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Smart levee monitoring and flood decision support system: reference architecture and urgent computing management

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Abstract
Real-time disaster management and decision support systems rely on complex deadline-driven simulations and require advanced middleware services to ensure that the requested deadlines are met. In this paper we propose a reference architecture of an integrated smart levee monitoring and flood decision support system, focusing on the decision support workflow and urgent computing management. The architecture is implemented in the ISMOP project where controlled flooding experiments are conducted using a full-scale experimental smart levee. While the system operating in the ISMOP project monitors a test levee, it is designed to be scalable to large-scale flood scenarios.

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1 Introduction

Smart levees are increasingly considered as an important part of a future flood protection infrastructure enabling real-time monitoring of flood embankments and early warning of approaching disasters [11, 13]. A flood early warning and decision support system needs to rely on advanced middleware services that provide urgent computing capabilities [1, 15], so that results of resource-intensive data analyses and simulations, required for decision-making in emergencies, are delivered in a timely fashion [2].

This paper describes a reference architecture of an integrated smart levee monitoring and flood decision support system focusing on decision support workflows and urgent computing capabilities. The presented research is performed in the context of the ISMOP project [4] which operates a full-scale experimental smart levee located in the Lesser Poland region.

Related research on architectures for urgent computing in the context of disaster management exists. In [14], a three-layer architecture for urgent computing is proposed. Urgent computing requirements are fulfilled by so-called urgent managers which wrap core services (data collection, reliability, security, etc.) without disrupting them. SIM-CITY [5] is an architecture
for urban-assisted decision support geared towards simulation-based scenario exploration. An architecture and urgent workflow for decision support in surge flood prevention is presented in [12]. Requested execution time is guaranteed by the CLAVIRE platform [20]. Typical approaches to urgent computing management focus on scheduling and execution of computational jobs in order to meet the required deadlines. The novelty of our architecture lies in a holistic approach to urgent computing management which encompasses all layers of the system, not just those dealing with computational jobs.

The paper is organized as follows. Section 2 contains an overview of the flood decision support workflow and components of the reference architecture. In section 3, details of the flood decision support workflow are explained. Section 4 presents the execution management and urgent computing features of the proposed architecture. Section 5 presents the ISMOP system from the user’s perspective. Finally, section 6 concludes the paper.

2 System overview

2.1 Flood decision support workflow

Fig. 1 presents an abstract overview of the flood decision support workflow. In general, three main tiers of data analysis become iteratively activated as the flood threat level increases:

- The first tier is anomaly detection. It is triggered periodically with a certain time interval. Anomaly detection provides the first indication of a potential threat in a given section of a levee. Typical methods for detecting anomalies include statistical analysis of time series [9] or machine learning [19], possibly combined with feature extraction [10].

- The second tier is threat estimation which involves further analysis of levee sections where anomalies have been detected, in order to assess their health and failure probability. Such analysis is required because anomaly detection alone is usually not sufficient – e.g. due to low reliability of results generated by the detection algorithm [19]. A typical analysis that can be performed in this tier is levee stability simulation [13]. The result of this step is a levee health map that can be reviewed by decision makers who then decide whether the alert level should be raised.

- The third tier is risk assessment. This is the most computationally intensive step. It is initiated when the end user decides to raise the alert level and switch the workflow to

![Figure 1: Flood decision support workflow (abstract overview).](image)
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