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Tibaηsim: Information Access for Low-Resource Environments

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Abstract In Africa, and other places around the world, there are numerous people who do not have access to information from the World Wide Web or other digital sources. This is not an issue of infrastructure only, but also of cultural and social factors, including low literacy. Most rural communities in the Northern Region of Ghana fall in this category, where information in written form and/or English is not accessible due to the inability of majority of community members to read and write. This paper presents Tibaηsim (originally "RadioNet"); a case-study of an appropriate ICT4D methodology in the development of an information delivery system hosted in low-resource areas, with empirical data from context analysis from the rural communities and other stakeholders. The paper also presents an evaluation of the system and the methodology, by way of User Evaluation and System Monitoring. The paper also shows how contextual issues are catered for through the methodology used. Tibaηsim focuses on available technologies and appropriate information formats by providing a system that relies on GSM and FM Radio, in the local language(s) of the community. Tibaηsim was deployed in 5 rural communities, reaching a total of almost 1000 people, providing them primarily farming-related information.

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1 Introduction

The digital divide is a problem that has plagued the world since the inception of the World Wide Web [1]. Only about 24.4% of Africans are connected to the internet [2]. The reasons for this low level of access, and subsequently to relevant information are; Lack of Infrastructure, Low Incomes and Affordability, User Capabilities; basic literacy and digital literacy, Lack of Incentives for Access; lack of awareness, relevant content, and cultural or social acceptance [3].

This paper presents Tibaηsim (a Dagbanli[1] word that translates to "Our Knowledge"); a case-study of an appropriate ICT4D methodology (see Fig. 1) in the development of an information delivery system hosted in low-resource areas with empirical data from context analysis from the rural communities and other stakeholders, which guided the design process and produced an information delivery system for rural communities. The paper further presents an evaluation of the system and the methodology, by way of User Evaluation; an analysis of Usability, Learnability, Availability. The paper shows how the aforementioned issues are catered for through the iterative and user-centered methodology used.

1.1 ICT Challenges in the Rural Context

In Ghana, voice-telephony, radio, and television are existing systems that function adequately, where the former two are more utilized in rural areas. However, there is an urban-rural divide, which means even further deterioration of services in the rural areas [4]. This is clearly seen in the areas of electricity and Internet connectivity which are often unreliable in rural communities [5]. Ghana has a literacy rate of 76.67% and a youth literacy rate of 90.6%. However, the rural north, which happens to be a major food source for the country, retains the lowest literacy rates [6]. Information available online is heavily biased toward text and thereby discriminates against those who cannot read and write [5]. Another barrier to connecting the unconnected has been that they do not find the information to be locally relevant enough to warrant the effort to gain access to it [3].

In the attempt to circumvent the issues of lack of infrastructure and unaffordability, it is important to center innovation on "technology-in-use" as opposed to "technology-as-invention" [7]. The extreme increase of mobile telephony in rural Africa [8] has led to the emergence of ICT4D projects, research and solutions that

[1] https://en.wikipedia.org/wiki/Dagbani_language.

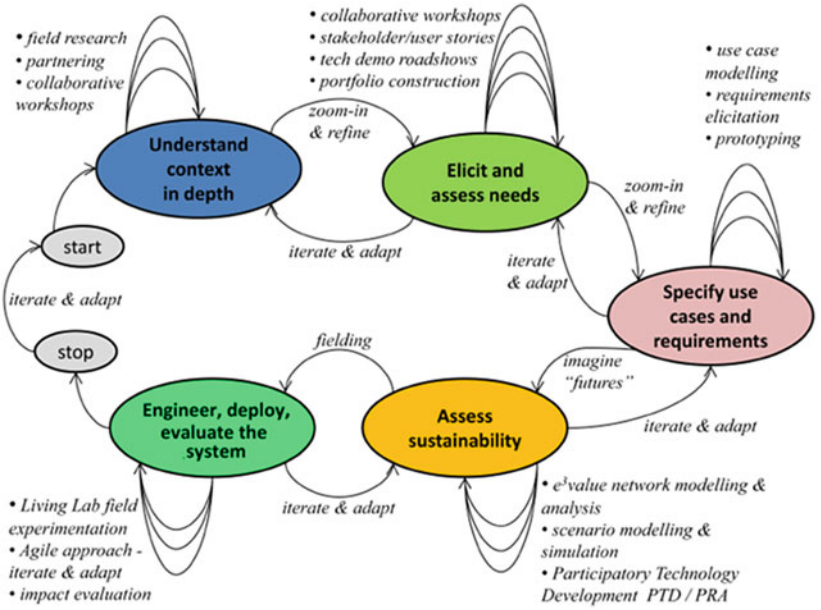

Fig. 1 Methodology

aim to utilize these existing technologies, namely, SMS [9, 10], Mobile Web [11], Voice Technologies [12], and Radio [12, 13] to aid various aspects of development. Some of these have failed completely [10] due to their reliance on technologies that are circumvented by low literacy (namely, SMS) and for the same reasons, some have not been able to scale up effectively in the rural areas [9] since, based on empirical evidence, SMS is hardly used by folk in rural areas in Ghana [6].

2 Methodology

This study used a collaborative, adaptive, and iterative methodology (see Fig. 1) to identify and tackle the issues from a socio-technical standpoint [5]. The study also forms a validation of the methodology by providing a practical application to an information system design and implementation.

The research focused on East Gonja District of the newly formed Savannah Region of Ghana. Five (5) communities were selected; typically small communities with about 20–30 households with roughly 200–250 people per community.

The evaluation of the issues pertaining to the digital divide, workshops with multi-disciplinary groups, and interviews with stakeholders enabled us to *understand the context in depth* (see Fig. 1). Coupled with the understanding of the operational needs

for the various stakeholders, led to aid *elicit and assess the needs* (see Fig. 1) of the proposed system.

Through an iterative process, stakeholders and end-users provided insight into the needs of the system. The key idea is to create an information access system for local communities by providing an FM broadcast system. This will enable rural communities to get access to relevant voice-based information in their own language(s). This will involve the design of a low-cost system, built on the Raspberry Pi with Solar-Power Banks that stores recorded voice fragments over GSM calls and broadcasts it over FM on short-range.

2.1 Key Requirements

Following an understanding of the context and the needs analysis, as well as considering the technologies available, the following are the key requirements of the system.

2.2 Non-functional Requirements

- Maintainability—NGOs/Companies and Institutions should have the ability to maintain the system and update information with ease.
- Availability—Users should have the ability to reach the system at all times. As such, barring mobile network issues, the system should be hosted on a platform that will be available at all times.
- Scalability—The system must have the ability to scale to different locations and for any number of subscribers and the system should be easily replicable.
- Reliability—The system must ensure that information is as accurate as possible.
- Usability—The targeted user group creates a requirement of simplicity in the user interface.
- Cost-Effectiveness—The whole system must work together to be financially sustainable.

2.3 Functional Requirements

The functional requirements are shown in a MoSCow format as follows Table 1.

Table 1 MoSCoW

Must have	Interactive voice response
	Local language(s)
	Regular information updates
	Short-range radio (FM) Transmission of information
	Monitoring
Should Have	Uninterrupted power supply
Could have	Community-level subscription-based service
	Wide-range radio (FM) Transmission of information

3 Implementation

3.1 Development

Based on the Context Analysis and Needs Assessment, Use-Case and Requirement Analysis, and the Feasibility and Sustainability Assessment, the various components of the system were *engineered, deployed and evaluated* (see Fig. 1) in multiple iterations with adaptations in a Agile approach coupled with an adapted living lab approach [5].

Tibaηsim was built on the Raspberry Pi 3B+,[2] tiny credit card size computer that was designed in the UK by the Raspberry Pi Foundation. The Raspberry Pi 3B+ runs a Quad Core 1.4GHz Broadcom BCM2837 64bit CPU, with 1GB RAM (2GB and 4GB RAM versions available) and requires a power supply of 2.5A. It also has a 40-pin extended GPIO, of which, vital to this project, GPIO Pin 4 transmits its FM signals. Tibaηsim also required a Huawei 3G Modem that is chan_dongle capable [3] and a GSM Sim Card. A power bank was also added to the package to ensure uninterrupted power supply.

The Kasadaka platform was used for the system's audio input module. Kasadaka enables the development and hosting of voice-based information services, targeted at low-resource environments. The VSDK allows for the rapid development of voice service (prototypes) in a web-based development environment [14]. This enables Information Providers to call into the system to leave messages, and at the backend, on confirmation, the audio fragment is stored in Kasadaka's file storage.

The Tibaηsim FM Broadcast System was built using Pi-FM-RDS which generates an FM modulation. It can include monophonic or stereophonic audio. The transmitter uses the Raspberry Pi's PWM generator to produce VHF signals [15]. The Broadcast System of Tibaηsim is the main user interface for the End-User. The system reads the audio files from the file storage system of the Voice Input Module and broadcasts them on a loop on FM at 107.9MHz.

[2] https://www.raspberrypi.org/.

[3] http://asterisk-service.com/en_US/page/chan-dongle-modems.

4 Evaluation

The System Usability Scale (SUS) is designed to obtain subjective feedback on overall usability and user satisfaction [16]. Apart from the 10-item SUS Score, using factor analysis, the SUS is able to provide additional information via two sub-scales: an 8-item "Usability" and 2-item "Learnability" scale [17, 18]. The SUS involved the administering of the test to all 106 participants after their use of the system. It is important to note that translations (in the right context) were necessary to effectively administer the SUS as it has been found that there is a possibility of a lack of comprehension in some of the SUS questionnaire items for even non-Native English speakers [17].

For reliability analyses of the data, the SUS showed good internal consistency (alpha = 0.743) [19] with an SUS Score of 80.52 (an Adjective Rating of "Excellent"), Learnability value of 71.93, and Usability of 82.67. The high scores for SUS, Learnability, and Usability, indicates a high quality of end-user's experience and the ability to utilize it with little to no prior training.

The Context Analysis and Needs Assessment of the methodology used necessitated the solicitation of required content from the end-users. Being involved in the development process, end-users as well as stakeholders were able to clearly specify the type of information that would be relevant to them. Empirical data was also gathered on the type of content end-users would find relevant. Notable among information considered relevant in the research area are *Crop Farming Practices*, *Market Prices*, *Information on seed*, *Climate Information*, and *Placing ads for sales of produce*. Of note is information from the World Wide Web, and example being climate information; this requires more technical work to enable automated updates to the system and was implemented as a separate integrable system dubbed *Mr. Meteo* [20]

Cost-effectiveness is of utmost importance and considered a Non-Functional Requirement (see Sect. 2.2). As such, design choices were made for low-cost hardware and open-source software (see Sect. 3.1). The system is also designed to enable rapid and little to no cost setup. For purposes of sustainability, it is imperative that running costs and affordability are catered for and as such, design choices are made to facilitate low-cost maintenance and affordability to end-users.

5 Discussion

Development and/or deployment of ICT systems for low-resource areas comes with a myriad of challenges [5], some general and others pertaining to the particular system. This is important to any study, being that these are issues that are not always readily apparent.

Development of systems for low-resource environments with the methodology used requires physical visits (possibly several) to communities. Some communities are remote, with bad road access, making the required multiple visits tedious. This,

on the contrary, is the very reason why information access for such communities is vital. In this project, all communities were remote, with bad road access, but visits were necessary for information elicitation and deployment. However subsequently, it will be possible to deploy with the help of Agricultural Extension Agents who, as part of their existing jobs, visit these communities from time to time. Information dissemination through ICTs rely on telecommunications networks, but unfortunately, many rural communities lack sufficient access. In some rural communities in Ghana, there is little to no 4G, sparse 3G, and patchy GSM reception. This needs to be taken into account to build systems that do not require constant internet access, high bandwidth, constant uptime, etc. The details will depend largely on the particular community. The next iteration of development will use an outdoor, waterproof enclosure coupled with solar-power supply in addition to GSM boosters to augment the reception to the device.

In many developing countries, hardware needed to build ICT systems may not be readily available. For Tibaηsim, the required hardware (Raspberry Pi 3B+ and Huawei 3G Modems) had to be imported into the country due to its unavailability in Ghana. This caused some delays with the initial pilot.

Finally, a project specific issue worth mentioning; the FM broadcast range of the Raspberry Pi 3B+ with a simple wire antennae is about a 120 m. As much as this covers enough of the communities, the ideal would be a wider range to cover entire communities and cater for larger communities. The next iteration will consider boosting the range of the FM transmission. This however would require liaising with the National Communications Authority[4] in Ghana once transmissions begin to exceed official community ranges and/or becomes a commercial product.

6 Conclusion

Information access remains a problem in many parts of the world [1]. Developing countries, like Ghana, have numerous rural communities that have little access to up-to-date and relevant information [2]. Telecommunication infrastructure is lacking in these communities and limited, mostly, to GSM reception and there are other major issues like unaffordability of Internet-capable device and Internet and voice services, low levels of literacy, and unavailability of relevant content which further compounds the issue [3]. Available literature points us toward the use of "technology-in-use" [7]; in the case of Ghana, mobile telephony and FM radio, concentrating on voice technologies [12] and local languages.

This paper has presented a case-study of an appropriate ICT4D methodology [5] in the development of an ICT4D system which is hosted and used in low-resource environments. Empirical data from rural communities and other stakeholders was used, iteratively, to design a low-cost, voice-based information system for rural communities meeting the contextual requirements and operational goals of the various

[4] https://www.nca.org.gh/.

stakeholders. Furthermore, a System Usability Score (SUS) [16] test was administered to 106 community members from five (5) communities where the system was deployed and we presented an analysis of the SUS, Usability and Learnability scores which indicate that the requirements of the end-users were met and the system is easily used and learned.

Information is a very important commodity for development [21]. As such, bridging the digital divide is vital, not only to developing countries, but to the world, as the successes of attaining the Sustainable Development Goals (SDGs)[5] will benefit the planet as a whole. The process of systems development for low-resource regions is therefore critical to the successfully attaining SDGs. This process is not trivial and requires an appropriate methodology that is collaborative, user-centered, and iterative. This aids to fix issues that exist for the stakeholders and end-users as opposed to fixing perceived problems. The Tibaηsim project shows this development process for low-resource areas practically and hopes to serve as a guide for future projects.

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