IT Infrastructure Enabling Open Access for Flood Risk Preparedness in South Africa

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ABSTRACT

The paper focuses on the information technology infrastructure required for the evaluation and monitoring of risk relating to floods in South Africa. It may be argued that in the context of developing countries, flood preparedness is more valuable than the actual response to a flood disaster. The paper looks at this flood preparedness in the context of informal and semi-formal settlements. An information technology infrastructure is proposed that will allow decision makers to be alerted to possible flood high risk areas, and in so doing maximise preparedness.

Keywords

Sensor Web, Risk Preparedness, Open System, Flood Lines

INTRODUCTION

Informal Settlements are deemed by the UN as areas where groups of housing units have been constructed on land to which the occupants have no legal claim. These areas are characterised by rapid, unstructured and unplanned developments. They are common features of developing countries and are typically the product of an urgent need for shelter by the urban poor (Huchzermeyer, 2001; Mason and Baltsavias, 1997; United Nations, 2004). Informal settlement growth in metropolitan areas of South Africa has increased in the past decade as a result of the abolishing of the legislation implemented by the apartheid government that prevented urbanisation (Ferreira, de Meyer, Loots and Keyise, 2002). As a result of the sudden post apartheid increase in urbanisation, metropolitan areas in South Africa are very dynamic, resulting in the rapid change of the spatial patterns and land use associated with such areas.

Floods cause tremendous damage on the African continent. Some statistics on flood related incidents across Africa: Cape Town, South Africa, floods hit 25 Informal settlements with thousands of residents displaced (www.iol.co.za, 2008). In Southern African countries the latest figures from national disaster authorities estimate 927, 710 people affected since October 2007 (OCHA, 2008). Over a three decade period, approximately 22 countries have been hit by floods that affected over 1.5 million people and left over three hundred dead (AFP, 2007). Informal and semi-informal settlements, due to lack of proper infrastructure are the most vulnerable to floods.

The research is aligned with the IRMA project which intends to deliver a pre-operational open infrastructure and access-platform, assessed by end-users in operational scenarios. The research questions to be addressed by the paper is exploring the possibility of an open infrastructure within IRMA that will facilitate decision makers in assessing and continuously evaluating flood risks, so as to increase preparedness. Most important is to demonstrate the effectiveness of open systems, within the context of Africa, when dealing with disaster preparedness. The research is further delineated by assessing only those members of the community that are not directly constrained by town planners. These members are those that fall into the informal and semi-formal housing sector.

The following section explores some of the background relating to disasters and sensor webs. In the architecture section we display the results that have been attained thus far. The paper completes with a section on continued research and then conclusions

RISK PREPAREDNESS AND THE SENSOR WEB

Informal Settlements in a South African context are dense settlements comprising communities housed in self-constructed shelters under conditions of informal or traditional land tenure (Hindson and McCarthy, 1994; Richards, and O'Leary, 2007). Generating spatial models of informal settlements using remote sensing imagery has been a popular means for monitoring them. Currently in South Africa, spatial modelling of informal settlements has been carried out using mostly aerial photogrammatic mapping methods (Mason and Baltsavias, 1997). Any satellite images used are usually of a medium spatial resolution (van der Merwe, 2006). The resultant products are, in many instances, unrelated to user requirements in terms of accuracy, time and resolution (van der Merwe, 2006).

Disaster preparedness tries to forecast extreme events, attempt to mitigate the impact of disaster, respond to disaster and cope with consequences of disaster. Strategies for disaster preparedness include awareness of event that is most likely to happen at a particular time and at a specific geographic location, risk and vulnerability assessment, response mechanisms, coordination, information management, and early warning systems (IFRC 2000). One element in risk preparedness is an effective early-warning mechanism. This can be achieved through use of flood lines. Flood lines describe the elevation points of dams and banks of rivers when flooding occurs. The elevation points can be determined from history of floods in a particular area or using computer simulations that produce flood lines with a 2 – 100 year return period (http://www.aed.co.za). Monitoring flood lines using Sensor Web technology, discussed below, can play a major role in achieving a suitable early warning mechanism, and thus improve disaster preparedness.

Previous attempts have been made to assess flood risk potential within Africa, these efforts have focused more on the social aspects relating to floods (Khady, 2007 ; Kundzewicz *et.al.*, 2002). Other efforts have made once of assessments of flood risk within a given context (Napier and Rubin, 2002; Vermaak and van Niekerk, 2004). Our work understands that both flood potential and informal settlement development are two phenomenon unfolding at different temporal scales. In order to provide a more accurate and effective solution continuous modeling and detection of both phenomenon must be maintained and relevant risk alerts raised when it is appropriate. In order to address this we focus on the IT technical implementation issues relating to the realisation of such a system. However integration of the formal know how and social impacts studies into the IT framework provided here is likely to present the ultimate solution.

A mechanism allowing for access to data is the use of an open service oriented architecture such as the Sensor Web:

> "An open complex adaptive system organised as a network of open sensor resources, which pervades the internet and provides external access to sensor resources. By open sensor resources, we include any open system, including sensor networks that are a source of sensor data or sensor meta-data (van Zyl, Simonis, and Mcferren, 2008)."

In terms of computational systems openness is encapsulated in the interfaces of the system and interoperability arrangements in the form of open standards (Hewitt, 1986; Chau and Tam, 1997).

One effort that has gone a long way towards the realisation of the Sensor Web is the standardisation process that exists within the Open Geospatial Consortium (OGC) under the name Sensor Web Enablement (SWE). SWE proposes three standardised service interfaces and three standard data encodings. The service interfaces take the form of; Sensor Observation Service (SOS), Sensor Planning Service (SPS), and Sensor Alerting Service (SAS). The data encoding are Observations and Measurements (O&M), Transducer Markup Language (TML), and Sensor Modelling Language (SensorML) (Na and Priest 2006; Botts, 2006; Simonis, 2005a; Simonis, 2005b).

The SOS provides a standardised interface for accessing sensor data and usually serves data encoded as O&M. The SPS provides a standardised interface for tasking of sensors and checking the feasibility of tasking operations. The SAS is a standardised interface that allows for subscriptions to alerts relating to future observations. SensorML provides a standardised encoding for describing all sensors and sensor services relating to the OGC SWE stack (Botts, et al.).

IRMA METHODOLGY

The IRMA project that this work forms a small part of involves a formal software engineering approach. The entire software development life cycle from requirements gathering to eventual product deployment will be followed in the context of a multi country and organisation consortium. Initially a set of scenarios will be developed, based on a formal methodology developed, as part of the project that will focus on different disaster types in various African countries. These scenarios serve as references for a future larger scale deployment of the platform and its components. The scenarios will be expanded into accompanying use cases. These scenarios and use cases will form the basis on which an architecture that is both accessible and open will be developed. The multi scenario approach will lead to a architecture that is generalisable to other cases. The architecture will be realised as package that can be redeployed and will be relevant due to the interaction with the eventual owners through out the process. Further the platform provides the facilities for prototyping risk management systems and for supporting a rapid development of applications services such as Bushfire, Flood, Desertification and Urban Risks (IRMA, 2008).

ARCHITECTURE FOR AN OPEN RISK PREPAREDNESS SYSTEM

The research describes a case study to show the feasibility of the IRMA approach in South Africa. A set of use cases, seen in figure 1, are developed and provide the context for the case study. Using the set of use cases a high level architecture is developed. The architecture describes the components in the form of services that will make up the system and the standardised SWE interfaces they will realise. The implementation of the architecture will validate as to the feasibility of the solution proposed. The openness of the solution will be evaluated through out. Below is given research in progress and shows the proposed architecture for the solution.

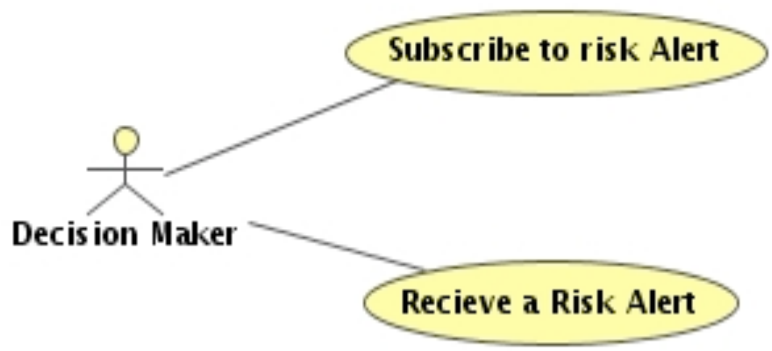

Figure 1. Use cases for risk preparedness system

DATA VIEW

Flood Lines are a way of indicating levels of water under normal and flood stream conditions. These lines are formed by joining a series of elevation points along the river banks. The elevation points at any point are highly affected by topography and terrain. One way to achieve accurate elevation points is by using Digital elevation models (DEM) and hydrology models (Tarboton, 2003).

An existing system the Informal Settlement Information System (ISIS) will be used to detect informal settlements (Parbhoo and Moodley, 2007; Parbhoo, 2009). The system detects informal settlements in real-time from multiple high resolution satellite image sets over the Alexandra region, a suburb in South Africa, from high resolution (0.60m - 2m) Quickbird imagery. In the ISIS application two bands, the Panchromatic and Multispectral bands, of the Quickbird satellite image data are processed through a series of image processing steps in order to extract key features that aid in identifying informal settlements. ISIS was developed on the Sensor Web Agent Platform (SWAP) an advanced Sensor Web architecture (Moodley and Simonis, 2006).

Services View

The services that make up the system can be seen in figure 2 and are further described below.

Informal Settlements SOS

In order to provide observations relating to the location and dynamics of informal settlements the use of a SOS is proposed. A SOS is well suited to this purpose as it is able to provide time series data. The algorithm used within the ISIS application will be used as the source of data for the proposed SOS.

Informal Settlements SPS

In order to parameterise and control the function of the models and algorithms relating to the Informal Settlement SOS a SPS is provided. The SPS allows for tasking of reruns and of runs on specific regions using higher resolution data.

Flood Lines SOS

In order to provide flood-lines a SOS is used. The SOS offers up the locations of the flood-lines as O&M. Although the flood-lines used are static in nature, generated using hydrological models and DEM, it is possible to include dynamic algorithms to generate the flood lines. These dynamic algorithms might include machine learning techniques and other automated feature extraction methods.

Risk SOS

The Risk SOS would use the both the Flood-lines SOS as well as the Informal Settlements SOS as sources of data. For a first run the course grained data from the informal settlements SOS will be used. This provides a lower resolution but quicker intersection test. Those areas where 50 year flood-lines intersect with Informal Settlements would be marked as high risk. The process then forms a feedback loop in which the Informal Settlements SPS is tasked to rerun the models relating to the regions of high risk using higher resolution data. This effectively allows for an automated zooming in on the areas of high risk to obtain a better view.

Risk SAS

In order to provide access to risk notifications a SAS is provided. Decision makers or other members of the community can use the SAS as a way of subscribing to alerts relating to changes in risk as a result of either the dynamics in flood-lines, or more likely the dynamics of informal settlements. The risk SAS provides an alerting service for the Risk SOS

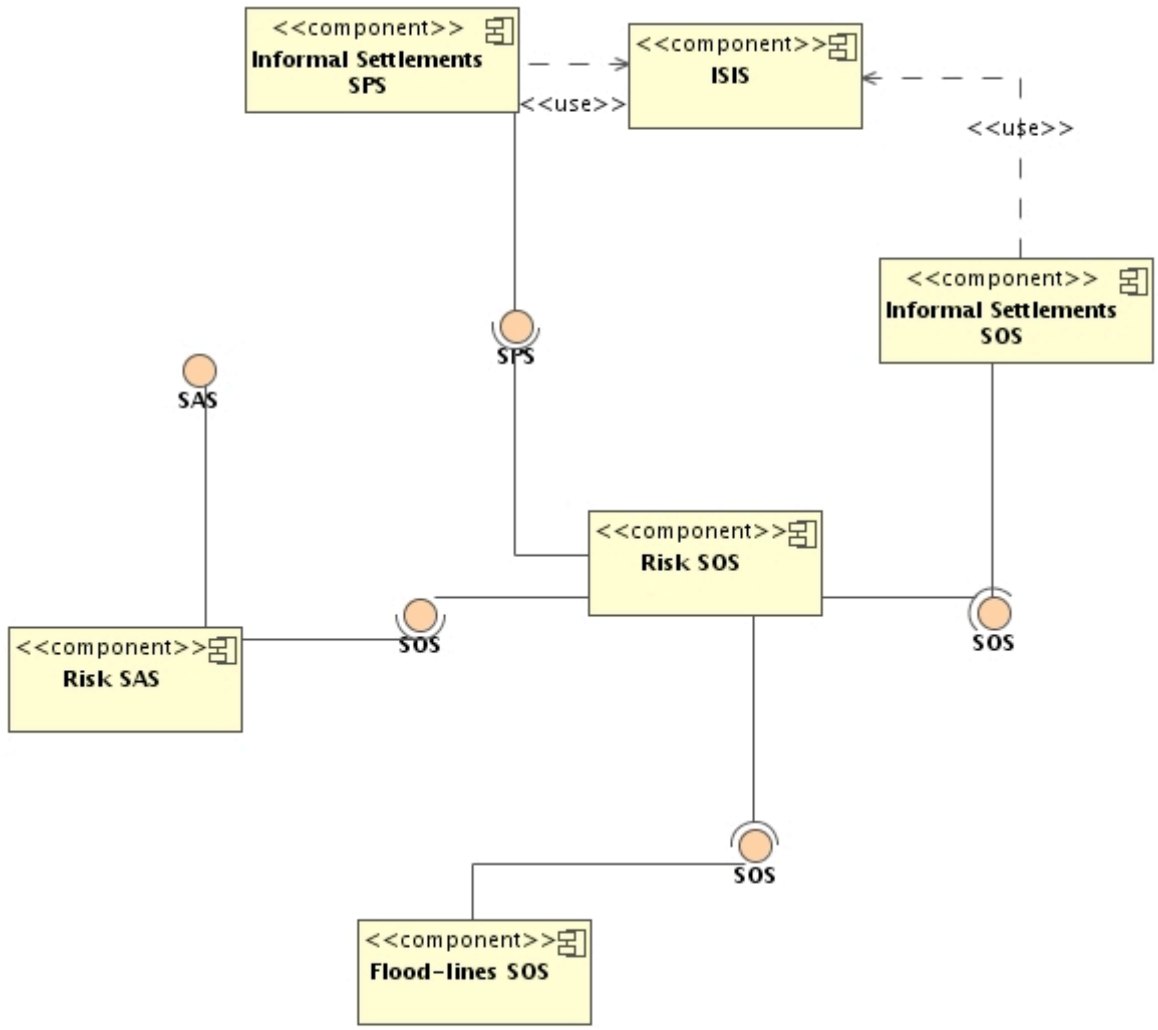

Figure 2. Architecture overview of risk preparedness system

CONTINUED RESEARCH

Future research will look to extend alerts not only to those that subscribe but also to those members of society that are located within high risk areas. Investigation will be carried out on how best to communicate with members of the community. Further the components developed for the research project will be contributed to the GEOSS Architecture Implementation Pilot process and GEOSS in general here the true openness of the components will be evaluated in the context of a global system.

There are however some specific challenges that are foreseen. Firstly despite the good intentions and the possible quality of the system obtaining community buy in is always a difficult task. Also trying to ensure that the intended community that the project targets is reached is an additional issue. Further should the system be deployed as a successful prototype obtaining continuous funding for its operation beyond the life of the project will be difficult. On a more technical side continuous access to quality data within developing countries is challenge and the open standards described above will need to be refined within the context of developing countries and there resource constraints. These constraints include access to internet bandwidth.

CONCLUSION

The proposed architecture has one overarching non-functional requirement of openness. Open system not only facilitate interoperate but also the components that make up the system are more likely to be used in further or unrelated and future applications. This extended use will intern increase the total return on investment for the project and the components. The system will provide a practical solution to the mitigation of flooding affects on informal settlements. The potential lives affected by the system can be large and an operational version of the proof of concept could have far reaching positive social implications.

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