Experiences integrating autonomous components and legacy systems into tsunami early warning systems

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Introduction

Fostered by and embedded in the general development of Information and Communication Technology (ICT) the evolution of Tsunami Early Warning Systems (TEWS) shows a significant development from seismic-centred to multi-sensor system architectures using additional sensors, e.g. sea level stations for the detection of tsunami waves and GPS stations for the detection of ground displacements. Furthermore, the design and implementation of a robust and scalable service infrastructure supporting the integration and utilisation of existing resources serving near real-time data not only includes sensors but also other components and systems offering services such as the delivery of feasible simulations used for forecasting in an imminent tsunami threat.

In the context of the development of the German Indonesian Tsunami Early Warning System (GITEWS) and the project Distant Early Warning System (DEWS) a service platform for both sensor integration and warning dissemination has been newly developed and demonstrated. In particular, standards of the Open Geospatial Consortium (OGC) and the Organization for the Advancement of Structured Information Standards (OASIS) have been successfully incorporated. In the project Collaborative, Complex, and Critical Decision-Support in Evolving Crises (TRIDEC) new developments are used to extend the existing platform to realise a component-based technology framework for building distributed TEWS.

Challenge

The integration of legacy stand-alone systems and newly developed special-purpose software components into TEWS using different software adapters and communication strategies to make the systems work together in a corporate infrastructure is a demanding task. The associated task management and data conversion between the different systems is complex and often underestimated. The integration of sensors, e.g. providing seismic and sea level data, and the utilisation of special-purpose components, such as simulation systems and dissemination facilities, is a crucial mission on the successful implementation of TEWS. Practical approaches and pragmatic software solutions are hard to find and implement in the environment of TEWS requiring stable, resilient and scalable solutions for near real-time information management.

Information flows

According to USIOTWS (2007) the key operational components of a TWS are to provide real-time monitoring, alert of seismic and tsunami activities, timely decision making, and dissemination of tsunami warnings, advisories, and information. A TWS enables and controls upstream and downstream information flows. The overall information flow includes three segments (Fig. 1): 1) Upstream: Acquisition of sensor data and transmission to the warning centre including processing and event detection; 2) Decide-and-act: Information flows within the warning centre including situation analysis, decision support and warning dissemination planning; 3) Downstream: Preparation of customised tsunami messages for the dissemination via selected channels (Wächter et al., 2012).

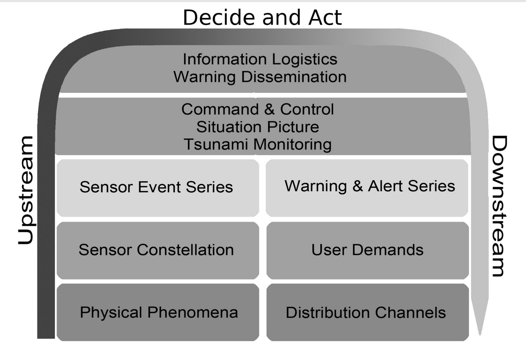

Fig. 1. Information flow in TEWS with Upstream(sensor data, context information, dynamic analysis), Decide-and-act (decision finding based on context analysis, evaluation of alternatives, initiation of warnings), and Downstream (generation of customized warning information, dissemination via different channels, control actuators).

Upstream

The upstream information flow delivers observations about physical phenomena measured by sensor systems (Fig. 2) necessary for decision support processes into the warning centre. For each sensor system the upstream includes complex processing and transformation steps. Time series data measured by sensors have to be filtered and analysed in order to extract relevant events for decision making. The resulting aggregated data sets represent the input important for the decision support components of the TEWS (Wächter et al., 2012).

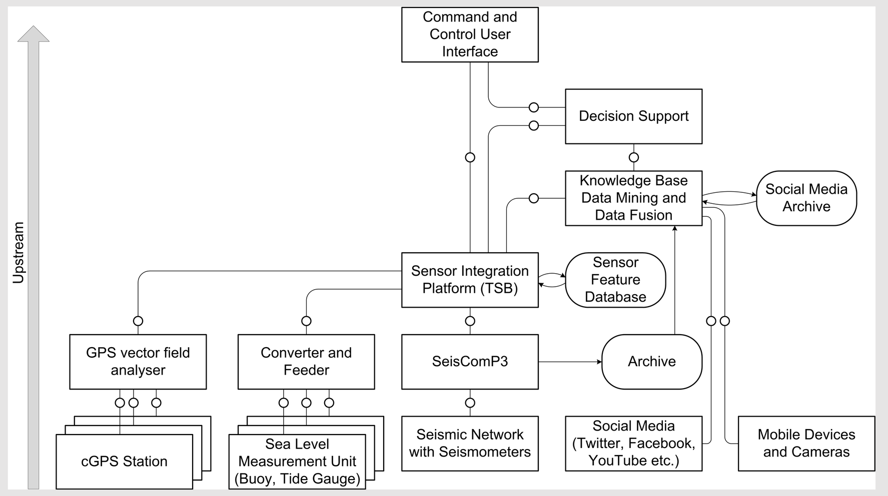

Fig. 2. Conventional and unconventional sensors and sensor systems integration for decision support processes.

Geo-distributed heterogeneous data management is at the heart of future TEWS architectures for decision-support. Data sources include tide gauges, buoys, seismic sensors, Web 2.0 feeds to crowd source 'unconventional' measurements of tsunami wave propagation. The resulting system of systems approach requires a multi-bus architecture with scalable and high performance messaging backbone. Furthermore semantic interoperability between heterogeneous datasets has to be overcome (Middleton et al., 2012).

An important approach for smooth sensor integration is a standardised interface between the warning centre and a sensor system. Despite the fact that most sensors have their own (proprietary) protocols for data exchange and commanding, the sensor system provides a high level of abstraction to receive commands or requests from the warning centre. In order to manage this multitude of sensors the integration platform TSB was introduced as an additional intermediate layer to provide the required flexibility for sensor integration. Additionally, this layer offers a uniform interface for end user applications, e.g. the decision support system (Fleischer et al., 2010).

Decide-and-act

The concrete decision processes are executed in the decide-and-act segment of the overall information flow. In this segment sensor events have to be analysed in order to determine if a tsunami has been triggered. Depending on this decision the concrete risks for defined coastal areas have to be determined. This process is supported by what-if prognostic tsunami propagation models delivered by the simulation component (Wächter et al., 2012).

The development of new TEWS requires the modelling of spatio-temporal spreading of tsunami waves both recorded from past events and hypothetical future cases. The model results are maintained in digital repositories for use in TEWS command and control units for situation assessment once a real tsunami occurs. Thus the simulation results must be absolutely trustworthy, in a sense that the quality of these datasets is assured. This is a prerequisite as solid decision making during a crisis event and the dissemination of dependable warning messages to communities under risk will be based on them (Fig. 3). This requires data format validity, but even more the integrity and information value of the content, being a derived value-added product derived from raw tsunami model output (Löwe et al., 2012).

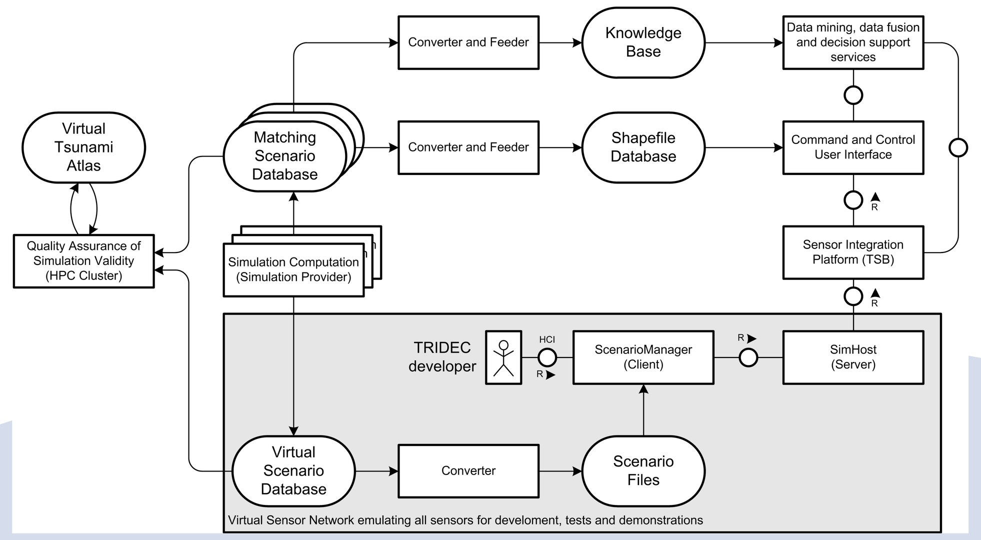

Fig. 3. Integration of simulations.

Furthermore, in the development of TEWS the use of established and recognized standards is an essential factor at all levels of the system for the functioning of the entire system. The individual components, the data used, and results of various efforts are based on different models, technologies and data formats. When integrating the results into the overall system the used proprietary technologies and data cause additional complexity. A successful integration of results into an overall system depends on the choice of the used formats and their support. In this context, tsunami simulations are considered as data that are used by various components of a TEWS for different purposes. Unfortunately, the data format is not sufficiently discussed yet in an appropriate forum with experts. This drawback has to be handled by specific components to allow utilization of simulations and simulation systems (Lendholt et al., 2012).

The utilisation of simulations include the integration of simulation systems capable of on-the-fly computation (Fig. 4), e.g. realisied with graphics processing units (GPU) computing. Simulation systems taking command line parameters and producing the required simulation data via files are available in different versions and are tasked with different parameters.

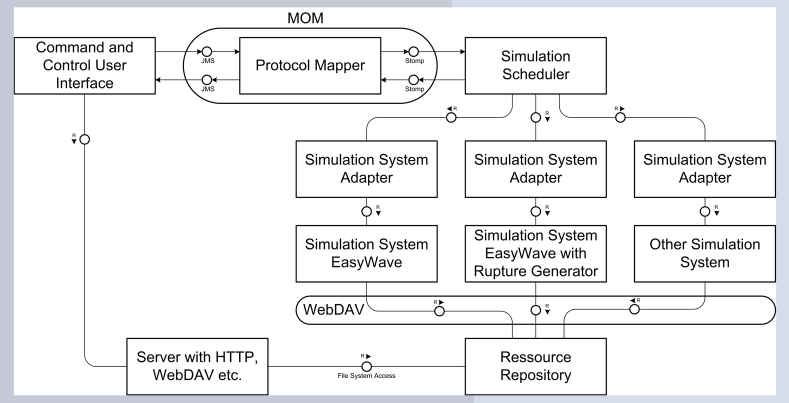

Fig. 4. Integration of simulation systems.

A simulation scheduler receives simulation requests and triggers a simulation adapter for simulation requests. Once a computation is finished the scheduler anounces the simulation results. The simulation adapter can run multiple simulation processes in parallel. After the simulation computation is finished the adapter post-processes the data and converts them into the required format. Finally, the converted data is stored in a repository and information to access the simulations is returned to the tasking system component, e.g. the graphical user interface (GUI) of the decision support system (DSS).

Downstream

Based on the input of the decide-and-act segment the downstream information flow (Fig. 5) includes the transformation of tsunami hazard information into customised warning messages and situation reports delivered to defined target groups, including authorities, the public in case of emergencies, and other regional as well local warning centres (Wächter et al., 2012).

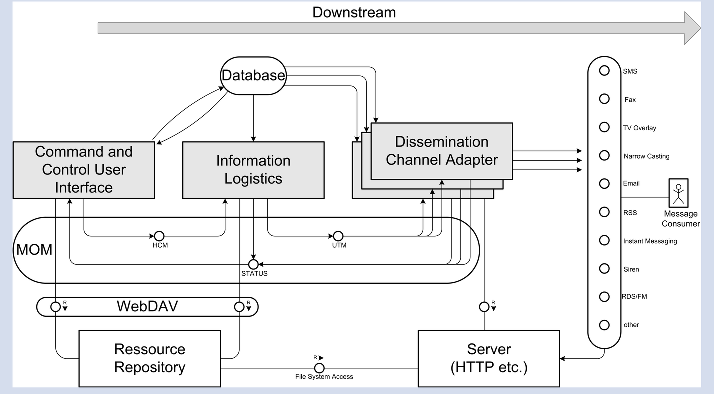

Fig. 5. Integration of (proprietary) dissemination channels in downstream information flow.

Conclusion

Haner et al. (2011) summarize that the key challenge is establishing communication infrastructures of interoperable services through which management of dynamically increasing volumes and dimensionality of disparate information is efficiently possible. To this end, a future architecture will be based on service-oriented architecture (SOA) 2.0, an event-driven extension of SOA principles. This approach supports creating high-level business events from low-level system events. High-level events are created by analysing real-time data from system components enhanced with details such as dependencies or causal relationships discovered by correlating other events and additional information. Even more important, this allows collaborating systems to respond dynamically in real-time, automate decision processes, or to autonomously take actions to react on unique event patterns.