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Architectural Framework for Hazard Warning Systems

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Abstract

To protect from various threats caused by humans or by natural phenomena, there is an increasing trend to develop complex technological and computational infrastructure for managing hazards and delivering efficient warning capabilities. These information systems are often created and maintained by consortia of multiple institutions, sometimes from different countries; such a consortium may be assimilated to the extended definition of an enterprise, where organizational units collaborate for the common goal of mitigating environmental risks, through computational and physical artifacts with different ownership. The resulted architecture contains both hazard-specific artifacts - like sensors for measuring pollution parameters - and hazard-independent ones - like notification senders or map visualizers for geographically annotated information. Based on the example of consecrated enterprise architecture models, this paper proposes a framework for describing the architecture of hazard warning systems, identifying three perspectives correspondent to three main stakeholders, and classifying the artifacts in respect to computational and physical views.

Keywords: Software Systems Modeling; Enterprise Architecture; Cyber-infrastructures; Hazard Management

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1. H-Geo Architectural Framework

System complexity has often been approached through decomposition in terms of multiple views, based on various classification schemas. The most famous model in enterprise architecture is the Zachman Framework, introduced in the eighties and organized as ontology for defining a matrix of architectural artifacts [1]. The rows correspond to *perspectives* of various stakeholders, and each column adds a focus specific to a primitive

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interrogative. J.A. Zachman did not introduce any method for the application of his model, but this was done by two other approaches: Federal Enterprise Architecture (FEA) and The Open Group Architecture Framework (TOGAF), who proposed an architecture development methodology and a process respectively [2]. The Zachman's matrix was also modified in the Treasury Enterprise Architecture Framework (TEAF), defining *perspectives* for architecture planning, ownership, designing and building, and *views* regarding functionality, information, organization and infrastructure [3].

1.1. H-Geo Perspectives and Views

Hazard management has been considerably improved with the support of systems that include artefacts for warning and alert management [4]. As any hazard warning system is deeply interdisciplinary, the H-Geo framework describes the system for 3 perspectives:

- *Hazard Perspective* – representing the concerns of experts in natural phenomena specific to various types of hazard,
- *Emergency Perspective* – for professionals in emergency situations, and
- *Geospatial Perspective* – corresponding to areas derived from geographical sciences.

Each of the three perspectives has to consider 2 views:

- *Computational View* – modeling the software architecture, composed of various program modules, components or services, and
- *Physical View* – consisting of physical devices like computer hardware, sensor networks, measuring instruments, mobile phones and telecommunication networks.

1.2. H-Geo Architectural Artifacts

After defining the relevant perspectives and views, we identified the main types of architectural artifacts that have to be included into a typical system for hazard warning management. The artifacts of the H-Geo architectural framework are included in Table 1. Generally, there is one type of artifact for each "perspective – view" pair correspondent to a matrix cell, as follows:

- *Acquisition* – containing the physical devices used for various measurements;
- *Warning Software* – consisting of programs implemented for transmitting notifications;
- *Warning Devices* – identified as the physical view necessary for transmitting the warning software;
- *Geographical Information System (GIS)* – seen as the computational view required for data analysis and interactive visualization;
- *Global Positioning System* – the physical view correspondent to *GIS*.

Table 1. H-Geo Architectural Artifacts

Perspectives	**Computational View**	**Physical View**
	Data Collection	Acquisition
Hazard Perspective	Prediction	
	Decision Support	
Emergency Perspective	Warning Software	Warning Devices
Geospatial Perspective	Geographical Information System	Global Positioning System

The computational view of the hazard perspective has become more complex with the new research trends to deliver early warning and to automatically guide response actions, in order to increase coordination and efficacy. As a consequence, we identified three representative architectural artifacts, generally implemented for this H-Geo matrix cell:

- *Data Collection* – composed of non-homogeneous elements with diverse complexity, from simple files to entire information systems that originate data about the hazard of interest,
- *Prediction* – containing data intensive applications for scientific computing based on mathematical models, and
- *Decision Support* – consisting of artifacts dedicated to risk and vulnerability assessment, artificial intelligence, rule-based engines and even critical process models.

2. H-Geo Applied to Nuclear Warning Systems

The main objective of N-WATCHDOG project is the anticipative assessment of the fast dynamics of territorial vulnerabilities induced by nuclear facilities, including decision support for near- and far-field countermeasures.

The project introduced the following implementations for the H-Geo architectural artifacts [5]:

- *Data Collection*. N-WATCHDOG system collects data related to nuclear emissions from interactive web maps, as well as meteorological forecasts from public websites;
- *Prediction*. It concerns the atmospheric dispersion of radioactive emissions, which may affect the population not only in the proximity, but also at large distances. The system implements Puff Trails and Plume models;
- *Decision Support*. It is based on rules organized in decision trees and it has two components: the near-field radiological assessment and far-field vulnerability assessment [6], evaluated by integrating several indicators;
- *Warning Devices*. Currently, the warnings are obtained through a desktop application running on a personal computer. The N-WATCHDOG system is going to be transformed into a web solution, also available to other stakeholders;
- *Geographical Information System.* The geographical information is treated with geo-location services, using Google Maps API and Google Earth Plugin API.

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