VU VRIJE UNIVERSITEIT AMSTERDAM

Small hardware solutions for voice services

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Abstract

The question as to what extent ICT can play a role in a development context remains a subject of debate. New implementations are brought forward that seek to successfully prove the usefulness of ICT in developing countries. ICT4D has been a growing field of interest in recent years. In this paper a focus will be laid on the concept of using voice services on small-hardware devices as there are both advantages and disadvantages. Several small-hardware devices will be brought forward, analyzed and discussed to highlight the concept of using small-hardware. A use case has been provided that analyzes the process of software development in combination with small-hardware. This research further contributes information to the use of small-hardware and voice services in Third World countries.

Preface

When I started looking for a subject to do my Bachelor thesis about I already knew that I wanted to do something with development aid and as a Computer Science student I wondered how ICT can contribute to development in developing countries. I have always been interested in development aid but I never really saw the possibilities of ICT in this field and I have to admit that I never heard of the term ICT4D before I started with this thesis. I was therefore quite enthusiastic to learn that there was already a separate field of study within ICT that focuses on development aid and that it has its own specific literature and symposiums for example.

I wanted to use this thesis to not only try to make a contribution to the field of ICT4D but also to find out the different aspects of ICT4D and think about the role that ICT can play in a development context. I therefore consider this thesis to also contribute to my own personal understanding of this subject and how I as a future computer scientist can contribute to development aid. I have always wanted to end up doing development aid and I believe that this thesis provided me with new insights and thoughts on this subject.

I would like to thank my supervisors Christophe Guéret and Victor de Boer who have been a great help in introducing me to the field of ICT4D and for their input and ideas. I am also very thankful for providing me with the necessary tools to do my research.

'As we work to create light for others, we naturally light our own way'

Mary Anne Radmacher

Content

Introduction

The use of information and communication technologies has gradually brought major changes to modern-day Western societies. It has changed the way we communicate with each other and it has provided a platform for new economic opportunities. This provides an interesting question as to what extent ICT can contribute to the development of Third World countries. ICT4D[1] refers to the concept of ICT and development and can be described as the involvement of information and communication technologies that allow development in developing countries.

The field of ICT4D has received growing attention since the 1990s which as Heeks (2009) argues can be contributed to two events: the general availability of the Internet and the Millennium Development Goals. The Millennium Development Goals[2] have been created by the United Nations and they range from "halving extreme poverty to halting the spread of HIV and AIDS and providing universal primary education" (UN) by the year of 2015.

The initial focus of what is often referred to as ICT4D 1.0 focused on the introduction of recent technologies like the Internet but these projects often failed as they proved to be unsustainable in the development context (Tayoma, 2010). In recent years an important shift has been made as the emphasis of ICT4D projects came to rest on existing technologies that were already used en masse. "Where ICT4D 1.0 imposed preexisting designs and expected the poor to adapt to them, 2.0 designs around the poor's specific resources, capacities and demands" (Heeks, 2008).

This thesis focuses on the application of ICT4D 2.0 in an African context. Africa often poses a difficult terrain for ICT4D projects because of technological and geographical difficulties. Despite these difficulties a great rise has been seen in the use of mobile phones in Africa, "mobile phone subscriptions on the continent have risen from over 16 million in 2000 to 376 million in 2008 – or one-third of sub-Saharan Africa's population" (Aker and Mbiti, 2010). The mobile platform provides a large user base and it is therefore an interesting field of study to examine its possibilities, advantages and disadvantages. In particular this thesis will elaborate on this and focus on the implementation of small-hardware and mobile connectivity.

The research question that is analyzed to investigate this further is:

Can voice services successfully be implanted on small and cheap hardware devices in a development context?

To study this question the next chapter will explain the meaning of small hardware and voice services and why they are interesting to use. The *strategy* chapter will discuss the system design and several small hardware devices will be presented. The *use case* chapter will present the use case that has been build and implemented to give insight in not only the concept of using small hardware but also the process of developing a system that has to perform in a

[1] Information and communication technologies for development

[2] For a full list of the MDG's: http://www.un.org/millenniumgoals/

development context. The *Results and evaluation* section will address the findings of the project and the *Conclusion* will present the things that were learned and the conclusions that can be drawn. The problems that were encountered will be addressed in the *Discussion* section together with the future expectations.

Research

My research focused on the use of voice services on small-hardware in a development context. In this thesis small-hardware refers to the use of small, compact and often inexpensive devices. Examples of small-hardware are the Raspberry Pi [3]and the Wandboard Quad[4], both allow the possibility to install and run different Linux distributions. These devices poses properties that can be well used for a development context. Small-hardware has the advantage that it has a very low power consumption and this allows the possibility to set up a system in remote areas that have no access to an electricity network, with the help of solar power for example the device can be powered up. Another advantage is that small-hardware is inexpensive, this results in several advantages. First it can be more attractive to stakeholders as less funding is required for the hardware side of a project, also in case of theft or hardware failure the damage is relatively speaking low as the device can be replaced for a small amount of money. It therefore remains an interesting concept to what extent small-hardware can contribute to better and cheaper voice services.

Voice services refer to the possibility of using voice to interact with a certain device. This provides great benefits as this can open up the way for illiterate people to access certain content (Edim & Muyingi, 2014). As literacy rates in certain African countries belong to some of the smallest in the world[5] voice services can provide a solution to stimulate the illiterates access to ICT services. Voice services allow large pieces of content to be available as large fragments of information can be communicated to the user, a popular standard for developing voice services is Voice-XML[6].

Voice-XML is a web standard mainly used for developing powerful voice applications. The format is based on XML and is developed by the W3C[7]. It is widely used for audio and interactive voice response applications.

Earlier projects have been set up that evolve around a voice service and in this regard the Vrije University has been responsible for developing several voice applications that are currently deployed in Mali (van Aart et al., 2013). One of these is the Radio Marché project that enables farmers to promote their products on radio. The system uses a combination of cell phone, voice and web technologies. The Radio Marché system can be considered as a great example of ICT4D 2.0, where a system has been built around the demands of a community and on existing technologies like mobile phone connectivity that are widespread.

[3] http://www.raspberrypi.org/
[4] http://www.wandboard.org/
[5] https://www.cia.gov/library/publications/the-world-factbook/fields/2103.html
[6] http://www.voicexml.org/
[7] http://validator.w3.org/

The Radio Marché project shows that the mobile platform allows the users to interact with the system at any given time and therefor can speed up the process of information transition.

I have highlighted this project as it relates to my own research in the sense that it is an already working and deployed system and it can therefore provide insights into the hardware and software that is required and the different demands that such a system needs. The first part of my own research will focus on the hardware-side where I will examine the possibilities to develop voice services on small-hardware devices and if they can operate well in a development context. The second part of my research will focus on building a small weather application that works with VXML to provide insight into the software development process and the possibility that it can be used as a framework for future weather applications in a development context.

Strategy

System design

To set up a system that can create a voice service on small-hardware I made use of and tested several different small-hardware devices and software. I initially planned to start with the Raspberry Pi. The following software and hardware components were used to set up the initial voice service application.

- Asterisk[8] - is a free and open source framework that allows the possibility to build powerful communication applications like IP PBX systems and VoIP gateways.
- Mobile phone - I used a BlackBerry Pearl 9105 from April 2010 with a SIM-card. The phone allowed the possibility to use a USB connection and Bluetooth.
- Raspberry Pi - can be considered as a small and cheap computer that was launched in 2012. I made use of the B-model that included 512MB of RAM and 2USB ports, by default the Raspberry Pi has no Bluetooth capability.
- Voxeo Prophecy Voice-XML[9] - is part of the extensive Voxeo Evolution portal that offers a wide range of services to create and test IVR applications. For my application I used the possibility to host Voice-XML files and link these files to several contact methods like a Skype VoIP.

The Voxeo voice browser is a very important part of the system as it allows the possibility to call and connect to a VXML file. The diagram below illustrates the abstract model.

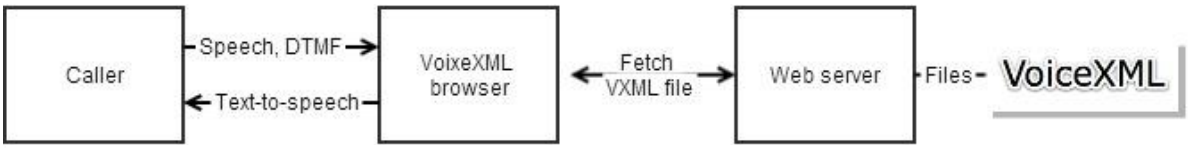

Figure 1: Voxeo Evolution abstract model

There are several contact possibilities for the caller like calling to a Skype number or SIP VoIP. The Voxeo voice browser will fetch the VXML files from the web server and parse the content of the VXML files. It can return speech to the caller and it can also receive input from the user

[8] http://www.asterisk.org/
[9] https://evolution.voxeo.com/

by speech or DTMF[10]. This provides a very easy way to connect to and process a VXML-file. The voice browser is very modular as it can be accessed by several contact methods. It can be easily reconfigured to accept another VXML file. Once the voice browser is configured the system can be contacted at any moment and does not need a device to be turned on. It is also possible to call to the same Voxeo Skype number with different accounts at the same time and this means that multiple users can make use of the system at the same moment.

The following diagram illustrates the general idea of how the voice service should operate, the interaction that takes place between the several actors and the relationship that is included.

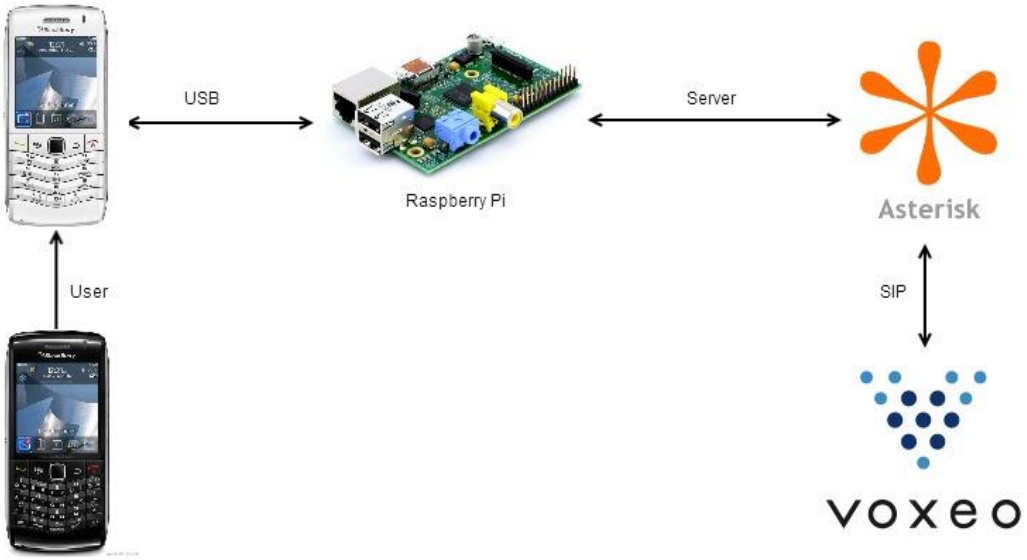

Figure 2: Proposed system design

The idea is that a user will call the phone number from the SIM card that is inside the mobile phone attached to the Raspberry Pi. The Raspberry Pi has an Asterisk server running that connects the mobile phone connection to the Voxeo application that is linked to a certain SIP VoIP. In this way the user can interact with a voice service in a decent amount of steps.

System development

When I started the project the first thing that needed to be configured was the Raspberry Pi. The Raspberry Pi does not have any internal storage so a Linux distribution needed to be installed on a SD-card. The distribution that I installed was Arch Linux. After doing some initial configuration to the Arch Linux distribution like installing a graphical interface I started with installing and setting up the Asterisk connection. First I started to install Asterisk from source but this proved to be a tough challenge. I then learned that installing from a package manager proved to be more successful. I first tried to configure the Asterisk server to connect with the Voxeo SIP VoIP client but this proved to be unsuccessful. The documentation about this was coming short and pairing the device to Asterisk also posed difficulties as additional documentation about this was lacking. As the Raspberry Pi does not have a Bluetooth adapter

[10] Dual-tone multi-frequency signaling, used to signal which button is pressed

I wanted to connect my mobile phone to it by using a USB cable. Unfortunately my mobile phone was not recognized and attempts to connect it failed. Next to these problems I also noticed that the Raspberry Pi sometimes performed slow during simple tasks and I therefor consider its RAM to be too low to be able to run a voice service properly. The Raspberry Pi B-model has 512MB of RAM and I would recommend a minimal amount of 1GB of RAM for a more stable system.

I therefore decided to try the more powerful Wandboard Quad that includes a 2GB RAM. Unfortunately I experienced problems with the video output as it did not show the left part of the screen. Nevertheless I was able to install Ubuntu and then Asterisk from the software center. Also a separate Bluetooth package needed to be installed. After successfully pairing the Wandboard Quad to the mobile phone I noticed that the connection was not very stable and occasionally got disconnected. I also consider a direct USB connection to be preferable as a constant Bluetooth connection will consume more battery power. For setting up the Asterisk server I experienced the same problems as with the Raspberry Pi so this attempt also proved to be unsuccessful. Next to that the Ubuntu distribution was not very stable and crashed very often, after a while I therefore tried a Debian distribution.

The third device I configured was the MobiGater[11]. The MobiGater was released in 2007 and has the ability to call to a Skype account. It provided me with the possibility to call to a SIM card and connect to a Skype account from the Voxeo Prophecy platform and this proved to be successful. The MobiGater was attached to a Windows laptop with a USB cable and this also provided the possibility to run a database on the same system that can transfer information to and from the database. A drawback may be that the MobiGater is not supported anymore and that documentation about how to configure it with Asterisk is lacking.

The OfficeRoute[12] is the last device I worked with and is also the most expensive but it has a lot of built-in features and it can have up to 4 SIM cards installed. I was able to configure it by connecting to the device using my web browser. I initially started to set up an internal IVR and I was able to route a call to the internal IVR but the IVR script showed to be very basic and unfortunately does not support interaction with PHP. I then tried to set up a connection with a SIP-line, I was able to route the call to a SIP-line but the SIP settings could not verify if the given input was correct and the documentation was not very clear and extensive about what kind of input was required. I was totally dependent on the documentation on the website of the OfficeRoute, as the device is expensive there is almost no documentation available from other users.

[11] http://www.mobigater.com/

[12] http://www.2n.cz/en/products/umts-gateways/officeroute/

Use case

Now that I had the possibility to connect to the Voxeo Prophecy platform using the MobiGater I was able to start designing a working voice service application. The voice service application will be built around a weather application that is currently being developed to be used in rural areas in Burkina Faso[13]. I first attended the processes of acquiring the requirements and getting to know the function of the system. This information was provided by dr. van Aart from the Vrije Universiteit who is working on the weather application. The weather application will involve farmers that have simple instruments to measure the amount of rainfall, the farmers will transfer this information by calling to a central point where the data is processed and eventually stored in a database. This weather application has several users:

- Donors - want to receive data about agricultural activity.
- Farmers - collect and transfer the rainfall data and use that data to decide what to cultivate.
- National meteorological institute - gain insight into hydrological activities.
- NGO's – gain insight into re-greening activities.

By adding voice services to this application it can speed up the process of transferring data between several actors of the system. By building an IVR system based on the requirements it allows the farmers to send their data immediately into the database by selecting the correct input. As the database has a standard format this saves processing time and the farmers are able to send their data at any time so this will not require the availability of an operator. The table below shows how the data will be stored.

	date	location	measure08H	measure18H	measureTotal
	20140615	Batie	0.1	0.0	0.1
	20140615	Banfora	0.0	0.0	0.0

Table 1: pluviometry database storage

Based on this new data more data will be available from more locations and better weather predictions can be made. To this end I have implemented a voice service that allows users to receive up to date information about the weather expectation. Users will dial a number that is connected to the Voxeo Prophecy platform and have the possibility to select the location where they want to receive information about. The user has the possibility to interact with the service by using DTMF or voice. I have also build a voice service for the farmers so they are able to send their data by calling to a specified number.

[13] http://meteo.w4ra.org/

Results and evaluation

The system as proposed cannot be deployed yet as the weather application is in its development phase. Despite this a framework has been built according to the proposals that were mentioned. I have been able to set up a voice service where users can call to and interact with the device using voice. The users will hear the weather forecast from the region that they specified. I was also able to let farmers call the system and sent their data. With the MobiGater connected it is now possible for a user to request a specific piece of information for example by phone, in this case the weather prediction. The system shows that with only a few components a complete voice service can be set up.

Unfortunately I wasn't able to meet up with the expectations of the first part of my research. The small-hardware devices proved to bring its own challenges of working with Linux and correctly configuring the device. Unfortunately a lack of proper documentation often resulted in a long period of time trying to find the right configuration. The initial installation of Linux and understanding the system also required some time. Because I tried several Linux distributions each distribution required its own answer in terms of using the console and configuring the software and at some points I had to decide to move on. Technically speaking I believe it should be possible to run the system as proposed in figure 2 on a Wandboard Quad.

Despite the configuration problems the Raspberry Pi also showed that it lacked enough RAM to operate well with large programs and this often resulted in a freeze. The Wandboard Quad also had this problem as the Ubuntu distribution did not prove to be very stable and also froze quite often. Unfortunately Asterisk only runs on Linux and therefore I did not had the possibility to configure and understand the software on a Windows computer. This would have given me the chance to try to develop a working system and help me set up a Linux distribution. It can be noted that the use of Linux in a development context would mean that there are few people available who can configure or repair a Linux system. Linux does have advantages for small-hardware, as a user you are able to select which parts of the system are to be installed and therefore only the necessary elements can be installed leaving more hardware resources available for the task the system is designed for.

Conclusion

The goal of this project was to examine the possibility of running voice services on small and cheap hardware. In that sense the research has shown that introducing small-hardware results in additional challenges. The largest challenge proved to be to work in Linux where I had little experience with. This might also be the case in a development context, where it can be expected that there are only a minimal amount of people that are able to work with Linux. This concludes that when configuration needs to be done there needs to be someone around who is capable of working with Linux. The implementation of small-hardware also results in less computer power available, this means that tasks will be performed slower or not even possible to be executed at all.

Nevertheless the use of small-hardware does have benefits in the sense that a cheap system can be set up using only a few components. This advantage becomes more interesting when a large amount of hardware devices are needed. The implementation of voice services has shown that it can speed up the process of information transition between several actors and that more services can be made available. The amount of content that therefore becomes available is endless.

Discussion

The limitations of the research were that a lot of time was spend on figuring out the possibility of configuring the small-hardware to work with the other actors of the proposed system. This proved to result in the failure of setting up the system as proposed. Unfortunately I was therefore not able to deliver a working system on small-hardware. This also showed that the implementation of small-hardware might take some time, especially for someone with no Linux experience.

During the research I did not really find great benefits that would prefer using small-hardware over normal devices. The fact that small-hardware had to be hooked up to a monitor for configuration made it even less-mobile and not so much cheaper than a laptop. When a device is configured properly it can however work without monitor. When it comes to the cost aspect of using small-hardware the difference is not that great for a single device that it would make a significant impact on saving costs. Only when a large amount of hardware devices are necessary, small-hardware might become interesting.

Nevertheless it is always an interesting question to ask whether it is possible to create even smaller and cheaper solutions than the existing ones. In that sense it depends on the requirements and expectations of a system. There are situations where small-hardware will perform better than normal hardware and as this application has shown there are also situations where it won't.

This research has shown to me that future research can focus on the question as to what extent these small scale and cheap devices can contribute to more projects that are started from the community itself. As small-hardware is cheap it is interesting to know what this can mean for projects that are started by the community and how they can experiment with developing ICT systems themselves. In this way more people will have experience with developing and using ICT systems.

Literature

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Appendix

The Skype contact number for the Voxeo voice application is:

+990009369991494242

Source code will be published on:

https://github.com/stephan4d/ICT4D