The power of knowledge sharing: innovative ICTs for the rural poor in the Sahel

> Knowledge is power. Information is liberating. Education is the premise of progress, in every society, in every family.
>
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Abstract. Inaccessibility of knowledge has a great influence on the lack of development in rural areas in Sub-Saharan Africa. Poor infrastructure and lack of education are just a few of the factors that result in communication gaps between experts and rural laymen. This research examines a methodology that follows a sequence of steps in order to provide the rural poor with knowledge sharing ICTs. A field trip was conducted by an interdisciplinary team of researchers in order to acquire the information needs of subsistence farmers in rural Northern Ghana. A generic rapid-prototyping platform (Kasadaka) and a voice-based veterinarian information service (DigiVet), built on a Raspberry Pi computer, are introduced. DigiVet supports subsistence farmers in the diagnosing process of their diseased livestock and on bringing them into contact with veterinarians. There are a set of constraining and enabling factors that complicate the deployment of innovative ICTs in rural development areas, such as lack of internet and a high illiteracy rate. The Kasadaka is developed to be scalable, robust and sustainable, in order to operate in these context specific conditions. The further development of the prototypes in the near future will meet the information needs of the rural poor and thus reducing the knowledge gap.

Keywords: ICT for Development, ICT4D, Mobile application, Low literacy users, Semantic data, Knowledge-based system

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1 Introduction

Inequalities in living conditions between rural and urban development areas in Sub-Saharan Africa (SSA) have been increasingly affecting the rural poor[1]. They have to cope with socio-economic development factors such as malnutrition, hunger, disease and illiteracy on a daily basis[2]. While urban areas are rapidly developing both economically and socially, the development of rural areas stays behind. Knowledge is a key factor in enhancing the socio-economic development of those people who are being excluded from a rapidly developing society. However, the uneven distribution of knowledge, along with constraining factors such as poor infrastructure, lack of resources, geographical and social isolation and lack of education are making the sharing and acquisition of knowledge inaccessible to them[3].

Living in the digital age, innovative technologies are intertwined with the way in which we live our lives and manage our work. It is almost impossible to imagine a world without Information and Communication Technologies (ICTs). Unfortunately, the rural poor often do not have access to these technologies. ICT for Development (ICT4D) aims to bridge the digital divide and enable poor and marginalized people to have access to ICTs in order to enhance socio-economic development. The information needs and knowledge gaps often require expertise from outside of the community. However, because of the aforementioned constraining factors and a communication gap between rural laymen and experts, expertise does not often reach these communities. Access to knowledge has partly been facilitated by first-generation mobile phones, the local radio and televisions. Unfortunately, the poor condition of the electricity- and telecommunications networks makes them unreliable[3].

1.1 Contributions

This research is an interdisciplinary collaboration between researchers from the departments of Social Science and Computer Science at the VU University in Amsterdam, the Netherlands. It examines the contextually relevant knowledge and information needs of the rural poor. The aim is to eliminate these needs by providing context specific information services. The study was conducted in both Amsterdam, the Netherlands and in the Upper East region in Ghana. The applied method revealed that the subsistence farmers in Ghana have numerous information needs and knowledge gaps that could be transformed into suitable use case scenarios. These use cases provide the basis of a set of information services build on a sustainable, generic ICT tool. The contributions of this research are:

- Methodology: Computer Science as a field study
- Application of methodology to study the role of knowledge sharing in Northern Ghana
  - Generic problem identification
  - Technical requirements

– A case study - specific systems design

Part of the research was the development of the Kasadaka, an innovative and sustainable rapid prototyping platform. The aim of the tool is to enable the rapid development of information services based on local information needs. One of the services that arose from the acquired information needs from our field trip in Ghana is DigiVet. DigiVet is a prototypical visual and voice-based digital veterinary information service that supports farmers in diagnosing their diseased livestock. This service specifies how knowledge acquisition and sharing among the rural poor can be enhanced by the use of innovative ICTs. By providing farmers access to this innovative ICT, the expectation is that it will serve the needs of both farmers and veterinarians, while monitoring and curing sick animals.

DigiVet is currently a proof of concept, but will be further developed by the team of VU researchers. The near future will reveal whether DigiVet and the Kasadaka can make a difference in the acquisition and the sharing of expert knowledge. Fortunately, great interest has been showed in the further development of both systems.

2 Background

This section expands on both the context in which the aforementioned methodology is held and on ICT for Development (ICT4D) research in particular.

2.1 The research context

The term *digital divide* refers to the gap in access to and use of Information and Communication Technologies (ICTs) and the internet either within developed countries or between developed and developing countries[4]. In the digital age, this gap is causing the already marginalized rural poor to be increasingly excluded from society[5]. The digital divide in non-metropolitan communities is mainly perpetuated by the lack of electricity and internet connectivity. Most of the approximately 600 million people in Sub-Saharan Africa (SSA) that are without electricity live in rural areas[6], where the environmental and societal conditions make it difficult for them to keep up with the fast developing urban people. These conditions are sustained by a lack of information and expertise. Knowledge sharing facilities in rural communities are being limited by a shortage of expertise, reachability of expertise and a communication gap between rural laymen and urban experts. Section 4.3 will elaborate on these factors. While they are global phenomena that occur in both development and developed regions, this paper primarily focuses on their occurrence in rural development areas.

2.2 ICT4D

ICT4D focuses on making a difference in the lives and livelihoods of poor and marginalized people with the help of the internet and other ICTs. The concept of development is subject to different perspectives from bottom-up to top-down[7]. The top-down approach focuses on transferring Western socio-economic ideals to a development context. The consequence is that the development needs of the poor and marginalized are often not met[8].The lack of accountability and knowledge of the realities of what is happening with society's lower class led to the bottom-up development perspective. This approach is more community-based, has an participatory approach and is non-hierarchical. An earlier perspective of development being merely concerned with economic growth is not extensive enough. Participation and empowerment are important factors that should not be underexposed.

3 Methodology: Computer Science as field study

Conducting Computer Science fieldwork in a rural development context requires a clear methodology. For this methodology to be successful, it is crucial to assemble a powerful team and to collaborate with local partners. This chapter discusses the generic methodology that can be used in order to develop sustainable and information providing ICTs. It can be used in the cross-domain development of innovative ICTs, which meet the local information needs of the rural poor. The approach we used corresponds to the Agile Software Development approach. Agile development methods focus on developing software, while taking into account the changing needs of the customer. Agile Methods were introduced as an alternative to the traditional Requirements Engineering approach, which is mostly documentation driven. Agile aims to work closely together with both customers and developers, which makes this a suitable approach for rapid adaptations, should the need arise. Agile methods are people-oriented, they aim to produce based on people's expertise rather than on simply following documentation[9]. The iterative character of Agile development is also reflected in our methodology, in which we maintain a cyclical approach. This approach consists of the elements analysis, design, implementation, and testing[10]. By following this iterative process, the prototype will be better attuned in serving the local information needs (figure 1).

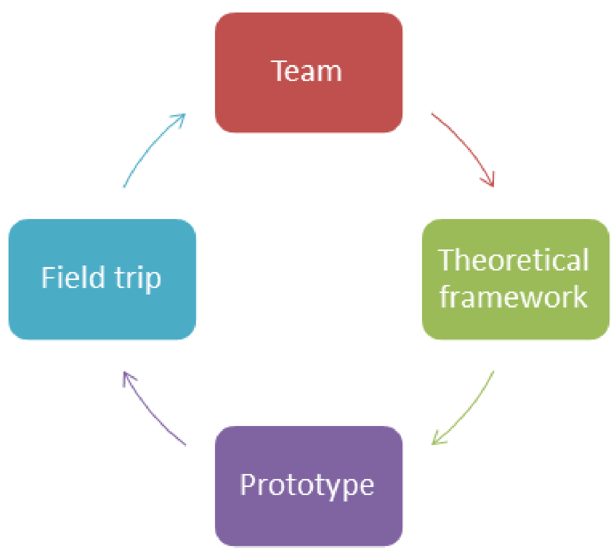

Fig. 1. Computer Science as a field study

3.1 Interdisciplinary Team

First, an interdisciplinary team should be put together. This cooperation between individual disciplines will provide the various perspectives that offer profundity and that are relevant when conducting the field trip and developing a prototype. These disciplines all have their own approach, which is why it is important for them to stay both critical and open minded at the same time. Interdisciplinary research enables focusing on complex problems which are not entirely discipline specific. Multiple disciplines can all constructively contribute to solve the problem.

The interdisciplinary approach of this research focuses on getting a deeper understanding of context specific constraining and enabling factors, as well as the socio-economic conditions and the technical requirements that need to be pointed out to develop valid ICTs. In this research, a social scientist and a computer scientist were assembled, which has proved to be very enriching for both disciplines. The social scientist mainly focused on establishing a theoretical framework, while the computer scientist aimed to develop a rapid prototyping tool by means of earlier conducted work.

3.2 Theoretical Framework

The theoretical framework is a crucial part of the research, it describes the theory that is needed in order to solve the practical problem. In this research, the main question is whether there exists a set of information needs among the rural poor in SSA. And if so, whether we are able to develop a sustainable and generic rapid-prototyping tool that aims to provide the needed information.

Studying literature and earlier work conducted by researchers and organizations that operate in the same field adds greater clarity to the challenges, requirements and focus points that lay ahead. The entire research depends on the way in which the methodology is implemented, which is why one should have a clear sequence of steps in mind. However, during the field trip it will transpire that some matters do not happen quite as one expects them to. It is therefore of importance to constantly examine whether the theoretical framework actually corresponds with reality.

3.3 Prototype

The earlier work described in the theoretical framework gives an idea of what the prototypical design of the rapid prototyping tool should contain. Our research is based both on earlier conducted work in the field acquired from partner researchers and on the conducted field trip. Researchers from Web Alliance for Regreening in Africa (W4RA) provided us with information on several of the socio-economic and environmental context specific requirements and limitations that should be taken into account when developing the prototype.

The prototypical design should be made as simple as possible, since further developments depend on input of the end users, and because the end users do not possess any technical knowledge. The prototype should be affordable and preferably supportive of open source software, allowing possible local developers to contribute to the development of the prototype. The content of the prototype is based on the local information needs and knowledge gaps among the local population and thus cannot be completed prior to the field trip.

3.4 Field trip

When conducting the field trip, local partners play an essential role in providing multiple perspectives. They are often armed with a long history of working in the rural development context and have an extensive knowledge of the local population. Local NGOs and researchers could possess fast amounts of data regarding the environment, the culture, norms, values and customs which are of importance.

With the arrival of the team in the focus area, the sample group should be established. Ethnographic research should be conducted in order to learn more about the local population. Crucial are the profession, age and gender of the informants. Observing their lives and livelihoods gives a detailed understanding of the societal, technical and environmental constraining and enabling factors that arise when developing contextually relevant ICT services[9]. Bringing a qualified interpreter diminishes miscommunication caused by language barriers and cultural differences between informants and researchers. By qualified we mean someone who knows both languages by heart and who understands the norms, values and local customs of the informants.

The most ideal approach would be to conduct a longitudinal research in the research area. Primarily the first time it is important that the researchers stay in the research area for a certain amount of time. This minimizes misconceptions that may result of a too limited amount of time to thoroughly evaluate processes and experiences. Ethnographic research observes people's behaviors in their locally specific context. In their field work, researchers observe and interview people in order to get a better understanding of why and how they do things. Ideally, ethnographic field work is conducted by staying in the field area for a long time. However, many researchers will conduct multiple shorter field trips instead of conducting one longitudinal study. This may be caused by lack of time or resources[11]. Unfortunately, this was also the case in this research, due to lack of resources and time, we could only spend a limited amount of time in the research area. However, as covered in section 5.5, a new team visited the area in order to ascertain that the acquired use cases corresponded with the local information needs, and to test the Kasadaka.

The informants provide the researchers with the information needs that are vital to the development of the system. Once the acquired information needs are translated into use cases, the MoSCoW method is applied to prioritize them and select the ones that are then transformed into use cases. Use cases focus on the human-computer interaction, describing the sequence of steps a user has to take in order to utilize the system[9].

3.5 Second iteration

As mentioned in section 2.2, the theoretical framework may differ pre- and post the field trip. The experiences acquired during the field trip might change the perspectives of the researchers and the theoretical framework should thus be adjusted accordingly. The same goes for the prototypical design. The information needs that were acquired during the field trip and the context specific conditions may differ from what was expected based on literature studies and earlier conducted work. The crucial next step is to process these adaptations into a new prototype. This step matches the Agile Development Method, since the input for the differences is based on the customers, or informants in our case[9].

Once the feedback of the end user has been processed into a new prototype, a new team should be put together in order to conduct the next field trip. This team elaborates on the earlier field trip and has a greater understanding of the context specific constraining and enabling factors. During this field trip, the prototype will be tested and new feedback from the end users will be acquired. This iterative process of acquiring feedback and processing it into a prototype is repeated until both the end users and the researchers agree that the prototypical design meets the information needs of the end users.

3.6 Sustainability

Maintaining sustainability in the development of innovative technology is crucial but difficult to achieve in ICT4D projects. Implementation of the ICT tool is one thing, but keeping it up-to-date and reliable is another. Frequently traveling to the research area is expensive and not efficient. Grassroots innovation focuses on enabling local users to become software developers themselves[12]. The team that is part of the cyclical process in figure 1 now consists of researchers that work closely together with local designers, developers and researchers. This collaboration will guarantee the reliability of the tool and that will enhance community based sustainable development. Using open source and affordable ICTs enhances the accessibility and provides local professionals the opportunity to participate.

4 The role of knowledge sharing in Northern Ghana

We have applied the aforementioned methodology in our own research. This section covers the field trip that was conducted by our interdisciplinary team and its findings.

4.1 Research Design

Team An essential component of this research is the case study that was conducted in Zanlerigu village, Upper East Ghana. Our team consisted of Social Scientist Myrhte van der Wekken and Computer Scientist Awa Gossa Lô, who stayed there for one month in February 2015. The interdisciplinary nature of the team played a major role in the way the research was carried out. Reflecting on the experiences and decisions made, both during the field trip and afterwards, enabled us to reason more profoundly.

Theoretical framework The theoretical framework was established by conducting both an extensive literature study and interviews with W4RA researchers. They provided us with the necessary contextual information that they have acquired during their numerous case studies in SSA.

In order to support the regreening of dry areas, W4RA organizes workshops in Burkina Faso, Mali, Ghana and Niger. These workshops include ICT professionals, computer scientists, Non-Governmental Organizations (NGOs) community radio stations, experts in sustainable land management and farmers. Their aim is to develop ICT services that support regreening activities in rural, often remote areas in the Sahel. Most of the farmers cannot read or write and do not use the internet, which is why W4RA integrates voice-based mobile web services and the radio. By integrating these, W4RA aims to create ICTs that support people in communicating and sharing knowledge and information, regardless of their gender, origin, financial situation or age. The VOICES project, which was funded by the European Commission under the 7th Framework Programme for Reseach and Technological Development (FP7), was created by members of W4RA and focused on voice-based technologies[13]. Its aim was to support rural communities in sharing local, indigenous knowledge and information with the help of ICTs and the local radio, using spoken web content instead of text. Our research continues this way of thinking, by examining and developing voice-based technologies for subsistence farmers in SSA.

Prototype The information that W4RA provided us formed the input of the rapid prototyping tool that was developed before the field trip. This tool, known as Kasadaka, contained some of the context specific requirements that were acquired due to the work of W4RA. For instance, the tool is voice-based, affordable and can easily be processed in the existing technical infrastructure.

Field trip The field trip took place in Northern Ghana. W4RA brought us into contact with professor Saa Dittoh at the University of Development Studies (UDS) in Tamale, Ghana, who was responsible for our transport and accommodation. He provided us his family home in his birth place in Zanlerigu. This village is suitable for our research because of its remote and rural character and its inhabitants, consisting of mainly poor, subsistence farmers. Our qualitative research method consists of semi-structured conducted interviews with subsistence farmers and observing their daily lives and livelihoods. By actively taking part in their daily activities, we gained an in-depth understanding of their customs and motives.

4.2 Context: Ghana

The Upper-East region, with its capital Bolgatanga, is situated in the northeastern corner of Ghana. The region is characterized by two seasons: the rainy and the dry season. The rainy season lasts from May/June to September/October, during which the average amount of rainfall is 800-1.100 mm. In the dry season, from November to mid February, the air is dry and dusty. The nights can get rather cold, with temperatures as low as 14 degrees centigrade. At daytime, however, the temperature can rise to more than 35 degrees centigrade. The difference between Southern and Upper-East Ghana is that the latter has a very low humidity[14]. The region houses one of the highest amounts of farming families of the country (96.7%). The majority of the farmers is smallholder farmer, meaning that they own at most two ha of land. According to an in 2010 established census on the Ghanaian population, roughly 52% of the people above the age of 11 living in the Upper East region is illiterate[15].This percentage is much higher under the subsistence farmers living in this region.

4.3 Anthropological findings

M. van der Wekken conducted fourteen semi-structured individual interviews (eleven men and three women) and two focus group discussions consisting of 29 participants and 105 participants respectively. Anthony Dittoh, the brother of our contact person from UDS, knows the village and its inhabitants by heart and provided us with the interviews and the first focus group. The second focus group was organized by an advanced farmer, who is one of the eleven men we interviewed.

The in-depth semi-structured interviews aimed to find out how situated knowledge is shared and stored with the currently available infrastructure, and how ICTs can support and improve this. The information needs that were acquired include information on farming techniques (soil and cropping techniques), weather forecast, market prices, micro credits and health of livestock. Access to these types of information will make the subsistence farmers more prone to both environmentally and socio-economic changes.

In order to develop knowledge-sharing ICTs for rural development contexts, several context specific techniques are required.

Shortage of expertise 80% of the SSA farmers are smallholder farmers, their main purpose of cultivation is for their own consumption[16]. Merely the surplus that is left at the end of the dry season is meant for selling. Being able to feed their families has become increasingly challenging for farmers, with factors such as climate change, natural disasters, and reduced biodiversity being ever more present. Climate change, for instance, is responsible for an increase in crop failure, loss of livestock and increasing water scarcities[17]. The required expertise that is needed to address these issues is lacking in rural communities, which has severe consequences.

Innovative ICTs can deliver the up-to-date information that is crucial to close the information gap between laymen and experts. Delivering the ICTs to the very people that are being marginalized because of their financial situation, geographical location or gender, is crucial for the socio-economic development of a country[18].

Reachability of expertise Rural communities are often isolated and inaccessible, excluding them from socio-economic development. Experts that come from outside the rural areas have a hard time reaching these communities. Unpaved roads filled with holes make it difficult to access them. Means of transport are unreliable, since the old vehicles that people use are not always build to handle these roads. Especially in the rain season, the quality of the roads is too poor to allow safe transportation[19]. Distance is another reason why the reachability of expertise can be low. Scarcity of expertise in the surroundings of the rural areas increases the time it takes to deliver the on-site support which is sometimes required, making it too time consuming. A technical requirement in this context is a systems' ability to deliver information without having to overcome a physical distance.

Communication gap between experts and non-experts Education, geography and world view are psychologically and physically separating African policymakers from the rural poor. The absence of adequate internet infrastructures and ICT applications will only increase the gap in knowledge and development. Disadvantaged groups, such as the rural poor, typically do not have access to quality education. In order to improve healthcare and reduce poverty, malnutrition, hunger, illiteracy in current and future generations, quality education is crucial[20].

The Food and Agriculture Organization of the United Nations (FAO) is funding several projects that are meant to ameliorate the process of interaction between experts and non-experts. iCow, for instance, helps Kenyan farmers to manage their cows' estrus cycle and milk production, by bringing them into contact with veterinarians through an SMS information service[21]. Another project uses Digital Pen Technology in Eastern and Southern Africa to collect and manage reports regarding the health and mobility of animals[22]. These projects are great examples of how ICTs can assist smallholder farmers in managing their farms. The disadvantage, however, is the prerequisite that farmers know how to read and write, if they wish to use the ICTs. Including the very people that are increasingly excluded from society, such as illiterate rural farmers, can be achieved by developing customized ICTs for them.

Illiteracy rate A lot of African countries are dealing with illiteracy and a high number of languages. According to UNESCO, 38% of the African population is illiterate. Due to the efforts of the State in collaboration with different NGOs, an increasing number of children in Sub-Saharan Africa are enrolled in primary or secondary schools. However, in rural underdeveloped regions, the illiteracy rate remains higher than in urban areas. Illiteracy is not the only problem in these areas, the number of different languages is another. Most of the African countries have one or two official languages that are spoken. In fact, in Africa, there exist over 2000 languages[23]. The provided service should support the languages that are spoken by most people in the area, since it is too complex to include all the individual languages.

4.4 Technical Requirements

Voice-based functionality Because of the the inability of the majority of the rural poor to read or write, a large range of ICTs is inaccessible to them. The internet, or Web of Documents, consists for the most part of text, which makes it impossible for the illiterate rural poor to use. The inaccessibility to online information content contributes to the further marginalization of the rural poor. Text-based information services should, in the case of illiterates, be replaced with voice-based technology.

Lack of internet While the number of areas that support internet connectivity is growing rapidly, there is still a large gap between the growing rate in rural and urban areas in developing countries. In SSA, the internet connectivity opportunities between different areas are distributed unequally, due to lack of governmental support and economic interest from telecommunication companies. Internet traffic in rural African areas is quite different than in the rest of the developed world[24]. Instead of using the internet, the focus should be on using what technical infrastructure they are currently using. Since the construction of new internet wiring is not the aim of this project, the focus should be on the means of communication that are currently available in rural communities.

Lack of resources Subsistence farmers living in remote, rural areas in SSA generally have low incomes. The crops they grow are mainly used for their families consumption. The surplus that is left at the end of the dry season is sold at one of the local markets. The farmers in Zanlerigu village earn an average amount of 500 to 1500 Ghanaian CEDI a year, converted to dollars this is in between 125 and 375 US dollar a year. Whenever the farmers are in need of money and none is left, they can choose to sell their livestock. When asked about whether farmers would be able and willing to pay for the use of an ICT device that could provide them with relevant information, they answered that they would. They also stated that they do not have a lot of money to spare, which is why it is important that the device is affordable. The system should thus provide laymen with information, without it costing them a fortune to acquire it.

5 Case study solution: A visual and voice-based digital veterinary service

One of the information needs that the subsistence farmers in Northern Ghana indicated is the need for veterinary information. This chapter covers the the veterinary service DigiVet that is built on the Kasadaka.

5.1 What is the concrete problem?

During one of the interviews conducted in Zanlerigu village, one of the farmers stated:

> "I would love to hear information on how to take care of the animals. For instance, if I would hear information on how to feed them and how to take care of them if they are sick, that would help a lot. If the vet could give me this information via the mobile phone I would use it. I would gain knowledge on how to take care of the animals. So it would not matter if the vet would come in person, because I can do the procedure myself." - David, subsistence farmer, Zanlerigu Ghana, March 2015

Morbility and mortality of livestock have a major impact on farmers. Animals are seen as a form of savings; whenever a farming family is in need of money, they can opt to sell one of their animals. Livestock is not only crucial as income, but also for giving milk, meat, manure for crops and as means of transport. The fact that the death of livestock cannot be prevented has multiple causes, one of which is shortage of expertise in the livelihoods of the farmers. According to an assessment on farmers living in three regions in Northern Ghana, diseases of animals was considered the number-one problem[25]. Several farmers brought up the need for information about livestock diseases and spreading thereof. A lot of animal diseases require a certain expertise of disease patterns and medication that the smallholder farmers in SSA do not possess. Veterinarians on the other hand, do have the knowledge required to cure diseases. A lack of knowledge about the diseases is one of the reasons why the mortality rate of livestock is high.

5.2 Choices

The aforementioned technical requirements ask for specific design choices in the prototype. For instance, because of the high ratio of illiterates among the rural poor, the prototype is *voice-based instead of text-based*. Since Africa knows a high number of different languages, the next iterative development cycle should identify the specific languages that are spoken in the field trip area. Voice-based functionality for the individual languages means that the voices should be recorded.

The lack of expertise in combination with the inaccessibility of rural communities require expertise to be available from within the community. A sustainable system that contains the *knowledge of experts* should reduce the communication and knowledge gap between experts and the rural laymen.

Because of the unreliability of electricity in rural communities, *renewable energy such as solar energy* is a more reliable option. Lack of internet asks for an offline solution which can still transmit bits of data over a long distance. One of these solutions is *Semantic Data* (SD).

The Semantic Web is currently particularly accessible to developed countries. The role that Semantic Data could play in the knowledge sharing aspect is major. SD is light-weight and is therefore fit to share bits of data. Every bit of data can be interlinked with other bits. Combining this data may result in new, valuable information[26].

Scenario The scenario below discusses a scenario in which subsistence farmer Kofi uses DigiVet. He notices that one of his cows is behaving strangely and suspects that she has fallen ill. Kofi decides to consult DigiVet to figure out what is wrong.

Kofi walks to the the house of the villages' chief and indicates that he wants to use DigiVet.

Kofi logs into the system and a voice talks to him in his language of preference. The first few questions are more general, afterwards they become more specific:

- Voice: Welcome to DigiVet, please select the species of your sick animal by tapping on its image.

Kofi taps on the picture of a cow.

- Voice: Please indicate whether the symptoms are outward or inward. The red part of the screen means *outward*, the green part means *inward*.

Kofi indicates that his cow has outward symptoms by tapping on the red part of the screen.

- Voice: Does your animal show signs of weakness? If no, tap the red part of the screen. If yes, tap on the green part.

Kofi taps on the green part of the screen, indicating that his cow shows signs of weakness.

After answering a complete set of questions regarding the symptoms of his sick cow, the outcome screen is shown to Kofi.

- Voice: It seems that your cow has Anaplasmosis disease, an infectious blood disease caused by the rickettsial parasites Anaplasma marginale and Anaplasma centrale. This disease is not contagious, but is transmitted most commonly by ticks. Affected cattle either die or begin a recovery within 4 days after the first signs of the disease. Since this cow is detected during the early stages of the disease, it is best to contact a veterinary. Below, a list of the top 2 of best veterinarians has been listed. Please select the veterinarian you would like to contact.

Kofi recognizes one of the veterinarian that he has contacted before and taps on his picture. The voice thanks him for using DigiVet and tells him that the veterinarian will call him for further details.

After two hours, Kofi is called by the veterinarian who has received the data regarding his sick cow. He briefly explains that the cow can be cured by medication he can provide for. Kofi accepts his help and the two make an appointment for the veterinarian to cure the cow.

5.3 Implementation

DigiVet is a visual and voice-based digital veterinary service, built on a Kasadaka. The service supports rural subsistence farmers in diagnosing and curing their diseased livestock, by bridging the knowledge gap between veterinarians and farmers and bringing them into contact with each other. Currently, DigiVet is a proof of concept developed on a Raspberry Pi computer. The Raspberry Pi was chosen because of its affordability and its powerful content in proportion to its small size. An HTML page, displayed on a screen connected to the Pi, represents a prototype of the user interface. The steps are supported by English speaking speech segments. The Raspberry Pi is connected to a 3G GSM-dongle that contains a SIM-card. In order to establish a telephony connection, Asterisk is used. Asterisk is an open source IP PBX platform[27] that enables to call and send SMS messages from a Linux based computer to a mobile phone.If a user taps to contact an expert, an SMS message containing a URL is send to the phone number of the person that is selected. This URL contains the outcome of the diagnosis made by the system.

DigiVets' interface is user-friendly and does not require prior technical knowledge. The prototype has been developed in HTML/CSS and JavaScript. The added images are identifiable for the end users and provide a clear and simple structure. The prototype contains both text and an English speaking voice that guide the user through the service. In future versions, the text will be removed, since the end users are illiterate.

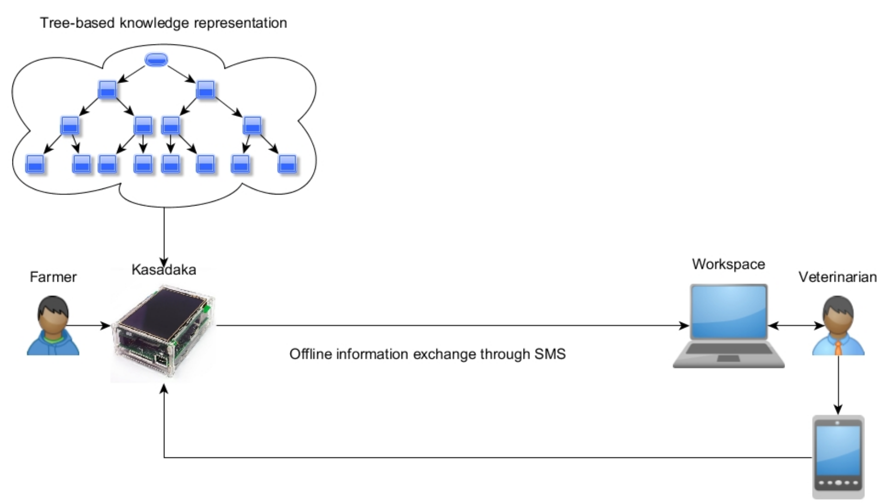

Fig. 2. DigiVets' overall architecture

DigiVets' objective is to guide users through a set of questions regarding animal diseases and symptoms towards a specific outcome. Figure 2 displays the overall architecture of the system and the interaction between the farmer and the veterinarian. The tree-based knowledge representation on the left represents the different questions that are asked depending on the choices of the user. This part of the system is voice-based, meaning that all of the steps are explained to the user in the local language. The steps either guide to a most probable disease or a sequence of steps that the farmer can use in order to cure the animal. DigiVet provides the option to contact a veterinarian, for instance to consult him on medication or outbreak prevention.

Once the outcome is determined by the system, the user can sent a SMS message to a veterinarian of choice. This message contains the semantic data that is extracted from the diagnosing part of the system in such a way that it fits the limited amount of characters that one SMS may include. In order to comply with these restrictions, a reducing technique is used in which the states and outcome are placed in a URL. The Semantic data is send to the expert, who can then see in one glance what case of illness he has to deal with.

The advantage of using Semantic Data is that it can be re-use in combination with other bits of data. By interlinking these bits, new patterns can arise that may be relevant in order to prevent spreading of contagious diseases. Once the farmer has obtained and analyzed the data, he can contact the veterinarian by phone in order to make an appointment. Semantic data is send to the veterinarian by means of a text message. This data can be used by the veterinarian in order to monitor diseases in livestock and possibly prevent new outbreaks. In this way, both the farmer and the veterinarian will be able to perform their job more efficiently.

Figure 3 displays the tree-based knowledge-representation that is the decision making part of the service. The green branches represent the specific sequence of steps followed by farmer Kofi of the scenario from section 5.2.

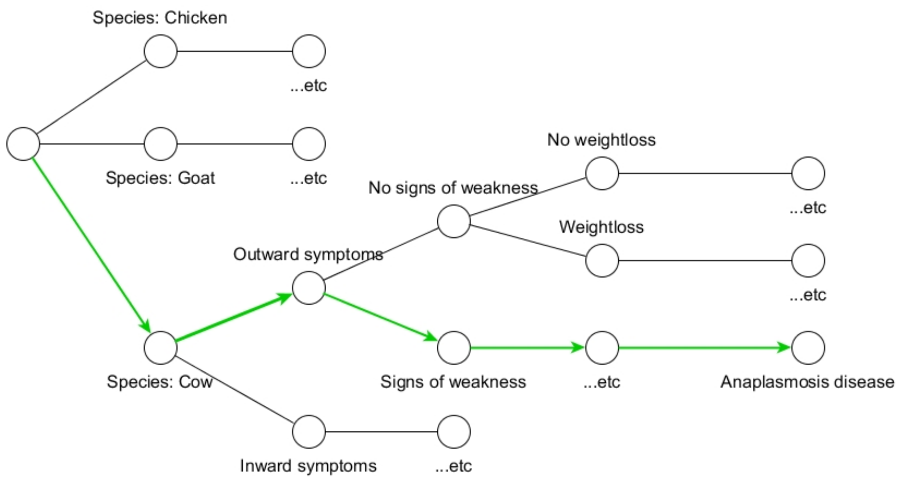

Fig. 3. Tree-based knowledge representation

5.4 Design

A prototypical design has been developed for DigiVet, which is a simple representation of the final service. Figure 4, 5 and 6 display the three different states of Digivets' user interface.

Fig. 4. Opening screen

Fig. 5. Symptom screen

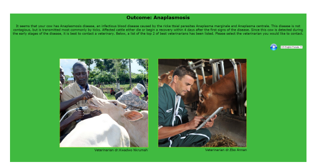

Fig. 6. Outcome screen

Figure 4 shows the opening screen, which is the initial state of the DigiVet service. It shows an overview of the livestock that lives in Zanlerigu village. The presence of certain animals is context specific, for the prototype we chose to include the animals that live in Zanlerigu. When the user taps the touchscreen to select an animal of choice, he is guided to a screen similar to the symptom screen in figure 5.

There is both a red and a green part of this screen. These colors represent the choice that the end user makes following a question asked by the voice guide. The choice of colors is equal to a traffic light, with red meaning: 'yes, I recognize this symptom in my sick animal' and green meaning 'no, I do not recognize this symptom'. Of course, the identification of the meaning behind these colors is culturally specific and should be determined in accordance with the end user.

Every time the user taps on a part of the screen, a new question arises, until an outcome screen appears, as displayed in figure 6. The voice explains to the user what the most likely outcome of the disease is. A short description of the disease follows, together with a sequence of steps that should be taken in order to cure the animal. Of course, there are also diagnoses that are incurable. In either case, the user is provided the opportunity to select a suitable veterinarian to consult.

Once the user has selected a veterinarian, DigiVet sends a SMS message through the GSM dongle to the mobile phone of the veterinarian. This message contains a summarized version of the steps and outcome of the service in semantic data. The veterinarian that receives the URL is able to detect the different symptoms and the most likely diseased that were identified by DigiVet.

5.5 Second iteration

In May 2015, W4RA organized a collaborative workshop together with a team of researchers from UDS, in Northern Ghana. The goal of this workshop was to discuss and identify situated information needs, with the aim to improve food and water security in the Sahel. ICTs are seen as the tools that can close the bridge between an information need and its solution. As part of the trip, the researchers presented the idea of DigiVet to the researchers from UDS. According to them, there is a high need for better information and communication between farmers and veterinarians. When visiting Guabuliga, a village in Northern Ghana with about 2000 habitants, they were told that every day a cow was dying of a yet to identify cause. During the visit, a veterinarian was present alongside the W4RA and UDS researchers, who was then brought into contact with the chief of the village. This veterinarian performed a post-mortum examination and found that the death of the cows could be linked to enlarged organs due to pesticides.

The importance of close contact between a qualified veterinarian and farmers was made very clear by this example. The DigiVet was well received and, when implemented and evaluated thoroughly, could support both farmers and veterinarians, while saving the lives of animals.

5.6 Evaluation of the prototype

The DigiVet prototype does not yet contain knowledge that was acquired by local veterinarians. However, this is crucial in order to improve the reliability of the service. The information on disease patterns is currently derived from the internet, which is created for the largest part by and oriented to people living in the Western world. Ghanaian livestock differs from western animals in the sense that their dietary, appearance and needs are adapted to the context specific resources and environmental conditions. Some diseases can only be found in the West, others are characteristic for rural development areas. Since this is a proof of concept, there are several improvements that have to be made before deployment. Further adjustments aimed to improve the DigiVet prototype will be addressed in section 7.

6 Generalizability

The ultimate aim of the Kasadaka is its potential to enable development and implementation of contextual relevant ICT services. However, it is not easy to develop a system that can be standardized on one hand, while remaining context specific on the other. Standardizing the ICT tool enhances the efficiency of developing new use cases for similar contexts. At the same time the question remains as to what extent the innovative ICT is scalable; how well does it function when it is changed in context or size in order to meet the information needs of a larger amount of people[29]. The focus of this section is on those factors that are generalizable in developing a knowledge sharing ICT for remote and rural development areas. Suitable solutions to these factors are processed in the development of a generic and scalable ICT that still meets locally relevant information needs.

6.1 Generic class of problems

Remote and rural areas in Sub-Saharan Africa bear similarities when it comes to knowledge acquirement, sharing and storing. As mentioned in section 4.3, several development issues make it difficult for the rural poor to acquire expertise in the issues experienced by them.

Rural communities, often inaccessible and isolated, are subject to expertise coming from outside of the area. This expertise can be supplied either by experts physically coming on-site or by communication by means of first-generation mobile phones. Both of these options come with their own set of barriers. The former is hindered because of distance and poor transportation to and accessibility of rural communities, while the latter is inhibited by the communication gap between the expert at one end and the rural layman at the other end. This communication gap is not just a development problem, but also exists in developed areas. In remote and rural development areas, however, lack of education, illiteracy and an increasing digital divide are inhibiting factors.

Lack of electricity and internet connectivity make most of the available technologies unreliable. The dry and hot climate demands robust and sustainable ICTs that are adapted to these environments in order to function properly.

6.2 Kasadaka: a rapid prototyping platform

The case study in Ghana provided us with a set of use cases that meet the information needs of the local population. A rapid prototyping platform called *Kasadaka*, or 'talking box' in Twi language, was build that would enable the efficient conversion from use cases to operating information services. In order for the Kasadaka to function in an environment as described in section 4.2, some technical specifications were made both hardware and software wise.

Ultra-Low-Cost and small-sized hardware Hardware requirements mainly focus on sustainability in handling the environmental conditions. The hot and dusty environment ask for a *robust technological design* that is *affordable* and *available* in the development areas. Should the hardware break down, it has to be easily *replaceable*. The Kasadaka can run on any Linux supporting device. The Raspberry Pi was chosen as the computer because of its affordability ($43 dollar at the time of writing) and its powerful content in proportion to its *size* (credit-card sized). Ultra-Low-Cost computers such as the Raspberry Pi are becoming increasingly popular, enabling people of all ages and backgrounds to learn more about computing and programming. Another reason why the Raspberry Pi outpaces competition is because of its large scaled community of people all over the world and the open source software that can be run[12].

Since the Raspberry Pi supports open source software, attracting bright and highly motivated developers to contribute when needed. The Kasadaka runs on solar energy provided by a solar panel that supports the Raspberry Pi. A solar chargeable battery is included to make sure that the Kasadaka operates continuously.

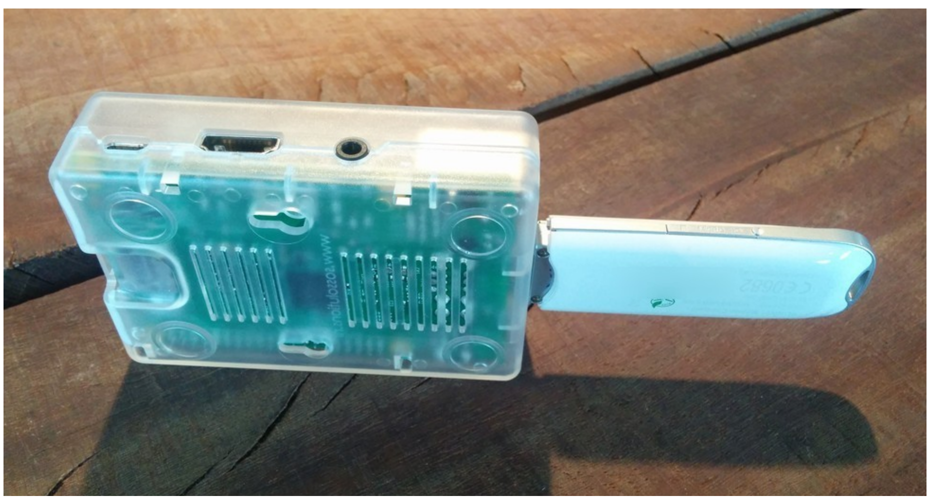

Fig. 7. The Kasadaka

Voice-based software The system is voice-based, giving illiterates a platform to share and receive knowledge. Voice-based technologies are crucial in the process of including marginalized people in today's society. The VOICES project and IBM[28] have been exploring and implementing voice-based services for both the web and information services for years. Asterisk is used to give the Kasadaka telephonic functionalities. Asterisk is an open source IP PBX platform that enables to call and send SMS messages from a Linux based computer to a mobile phone. The information services are provided by Asterisks' adaptable dial plan functionality. All the information services can be programmed in the dial plan using sound segments recorded in the language of the end user. Due to its ability to function as a voice-based rapid-prototyping platform, the Kasadaka both functions as a scalable generic ICT and meets the locally relevant information needs.

6.3 Discussion of generic method

To successfully develop ICTs that meet the information needs of the rural poor, it is of great importance to know their contextual background. Their information needs are contextually dependent and cannot solely be extracted from literature studies. Observing and interacting with the end users, as well as using a participatory approach as described in chapter 2 is the only way to get a good impression of their lives, livelihoods and needs. The generic class of problems could not have been established without the field trip in Ghana. Not only is it crucial that the researchers develop the ICTs based on the input of the end users, but the iterative process of acquiring feedback from them is essential to adapt the system to meet their needs.

7 Future Work

This paper covered the prototypical design of an information system aimed at supporting subsistence farmers in Sub-Saharan Africa in diagnosing and treating their sick livestock. The prototype that has been developed thus far is simple and still very limited. In order to alter it from a proof of concept into a system that can be implemented, several factors have to be adjusted.

The veterinary knowledge that the prototype contains is rather limited and not yet context specific. We have established contact with an animal health researcher from UDS. She will hopefully provide us with the information that is necessary to adapt the system in order to fit into the local context. For instance, a list of diseases that occur in the area should be established, as well as the symptoms that are associated with these. Once we have processed this knowledge into a second prototype of DigiVet, we will be able to test it in the research area. The feedback that the subsistence farmers will give us will clarify whether the system is comprehensible and useful in its current state.

Another part of the prototype that should be adjusted is the implementation of local languages instead of it solely supporting English. Processing these language will require a new field trip to the research area, which was not feasible in the limited amount of time of this study. The local languages are entirely context specific and may vary per village. Audio recordings will have to be made with the voices of local people, in order to be recognizable to the end users.

Future work should reveal whether the methodology mentioned in section 2 is adequate or whether it needs adjustments. We will further develop the Kasadaka tool as well as the DigiVet service that it contains. New developments can be followed on http://www.kasadaka.wordpress.com/.

8 Conclusion

The digital divide is one of the inequalities that exists between urban and rural development areas in SSA. ICTs and the internet could play a major role in providing the information and in reducing the knowledge gaps that contribute to the further marginalization of the rural poor. Unfortunately, due to poor infrastructure and lack of resources and education, ICTs are to a large extent inaccessible to these people.

This paper examined the role of innovative ICTs in the knowledge sharing process between experts and laymen living in rural development areas in SSA. The core of this research was a methodology directed at the development of a rapid-prototyping platform called Kasadaka, which supports the rural poor in acquiring context specific information. This methodology approaches computer science as a field study, by following an iterative sequence of steps that result in a set of information services that meet the information needs of the end users.

Our research is based on this iterative methodology, in which our research partners from W4RA provided us with context specific information. Armed with the Kasadaka, an interdisciplinary team of researchers from the VU university in Amsterdam conducted a field trip in rural Northern Ghana. This trip allowed us to gain an in-depth understanding of the lives and livelihoods of subsistence farmers. The acquired information needs provided the input of the context specific use cases that were transformed into prototypical information services.

The constraining and enabling factors that we found in Ghana confirmed our earlier thoughts of there being a poor electrical and internet infrastructure and a lack of resources. Additionally, we found that the inaccessibility and isolation of rural communities as well as the lack of education results in a communication gap between experts and rural laymen and an overall lack of expertise.

DigiVet is a great example of how a context specific information need can be transformed into a prototypical information service. The voice-based character and its simplicity enable illiterates and uneducated people to use the service, reducing their marginalization. The system brings farmers into contact with veterinarians, which reduces the communication gap between the two and supports them in the process of curing diseased livestock and preventing outbreaks.

Future work should reveal to which extent Kasadaka and DigiVet in particular will benefit the rural poor. The fact that they are affordable, can be interwoven into the existing infrastructure and usable for illiterate and uneducated people offers promising prospects of making tailor-made ICTs accessible for the rural poor.

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