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Moving Beyond Traditional Emergency Response Notification with VoiceXML

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Abstract:

This paper describes a Geographical Information Systems (GIS)-based response management architecture that combines GIS capabilities with web-based voice translation technologies such as VoiceXML to effectively coordinate the emergency response notification activities. The paper highlights some of the critical shortcomings of existing emergency response systems and proposes an architecture that addresses these limitations. The proposed architecture uses newer technologies to develop a seamless response notification system that requires minimal human intervention. The EVResponse is an application built around this architecture to provide real-time reporting capabilities to both decision makers and first response units.

Keywords: Geographic Information Systems, Emergency Response Notification System, EVResponse, Web Services, Decision Support Systems, VoiceXML

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INTRODUCTION

Federal, state and local governmental agencies have a wide range of responsibilities in managing and responding to various natural disasters, such as hurricanes and tsunamis, and unnatural emergency situations, including bioterrorism attacks and toxic spills. Complexity associated with the handling of emergencies that typically cover wide geographic areas dictate the need for powerful computer software to enable effective and quick dissipation of timely notification to the affected areas. Geographic Information Systems (GIS) -based applications allow the referencing and analysis of spatial data and are heavily used by decision makers to provide critical crisis-specific support. In this regard, several GIS-based emergency response systems have been developed to assist governmental agencies to analyze, manage and respond to crisis such as floods, forest fire and chemical spills (Fuhrmann et al. 2003; Gunes and Kovel 2000; Keenan 1997; Mennecke, Crossland, and Dangemond 1994; Stone 2004). Emergency Response Management usually revolves around the activities immediately prior to, during and post crisis, and focused mainly on saving lives and minimizing damages to property (Gunes and Kovel 2000). In crisis management contexts, the timeliness of a response may be determined with reference to a fixed instant in the form of an absolute action threshold. This establishes the last possible point in time where any solution is available. Once an action threshold is passed, a crisis is no longer containable; whatever adverse consequences a problem portends are thereafter inescapable. Timeliness and access to real-time updates of the situational factors in the affected zone play a critical role in ensuring effective crisis management decisions. The break down of emergency management coordination processes in the aftermath of recent disasters such as the SARS outbreak in Southeast Asia (Devadoss and Pan 2004; Xue and Liang 2004), the Tsunami destruction along the pacific rim (Van de Walle and Turroff 2007), the hurricane Katrina devastations on the Gulf Coast and even most recently, the Virginia Tech Shooting incident (Collins 2007), re-emphasizes the importance of research on the design, development and evaluation of effective emergency systems (Van de Walle and Turroff 2007).

The combination of communication and coordination is key to an effective response system to ensure timeliness, correctness and clarity of response notification to the people, households and businesses in the affected area (Manoj and Baker 2007; Yuan and Detlor 2005). An effective emergency response system should support the efforts to mitigate the impact of disaster, enhance preparedness and assist in responding to disasters with follow-up and recovery plans. Such a system should ideally help to accurately plot the geographic location of the disaster based on user inputs, notify first responders and provide detailed information about the crisis to the emergency response planners. Furthermore, the system should have reporting features to help incident tracking and reporting for post crisis analysis and risk assessment. Post crisis analysis is a core activity undertaken by emergency management teams so that historical incident data can be used to improve strategies to handle similar crisis in future.

Although existing emergency response systems incorporate many of the above features, they still lack in robustness

CONTRIBUTION

This research makes contributions to practice and Information Systems (IS) design science research. The importance of design science research for developing Information Technology (IT) artifacts or applications is as important as IS theoretical research. Emergency response management systems are IT applications that provide decision support in crisis situations where collaboration and coordination of different groups such as fire marshals, paramedics, first response systems, and environmental protection agency personnel are critical.

The paper describes a special GIS-based response management system that combines web-based voice translation technologies such as VoiceXML, web services and XML to effectively coordinate the pre, current and post crisis management activities. The new VoiceXML 2.0 standard and the use of voice-forms have found a large number of successful application areas in the private sector such as Interactive Voice Response (IVR) Systems. However, little research has explored the potential of VoiceXML 2.0 incorporated into GIS for emergency response management. Moving this technology into the public sector and specifically to the emergency management arena, in our view, is long overdue. VoiceXML provides a reliable, bidirectional response notification mechanism that helps remedy some of the drawbacks and limitations of traditional systems. Built-in support for multi-modal, multi-device notification through easy Text-To-Speech translations and communication via Common Alerting Protocol (CAP), Open GIS Consortium (OGC) interface allows fast dissemination of vital information which helps lessen the impact of disasters on human lives and properties. The use of web services tiers provide an HTTP transport interface that other agencies can use to access reports and historic data in a collaborative decision making environments.

EVResponse is an instantiation of the architecture which is currently under evaluation in several state agencies. We believe this to be an interesting instantiation to address information dissemination issues particularly notification services, information filtering and summarization.

to reach out to the common mass effectively and convey critical life saving and property conserving notification messages (Gunes and Kovel 2000; Stone 2004). Currently most emergency response systems in place are unidirectional. Whether it is a pole bellowing a siren or a sophisticated reverse 911 systems channeling pre-recorded messages (Weaver, Gruntfest, and Levy 2000) to residents to warn of an impending emergency, there is no real means to interact or analyze responses received from the affected people. In addition, most existing systems require extensive human intervention to communicate evacuation plans and notifications to the communities most likely to be affected by the crisis. Since notifications are best communicated via telephones, the communication process is slow, time consuming and places high demand on the personnel. The situational complexity is usually made worse due to the immediate unpredictability of the effects of the crisis as well as the inability to provide comprehensive spatial information (operational – such as spatial prediction of the coverage area following a toxic aerosol leak and, tactical – such as cordon traffic from a particular direction) to the first response teams in a real-time manner.

This paper presents a GIS-based decision support system for emergency response management that takes advantage of the functional benefits of VoiceXML. The architecture integrates other diverse Internet-based technologies (such as XML standards-based protocols like EDXL and web services) and combines it with GIS mapping data to provide decision makers with comprehensive information specific to the crisis situation in a dynamic and timely fashion. Web services allow other applications to access the relevant data as well as agencies and managers to access web-based reports. Multi-device, multi modal support ensures that location specific emergency plans and evacuation notifications can be directed to newer, more popular Connected Device Configuration (CDC) devices such as PDAs, web enabled mobile phones, MMS pagers and other smart devices. Responses and valuable information from the people can also be captured and made available to the emergency response team. The paper is organized as follows. The next section provides a brief background on related work and the application of GIS software in emergency management systems. A preview of the capabilities of VoiceXML and web services that can be employed to enhance the power of a GIS-based emergency response system is also presented. The paper then describes the proposed architecture, followed by the description of a real world implementation of an emergency response management system, the EVResponse application that was built using this architecture. The third section highlights the architectural benefits that make EVResponse superior to other existing systems. The paper concludes by summarizing the strengths and limitations of the architecture that opens interesting new avenues for research in the future.

Related Work

Crisis management requires the collaboration and coordination of different groups (fire marshals, paramedics, first response teams, Environmental Protection Agency personnel, etc.) working together to disseminate information and provide diverse services to people in and around areas where crises have occurred. Handling the situation is further complicated by the fact that the responding personnel are rarely housed at the same locational facility. In addition, there is an urgency with which the communities in the disaster zone have to be contacted. All these factors amplify the need for an efficient automated communication and management system to initiate the response process with minimal user intervention.

Geographic information systems (GIS) represent a class of decision support tools that are attracting increasing interest in both the academic and practitioner communities (Horan and Schooley 2007; Mennecke, Crossland, and Dangemond 1994, p. 506). Information sets specific to geographically accurate locations in space can now be created by combining special data with textual, analytical and graphical data (Mennecke, Crossland, and Dangemond 1994, p. 506). As such, GIS offers immense value in disciplines ranging from natural resources and forestry to environment industries. GIS is also making inroads in business and management functions such as logistics, site management, facility management, marketing, distributions, public policy and planning (Mennecke, Crossland, and Dangemond 1994, p. 506).

Integration of mapping data using GIS provides decision makers and emergency management personnel with powerful capabilities to make informed decisions and to share knowledge with others using visualization and interpretation of spatial data (ESRI 2004). GIS extend the capabilities of traditional database systems in that they enclose spatially-referenced information (cartographic coordinates, layers, etc.) as well as textual data (attributes and aspatial data) making them powerful tools for advanced modeling, designing and planning, and imaging capabilities for spatial analysis (Chrisman 1997; Sugumaran and Sugumaran 2003). As such, GIS have a wide range of application in organizations typically providing decision support (Pick, Viswanathan, and Hettrick 2000). In fact, GIS applications are taking on prominent roles in business as well as in governmental agencies (Fuhrmann et al. 2003; Grimshaw 1999; Pick, Viswanathan, and Hettrick 2000). GIS thus serve as an effective decision support tool because of their ability to visually display data in the form of maps (Speier and Swink 1998). Further, GIS are now widely used in emergency management. IT investments, especially emergency response systems, can gain an upper edge by combining spatial maps with crisis specific information to provide better decision making and analysis tools to quickly respond to a crisis situation. The ability of GIS to capture data by digitizing, scanning digital imagery or aerial photography, to manipulate the data, to form data queries, and most importantly to visualize the data, allows domain experts to quickly access geospatial information during emergencies (Gunes and Kovel 2000, p. 137).

Crisis scenarios are characterized by rarity, uncertainty, high and broad consequences, complexity, time pressure and require collaboration among multiple decision makers (Mendonca 2005). A GIS-based emergency response management system can aid the decision makers' cognitive activities such as categorization, search, assembly, constraint satisfaction, communication and inference to effectively deal with extreme situations (Mendonca 2005). Although GIS enable us to integrate spatial data with crisis specific information for emergency management, current emergency response systems suffer from a serious shortcoming of being unidirectional with limited interaction capabilities. Further, the systems require extensive human intervention for managing the different phases of the crisis lifecycle. New standards of VoiceXML 2.0 provide a robust approach to interpret actual spoken syllables and synthesize speech into markup specifications that can easily be transported via simple transfer protocols like HTTP. Incorporating VoiceXML into GIS-based emergency response system offers the potential to develop highly powerful yet simple means for addressing the shortcoming of existing disaster response management systems. However, to the best of our knowledge, no research has explored the potential of VoiceXML 2.0 incorporated into GIS for emergency response management.

THE PROPOSED ARCHITECTURE

It is implicit that information needed to handle crisis situations can add value when combined with persistent and spatial data. Persistent data can be made available through the use of wireless technologies and small profile devices. Spatial data can be made persistent using GIS-based mapping software. VoiceXML can be an efficient means of communicating notifications and customized messages (such as evacuation routes, emergency planning tips, etc.) using automated speech recognition, Text-to-Speech conversion and Call trees features. The proposed architecture in this paper integrates these various technologies, and consists of four main components - Knowledge Source, Application Integration and Logic layer, VoiceXML Parser and Connected Device Configuration (CDC) profile Interface, as shown in Figure 1.

Knowledge Source

The knowledge source serves as the data layer and consists of a spatial database (GIS dataset, vector and raster data for multilayering) and a knowledge base (crisis specific information, historic data, reports, community and response team contact data). Spatial data is available from various third party professional geographic mapping companies. The GIS mapping layer is built on this spatial data infrastructure (SDI) enabling easy and rapid access to pre-pruned geographic data. The knowledge base stores detailed information of past crisis situations with the associated prescribed responses defined by various governmental crisis and evacuation planning agencies. The cognitive *search* activity to retrieve or infer a referent appropriate to the situation is provided by this module (Mendonca 2005). The knowledge base also contains contact information of the response personnel and the community. Besides home, office and cell phone numbers, the knowledge base also stores device connectivity information (multi-device data) of the response personnel and individuals in the community.

Application Integration and Logic

The Application Integration and Logic Layer provides reasoning logic for matching new cases to pre-classified case categories based on similarities and presents the decision maker with the accurate response protocol. This provides support for the *assembly* of cognitive activity where one or more procedures are derived from the referent cases (Mendonca 2005). It also maintains the Document Object Model (DOM) translation logic to parse location specific GIS data into descriptive XML documents. This layer also includes a web-based mapping engine to translate the GIS data into dynamic maps deliverable as web pages. Web service '*ties*' for sharing geospatial information with other applications as well as reporting and real-time logging functions are managed in this layer. Interaction with this layer is mainly via a web interface that allows authorized decision makers to generate reports for each crisis situation. For example, one crucial emergency response metric is the response notification time, the time it takes to notify the community of an incident and the required precautionary measures to be taken. The reporting and logging module within this layer offers the ability to generate post crisis reports that will enable involved agencies to proactively strategize actions and continuously rate the effectiveness of the overall notification response strategy used. Since the requirements of day emergencies differ from those of major catastrophes, this component of the system is designed with scalability in mind. Specifically, the design of Connected Device Connectivity Notification Interface and the use of web services enable easy binding with legacy and new crisis management systems to invoke assistance from other first response teams when necessary. This component orchestrates the communication of crucial crisis information and the coordination of response teams through a centralized interactive web interface.

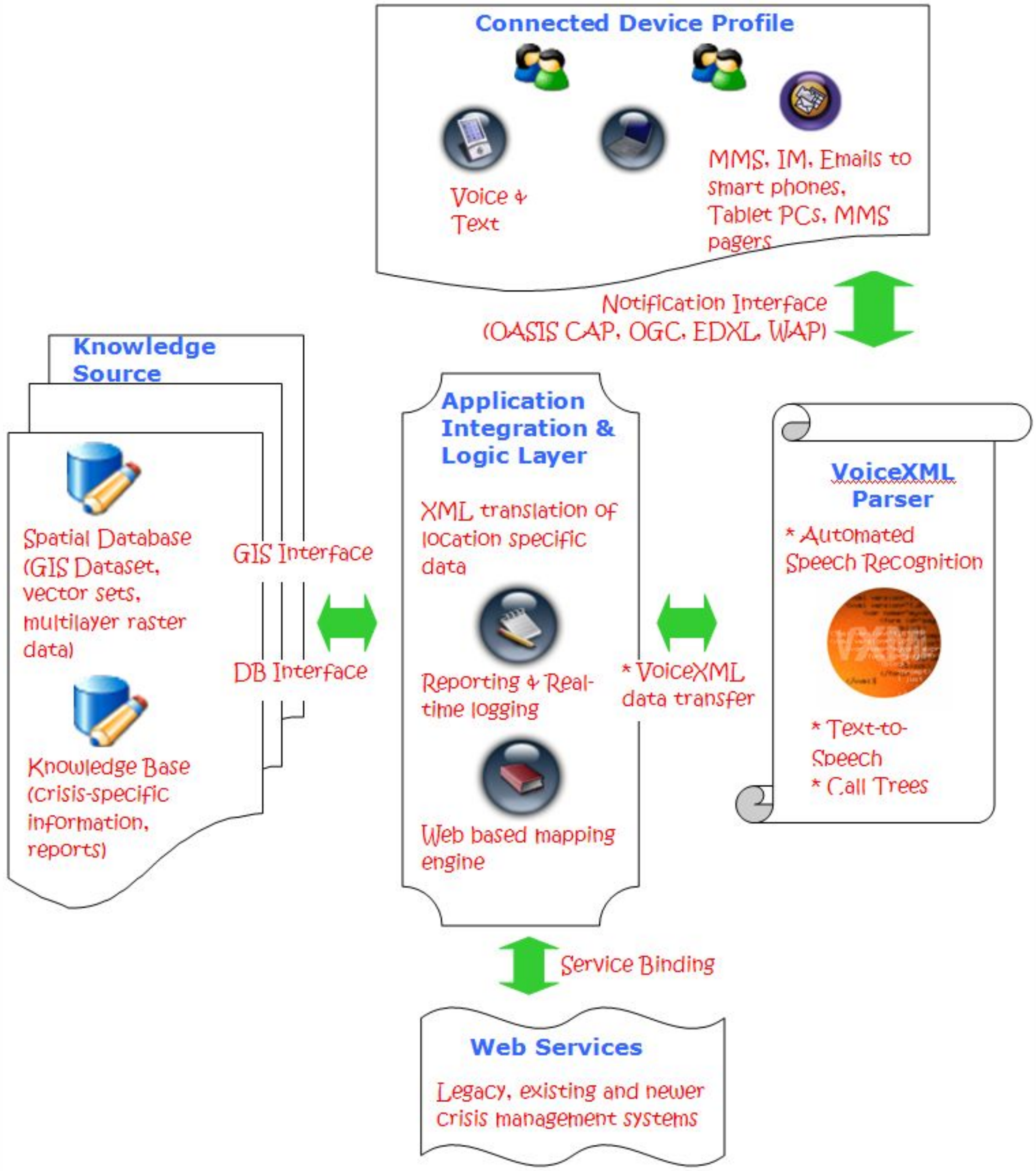

Figure 1: The proposed architecture.

VoiceXML Parser

Traditional emergency response systems have limited interactivity, restricted functionalities and require human intervention to collect responses and trigger actions. New W3C specifications of VoiceXML 2.0 endorse Text-to-Speech (TTS) conversion and Automatic Speech Recognition (ASR). The standards also allow spoken syllable interpretation and speech synthesis to markup tags for easy formatting and transport. This newer version of the VoiceXML standard can enhance the interactive features of the web-based response system by providing data access using audio dialogs, thereby overcoming the limitations of text-based unidirectional broadcasts. Miscommunication due to accents and dialectical expressions which is inevitable in any response management system is handled in the architecture using 'Voice Forms'. Creation of flexible and powerful 'Voice Forms' authored using VoiceXML 2.0 enable two-way communication between the sender and the recipient. Solicited and unsolicited voice data can then be collected for better synthesis of situational information. This supports the decision makers' cognitive activity of *categorization* to recognize occurrence of unplanned contingencies (Mendonca 2005). 'Voice Forms' can capture audio files in addition to primary data types such as text strings, date, time and numeric. They can interface with any ANSI SQL database (e.g., Oracle, DB2 or SQL Server) for storing the form and field responses from the user. Voice libraries in the knowledge source validate the recipient's response against a finite set of possibilities of vernacular variations due to regional or social distinctions. Responses are then stored to a database or as XML Document Object Model (DOM) trees. This information can be used to trigger related actions or as inputs to other applications.

Notification Interface

The notification interface for data transfer to the connected devices utilizes open standards (OASIS and OGC) - based Common Alerting Protocol (CAP). CAP is an open, non-proprietary data interchange format standard commonly used to disseminate warnings and notification messages between alerting technologies (Botterell and Addams-Morring 2007). CAP permits integration of multiple emergency systems such as TV/radio-based alert systems, cellular alerting and Reverse 911. The open standards-based approach allows the proposed architecture to support various forms of operational warning systems independently developed and deployed throughout the nation. This satisfies the *constraint satisfaction* cognitive activity requirement by ensuring that the procedures for new situations are executed in a timely fashion (Mendonca 2005). The architecture allows notification messages to be customized to the granularity of individual houses. Responses and valuable information from message recipients can also be captured and made available to the emergency response teams via intra organizational communication using Emergency Data Exchange Language (EDXL) translations.

Web Services

The use of web services allows for easy integration with other stand alone applications or governmental services currently in place or to be implemented as part of future emergency response expansion and improvement plans. For example, the web service '*ties'* can be used to provide access to reports, maps and customized notifications independent of operating systems, platforms and remote application dependencies. Additionally, all relevant listings of the system capabilities, contact information and feature descriptions can be exposed to collaborating agencies in a seamless manner. This will become more prevalent as more and more emergency response teams move towards unifying their systems using web technologies. Web services modules facilitate effective *communication* and collaboration between human decision makers (Mendonca 2005). Table 1 provides some examples of web service *ties* (accessible through client side stubs) and their corresponding response components.

Table 1: Examples of Web Service Ties and their response components

Web Service Ties	Utilized Standards API
• getMap(areaCordinates)	• OGC Communication Standards
• getActorNotification(callTreeXML)	• VoiceXML Tagging
• getACidSpillResponseNotification(CAP, VXML)	• CAP & VoiceXML Parameters
• getCapabilities(query String)	• ODBC & OGC Communication Standards
• getContacts(fireMarshallName)	• ODBC & OGC Communication Standards

Connected Device Configuration (CDC) Interface

The Connected Device Configuration (CDC) defines the application programming base for delivering information to the presentation layer on highly portable but resource-constrained devices such as smart phones, multimedia messaging service (MMS) pagers, personal digital assistants (PDAs) and tablet PCs. XML and Extensible HTML (XHTML) content can be transmitted to wireless enabled CDC devices using Wireless Application Protocol (WAP). CDC interface allows dissemination of profile specific information by supporting a wide variety of CDC profiles that currently proliferates the communication devices market. The application layer maintains the algorithm to identify the correct user-agent (browser type and version) on the device and consequently render the data in the right format so that the content is clearly presented to the targeted device profile. The reasoning abilities of this interface that enable identification of the independent physical devices and profiles meet the *inference* requirement of the cognitive activity (Mendonca 2005). With the ever growing popularity of CDC devices among the public, it is only sensible to provide an interface that can communicate with PDAs, SMS pagers, mobile phones and other smart devices, especially since these devices have replaced the traditional landline telephones as the preferred way to stay connected.

THE EVRESPONSE APPLICATION

EVResponse is a GIS-based emergency response management system that was implemented using the proposed architecture. The effectiveness of combining GIS capabilities with the functional benefits of VoiceXML to help decision makers in coordinating the pre, current and post crisis management activities is being tested by various county and state level emergency planning agencies. For the sake of describing the application, consider a real world scenario where an apparent toxic chemical agent leak has been reported to the Environmental Protection Agency (EPA). The officer on duty initiates emergency response by verifying the authenticity of the report. This is done by contacting other governmental agencies and conducting spatial analysis to identity the location of the crisis and disaster prone neighborhoods. With web-based access to the underlying system, the officer can input a new incident, interact with the GIS map to access an incident area and study the surrounding, create an evacuation region and generate an incident specific notification message. The officer can also lookup phone numbers of all identified households and businesses, trigger dial outs and deliver notification messages with options to collect and store responses.

The web-based GIS mapping engine helps the officer to specify anchors on the map to start the emergency response planning. Once the officer specifies the type of crisis and all known relevant information in the EVResponse Interface, the Application Integration and Logic layer generates what it recognizes as the doctrinally-proper or administratively-approved response decision. The officer can query the knowledge base (for sub-plans, contact information of response teams, etc) or the spatial dataset (for call region geo-references, demographic information, identify susceptible or danger zones) or both for specific data or reference points. The officer can then activate the geocoding of the call region to be immediately notified according to the significance of the crisis. The Application and Integration Logic layer uses the geo-spatial dataset and the call region data to generate a call list for the emergency response. The notification message pertinent to the crisis is automatically made available to the officer. The officer has the option to customize the message or approve the narrative. The notification message is translated by the XML translator in conjunction with the VoiceXML parser to convert the text message to speech. The 'Notification' tab shown in figure 2 guides the officer sequentially through the different steps. The EVResponse interface shown in figure 2 presents the user with a dynamic map of the affected area that is updated based on inputs from the field teams. The web interface allows the officer in charge to monitor the progress of the incident in real-time through any connected device such as a tablet PC or a web enabled smart phone.

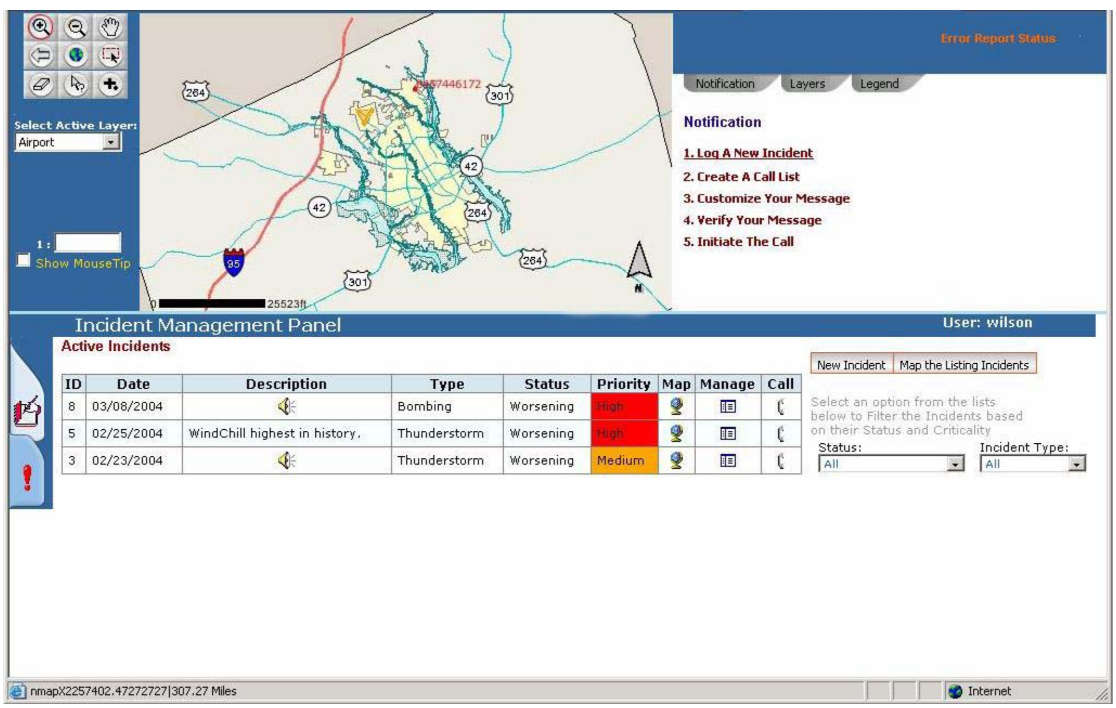

Figure 2: Status monitoring through spatial analysis (pre, current and post response).

Call trees are developed by the Application Integration and logic layer and also trigger the automated notification process to dial end user telephones or send message to other CDC devices registered under the user. The creation of call trees allow sequential attempts to contact a person using all available device registration information stored in the knowledge source. For example, the system will automatically attempt to call the cell phone number followed by the office number or send an MMS to the smart phone, in case no response was received by calling the home phone number. The officer can access detailed reports on calls made, successful and unsuccessful calls, and other activities associated with the notification creation and delivery process (using the Notification Log function as shown in Figure 3). The use of VoiceXML allows translations from text to speech that can be transmitted to voice devices as well as receive and map response from the person. Acknowledgement of receipt of notice from the person can be translated back to XML and stored in the database for analysis or forwarded to response teams already in action. Figure 3 shows a sample call list that will be generated by EVResponse once the officer has authorized the appropriate sub-plan to deal with the crisis and the decision to contact the community has been reached.

Figure 3: Event reporting and response evaluation.

BENEFITS

The proposed architecture has several advantages over traditional systems in emergency notification. Table 2 provides a comparative analysis of the proposed architecture and traditional systems along functionalities (Fuhrmann et al. 2003; Yuan and Detlor 2005) crucial for effective emergency response notification systems. The EVResponse application uses this architecture to provide a flexible notification system customizable to meet the needs of diverse crisis scenarios. For instance, the response notification needed to protect people against a threatening hurricane would be different from what is needed to warn the community about a toxic chemical agent spill. The use of VoiceXML provides fast translation of text to speech and can use Speech Synthesis Markup Language (SSML) to render the synthesized speech to the user, while incorporating actual characteristics of spoken instructions given by the application to the end-user, such as pitch, speed or volume (NewsForge 2004). All this can be accomplished by the use of simple internet browser-based Voice Forms. VoiceXML also enables the capture of user responses using Automated Speech Recognitions (ASM) which can then be stored to the database in textual format or as XML DOM trees. Interactive dialog with the recipient through VoiceXML interfaces helps in identifying those who might be in need of additional assistance. The use of open standards-based technologies (XML, VoiceXML, GIS data specs) enhances interoperability and reduces future expansion and system integration costs.

Integration of web services into the architecture offers tremendous benefits. It allows easy discovery of other external geographic datasets which in turn offers significant labor saving potentials. As the web presence of governmental agencies become more pronounced in the future, dynamic interaction between disparate systems (GIS and non-GIS) will become easier through the use of web services.

Accurate identification of the location of the disaster and mapping of the communities that need to be contacted and notified about the disaster is highly critical since delays in initiating response process could make every action taken to address crisis unfruitful. Using GIS as a core component of the EVResponse application provides the ability to accurately identify these geographic locations through a browser interface. Creating call trees using VoiceXML seems to be the plausible solution to initiate multiple alerts with minimal human intervention and trigger dispatch of emergency management teams to the crisis locations.

Use of web service tiers provide an HTTP-based transport interface that other agencies can use to access reports and historic data in a collaborative decision making environment. Decision makers from different departments irrespective of their geographical location can perform trend analyses to help them rate and evaluate the effectiveness of the response along predetermined evaluation metrics. This invaluable ability to access real-time dynamic data from multiple sources using web services will also help officers perform situational analyses and thereby leverage existing GIS investments across different local, state and federal agencies. It also helps to create an iterative environment focused on improving the existing crisis management strategies to handle similar situations more effectively in the future.

Table 2: Comparative analysis of the proposed architecture and traditional emergency response notification systems

Functionality	The Proposed Architecture	Traditional Systems
Messaging and priority queuing	VoiceXML allows easy message prioritization using XML tags.	Prioritization is non existent or a manual process.
Multi-modality	Customizable text message (or Voice translation using VoiceXML delivered to all devices simulataneously).	Mostly limited to pre-recorded generic messages delivered to phone (standard text messages are emailed or faxed which point recipients to check their voice mail).
VoiceXML	Text-to-Speech, Speech Recognition Grammar specification and Automated Speech Recognition allow higher level of interactivity.	VoiceXML not available.
Ability to collect user responses	Collects responses which are mapped, and can be integrated with other applications and reporting software.	Limited availability through 'reverse 911' systems.
GIS capabilities	Provides tightly integrated, web-based GIS capabilities.	Provides desktop and web-based mapping.
Location specific notification	Higher granularity through integrated GIS and map control, based on user definable attributes, such as zip codes, address location, etc.	Available through GIS software with limited drill down functions.
Notification interface	Utilizes open standards-based Common Alerting Protocol (CAP) for data transfer to connected devices. Supports EDXL for inter and intra organizational communication.	Proprietary standalone systems that are independently developed and deployed.
Multi-device connectivity profile	Renders XML, EDXL, and XHTML content over Wireless Application Protocol (WAP) for a variety of current and future Connected Device Connectivity (CDC) devices like cell phones, MMS pagers, PDAs, smart phones, and tabled PCs.	Mostly restricted to unidirectional channeling of pre-recorded messages.

CONCLUSION

The recent extreme crises such as Tsunami, SARS, Katrina and Virginia Tech have revealed inadequacies in emergency response management systems and impact of delayed response to emergencies (Collins 2007; Devadoss and Pan 2004; Klashner and Sabet 2004; Xue and Liang 2004). Emergency response management is a collaborative effort requiring coordination among several local, state and federal agencies as well as specialists in crisis planning and response logistics. In a crisis management context, the timeliness, correctness and clarity of response notification and the speed with which the notification is communicated to the people, households and businesses are critical determinants that influence the adversity of the consequences from the disaster. GIS provides useful geospatial information in emergency management. Existing emergency response management systems are mostly characterized by unidirectional messaging with limited interaction capabilities, requiring extensive human intervention.

In this paper we present a state-of-the-art emergency response management architecture that integrates web services, GIS, VoiceXML and knowledge store. The architecture takes advantage of newer mature standards of VoiceXML 2.0 and novel technologies associated with open web standards to develop a seamless response notification system that requires minimal human intervention. EVResponse is a distributed application built upon the proposed architecture. It uses a simple, yet innovative approach to logically combine spatial and crisis specific data to enable authorities coordinate and take informed decisions in a timely fashion. Visualization mechanisms using GIS data layers enhance perception (identify information needed to manage the crisis), comprehension (combine information from knowledge base with feedback from the crisis zone) and projection (ability to make effective predictions based on the evolving dynamics of the situation) by presenting only information pertaining to the crisis (Endsley 2000). Additionally, VoiceXML provides a reliable, bidirectional response notification mechanism that helps remedy some of the drawbacks and limitations of traditional systems. Built-in support for multi-modal, multi-device notification through easy Text-to-Speech translations and communication via CAP, OGC interface allow fast dissemination of vital information that will help to lessen the impact of disasters on human lives and properties. VoiceXML also offers a flexible approach to synthesize speech and acoustics.

The architecture presented in this paper only looks at the use of VoiceXML for bidirectional message transactions in an emergency situation. The ability to translate voice to text implies that the real power of VoiceXML is yet to be fully utilized. Tremendous research opportunities exist to explore how VoiceXML can assist in making intelligent decisions based on semantic interpretations. Future research can look at ways in which semantic interpretation can be applied to extract and translate text from the output of a speech recognizer based on incident-specific inputs.
EVResponse is currently under evaluation at selected county and state level emergency planning agencies in the United States. Evaluating the effectiveness and efficiency of the solution and addressing issues that arise through a longitudinal study will help identify the shortcomings of the application. Feedback from these agencies will be useful to identify the deficiencies and enhance the robustness of the architecture.

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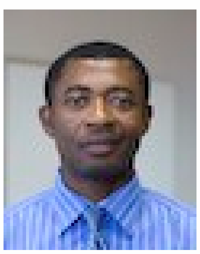

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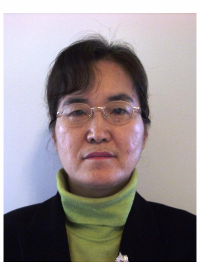

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