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German Indonesian Tsunami Early Warning System (GITEWS) - Decision Support in Tsunami Early Warning

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Abstract:
This presentation provides an overview over the studies so far done in knowledge acquisition for the GITEWS (German Indonesian Tsunami Early Warning System) project.
Research has been focused on the implementation of a decision support environment. For this, flowcharts from the operative tsunami warning system for the pacific ocean were analysed. This was done using expert system toolkits. From the experience gained so far, a bottom up knowledge modelling process of the GITEWS sensor systems is perceived as optimal. In parallel, the know-how and best practices of experienced Officers on Duty needs to be mapped in knowledge bases.

Keywords: Tsunami Early Warning; Decision Support; Expert Systems; D3

1 Overview - GITEWS

The German Indonesian Tsunami Early Warning System (GITEWS) is the result of a joint declaration by Germany and Indonesia. The aim of GITEWS is the implementation of an effective Tsunami Early Warning System (TEWS) for the Indonesian region.

The project is embedded in the international endeavours for an integrated solution for the entire Indian Ocean coordinated by the UNESCO (Intergovernmental Oceanographic Commission of the UNESCO 2006).

The GITEWS project is accomplished by a consortium of the following German institutions:

- Geoforschungszentrum-Potsdam (GFZ),
- Alfred Wegener Institute for Polar and Marine Research (AWI),
- Federal Institute for Geosciences and Natural Resources (BGR),
- German Aerospace Center (DLR),
- Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ),
- GKSS Forschungszentrum,
- Konsortium Deutsche Meeresforschung (KDM),
- Leibniz Institute of Marine Sciences (IFM-GEOMAR) and
- United Nations University, Institute for Environment and Human Security (UNU-EHS).

The Indonesian partner organisations are the Ministry of Research and Technology (RISTEK), the Meteorological and Geophysical Agency of Indonesia (BMG), the National Coordinating Agency for Surveys and Mapping (BAKOSURTANAL), the Agency for the Assessment & Application of Technology (BPPT), the National Institute for Aeronautics and Space (LAPAN), the Indonesian Institute of Science (LIPI), the Department of Communication and Information Technology of the Republic of Indonesia and the Secretariat of National Board for Disaster Management and IDPs (BAKORNAS PBP).

R&D work of this multifaceted project is done in the following work packages:

- Earthquake Monitoring
- Ocean Instrumentation
- GPS Technology
- Early Warning and Mitigation Center
- Tsunami Modelling

Comprehensive Capacity Building activities like academic and technical training and education and organisational consulting prepare the effective and sustainable establishment of the developed tsunami warning components in the region.

1.1 The Indonesian scenario and the proposed structure of GITEWS

Indonesia always is prone to catastrophic tsunamis due to its geological situation. The nations main islands are located next to the Sunda seismogenic zone.

The spatial nature and temporal development of the phenomenon tsunami is highly dependant on the specific geological situation. Both, location of sensors and workflows for processing and coordination of sensors are critical to produce precise punctual warnings.

The planned TEWS integrates several sea-, ocean bottom- and land-based observation networks. It features broadband seismometers and accelerometers, GPS land stations, tide gauges, ocean-bottom pressure sensors as well as GPS buoys.

Effective tsunami warnings will be derived from sensor recordings, simulation data and geospatial data. Local and regional warnings will be disseminated to the responsible stakeholders.

1.2 Problem Fields and Challenges

1.2.1 Low Level System Integration

There is a large variety of complex sensor types in the overall observation network. All these sensor systems must bel managed. Procedures must be established to use their measurements and observations. For each sensor system, parameters for decision making must be specified in order to integrate them in workflows and the overall decision making processes in tsunami detection and warning.

1.2.2 High level integrations & Challenges

Within the Tsunami Early Warning System environment, the matching of simulated numerical models of tsunami-wave propagation with topographic data, vulnerability and risk models is one of the most challenging aspects. A large number of heterogeneous data types have to be integrated in a suitable way. Adequate visualisation of relevant data is essential for decision making and to provide multiple target groups with information specific to their individual needs.

The due proportion of automated decision-support-functionality for the support of the final human analysis and decision making needs to be set.

The critical questions are: How much automation can be realized without taking out too much of the human responsibilities? How much interaction is possible without overwhelming human capabilities?

1.3 Deployment

GITEWS will be implemented at a national Early Warning and Mitigation Center (EWMC) in Indonesia. Sensor data is collected at the Center, stored and analyzed. In case of an event, warning messages are created and disseminated. In the long-term, the system shall be applied to other regions. As well as handling tsunamis, long-term it shall be able to handle a range of other natural disasters, such as storms, land slides and volcanic eruptions.

The Officers on Duty (OOD) at the Center will have extensive knowledge in different tsunami-relevant fields, such as seismology, regional geology, GPS, oceanography, geo-physics and many more.

2 Knowledge Based Aspects of GITEWS – preliminary studies by GFZ

GITEWS is a complex integration project with heterogeneous data and functionalities. Knowledge based applications are being evaluated for several tasks and different levels of the overall system.

This presentation focuses on the sub-domain of the interface between human operator and software system and in the following presents the preliminary studies by GFZ Potsdam.

2.1 The Officer On Duty

In the case of a tsunamigenic earthquake event, the personnel in the local Early Warning and Mitigation Centre (Officer on Duty) must react fast and adequate. The travel time of a suspected tsunami wave is the ultimate constraint for issuing warning messages. The time span remaining until the waves' landfall on Indonesian shores can be less than fifteen minutes. Because of this, the OOD must be presented immediately with the most supportive sensor data products and thematic maps for situation assessment, to locate potentially threatened areas and to generate warning bulletins if necessary.

2.3 Timescales

The overall performance of an EWMS is measured on two different time scales.

2.3.1 System time defines the response times of the whole sensor system, including anomaly detection, data logistics including the delivery of relevant information to the EWMS (warning cycle).

2.3.2 Social time defines the timespan for human actors to act, decide and possibly produce a warning dossier (response cycle). This definition of social time excludes the distribution processes necessary to disseminate the warning dossiers.
If the processes on both time scales are not synchronized, the performance of the overall system will decrease (Dombrowski 2005): If the social time can not keep up with the system time, the software/sensor infrastructure will be perceived as enigmatic and uncontrollable by the users.

2.4 Timescale synchronization

Within GITEWS, an improved infrastructure of sensor systems will be deployed. The required amount of system time is likely to decrease in comparison to existing systems, while the amount of available sensor data will increase. This must be balanced in the domain of social time. Knowledge based components can be used to speed up the human decision finding process if necessary. This can be done by monitoring all computer-based documents and files generated during the human decision making process. This includes assumptions and decisions by the OOD which are stated through a GUI or web-interface.

Because of these options, GFZ considers the use of a knowledge-based approach in GITEWS and other systems.

2.4.1 System Monitoring The health of the available sensor networks and the validity of the received observations and measurements have to be monitored and abnormal conditions (anomalies) must be reported. Analysis of operative warning systems has shown that outage

rates of 10 – 20 % within each sensor systems occur frequently in real world deployment situations (CONOPS Team 2006).

2.4.2 Enhanced Mapping The integration of knowledge-enhanced mapping enables the use of optimized thematic map products and diagrams. This step helps to synthesize information of different types and sources into unified data representations. It minimizes the effort on the part of the OOD to translate sensor system information into the datas' social meaning (Department of Homeland Security 2006). Also, representations of the quality, reliability of the currently available data including certainty measures can be provided.

2.4.3 Support for the OOD

The support of the OOD personnel by suitable knowledge-based software tools can improve the situation assessment, validation, information reconfirmation and decision making. This approach also allows to monitor and store the decision process of the OOD for post-situation analysis and performance improvement.

This will help to minimize errors, maximize effectiveness and save lives.

For this, a Critique System is suggested: In the medical domain, a critique system is an expert system containing specialized knowledge which supports a physician. This is achieved by comparing diagnoses against best practice standards, constraints, checks for inconsistencies and omitted examinations.

For the GITWES approach to support the OOD, the term "buddy system" is used: In recreational diving, the mandatory dive partner is referred to as "buddy". The buddies role is to monitor the divers actions and to provide support when necessary.

2.5 Knowledge Acquisition

2.5.1 Multi-Level Knowledge Modelling

The analysis of the range of knowledge based components suitable for GITEWS is currently done on multiple levels, following two strategies:

2.5.2 Bottom Up Knowledge engineering and generalization for the sensor systems will be conducted in a bottom up approach, beginning with the establishment of temporal and spatial patterns from sensor observations. Knowledge products of higher order will be derived from them. Finally complex reasoning is done on the intermediate constructs to provide "Sense Making Methods" (Department of Homeland Security 2006).

2.5.3 Top Down The top-level analysis of existing knowledge structures in other warning systems enables the alternative view on the challenges binding the whole system together.

2.5.4 Case Study: Analyzing existing Tsunami Flowcharts

The work was begun by analyzing existing, manuals for tsunami-prone scenarios at the Pacific Tsunami Warning Centre, Hawaii (PTWC). There, the required inference processes are encoded as flowcharts to be adhered to if an anomaly occurs.

They are tailored to match the perspective of the Officer on Duty, combining several aspects of tsunami-relevant knowledge domains. This high level product was derived by drawing information from many tsunami-relevant sub-domains and work experience.

Analysis of the PTWC flow charts resulted in reverse knowledge engineering: The contents of the charts were cast in a knowledge base, which was reorganised. The dialogue-component was reconstructed (immediate OOD/System interaction) by using more flexible structures beyond categoric binary trees. Thematic differentiation was used to partition domain specific knowledge (seismic, spatial, dissemination products).

These steps were taken without the addition of new domain-specific knowledge.

2.6 The Expert System Shell Toolkit D3

An expert system shell toolkit is a construction tool to create expert systems for specific knowledge domains. Such an expert system consists of a knowledge base for its specific domain and the software components necessary to infer solutions for tasks in the real world. The D3 toolkit was selected since it allows flexible GUI-based knowledge acquisition, rapid prototyping and knowledge refinement.

D3 is developed by the Chair for Artificial Intelligence and Applied Informatics at the University of Würzburg (Puppe 2001).

2.6.1 Prototypic Mapping Application A lisp-based version is used to generate reports from inference runs. Combined with FOSS GIS tools like GRASS GIS and UMN Mapserver, it is used to create custom mapping capabilities within the EWMC. FOSS GIS approaches provide unique benefits for disaster management regarding the reliability of critical software components (Löwe *et al.* 2003, Löwe 2004).

2.6.2 Web-based Application The java-based D3 KnowMe tool was utilized for general knowledge modelling, agile restructuring, and the set-up of case repositories. The introduction of a commercial spin-off software at GFZ is currently being evaluated.

2.6.3 Agile Knowledge Modelling is used to derive reusable modular patterns from the already acquired domain knowledge. This approach checks for bottlenecks in the inference processes.

When moving from binary decision trees to scoring rules and heuristic problem solving, the specialists in that particular field of expertise (domain experts) must try to rate all correlations between the findings and the solutions. To verify the rule-bases set-up in this process, case bases must be established.

For refinement strategies, a correct case base can be used, which requires a feed-back process between the knowledge engineers and the domain experts.

Conservative Refinement strategies alter only scoring points of existing rules without the introduction of new rules. Further, an analytical refinement strategy adapts only the relevant scoring points of rules that have actually been used.

These approaches have been applied so far in the medical and botanical domains (Baumeister 2006).

2.6.4 Temporal Aspects: D3 has been mainly used in the medical domain, where temporal reasoning is an important aspect (Keravnou *et al.* 2005). The monitoring of the sensor streams of individual sensor data streams within a TEWS compares well to D3-based automatic monitoring systems for anaesthesy, where sensor observations of the patients health status are continuously checked for temporal trends and abnormal values.

3 Summary

This presentation provides an overview over the studies done so far in knowledge acquisition regarding GITEWS and similar projects.

Research has focused on the user interface between the software/sensor systems and the human operator in a early warning and mitigation centre (implementation of a decision support environment). For this, flowcharts from the operative tsunami warning system for the pacific ocean were analysed.

This was done using expert system toolkits. Knowledge bases were set up using the D3 software, which is highly suitable for rapid knowledge prototyping.

From the experience gained so far, a bottom up knowledge modelling process is proposed for sensor systems.

In parallel, the know-how and best practices of experienced Officers on Duty needs to be mapped in knowledge bases.

Since the development of the knowledge based components follows the implementation of the sensor networks, a next step will be the integration of time series from individual sensor systems.

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