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IoT-based Urban Security Models

Mahyar Tourchi Moghaddam
University of L'Aquila, DISIM
Italy
mahyar.tourchimoghaddam@graduate.univaq.it

ABSTRACT

The era of Cyber-Physical Systems (CPS) and IoT [1] gives rise to the necessity of multi-proficiency in software, hardware, and the Cyber-Physical Space (CPSp) wherein the IoT components are deployed. Focusing on software engineering aspects, this research proposes a model-driven engineering approach to engineer CPS and model pedestrians flow. To this end, design-time decisions and run-time data ought to be fused to improve the efficiency of crowd monitoring and emergency handling. Moreover, the research aims at building some mathematical models applicable as the core of the system controller to facilitate optimum route selection, crowd movement prediction, and hazard diffusion detection; while considers the architectural characteristics of the complex area to be evacuated.

CCS CONCEPTS

•**Software and its engineering → Software architecture**; •**Computer systems organization →** Embedded and cyber-physical Systems.

KEYWORDS

Cyber-Physical Systems, Urban Security, IoT, Network Flow, BN

1 PROBLEM SPECIFICATION

In the general context of situational aware IoT systems, the research focuses on pedestrian flow management through IoT technologies. In this regard, the main question is:

"How we optimally model, monitor, analyze, simulate, and architect IoT-based indoor and outdoor environments to best handle the surveillance and evacuation whenever needed?**"**

However, the main challenges to be surpassed are:

Static evacuation plans shortcomings. Design-time evacuation maps that are generally designed by civil protection operators (we collaborated with), provide static plans that show pre-selected routes through which pedestrians should move in case of emergency. This kind of models may work in low congested spacious areas; however, the situation may barely be imagined static in case of a disaster. These maps expose several limitations such as: *(i)* ignoring the congestion or danger of each route and area; *(ii)* leading all pedestrians to the same route and making that area highly crowded; *(iii)* ignoring the individual movement behavior of agents; *(iv)* lack of architectural-based evacuation simulation support.

Human behavior prediction challenges. In order to guide people towards emergency exists, learning their local usual/unusual behavior is momentous; since they may respond differently to guidelines and react heterogeneously, especially in case of age, health and social diversity.

Design-time software architecture limitations. The design and realization of a flow management system involve solving many challenges at architectural level. However, design-time architecture cannot satisfy highly spatiotemporal sensitive applications like emergency evacuation and the software architecture should be actively modified via dynamic adaptation.

Legal and ethical codes constraints. Privacy risks, data protection and ethical issues should be considered for the evaluation and implementation phases of the research project. It can involve the components of IoT system such as smartphone apps, sensors, RFID tags, and social media data protection.

2 RESEARCH HYPOTHESES

The initial hypothesis is that the model will be performed in indoor and outdoor smart areas equipped with IoT devices, to provide real-time data. Furthermore, since prediction of every single human reaction dealing with a disaster or jam is quite impossible, we claim that the current research examines the most considerable human aspects, such as perception, velocity adaptation, and panic.

3 RESEARCH CONTRIBUTIONS

The main contributions of this study are: *(i)* modeling and architecting an IoT environment with an emphasis on surveillance applications; *(ii)* addressing a suitable real-time adaptation for the proposed IoT architecture; *(iii)* designing a simulation tool that whilst model the cyber physical space environment in design time, be capable to support the real time applications as well; *(iv)* creating mathematical models as a core of the system controller, to handle the situation tracking and emergency evacuation; *(v)* bridging between the proposed model and industrial applications.

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3.1 IoT Architecture Styles

Following a systematic study, we introduced a layered IoT architecture based on edge intelligence and IoT elements collaboration. It is composed of the following layers. *Perception layer:* represents the physical sensors and actuators of IoT system to collect information. *Processing and Storage layer:* as the central IoT component, stores and analyzes the data gathered by perception components. *Application layer:* determines the class of services provided by IoT; and *Business layer:* manages the IoT system for its specific goal.

3.2 IoT Environment Modeling

CAPS-ES modeling environment is developed to model a CPS. CAPS-ES (an extension of CAPS [1]) is able to create a combined *software*, *hardware*, and *physical space* view, specific for surveillance and emergency evacuation handling. CAPS-ES supports the system with early disaster detection and provides the best architecture to satisfy the desired evacuation time. As an example, the software architecture viewpoint corresponding to hazard detection and crowd evacuation in an indoor area is presented in Fig 1. The model consists of: *(i)* disaster detection based on sensory data fusion; *(ii)* the controller decision making based on the sensory values and network flow model; *(iii)* actuators function to handle the desired crowd routing (e.g., by opening and/or closing the turnstile doors periodically).

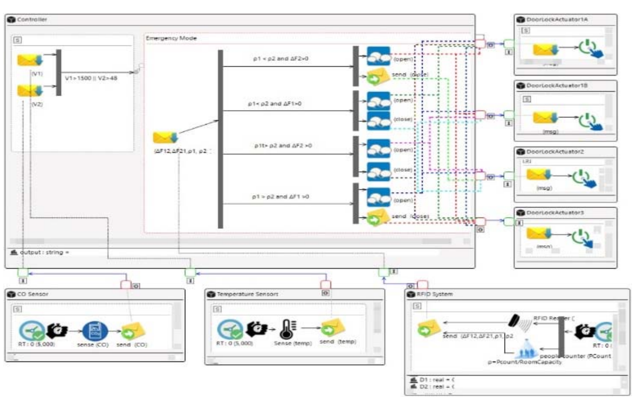

Figure 1. **CAPS-ES Software Architecture model**

3.3 Real-time Adaptation

Software adaptation is necessary for systems that need to change their behavior while running. In IoT environments, system shall be consistently self-aware, and ought to adapt its own functionality in response to any unspecified change such as a disaster. This adaptation can take place in algorithm, configuration, or architecture. The latter guarantees a better system functionality whilst dynamically replaces and changes the components in run-time.

3.4 Simulation

Simulation tools can model a digital version of the physical environment, in which a set of sensor nodes are virtually distributed. For our IoT system modeling purposes, we are developing an agent-based simulation tool to be able to model the normal and emergency situations dynamically. The tool should be capable to *(i)* examine the building architecture regarding its evacuation capacities, even before constructing it; *(ii)* perform continuous simulation to design evacuation plans; *(iii)* be fed with dynamic sensory data for real-time applications.

3.5 Controller Logic

Following models are the computational core of the controller to find the optimum solution for an emergency evacuation.

Data Fusion. Run-time data collection using various disaster detectors and fusing those data to enjoy more dependable results. A Fuzzy-Bayesian approach is developed for this section.

Network Flow. The model is described by a graph with nodes corresponding to the rooms set and arcs to passages between adjacent rooms. The model formulates and solves the emergency handling problem with minimizing the evacuation time hence maximizing evacuated people in a given time.

Dynamic Bayesian Network - DBN. The application of DBN on crowd emergency evacuation is prediction of the posterior condition of pedestrians and hazard, to: *(i)* keep track of the number of people located in each area at specific time steps; *(ii)* predict posterior position, velocity, and direction of pedestrians; *(iii)* model and calculate the crowd flow between areas; and *(iv)* to model the hazard diffusion.

4 EVALUATIONS

Concerning the experiments, the "Florence Uffizi Galleries" has been chosen as an early stage running example [2]. The second crowded area was "Palazzo Camponeschi" that is a historical palace in L'Aquila city centre. The improvement of research is projected during the next two years through various validations.

5 RESULTS

Achieved. So far, this research aimed at evaluating the CAPS-ES environment, however, a vast investigation is needed to develop an embedded real-time adaptive architecture. Development of the mathematical models is having a proper progress as well.

Planned. The next two years of my PhD is planned to be spent at different universities (Chalmers University, Malmo University, L'Aquila University, Polytechnic of Turin) and companies (Fabbrica Digitale, nExpecto, etc.). In the next sprint, we will mainly enrich our knowledge of agent-based simulation for CPSp modeling. We will also improve the initial architecture and related support mechanisms and methods. We plan to exploit more concrete reference use case under support of our industrial partners in Sweden and Italy to provide the project some more concrete real-world experiences and scenarios to reason upon.

REFERENCES

[1] Muccini, H., & Sharaf, M. (2017, April). CAPS: Architecture Description of Situational Aware Cyber Physical Systems. 2017 *IEEE International Conference on in Software Architecture (ICSA)*. (pp. 211-220). IEEE.

[2] Muccini, H., & Moghaddam, M. T. (2017, September). A Cyber-Physical Space Operational Approach for Crowd Evacuation Handling. *In International Workshop on Software Engineering for Resilient Systems* (pp. 81-95). Springer.