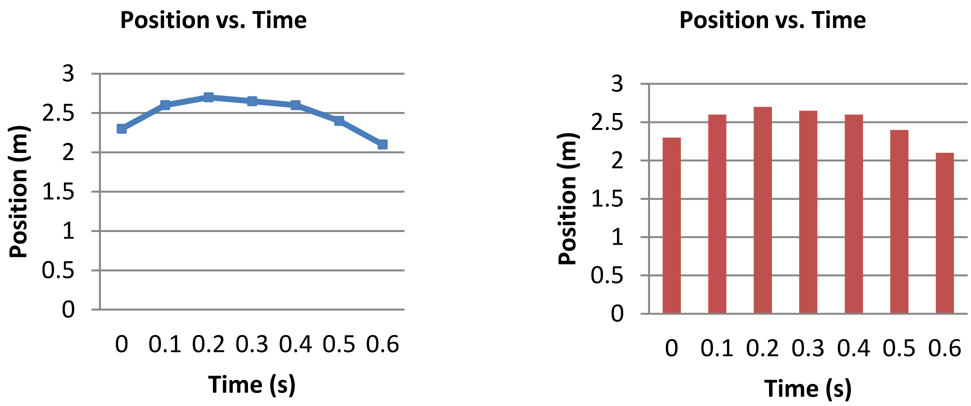


Figure 3.14 Point charts vs. bar charts to show position vs. time.

A single chart can combine two or more sequences of data to build a multiple bar chart with a line graph that also has points (Figure 3.15) [98]. For example, scatter plots are point dependent charts that represent change in time [52]. However these are restricted to 2-8 sequences of data in one graph or chart to avoid overcrowding the visualisation display [98]. A combination of two datasets with disease information from different areas can be easily compared to observe how the two areas differ in the number of disease cases reported.

Figure 3.15 Combination of bar chart and line graph for multiple datasets [98].

Circle graphs are techniques suitable for visualising quantitative data by using spirals with plotted lines, bars and markers on the circular area to represent any type of data (Figure 3.16). These are usually suitable for visualising quantitative data. Spirals must be accompanied by different attributes like colour, texture and size to distinguish between different values and for attractiveness. Spirals are successful for visualising circular data because of their ability to detect cycles and compare periodic datasets [98].

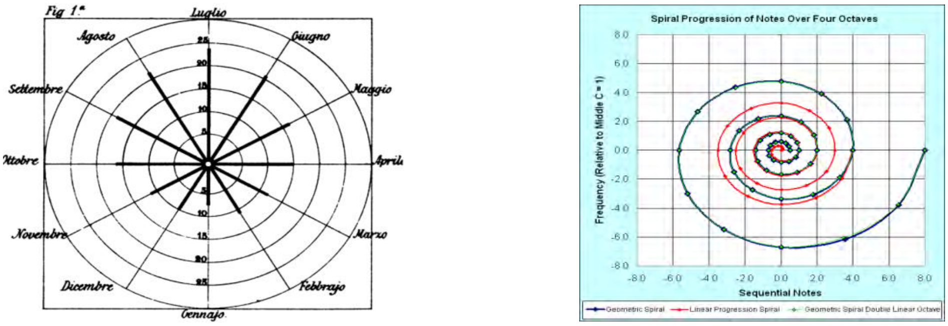


Figure 3.16 Examples of spiral circle graphs [38].

3.3.2.1 *Temporal Data Characteristics*

Temporal data has four important characteristics that depict change through time in temporal visualisations. These include the magnitude, shape, velocity and direction of change [33]. The change in magnitude is the calculated difference of measurement between two points. The shape of change is shown by the path followed by values of a dataset. The path can show upwards, downward or sideways changes. A user is able to observe if the values have changed or remained constant with time. Figure 3.17 illustrates the two characteristics, magnitude and shape of change, which depict change in time. From the diagram, the magnitude of rabies and influenza are approximately 10 and 18 respectively. This is achieved by subtracting the last value measured from the first value measured, e.g. from Figure 3.17, rabies starts at 17 cases and stops at 7 cases; the difference between these values becomes the magnitude. The shape of the lines for both influenza and rabies clearly show increases and decreases in the number of reported cases of the diseases.

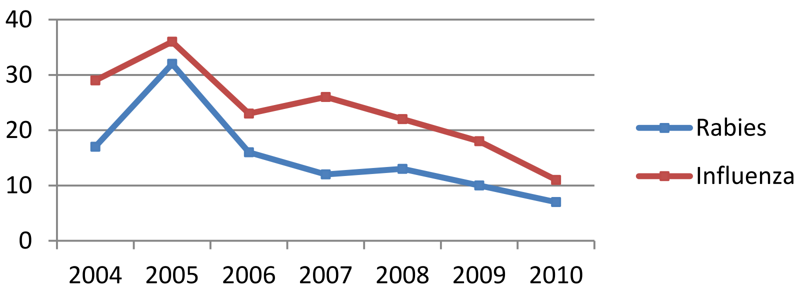


Figure 3.17 Line graph to show the magnitude, shape and direction of change.

The change in velocity depicts the rate or speed with which change occurs. This can vary between slow, moderate and fast. For two given datasets that are being compared care has to be taken because different slopes do not necessarily mean the same change in velocity

(Figure 3.18). To ensure that two datasets can be compared and show the same slope, we use a logarithmic scale (Figure 3.19).

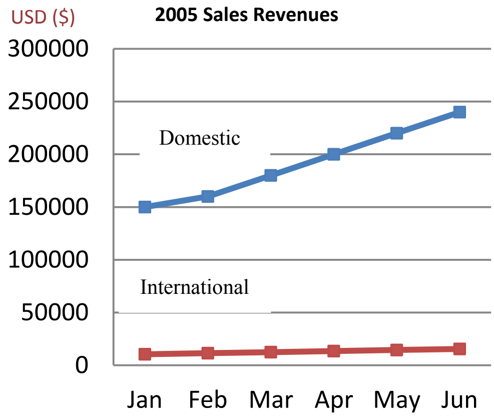


Figure 3.18 Velocity of change, adapted from [33].

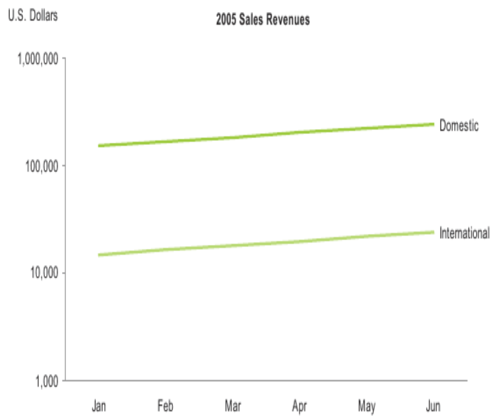


Figure 3.19 Velocity of change using a logarithmic scale [33].

If the data is to be correlated with other data then another visualisation besides line graphs should be used especially if many datasets are being visualised [33]. For example, scatter plots can effectively visualise two correlated datasets which have quantitative features [33]. Direction of change is the trend of data change. Usually a trend line is placed in the data to act as the basis for observing ups and downs of data along the line [33]. The line could be the average expected direction of data flow. The trend line on the graph shows the expected increase in the length of individuals as time passes (Figure 3.20). The line is created by finding the best-fitting straight line through the points and for accurate predictions, the position and slope are calculated using statistical techniques like linear regression. This prevents misleading results. Although trend lines are very useful in observing changes in data over time, which can lead to effective decisions, they have no scientific validity in extreme cases where other potential factors can affect the data and so require different decisions to be taken.

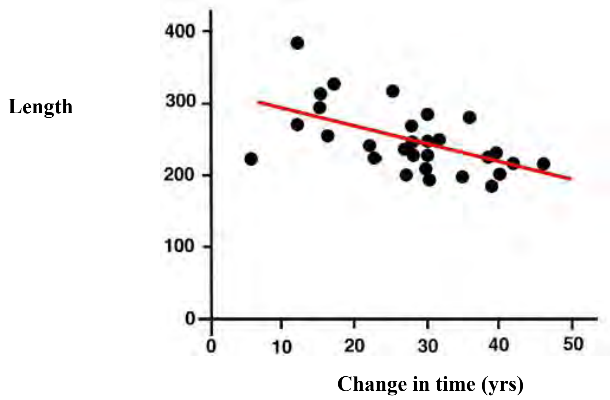


Figure 3.20 Scatter plot with a trend line to show length vs. time
http://webvision.med.utah.edu/book/the-electroretinogram-erg/the-electroretinogram-clinical-applications/.

Pie charts are circles that have sectors in them and they are used to illustrate proportions of object quantities usually in percentage form (Figure 3.21). These can be used in visualising the proportion of the type of disease cases e.g. dead, suspected and confirmed cases of affected animals or individuals. They are known as a good statistical tool but are criticised by many because if there are many sections, it is difficult to compare those sections or even compare two different pie charts that are related.

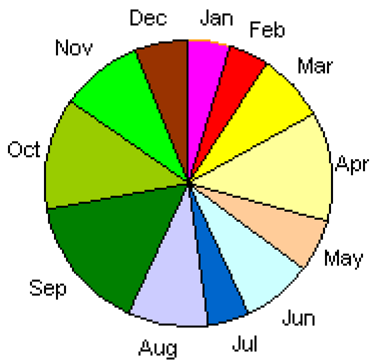


Figure 3.21 Pie chart use
(http://www.education.vic.gov.au/studentlearning/teachingresources/maths/mathscontinuum/mcd/M37508P.htm)

3.3.2.2 *Adding Interactivity to Temporal Data*

The visualisation of temporal data has challenges. One of the challenges becomes evident with the visualisation of large datasets [98]. This is because large datasets can result in overcrowded displays making the visualisation difficult to read. However, there are ways of dealing with this problem. This can be achieved by using the information hiding concept or by combining concepts like overview and detail or focus and detail [98]. Such concepts are characteristics of interactive visualisation. Information hiding as the term says, hides information that is irrelevant to the user and only displays information that is important [98]. Users are given the ability to specify what they want to observe and the system displays only that information. This promotes the visualisation of selected events and is known as an event based approach.

Interactions help users to think broadly about what they are viewing or what they could view [33]. The use of charts can be enhanced by using interactive practices such as scrolling, zooming, focusing and linking and brushing especially in large datasets [98]. Scrolling increases the area of view for large datasets that cannot fit on the screen but analysis is only possible on the visible area [98]. Zooming allows the user to increase the resolution of the display normally to view interesting areas of the display [98]. Analysis is however also limited to the visible area. Focusing and linking allows the user to perform other tasks on the selected area of focus e.g. clicking the areas [98]. Brushing involves using an input device to select a subset of data items usually to highlight the subset or to delete it from the view or to de-emphasize it. Brushing can enrich the display by providing more information e.g. on mouse over an area, a window can popup to give more information [98].

There are important aspects to be considered for the effective visualisation of time series data that have been compiled. These improve the analysis, comparison, contrast and summary of temporal data. The points include:

- Identifying the appropriate technique to visualise the different types of data.
- Using techniques that demonstrate visualisation capabilities for large datasets.
- Detecting periodic behaviours or trends in a given dataset.
- Supporting the comparison between various values of a dataset.
- Supporting the comparison of multiple datasets.
- Identifying distinct values in a given range of single or multiple datasets.

Gapminder (Figure 3.22) is software used for the animation of statistics. It can illustrate temporal visualisations effectively and it is an interactive visualisation that allows the user to change the data to view together with its characteristics. The data to be viewed varies widely; a user selects the kind of data they want to view, for example, health issues, population statistics, life expectancy statistics and so on. This makes it an application that is flexible and the user can view all the data statistics they have desired to know from one place. It has two views, chart and map view of data, depending on the purpose of viewing the data.

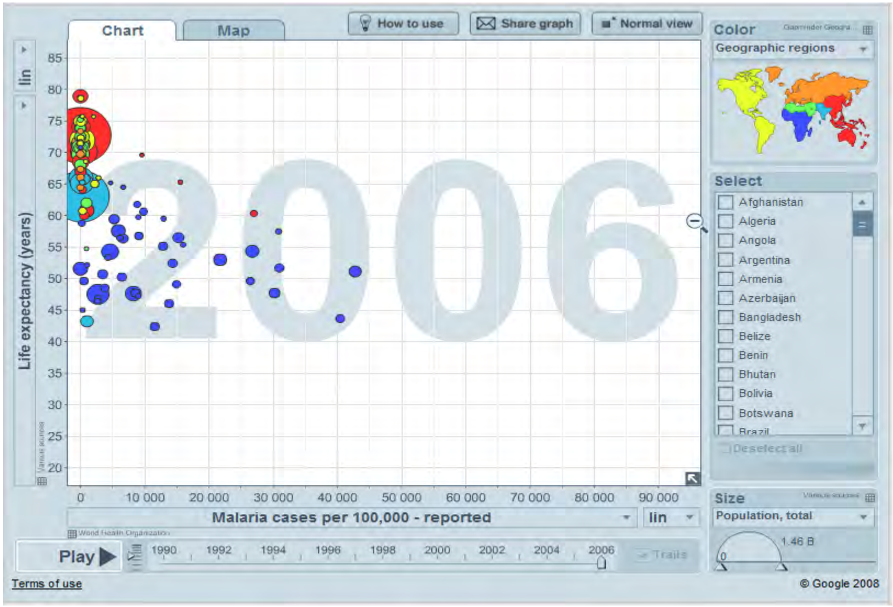


Figure 3.22 Gapminder
(http://www.gapminder.org/world/).

Gapminder has coloured regions that the users can select and even change according to their preferences. Temporal visualisations are made possible through the use of animations that can be user controlled. The user has the option to play the animation so that data values can change through a selected time interval. The user can also select times to view the data by clicking on the timeline. The time dates back to the 1600 thereby improving the epidemiological analysis of data. Because the data values can be many, it uses trails or links points using lines (line graphs) to prevent confusion about the data flow from one time to another. This has the ability to depict increases, decreases and constants in the flow of data. Each dataset is represented by a different colour for a particular region so comparisons of places are made easier. Symbol size is used to quickly identify and analyse values of respective areas.

A user can select one country to view for a chosen dataset type. The country is selected either from mouse-over or on the checkboxes on the side-line. As each region to view is selected, it becomes active by masking the colours of the other areas. This distinction between areas makes it easy to understand changes of data through time. To compare two areas then two countries are selected and compared together. Gapminder is a very good illustration of temporal visualisation through animations that are used. Being able to change time-to-view and see data changes through time is important in knowing how statistics have increased or decreased through time.

3.3.3 Spatial Visualisation Techniques

Though geographical datasets have become complex, they have also become easy to view due to the availability and application of visualisation tools to improve the strategies for information display and for better analysis mechanisms, e.g. GIS [36]. The techniques used to solve spatial challenges are mainly to uncover the structure and hidden relationships in data and to stimulate recognition [36]. Geospatial data is recommended for its ability to demonstrate structure and patterns within datasets. The GIS tool supports the visualisation of geospatial relationships and patterns [46]. GIS is software that represents earthly features like cities, roads and rivers on a computer. Its purpose is to visualize, question, analyse, and understand data about various activities [46]. The importance of relating data is to identify patterns so as to interpret and make sense of what is being observed. This in turn can lead to problem solving and taking immediate response to the problems.

Maps have been historically used to represent the spatial characteristics of datasets [42]. They are acknowledged for providing an excellent means for "visualizing and analysing geographic data, revealing trends, dependencies and inter-relationships" [47]. They make it possible to acquire, store, manage, and geographically integrate large amounts of information from different sources, programmes and sectors in search for unknown dependencies and answers to questions of the user [63]. An example is that two spatial data values can be understood separately but to understand them and discover relationships, it is easier to geographically locate the two values for comparisons [36]. When put together the relationship between them cannot be readily observed. The spatial representation of the two values can promote analysis and the discovery of a relationship which can help draw conclusions and make decisions [63].

There are different forms of maps that can be used. One example that is commonly used is choropleth maps, thematic and cartographic maps. Nowadays cartographic maps are considered better than choropleth maps because the size of each component of a map is proportioned to the population of that area [89]. Choropleth maps have one size proportion for all areas. Figure 3.23 illustrates the differences between the two map types. However because the effectiveness of cartograms when compared to choropleth maps in the visualisation of data is sometimes not evidently understood in some disciplines like the health field, cartograms are still not being used [89]. Literature research is still being conducted to compile the advantages and find reason for using cartograms for health data visualisation. Despite the differences, these maps are all mainly characterised by colour selections, data classification and the choice of units to display [89].

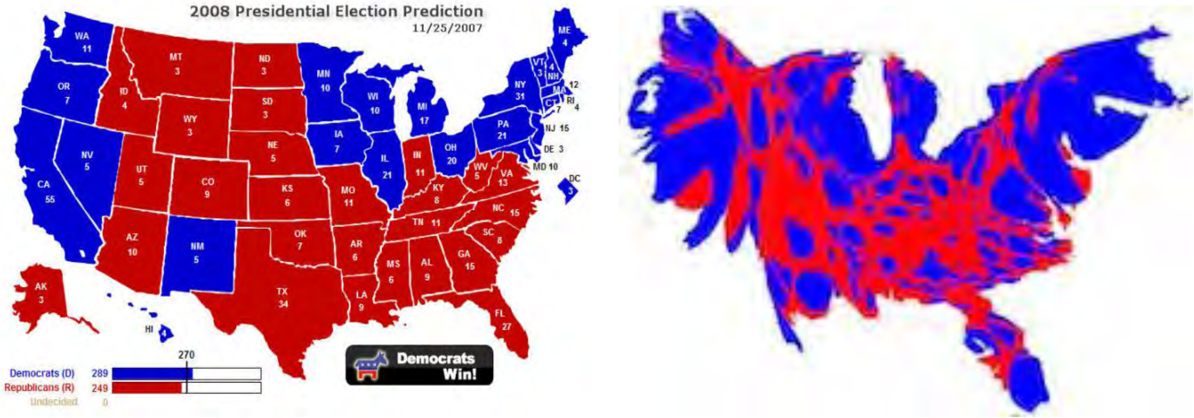


Figure 3.23 Choropleth vs. Cartographic maps
http://sarahpopesblog.blogspot.com/2011/04/nominal-area-choropleth-map.html.

Choropleth maps present components that represent states, municipalities, countries and census tracts [10]. They are mainly represented by colours that indicate the variation of the data being displayed [10]. As already stated in the visualisation properties, maps visualise quantitative or qualitative data. Quantitative data includes counts, ranks and derived values. These are usually represented on maps using symbols with well defined colour intensity and symbol size properties for the given areas [10]. On the other hand, qualitative data can be represented by colour hue and symbol shapes on maps. One therefore has to identify the data to visualise and then decide which symbols to use.

The importance of using colour intensity is that it brings order to the data being displayed; users can easily distinguish between two groups of values [10]. Figure 3.24 illustrates the use of colour to represent order in the area components of a map. The hue and lightness intensities are difficult to design especially for inexperienced cartographers and so the use of readily made sequential colour schemes is recommended [10]. Readers also have preferences when it comes to colour choices, they are known to find some colours more attractive than others [10]. Because colour blindness is a common problem, various tools can be used to correct the appearance of problematic colours; this is to ensure that a system caters for all users [10].

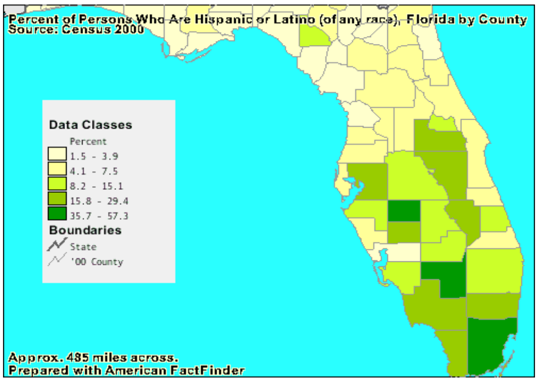


Figure 3.24 Illustration of colour intensity on a map

http://johnkeim.blogspot.com/2010/04/classed-choropleth-maps.html.

Besides the choice of colour when using maps, data can be grouped to form classes that represent distinct levels of information. Colour and classes are often used together e.g. data values ranging from 1-100 may be grouped as a low class represented by a green colour [10]. Depending on the dataset being used, data can be classified using quantiles or equal intervals, use of standard deviations and other methods like Jenks which minimise variation within classes and maximises variation between classes. Figure 3.25 illustrates the differences of some of the ways of data classification. These differences in the number of values in each class show how the choice of data classification is important. The data on the side of the classes represents the number of values per class interval.

Deaths /1000	Num/class
23.59-40.61	391
21.55-23.58	391
19.23-21.54	392
0.0-19.22	390

A. Quantile

Deaths /1000	Num/class
30.47-40.61	22
20.32-30.46	980
10.16-20.31	556
0.0-10.15	6

b. Equal intervals

Deaths /1000	Num/class
26.01-40.61	144
21.67-26.00	622
17.73-21.66	570
0.0-17.72	228

c. Jenks classification

Figure 3.25 Classing data to show how colour intensity is used to represent data, adopted from [10].

Each method results in a different pattern of results especially if it has extreme values that are far from the rest of the other values [10]. Such extremes must be grouped separately from the other values. When using colour scales, little variation between shades of a chosen colour and categorising the data into many classes can be problematic hence care should be taken in having the correct number of classes to represent data, usually a maximum of seven classes is recommended [10]. A high number of classes may cause confusion from users because they might not be able to distinguish between the colours of different classes.

Different classes of data can also be represented by proportional symbols [10]. This involves the visualisation property of size in the choice of variables to use. Each symbol size represents a range of data values. When the symbol sizes are assigned to classes, they are known as graduated symbols. An example is when one dot represents 100 disease cases. Careful considerations are important when using proportional symbols because if the dataset comprises of large data ranges it becomes impractical to use in demonstrating change in quantities [10]. These symbols are placed on the areal components of maps e.g. on the cities and points or in the centre of the areas. Figure 3.26 shows the proportional symbols with 1 Walmart shop being represented by the smallest value and the biggest circle representing 100 Walmart shops found in USA.

Figure 3.26 Representation of proportional symbols [38].

The alignment and proximity properties of the symbols on the maps must also be studied to improve the overall design of the system [10]. The ultimate goal is to develop an interface that addresses all problems of geographic visualisation of a given dataset. This is achieved by mainly focusing on symbols that are being used, legends of the map, overall display of objects on the interface and interactive abilities with clear boundaries on what can and what cannot be viewed [36].

3.3.3.1 *Adding Interactivity to Spatial Data*

The point of having geographic visualisation is because of the cognitive and problem solving that results from manipulating spatial techniques like maps. This has been improved by developing maps that are interactive and highly interactive [63]. Interactivity facilitates two way collaborations between computers and users by using languages that both sides can understand [36]. The user can instruct the system by selecting a region of the map and data about that area is then given in detail. Figure 3.27 shows a selected region of New York, data about New York is shown in a small window which only appears when a user clicks on that region. The modern change in the way that maps can be manipulated eases the process of viewing data in real time [63]. The instant changes to what can be viewed and the number of components to view prompt the users to be analytical and so make decisions after exploring the data from all angles.

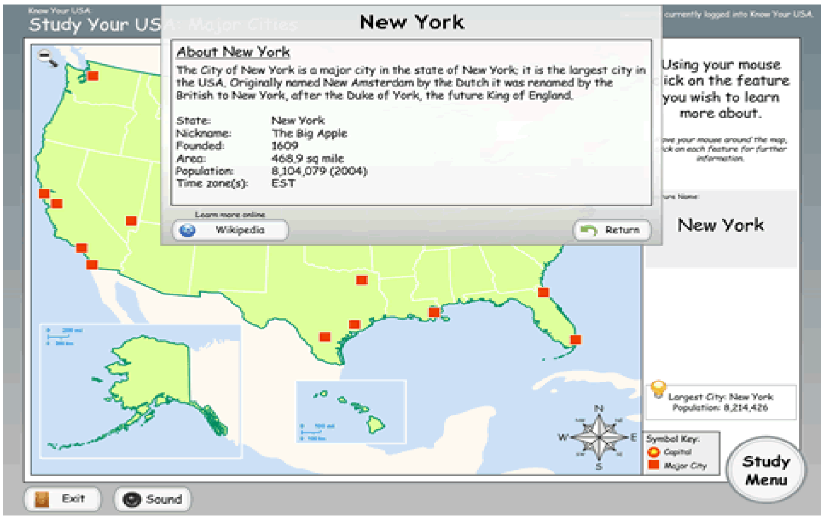


Figure 3.27 Demonstration of interactivity [18].

Interactivity is supported by the application of filters through queries that answer questions like what and where and also show what collaborates in the values of a dataset [36]. The process involves the user requesting information and the interface connecting the user to the computer filters the results and displays them to the user [77]. This makes it easy to search a large database which would otherwise be very time and energy consuming [77]. Although interactivity is an excellent way to promote human computer interaction, it has the ability to mislead users therefore during design one has to determine what they want to retain or ignore when using the queries to select data [46].

Currently GIS is one of the spatial tools used to visualise environmental data interactively [77]. Environmental data is characterised by the change in space in a particular time. Most of the principles and properties of visualisations that have been discussed in this chapter are demonstrated in GIS systems. For example, GIS uses sized circles to differentiate between data values and it also uses coloured symbols to show different datasets. GIS systems visually present data in a form that users can understand and use for analysis. They can easily manage, manipulate and display spatial data [77]. However GIS systems have the disadvantage of not being easily integrated with other systems and it is mainly useful to users with knowledge of how the system works only if they have the software [77]. Figure 3.28 shows an example of a GIS map application known as Google Earth.

Figure 3.28 Google Earth that has been created by GIS software

http://www.gearthblog.com/blog/archives/2008/05/more_gis_information_for_google_earth.html.

Interactive visualisations are usually linked to large databases as a source of information. This places high demands on the graphical tools and the software required in visualising data. Interactivity can be summarised by saying it is the ability of the computational system to offer deeper understanding of a dataset by the user, interact with other users, promote the user to control the system and provide tools for visually presenting spatial data and exploring information from databases for easy analysis so as to give the user enough information to draw conclusions [36, 76]. The important ways of demonstrating interactivity is by using animations, timelines and the visualisation tasks discussed at the beginning of this chapter. These included overview, zooming, filtering, details on demand, relational, historical and extraction characteristics. Details on demand are further described by concepts like focusing, brushing and linking. Focusing is when a user has the ability to highlight subsets of data either through programming code or through user actions like keyboard input [62]. Brushing highlights data by selecting them on the display interface using a computer mouse. Linking allows the simultaneous highlighting of objects for multiple views [62].

3.3.3.2 *Principles of Effective Interactive Mapping for Disease Incidence Data*

Although they have visualisation properties, maps also have their own principles that support interactivity. These principles indicate that one cannot design a map for visualising data without following certain principles for guidance. The similarity observed from the general map principles with some of the visualisation properties notify us that these can work together to build a great design. When viewing disease data, these principles are designed to help interpret map visualisations and promote rapid understanding of information. It would be unsuitable to design a site that requires the user to think deeply about how the map is designed or to criticize the way that the components are positioned. The principles that are considered important when visualising disease incident data include [21]:

1. **Choose the optimal aggregation scheme:** This principle states that one has to set a temporal scale that is easily visible. The scale can have a high frequency such as daily, weekly, or monthly occurrences i.e. have a timeline for the data.
2. **Choose the correct colour scheme and legend:** The aim here is to minimize the user effort in locating and comparing the key information on the interactive maps. This principle also involves the use of colour hues and their degree of saturation. Each colour gradation, that usually demonstrates different classes of data, must be easily identified and distinguished to bring clarity of distinct data values.
3. **Choose the correct frame speed:** Speed should be adjusted to a suitable pace depending on the size and complexity of the data being displayed on the map. This is because time is needed to focus on the variables used on the map, to understand resultant variables and their spatial patterns and to look for relationships between data variables.
4. **Think like the viewers:** This principle states that the usefulness of interactive maps is in the ability to make the map simple, informative and attractive. Since the map is built for users, the map must meet the requirements of the users as much as possible. This principle also discusses the challenges and solutions associated with user watching and learning from interactive maps i.e. disappearance, attention, complexity, confidence.

5. **Incorporate control interface:** Interaction with interactive maps, such as the use of buttons like play, stop and pause control the information to view thereby allowing users to analyse the data at their own pace.
6. **Understand the limitations of interactive maps:** This principle states that "interactive maps must represent a delicate balance between being useful versus incomprehensible from cognitive and perceptual information overload" [21]. This means that it should be balanced so that the interactivity can improve the system instead of limit it.
7. **Be open to improvement:** Interactive maps require careful interpretation and they should easily accommodate improvements into the system. For example, if another dataset has to be included into the system.

3.3.4 Spatio-temporal Visualisation Techniques

The spatial and temporal visualisations can be combined to form spatio-temporal visualisation. They are popular because most datasets show relationships between changes in time and particular spatial regions. This type of visualisation is known to be useful for environmental monitoring, impact assessments, decision making, real time navigational systems, resource management and so much more [90]. Epidemiologists are mainly concerned with the historical exposure to environment contaminants and the factors that influence the distribution of diseases. This is because such information helps in discovering disease trends and patterns and the relationships between time, space and diseases thereby bringing out information to improve previously used preventative measures during outbreaks. Visualisation tools can assist in this because they are stated to have the ability to examine spatial and temporal relationships of the environment [65]. Figure 3.29 shows how temporal and spatial visualisations have been used together to demonstrate a spatio-temporal visualisation. The time selection is through a drop down list and the spatial visualisation is through a map. As time changes data on the map also changes.

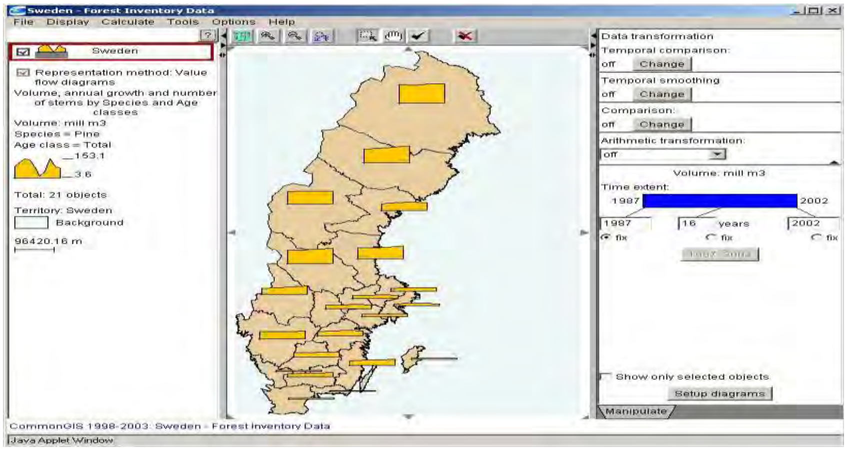


Figure 3.29 Illustration of spatio-temporal visualisation [38].

As noted by Stephen Few, tools are being used for answering the “what, where and when” questions [33]. GIS as already stated has the ability to answer the “what and where” questions e.g. by showing the location of problems in hospitals, schools and industries [46]. However if a user wants to understand when the problem started and how they have improved over the years it becomes problematic to use GIS. Only animation tools are used to depict change over time. This is time consuming and can result in errors because each map has to be created individually.

Due to such problems, spatial and temporal visualisations have been integrated to answer “what, where and when” questions. These visualisations demonstrate a continuous transition over time enabling effective analysis, evaluations and querying of datasets [65]. One visualisation tool used for spatio-temporal datasets is life-lines [65]. This tool is used to show different categories and incidents of events arranged along an adjustable timeline. This tool identifies possible exposures to problematic areas at any point in time, reduces the chances of missing information, streamlines the access to details and is always simple and tailorable to various applications specifically the health care projects in this case. Spatio-temporal visualisations support datasets in which time is critical e.g. disease outbreak surveillance [65]. The tools used to support this enable users to examine spatial maps for patterns at any specific time.

The continuous transition over time is promoted by interactivity. Since the source of information is usually a database which stores large amounts of data e.g. with fields that answer the “what, where and when”, the answers or results can be interactively re-visualised according to user specific queries. Visualisation interfaces to support this must therefore be carefully built to assist in the display of the results. Interactivity in maps is also demonstrated through animations that result from static maps. Interactive maps are built from the concept of animations. Because of this, there are three kinds of spatial maps that have been commonly used in representing geographic data on the web and these include static, animated and interactive maps.

Static maps are maps that can be viewed and copied or printed but are not editable. The advantage of this approach in designing maps is that the data has been analysed and the user can easily incorporate them in documents [71]. However, these advantages also bring difficulties because all decisions behind the data on the map have been completed by someone else and therefore the visualisation might not meet the user's specific needs. This means that data is for an exact time and hence the map does not demonstrate a continuous change over a given time period. One has to view many static maps to view change in time. Because of this, static maps are only suitable for answering spatial problems on datasets that can be represented on one map for a particular time. Figure 3.30 demonstrates a spatial map that visualises the West Nile virus in the year 2008. This map clearly answers the "what and where" questions. The "what" is shown by the description of the map and the "where" is indicated by the red and blue shaded regions that respectively represent positive and negative cases of the West Nile virus. The blue areas represent areas that have not been affected positively by the virus.

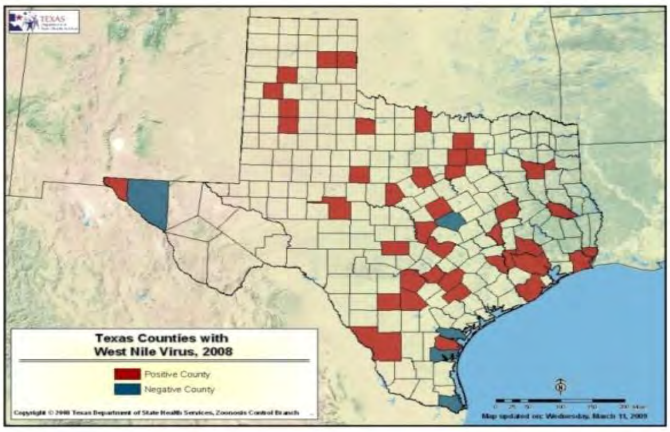


Figure 3.30 Static map of Texas showing areas affected by West Nile virus
http://www.dshs.state.tx.us/idcu/health/zoonosis/mapping/maps/.

Animated maps are closely related to interactive maps; however the success of animated maps depends on the time frame of viewing the data given [71]. Users need time in between two different images so as to study the information each picture displays. This means that the time interval should be neither too slow nor too fast for the user to obtain useful data. If the animation runs too slowly then the user might get bored with viewing large sets of data. If the animation is too fast, relationships become difficult to observe with rapid changes to the data values. This can be frustrating to the user since the interface cannot be interactively controlled.

Figure 3.31 shows a map that plays an animation with data from the 26th of April to the 14th of May with a time interval of 1-2secs for data change. At this rate, it is difficult for a user to observe all areas and analyse relationships each time a new picture is shown. Gapminder gives an example of avoiding the issue of speed. This is because the speed of the animation is controlled by play and stop buttons. The rate of movement is also controllable, allowing a user to choose a fast or slow pace when viewing data thereby promoting user interaction [62]. This means that animations when combined with controllers can effectively demonstrate changes and relationships between data values as time changes. Figure 3.31 also uses colour intensity to clearly show the severity of reported cases observed in each region.

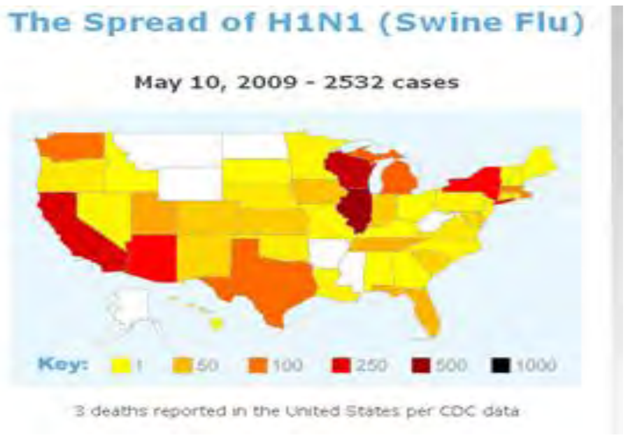


Figure 3.31 Use of animation in the representation of the H1N1 outbreak dispersion.

Interactive maps are innovative illustrations of geographic data that show changes over time [21]. Interactive maps permit the users to access the data and tools needed for manipulating data [62]. The user has control over what they view when they want to view it. Because of this the “what, where and when” questions to support spatio-temporal patterns are answerable. Unlike animated maps, interactive maps consist of control buttons for stop, play, move forward or back one frame, and replay which assist the users to investigate the interactive map at their own pace. Rather than simply recognize fixed disease patterns, interactive maps allow us to investigate variable trends thereby increasing the ability to understand problems like disease outbreaks e.g. where they started and when they started and how they have changed over given periods. Interactive maps probe the cognitive abilities of a user and so lead to decision making that can solve many problems [63].

Figure 3.32 demonstrates how spatio-temporal features can be visualised. This is supported by the combination of the timeline and the map. The "what" is answered by the indication that the map is visualised for understanding disease patterns and the "where" is shown by the areas of the map. Each affected region is highlighted and easily observable. The timeline answers the "when" question. This is because the user can choose the time for when they want to view the data. The play button at the bottom shows the transition of data values over the weeks of 2009. The user can 'stop' or 'pause' the animation to clearly observe changes at their own pace. The presence of the graph and the pie chart and data tables promotes the comparison and contrasting of data to improve data analysis.

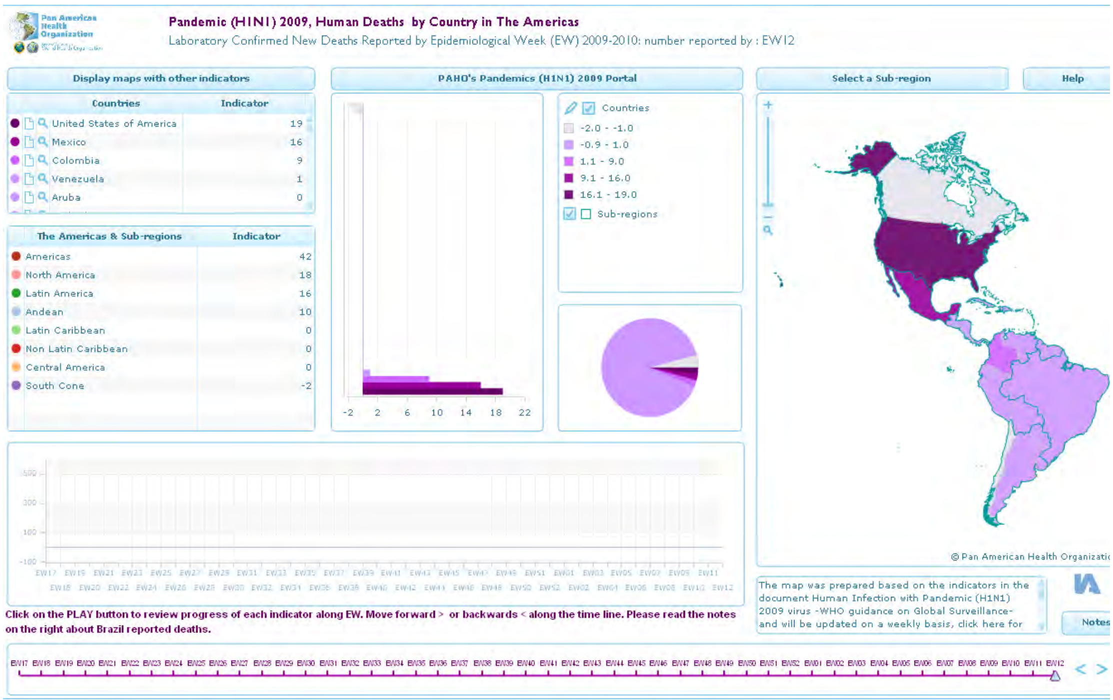


Figure 3.32 Interactive map which changes according to user requests
http://new.paho.org/hq/images/atlas/en/atlas.html.

In summary, static maps allow the identification of spatial patterns that exist, recognizing where they exist, how they exist, and providing a platform for comparing and contrasting the spatial differences in the datasets. Animated mapping was developed to improve static maps; however interactive mapping provides better alternatives to what animated maps were aiming to achieve [59]. In addition to what static and animated mappings offer, interactive mapping deepens our understanding because researchers can extend their investigation of when and where diseases emerge, to how they spread, for how long or where they persist, and so identify differences in their spatio-temporal features.

3.4 Disease Visualisation

Since the literature behind visualisation has indicated its ability to visualise large amounts of information to identify relationships and data trends, we therefore attempt to incorporate the visualisation techniques that support the delivery of disease surveillance data [36]. Examples of successfully deployed disease visualisations include systems like the ones on the HealthMap, PAHO, Flu Tracker (Figure 3.33) and GLEWS websites. The success of information visualisation demonstrates the ability to transform data into useful information that can be used during zoonotic outbreaks. The large amounts of zoonotic related data are often difficult to evaluate, compare and contrast easily. The volume of data makes it difficult to observe the disease outbreak conditions in order to provide users with quick precautionary measures, hence the need for proper visualisation techniques.

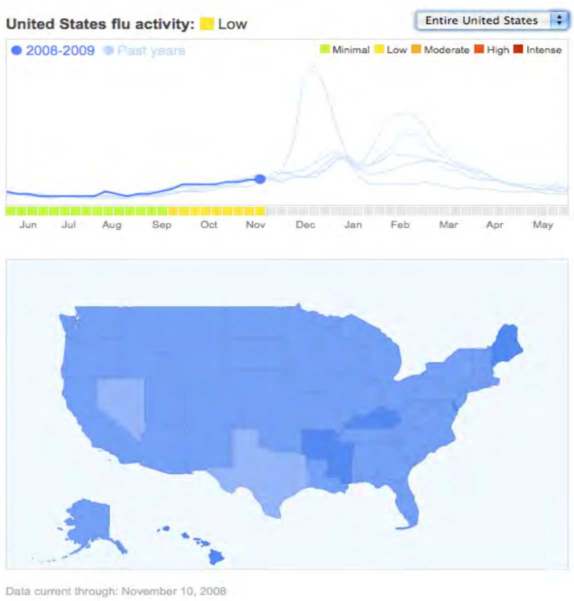


Figure 3.33 Successful use of spatio-temporal visualisation with Flu Tracker (http://flutracker.rhizalabs.com/).

Datasets like disease information are being linked with spatial and temporal characteristics to help clarify and answer problems [36]. This was not possible in the past but now it is of importance because it improves the efficiency of data analysis [36]. The visualisation techniques discussed in the previous sections can support disease information visualisation and so make it easier to manipulate data in near-real-time. This is important in health environments that are trying to minimise the effects of disease problems on lives.

The importance of using new visualisation to display zoonotic disease information is because there is need to improve or build systems that can easily visualise where and when an area is facing an outbreak. Modern visualisation technologies allow the delivery of near-real-time intelligence for a variety of disease information to suit all kinds of people with different needs. Traditional technologies like phones, paper based reports, faxes, and more cannot be easily manipulated. Excluding phones, the disadvantage of these technologies is their inability to allow a two way communication such that the user can ask questions and immediately get feedback. On the other hand, the use of new technologies like web-based information systems is more advanced to promote the manipulation of data to suit the needs of the user since a user can ask questions and instantly obtain results [31].

Spatial visualisation is specifically useful for emergency issues and zoonotic disease outbreaks are an emergency [24, 54]. This is because emergency issues are critical whether to lives, property and more and if the extent of the problem is clearly understood then the chances of preventing major effects are increased. For every disastrous event, like tsunamis, and earthquakes, that can occur it is important to know the location and distribution of the problem so as to be able to send rescue equipment before more damage occurs. Because of this, spatial visualisation is predicted to enter more disciplines in future [24].

The rapid response to disease outbreaks requires the prompt and continuous accessibility of information usually in the form of case statistics in affected areas and epidemiological reports [95]. Maps can readily show affected areas during outbreaks and one can analyse the data just from looking at the affected areas [54]. Timelines can show when regions were affected and this is important in determining if the disease is decreasing or increasing over time and in observing the times when the disease is at its highest levels. Because of these characteristics, spatio-temporal visualisations have become an important way of easily identifying the trends of outbreak diseases and are therefore supported in the visualisation of disease surveillance information [92].

The importance of maps in the reporting of health issues lies in their ability to depict change through the trends, dependencies and inter-relationships they illustrate [54, 59]. The visualisation of disease cases on a map can offer clues about the source of the outbreak. It is difficult, especially for the public to memorise the positions of affected areas around them. Maps eliminate this problem by enabling one to relate different geographic areas. Maps have evolved to reference information not only by space but also over time periods due to their interactivity. This has created new opportunities for analysing information thus following variable patterns in space over a lengthy period of time.

Nowadays, maps are being designed in ways that promote human-computer user interactions [91]. Adding an interactive element to maps makes them more flexible when choosing the information to view considering the different details each user may need to view about diseases. Users can control what they want to observe as opposed to viewing what developers think they want to view [91]. An example is that a user may want to view the diseases in one region of the country as opposed to viewing the diseases in all regions. This is achieved by developing an active connection between storage places, like databases, and maps thereby enabling automatic updates to be reflected on the maps as per user requests.

For problem solving processes, as already discussed in previous sections, time is critical for environmental problems like disease outbreaks. Because of this maps are combined with temporal visualisations to improve analysis, epidemiological searches and support the advantages of spatio-temporal visualisations. Since disease outbreak data is mainly characterised by place, time and disease attributes like name and species it affects, it becomes suitable to incorporate spatio-temporal visualisation features into disease surveillance data for quick and efficient analysis of data. Rapid analysis will promote rapid decision making and rapid responses to deal with affected areas thereby reducing the outbreak impacts.

Generally, data analysis is the process of summarizing data into useful chunks that can aid in making decisions and making conclusions. Visual analytics on the other hand is a term that describes analytical reasoning that comes due to data analysis on visually interactive interfaces [20]. Visual analytics is known to “integrate new computational and theory-based tools with innovative interactive techniques and visual representations to enable human-information discourse" [20]. Because of interactivity, immediate analysis of data is made possible which can hasten the way that disease outbreaks can be controlled. Some of the important reasons for disease analysis are to:

- Understand trends, patterns and view past and present situations of diseases
- Determine events that have caused current disease outbreaks
- Discern future exceptional possibilities or routes to take from the current observations
- Examine current events for warning signs
- Determine the intended action to follow in cases of outbreaks
- Support individuals in making decisions during crisis

It is paramount that the features and properties of visualisation are incorporated for the purpose of solving problems brought by the presence of zoonotic diseases. This is because during outbreaks where there is uncertainty, time limits, lives and animals at stake, decisions have to be immediately taken from the gathered data about the status of the outbreak. If the data used in decision making is easily extracted from the mass of data and can easily be analysed and understood in a limited time frame, then decisions, awareness and preventative measures can be taken quickly. Since traditional methods of disseminating data are still in practice, new technologies, like web-based visualisation techniques, should be incorporated to improve, complement their sluggishness and be alternatives in distributing data more rapidly. The discussion of these techniques in this chapter supports their incorporation into disease surveillance for better systems.

3.5 Conclusion

This chapter has described what visualisation is and why information needs to be visualised. It highlights the important properties of good visualisations and describes each of these properties in detail showing why it is important to consider them when designing an interface that represents complex forms of data. From this chapter, temporal, spatial and spatio-temporal visualisations have been identified as important aspects of information visualisation and relevant features of disease information systems. For any system that has spatial relationships and is concerned about change in time or comparison of data, maps, timelines and charts should definitely be part of the design system. Due to great advances in technology, the importance of interactivity characteristics in visualisation interfaces is highlighted and explained in detail to demonstrate its importance in promoting user to computer interaction. This chapter has shown that static visualisation techniques are a limit and hindrance to obtaining more information on any interface. Lastly, the chapter observes the general information about visualisation techniques and suggests the ones that can be suitable for representing disease surveillance data. The next chapter will analyse the visualisation techniques that are currently being used on the web and compare them to the findings made in this chapter.

4 Website Analysis

4.1 Introduction

As already stated in Chapter 3, several visualisation techniques have been found favourable for visualizing disease surveillance information. Since the aim is to propose a web-based prototype system, the collection and analysis of web-based reporting systems that are created by various countries, which are used for reporting disease information during outbreaks, can provide detail about the current state of web-based visualisations. Following the observations made in Chapter 3, the visualisation techniques found to be suitable for representing disease information included analytical, spatial, temporal and spatio-temporal visualisation techniques. This chapter therefore investigates the use of these visualisation techniques on selected local and global web-based systems from both developed and developing countries such as the Chief Directorate reporting site which is a national specific site for South Africa and GLEWS which is a worldwide disease reporting site. It also seeks to observe the disease information that is displayed on the visualisation techniques with reference to the suggested design information for displays from Chapter 2.

The investigation involves observing how web-based systems are designed for disease reporting, what attributes they present and whether they are using the visualisation techniques that literature highlights as important for effectively providing information to the relevant audience. The audience usually comprises of the veterinarian practitioners, the government and the public. The purpose of this is to examine the application of visualisation in the delivery of disease surveillance data on web interfaces. This analysis is important because thorough literature research around similar systems can effectively guide this research since other organisations have attempted using the web to report zoonotic disease information. The results obtained may assist in proposing and developing a similar system that is tailored for the South African needs of reporting zoonotic disease information during outbreaks.

4.2 Methodology

In order to perform the analysis on the websites that are used for reporting zoonotic disease information, currently deployed websites that are used for reporting disease information were selected. This is because the system to be proposed should also be a web-based system. The website analysis was conducted for the purpose of understanding the system requirements found on currently deployed disease reporting systems. Only websites that provide infectious disease reports were included in this investigation. A majority of the sites are globally recognised sites that report diseases across the world. The remainder of the sites are those that are created for reporting regional disease information that is usually specific to a country or town. A broad as possible collection of disease reporting websites were surveyed for this investigation. Due to this, it should be acknowledged that other websites that are not used in this analysis could also provide valuable information about disease reporting systems. Guided by a research conducted by Pappas, et al., the criteria used in choosing the websites included:

- Freely accessible websites.
- Regularly updated sites (evaluated through the 'last updated' date on the website).
- Websites that focus on zoonoses or any other infectious diseases.
- Information relevant to the animal health authorities and the general public.
- Regional or global websites.

Forty eight websites were found for the purpose of this analysis (
Table 4.1). The chosen 48 websites are used in this investigation because they are immediately available on the web to supply information about disease outbreaks and other related information. From the total of 48 sites, 40 of the websites are sites that are not specifically created for the needs of South Africa. A detailed list of the 40 global websites used is given in Appendix A. Pappas, et al, studied content of the available WWW resources on zoonoses. According to Pappas, et al.'s research, a list of 54 readily available websites that specialize in the delivery of zoonotic health information is given [69]. However, because five out of 54 of the websites were still active by the time of this investigation, only these five were included in this analysis, the other 35 websites were found from the internet or through referral.

Table 4.1 Breakdown of how the websites were chosen (x = 0).

Origins of site found	**Number of sites found and used**	**Sites found but not used**
Sites from Pappas's paper	**5**	49 (Commented on by Pappas but not used in this research due to being no longer available)
Randomly found from the internet (but not from Pappas' paper)	**35**	**X**
South African Sites *Province sites* *Country sites*	 **7** **1**	 2 (Not available for use) **X**
Total number of sites used	**48**	

The other 8 websites used in this analysis are taken from the currently deployed South African websites (
Table 4.1). Each South African province has a website that is used to report disease information for its region. However, only seven out of nine provincial websites of South Africa were included in this research because they were active and in use, the rest were inaccessible. An additional site that was recommended as important for reporting diseases in South Africa was also surveyed to make a total of 8 South African sites. The purpose of observing the South African websites is to observe the visualisation techniques used and the system requirements of disease reporting systems of the country. The 8 South African websites are studied separately from the 40 websites that are not only dedicated to South African needs.

Each of the websites was studied in great detail to observe if they use appropriate visualisation techniques for disease reporting, according to Chapter 2 and Chapter 3. The study also included identifying the attributes that Chapter 2 has stated as necessary information in disease reporting. The results obtained were captured into a table to support analysis of the sites. This made it easy to compare and contrast the information found on the websites so as to determine the figures behind information that is displayed on different websites. The analysis aids in discovering if the visualisation techniques or variables that are considered suitable, as studied in Chapter 3, are being utilised and if they offer useful information (Chapter 2) to users of such web-based systems. This is important because visualisation techniques that clarify information are significant in sending the reported message to the users.

Counts made of sites that use the spatial, temporal, spatio-temporal and analytical visualisation techniques can provide an insight of what is commonly used, and if most of the sites should be indicating use of the observed characteristics or visualisation variables and techniques. To perform this, each characteristic of the gathered information results is worked out into totals (e.g. the total number of websites that provide information comparison purposes). Each of the bar charts used shows percentage counts of selected disease attributes; these attributes are derived from the disease information obtained in Chapter 2 and the common information observed from the websites used in this analysis.

From the literature around visualisation, Chapter 3, we already know the visualisation techniques that could be appropriate for reporting diseases. From Chapter 2 the information that should be displayed when reporting zoonotic disease information is also suggested. This investigation will therefore look out for spatial, temporal, analytical or spatio-temporal visualisation techniques used for disease reporting and the information that they should display. This is mainly to understand if the most effective visualisation techniques are being applied when designing systems for disease information reporting. It also helps determine how information delivery can be improved by encouraging the adoption of the traits found on the observed websites by new developing systems.

4.3 Limitations

It was very challenging to find the major disease reporting websites. This is seen from the websites that are studied by Pappas. Most of Pappas' sites (49 out of 54) considered to be related to zoonotic disease information were not available at the time of this investigation which led to their exclusion. The other major problem about availability of the sites is also observed from the fact that even after this investigation some of the sites (3) that were used in this analysis have become unavailable.

4.4 Results

The first analysis was conducted on websites that are found globally but outside South Africa. This included 40 websites that are mainly developed for the European and American regions. After observing the selected websites for available visualisation techniques, three types of visualisation techniques were found to be most common. These three visualisation techniques also represent the observed techniques that are considered appropriate for representing disease information according to Chapter 3. The three visualisation techniques observed from this investigation include charts that fall under analytical visualisation techniques, maps that fall under spatial visualisations and tables that can partially fall under both spatial and analytical visualisation. Because temporal visualisations cannot work on their own without other data, they cannot be observed individually and therefore they will be observed together with the spatial or analytical techniques. This is also because for any information viewed, relevant time should be stated. Some websites have a combination of two or more techniques to visualise data. Each occurrence of a new technique is tallied, meaning that there can be more than one visualisation technique on each site but each is counted separately from the other. The summations of websites that use any of the selected visualisation techniques at any particular time are counted to determine the proportions of different visualisation techniques for comparison and analytical purposes. This information helps to reach a conclusion about visualisation techniques that are currently being used.

25% websites indicated the use of charts to report disease information. 65% of the websites use maps to report disease information and 28% websites use tables for the same purpose (Figure 4.1). The remainder of the sites still use only text to describe data and these make up 23% of the 40 websites used in this investigation. The count observed from the websites show that maps are the most common visualisation technique across all websites.

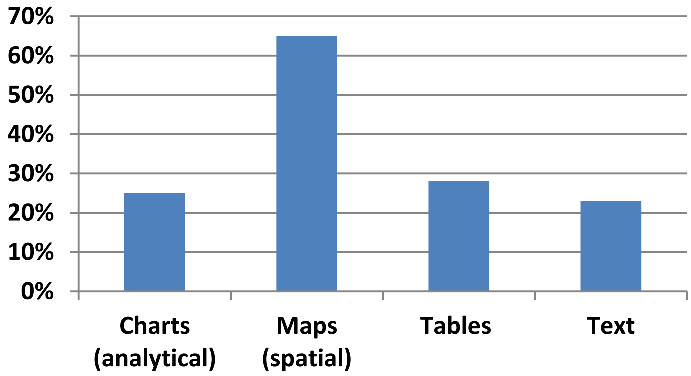


Figure 4.1 Number of websites representing the visualisation techniques they use.

Each class of the resultant visualisation techniques was decomposed to gain more understanding about their use. This involves analysing the type of maps used or understanding the different types of charts or tables used and observing the information found on each of the techniques. Since this research seeks to avoid heavy text-based websites, the sites that use text only to report information are useful only to provide clues on the type of information to report. The following sections give the results observed from this investigation.

4.4.1 Types of Maps Used for Visualising Data

This study centres on the 65% of the websites that were found to use maps as a visualisation technique for reporting diseases. These websites are studied to observe the type of maps that they use. As already discussed in Chapter 3, maps are categorised into three, i.e. static, animated and dynamic map types. Each of the sites was therefore studied and the type of maps that they use were observed and counted.

The results indicated that 54% of the maps are static in nature, 38% are interactive or dynamic maps and 8% are animated maps (Figure 4.2). From the results, there seems to be a high number of sites that use static and dynamic maps with static maps (54%) being the commonly used maps for visualising infectious disease information. Animated maps (8%) are the infrequently used map types.

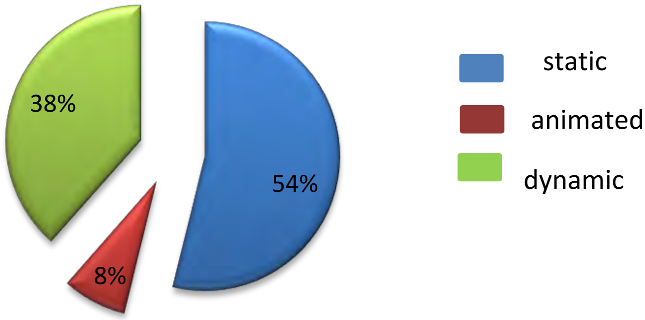


Figure 4.2 Data showing the types of maps used by the 26 websites observed.

4.4.2 Attribute information of Maps

Since visualisation is mainly to display abstract data [19], the information that visualisation techniques display is very important and essential for use during outbreaks. Users need simplified information that is readily visible at a glance. The information known to be essential to users includes the location of the disease outbreak, the number and status of affected animals or people in an area, the severity of the outbreak and preventative measures (Chapter 2).

Figure 4.3 shows a summary of the attributes observed from the websites that use maps to visualise zoonotic disease information. As already stated the x-axis attribute labels of the chart are taken from the common information observed from the sites and data gathered from Chapter 2.

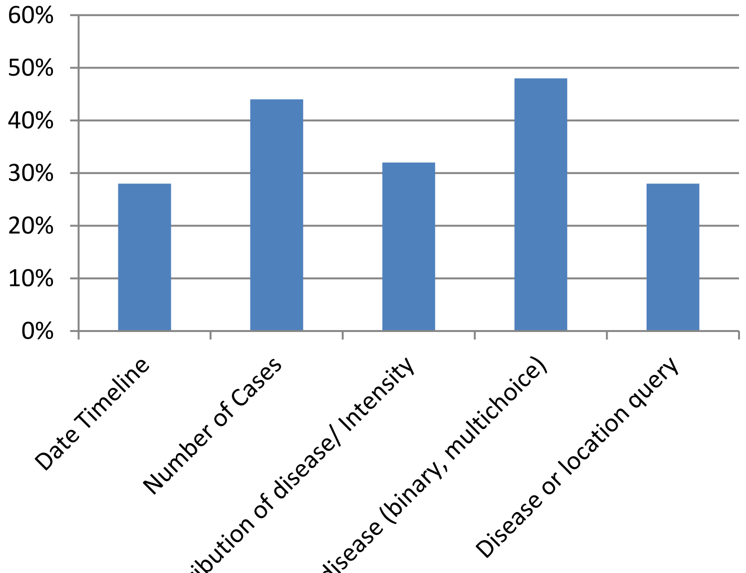


Figure 4.3 Important attributes found in all types of maps.

Besides the spatial relations of disease cases that maps bring out clearly, the most identifiable characteristic of data displayed by map visualisations is the status and distribution of a disease. As shown by

Figure 4.3, the information about a status of disease is shown on all map visualisations. This information is important because different precautionary measures should be taken for different disease statuses and distributions. For example, quarantine measures or isolation can be organized to control the spread of a disease only if animals in a particular area are suspected to contain a zoonotic infection. A much more detailed update is helpful only if the precise disease status is known, however some maps only give a bilateral report of areas that are either positive or negative of a disease outbreak. Following is a list of the possible disease case statuses that the map websites showed. All websites show details of confirmed cases, be it in quantitative values observed in an area or as a qualitative confirmation of the presence or absence of an outbreak in an area.

- Cases suspected, identified or reported (8%)
- Cases not reported or submitted for testing, negative or removed (15%)
- Confirmed or positive cases or outbreaks (100%)
- Cases submitted for lab testing (4%)
- Cases of dead or fatal reports (19%)
- Human reported cases (8%)

In most maps, the quantitative aspect of a disease is also important. 44% of the websites give detail about the actual numbers of reported cases. The number of cases found in one area may be represented by different symbols that vary in colours, sizes and shapes. The shapes can be rounded or oval shaped whilst the colours range widely with red, orange and yellow being the most common colours used (Figure 4.4). We observe that the colours used on the analysed maps ranges from yellow (38%), orange (19%), red (54%), blue (23%), pink (8%), green (8%), grey and purple (each 4%). Red seems to be the most used colour for confirmed or positive disease cases. From the observations, the symbols well suited for representing quantities are characterised by colour hue, saturation or colour intensity and symbol size.

Figure 4.4 Colour usually used to represent severity of an outbreak in each area [38].

The other disease characteristics include the date when the disease was reported and the name of the disease, this is shown in all sites. Other information includes sample information that can be collected for laboratory tests, the laboratory findings, the reasons for alerting the public and the ID number to represent the disease. However, only one of the sites provided this much detail of disease information. Even though the maps show the location of the affected area, the name of the affected area is also given on popup windows. A description of the species affected by the disease is also highlighted so that concerned parties can know which animals to observe for each disease. To offer accountability to users, the organization that confirms the outbreak disease is given in some popup windows. A link to more information is also supplied so that users can read more about the disease and also view pictures of the symptoms.

Data is categorized into different case value intervals (Figure 4.5) to demonstrate different levels of outbreak severity or intensity. From this figure we also observe that the colours used range from yellow, orange and red which are the common colours used. Each site uses a combination of two or three case values with others using a range of colours that have various saturation levels. 32% of the observed websites indicate the need for information about the disease severity or intensity. The levels are divided into intervals that can be counts, ranks, or derived values such as rates and percentages. Usually the number of cases displayed is classed into such intervals depending on the cases observed in the area hence indicating severity of disease with each class interval. Each of the classes is represented by different colours or textures on the map area where the disease is observed. For example, one interval may be for all areas with cases below a hundred using a light colour or distinct texture to indicate that the area is not severely affected. The pattern observed from the websites shows that lighter colours and smaller symbol sizes indicate less disease cases whilst darker colours and larger symbols tend to indicate a high number of reported cases. From Figure 4.5, the brick red colour which is dark indicates a high number of reported incidences when compared to the light yellow which indicates no reported incidences. As the colour gets darker from the light yellow to the brick red, the number of reported incidences also increases. This explains the concept of colour intensity or colour saturation discussed in the properties of visualisation, Chapter 3.

Figure 4.5 Intervals to show different levels of data.

The other characteristic which is mostly identified on these websites especially with interactive maps is the presence of timelines that enable the user to choose the time period for data they want to view. Timelines are not observed as separate visualisation techniques because they cannot work on their own, they need to work with other visualisation techniques since the questions what, when and where need to be answered at one time. Timelines can be presented as daily, weekly, monthly or yearly time intervals. From the websites being observed in this study, a timeline is either in the form of a drop down list (12%) or a date slider (4%). Some maps put dates on the popup windows and have no timeline. The timeline allows the user to interact with the map and control dates for when they want to view data. However interactive timelines which provide more detail are mostly visible in interactive maps. The maps which are not interactive, e.g. static maps either show data for a particular month in a given year or for the whole year on one page of a map. This is observed as a heading above the static maps (46%). Animated maps are a series of static maps showing data for different times so that one may find relationships in the change in time as the animation plays, e.g. the animation can show data for the months of a selected year.

Interactive maps respond to mouse clicks or mouse-over events. For example, when a user mouses over or clicks a region on a map, a popup window appears. The information displayed on this popup window varies with each map. 31% of the maps open a popup box when clicked. Some show similar data but in general all popup boxes can show any of these: reporting dates, observation dates, disease name, laboratory findings, species affected, reason for alert and possibly more. The presence of the popup window promotes interactivity so that the user can hide the information they do not want to view and make visible the information they want to view. This is because each user may primarily be concerned with areas that surround the position of their location. The other option is the side-bar in replacement of or together with a pop up box, 8% of the maps show this. Side-bars show more information because they are placed on the side of the map and hence have more space for displaying more information.

As already stated, there are some essential attributes or characteristics of diseases that should be visible to the user. All the maps used in this investigation show the disease name, the location of the disease, the status of a disease and the time for which the information is displayed. However there are some maps that show more detail than others and these are the differences that this investigation was observing in order to ascertain which attributes are recognised by different sites.

4.4.3 Attributes of Tables

Since all tables are basically made up of rows and columns of categorised data, only the attributes that the tables display can be observed. The prevalent attributes found in tables that display and report disease information include outbreak locations, status of the disease in those areas (27%), disease names, timeline (day, month or year) of outbreak occurrence (63%), number of positive or confirmed disease cases (55%) in an area together with the species that the disease affects. Some other tables go on to give the number of people or animals affected by a disease discovered in a given area and even the mode of outbreak transmission. However, only 18% of the tabulated sites provide human information.

The basic information shown by the visualisation techniques also includes case numbers which form 80% of all map websites (Figure 4.6). Information about the intensity of the disease and the names of reported diseases which can be referred to by codes is also provided on tables. Additionally, some tables include information about the different modes of transmission together with their trends and these constitute 10% of all the observed tables found on websites.

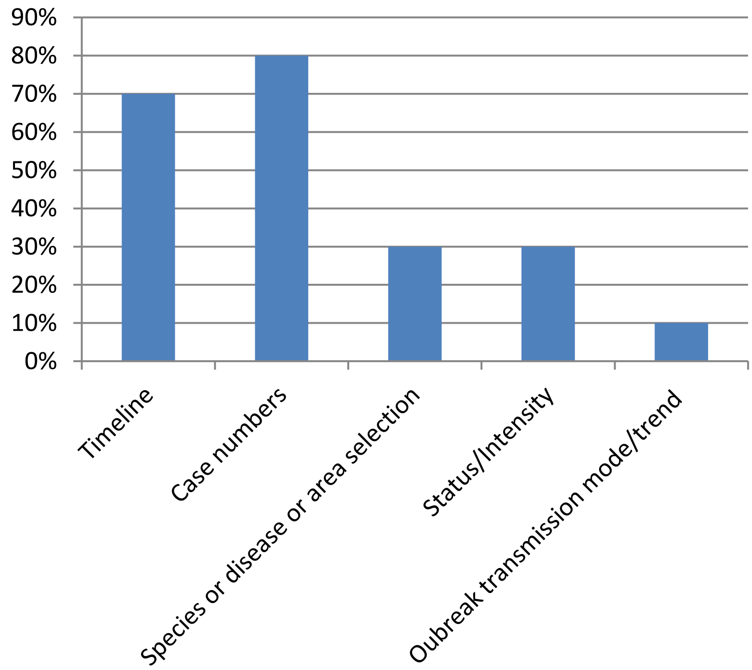


Figure 4.6 Summary of tabular attributes.

The other information shown on tables includes the country of disease origin, and the dates when the disease was observed. Some tables indicate the number of affected people as compared to the usual statistics on the affected animals. The animal status information includes the number of dead, killed and suspected cases. Dead animals naturally die from the disease whilst killed animals are those that are eliminated through slaughter procedures. The total number of disease outbreaks and their accumulative values are also indicated so as to know how many outbreaks are being faced within a particular time.

A majority of the tables (80%) are static in nature. The information displayed states the case status of infections observed in a given area. However, some of the tables have adopted similar concepts as interactive maps since they can be queried. From the 11 websites that use tables to visualise data, only 2 of the tables demonstrate interactive abilities. This is achieved through queries that let a user choose the type of disease, the geographical area affected and also the time period to view data. The more interactive tables are colour coded and can be queried to obtain more information. However for more clarity, the tables can also be combined with other visualisation techniques like another smaller table, or maps and charts to support interactivity. For any visualisation techniques like maps, charts and timelines, to be interactive, they derive their information from tabulated databases.

From the analysis, 70% of the websites use timelines to demonstrate temporal relationships. Temporal relations are shown by the dates as a heading for the tables or as one of the fields of the table. For interactive tables a drop down list is given for the user to select the time for which they want to view the data. However, the usual trend of demonstrating change in time on the observed tables is by having time in dates as one of the table columns. A column with rows of different dates, usually at monthly intervals, illustrates change in time.

4.4.4 Charts as Visualisation Techniques

Some websites use charts to show the case levels of a disease in each area for a particular period. Figure 4.7 shows how one website has used a bar chart to represent its data. The chart shows the total number of events that have been reported in a region. The data timeline is of monthly intervals and represents confirmed and unconfirmed cases of a disease by using differently coloured bars on the chart.

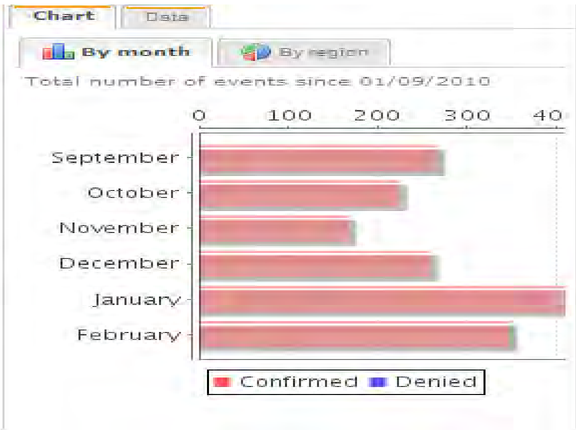


Figure 4.7 Example of the use of charts for representing data case values by month [38].

From all the chosen websites, the sites that choose to use charts as a visualisation technique show the least amount of information. Charts come in various forms. Some sites use line and bar charts whilst others use pie charts and some use a combination of all the chart types. Figure 4.8 shows the type of charts used by the websites.

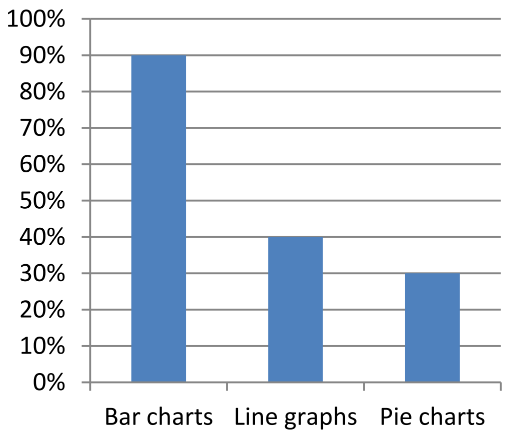


Figure 4.8 Chart types used.

Apart from the different types of charts available for use, what is important is the information displayed by those charts. The status of a disease and the number of cases observed is common for sites that use chart visualisation techniques. This is shown by the value of 90% of the sites including this information on all disease reports (Figure 4.9). 20% of the charts also provide human case information. The information also includes the name of affected regions, the rate of infection and the data about taking the correct samples for lab testing.

The name of the affected regions usually forms the x-axis values of the chart with the y-axis showing the case numbers observed in that area. The rate of infection is important so as to know how fast the outbreak is spreading and to ensure that with time of taking control measures, a decrease can be observed. Data can also be categorised into different groups to help distinguish between elements. Charts also show analytical comparisons between data.

The basic information shown on charts also includes temporal information about the data at a particular time. This is a timeline shown on 50% of the charts. The timeline is shown in weekly, monthly or year intervals. It is easy to view change in time using some of the charts. Only one of the sites has a timeline with slider to show chart information observed weekly and the others have the time as a heading of the chart. Only 30% of the charts can be queried to promote interactivity such that one can choose a date or month and then disease information changes accordingly. The information displayed on charts ranges from months to years for any given region. The interactive charts show regions of infection, weeks of observation, number of cases, movable date slider, and categorized number of cases in pie charts. Following is the summarized attributes found on the charts of all websites used in this investigation.

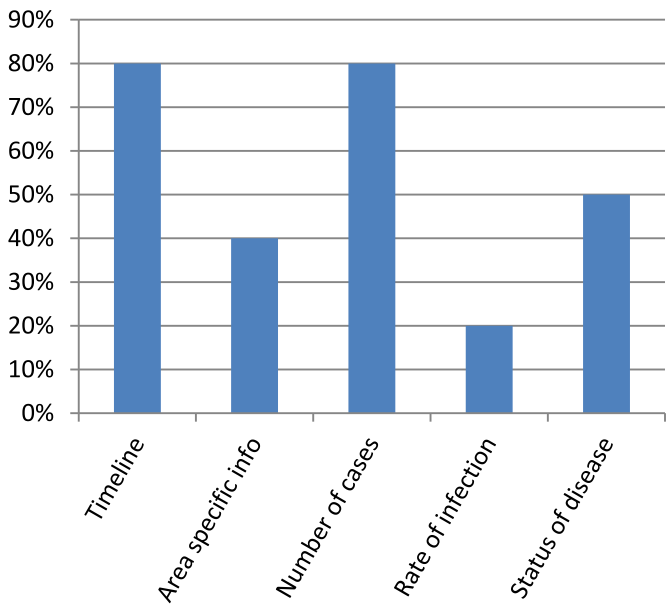


Figure 4.9 Attributes of charts.

4.4.5 Information found on Text based Websites

Approximately 23% of the websites are text based. The information displayed on these websites is predominantly in the form of news bulletins or outbreak reports. The information found on text websites includes zoonotic disease information like causes, effects, diagnosis and treatment of various diseases and disease descriptions with their symptoms indicated in picture form for some websites to aid in identifying affected animals. Some websites offer information about specific zoonotic groups or diseases, e.g. a site can offer information about Avian Influenza only or a site can offer information about diseases that affect poultry. Because zoonoses are epidemic diseases, information on major epidemic diseases is also offered together with general information about animal and human health. Other information includes information about preventative measures and early awareness measures for various zoonotic diseases. They also provide outreach and training information on how to control zoonoses during emergencies. The websites also link to other related sites that can provide more detailed information about occurring outbreaks. Usually this is offered by listing diseases that one can select to read more about. For ongoing outbreaks, information is given about the steps that are being taken to control a problematic disease. The sites also allow viewers to sign up for newsletters, news reports about the zoonotic diseases that affect the areas they reside at and selectively the areas surrounding their origins.

4.4.6 Analysis of the South African Websites

A study to investigate the visualisation techniques used by South African websites illustrated the ways in which disease information is reported. As already stated, only 8 officially recognised websites were active at the time of the investigation and therefore only these were studied in detail. The Eastern Cape and Gauteng provinces have no active sites for reporting zoonoses and so are excluded in the analysis. The data used is information that is observed from each of the sites and the information from Chapters 2 and 3. This information is grouped such that each site is observed for similar traits. Table 4.2 gives a summary of the information reported on the analysed South African websites.

From Table 4.2, some of the details given by the sites are the disease names, characteristics, symptoms, and mode of transmission. This is a text-based explanation of the disease. However, the Western Cape site give great detail about zoonotic diseases and even uses pictures to help users identify the disease symptoms of any zoonotic diseases that could be affecting their animals. The other important information placed on the sites is data about how to control the occurrences of the diseases. Only one of the sites shows evidence of previous encounters with diseases, in the form of epidemiological data.

38% of the sites also give updates of the news reports about any occurring outbreak cases. However none of the sites provide near-real-time information about existing zoonotic disease outbreaks. Each of the sites provides information to users about how to report diseases that they are suspecting, be it from their animals or from neighbouring areas. Besides using the web as a communication medium, there are other communication mechanisms that these sites have adopted to complement website reporting. These include the use of newspapers, radios, posters, flyers, loud hailers, school visits and awareness projects.

Table 4.2 Visualisation techniques and attributes observed from South African sites (x = technique not used).

South African Site Name	Tables	Maps	Graphs	Text
Northern Cape	X	x	x	• disease name • symptoms of the diseases • news report updates • offers control measures during outbreaks or on observation
Western Cape	• Interactive tables	X	x	• disease name • symptoms with pictures for more clarity • control measures • epidemiological report with dates shown as headings • news report updates
Mpumalanga	X	X	x	• only provides information on how to report any suspicious suspected diseases cases
Limpopo	X	X	x	• disease name • symptoms • control measures • news report updates
Kwazulu-Natal	X	X	x	• disease name • symptoms • control measures
North West	X	X	x	• only offers telephone and address numbers of veterinarians who can help if one observes or suspects a zoonotic disease
Free State	X	X	x	• offers a dynamic map that when clicked queries for veterinarian disciplines and offers addresses and phone numbers
South Africa: Chief Directorate site	• Interactive table • Timeline in a drop down list of month and year • Drop down lists allow selection of disease, species, province and district areas	• Static maps	x	• Disease name and description of disease • Disease symptoms with pictures • Species it affects • Province or district where observed • number of observed outbreaks • the number of affected or confirmed cases • number of dead animals • number of quarantined/killed animals

From the gathered information, the information is grouped and summarised to obtain the overall statistics about information found on the websites of South Africa. Figure 4.10 shows a summary of the information obtained from the available and active South African websites (8 websites – see page 67) selected for this analysis.

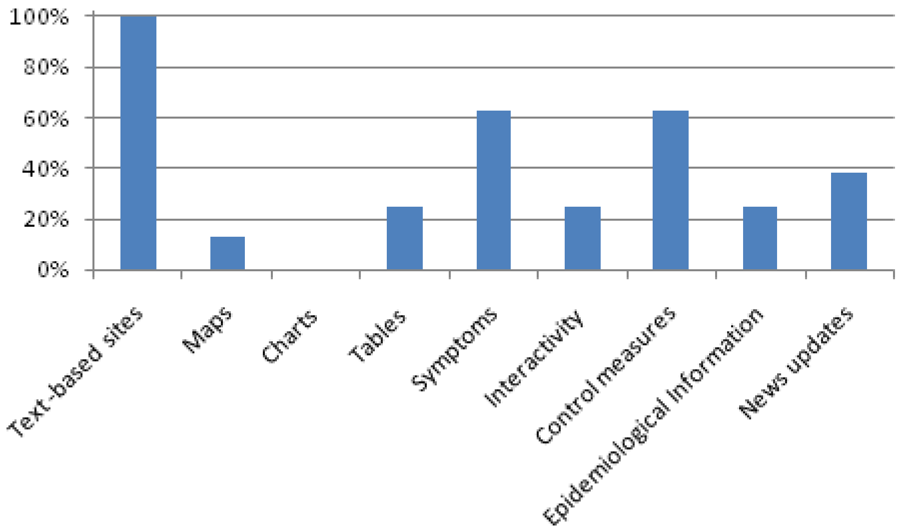


Figure 4.10 Information from the websites of the provinces of South Africa.

The Chief Directorate Food and Veterinary Services site gives a detailed description of diseases and their symptoms with pictures to aid the description of the disease forms. Compared to other South African sites, this site allows the storage of information that is almost up to date. The Chief Directorate site basically consists of a form that a user can interact with by submitting queries (Figure 4.11). The forms used are interactive through the use of a database that can be queried so that one can view data according to a timeline which is built in the form of drop down lists. The timeline is divided into yearly or monthly intervals so that a user can select the month and year for which they want to view the data. The query results are then returned to the user in the form of a table list. The data as clearly seen from Figure 4.11 represented by this site includes a selection of the location of the information being searched for at province or district levels. It also queries the disease to search for together with the species affected by that disease. The results of the query include data about the number of affected, dead and killed animals and counts of observed outbreaks in the area being observed.

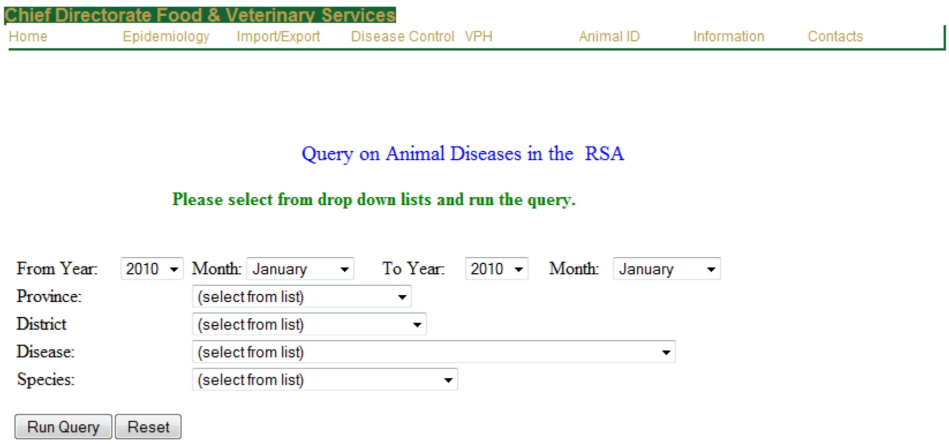


Figure 4.11 Chief Directorate page to show the interactive forms

http://www.nda.agric.za/vetweb/epidemiology/Disease%20Maps/Anthrax%2093%20to%2007%20species.pdf.

For more explanations the data can be viewed in the form of maps. However the maps used are static and cannot be manipulated in any way. The public can report diseases online through forms or call relevant authorities from a list of contacts available on the sites. The site is updated yearly and so makes it difficult to get near-real-time data. At the time of this investigation, the 2010 data was not yet available. The database that stores the disease information consists of over 24000 records of data when counting from the year 2000 to the year 2009, each containing eleven fields. Because of the many records, the site is heavily texted and can be difficult to read through or to identify relationships.

4.5 Discussion

According to this investigation, the high number of maps as a spatial visualisation technique propels the assumption that most designers have recognized the success of using maps to visualise the spatial characteristics of disease information. However literature states that dynamic or interactive maps provide more information and yet static maps are still the most highly used maps from the analysed websites. This shows that even though interactive maps have been discovered to give more detail, they are still not yet fully used in the reporting of zoonotic disease information. One of the reasons for this is that static maps are easy and quick to create through the use of computer mapping and GIS software, they always involve less labour and they require fewer server resources to distribute. However, the 38% that use dynamic maps shows that it is possible to use interactive maps to provide information that users can control at their pace. Since only 8% of the maps are animated, the developers for these sites have presumably concluded that animations that cannot be controlled are difficult to view and analyse and most users find them unfavourable. Maps represent the spatial features of data and the temporal features shown together with maps are indicated by date sliders, drop down lists and timelines. When these visualisation techniques are used together, they demonstrate spatio-temporal relationships which are favourable in the visualisation of disease information.

When the disease information to be reported for use during outbreaks is studied from the literature around disease reporting (section 2.5.1.2) and the results gathered from this investigation are compared, the findings are closely related. The location of the diseases and their status are seen as important. However, only the websites of South Africa supply information about the disease symptoms and the species that are most at risk to the zoonotic diseases. The sites outside South Africa only concentrate on transmission methods.

The numbers of cases shown are represented by colour coded variables in the form of circles, squares and pointers. The websites that give exact numbers of the reported cases make up 48% of all websites used in this analysis. The status of the disease cases shown are those that have been discussed and 44% of the websites give detail on this. The colour codes follow the interval grouping already seen with maps, Chapter 3. The use of colours supports colour saturation which is found amongst the properties of visualisation (section 3.2.2). It also supports the use of colour as a principle of mapping (section 3.3.3.2). These clearly show differences in the intensity of the disease cases in each area. Colour is therefore useful in clarifying useful information on different visualisation designs.

As already discussed in Chapter 3, for large datasets tables cannot clearly show spatial or temporal relations. It takes a lot of time or energy to compare many rows of data. Firstly this is because from a table it is difficult to relate two geographically linked areas. One cannot tell the areas that are close together or far apart. This information is important because areas surrounding an affected region are more at risk when compared with far away areas. Charts also cannot show how different areas are geographically located with respect to each other unless one has knowledge of the names and positions of the geographically linked areas. Such knowledge would bring clarity for users who find difficulty in recalling the location of different regions but need to frequently refer to them.

Usually interactive visualisations convert tabulated data into controlled visualisations that clearly show differences in the spatial and temporal data. Tables are good visualisation techniques for small data but with large datasets, they do not promote most of the properties that we discussed to be suitable for demonstrating spatial and temporal visualisations. They only organise data into sections that can be read chronologically. The visualisation properties demonstrated by these tables include colour codes of the rows in a table. The data mostly shown by tables is text based and has to be studied even if the table has thousands of records.

Interactivity promotes the filter and extraction visualisation tasks to be considered when designing visualisation systems. This is achieved through the queries that are submitted by users to obtain specific data that gets filtered from large databases and are visualised on maps, charts or other smaller tables. The interactivity is communicated to the system through mouse clicks usually on maps or on the variables found on maps. Usually the clicks open popup windows and perform zoom selections that are examples of brushing and focusing. When the clickable areas are selected, they open popup windows that show the characteristics of the diseases found in that area.

The visualisation tasks discussed in the beginning of Chapter 3 are made possible by interactive features added to the sites. For example, the visualisation displays give an overview of the disease information being reported and interactive features like zoom sliders are used to zoom into the data to view areas of interest. The ability of some of the visualisation techniques to be interactive encourages users to view only those items that they find interesting and to mask those that they do not want to view at any particular time. The use of search queries and the presence of drop down lists in some sites allow the users to demand details they find important. The use of maps clearly shows relationships between geographical areas, and bar charts also show distinct relations between disease case values. Some of the websites have control buttons to direct the system and retrace steps. However these tasks as already stated are mostly seen from interactive visualisation techniques thereby further accentuating the need for using interactive maps, charts and tables.

Although line graphs are known to clearly show change over time, most of the sites in this investigation are not using them. The line graphs can be used to represent data with change over time throughout the months or weeks of a year. Most of the sites however use bar charts to represent case values of affected animals and dead or killed animals. Some use bar charts to show the case numbers of different diseases found in an area at any particular time. Because the data values are represented by less than ten bars, the bar chart is not crowded and can clearly depict changes between values.

The information gathered from South African websites evidently shows that South Africa has not fully adopted the use of visualisation techniques to deliver disease information. This is evident when they are compared to the other sites already discussed. Newspapers, radios and televisions are still the most used reporting mediums. Newspapers and televisions can display visualisation techniques however these are static and cannot be manipulated, they can only be observed. They are also one-way forms of communication which do not allow immediate feedback to questions that readers or viewers may have and users cannot query the information that they want to observe. Most of the reasons for not fully adopting these new systems involve problems with updating the web systems because of the heavy use of text. The reason for visualising data is to avoid text that is tedious and unfavourable to most users especially when comparisons and contrasts are important to the user. However if a system is designed to automatically update information that can be viewed, the system becomes favourable to manage since minimum human labour is used. This makes interactive visualisation an important part of reporting disease information.

The Chief Directorate site clearly promotes the surveillance success factor of keeping epidemiological data which can be useful during outbreak crises. This is because the data found on this site dates back to the years of 1994-2009. Epidemiological data has already been stated as important (Chapter 2) and all the static maps or charts do not show change over time so as to analyse the evolution of animal diseases and to monitor the effectiveness of disease control in previous experiences. Programmes or measures taken in solving previously experienced outbreak problems help solve major challenges for veterinary services in those cases where the location of diseases or their intensity is unknown.

Overall, the South African websites use a lot of text which is time and energy consuming to read through. The tabular information provided by the chief directorate site makes analysis difficult due to the many lines of data since the database that stored data has records that are over 24 000 in number. This could be one of the reasons why the site updates lag behind by a year.

4.6 Conclusion

In addition to the supportive literature already studied in Chapter 2 and 3, this chapter has assisted in concluding that maps are presently the most popular spatial visualisation technique for visualising zoonotic disease information during or prior to outbreaks in many global countries. Timelines which are used together with other visualisation techniques are also important for demonstrating temporal relationships. Bar charts also distinguish between different values of a dataset. Visualisation techniques have become interactive to display diverse amounts of information and to support advanced data queries that are flexible to user requests. The attributes displayed on the visualisation techniques are important and they play a huge role in ensuring that proper information is made available to users hence a summary of the information that has been found to be displayed on the currently deployed websites has been highlighted. Regardless of the choice of visualisation techniques used, all of them have the same goal although some enhance clarity more than others, e.g. maps clarify spatial relationships when compared to other visualisation techniques. Because interactive visualisations display more information, the need for improved visualisation techniques is apparent in some websites which still use static visualisation techniques. This can support spatio-temporal features that are favoured for disease reporting systems thereby effectively improving the current ways of reporting disease outbreak issues. The observed sites show the presence of most of the data that is stated in Chapter 2. According to Chapter 3 the proper visualisation techniques chosen by some sites still do not bring out all the information clearly but the combination of the techniques of some sites shows that other developers have got the visualisation of disease information right.

5 User Requirements Analysis

5.1 Introduction

As part of the participatory design approach, to ensure that relative entities are involved in the design of the web reporting system, participants were chosen for the purpose of conducting a requirements analysis. One of the requirements of designing computer systems for the representation of data is the need to know the requirements of the possible users of that system. Since selecting and creating the most effective design usually requires considerable knowledge, an exploratory study of the user requirements can bring great insight to the successful development of a disease reporting system. Creating a system that specifically addresses the needs of a user would therefore be more effective if the users are included in gathering the requirements of the system as opposed to creating systems with assumptions on what users want.

The purpose of this study is to gather important information that users consider as necessary when visualising disease data. It also aims at finding preferences of the techniques that can effectively visualise data by allowing participants to evaluate the extent to which each visualisation technique observed meets the usability requirements. For this reason, it is essential to assess the available visualisation techniques to answer questions of how they display data and what information they display. The impact of the gathered requirements can determine the success or failure of the system hence their importance. The results can determine the techniques and information to be found in a disease reporting system. This can lead to the proposal and development of a suitable prototype system that can incorporate all the gathered points into the interface design.

5.2 Methodology

The possible users of a disease information system include largely the veterinarians who are usually the source of information required during or prior to disease outbreaks. However, since there are restrictions on the information that can be reported to the public during disease outbreaks, all veterinarians have to be careful about the information that they release. To ensure this, sometimes awareness programmes about disease information are performed only if the government gives consent to supply that information to the public. Because of this, the task of eliciting requirements from users relied on veterinarian authorities.

The types of veterinarian authorities found in the field are diverse depending on the tasks of each veterinarian or the environment that they work in. Examples of the different types of veterinarians include general, specialists, wildlife, exotic, marine and equine, farm and state veterinarians [64]. In order to obtain fair results that are inclusive of all veterinarians, the types of veterinarians had to be considered when selecting the veterinarian participants to use in this analysis. Four veterinarians from Eastern Cape were selected; one private veterinarian who specialises in problems related to wildlife animals, one general veterinarian, and two state veterinarians. The general veterinarians deal with problems that are related to common household pets like dogs and cats, livestock like chickens and cattle, and exotic animals like birds and reptiles. The state veterinarians are mainly concerned with animal welfare, responsible for monitoring the existence of diseases in animals and have a right to the restriction of animal movement within and across state lines. The wide range in the type of veterinarians chosen for this analysis is a representative sample of potential users. This improves the quality of the results since all veterinarians are catered for and hence the outcome can help in reaching a favourable decision about the user requirements for disease reporting systems. It also increases the variety of the results obtained thereby making the results more concrete to suit different types of user needs. This is because each type of veterinarian has their own specific tasks, requirements and measures that they find interesting or important for a reporting system.

Face to face meetings are known to produce effective results and because of this, a one on one brainstorming session of sharing and obtaining data was chosen [19]. Each of the participants was contacted before time for the meeting to elicit participant feedback. Brainstorming is a technique for generating ideas shared during group meetings [100]. This method was selected because it is known to have the ability to generate ideas that can effectively solve a problem [100]. Brainstorming is also known to be a method that is energetic and openly collaborative, thereby allowing participants to build ideas from each other. Because of this, each selected participant together with the researcher and two supervisors formed a group of four to share ideas that arise with the reporting of disease information. The group selection helped to bring out more ideas, criticise other ideas since different types of veterinarians were involved which means that different types of veterinarians were being represented. This process was repeated for four participants to obtain more ideas and to build from the experiences of each session that had been conducted.

Four veterinarians who participated were all obtained from the Eastern Cape region. The sessions were then organised to be conducted either at Rhodes University or at the participants' offices. Only one of the participants came to Rhodes for the brainstorming sessions and the rest of the participants preferred to have the sessions at their offices.

To obtain significant results from the chosen participants, a semi structured interview was chosen. A list of questions was also prepared for the process to be orderly conducted and for all sections to be covered. The questions asked during the sessions are given in Appendix B. The questions resulted from the information that was obtained from Chapters 2, 3 and 4. The web analysis (Chapter 4) and the literature research studies around disease information reporting and visualisation (Chapters 2 and 3) suggest suitable visualisation techniques of disease reporting systems together with the attributes to display for those techniques.

The questions to ask were therefore categorised into three sections. While doing the literature review (Chapter 2) certain questions become evident. These questions are related to the information that is to be included when reporting zoonotic diseases especially during outbreaks. Chapter 3 (visualisation) resulted in questions that centre on the choice of visualisation techniques that can suitably display the information gathered in Chapter 2. Lastly Chapter 4 (website review) resulted in questions that are guided by the zoonotic reporting web systems that already exist hence observing the web features that are common to most systems and also determining if the commonly used features are the best to use from the user perspective. These questions were used in the brain storming sessions and they guided the participants into giving out information that is required for designing a reporting system for zoonoses. Each participant was able to state how important some information attributes are and if a particular component is needed, wanted or not wanted in the final developed system.

In order to encourage the participants in visualising a possible system, they were each presented with screen shots of existing disease reporting systems. The screen shots showed diverse visualisation techniques that are currently used on disease reporting web-based systems. The screen shots therefore provided visual descriptions of how the reporting system of South Africa could be developed thereby encouraging the participants into commenting about different designs and in making their own perceptions about what could be a suitable reporting system. The screen shots also acted as a building block to obtaining more creative ideas from the participants since the participants could visualise the completed system that they would find suitable.

Screen shots provide a means of analysing how people react to different design systems by observing what attracts them, looking for trends in most selected techniques and component designs. Each of the screen shots was being used as mock-up of a disease reporting system that can serve as ideas of a similar system that could be developed later. This is because screen shots usually mimic the functional systems and have the ability to provide sufficient detail for interface analysis. As each participant selected their options on different screen shots, comparing and selecting preferred options, explanations were offered and afterwards another screen shot was presented to the participant. Appendix C shows screen shots of the currently used visualisation techniques such that users can critic those techniques and give a detailed view of their preferences from the wide range of options that the list offers. Figure 5.1 gives a picture of the interviewer showing different screen shots to one of the participants.

Figure 5.1 Researcher presenting screen shots to one of the veterinarian participants.

To begin with, as requested by the Ethical Standards Committee of Rhodes University, a voluntary acceptance to the brainstorming session was undertaken (see Section 5.2.1). Each of the brainstorming session was scheduled to last for approximately an hour. The brainstorming session opening comprised of a detailed introduction of the research to help participants understand the purpose of the study and the role they fit into in the whole process. This included the background and the aim of the project. In relation to the background given, this led to them opening up and talking about the general problems that they encounter on a daily basis. Later on, the prepared specific questions were then asked and each participant gave their own opinions on what is important and what is not. Afterwards to close the session, a summary of the participant's views was mentioned so as to quickly correct any misunderstandings and mistakes. This ensured that the results obtained were precisely understood.

In order to keep track of the results obtained from each brainstorm session and for purposes of easy analysis, all sessions were recorded at each participant's consent. For easy and repeated analysis of the feedback results and to remember the major points of the brainstorm session later, at each participant's approval, each brainstorm session was recorded. This made it easy to repeatedly concentrate on the participants and assess what they wanted and so pick up points that could be important to the final development of disease reporting systems. The attention given to the participants allowed the observations of how the users were communicating their ideas. This includes observing their facial expression, eye contact and posture. However, this was just to ascertain their interest for the session especially about the topic being discussed. The results from this investigation were then gathered and organised into a tabular form for easy analysis of the results and to draw conclusions about what users want. From the tabulated data, counts were taken to clearly view the difference in values for each of the four participants. The results obtained were then compared and contrasted to what literature states about disease reporting systems and what the web currently displays on such systems. This is to observe the incorporation of user requirements in disease reporting systems.

5.2.1 Ethical Considerations

The Ethical Standards Committee of Rhodes University has a policy that protects the rights and dignity of human subjects involved in all research conducted within the University. The policy follows guidelines that ensure that all human subjects freely give consent to participate after having received adequate information about the project. Below is a summary list of the guidelines that were followed to ensure that all participants are protected.

- **Information to Subjects**

The researchers identified themselves and stated their association with the University. Each participant was given a summary of what this project is about, i.e. a description of the nature, purpose and usefulness of the research project. Some participants even obtained project papers before the meetings so as to know more about the project beforehand. Afterwards, the role of the participants in the success of the project was outlined. This gave the participants an idea of what is expected and the ability to choose to be part of the project research.

- **Informed Consent of Subjects**

With all project knowledge given to the participants, they then decided if they wanted to continue being part of the project. On agreement, each participant was requested to sign a consent form (see Appendix D) for written evidence. Clarity was highlighted to the participants about their freedom to withdraw from participating in the project at any time even after giving the written consent or after the project commences.

- **Risks and Benefits to Subjects**

To avoid participants being liable in participating in this project in case the project can negatively affect the environment, all anticipated risks and methods of protection of confidentiality and anonymity as well as any legal limitations to be encountered were outlined. Any benefits to participants were also explained here.

- **Privacy of Subjects**

To elaborate on privacy policies, the researcher explained how information would be used and stored to maintain confidentiality. The terms in revealing or withholding all information about participants that is not already in the public domain was explained further, e.g. all information would not be transferred to individuals outside the university and assurance that the information would be kept safe and would never be altered as well.

- **Anonymity of Subjects and Confidentiality of Data**

To enhance security measures around each participant, each participant was informed that their identity would not be visible when using data. This included anonymity in both the published results of the project, and in the records stored for possible re-use. In case of reuse of information obtained for other related projects conducted within the University, it was emphasized that no further consent from the participants would be requested.

5.3 Limitations

The possible users of a zoonotic disease information system include veterinarians, the public (affected patients or citizens) and the medical doctors. Since the veterinarians are the source of the veterinary information, laboratory statistics and preventative measures, the system being created is mainly targeted and limited to only veterinarians. The public would yield useful information but there are restrictions in the release of information that they can view. Only the veterinarians suggest the information to release to the higher authorities for approval hence why the public is not included in this analysis. The scope of this project involves understanding the needs of veterinarians that deal with zoonoses hence why the medical doctors are not involved in this analysis. However, the patients and the medical doctors are an important part to disease surveillance as already explained in Chapter 2 and so this ought to be considered in future considerations to similar projects.

One of the major limitations faced when performing this investigation is the availability of veterinarian participants. Users were constantly busy and scarcely available to specify the requirements that are needed before specifying the functionalities of any disease reporting system. As a result, this analysis only included results obtained from four veterinarian participants. One can argue that four participants may not be adequate for making solid conclusions, however due to the location of the researcher being in a small town (Grahamstown) there are limited numbers of veterinarians available to increase the number of participants for this investigation. Due to limited resources and the location of the researcher this analysis could not be performed outside of the Eastern Cape. This therefore means that only the Eastern Cape veterinarians were used making the requirements specifically suitable for the Eastern Cape. Because of this limitation a suitable method, like the brainstorming method that included 4 people per session, of requirements collection had to be chosen to minimise the compromise on the number of participants. The other limitation faced was that besides having communication and reporting problems in the veterinary field, they wanted to address or point out other problems faced. As a result the sessions had to be closely controlled to avoid drifting away from the subject and some participants were given time to state other problems faced when the session ended.

5.4 Results

The first observation that each participant mentioned was the need for communication in the veterinary field. They stated that there are so many delays in the communication of information that state veterinarians get to know about outbreaks when many animals have already died. The participants stated that they largely depend on hearsay in order to obtain information because of not having platforms for sharing information. Because of this, they found that a web-based platform for sharing and reporting disease information would be a useful system unto them. They recognised that the information that they usually know about is the information around areas that they work at and at other times the areas that surround their location. Some even mentioned that at times they hear of an outbreak affecting other provinces long after it has passed. Due to this, they became enthusiastic about adding input to a zoonotic disease reporting system that could be developed to help solve such issues.

Initially the participants were asked about the features that they would like to see on the system. After a series of questions, each participant was then asked suggest the important information that they would like to view on the sites. This provided a detailed summary of visualisation techniques and other important attributes that they found appropriate for a zoonotic disease reporting system. After the sessions, all the information obtained from the audio recordings was gathered and organised into tabulated form. The tabulated heading fields resulted from the questions asked and the voluntary information that the participants provided. The heading fields are also guided by the information obtained from Chapters 2, 3 and 4. Table 5.1 and Table 5.2 indicate the different attributes desired by each participant. These tables give the general features that the veterinarian participants preferred (from the questions asked) to view on a disease reporting site. They include the visualisation techniques and the general system features that each participant found favourable to the reporting of zoonotic disease information.

Table 5.1 Summary of visualisation techniques to be preferred on a reporting system (x = technique not preferred).

Visualisation Technique	Participant A	Participant B	Participant C	Participant D
Maps	Colour-coded and clickable maps	Dotted or colour-coded map	Colour-coded dotted map	Dots or a colour-coded map according to severity
Charts	Bar charts and line graphs	Bar charts	Any chart depending on data	Bar charts
Tables	x	X	Tables if it compares only a few case values or areas	x
Text	Minimum text	Minimum text to direct user in using system	Link to more text	x

Table 5.2 System design attributes to be preferred on a reporting system (x = attribute not preferred, ✓ = attribute preferred).

System Design Attribute	Participant A	Participant B	Participant C	Participant D
Side-bars vs. popup	Side-bars	Side-bars or popup	Side-bars	Both side-bar and popup
Zoom and abstraction features	x	X	X	✓
Timelines	✓	✓	✓	✓
Drop down lists of diseases	✓	✓	✓	✓
Flagging of diseases (for integrity purposes)	Veterinarians and state veterinarians	State veterinarians or higher authorities	Higher authorities	Both veterinarians and state veterinarians with different levels

The participants stated that maps would clearly show differences in the severity of cases on certain areas of the map and the surrounding areas hence must definitely be present in the reporting of diseases. This was highlighted as important because the diseases are infectious and the ability to view spatial relations would permit the possibility of predicting the direction that the disease outbreak would flow. In order to easily analyse the information, some techniques that aid in easily observing differences between values could also be incorporated into the system. These techniques included bar charts, pie charts and line graphs. Bar charts were observed to be the ones recommended by 3 out of 4 of the participants. The use of charts to help users analyse the reported cases is a favourable feature because charts can compare different strains of a disease, compare the status of a disease for different years at the same time of the year and also compare the number of suspected cases vs. dead or confirmed cases. The participants found that comparing diseases for different times is a very useful way of preventing mistakes faced during previous outbreaks. Many stated that in order to avoid crowding the system details, a bar chart can be used and no table of highlighting other values is necessary. Hence the choice had to be made between bar charts and tables and bar charts were chosen as more attractive and easier to understand. Because the participants also recognised that text can be time and energy consuming and to avoid crowding the system, a link to more information could be useful in encouraging those who require more information to read more.

Besides the visualisation techniques to use, the other feature was a detailed popup or side-bar to present more data about the disease or the area affected. A popup window is an element of computer interaction that usually opens to give brief information on mouse-over an area. A side-bar is a feature which allows the user to read more about the area on mouse-over; it provides the user with more information if compared to popup windows. The participants determined that since a side-bar gives more space to provide detailed information, it is therefore favourable to them. From Table 5.2, it is clear that the zoom feature is not really necessary to the participants since only one of the participants required it. The participants stated if it was possible to view all the data on the screen at a glance then the zoom feature was not necessary especially since the coordinates of the affected farms was not visible for the public view. An interactive timeline was suggested as mandatory to the design by all participants. And the preferred suggestion was for a date slider or a drop down list. However because a date slider is visible to the user since it is indicated by a line on the design interface, it was selected as the most functional.

One of the problems that the participants worried about was the need to define who flags diseases on the system. This varied from suggestions of having every veterinarian flag a disease, having state veterinarians flag the disease or only higher authorities. The other suggestion was to allow all veterinarians to flag a disease as confirmed or suspected but at different levels. The concern behind the person who flags diseases in different areas was because false alarms can cause panic and so result in the wastage of resources in taking precautionary measures used in preventing a disease outbreak that does not exist.

The importance of previous information about similar cases was also highlighted as important. The paperwork on previous cases prevented them from readily accessing the information about previous occurrences for similar outbreaks. The electronically stored reports are not situated in one area, so to easily flip through different times made it time consuming to meet the information need rapidly. The need for using techniques like controlled timelines would be useful in easily analysing, comparing and contrasting, cases that have been observed in previous times so as to know what precautions to follow and the ones not to be followed.

Although the participants were concerned about how the data is visualised for easy visibility, their main concern was the data that is represented by the visualisations. Each participant was asked to explain in detail about the information that is important during outbreaks. Table 5.3 was therefore created to analyse the information obtained from the participants in great detail. The table gives a detailed summary of the written information that can appear on a side-bar since all participants found side-bars to be more desirable than popup windows. Usually when a map is used, each region has information that is specific for the diseases found in that area. That information is important to get more insight on what is happening in that area. The information can be summarised and presented the side-bar that dynamically changes information as the user clicks on a selected area of a map. Table 5.3 shows a summary of the feedback obtained about information to display on a side-bar.

Table 5.3 Wish list of features or details to be found on a side-bar (x = not preferred feature, ✓ = preferred feature).

	Participant A	Participant B	Participant C	participant D
Number of cases resulting in outbreak • *Suspected* • *Confirmed* • *Mortalities*	 ✓ ✓ ✓	 x ✓ x	 ✓ ✓ ✓	 ✓ ✓ ✓
Veterinarian information on samples to take for lab testing • *Diagnostic samples to take for lab testing for various diseases* • *Equipment to carry*	 ✓ ✓	 x ✓	 ✓ X	 ✓ ✓
Type of disease • *Controllable* • *Notifiable*	 ✓ ✓	 ✓ ✓	 ✓ ✓	 ✓ ✓
Information about the disease				
• *Symptoms*	✓	✓	✓	✓
• *Description and links to more information*	✓	✓	✓	✓
• *Species at risk*	✓	x	✓	✓
• *Date of observation*	✓	x	✓	✓
• *Control measures*	✓	✓	✓	✓
• *Steps to be taken by veterinarians if disease is confirmed e.g. Quarantine*	✓	x	✓	✓
• *Transmission ways*	✓	x	x	✓
• *Human contact information*	✓	x	x	✓
• *How fast the disease spreads*	x	x	x	x
• *List common/ problematic diseases in an area*	✓	✓	✓	✓
• *Sort diseases according to severity*	✓	x	✓	✓
• *Regulations to follow with regard to a confirmed disease*	x	x	x	✓
• *Epidemiological information about similar disease outbreaks*	✓	✓	✓	✓

The information that is placed on the side-bar for the public varies greatly. Most of the information common to all veterinarians included the display of the number of cases for suspected, confirmed, fatal and laboratory cases observed in each area. This is the information which is most important to the participants because it determines the course of action to take with each status update. Only one participant was against the idea of showing suspected and mortality cases in the report. This participant stated that it makes the livestock keepers panic and that is not needed during outbreaks.

Diagnostic information seems to be especially necessary and desirable because it is noted that many veterinarians make mistakes when they go out to the field to obtain samples of the affected animals. In most cases the samples that are taken to the laboratories are incorrect and one has to redo the whole process which wastes time especially in cases where the animals used for the samples have been buried already. Because users have different requirements when they use reporting systems each type of user desires to view certain data that is relevant to them. For example, the public does not need to know what samples to collect for laboratory tests and yet a veterinarian requires such information. This means that the information can either be separated into two groups or the data can be placed in such a way that a user selects what they want to view and ignore what is irrelevant to them.

Notifiable diseases are those that have to be reported to the government authorities. This is a law that has to be followed so that pandemics are minimised or prevented by following early warning procedures. A controllable disease is one that need not be reported to higher authorities because it can be managed easily without causing alarm, usually these are confined to one area and they do not spread. The participants found that it is important not only to report the diseases that result in outbreaks but to report all zoonotic diseases that are reported in an area.

Symptoms, disease type and description, animals at risk, date of observation, control measures, transmission ways, and steps to take if animals are infected, human contact information are features that were identified as very important. This information was suggested as mainly important for the general public. One of the participants indicated the importance of describing the disease considering that there can be more than one strain of a disease type, e.g. horse sickness comes in different strains and it is important to know the exact one being reported at any given time to ensure following the appropriate preventative methods. In addition to this information, information on how fast the disease is spreading, details on the usual problematic diseases in an area, list of diseases sorted according to severity, temperature of an area during outbreak, regulations to follow with confirmed diseases, and diagnostic information were identified as more important for the veterinarian authorities. A list of the most common diseases observed in an area and arranged according to severity was suggested as useful in easily identifying problematic diseases in the map area selected.

5.5 Discussion

The features initially analysed are the visualisation techniques preferred by the participants. All the participants found maps very useful as a spatial visualisation technique. This shows how important maps are when used for differentiating information about areas that are geographically linked together. The characteristics of the map were suggested to be either colour coded or to have dots in order to represent the number of cases and the severity of the outbreaks in a selected area. Some of the approached participants recognised that dots can be used to quantify values in an area. However they argued that the use of dots can be unfavourable when visualising a constantly increasing number of cases in one region because they can make the map crowded and therefore make it difficult to read. Figure 5.2 and Figure 5.3 demonstrate the disadvantage of using points for visualising a high number of cases.

Figure 5.2 Favourable use of symbols in data visualisation [38].

Figure 5.3 Unfavourable use of symbols in data visualisation
http://irevolution.net/2009/03/16/crime-mapping-analytics/.

In Figure 5.2, if each red square represented a confirmed case of a disease in the area where it is placed, it would be easy to observe the affected areas and how many the cases are in each area. However, from Figure 5.3, the area that is circled is difficult to read and one cannot count the red circular dots that represent each case in the area. The more cases there are the more difficult it is to understand what the position of the dots is or what they mean. What one will know is that there are many cases in the areas the dots are placed in but because each area has its own population numbers, it will be difficult to know how severe the disease outbreak is in those areas unless stated. From the principles of visualisation, overcrowding a system has been identified as unfavourable and should be avoided (Section 3.2.4). This therefore left the option of choosing colour coded shades to indicate the status of the disease in an area at a glance. This ascertains the success of using colour saturation in showing severity of diseases that can be easily viewed at a glance.

As stated in Chapter 3, temporal visualisations are important in reporting disease information. The participants recognised this and therefore found a timeline necessary for visualising change in data. They each found a linear timeline easier and clearer to use. The participants promoted the use of timelines due to the fact that epidemiological data is important when dealing with zoonoses. Epidemiological information is recognised as one of the critical success factors of disease surveillance and the participants confirm this.

The need to compare values is also highlighted by the participants as important. Similarly to the literature around disease reporting and visualisation techniques, bar charts have been chosen as a technique that can easily distinguish between few distinct values. This is true because the data that the participants stated to be important for analysis included comparing the case values (dead, confirmed, suspected and killed animals) and comparing confirmed cases for different months or throughout the year. Since these values are less than 10, bar charts can be highly effective in showing the differences.

The question about who flags the confirmed diseases on the system seems to be a sensitive issue. Due to this, the higher authorities responsible for allowing such a system to be a national reporting system would have to discuss the veterinarian personnel who may flag diseases at any time. This is important because protocol does not allow every veterinarian to declare the existence of an outbreak which causes delays in taking preventative measures (one month lag) yet zoonotic diseases are time-limited diseases that need to be reported rapidly. Considerations have to be made to ensure that the reporting of diseases does not take as long as one month which is what the veterinarians stated as the time lapse of distributing news reports about occurring diseases in an area. The importance arises from the fact that in a month time lapse, most diseases would have spread widely and hence they become difficult to control.

From the results of the web analysis, popup windows seem to be the most commonly used whilst side-bars and links to other pages are not frequently used in explaining and giving out more information. In this analysis, the participants showed more interest in side-bars because they have the ability to provide more information. What the participants suggested was that on mouse over or mouse click on the map area, the side-bar will be automatically updated to show information about that selected area. The user can then decide if they need to read the detailed information about that region from the side-bar.

The detailed information to be placed on the side-bar ranges widely from the participant's perspective. Besides the information suggested by the literature, e.g. the disease name, the area affected, the species affected, control measures and transmission methods, there is other information recognised as important. The web analysis (Chapter 4) recommended additional features like dates and the severity of diseases as necessary when reporting zoonotic diseases. However the participants found even more information useful. This is information about the disease description and the symptoms of the disease. Most of the sites analysed give a link to such information but the participants found it favourable to view the information about the detailed description of a disease as each area is selected. Human contact information, the rate of disease spread and the severity of cases are additional attributes found useful. The severity of cases on the side-bar may be represented by three states, low, moderate and high.

The other information found favourable by the participants includes the information required specifically by veterinarians. This is information about the measures to follow if an outbreak exists in an area. An example of such a measure includes quarantine procedures. Other veterinarian information includes regulations to follow when taking precautionary measures. This is because of the restrictions that the government imposes when infectious diseases especially notifiable ones are being reported. The other information, suggested through the literature discussed in Chapter 2, which was not stated by the participants include stating information about areas at risk and contact information for when a user wants more information. However, such information can then be incorporated in the system prototype that is being proposed so that all disciplines concerned are catered for.

5.6 Conclusion

The observed patterns in the similarity of choices by different participants indicate the need for supplying users with detailed information about diseases. Users do play a large role in the design process of a reporting system. This is observed and confirmed by the variety of opinions that each of the veterinarians showed. It is therefore important that these are taken into consideration when building a reporting system. The features that each participant desires must be thoroughly studied so as to find ways of integrating them together to develop a system that incorporates all the observed attributes. This is regardless of the fact that a feature is desired by only one individual because that individual can represent part of the population at large that could find the same feature interesting and favourable. The discussion of the results obtained in this analysis shows how the results relate to the literature around requirements for disease reporting systems and the visualisation of information discussed in Chapters 2 and 3. The information obtained has given a clear view about what users find important from zoonotic disease reporting sites.

6 Prototype Design and Implementation

6.1 Introduction

Following the literature study and the analytical studies performed in the previous chapters, a prototypic reporting system is proposed for development. The design will incorporate each of the design attributes suggested as important, popular and essential. This chapter discusses how the proposed system is designed. After the proposal, the system is implemented from the data gathered in Chapters 2, 3, 4 and 5. This is to ensure that the system supports the requirements of a disease reporting system. Chapter 3 has suggested the visualisation techniques that are suitable for displaying different kinds of data. Chapter 4 has shown what is being commonly used on the currently deployed web systems. Chapter 5 gives detail on what users find important in any disease reporting system. The information to be included and visualised is taken largely from the studies made in Chapter 2 and Chapter 4. The combination of all the gathered data helps to build a system that can be used in reporting disease information during disease outbreaks. This chapter also considers the tools that can assist in implementing the proposed design system and effectively incorporate all the gathered requirements. Careful consideration is also given to ensure that the principles of developing effective interactive maps and all the other principles for development are followed during development.

6.2 System Design

The selected visualisation techniques classify the system representation according to user requirements, literature behind disease surveillance, visualisation and results from the analysis of visualisation techniques used on current websites. The system to be designed focuses on representing abstract data about zoonotic disease reports and using visualisation properties and tasks to engage the user. This is because the information that effectively defines the requirements of a web-based system for delivering disease information reports has been gathered. The presence of the web systems that are used for reporting disease information have demonstrated that as Chapter 2 states, web-based systems are now being used to rapidly distribute disease information during outbreaks. The detailed studies and analyses made about the different visualisations techniques used have also demonstrated that the way that information is presented for its effective use can be improved. Lastly the user analysis study has confirmed the requirements needed in designing a system for disease reporting.

Because literature research has shown that disease information has spatio-temporal characteristics (Chapter 3), the design should ensure that these are incorporated into the system. The map visualisation technique can represent the locations that are affected by outbreaks confirmed. This will support the spatial relations of the data such that if a disease is confirmed in one area then the surrounding areas are monitored to prevent spread to those areas. The linear timeline can be used for demonstrating temporal relations. These two can be designed in such a way that they depend on each other thereby supporting the spatio-temporal relationships. This means that when the arrow on the timeline is moved then data changes on the map accordingly.

From the information studied, variables defined by size, shape or colour can be placed on the map or the map areas can be defined by colour and texture. However, since the use of point variables on the map can be unfavourable if the numbers of reported cases are many, the design then reverts to using colour saturation on the map areas to represent severity. This is what the results from the user analysis found desirable. This means that the statistics on the current data can be classed into different groups that can define different levels of disease severity in an area. Because the values used range from 1 to 5000, with most areas showing cases that commonly range between 100 and 1000, the data is classified using the quantile method (Chapter 3). This resulted in 6 classes of data. The severity of a disease in an area is important and so ways in which this can be easily visible to the user is explored. The colour saturation will distinctly differentiate between the classes so that users can easily identify areas with high disease levels. In order to achieve this, the colour used is red. This is because red is a colour that alerts and gets the attention of viewers. The more saturated the red colour the more at risk the area is.

Since the need to compare data for current and previous months or years is paramount for analysis, bar charts together with line graphs are selected to analyse differences between the data. The data to be compared includes finding relations in the numbers of dead, killed, suspected and confirmed cases. Analysis also involves comparing the increase in reported cases about a particular seasonal disease which occurred in the same month but in different years, e.g. the number of cases reported in one month of a certain year can be compared with the number of cases reported in the same month but of the previous year to determine if the occurrence of the disease increases or decreases with time. Some participants suggested that since some diseases like horse sicknesses, come in different strains, these can be compared together as well to easily visualise the prevalent strains. A combination of the bar chart and the line graph will be suitable in comparing the number of disease cases. This is because most participants selected them as favourable and literature also finds them useful for effectively demonstrating the shape and velocity of change and this is important in observing how the disease has changed over time.

The other important information to be placed on the side-bar that the participants found favourable compared to popup boxes mainly includes the properties and characteristics of the observed disease. This is information obtained from existing websites and the research literature that has been explored about disease information. This information includes the disease description, symptoms to look out for, species at risk, transmission mechanisms including human contact information, exact data or observation, control measures for the public to follow and the steps to take if one is a veterinarian.

To promote user interactivity, the design allows the user to select a disease through a drop down list with all the notifiable and controllable diseases. Interactivity is also supported by clickable map areas, movable timeline and dynamic box with information about the disease. The visualisation tasks (section 3.1) of data extraction, filtering, details on demand and traceable steps are incorporated into the design so that the user can gain clarity about data and can also select what is important to them. The user must be able to get an overview of the diseases that are occurring in the whole province of Eastern Cape and also be able to observe the affected areas at one particular time of the year. However interaction must not be overdone to avoid a design that is confusing.

After identifying the attributes to use in the design, these are organised together to form a final representation of the system display. Careful consideration must therefore be placed on the overall arrangement of the variables in the system interface. Following the visualisation study in Chapter 3, the visualisation techniques and their variables must be well aligned and contrasted to promote a design that is attractive and clear to the user. Figure 6.1 shows the prototype sketch of the proposed system. Following the design process is the implementation of the system.

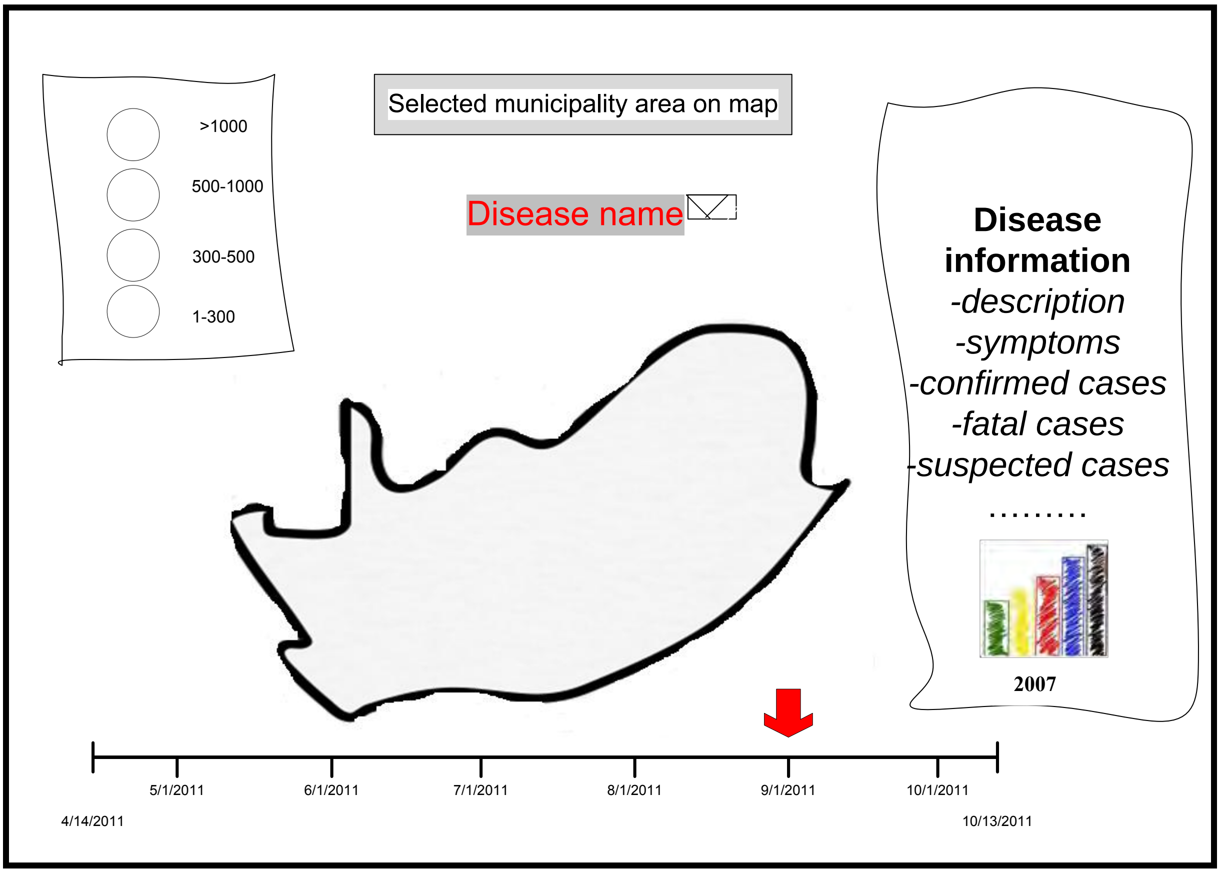


Figure 6.1 Sketch of the proposed system design.

6.3 System Implementation

From the proposed design, we are now able to develop the prototype. The designed prototype gives a functional approach to analysing the reporting system. The outcome of a design can be influenced by the tools chosen to build the system. The tools have to understand the problem and depict it properly, incorporate user experiences and be flexible for any changes and so deliver accurate results. The tools chosen should support the proposed system design fully to ensure that all requirements are captured into the developed system.

To begin with, the necessary requirements to build our system prototype are identified. For example, there is need for a source of information which is a storage database system like MS Access, Oracle or MySQL. The disease information that has been suggested as important requires a storage medium that can easily be accessed when requested. A tool that supports the development of the front end of the interface must also be chosen. Through research on such tools, Flash, Flex and Silver-light are examples of software applications that can support the development of such web-based applications. These applications are selected for their ability to develop interactive designs. Because the interface promotes interactivity, the database should supply information that can be displayed on the design interface upon user requests. Since the requirements of the system have been identified, the tools to use are then chosen to support the design requirements of the system. Table 6.1 shows a summary of the design requirements and the tools or software that can support them. The following sections give a description of each of the tools or software chosen for use in the system development.

Table 6.1 Matching system requirements to the tools.

Requirements	**Tool or Software to use**
1. Storage medium for disease information to display	MS Access database
2.Interactive tool to design the interface system and deploy it on the web	Adobe Web Standard CS3 which consists of applications like Fireworks, Flash and Dreamweaver
3.Mediator between Flash and the database	Java XML Sockets
4.Facilitator for database to Flash communication	Open Database Connectivity (ODBC)
5. Platform to enable organizations to deliver web-based interfaces on the internet	Internet Information Services (IIS 7.0)

6.3.1 MS Access Database System

Access is known to be the most popular database program that is favourable to those who are not IT professionals because most individuals are knowledgeable with Microsoft products. Access can also cost effectively solve a wide range of database related problems. Since the system developed will need to be understood by its users, who are veterinarians by profession and so have less computer related knowledge; MS Access becomes the best database option to use to accommodate those who are not experienced with recent versions of database applications like SQL servers. MS Access is favourable in this design because it requires less code than other database alternatives and is known to be an effective platform for prototyping because it promotes rapid application development. Access is also compatible with many data sources, including SQL Server; therefore it can be changed to other database types when necessary. The fact that Access allows professional developers to create sophisticated multiple user applications added to its choice in the development of the proposed system.

6.3.2 Adobe Web Standard CS3

From the various selections of software packages that can achieve the same results, Flash is chosen because it is inexpensive and is very easy to use with minimum code needed. If code is used, it is not difficult to learn even for users who have never used it before. Flash is the largest installed base and hence many people can access Flash applications easily. It also has a large developer base meaning it provides room for improvement since many developers have experience with it and for small files, it is very quick to load.

Flash is chosen to develop the system interface because it has the ability to visualise web communication interfaces, rich media and visual communications media effectively [1]. It has the ability to develop attractive and interactive interfaces for desktop and phone applications which is what this project aims for, an interactive interface which is flexible for adaptation to any other medium besides the computer. It promotes the development of an interface that can easily be controlled. It also consists of different applications within it e.g. Adobe Fireworks, Adobe Flash, Stock Photos, Dreamweaver and more. Fireworks is used to convert bitmap images into separate components that can be imported to the Flash application. The Flash application is also used to build the interface which includes the timeline, combo box and dynamic textboxes of our system design. Only these two applications of Adobe Web Standard are chosen because they are relevant to the design prototype that is being developed. Flash contains an object-oriented language called ActionScript. This language is closely related to other languages like Java and C# and so makes it easy to learn and use in developing the design. It is mainly useful for editing flash applications thereby enabling flexibility in manipulating interfaces and their objects. Due to these advantages, Flash is chosen as a tool for development for this project.

6.3.3 Java XML Sockets

One of the problems encountered when using Flash is that it does not connect directly to a database. Due to this, many problems were encountered in obtaining a suitable middleware application that can make the database communicate with the Flash application. Initially ASP was selected as the middleware, however because the final design output of using ASP and ActionScript 3.0 was not attractive, another option had to be selected. ASP can also work with ActionScript 1.0 and 2.0 however there were many holdbacks in the writing of code to promote connections. Time was wasted in finding a suitable middleware application until the selection of XML sockets was considered suitable in achieving the goal of connecting the database to the flash application in an efficient way that supports the design.

The middleware application can connect the Flash system interface to any database. This connection assists in obtaining information from a storage medium and displays it on the system interface. The middleware connects the Flash movies with the source of information to obtain results that have been requested by users. XML sockets connect the client to a server, such that asynchronous bidirectional communications can occur. This means that both the client and the server can communicate freely at any given time. Because of this reliable connection, they are favourable for connecting the database to the flash application since an open communication is required for the success of this system design.

XML sockets are therefore suitable for connecting interactively created systems to a database. Flash uses ActionScript which has a built in XMLSocket class that opens a connection with a server to continuously listen for requests. Numerous languages can be used to accomplish the task of building a socket server service, e.g. C#, C++, Java and Python. Because Java is known to be portable, highly stable with high performances and it can be used in many operating systems without changing any code, Java XML Sockets are used for connection. A socket service is designed specifically to let applications interact with other applications in near-real-time to support the functionalities of any system. The Java XML Socket server accepts incoming and outgoing requests depending on what the user wants as results. The use of XML Sockets offers near-real-time connections between users and the created interface so that upon requests, feedback is given immediately.

6.3.4 ODBC

In order for two applications with different file structures to communicate, they require the presence of a translator that enables the applications to understand each other. If the applications are compliant, this can be achieved through the use of an application programming interface known as ODBC. ODBC asks for the database file that an application wants to connect to and the ODBC driver connects them. In this case, in order to integrate the MS Access database to an interface, ODBC is used to integrate the two parts.

One of the first problems encountered in the design of this system was that the recent 64 bit machines do not have an ODBC application that allows the direct connection to a specified database. MS Access 2007 cannot connect through ODBC for 64bit windows machines. This is seen by the inability to create a DSN using Windows\system64\odbcad64.exe; the ODBC drivers for MS Access just do not appear. As a result, time was spent in figuring out new ways of connecting 64 bit machines to an ODBC database system. However, at the time of this design nothing had been developed yet to achieve this connection to 64 bit machines. However since most individuals still use 32bit machines and MS Access was already chosen for a database, a downgrade to 32bit was necessary to promote the connections of the Flash application to XML socket to the Ms Access database.

6.4 Flow of the System

All the described tools are essential parts of creating the proposed system. Flash connects to the database through Java XML Sockets. The socket listens for requests and responses. Flash then sends a request to query the database and the database responds with the requested information. Since Flash cannot communicate directly to a database, the Java XML socket acts as an interpreter that processes all requests and responses so that Flash and the database can understand each other. The socket communicates with the database on behalf of Flash to request for information and the socket also communicates with Flash on behalf of the database to give responses. For the result data obtained from the database application to be compatible with the Flash application, ODBC is used to translate the requests and results so that they can be understood when received. In order to test if the developed system is web compatible, the Flash software package asks for permission from IIS to access the web server. IIS allows Flash to send requests and obtain responses through the internet. The process flow of the development is shown in

Figure 6.2.

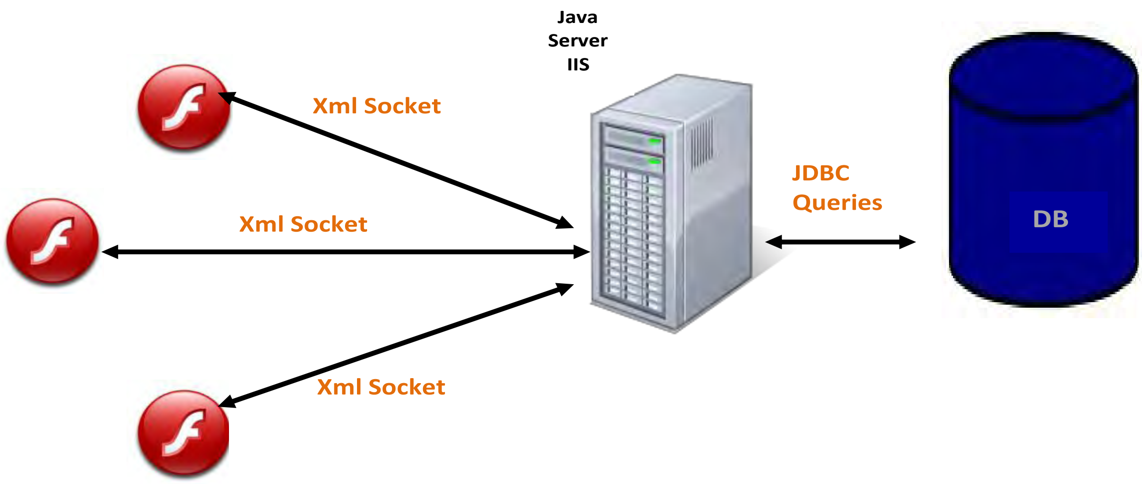


Figure 6.2 Flow Chart to show how the system works.

6.5 Developing the Front End Design of the System

From the designed prototype, there are 3 major parts of the design interface, that is, the map, timeline and the key. The rest of the design components include dynamic text boxes and a drop down list. The map is developed using the Adobe Web Standard CS3 software applications. One of the applications that are initially used in the development of the map is Adobe Fireworks. Fireworks provides innovative solutions to graphical problems and is specifically known for designing and manipulating web graphics. Some of these solutions include new creations of bitmap and vector images, editing of existing images, performing image effects like on-rollover events and on-mouse-over events, reducing and expanding images without compromising their quality and automating repetitive tasks. Adobe defines Fireworks as "a unique hybrid vector and bitmap tool that delivers the most efficient design environment for rapidly prototyping websites and user interfaces, and creating and optimizing images for the web" [1].

The need to have selectable components of the South African map makes the Fireworks application suitable due to its ability to manipulate images. Fireworks operates on bitmap and vector images because computer based graphics displays graphics in either of these two forms. One of the characteristics of our proposed interface is to allow the user to click on the areas of the map. Because of this, the bitmap image map of South Africa, which was obtained from one of the Grahamstown personnel who deal with mapping, is converted into a compact map with separate components that represent the municipalities of South Africa (Figure 6.3).

When the converted map components have been created, each of the components is then imported to another application program of Flash known as Adobe Flash CS3 professional.

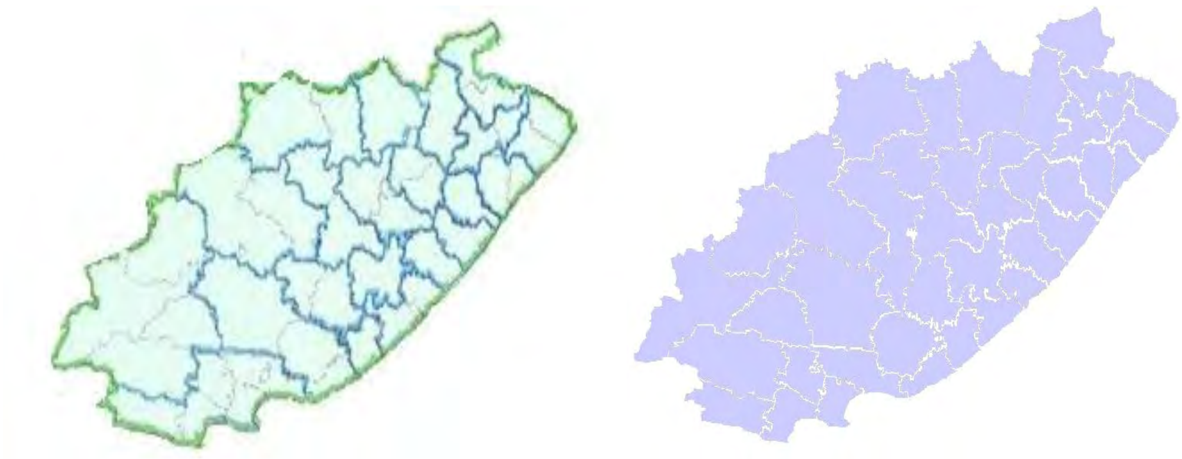


Figure 6.3 Bitmap to a compact map of the municipalities of Eastern Cape, South Africa. (Map generously donated by Garmin South Africa).

Flash adds functionality to each of the district municipality components. Initially, each of the components is converted into symbols that Flash understands. Flash uses symbols like a button, movie clip or graphic. A symbol is a reusable object created in Flash. A graphic symbol is a reusable static image that can be animated; it is converted into a single controllable object. Button symbols are those that add interactivity to flash movies by responding to mouse events (clicks), key press or rollover events and other actions, they are mainly used for timeline navigation. The movieclip symbols are reusable objects of Flash movies. They comprise of one or more graphic/button symbols. They are favourable in that one can control them by using the ActionScript code to change their properties, e.g. dimensions, position, colour and alpha. In this case, all the map components are converted into movie clips since they need to be further manipulated using ActionScript. These movie clips are then named according to the municipality areas that they represent so as to be able to refer to them when using the code to manipulate them.

Flash allows for the creation of an interactive timeline that will display required information when the user clicks over certain sections. The first step is to create the timeline using flash components. This is achieved by drawing a simple horizontal line with event objects, which are the perpendicular lines, and textboxes to indicate the time and information where something occurred. This is followed by programming the timeline to display appropriate information, provided by the Access database which stores the disease information, when each time event is selected. Figure 6.4 shows the developed design of the timeline.

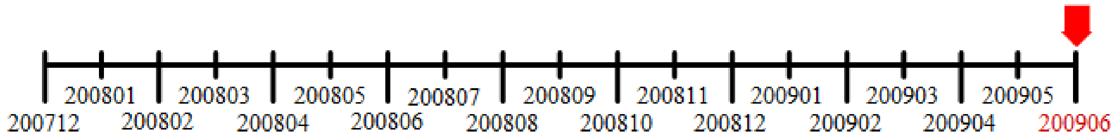


Figure 6.4 Selectable timeline with monthly intervals.

From the information obtained from the previous chapters, the most important information to be observed first is the disease name, the affected area and its surrounding areas, the severity of the disease or outbreak in an area, the date and then the other information about the disease. Because of this, the map shows the location of the affected area in relation to other surrounding areas and the timeline shows the date. There is need to also show with clarity, the name of the affected area at one glance, the disease being observed in that area, the severity of that disease indicated by the number of cases that have been confirmed and then the other information.

From Chapter 3, one of the visualisation properties states that colour saturation is a good way of indicating severity. Some of the websites have also demonstrated the use of this concept. Due to this, since the red colour is the most common and is good at representing endangered areas, it is then saturated into 5 levels to demonstrate different levels of severity. Light red indicates few cases. A dark red colour indicates a higher number of confirmed disease cases in an area. This results in the development of a key that can be used by viewers to conclude how severe the outbreak cases are and also to observe if surrounding areas have been affected as well or not. The default light purple colour of each map component indicates all areas that have no disease case reports for any disease at a particular time.

A combo box is built to hold all the zoonotic diseases that can be reported in South Africa. A combo box is an object that holds different kinds of data in a list such that one chooses one option from the list. When a disease is selected, the selected disease name is shown in red which is a different colour to the ones that are not selected from the combo box; this is mainly for clarity purposes. Besides the combo box, the window also has two dynamic textboxes that can change data value at any given time. One of the dynamic textboxes is for displaying the name of the selected area and the other is for the other disease information that needs to be reported on the site. The final overlay of the developed front end design of the prototype system which will appear to the user is given below (Figure 6.5).

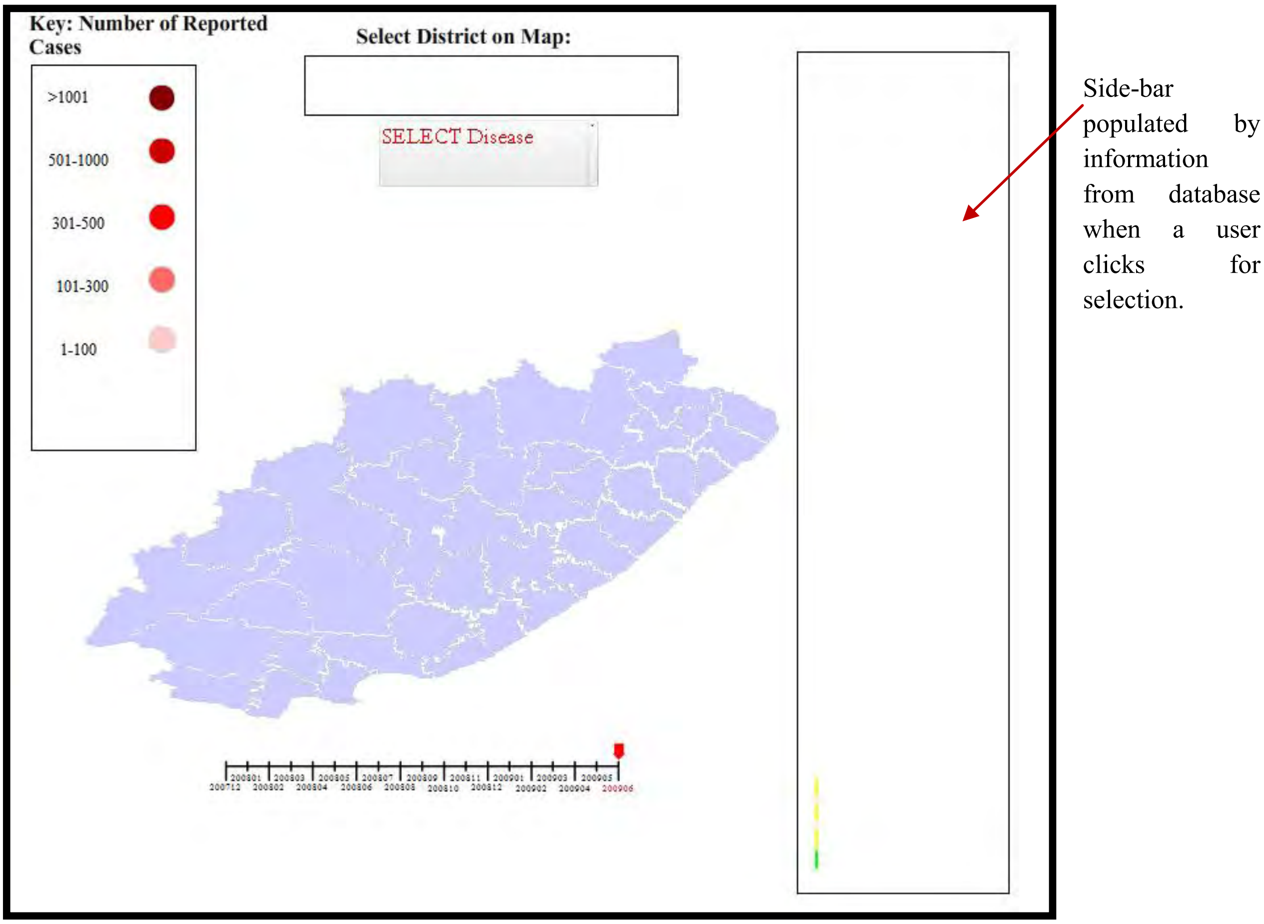


Figure 6.5 Final system design.

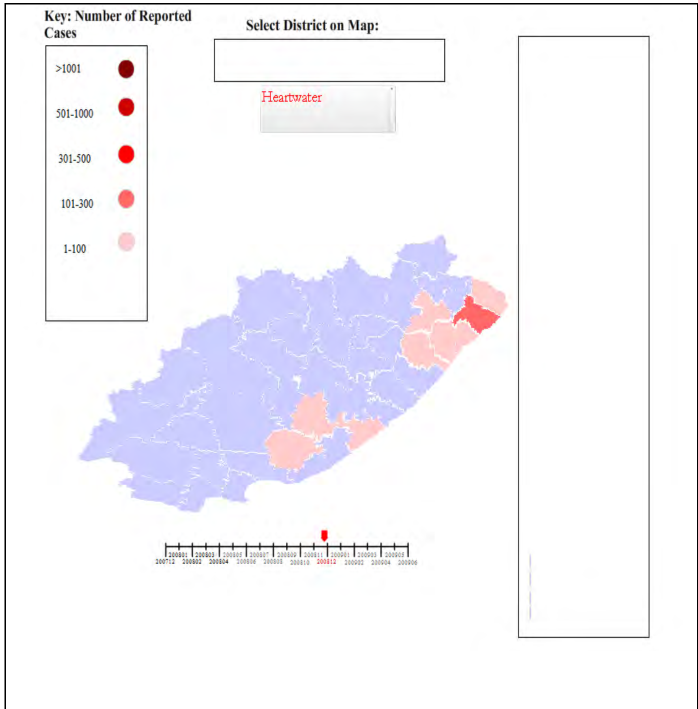
6.6 The Back End Design of the System

In order to control navigation and other interactive elements, to add functionality to the elements, Flash uses the ActionScript code. As a user selects components on the system the backend processes the request to obtain feedback. As already stated, Flash has a built-in support for socket connection with the XMLSocket object which establishes a communication channel with the socket server application. It is based around XML as a data-format for handling requests and responses. Three of the created components, i.e. the timeline, combo box and movieclips of the map areas when selected invoke the function at the back end. This function takes the date, disease name and municipality areas held by the timeline, combo box and movieclip areas respectively. Once there is selection or interaction from the user, ActionScript uses SQL statements to query the database accordingly. The Access database then returns the data to display on the system in response to a user request.

Because the first aim is to answer the "what, where and when" questions (Chapter 3), the query statements hold information that answers these questions. The "what" is the selected disease from the drop down menu list, the "where" is the selected area of observation from the map components and the "when" is the selected time on the timeline. The timeline has a default value which is the most recent month and year on the timeline. To change and view data about that disease for different times, one moves the arrow across the timeline to the desired times. This ability supports the spatio-temporal characteristics of visualisation which allows observations of data changes with time. The data is then sent to query the database through Java XML sockets.

As already described we opted for Java XML Sockets to connect the Flash application to a database. Using ActionScript one can connect to an XMLSocket server, send and receive XML-formatted data, and close or open connections to the server. The server listens for a connection, which when established by a client allows request to be sent in the form of MySQL statements that then query the database. When the Java Socket receives the query, it searches for data from the database. Depending on the results obtained, Java executes the statement and arranges it so that it can be sent back to the Flash application for display on the system interface. When the data reaches the Flash application it is instructed to display it on a dynamic textbox that represents the side-bar stated in the prototype design sketch. The text arrives as an XML document hence it is converted into text that can be understood by the user. The textbox will contain text that describes the disease, states the exact number of confirmed, fatal and outbreak cases observed in that area. It also displays a graph which compares observed cases for that time for easy comparison of confirmed, outbreak, killed and dead case values. The connection closes when a response is received. Table 6.2 gives three views of the design system in action after user requests.

Table 6.2 Final views of the developed system in action.

<table>
<tr>
<td>
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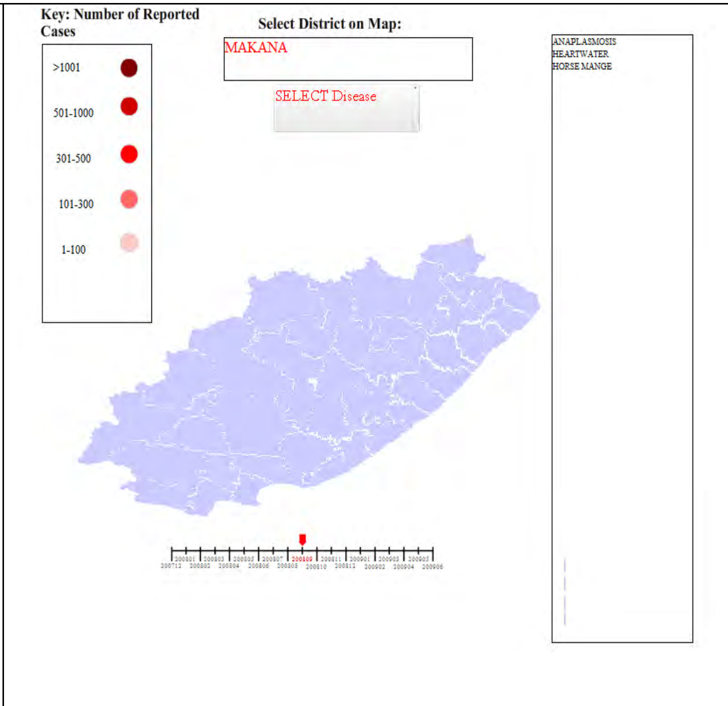
<td>
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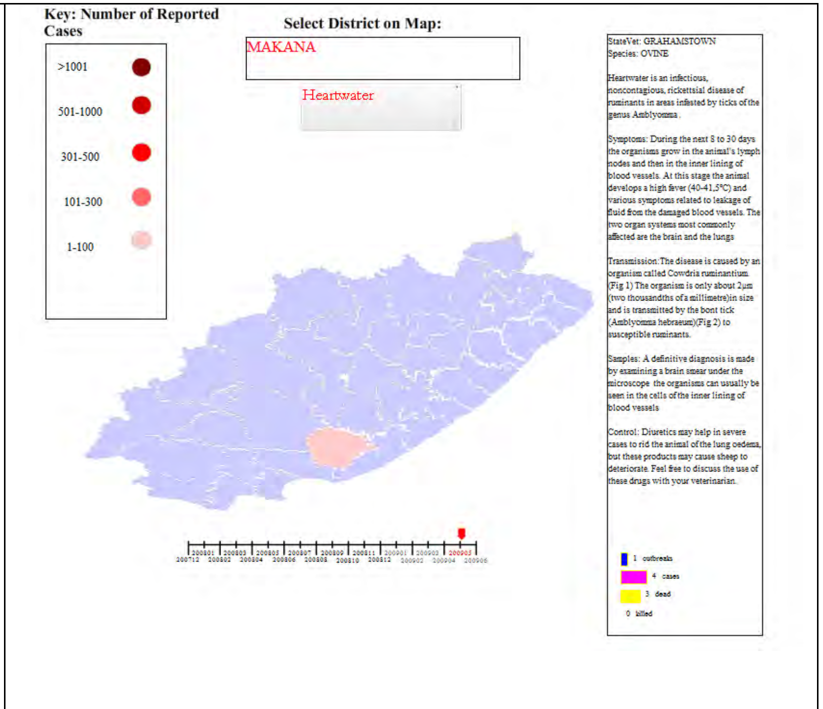
<td>
</td>
</tr>
<tr>
<td>1. This view shows the response when a user needs to see all areas that are positive for the “Heartwater” disease in “December 2008”. From the map, 9 areas have been affected by Heartwater in this time. Eight municipal areas have low positive cases of between 1 and 100 and one area has a higher number of reported positive cases of between 301 and 500.</td>
<td>2. This view shows the diseases reported in one municipal area “Makana” in “September 2008”. It lists the diseases on the side bar. This is useful for knowing all the disease outbreaks reported in a chosen area for a certain selected time. Above 3 diseases (anaplasmosis, heartwater, and horse mange) were found in the month of September 2008 in Makana municipality.</td>
<td>3. This view allows the user to select both an area and a disease for a certain time and obtain detailed results on the side bar. In this case the user wants to know details of any “Heartwater” disease cases reported in “Makana” municipality in “May 2009”. The user can then read on the side bar to understand more about that outbreak. The coloured bars at the bottom form the graph to compare data values.</td>
</tr>
</table>

The Adobe Dreamweaver application allowed the previewing of the developed system on a simple website that was created for deployment. IIS allows the system to be easily deployed on the web because its task is to manage all web applications including any database connections involved. Following the completion of the system development and its deployment on the web, the next step is to evaluate the prototype to ensure that it has been built to the users' satisfaction. The evaluation is to check if the visualisation techniques important for disease reporting have been used, check if the system supports visualisation properties and tasks together with other map principles and also check if user requirements have been incorporated into the system. In order to achieve this evaluation a mini focus group is used to assess the system and obtain more information that could improve the system.

6.7 Conclusion

This chapter proposes a system and describes the implementation of the system design. It has described how the system was designed from the information that has been gathered in data analysis and also demonstrated how the development phase of the project was conducted. This chapter has described the important sequence and points of developing a disease reporting system. This is initialised by identifying the appropriate tools for development which is followed by the description of how these tools are to be used in developing each section of the prototype design system. Adobe web standard has been highlighted as a good visualisation tool for developing interactive rich applications. Despite the challenges faced, the developed prototype system is concluded as meeting the expectations of the proposed prototype design.

7 User Analysis of the Developed Prototype

7.1 Introduction

Although the user requirements have been incorporated into the developed system, another user analysis on the actual system could be more effective to check if the system offers necessary information and runs as expected. The possible users of the created system can be of assistance in evaluating the developed prototype system. The developed prototype is therefore taken back to selected veterinarians for further analysis and to check if the requirements of a disease information system have been met. This is mainly to probe the user perceptions about the system thereby identifying where the system is lacking and where its strength lies.

The findings from this study will provide ideas that allow a concrete proposal for developing a prototype system. Subsequently, the results of this study lead to a final analysis of the functions of the proposed prototype system so that one can understand its abilities and observe if they meet the needs and expectations of its users. This means that all the results obtained from the investigations made in this chapter and in Chapters 4 and 5 will be compared, discussed and conclusions reached on the proper system to develop for disease reporting. The prototype system can then be suggested as suitable for development beyond the prototype stage to higher authorities who are responsible for officialising such systems.

7.2 Methodology

In order to validate the developed design (Chapter 6), further user analysis on the developed system was conducted. Since the aim of this analysis was to observe if the system includes what users want, need and like, a mini focus group was chosen as a method of obtaining this information because it encourages the discovery of what users like, want and need from any system. This investigation was mainly to verify the system requirements that have already been gathered from the literature (Chapter 2), web analysis (Chapter 4) and the user requirements analysis (Chapter 5). Since the problem was to identify the techniques that could be used in reporting diseases and coming up with ideas of what to display on the techniques, the focus group session was conducted in a semi-structured interview. The selected focus group provided a favourable setting in which new ideas or improved ideas were given around the issue of disease reporting. The semi-structured interviewing of the participants allowed the participants to provide ideas before being shown the developed prototype system, then after seeing the system, they were able to criticise it for improvement. The use of both these methods at one time strengthened the feedback obtained from the group participants.

The main purpose of initially conducting the focus group in a semi structured interview process was to understand the participant's expectations of a disease reporting system before they could assess the system. This is because an interview is a fact finding technique of collecting information from people on a face to face interaction [100]. It is known to be the best technique for emphasising the needs of people mainly because it helps to discover, clarify or verify facts, get users involved, identify requirements, and solicit ideas and opinions [9, 100]. Although conducting interviews is time consuming, interviews are known to be a good means of conducting in-depth discussions of issues from a small group of individual participants [55]. The semi- structured interview session therefore allowed each participant to be asked questions and to also hear their general views about disease reporting during outbreaks.

The focus group method is another method for collecting user requirements. It involves a small group of people with similar interests that sit together to share and react to ideas and designs they observe [51]. Focus groups come in many forms, e.g. mini focus groups (3-6 members), or traditional focus groups, (6 to 12 members). Mini focus groups limit the range of experiences because they are smaller, however, they are known to be more manageable, easier to recruit and are good for encouraging longer and deeper answers [51]. Although focus groups have their disadvantages, like having results dominated by certain individuals during discussions, their advantages can be useful to this investigation. The value of using focus groups is in their ability to elicit different opinions and also observe how others react to those opinions. It can stimulate new ideas and result in comments that would otherwise not be possible from conducting other user requirement techniques. This is known as a synergy, it means that the interaction or cooperation of the participants had the ability to produce a combined effect greater than the sum of their individual effects. They can determine if the idea behind a design system is rational, appropriate and attractive. The focus group method therefore made it easy to observe what the majority of the participants found favourable to the design and the suggestions that they thought should be incorporated into the system.

In order to perform this test, a group of interested participants were identified and used for this investigation. One state veterinarian, who many of the Eastern Cape veterinarians referred to as an individual who is very interested in incorporating technology to the veterinary field was emailed to request an interview for this investigation. This then resulted in 3 participants, the state veterinarian and two other general veterinarians, who were interested to be part of the investigation. The use of veterinarians as participants to test the developed system is due to their familiarity with common problems of veterinary information reporting and the governmental restrictions behind what ought to be reported to the public. This investigation was conducted at the participants' veterinarian offices in one of the municipal areas of the Eastern Cape.

Similarly to the user analysis in Chapter 5, the procedure followed first involved the signing of a consent form by the leader of the user participants (see Section 5.2.1). This was then followed by explaining what the project is about. This included informing the participants about the analyses that had already been made so that they know where the developed system resulted from. The participants were also aware of the user analysis study conducted for the purpose of obtaining more requirements for designing the system. After this explanation, a demonstration of how the system works was then given. This initiated the flow for discussing the system design.

In order to examine the results more carefully, with permission from the head of office, an audio recording of the discussion was part of the process so that a close analysis of the data can be made after the session. Instead of providing users with questionnaire forms, with their permission an audio recording was more appropriate such that the flow of the discussion could not be interrupted. The audio recordings taken during the session of interacting with the focus group members provided information that was analysed to make conclusions about the developed prototype.

To reach the aims of this investigation and to encourage users to think broadly about the prototype system, the discussion session was accompanied by prearranged questions. The group of participants were asked questions (see Appendix E) in order to encourage a discussion among the participants so as to understand and determine the different views that resulted. The questions included views about the usefulness of the system design, e.g. how beneficial the system is to the participants. The questions also included obtaining information about the attractiveness of the system design to ensure that there is a pleasing aspect in exploiting the system, e.g. the suitability of the colours used on the system design. Other questions answered queries about accessibility to information, e.g. is the information easily searchable when one queries the system. Some other questions were to check how interactive the system is, and what the participants preferred to see especially concerning the appropriateness of the visualisation techniques used and the information being displayed by the system. The majority agreement among participants was then observed from the discussions and the strength of the disagreements was also determined to draw out conclusions that would improve the developed prototype system.

Since the users were discussing a system that they could practically test, it became even easier to find faults and realise what is missing and ask questions about why certain techniques were used to display certain data or why other techniques were not used. This is because a functional design can probe the user to think broadly about the subject thereby removing some of the limitations of using paper mock-ups of the system. The participants' critics can give their views about what is good and what is not favourable about the system together with information on what is lacking. The results of this investigation then led to conclusions on the overall impression of the system to its users. This then led to the final changes to the design of the developed prototype.

7.3 Limitations

The major hindrance faced was finding or organising a large group of participants to help analyse the created system. The problem with using traditional focus groups is the difficulty faced in gathering many individuals to create a strong team that can work together in analysing a designed system. Due to this, in this analysis, difficulty was faced in forming a large group. This led to the choice of a mini focus group. However, the problems associated with traditional focus groups could have been solved by having two mini groups. Unfortunately, veterinarians are busy people who rarely gather in one region for group meetings due to the always required urgent duties that affect their own regions and because of this, a second mini group could not be organised as well. However, to minimise this limitation, the researcher occasionally asked the group questions to keep the discussion on track.

7.4 Results

Although the participants have previously seen similar models from the websites of developed countries, they were fascinated to use a system with data that is relevant to them. They engaged in the discussion giving their own perspectives and suggestions. The participants found that they needed guidance on how to use the system. They suggested that the system should instruct users about how it works; this could be placed on the website that loads the reporting system created or on mouse over events to any of the components of the system. For example, mousing over the map should tell the user what will happen should they click on the area they are on. It should also give critical information that encourages the user to read the side-bar e.g. a popup window could appear with particular information. This information comprises of the name of the area being observed, disease name, severity of the disease, number of cases reported together with an instruction to click on the map area for more information on the side-bar.

The participants found the use of a timeline to provide information about similar cases very useful. They suggested that all the historically available epidemiological information make analysis effective. However, the information to be displayed should begin with a monthly interval update on the timeline; and they suggested that with stability of the system, this could be improved to weekly interval updates that can in turn be reduced to days. The other suggestion pertaining to the timeline was to make the timeline more flexible since all the available epidemiological information can be relevant to an outbreak crisis. Instead of having the timeline stop at information for October 2007, as seen from the designed system in Chapter 6 (Figure 6.5), it should stop at the last available information on the database which is January 2000. The Gapminder demonstrates such a timeline. The other suggestion on timelines was to make the timeline react to play, pause and stop buttons so that an animation can also be possible. Gapminder also demonstrates this. The user is therefore given an option of selecting the time that they want to view the data for or playing the animation and observing how the disease cases have changed over the months or years.

The use of a map in visualising affected areas was also one of the design components they found favourable. This is because they found it easy to observe affected areas at a glance and identify relations in affected areas. Since the suggestion of having two views for the general public and the veterinarians arose, the zoom feature is now a necessary feature so that veterinarian authorities have the ability to zoom into individual locations of farms. The use of different colour saturation levels (i.e. the dark to light red colours used on the developed system) to indicate severity of a disease in each area on the map (to indicate the number of reported cases) made it easy for them to differentiate outbreak severity for various areas at a glance.

The charts to be used in representing comparative case information brought about the suggestion to make this technique highly interactive to improve analysis of information by easily performing comparative tasks. The participants stated that veterinarians perform many comparative analysis measures and each disease usually requires different comparative methods. Because of this, the importance of systems that analyse data is highlighted as paramount. Instead of having static charts, they can be made interactive. For example, the interactivity can be improved by allowing users to choose which diseases to compare and which months or years to compare and even which chart technique to use. Basically choosing the data to compare can improve the results obtained for users to extensively understand differences in disease case values and so draw useful conclusions.

One participant suggested that the information on the side-bar should include the humidity and temperature values of the affected areas at the time of an outbreak. This is because humidity and temperature are known to be contributing factors in the prevalence of epidemic diseases. Knowledge about temperature and rainfall levels can help veterinarians prepare for possible outbreaks in cases where a pattern is observed. This idea resulted from one of the experiences that they faced as veterinarians. They acknowledged that the presence of heavy rains at one occasion should have predicted the rift valley fever that later occurred but because of the absence of such systems, the increase in rainfall was not regarded as significant since they could not readily observe the areas affected through a spatial visualisation like a map. Another feature suggested as useful and hence must be added on the side-bar included information about predictions of disease and cost information that could result from delaying control measures.

One of the suggestions made by veterinarians was the development of a site that has two sections, one for the general public needs and one that caters for the veterinarian needs. This brings more clarity on the requirements of the different users that the system is built for since all entities have differing needs for using such a system. This division of the system into two sections is mainly to assist the veterinarians in supplying appropriate information since they are responsible for sifting information that can be viewed by the public. This can be achieved by the inclusion of user accounts for veterinarians to ensure a restricted access to other sensitive information. This idea stems from the governmental policy of not informing the public about every suspected disease that could cause panic and uncertainty to the public. The public should therefore be limited to disease reports that have been confirmed. However the veterinarians should know about any suspected disease cases surrounding their areas so that disease cases can be identified at their roots for rapid control.

Currently there are government regulations about the personnel who can flag a disease as suspected or confirmed and these are normally state veterinarians. If every veterinarian flags a disease as confirmed then there is no accountability which leads to false alarms and errors that can lead to unnecessary expenses. Therefore, depending on different levels of authority, the system can allow only the authorised veterinarians to flag a disease as suspected or confirmed to avoid false alarms. For accurate preventative measures to be taken, the veterinarians should know the exact origins of a disease in order to prevent spread by confining it to a particular area. However because confidentiality is important to farmers since a farmer can receive negative publicity if a disease is reported on their farm, such information cannot be made public. This is the reason why the developed system does not georeference the specific farm locations. However by creating hierarchies of accessing information (restricted by passwords), the participants thought veterinarians could have access to this information that the general public cannot access.

The sharing of information and promotion of transparency also prevents veterinarians from separately working on similar problems without all the necessary knowledge. Veterinarians know the number of cases that indicate an outbreak. When the number of suspected cases keeps increasing in one municipal area, different veterinarians in that area can collaborate to rapidly deal with the disease instead of working individually.

To achieve even better results through the use of different accounts, lab technicians could flag the diseases as confirmed or suspected as soon as they finish performing laboratory experiments. This can minimise the problems of making mistakes when information is kept over longer periods and also preventing the continuous entry of bad data into the database storage system. Most veterinarians perform these lab experiments themselves. This can improve the speed with which diseases are confirmed since some veterinarians that were interviewed before this project, which resulted in the starting of this project, stated that there is a one month lag from the time a disease is reported to the time of its confirmation. This could be reduced to a week or even less thereby improving the time of dealing with diseases. The veterinarian restricted views can also provide a way of accountability by ensuring that one provides a signature for flagging a disease as suspected so that if more information is required about their findings then they can be contacted. Higher authorities can then analyse this information to confirm cases and select that which is suitable for the public view.

The focus group brought to attention the fact that the database that is being used for storing data about diseases is only updated yearly. This information makes it difficult to have a near-real-time visualisation interface hence the future suggestions for the system to promote technologies that readily update the system such that other technologies can diagnose an animal in the field before confirmation test can be made. As soon as the disease is suspected then the veterinarians can be made aware through the updating of the interface that is viewed by them only. This will make veterinarians be on the lookout for any similar cases such that precautionary actions can rapidly be followed.

Overall, the system was found to be interesting, useful and a beginning to bringing technology into the veterinary field. Most participants however felt that a system for veterinarians should be priority because despite the fact that the public do not have a formal platform to obtain data, they are usually informed and diseases are sometimes controlled before they spread widely. They felt that the root of the problem is to ensure that veterinarians are aware of what is happening around them so that even when the farmers come with infected animals they have an idea about what the problem could be. If farmers come with similar cases then they could suspect a possible outbreak in the area and so follow the right procedures in dealing with predictable issues. Following is a summary of the suggested points throughout this analysis:

- Instructions on mouse over on how to use the system.
- Popup window should highlight important information before user clicks on the map area.
- Timeline updates should be decreased from monthly to weekly to daily with time.
- Timeline should date back to the oldest available information on the database.
- The timeline should have play, pause buttons for animation purposes.

- The system should have two views, one for the general public and the other for veterinarian authorities. These should be one system with different levels of access to information that is restricted by passwords and user accounts.
- With code signatories, veterinarians should be able to flag suspected diseases for veterinarian views only.
- Georeference farms for veterinarian views.
- Zoom feature to see individual farm locations.
- Charts should be more interactive by allowing users to choose diseases, time or areas to compare and even allow the user to choose the chart to use for suitable comparison. One of the main reasons highlighted for having interactive charts is to compare cases of a disease for a selected time with the cases of that disease at the same time but for the previous year. This is to observe if changes for the better are being achieved.
- Information to display on the side-bar should include humidity and temperature information.
- Expected predictions of disease outbreak spread or cost to be used or losses to be endured can also be included.
- From suggestions of all users used in this thesis, users should be able to log into the system site and register for updates whenever there is a suspected outbreak in their areas or the surrounding ones.

From the results obtained throughout this study the following diagram (Figure 7.1) demonstrates what the new proposed prototype system would look like. This system is built up from the already proposed and designed prototype system. Most of the newly added features are for the veterinarians' use. The main feature is the alternative view of observing a map with Georeferenced farms. The zoom feature also promotes the veterinarians to focus of selected areas of interest. However to access the information the system will require a username and password. The public will not be able to access this information that they are restricted to obtain by the government regulations. The help button allows all users who do not understand the system to read more about how to use it. The register button allows users to subscribe to news reports about diseases in their areas of interest to receive information either by email or phone. The buttons of the timeline i.e. *play stop and pause*, allow an animation of the reported case events thereby promoting the easy viewing of change in time at the user's pace. More information is also added on the sidebar together with two chart views for analysing the number of disease cases reported each year for similar outbreaks.

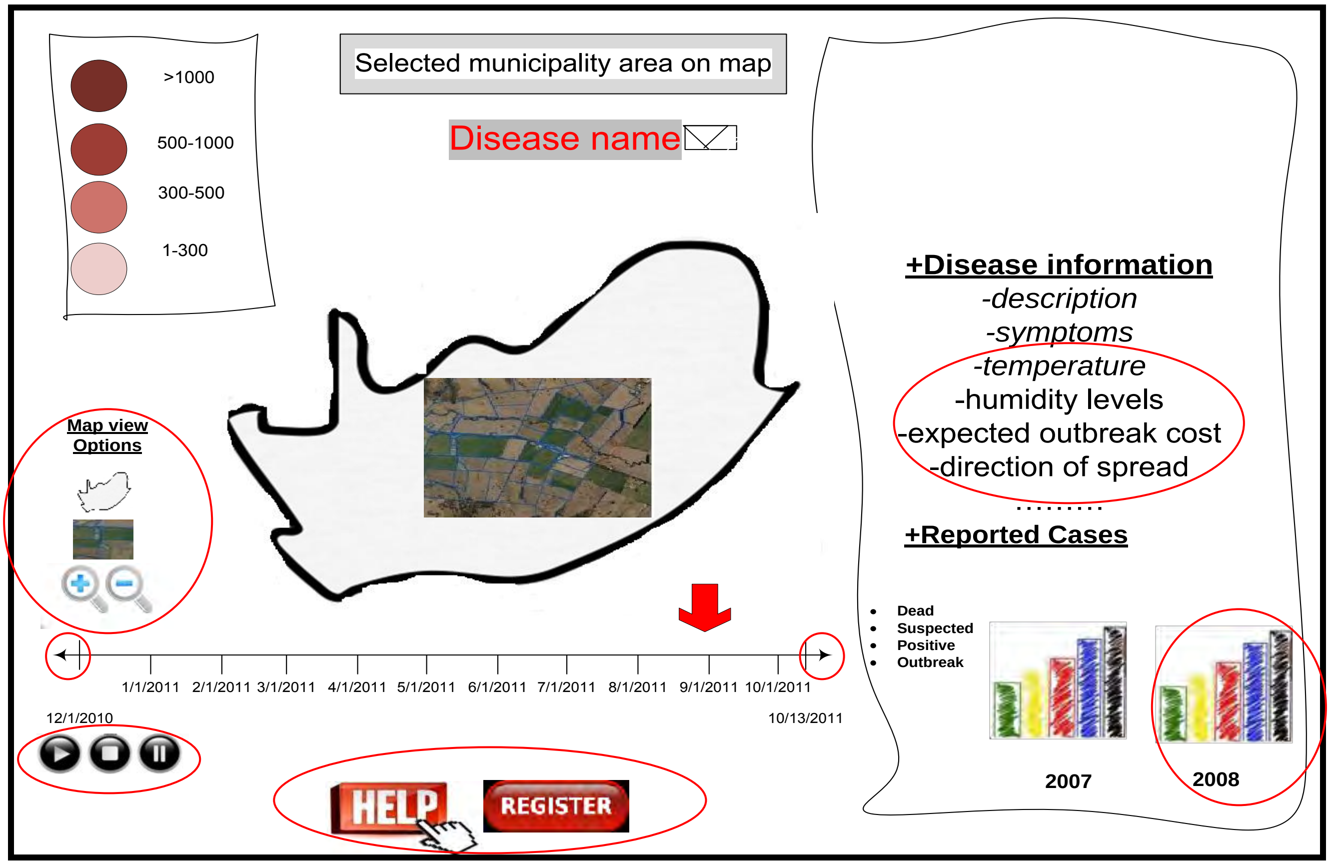


Figure 7.1 New prototype design (red circles = new features added on previous prototype (Figure 6.1)).

7.5 Discussion

The focus group gave a highly detailed response to the created system. In addition to what was visible to them other ideas were brought up. Since the participants were three, the use of the triangulation was used in making conclusions about the results obtained from the participants of the group. Triangulation is when more than one approach is used to enhance confidence in concluding the findings of research questions. This is because the agreement of two participants over one participant provided a platform to assess the importance of the idea being discussed.

The system offers users a lot of interactive views of data. One view that is offered is a list of diseases affecting one area that can be observed by clicking a region and not specifying the disease to view. When the user clicks on an area a list of the diseases that have been reported in that area at a selected time are listed on the side-bar. On the other hand, when a user selects a disease, all the areas affected by that disease are highlighted in colour intensity according to the classes that have been defined when proposing the system. This means that, all the areas with highly reported disease cases can easily be identified at a glance so that surrounding areas can take precautions and affected areas can follow instructions of eliminating the problem. Because of this, the participants all agreed that maps clearly show the areas affected thereby answering the "where" and "what" questions.

If one wants to study only one area then they can click on the area from the map and then a list of useful information can be placed on the side-bar. To view how the information has changed over the months or years, the user can play controlled animations or they manually click on their times of interest on the linear time scale. This answers the "when" question and promotes the surveillance critical factor of showing epidemiological data. The colour changes on the map area as time changes can inform the user about any increases or decreases in the number of cases. The users can also observe the line graph or bar chart that is automatically generated as data is placed on the side-bar.

The created system can compare values of one year with values of the previous years and can pick this up the temperature changes that the focus group thought was necessary to be added as information on the side-bar. The veterinarians can therefore be ready for the outbreak if it cannot be prevented. Designers may not know the information that users want to compare, however allowing users to choose the information that they want to analyse from a list of months for a selection of disease names can promote interactivity.

Two of the participants agreed that the popup window should show more information rather than the name of the area being moused over and instructions to click for more detail. This is because they felt that there is a need to encourage the users to want to know more information about that area. Due to this, the additional information suggested as information that can stimulate questions from a participant includes the state of the disease/s found in the selected area, the number of affected animals or people and the severity of the disease. One of the participants however thought that if the data changes on the side-bar with each click then they should do so to obtain more information instead of having both popup windows and the side-bar showing part of the information.

The most creative suggestion stated by the members of the focus group was that of having two sections of the system, one for the veterinarians and one for the general public. This suggestion answers a lot of questions that were observed in the analysis made in Chapter 5 and the results obtained in this investigation. If veterinarians can login to the system then every subscribed veterinarian can flag a disease as suspected for other veterinarians to view. The use of a password can ensure that only veterinarians can open the veterinary section of the disease reports. For example, veterinarians will have the ability to view both suspected and confirmed disease cases. And a further restriction can be made such that veterinarians registered in Eastern Cape cannot be seen flagging diseases in other provinces. The public and the veterinarians may view the same design system but with veterinarians having additional data that answers the needs of veterinarians such as regulations and the precautionary measures to take for each confirmed outbreak. This suggestion came about because two of the participants thought it unnecessary to have some other information about the diseases since they know the diseases and therefore do not need to read information about it all the time.

The creation of separate pages also indicated possible improvements in the rapid release of lab results such that diseases are confirmed early and can therefore be dealt with rapidly. This can ensure that instant updates to the system are made possible always thereby supporting near-real-time disease reporting. The separate pages also make it possible for veterinarians to view the origins of a disease from the farm level. This means that veterinarians can be able to view georefenced data. As soon as a disease is confirmed in one farm then precautionary measures can be taken before the disease spreads to other nearby farms. Other information like samples to collect should an animal be found dead can also be presented for the veterinarians since users do not really need to know such information. This can limit the problem of obtaining wrong samples thereby improving the common delays observed in the reporting system procedures. The other improvement of creating two sections to the system is that it enables veterinarians to work together in combating disease outbreaks. This can promote collaboration and communication which is another critical factor of disease surveillance systems.

7.6 Conclusion

Through the feedback that the participants have given, this investigation has shown how crucial the gathering of requirements is for the development of any system. The participants in this investigation have shown the importance of using spatial and temporal visualisations to report data. They have also provided suggestions on how the system can be improved. This has shown how focus groups can bring more insight about what a system requires. The comparisons of the results obtained in this investigation and the results obtained from the web investigation and the user requirements analysis (Chapters 4 and 5 respectively) have resulted in the final requirements needed to develop the zoonotic disease reporting system. The suggestions have therefore provided means with which the system could be developed to maximise its usefulness. This results in the proposal of a better prototype that meets the needs of disease reporting systems. The proposed prototype provides a platform with which a functional system can be developed for use.

8 Discussion and Conclusion

8.1 Introduction

This chapter discusses how well the created prototype system meets the demands of disease reporting interfaces and how it compares to other existing disease reporting systems. We assess if the created interface enhances the current ways used for reporting zoonotic diseases during outbreaks. The suitability of the system involves rapid availability of information in simple visual ways that promote its quick analysis. The results help draw conclusions that could assist in solving problems by promoting rapid decisions that minimise or prevent the extent of disease outbreaks. It is also necessary to discuss the extent to which the created platform successfully meets the needs of the users in obtaining disease information. This therefore brings a conclusion about the research matter.

This chapter also looks at possible extensions to the project. During the course of the project some ideas that can further enhance the project were gathered. Because they were beyond the scope of this project, they are therefore given as suggestions that can be incorporated into the system.

8.2 General Discussion

Currently the web is a good and modern interface for reporting zoonotic diseases. Literature (Chapter 2) has clearly indicated that the web is successfully being used as a medium for near-real-time communication. The ability of the web to disseminate large amounts of information globally within a short space of time is what makes it a rapid means of communication. Because information during outbreaks is time-limited, the web supports the reduction of time in the distribution of information. This brings us to the conclusion that the web should definitely be explored so that its advantages can be used to their full potential in the reporting of disease information to the public, government and veterinarian authorities.

Although literature has indicated that the internet can hasten reporting procedures, the exploration of its potential is vital for success. After observing the current state of web-based reporting, most developed countries have rapidly used the internet as a medium for disease reporting to improve health. Big organisations like WHO, PAHO, IOE, GLEWS all originate from developed countries. Their services even extend to dealing with zoonotic diseases that affect developing countries. However developing countries have failed to do the same for various reasons that include lack of resources, lack of knowledge, badly designed sites and heavy texted sites. This conclusion is drawn from the characteristics of the African countries' sites used in the web analysis (Chapter 4).

The developments of web-based systems that support visualisations to report disease information in near-real-time are becoming increasingly critical to the delivery of veterinary services. Modern systems now integrate data with advanced data queries to support interactivity and promote analytical and visual capabilities. South Africa has demonstrated its ability to use the web when reporting information, e.g. the existence of disease reporting websites. Nevertheless, the visualisation techniques used on its sites have mostly been text based. For this reason, the adoption of new mediums of information delivery has become a necessity. The analysis of the visualisation techniques used in general and those currently deployed by websites from developed countries indicate that it is possible to create attractive platforms that can rapidly deliver important disease information in South Africa. The detailed study of the visualisation techniques showed that they can be successfully applied in the representation of disease surveillance data. The existence of effective reporting models in developed countries also promotes the adoption of similar sites by developing countries.

The currently deployed websites that use the discussed visualisation techniques have demonstrated their ability to support spatio-temporal relations. This is because more than 60% of the websites have recognised the importance of spatial relations and so they use maps to visualise data. From these websites that use maps, 38% of the dynamic maps indicate that interactive visualisations which are the modern way of promoting human computer interaction are slowly being incorporated. The dynamic maps and timelines used support spatio-temporal visualisations. Gapminder, PAHO, GLEWS are examples of successful web models for interactive visualisations that can report disease information. This is because the appropriate visualisation techniques that best represent the spatial and temporal characteristics of disease surveillance data are being used and for countries that do not use them, it is only appropriate that they follow suit.

The feedback given by participants during the user analysis has shown how important users can be when creating systems that are useful. This is because from the South African sites, it is clear that the obtained user analysis requirements were not being met since they did not match what is currently found on the websites they use. Users are very important when developing interfaces because the success of the interfaces developed is measured by the degree to which the users find the system useful. This can only be achieved and incorporated by knowing and understanding what the users want as opposed to making assumptions about what their needs could be. Since the veterinarians are led by government policies, they know the restricted type of information to give to the public and this made them important as user participants in this study. The use of prototypes has made it easy to gather user requirements when building useable interfaces. This can then lead to the incorporation of their requirements and making them part of the development stage.

From the gathered information, it became possible to propose and develop a prototype. With knowledge about important factors that affect the creation of such systems it can be determined how all the relevant factors obtained can be integrated to build one robust system. Because the gathered factors matched up to the current requirements and characteristics of successful surveillance systems and how web-based systems and their visualisations can improve disease information reporting, those factors helped create a platform to propose and develop our own web system. Further user analysis has the ability to confirm that a system has been built correctly or not. As user participants interact with the developed prototype, ideas about how they can improve the system crop up and this then assists in proposing a better system.

The suggested prototype system varies widely with other global systems in the sense that it provides more disease information to the users. This is because it provides all the information required by a user in one area. The user is able to know what the disease is by reading its description and all statistics is given at a glance. No other system that has been observed on the web is customised for the veterinarians while this proposed system has a login to allow access to veterinarian authorities to access a separate site that the public views. This caters for both the veterinarians and the general public in viewing information since veterinarians noted that most of the sites are not of much benefit to them because of the limited information that is released to the public during outbreaks. The veterinarians also needed a system that will remind them of the samples to take while in the field for laboratory testing and this is not observed from any of the sites analysed in this research.

However, when comparing the developed site to the local websites, the system is far advanced. This is because it uses spatial and temporal visualisation techniques as compared to text which is common to almost all sites of South Africa. The system is much more interactive and users are able to view only the information that they are restricted to. With subscription to the system, concerned parties can read news updates on disease outbreaks through emails or SMS from their phones. This improves the distribution of information and ensures that people are always aware of what is happening around them. Because of this, the newly proposed prototype could be a great improvement to the health of both animals and humans since it is designed to enhance understanding and promote communication of reported information during disease outbreak crises.

8.3 Conclusion

According to our analysis, this project generated findings that support the use of the web as a medium for reporting disease information. It also generated findings that support the use of various visualisation techniques when reporting zoonotic disease information. Some of the important visualisation techniques like spatio-temporal visualisation techniques have been stated as appropriate for rendering disease information when reporting.

The current state of web-based reporting globally indicates that the web has been recognised as a reporting platform. This is because, according to the findings of Chapter 2, through readings of the literature surrounding disease reporting, there is support for the use of the internet to ensure near real-time disease reporting. The availability of web-based systems also proves the existence of such systems thereby showing that the surveillance critical factor of using web-based platforms in delivering information is being pursued. The observations made on the currently deployed websites, in Chapter 4, (the requirements and characteristics of successful web systems) show that they are partially successful. This is because some sites are not always available and the important disease information displayed is found in some websites and not found in other websites, and some visualisation techniques observed on the sites do not offer detailed information.

This research has demonstrated the use of visualisation techniques in reporting disease information by understanding what each technique can do and determining if it is suitable to represent disease information. Chapter 3 has shown that spatial and temporal visualisations are the most effective visualisation techniques for representing disease information. This is because of the spatial nature and time dependency features of zoonotic diseases. Maps are a very good way of showing geographical relations of disease data and therefore are chosen for use as a spatial visualisation technique. This has also been demonstrated by most sites analysed in Chapter 4. Interactive timelines with epidemiological data representations are good for representing temporal data. Some analytical visualisation techniques like charts have been demonstrated as useful for making comparisons with data. Line graphs are a great technique to illustrate change in time whilst bar charts have been seen to clearly show distinctions amongst categories.

The ways in which the information is visualised shows that newer technologies are being integrated into the veterinary field. This is illustrated by the number of dynamic web-systems, which promote interactivity (Chapter 4). This proves that the transition observed in the use of dynamic visualisation techniques instead of static techniques is present even though it is slowly being incorporated into disease reporting systems. As already discussed before, South Africa is unquestionably lagging behind when it comes to the incorporation of newer ways of using visualisation techniques on web systems. For sites that offer maps, charts and timelines, the techniques are still static and so this shows the need for a zoonotic disease reporting system. Because other global systems have adopted newer ways of using disease visualisation techniques, it is also possible for South Africa to do the same.

Users have been shown as important to the development of any system. This study has helped ascertain the necessary user requirements of disease reporting systems. The feedback that they provide, as observed in Chapters 5 and 7, brings detailed insight to what a system should display. Although they show their preferences in the visualisation techniques to use, they are much more effective in suggesting the information to display using those techniques for minimising outbreak problems. The criticisms that they gave about existing systems indicated that they are important in the designing of the platform for reporting disease information.

The project has identified important factors that merge data gathered from Chapter 2, information visualisations studied in Chapter 3, web-based requirements for disease reporting systems analysed in Chapter 4 and user requirements collected in Chapter 5. The relevant factors obtained from all the investigations conducted in this research have provided a platform for creating a system that integrates every characteristic that can make the system successful. This information helps design a system and ensures that all disciplines are considered and not neglected. Although information is gathered to help design the prototype system, further evaluation of the functional prototype system has shown that it can be helpful. The properties and tasks of visualisation that were highlighted in Chapter 3 together with information obtained from the analytical studies done in Chapters 4, 5 and 7 form the basis by which the system is evaluated for its success. This brings about critical points that have been overlooked when creating or designing the system, adds other important information, suggests ways of upgrading the system design thereby resulting in a system that fully meets the needs of its users. Chapter 7 has provided a sketch of a prototype system that can be suggested as a good prototype design for a disease reporting system in South Africa.

Overall, the proposed prototype appears to meet its goals which include using the web when reporting zoonotic disease data during outbreaks and also displaying that information in appropriate visualisation techniques. Since information is vital in the elimination of outbreak threats, the automatic conversion of data from its sources to graphical visualisations and the prompt response to user requests improves the speed of processing data. The system evidently demonstrates the influence of visualisation and interactive abilities in delivering disease information. The proposal of this system therefore creates an opportunity for South Africa to develop a robust system, from the proposed prototype, that can effectively report disease information to both the public and veterinarians during outbreaks.

8.4 Limitations

There is little emphasis on the existence of zoonotic diseases especially in developing countries since low priority is given to the teaching of zoonoses in medical programmes. This is because of the absence of a specific government policy or a legal framework to help control or monitor zoonoses. Moreover, the limited resources available to plan and implement such policies add to the challenge. Modern ICTs have also been proven difficult to accept in the society mostly in developing countries where people prefer to use common methods to communicate information. This problem remains challenging because it takes a long time to change human perspectives especially when they are convinced change will be complicated. The lack of internet enabled phones in the rural community is a hindrance in ensuring that all communities can be made aware of the emerging zoonotic outbreaks at any particular time. This remains a problem due to the weak public health infrastructure thereby it increases the vulnerability of communities to public health threats. Lack of computer knowledge when using modern technologies, especially in the rural community, prevents the access to vital information even if the health infrastructure is solid. Because of this, the rural community needs to learn how to use computers or internet enabled phones before they can use any system like the one created in this research. Although the results obtained from the brainstorming sessions and interviews conducted with various veterinarians of the Eastern Cape was helpful, using more veterinarians in this research could have provided more evidence of the requirements of a disease reporting system. The other limitation was the inability to travel to other provinces so as to make the study inclusive of all regions of South Africa instead of just the Eastern Cape.

8.5 Future Work

During the course of the research, various ideas that can be added to the developed system came up from the veterinarians. These are to enrich the system to offer more services that can assist in the reporting of diseases. Because these were beyond the scope of the project, they could not be incorporated into the developed system. These ideas can enhance the way that information is delivered for use during disease outbreaks.

One of the key points that make sites from developing countries successful is diversity in the sources of information. The information feeds into one system that is available to a wide range of users. The ability for veterinarians to flag a disease improves the diversity in the source of disease information. The problem that most veterinarians have is the inaccessibility of information about zoonotic diseases affecting the other areas of South Africa. This is problematic because the same disease can easily affect their regions if they are not readily prepared. These veterinarians state that they only have knowledge about the diseases affecting the areas they are associated with unless they somehow get hold of the newspaper reports for other regions. Most veterinarians access information about disease outbreak occurrences of other areas when the outbreak has been controlled. However this can improve transparency and better control diseases since the veterinarians can search for information about diseases flagged from any parts of South Africa.

The website to which the developed system is deployed can also expand the transparency of information delivery by having a section that allows users to subscribe for news reports about disease occurrences in their locations and surrounding areas. The reports can be sent through automatically generated emails or SMS as soon as the areas they select for alerts are flagged as confirmed for the public and both suspected and confirmed for the veterinarians. This can be helpful for farmers who have no time or cannot readily access the internet for information. Veterinarians can also choose to get updates about diseases in different provinces since the success of such an interface in one province leads to the further development of the system to include other provinces.

The developed system can be suggested as a platform to report all infectious diseases in South Africa regardless of their nature, i.e. whether they are zoonotic or not. This is important because one of the requirements to control zoonotic infectious diseases includes developing a health system that combines medical and veterinary informatics. The count of affected individuals becomes important when the zoonotic disease cannot be easily controlled. If these two fields can share information about diseases, they can assist each other in minimising the damage. The system can encourage medical health practitioners to take part in reducing the effects of zoonotic diseases by allowing them to report all zoonotic diseases related to their clients. A similar research can therefore be conducted with medical practitioners to obtain their own requirements that can be incorporated into this system to improve its effectiveness. This increases transparency and improves tracking the direction of disease spread.

After all the required information has been incorporated into the prototype system, an actual system can then be implemented with careful consideration of all the prototype design system. After the system has been created, the visualisations used can then be evaluated to observe if the users of the system are able to obtain the important information about zoonotic diseases during outbreaks. This will involve repeated user experience study work on the system until the approved system can be fully implemented and released.

8.6 Conclusion

This chapter discusses the characteristics of the newly proposed system and how it meets the goals and aims set at the beginning of this thesis. It gives a detailed overview of the success points of the system which is determined by comparing the obtained result to other existing systems and also through the gathered general information about reporting zoonoses on the web. The chapter also concludes the project by showing that web-based visualisation techniques are important in the reporting of zoonotic diseases during outbreaks.

References

[1] ADOBE. 2010. Adobe Creative Suite 3 Web Premium: Redefine the extra ordinary in Web Design and Development. [Online] Available: http://www.adobe.com/products/flash.html [Accessed 2010].

[2] AHMED, S. M., 2010. *The Role of the Veterinary Services in Food Safety*. 5th Dubai International Food Safety Conference. Dubai.

[3] ALLEN, M., VIMLA, L. P., CURRIE, M. L., CIMINO, J. J. and BAKKEN, S., 2006. Heuristic evaluation of paper-based Web pages: A simplified inspection usability methodology. *Journal of Biomedical Informatics*. volume 39, no. 4, pp. 412-423.

[4] ALPI, M. K. and KENAN, R. W., 2010. Exploring the State of Veterinary Informatics. [Online]. Available: http://espace.library.uq.edu.au/eserv/UQ:179865/n5_3_Thurs_Alpi_199.pdf [Accessed June 2010].

[5] ANDERSSON, A., HALLBERG, N. and TIMPKA, T., 2003. A model for interpreting work and information management in process-oriented healthcare organizations. *International Journal of Medical Informatics*. volume 72, no. 1-3, pp. 47-56.

[6] ATKINSON, L. N., SAPERSTEIN, L. S. and PLEIS, J., 2009. Using the Internet for Health-Related Activities: Findings from a National Probability Sample. *Journal of Medical Internet Research*. volume 11, no. 1, pp. e4.

[7] BARQAWI, B., HIJJAWI, B., NSOUR, M. and SHAKIS, S., 2008. *Overview & Challenges for Zoonotic Disease Surveillance in Jordan*. International Conference on Infectious Disease, Zoonoses, and Disease Surveillance in Iraq. Amman: Jordan.

[8] BRAA, J., HANSETH, O., HEYWOOD, A., MOHAMMED, W. and SHAW, V., 2007. Developing Health Information Systems in Developing Countries: The Flexible

Standards Strategy. *Management Information Systems Quarterly*. volume 31, no. 2, pp. 1-22.

[9] BRAY, K. I., 2002. *An introduction to requirements engineering*. London: Addison-Wesley.

[10] BREWER, A. C., 2006. Basic Mapping Principles for Visualizing Cancer Data Using Geographic Information System (GIS). *American Journal of Preventive Medicine*. volume 30, no. 2S, pp. S25-S36.

[11] BREZZI, M., JERN, M. and THYGESEN, L., 2009. *A web-enabled Geovisual Analytics tool applied to OECD Regional Data*. Reviewed Proceedings in Eurographics. Munchen.

[12] BRIANTI, E., ZIRILLI, M., POGLAYEN, G., GIANETTO, S. and DRIGO, M., 2007. Use of a Health Information System for the epidemiological Surveillance of Leishmaniasis in Urban Areas. *Veterinary Research Communications*. volume 31, no. 1, pp. 213-215.

[13] BRITTAIN, M. J. and NORRIST, A. C., 2000. Delivery of health informatics education and training. *Health Information and libraries Journal*. volume 17, no. 3, pp. 117-128.

[14] BROWNSTEIN, S. J., MADOFF, C. L. and FREIFELD, C. C., 2009. Digital Disease Detection -Harnessing the web for Public health Surveillance. *New England Journal of Medicine*. volume 360, no. 21, pp. 2153-2157.

[15] BRUCKNER, G., 2008. *New Challenges for the Veterinary Profession in Global Animal Disease Control and the Trade in Animals and Animal Products*. Sir Arnold Theiler memorial Lecture. Pretoria: University of Pretoria [Online]. Available: https://repository.up.ac.za/upspace/bitstream/2263/6958/4/2008_Bruckner.pdf [Accessed March 2009].

[16] BRUNO, L., 1990. Visualisation and Cognition: Drawing Things Together. *Representation in Scientific Practice Ed Michael Lynch and Steve Woolgar*. volume 6, no. 1962, pp. 1-32.

[17] BURROUGHS, T., KNOBLER, S. and LEDERBERG, J., 2002. *The Emergence of Zoonotic Diseases: Understanding the Impact on Animal and Human Health*. Washington: National academy press.

[18] CAMERON, R. A., 1997. *Active Surveillance and GIS as components of an animal health information system for developing countries*. Doctoral Thesis. Brisbane: University of Queensland, Department of Geographical Sciences and Planning.

[19] CARD, S. K., MACKINLAY, J. D. and SHNEIDERMAN, B., 1999. Readings in Information Visualization: Using Vision to Think. San Francisco. *Morgan Kaufmann*, pp. 1-295.

[20] CARD, S., GERSHON, N. and EICK, G. S., 1998. Information Visualization. *ACM Interactions*. volume 5, no. 2, pp. 9-15.

[21] CASTRONOVO, A. D., CHUI, K. H., and NAUMOVA, N. E., 2009. Dynamic maps: a visual-analytic methodology for exploring spatio-temporal disease patterns. *Environmental Health*. volume 8, no. 61, pp. 1-9.

[22] CHAN, H. E., BREWER, T. F., MADOFF, C. L., POLLACK, P. M., SONRICKER, A. L., KELLER, M., FREIFELD, C. C., BLENCH, M., MAWUDEKU, A. and BROWNSTEIN, J. S., 2010. Global Capacity for Emerging Infectious Disease Detection. *Proceedings of the National Academy of Sciences*. volume 107, no. 50, pp. 21701–21706.

[23] CHANG, H. and KIM, D., 2007. Key Functional Characteristics in Designing and Operating Health Information Websites for User Satisfaction: an Application of the Extended Technology Acceptance Model. *International Journal of Medical Informatics*. volume 76, no. 11-12, pp. 790-800.

[24] CHEN, C., 2010. Information Visualization. *Wiley Interdisciplinary Reviews: Computational Statistics*. volume 2, no. 4, pp. 387-403.

[25] CHENEAU, Y., EI IDRISSI, A. H. and WARD, D., 2004. The assessment of the strengths and weaknesses of current veterinary systems in the developing world. *Rev Sci Tech*. volume 23, no. 1, pp. 351-359.

[26] CHRISTOPHER, M. M. and HOTZ, C. S., 2000. Medical informatics in the veterinary clinical laboratory: an integrated subspecialty in diagnostics, resident training and clinical research. Revue med.vet. volume 151, pp. 569-576.

[27] COULIBALY, N. D. and YAMEOG K. R., 2000. Prevalence and control of zoonotic diseases: collaboration between public health workers and veterinarians in Burkina Faso. *Acta Tropica*. volume 76, no. 1, pp. 53-57.

[28] CRIPPS, J. P., 2000. Veterinary Education, Zoonoses and Public Health: A Personal Perspective. *Acta Tropica*. Volume 76, no. 1, pp. 77-80.

[29] DE LOTTO, J. R. and WITTY, J. R., 2009. The 'Swine Flu' Is a Reason to Plan, Not Panic. *Gartner*. [Online]. Available: http://www.gartner.com/resources/167800/167808/the_swine_flu_is_a_reason_to_167808.pdf [Accessed July 2009].

[30] DUTTA, P. 2006. Veterinary Public Health in India in Face Of H5ni Type of Avian flu Outbreak [Online]. Available: http://zunia.org/post/veterinary-public-health-in-india-in-face-of-h5n1-type-of-avian-flu-outbreak/ [Accessed 24 November 2010].

[31] FAIOLA, A. and HILLIER, S., 2006. Multivariate Relational Visualization of Complex Clinical Datasets in Critical Care Setting: A Data Visualization Interactive Prototype. *Tenth International Conference on Information Visualisation (IV'06)*. IEEE Computer Society. USA: Washington DC. pp. 460-468.

[32] FAO. 2009. Manual on Livestock Disease Surveillance and Information Systems [Online]. Available: http://www.fao.org/docrep/004/X3331E/X3331E01.htm [Accessed 12 June 2010].

[33] FEW, S., 2007. *Visualizing Change: An innovation in Time-Series Analysis*. Perceptual Edge. Visual Business Intelligence newsletter [Online]. Available: http://www.perceptualedge.com/articles/visual_business_intelligence/visualizing_change.pdf [Accessed November 2010].

[34] FOSTER, G. G. and MACKAY, M. C., 2009. A Web-Based Model for the Near-real-time Reporting and Surveillance of Zoonotic Disease Outbreaks in South Africa. *11th Annual Conference on World Wide Web Applications*. South Africa: Port Elizabeth.

[35] FREIFELD, C. C., MANDL, K. D., REIS, B. Y. and BROWNSTEIN, J. S., 2008. HealthMap: Global Infectious Disease Monitoring through Automated Classification and Visualization of Internet Media Reports. *JAMIA.* volume 15, no. 2, pp. 150-157.

[36] GAHEGAN, M., WACHOWICZ, M., HARROWER, M. and RHYNE, T.M., 2001. The Integration of Geographic Visualization with Knowledge Discovery in Databases and Geocomputation. *Cartography and Geographic Information Science.* volume 28, no. 1, pp. 29-44.

[37] GREENES, R. A. and SHORTLIFE, H. E., 1990. Medical Informatics: An Emerging Academic Discipline and Institutional priority. *Journal of the American Medical Association*. volume 263, no. 8, pp. 1114-1120.

[38] GOOGLE. 2009. http://www.google.co.za/imghp?hl=en&tab=wi.

[39] GWETU, M. V., 2009. *Web application by South African Health Institutions*. Proceeding SACLA '09 Proceedings of the 2009 Annual Conference of the Southern African Computer Lecturers' Association. USA: New York.

[40] HAMMOND, L., TODD, K. J., PAPADOPOULUS, S., NELSON, B., MAWHINNEY, S. and JOHNSON, F. C., 2002. Use of an Internet Based Community Surveillance

Network to Predict Seasonal Communicable Disease Morbidity. *The American Academy of Pediatrics*. volume 109, no. 3, pp. 414-418.

[41] HATTON, L. T. and LORENCE D., 2006. Assessing Domains of Uncertainty in Critical Web-based Healthcare Communities. *Journal of Medical Systems*. volume 30, no. 2, pp. 117-122.

[42] HOWARD, D. and MACEACHREN M. A., 1996. Interface design for Geographic Visualization: Tools for Representing Reliability. *Cartography and Geographic Information Science.* volume 23, no. 2, pp. 59-77.

[43] HUANG, S. C., 2008. *Icons versus words versus nonwords: Neural basis of human comprehension of meaningful or meaningless visual representations and a neuroergonomic approach of their usability*. Austin: University of Texas, School of Information.

[44] IVANOV, L. L. and BLUE, C. L., 2008. *Public health nursing: leadership, policy, & practice.* New York: Delmar Cengage Learning.

[45] JERRY M. J., ARDJOSOEDIRO, I., REYNOLDS, C., BOWMAN, J., MULLINS, G. and GENTHON, S., 2008. Agricultural Recovery Responses in Post-Pandemic Situations Arising From Major Animal and Plant Diseases. USAID. [Online]. Available: http://pdf.usaid.gov/pdf_docs/PNADN378.pdf [Accessed 2009].

[46] JIANG, L., ZHANG, A. and QINGWEN, Q., 2008. *Study on GIS Visualisation on Internet*. WiCOM '08. 4th International Conference on Wireless Communications, Networking and Mobile Computing. Dalian.

[47] JOHNSON, C. P. and JOHNSON, J., 2001. *GIS: A tool for monitoring and management of epidemics*. Map India 2001 Conference. New Delphi.

[48] KERREN, A., EBERT, A. and MEYER, J., (Eds). 2007. *Human Centered Visualization Environments*. Berlin: Springer-Verlag.

[49] KRAUSS, H., WEBER, A., APPEL, M., ENDERS, B., ISENBERG, H. D., SCHIEFER, H. G., SLENCZKA, W., VON GRAEVENITZ, A. and ZAHNER, H., 2003. *Zoonoses: infectious diseases transmissible from animals to humans* (3e). Washington: American Society for Microbiology.

[50] KROSCHEWSKI, K., STAUBACH, C., MICKLICH, A., KRAMER, M., KROSCHEWSKI, K., CONRATHS, F. J. and CARMANNS, R., 2006. Animal disease outbreak control: the use of crisis management tools. *Rev Science Tech*. volume 25, no. 1, pp. 211-221.

[51] KRUEGER, R. A. and CASEY, M. A., 2000. *Focus Groups: a practical guide for applied research* (3e). India: Sage Publications.

[52] LAMM, E. S., REED, A. D. and SCULLIN, W. H., 1996. Real-Time Geographic Visualization of World Wide Web traffic. *Computer Networks and ISDN Systems*. volume 28, no. 7-11, pp. 1457-1468.

[53] LAU, A. and VANDE MOERE, A., 2007. *Towards a Model of Information Aesthetics in Information Visualization*. Proceedings of the 11th International Conference Information Visualization (IV ’07). IEEE Computer Society. Washington.

[54] LAW, D., 2004. Mapping for Surveillance and Outbreak Investigation. *Focus on Field Epidemiology*. volume 5, no. 2, pp. 1-8.

[55] LAZAR, J., 2006. *Web Usability: A user-centred design approach*. Berlin: Addison-Wesley.

[56] LEYLAND, T. and CATLEY, A., 2002. *Community-Based Animal Health Delivery Systems: Improving the Quality of Veterinary Service Delivery*. OIE Seminar Organisation of Veterinary Services and Food Safety. Tunis: World Veterinary Congress.

[57] LOMBARDO, S. J. and BUCKERIDGE, L. D., 2007. *Disease Surveillance: A public Health Informatics Approach*. Hoboken, New Jersey: John Wiley & Sons Inc, pp. 51-102.

[58] LORENCE, D. and HATTON, T. L., 2006. Assessing Domains of Uncertainty in Critical Web-Based Healthcare Communities. *Journal of Medical Systems.* volume 30, no. 2, pp. 117-122.

[59] LU, X., 2009. *Web GIS Based Information Visualization for Infectious Disease Prevention*. Proceedings of the 2009 Third International Symposium on Intelligent Information Technology Application. Washington.

[60] M'IKANATHA, M. N., LYNFIELD, R., DE VALK, H. and BENEDEN V., CHRIS, A., (Eds). 2007. *Infectious Disease Surveillance*. Massachusetts, USA: Blackwell Publishing.

[61] MACAULAY, L., 1995. *Human Computer Interaction for Software Designers*. London: Thomson International Press, pp. 11-135.

[62] MACEACHREN, M. A., BOSCOE, P. F., HAUG, D. AND PICKLE, W. L., 1998. *Geographic Visualization: Designing Manipulable Maps for Exploring Temporally Varying Georeferenced Statistics*. IEEE Symposium on Information Visualization (InfoVis '98). North Carolina.

[63] MACEACHREN, M. A. and KRAAK, M., 1997. Exploratory Cartographic Visualization: Advancing the Agenda. *Computers & Geosciences*. volume 23, no. 4, pp. 335 - 343.

[64] MEGGITT, J. *What types of Veterinarians are there?* [Online]. Available: http://www.dailypuppy.com/articles/what-types-of-veterinarians-are-there/dc645dbc-b6a3-34c1-1231-85f347239066 [Accessed August 2010].

[65] MELIKER, R. J., SLONTICK, J. M., AVRUSKIN, A. G., KAUFMANN, A., JAQCQUEZ, M. G. and NRIAGU, O. J., 2005. Improving Exposure Assessment in

Environmental Epidemiology: Application of Spatio-Temporal Visualization Tools. *Journal of Geographical Systems*. volume 7, no. 1, pp. 49-66.

[66] MURPHY A. F., 2008. Emerging Zoonoses: The Challenge for public health and biodefens. *Preventive Veterinary Medicine*. volume 86, no. 3-4, pp. 216-223.

[67] OECD. 2003. *Emerging risks in the 21st Century*. France: OECD Publishing.

[68] PALMER, S., MORGAN, D. and BROWN, D., 2005. Early Qualitative Risk Assessment of the Emerging Zoonotic Potential of Animal Diseases. *British Medical Journal Publishing Group Ltd*. volume 331, no. 7527, pp. 1256-1260.

[69] PAPPAS, G., FRAGOULIS, K. N. and FALAGAS E. M., 2008. World Wide Web resources on zoonotic infections: a subjective overview. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. volume 102, no. 12, pp. 1181-1188.

[70] PARANTHAMAN, K., MCCARTHY, N., KENT, L. and GRAY, S. J., 2009. Invasive meningococcal disease: Completeness and timeliness of reporting of confirmed cases in Thames valley. *Public Health*. volume 123, no. 12, pp. 805-808.

[71] PLAISANT, C., 2004. *The Challenge of Information Visualization Evaluation*. Proceedings of the working conference on advanced visual interfaces. ACM: New York.

[72] POWEL, J. A., GRAY, M. and DARVELL, M., 2003. The Doctor, the Patient and the World-wide-web: How the Internet Is Changing Healthcare. *The Royal Society of Medicine*. volume 96, no. 2, pp. 74-76.

[73] RABINOWITZ, P.M. and CONTI, L.A., 2010. Human-Animal Medicine: Clinical Approaches to Zoonoses, Toxicants, and Other Shared Health Risks. In: Borack, J., 2010. *Book review*. volume 52, no. 11, pp. 1139-1140.

[74] RAGHUPHATHI, W. and TAN, J., 2002. Strategic IT Application in Health Care. *Communications of the ACM*. volume 45, no. 12, pp. 56-61.

[75] RHYNE, T., (Ed). 2009. *Visualisation Viewpoints: Data, Information, and Knowledge in Visualisation*. IEEE computer Society.

[76] RHYNE, T., TORY, M., MUNZNER, T., WARD, M., JOHNSON, C. and LAIDLAW, D. H., 2003. *Information and Scientific Visualisation: Separate but equal or Happy together at last*. Proceedings of the 14th IEEE Visualization 2003 (VIS ’03). IEEE Computer Society: Washington.

[77] RHYNE, T., IVEY, W., KNAPP, L., KOCHEVAR, P. and MACE, T., 1994. *Visualisation and geographic information System Integration: What are the needs and the requirements, if any?*. Proceedings of the conference on Visualization '94. IEEE Computer Society Press: Los Alamitos.

[78] ROBINSON, M.W. and DALTON, J. P., 2009. Zoonotic Helminth Infections with Particular Emphasis on Fasciolosis and other Trematodiases. *Royal Society*. volume 364, no.1530, pp. 2763-2776.

[79] ROBINSON A., 2003. *Guidelines for Coordinated Human and Animal Brucellosis Surveillance*. Rome, Italy: Food & Agriculture Organization of the United Nations (FAO).

[80] RUSTEN, E. and RAMIREZ, S., 2003. Future Directions in Agriculture and Information and Communication Technologies (ICTs). USAID.

[81] RWEYEMAMU, M., OTIM-NAPE, W. and SERWADDA, D., 2006. *Infectious Diseases: preparing for the future Africa*. Office of Science and Innovation. London.

[82] SCHAFER, S. K. and SULMAN, H., 2008. *Evaluating Health Information System for Developing Countries using Simulation*. IST-Africa 2008 Conference Proceedings. IIMC International Information Management Corporation: Namibia.

[83] SENAY, H. and IGNATIUS, E., 1999. *Rules and Principles of Scientific Data Visualization*. Washington: The George Washington University.

[84] SHIVUTE, I. M., OWEI, T. V. and MAUMBE, M. B., 2008. *The emerging ICT Use patterns for Health Service Delivery in Africa: Evidence from Rural and Urban Setting in Namibia*. IST-Africa 2008 Conference Proceedings. IIMC International Information Management Corporation, 2008: Namibia.

[85] SHNEIDERMAN, B., 1996. *The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations*. Proceedings 1996 IEEE Symposium on Visual Languages. IEEE Computer Society Press: Boulder.

[86] SMITH, D. R. and WILLIAMS, M. S., 2000. Applications of informatics in veterinary medicine. *The Medical Library Association*. volume 88, no. 1, pp. 49-51.

[87] SPICER, M. and GODSELL, B., 2010. South Africa as a Developed Country: Some Ideas from Business Leadership. *Business Day News*. [Online]. Available: http://www.businessday.co.za/articles/Content.aspx?id=127522 [Accessed December 2010].

[88] STONE, M., 2006. Choosing Colors for Data Visualization. [Online]. Available: www.perceptualedge.com/articles/b-eye/choosing_colors.pdf *[Accessed January 2011]*.

[89] SUI, Z. D. and HOLT, B. J., 2008. Visualizing and Analyzing Public- Health Data using Value-by-Area Cartograms: Toward a New Synthetic Framework. *Cartographica: The International Journal for Geographic Information and Geovisualization*. volume 43, no. 1, pp. 3-20.

[90] TAMAS, A. and RODRICK, F. J., 1999. Survey of Spatio-Temporal Database. *Geoinformatica*. volume 3, no. 1, pp. 61-99.

[91] THOMAS, J.J., BOHN, S., BROWN, J.C., PENNOCK, K., SCHUR and WISE, J. A., 1994. Information Visualisation: Data Infrastructure Architectures. Proceedings of the 7th international conference on Scientific and Statistical Database Management. *IEEE Computer Society*. Charlottesville.

[92] TOMINSKI, C., SCHULZE-WOLLGAST, P. and SCHUMANN, H., 2005. *3D Information Visualization for Time Dependent Data on Maps*. Ninth International Conference on Information Visualisation (IV'05). London: IEEE Computer Society.

[93] VAN DEN BOOMEN, M., 2007. Interfacing by Icons and Metaphors. [Online]. Available: http://metamapping.net/blog/up/CONF_interfacing_by_icons.pdf [Accessed January 2010].

[94] VAN DEN BOOMEN, M., 2008. Interfacing by Iconic Metaphors. *Configurations*. volume 16, no. 1, pp. 33-55.

[95] VARGA, M. and JACOBSON, Z., 2006. Applications of Network Visualisations in Infectious Disease Management. *Online Information for the Defence Community*. [Online]. Available: ftp.rta.nato.int/public//PubFullText/RTO/MP/RTO...///MP-IST-063-12.pdf [Accessed July 2010].

[96] WANTLAND, J. D., SLAUGHTER, R., PORTILLO, J. C., MCGHEE, M. E. and HOLZEMER, L. W., 2004. The Effectiveness of Web-Based vs. Non-Web-Based Interventions: A Meta-Analysis of behavioural Change Outcomes. *Journal of Medical Internet Research*. volume 6, no. 4, pp. 2-10.

[97] WARE, C., 2000. *Information Visualization: Perception for Design*. San Francisco. Morgan Kaufman Publishers, pp. 4-196.

[98] WEBER, M., ALEXA, M. and MULLER, W., 2001. *Visualizing Time-Series on Spirals*. Proceedings INFOVIS '01 Proceedings of the IEEE Symposium on Information Visualization 2001 (INFOVIS'01). IEEE Computer Society. Washington.

[99] WETHINGTON, H. and BARLETT, P., 2006. Usage and Data Collection Patterns for Novel Web-based Food Borne-Disease Surveillance System. *Journal of Environment Health*. volume 68, no. 7, pp. 25-29.

[100] WHITTEN, J. L., BENTLEY, L. D. and DITTMAN, C. F., 2001. Systems Analysis and Design Methods (5e). New York: McGraw- Hill Companies, pp.215-249.

[101] WHO. 2009. Integrated Control of Neglected Zoonotic Diseases in Africa. 2009. *Report of a Joint WHO/EU/ILRI/DBL/FAO/OIE/AU Meeting ILRI Headquarters*. [Online]. Available: http://whqlibdoc.who.int/hq/2008/WHO_HTM_NTD_NZD_2008.1_eng.pdf [Accessed February 2009].

[102] WHO. 2008. Food borne disease outbreaks: Guidelines for investigation and control. Geneva: WHO Press.

[103] WHO. 2006. Avian Influenza Control and Pandemic Preparedness in Asia. *Report of the Conference of Ministers of Health, Agriculture/Livestock*. New Delhi.

[104] WHO. 2005. The Control of Neglected Zoonotic Diseases: A route to poverty alleviation. *Report of a Joint WHO/DFID-AHP Meeting with the participation of FAO and OIE*. Geneva.

[105] WHO. 2004. Outbreak Communication: Best Practises for communicating with the public during an outbreak. *Report of the WHO Expert Consultation on Outbreak Communications*. Singapore.

[106] WILSON, K. and BROWNSTEIN, J. S., 2009. Early Detection of Disease Outbreaks Using the Internet. *Canadian Medical Association Journal*. volume 180, no. 8, pp. 829-31.

[107] WOODALL, J., 1997. Official versus Unofficial Outbreak Reporting through the Internet. *International Journal of Medical Informatics*. volume 47, no. 1, pp. 31-34.

Appendices

Appendix A

Lists the 40 websites used in Chapter 4 of this research. See electronic folder, Appendices, Appendix A.

Appendix B

Lists the questions that each of the participants, of the user analysis study (Chapter 5), were asked. See electronic folder, Appendices, Appendix B.

Appendix C

Lists screen shots that were shown to each user participant during the brainstorming sessions (Chapter 5). See electronic folder, Appendices, Appendices C.

Appendix D

This shows the consent form to be signed by each participant to obtain information during the project research. See electronic folder, Appendices, appendix D.

Appendix E

List the questions that the focus group participants were asked, for the user analysis of the developed prototype (Chapter 7). See electronic folder, Appendices, Appendix E.