Automated Natural Hazard Zonation System with Internet-SMS Warning: Distributed GIS for Sustainable Societies Creating Schema & Interface for Mapping & Communication

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***Abstract*—**The research describes the implementation of a novel and stand-alone system for dynamic hazard warning. The system uses all existing infrastructure already in place like mobile networks, a laptop/PC and the small installation software. The geospatial dataset are the maps of a region which are again frugal. Hence there is no need to invest and it reaches everyone with a mobile. A novel architecture of hazard assessment and warning introduced where major technologies in ICT interfaced to give a unique WebGIS based dynamic real time geohazard warning communication system. A never before architecture introduced for integrating WebGIS with telecommunication technology. Existing technologies interfaced in a novel architectural design to address a neglected domain in a way never done before – through dynamically updatable WebGIS based warning communication. The work publishes new architecture and novelty in addressing hazard warning techniques in sustainable way and user friendly manner. Coupling of hazard zonation and hazard warning procedures into a single system has been shown. Generalized architecture for deciphering a range of geo-hazards has been developed. Hence the developmental work presented here can be summarized as the development of internet-SMS based automated geo-hazard warning communication system; integrating a warning communication system with a hazard evaluation system; interfacing different open-source technologies towards design and development of a warning system; modularization of different technologies towards development of a warning communication system; automated data creation, transformation and dissemination over different interfaces. The architecture of the developed warning system has been functionally automated as well as generalized enough that can be used for any hazard and setup requirement has been kept to a minimum.

***Keywords*—**Geospatial, web-based GIS, geohazard, warning system.

I. Introduction

TODAY open systems are needed for real time analysis and warnings on geo-hazards and over time this can be issued using Open Source Geographical Information System (OS - GIS) based platform such as GeoNode which is being contributed to by developers around the world. To develop on an open source platform is a very vital component for better disaster information management as far as spatial data infrastructures are concerned and this would be extremely vital when huge databases are to be created and consulted regularly for city planning at different scales particularly satellite images and maps of locations. There is a big need for spatially referenced data creation, analysis and management. Some of the salient points that this research would be able to definitely contribute with GeoNode being an open source platform are facilitating the creation, sharing, and collaborative use of geospatial data. The research is aimed to surpass existing spatial data infrastructure solutions by integrating robust social and cartographic tools; at its core, the system is based on open source components GeoServer, GeoNetwork, Django, and GeoExt that provide a platform for sophisticated web browser spatial visualization and analysis. Atop this stack, the project has built a map composer and viewer, tools for analysis, and reporting tools; to promote collaboration, the GeoNode is designed on Web 2.0 principles to make it extremely simple to share data; easily add comments, ratings, tags; connect between GeoNode and existing GIS tools.To secure distribution, the GeoNode enables simple installation and distribution; automatic metadata creation; search via catalogues and search engines (Google). And to promote data collection the system is aimed to align incentives to create a sustainable Spatial Data Infrastructure to Align efforts so that amateur, commercial, NGO and governmental creators all naturally collaborate; Figure out workflows, tools and licenses that work to assure data quality; To promote data, constantly evolving, authoritative and always up to date; The idea is to create a full featured platform for helping decision makers easily compose and share stories told with spatial data.

An interactive WebGIS based geo-hazard communication system has been conceptualized and proposed in which once hazard level is fed in acceptable format (which could be best done by storing the information latitude and longitude area-wise and associating threat messages and mobile numbers in succeeding columns of the table) warning could be sent through mobile communication. The system functions by searching and matching the geo-address of the area as a tag to search the associated mobile information and message string to be transmitted. Once the table is accessed, the SMS program is initiated, and the mobile numbers filled in for the messages to be sent. It is sensible to develop a system using

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open-source technologies and software to as much an extent as possible. This avoids the problem of any proprietary issues and is cost-effective. Hence the proposed warning system has been developed using MySQL as the database management system, HTTP and HTML as the internet technologies, JAVA programming environment for system programming and mobile programming.

The system should be capable of utilizing the software interfaces through the internet in order to send messages to user mobiles, as well as utilizing the hardware interfaces in the case when a GSM modem or a mobile phone is directly installed in the computer where the developed system is running. The necessity of utilizing the hardware interface arises in case the availability of internet is scarce at any location. The methods, parameters, classes all remain constant in both software and hardware interfaces procedures, only the situation demand changes. The integrated working of all these interfaces leads to successful delivery of important warning messages to threat prone areas. The techniques are also useful for natural resource optimization, agricultural yield calculations and betterment, policy planning and long term goal setting.

The intensity of natural hazards in any region is an important parameter for many engineering activities but it is a cumbersome process to assess it manually [1]-[3]. A system having capability to prepare a map depicting intensity of any natural hazard and dissemination hazard information to affected users would be helpful for different activities [4]-[6]. For various disaster management and mitigation activities as well as for convenience of non-experts such a solution is worthwhile. It is known that given an input of causative factors and a knowledge base capable of inferencing output from input, susceptibility zonation can be done. The approach is to demarcate different functions experts perform to prepare a susceptibility map, be accomplished through equivalent functional modules in system. Broadly, Input Module, Understanding Module, Expert Module, Output Module, and Wireless Communication Module would constitute system [7].

Currently, our model is in place for landslide susceptibility warning which has a design generalized enough to be used for or types of natural hazards [8]. Reference [9] utilizes an inference scheme to categorize a region into different intensities of landslide susceptibility and [10]-[12] propose web-based programmed applications and solutions to disseminate hazard warning SMSes. The work has to progress in direction of including remote sensing satellite images and GIS layers as input, and also creating knowledge bases for different hazards viz. flood, earthquake, cyclone, forest fire etc. Early warning and impact assessment mapping of natural hazards can be built using Open Source Geographical Information Systems (OS - GIS) based platform such as GeoNode maintained at geonode.org. GeoNode is an open source platform that facilitates the creation, sharing, and collaborative use of geospatial data. The project aims to surpass existing spatial data infrastructure solutions by integrating robust social and cartographic tools and studies using Information technology, Geo-informatics and ICT for sustainable development, etc.

II. Objective of Proposed Research

Aim is development of an automated natural hazard zonation system with Internet-SMS warning utilizing geomatics for sustainable societies.

III. Proposed System

The initial architecture for the shared data concept using the system modules of the proposed system is shown in Fig. 1. The input module is a highly interactive interface having connectivity to Geographical Information System-Graphical User Interface as well as Wireless Communication for warning module [13]-[16]. The types of inputs correspond to the various causative factors sets for different hazard types. The Understanding Module is the intelligence embedded into the system for deciphering the input and access the correct knowledge-base. The understanding consists of a matching algorithm based on Complete Matching with Exact String match approach. The algorithm is a variant of brute force algorithm that has been adapted to the needs of the KB. This leads to understanding of the digital maps to correlate the information with the next functional module, i.e. the KB housed in the Expert module.

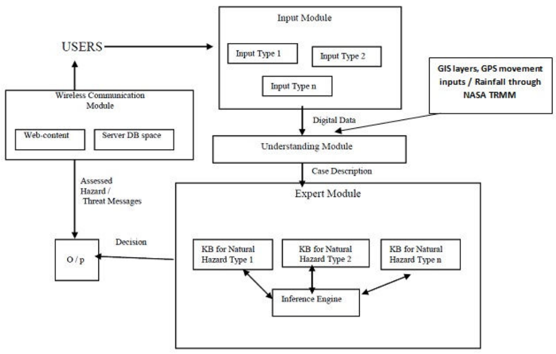

Fig. 1 Architecture of the system

Expert module houses the inference engine and knowledge database of the system [17]-[20]. The Output module (O/p) is responsible for accepting the classified hazard map and location based communication details. The Wireless Communication module is the warning functionality of the system and will be responsible for system information manipulation, processing and dissemination; Web-Content Handler sub-module for web-based processing; Trigger sub-module for Threat Extraction; and Communication sub-module for sending warning messages using interfacing with the GSM network. The GIS layers to interface to the Input module of the system and is responsible for the features creation pertaining to geospatial datasets. This is proposed to be interactive and shareable in nature with functionalities like geodata shape files, attribute data, web-content graphics and the click and point interface. The communication with the

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input module allows the GIS to effectively create a client – server computer architecture (Fig. 2).

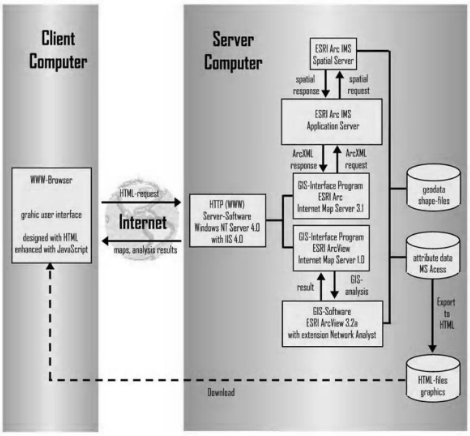

Fig. 2 User interface of GIS and web architecture

The input module in-turn communicates with the warning module to extract the mobile communication details which the user might want to display on the console via the GIS GUI. Domain specific SDI including data models, applications and services based on Open Geospatial Consortium (OGC) standards and their benchmarking/ evaluation are the building blocks of this proposed research, being taken care by the concept of GIS-GUI module. The conceptual schema (Fig. 2) provides insight about the components and the way they are used to create the final product. The main components are: The GeoSpatial Data Manager, GeoServer, GeoNetwork, and Map Composer. GeoServer provides an OGC compatible data store that can speak WMS, WFS, WCS and others in common formats like GML, GeoJSON, KML and GeoTiff. It can be connected to different spatial backends including PostGIS, Oracle Spatial, ArcSDE and others.

The Catalog: GeoNetwork: GeoNetwork provides a standard catalog and search interface based on OGC standards. It is used via the CSW interface to create and update records when they are accessed in GeoNode. This is a Django based project that allows the user to easily tweak the content and look and feel and to extend GeoNode to build Geospatial. It includes tools to handle user registration and accounts, avatars, and helper libraries to interact with GeoServer and GeoNetwork in a programatic and integrated way. There is a wide range of third party apps that can be plugged into a GeoNode based site including tools to connect to different social networks, to build content management systems and more. The Map Composer: GeoNodeClient: The main map interface for GeoNode is the Map Composer / Editor. It talks to the other components via HTTP and JSON as well as standard OGC services.

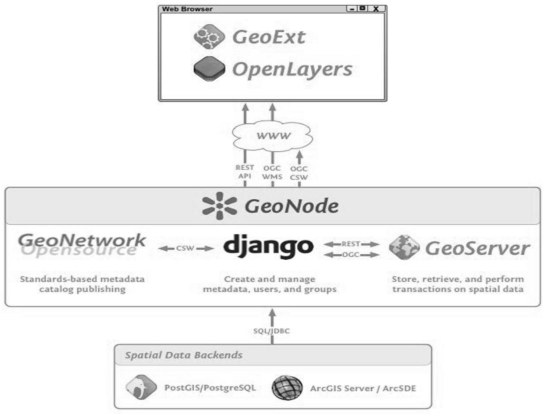

Fig. 3 Conceptual Schema

The interactive graphical user interface allows for data visualisation, manipulation and sharing (Figs. 2 and 3) and it integrates with the broad functionalities of the system as in Fig. 1. The overall architecture depends on the creation of knowledge bases for natural hazards to deduce the extremity of the occurrence. The methodology is that the input module of the system implements extraction, based on legend matching, of information about causative factors from thematic maps, satellite images, and GIS layers, addresses expert knowledge rules (qualitative approach), conducts pixel-based reclassification of input (compatible to KB) , results in evaluation of intensity of hazard on ratings of causative factors (deterministic method) and communication to user is achieved using existing cellular network infrastructure in a region. Proposed research should contribute to the development and application of OGC standards [21]-[24]. The proposal brings out the benefits of the study towards these goals and the overall requirement of setting up of SDIs in the country.

The proposed system architecture is based on the concepts of interactivity between geo spatial data management, internet and web-based processing, logical inferencing and communication technology. Hence the development of different modules, each of which achieves a specific set of tasks related to the mentioned technologies, such as the data needed by the geo-hazard warning communication system and the structure of data maintenance adopted inside the database module [25]-[28].

IV. Development

Phase I: In the first phase Systems Requirement Analysis would be done. It is needed to understand the scope of the work to be done. It is a complete process which allows the formulation of all requirements for the objectives to be met.

Phase II: In the second phase the architecture of the proposed system is to be developed. The initial research regarding the architecture for the given objective has been done. The framework (Fig. 1) includes functionalities categorized into input, understanding, expert, output or decision module and wireless communication module developed in accordance to the author's two research works

[9]-[13]. The expert module combines knowledge bases and inference scheme having a detailed knowledge representation scheme as shown in Fig. 1.

Phase III: System development is part of third phase of plan. As the figure suggests, integration of knowledge bases for natural hazards to be developed to meet objective. The methodology is that system implements extraction, based on legend matching, of information about causative factors from thematic maps, satellite images, and GIS layers, addresses expert knowledge rules (qualitative approach), conducts pixel-based reclassification of input (compatible to KB) , results in evaluation of intensity of hazard on ratings of causative factors (deterministic method) and communication to user is achieved using existing cellular network infrastructure in a region. This approach requires data to be processed only at one terminal as well as we do not need to run any or application separately for every mobile phone.

Phase IV: Validation of system using case studies and on-field verification at actual sites.

System (H/w - S/w) Requirements:

1. Dedicated development PC with minimum 3 GB RAM, 120 GB HDD, DVDdrive.
2. Linux Operating System.
3. Internet accessibility, JAVA-J2EE platform, JAI, JDBC-ODBC, MySQL.

The research is aimed to create a dynamic and real-time spatial data infrastructure (SDI) solution by the way of continual sharable activity imparted by internet and GeoNode (Figs. 2 and 3). At its core, the system is based on open source components GeoServer, GeoNetwork, Django, and GeoExt, elaborated in Fig. 3, that provide a platform for sophisticated web browser spatial visualization and analysis. Building on this stack, the present work utilizes a map composer and viewer, tools for analysis, and reporting tools which are facilitated by GeoNode. It is designed on Web 2.0 principles to make it extremely simple to share data; easily add comments, ratings, tags connecting between GeoNode and existing GIS tools.To enhance distribution, the GeoNode enables simple installation and distribution; automatic metadata creation; search via catalogues and search engines. And to promote data collection the system is aimed to align incentives to create a sustainable SDI to align efforts so that amateur, commercial, non-governmental organizations and governmental creators all naturally collaborate, figure-out workflows, tools and licenses that work to assure data quality, inorder to promote data, constantly evolving, convincing and always up to date. The idea is to create a full featured platform for helping decision makers easily compose and share developments with spatial data.

Expected Results and Impacts are:

1. Developmentofaninternet-SMSbasedautomatedgeo-hazardwarningcommunication system;
2. Methodology to interface different open-source technologies towards design and development of a warning system;
3. Method to integrate a warning communication system with a hazard evaluation system;
4. Modularization of different technologies towards development of a warning communication system;
5. Automated data creation, transformation and dissemination over different interfaces.

V. CONCLUSIONS

Sustainable societies need geographic information systems based management of resources not just in good times but during disaster mitigation also. Geo-spatial technology will serve that purpose a lot. A well informed society is a healthy society and for that cutting edge projects need to be implemented. Natural hazards are getting frequent hence maintenance of huge datasets pertaining to such phenomena becomes essential. Developing knowledge-based expert systems for hazard prediction and warning can serve the purpose. Real-time warning to people who cannot afford high end systems is becoming the need of the hour. The future society would welcome any endeavor based on popular, easily available and widespread technologies. Associating warning dissemination with hazard assessment is important. There have been systems for warning hazard and there have been numerous hazard assessment researches but the integration of the two domains has not been researched. Hazard warning has been researched by information technology experts and hazard assessment researched by environmental engineers and the case studies remain confined to the respective domains. This leaves incompleteness as far as the safety of end-user is concerned. A warning system with the ability to receive huge amounts of information from external source could be a solution to the problem. The information could be the output of another system viz. hazard assessment system. The functionality to associate with external information has to be developed. Research should lead to designing for popular usage. The hazard warning systems in use are expensive, site-specific and require elaborate administration procedures. They are designed using elaborate network of sitemonitoring devices, towers and even positioning instruments. Different groups of experts are required at the sites to administer the instruments. The alarm usually is handled by the experts who then notify authorities. This restricts the use of such systems. The deploying mechanism has to be such that technologies in common knowledge are used for the benefit of large number of recipients of warning. Inventing a system which is ubiquitous has been our aim. The system should not be limited in reach. It should be as pervasive as much possible. Sirens and announcements may be missed by many. The need is for individual notification in time in the hour of need. To increase the effectiveness of the system the use of prevalent communication technologies may be researched. The effect of the calamity can hamper the warning system also, hence a system which can tolerate local damages to a large extent and keep functioning, is ideally to be used. Easy operability, handling and upgradability are the hallmarks of sustainable development. One of the important criteria governing the effectiveness is the operating and maintenance overheads. Current systems are for one time deployment only and cannot be upgraded. They require expert operators and sensitive handling. The working of the system could be administered by experienced personnel only, hence confining proliferation in use. User- friendly systems are more acceptable by the masses.

Automating the system for maximum efficiency has been the principle behind the system. The performance of a system can be understood by the number of people it reaches and the time it takes to do so. A warning system can be really efficient by utilizing widespread mediums of communication and electronically reaching the people in real time over a mass medium. Utilization of prevalent technologies instead of new infrastructure is directed towards sustainable development. Warning systems have been researched to be developed with new infrastructure from the beginning of installation itself. The penetration of some of the commercial technologies gives opportunities for experimentations using those for hazard warning. The concept should be novel rather than applying new building blocks. The strength of the system lies in the innovativeness of design and framework of the system. The user community could be the immediate beneficiary if the research development could be implemented using prevalent technologies. Modularization of the methodologies of ICT based developments has helped with maintenance aspects of such a system. The definitions of procedures used for development of ICT have not been segmented but have remained as a sequence of start to end execution of commands often doing tasks redundantly. This approach has prevented such systems from being widely followed elsewhere. There should be modularization of functions and connections between modules of a system to give it a meaningful frame which could be easily understood by others, implemented and improved upon. Automated initiation, processing and output of information by the proposed system is done. For the efficient working of the system, it is imperative that the system is faster than the impending calamity. Human operation of warning systems during emergencies wastes precious time. Hence the concept of automated working of a system must be implemented which is lacking in current warning systems. Once the system is put to active state it will get initiated with the hazard information and the different modules will take up their processing tasks finally dissemination the appropriate message to the users.

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