A Veterinary Expert System for Remote Use

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Abstract

In this paper, the implementation of a veterinary expert system which allows for remote access through a mobile phone is examined. The background to the problem, including the circumstances the system would be used in, is discussed and the different tools available to assist in developing an expert system are examined. The process of acquiring the knowledge from experts and other locations for the expert system is then discussed and the various options with regards to the mobile interface of the end-user applications are examined.

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1 Introduction

In many remote areas, access to a veterinary professional is often restricted. Farmers and game reserve staff are often confronted with an animal displaying signs of illness, injury or distress and are forced to wait for the arrival of a vet. In some cases the person responsible may be unsure whether it is necessary to call for a vet, which can be a costly exercise. The delay in the arrival of medical attention can often be very distressing for both the animal and people involved. An expert system accessible in remote areas capable of diagnosing ailments affecting animals or advising on the necessity of calling a vet could greatly assist farmers and game reserve staff. The system could potentially provide a first line of diagnosis before a veterinary expert arrives and could also assist in verifying the diagnosis of a vet and provide assistance to the vet in diagnosing. Owing to the prospective users of the system not having easy access to a desktop PC during the normal course of their working day or while attending to a sick animal, the system should be accessible through a simple interface on a mobile phone.

2 Background to the Project

2.1 Expert Systems

An expert system aims to record the knowledge of an expert in a particular domain and then emulate the thought processes of the expert in making decisions using the acquired knowledge in that particular field [18]. It allows informed and reliable decisions to be made and conclusions to be reached on a matter in the absence of an expert to make the decisions [11]. One of the key points of an expert system is that it is interactive [6], querying the user for information regarding the situation and then reasoning decisions based on this information, using its stored knowledge and heuristics. As it moves further toward a decision, more focused queries are made of the user regarding the situation.

The structure of an expert system consists of four primary components [34]. The knowledge base stores the knowledge possessed by the system, which is used to mimic the decision-making ability of the expert, and includes both firm facts and heuristics. The working memory contains information provided by the user during a particular consultation session and the conclusions reached thus far based upon this information. The inference engine uses knowledge stored in the knowledge base and the information currently in the working memory to make new inferences and decisions. Lastly, the user interface allows the user to interact with the system, both to allow the user to provide information about the problem and for the system to provide feedback to the user.

An expert system interacts with the user querying it and by requesting information about the problem being faced and making assumptions and inferences based on the information presented to it. As it nears a conclusion it requests more detailed and focused information to allow it to draw an ultimate conclusion [11].

It also produces explanations of these solutions aimed towards the user of the system[3]. It is important that this functionality is present, as studies have indicated that systems which provide an explanation of how a decision was arrived at are more likely to be implemented and regarded as useful [3, 20]. As a human expert, such as a doctor, should be able to justify their conclusions when required to do so, so should the system be able to explain how it reached its conclusions. This allows the verification of the conclusions by an expert, where necessary [23, 11].

2.2 The Use of Mobile Phones

In the past, the expert systems which were developed were largely done so for personal computers, with network functionality not being considered, as it was often not present [17]. Since then, the popularity of the web has seen many expert systems shifting to becoming web-based and employing a server-client structure, where advantageous to do so, allowing for their remote updating and ensuring the latest information is utilised when a query is performed. The recent explosion in popularity of the mobile phone, and in particular the smartphone in the second half of the 2000s, has seen a rise in the number of expert systems with development targeted towards mobile phones as the expected devices which will be interacting with them.

A mobile-oriented expert system makes sense when considering the general working conditions of farmers and game reserve staff. Sick animals are unlikely to be in the range of a desktop computer, or within the easy reach and use of a laptop computer, making a system targeted at such devices impractical. A system where the user interface is presented on the mobile device and the processing is sent to a remote server over the internet would be more practical, as it would provide the mobility required and also allow the system to be easily updated with the latest knowledge and rules, as well as off-loading the processing to a more powerful device than a phone, many of which have limited processing abilities. Although the flagship and high-end smartphones today do boast impressive processing power[1][2][3], it is unlikely that all the potential users of the system would have ready access to such mobile phones.

A downside to the off-loading of processing and storage to a remote server is the resulting necessity to transfer the results of the interaction between the user and the system over the internet. Owing to the mobile devices anticipated to be used in accessing the system, cognisance of the availability and quality of mobile

[1] http://www.apple.com/iphone/specs.html
[2] http://www.samsung.com/global/microsite/galaxys4/
[3] http://www.nokia.com/global/products/phone/lumia920/specifications/

internet in the areas where the system would generally be utilised is important. South Africa's mobile operators claim to have almost universal, with the exception of portions of the Northern Cape, coverage in the country [4] [5], although this extends only to GPRS and EDGE. More advanced technologies such as 3G and later iterations are indicated as being more sporadic in rural areas of the Eastern Cape. In addition, operators tend to focus on urban areas when upgrading infrastructure, because of the larger consumer demand for services in those locations [31]. This indicates that a high-speed internet connection will not always be able to be relied upon, especially given the nature of mobile internet, with coverage and speeds differing greatly over relatively short distances in some location, as can be observed through the general use of a mobile phone.

2.3 Rural Farmers

An analysis of the literature regarding expert systems previously developed can provide insight into the potential challenges facing South Africa's farmers and game reserve managers. In China, researchers developed a web-based disease diagnostic expert system for pigs (Pig-Vet). In the beginning stages of the development, they interviewed farmers in the rural region they were targeting (northern China) to get an idea of the challenges farmers in the area faced [37]. The over-riding response from farmers was that existing systems which had been developed for them to use were overly intricate and they were often confused as to how to use the system. In a similar project, also in northern China, researchers asked fish farmers for their opinion regarding a fish disease diagnosis system (Fish Expert) which they were requested to evaluate. The results also indicated that many tended to struggle to understand how to use the system and comprehend what the system was trying to ask them [17]. A similar conclusion was reached in separate, unrelated studies after consultations with various other farmers, namely wheat farmers in Pakistan [16], Jamaican coffee bean farmers [19], Australian rural business operators [21] and farmers located in the Taw cachment region of Devon in the United Kingdom [24].

The researchers in the Pig-Vet and Fish Expert projects were able to draw up important factors to consider when developing the systems, based on their interviews with farmers who would be the users once development had been finished [17, 37]:

- Farmers would prefer the system to have two broad goals, namely prevention - containing the outbreak of a disease and preventing more livestock from becoming infected - and suppression - containing the effects of a disease on already infected animals as much as possible.
- The application should display different information to different users

[4] http://www.vodacom.co.za/personal/main/coveragemaps
[5] http://www.cellc.co.za/network-coverage-map

based on their level of experience in diagnosing ailments and their comfort in making diagnoses [18].

- The application should be intuitive and require little or no training in order to become proficient in the use of the application.
- A multimedia rich interface is an advantage. Providing images of symptoms and infections assists many farmers, who indicated they experienced difficulty in identifying symptoms based purely on textual descriptions. A drawback with the multimedia interface cited was the time taken to load images in some instances where the internet connection was, leading to frustration and hampering a speedy diagnosis [17].
- Jargon should be avoided when interacting with inexperienced users. Should the user be a vet verifying a diagnosis, jargon should be used in placed of simplified terminology.
- Allow users to provide feedback on their use of the system and the accuracy of diagnoses and decisions it reached.
- Once a disease has been identified, farmers would like to be provided with information on what possible causes of the disease could have been and suggestions on how to avoid it in future, if possible.
- Allow the relevant experts to update the rule and knowledge base online, to allow for a current and well-maintained system, ensuring increasingly more accurate diagnoses as time passes and the system evolves.
- Farmers would like to be able to approach the problem from two angles: the knowledge that the animal is sick and they would like to know what ailment has afflicted it; and the knowledge that the animal is sick and they suspect a particular ailment and would like to verify that this is the case.

3 Expert System Shells

A variety of tools, termed expert system shells, exist to facilitate the development of an expert system, to reduce the development time and remove the need to develop the entire application from scratch [25]. These tools consist of an inference engine and an interface to assist an expert in the construction of the knowledge base. The knowledge base and user interface for the application are provided to varying degrees when a shell is used [23].

There are various factors to consider in deciding whether to make use of an expert system shell or to code the system from the ground up. The use of a shell provides the advantages of speeding up the development pace of the system and providing for simpler maintenance of the knowledge base [28]. There are drawbacks, however, in the inference engine, as the reasoning cannot be customised, user interface, as some can be cumbersome and lack user-friendliness, and explanation facilities, as they cannot always be customised to specific requirements of the system being implemented. Programming the system manually does result in a longer and more complex development period, but means that all aspects of the system can be tailored to the particular system's requirements[28]. The use of a shell does not, however, mean that all the drawbacks mentioned will occur. Well-established shells can in many cases provide efficient performance and/or strong reporting functions while facilitating a drastically simpler development process. Many also allow for the development of a custom user interface for the end-users of the application.

The following expert system shells were examined:

3.1 Jess

Jess (Java Expert System Shell) is developed by Sandia National Laboratories in the United States[29]. Based on CLIPS (C Language Integrated Production System) and previously co-developed by NASA, Jess is a Java-based shell. Jess uses an improved version of the RETE algorithm - designed to be efficacious when comparing a large group of patterns to objects[8] - to process rules, and as such is very efficient in pattern-matching [11, 14]. The Jess developers have also extended the shell beyond the capabilities inherited from CLIPS. It possess the ability to inference using forward and backward chaining and has enhanced maintenance efficiency [30, 7]. Jess provides strong integration with Java, and allows access to Java APIs, facilitating the direct manipulation and analysis of Java objects, as well as the creation of object, calling of methods and implementation of interfaces without the compilation of any Java code [29, 27].

Jess is a provided on a propriety license and the distribution of the source code is not permitted. An academic license is provided free of charged by the makers [29], but the company charges several thousand dollars for a commercial license[18]. The use of the Jess for this expert system would therefore have implications for the future viability of the system.

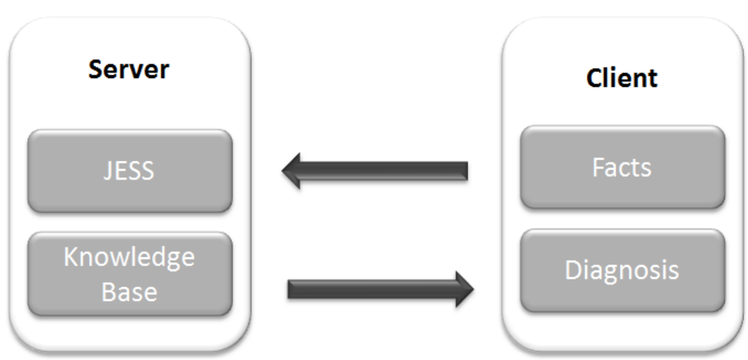

Figure 1: The basic structure of the proposed expert system, should JESS be used in its development and assuming the remote-based implementation. Adapted from [27].

3.2 Drools

Drools is based, like Jess, on Java and is an open source business logic integration platform [14, 18, 15]. The platform is a JBoss community developed project and is seen by some to be the premier open-source rule engine, currently [26]. The Drools rule engine supports forward-chaining and also makes use of the RETE algorithm for pattern matching to construct inferences [18]. Drools provides solid integration with Java, allowing the easy integration with the language. The rule engine is stout and provides many options of the development of rules for the expert system [18].

Drools assigns a higher priority to the speed at which a result is obtained than memory usage and can consequently cause memory problems in very large systems [36].

Drools is open-source software [18], licensed under the Apache license, meaning that the use of the system for this project would not result in future complications with royalties or license agreements to continue using the software.

3.3 Protégé

An ontology is defined[30] in the knowledge engineering field as "a systematic analysis of knowledge of some domains of interest, so that it can be shared by others". Another definition [12] often cited is "an ontology is a formal, explicit specification of a shared conceptualisation".

The original goal of Protégé was to attempt to help reduce the bottleneck involved in the acquisition of knowledge for an expert system [30, 10], discussed in Section 4. The thought process behind the first version of the software was designed around the idea that the acquisition of knowledge should occur in steps and that, after a step, knowledge elicited during that step could be used to produce tools for knowledge-elicitation in ensuing stages [10]. It was intended to allow users build other tools which were tailored to their specific needs and to help with the elicitation of knowledge for expert system knowledge bases. It has today evolved into a set of tools encompassing a wide range of functions.

Protégé is ontology based and is highly customisable, allowing users to develop their own structures and easily define connections between different items [30]. It is extensible and allows for the integration with other platforms, greatly increasing its appeal to developers of expert systems.

3.4 Integrating Protégé with Jess

Jess can be integrated with Protégé when developing an expert system [30]. Protégé is used for its ontology-based structure to construct the domain knowledge; the operational knowledge is constructed using the Jess rule system. As both Jess and Protégé are based on Java, they can communicate, through plug-ins, with other Java based systems. JessTab is a tool which has been developed to allow the two systems to communicate. Protege's APIs can communicate with JessTab, enabling the inference engine in Jess to operate as though it was the inference engine of the combined expert system. In return, JessTab allows Jess to access Protege's knowledge base when rules are fired. The structure of such a system is shown below in Figure 2.

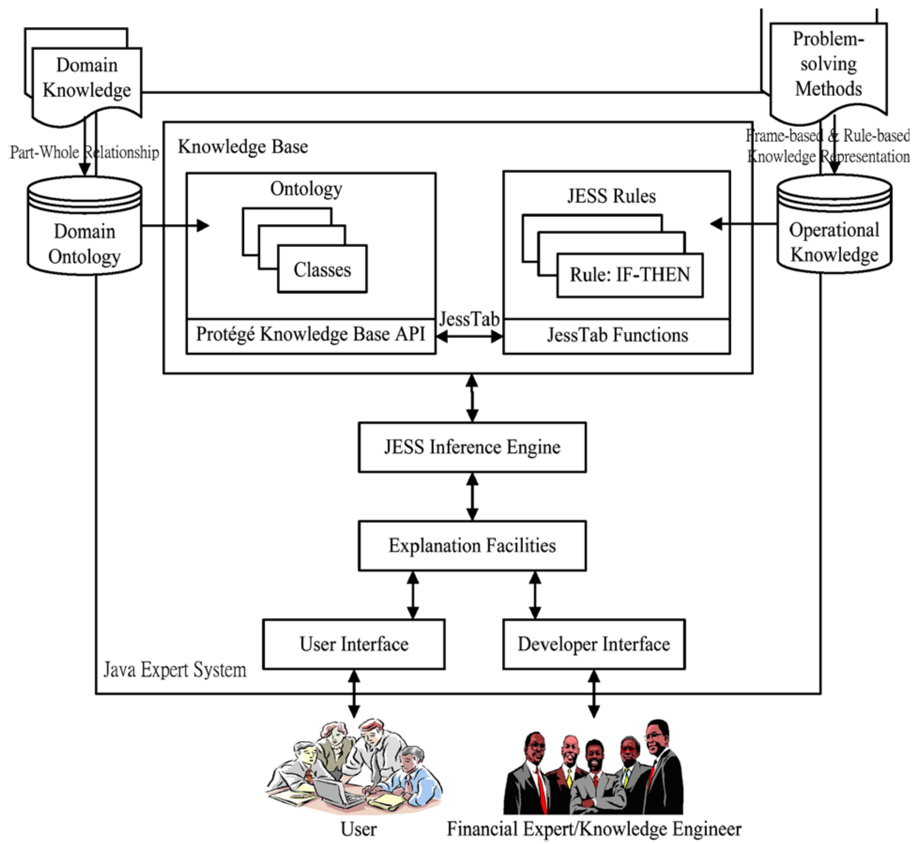

Figure 2: The structure of an expert system utilising Jess, Protégé and JessTab [30].

4 Knowledge Acquisition

The transfer of knowledge from an expert to the knowledge base is widely described to be the primary "bottleneck" [25, 10, 16, 37, 17]in the development of any expert system. Attention is therefore often placed on this process in an attempt to aid the smooth transfer of the knowledge. It is important for the person translating the knowledge into rules to gain a good understanding of the problem domain, to ensure that trivial mistakes are not made and that they do not move in blindly when translating the rules into the syntax required by the knowledge base [37].

In order to determine the needs of the farmers - the potential users of the completed system - questionnaires were distributed by the developers of the Pig-Vet system to 120 farmers to gather their opinions and needs [37]. Follow-up questionnaires were sent out to clarify any points of ambiguity or confusion, in particular where subjective answers could be provided.

The correct acquisition of knowledge is crucial to the eventual performance of an expert system. As such, the developers of the Pig-Vet system elected to follow a four-pronged approach to knowledge acquisition [37]:

- Experts in the swine veterinary field were interviewed in person. A large as possible group of experts was gathered to provide a large pool of opinions as a form of self-validation of the knowledge elicited during these interviews. Any differences of opinion could be resolved by a discussion within the group.

- Questionnaires were used to attempt to determine the quantity of subjective information used, as subjective information needs to be treated as such when developing the rules for the knowledge base. This type of questionnaire complements the interviews and helps to highlight any subjective discrepancies introduced in the knowledge acquisition process [2].

- A web-based system was developed to allow approved experts and farmers to update the knowledge database. Upon an update being made, a knowledge engineer would verify the changes and modify the knowledge base as appropriate. Feedback was provided to the person who performed the change. This allowed the reasoning process to be validated by an expert and helped ensure that any modifications to the knowledge base did not introduce inaccuracies.

- The developers conducted a literature review on the diagnosis of swine diseases, providing an additional knowledge source while the system was being developed. The familiarisation of the knowledge engineer with the subject matter allowed for simpler, more effective discussions with the experts and farmers, as they had a working knowledge of the subject matter.

The developers of Fish Expert followed a similar approach [17], similarly identifying the knowledge acquisition process as the bottleneck in the development process of any expert system. They stated that this is caused primarily by communication difficulties between the experts and knowledge engineers due to an understanding barrier between the two. The knowledge engineer is often unable to effectively understand the complex knowledge the expert is trying to convey [17]. The Fish Expert developers too elected to interview and distribute surveys to the farmers who were being targeted with the system to get an understanding of their needs and wants, and to also obtain an idea of their experience in dealing with ailments afflicting their animals. Human experts were interviewed to acquire the expert knowledge for the system and a web-based knowledge elicitation system was similarly developed to allow the knowledge engineers and authorised experts to aggregate facts and translate these into rules for the knowledge base.

Various other expert system development reviews were studied and most [6, 19, 16, 21]followed a similar theme to that discussed above - that of interviewing experts - through personal interviews and questionnaires and surveys, and also interviewing the potential users of the system, both to elicit their thoughts and preferences and to obtain any knowledge they possessed in dealing with their respective charges. Literature reviews and web-based systems for the addition of further knowledge were also frequently mentioned. An additional point mentioned by one group of developers [16]is that walking experts through case studies so that knowledge engineers can examine the expert's thought processes is beneficial to the knowledge elicitation process.

One paper [24] sought to highlight the importance of not discounting the knowledge possessed by the potential users of the system and to involve them in the knowledge elicitation process. This could be done through methods such as interviews and questionnaires. The authors argued that although the farmers may not be, for example, qualified vets, a farmer working with their animals for a long period of time would have picked up a hands-on trove of knowledge regarding the care of these animals. They discovered the importance of visiting the farms themselves and of observing the work occurring there to verify the information collected through interviews and questionnaires. A farmer had informed them how they separated clean and dirty water for the watering of portions of the farm in a previous interview, but they observed a farm-worker emptying dirty water in a supposedly clean canal above a watering point. They emphasised the importance of verification of claims made as a result of this [24].

5 Mobile Interface

As mentioned in Section 2, the user interface will form a key point of the application. While the intricate development which will be most vital to program correctly will take place in the rule base and inference engine, the user interface will determine the uptake of the system among its intended user, as it will be the only component they ever interact with. Careful consideration therefore needs to be given to the interface in selecting the most appropriate option.

There are three broad options available for interface development and these will be elaborated upon below:

5.1 Website

A mobile website could be developed, allowing the expert system to be accessed through a web browser on most mobile smartphones. The development of a mobile website provides the following advantages:

- A mobile website is generally universally accessible across the competing mobile platforms. While there are different versions of browsers on different operating systems, the development for these different browsers can be compared to developing for competing desktop browsers [4]. While there can sometimes be difficulties, these are generally able to be dealt with, unlike the incompatibility between native applications developed for different platforms. Here, just as an OS X application cannot run on Windows, an application developed for one platform cannot run on another.
- There are a limited number of differences between platforms that a developer is required to support [4].
- A mobile website is available immediately when the user follows a link to the site, whereas a native application typically requires the user to install the application through their device's app store [32].
- Changes to the user interface can be immediately pushed to users without the delay of an application approval process by the relevant store [32]. This advantage is negated in the case of Android, as Google Play does not require approval before updates are published. The user is still required to download the update manually, however.

Figure 3: Pig-Vet in images only mode during a diagnostic consultation. The interface is designed a web page to be viewed in a personal computer's web browser [37].

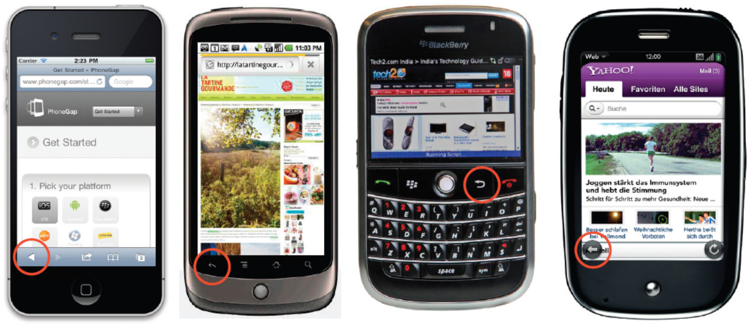

Figure 4: An image highlighting the common characteristics across the web-browsers on different platforms, such as the back button being present, despite the vastly different user interfaces of the operating systems themselves [5].

5.2 Native Application

The primary advantage in developing a native application is in the fluidity and feel of the resultant user interface. Whereas a website can feel disjoint from the operating system and be hampered by the unnecessary chrome of the browser's interface, a native application can take advantage of the SDK's native user interface tools and, provided it conforms to the platform's developer user interface guidelines, feel part of the operating system itself [4]. This results in a familiar feel to the user and can make the application feel more intuitive to use [32]. Native applications execute faster than web-based applications, although this advantage is normally more pronounced in processing intensive applications such as games [4].

The large drawback of developing a native application is that the system is concretely restricted to the platform it has been developed for [4].

A potential benefit of a native application is local storage. This would allow the option for the multimedia aspects of the expert system to be downloaded to the user's device while connected to a fast internet connection, such as Wi-Fi, and then be called up natively from the application, falling back to downloading them if they have not yet been downloaded or if an update is pending.

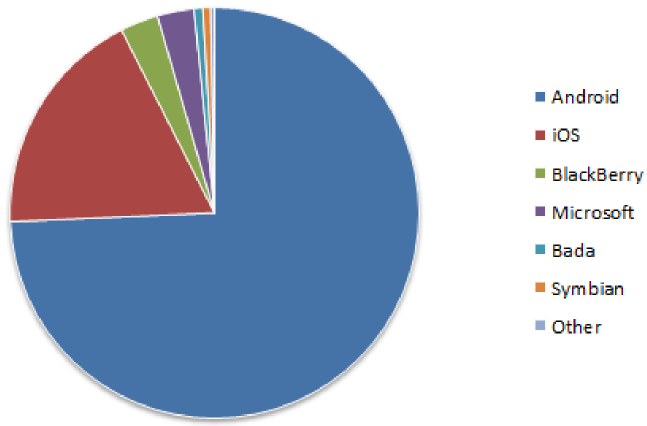

Figure 5: Worldwide mobile operating system market-share at the end of March 2013[9].

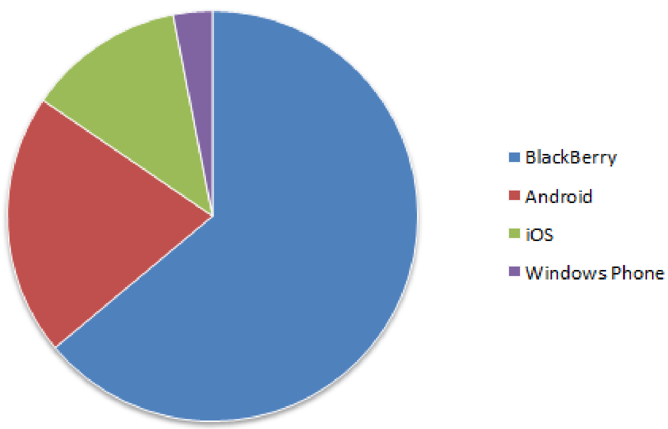

Figure 6: Vodacom smartphone mobile operating system market-share at the end of March 2013 [22].

The above figures demonstrate the worldwide and South African market share of smartphone platforms. Vodacom's breakdown has been used to reflect South Africa's in the absence of data for South Africa. As Vodacom claims approximately 53% of the South Africa cellular market [33], their data can reasonably used as an extrapolation point to draw conclusions about the South African market as a whole across the different operators.

Bada and Symbian's negligible presence can be discounted, leaving the four platforms depicted in Figure 6 as the competing candidates. Although BlackBerry claims an overwhelming portion of the South African market, the following reasons demonstrate that the development of an application native to their platform would be ill-advised:

- BlackBerry has released its new BB10 platform this year and it became available in South Africa at the end of February[1]. Of the 3.1 million BlackBerry smartphones active on Vodacom's network, the vast majority are of legacy BBOS5, 6 and 7. These platforms have been superseded by BB10 and the number of handsets running them and actively being used can be expected to begin a decline as more older models and phased out and replaced by devices running the new OS.

- The flat rated internet access is regarded as a primary reason for the high level of adoption of BlackBerry smartphones in South Africa, especially when compared to many foreign markets [35]. As BB10 does not make use of this service, this price advantage for the company has been removed for its future generations of devices.

- The current BB10 market in South Africa is more comparable to Windows Phone than to Android and it cannot be guaranteed that BB10 will reach near the same levels of dominance in the South African market as its predecessor systems to any degree.

A Mac computer running OS X is required to develop iOS applications for Apple's iPhone[6]. Excluding the purchase of a device for testing purposes, the lowest-price Mac in South Africa is R6600[7], rendering developing for this platform prohibitively expensive for the purposes of this project.

[6]https://developer.apple.com/programs/ios/develop.html

[7]http://www.zastore.co.za/category/15/mac-mini

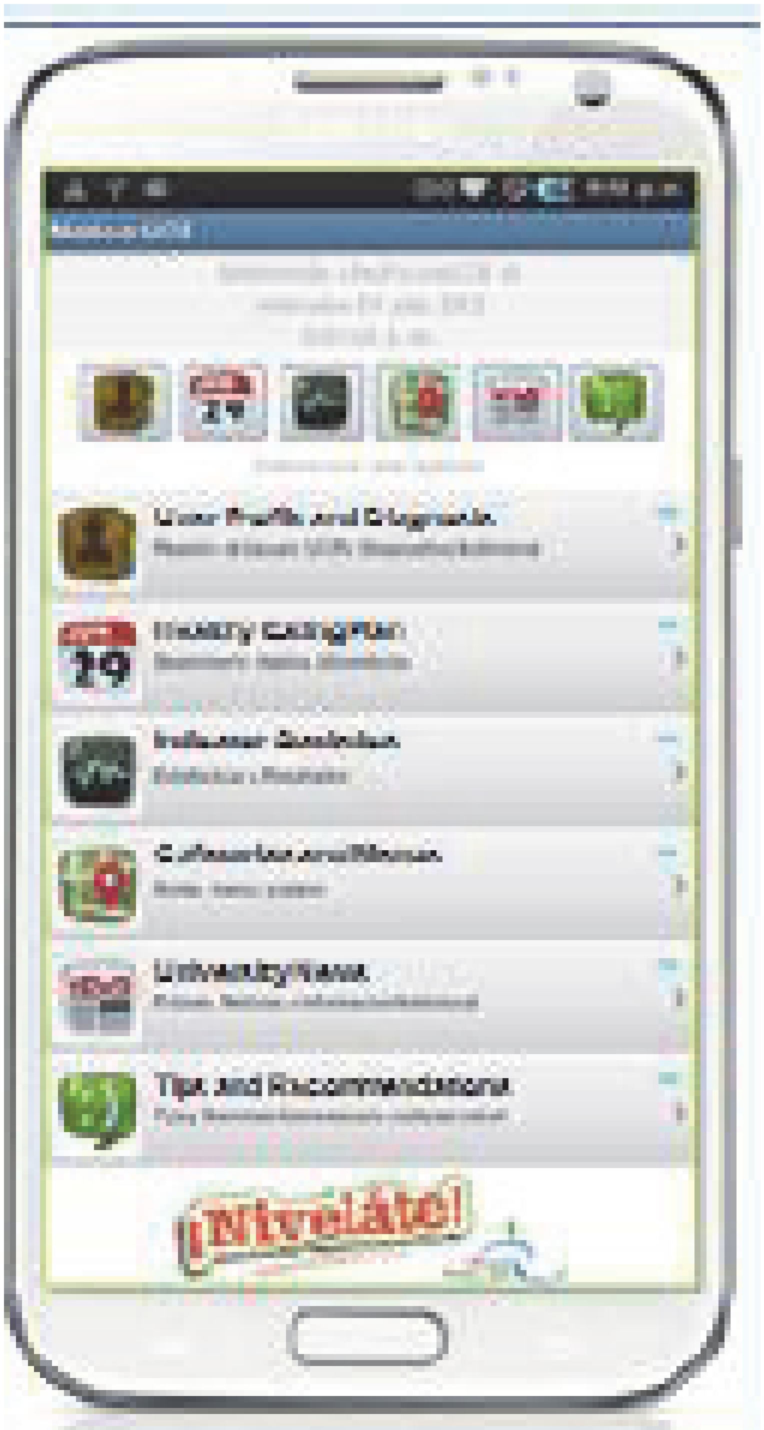
Tips and Recommendations

Figure 7: An image of a proposed nutritional diagnosis expert system [27], developed as a native Android application.

Figure 8: An image demonstrating how, despite all three images being of the same application (WhatsApp), the interfaces are vastly different and conform to the user interface guidelines for their host operating systems (iOS, Windows Phone and Android, respectively)[8][9][10]

5.3 SMS Based Application

The application could be made to be SMS based, with communication between the user (client) and the server occurring via SMS messages [13]. As SMS operates over standard GSM, this would remove the potential drawback of a mobile website or application - as these would rely on data - and which could pose a potential problem in areas with only EDGE coverage [13].

The use of an SMS based model would, however, drive the cost of using the service up, as both the client and server could potentially have to send multiple SMSs during the consultation, which would be more costly than data, particularly if data bundles are in place[11][12]. It would also not allow for multimedia capabilities, as images would have to be sent via MMS [13]. The process of sending multiple images in this way would quickly become cumbersome and expensive and remove the usefulness of a feature many users in previous studies have indicated a strong desire to see included.

[8] https://itunes.apple.com/us/app/whatsapp-messenger/id310633997?mt=8

[9] http://www.windowsphone.com/en-us/store/app/whatsapp/218a0ebb-1585-4c7e-a9ec-054cf4569a79

[10] https://play.google.com/store/apps/details?id=com.whatsapp&feature=search_result#?t=W251bGwsMSwxLDEsImNvbS5

[11] http://www.cellc.co.za/cell-phone-prepaid/99c-for-real

[12] http://www.cellc.co.za/smartdata-bundles

6 Conclusion

It has therefore been demonstrated that a mobile based expert system could benefit farmers in remote, rural areas and their potential views and desires for the application have been shown. These are only an indication as local farmer's needs and preferences may differ to those in other countries. Expert system shells have been examined and possible implementation options explored. Knowledge acquisition has been shown to be a critical aspect of expert system development and techniques have been explored to facilitate the process. Lastly, the potential user interface implementations have been briefly examined.

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