Detection of Safety Hazards Using Cooperating Chemical Containers

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ABSTRACT

This extended abstract presents a technology for artefact-centric development. Our demonstrator shows how the technology could be used to detect safety hazards that arise from improper storage of chemical containers. We augment real chemical containers with Particle Smart-its that allow them detecting hazards by exchanging knowledge about containers in their proximity. As it is prohibitive in these environments our system is independent of any external infrastructure. Our demonstrator is based on the architecture of a generic *Cooperative Artefact* that describes a physical entity that incorporates embedded domain knowledge, perceptual intelligence and cooperative, rule-based reasoning. This demonstrator accompanies our full paper in this year's conference.

Keywords

Smart Objects, Cooperative Reasoning, Safety Hazard Detection, Knowledge Acquisition

1. INTRODUCTION

Many ubiquitous computing systems and applications rely on knowledge about activity and changes in their physical environment that they use as context for adaptation of their behaviour. How systems acquire, maintain and react to models of their changing environment has become one of the central research challenges in the field.

Traditional approaches instrument devices, artefacts or entire environments with perceptual and computational hardware. The instrumentation of environments is the typical domain of wireless sensor networks [1]. Here, intelligence of individual nodes is often restricted to sensing and routing of the data in the network whereas sensed data is processed outside the network. Similarly, artefacts are typically tagged for identification (e.g. with RFID tags [5] or visual tags [4]) whereas the actual recognition and management of activities is situated in an infrastructure external to the artefacts. SPECs are devices that can be used for tagging artefacts. They recording basic activities and can be configured to send events to users [3].

This extended abstract accompanies a paper at this year's conference that introduces the problem of detecting safety hazard in a chemical processing plant [**?**]. More specifically, we focus on storage of chemicals: although staff are well trained, containers are sometimes still stored in hazardous ways. Detection of those hazards with traditional approaches is virtually impossible as environments that would need to be instrumented are not under uniform control (e.g. storage facilities of distributors or customers). Alternatively, we suggest an artefact-centric system in which Cooperative Artefacts (CAs) assess situations in the real world based on perception and cooperative reasoning without the need of any external infrastructure. In this paper we describe a technology intended for development of such artefact-centric applications. The actual demonstrator shows how improper storage of chemical containers can be detected.

STORAGE OF CHEMICAL CONTAINERS

Jointly with the R&D unit of a large petrochemicals company, we have begun to study issues surrounding the handling and storage of chemicals in the specific context of a chemicals plant in Hull, UK. Based on this collaboration we have identified a set of potentially hazardous situations that a system must be able to detect and react to, in order to effectively assist trained personnel:

1. Storage of dangerous materials outside an approved area for longer than a predefined period of time
2. Storage of materials in proximity of 'incompatible' materials, i.e. reactive chemicals may not be stored within a pre-defined safety distance
3. Storage of same materials exceeding a pre-defined critical mass

In this demonstrator we show a number of chemical containers that cooperate to detect theses three hazards without the need of external infrastructure.

ARCHITECTURE

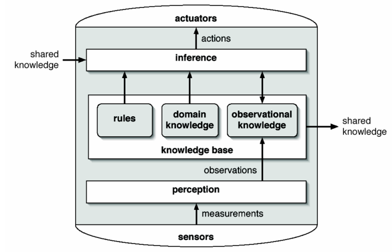

Figure 1: Architecture of a Cooperative Artefact

The software of chemical containers are based on the generic architecture of a Cooperative Artefact as depicted in Figure 1. The architecture describes a CA as a physical entity that observes its environment, cooperatively reasons about its own observations and those of nearby artefacts. Attached actuators allow the artefact to manipulate its immediate environment. Each artefact models aspects of its immediate physical world in a local artefact knowledge base. The perception process adds observations to the knowledge base by processing measurements from sensors attached to the artefact. The actual reasoning algorithm is part of the inference process that infers further knowledge based on a set of rules. Inference is based on local artefact knowledge and knowledge shared by cooperating artefacts. The inference process uses actuator rules to control actuators attached to the artefact.

The architecture itself is independent of a particular hardware platform. However, it is a defining property of a Cooperative Artefact that all computation is done by the artefact itself. This means that all components of the architecture must be feasible to implement on highly resource constraint embedded devices (e.g. [2]).

AUGMENTED CHEMICAL CONTAINERS

Our chemical container prototype consists of a plastic barrel augmented with a Particle Smart-its ([2]). Each individual container can observe its relative position and orientation to another container using four ultrasonic transducers that interface with the main Particle (cf. Figure 1). The containers also determine their position relative to additional ultrasound particles that mark approved areas. Light Emitting Diodes (LEDs) are used to signal if a hazard has occurred.

Figure 2: Augmented Chemical Container

COOPERATIVE REASONING

Each container models certain important aspects of the world. E.g. each container knows its content, with which chemicals its content is reactive, its mass and what the critical mass of its chemical is (if any). It also knows how long it may be stored outside an approved area. Further static knowledge includes the above rules that allow them to detect each of the safety hazards. Dynamic knowledge is based on the observations of the containers: whenever there is a nearby container a corresponding observation is added to its knowledge base. In the same way entries in the knowledge base are removed when containers leave the vicinity of an artefact. In addition, each container updates the knowledge base with information about how long it is already stored in an approved or unapproved area.

These changes trigger the actual reasoning process that evaluates if the container is involved in any hazard. Each of the above rules is evaluated by an inference engine that determines if any of the hazards has occurred. The inference engine operates on a subset of Horn logic, in which all domain knowledge, observations and rules are expressed. The evaluation of the rules specifically takes into account whether a certain fact should be available in the local artefact knowledge base or whether it should be available from a remote artefact. In the latter case, the inference engine sends a query to the respective artefact. The current rule can then be evaluated based on the results of the query.

Main user feedback is provided on the container using for example visual or audio cues. In our demonstrator a LED indicates a hazard that would allow trained personnel to identify the container and store it according to its regulations. In addition a tool allows to further investigate the artefact knowledge base, e.g. to determine the nature of the hazard In a similar way users could be notified on their handheld devices (e.g. mobile phones) if a hazard occurs.

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