Trustworthy and sustainable operations in marine environments

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Abstract

In order to address challenges and opportunities of engineering information systems for network-centric warfare, we have developed a prototype for trustworthy and sustainable operations in marine environments (TWOSOME). The system developed addressed qualities such as information fusion, target acquisition, and self-organization in open computational systems; comprised of distributed services. As such, the system prototype executes on a service-oriented layered architecture for communicating entities (SOLACE) and, furthermore, different perspectives of the prototype are visualized by means of a distributed interaction system for complex entity relation networks (DISCERN).

1. Introduction

The exercise of engineering software systems for network-centric warfare [1] boils down to one issue in particular – sustainable behavior in open computational systems [2]. A key aspect of the domain is automated management of unforeseen system events and dynamics. In open computational systems, new entities can enter and leave a physical environment at will. Computational or not, entities in such environments observe and interact with each other and such behavior is the origin of unpredictable events occurring. In order to make explicit a separation of concerns in engineering and sustaining qualities in such systems, we introduce a layered perspective involving the dimensions of environment, fabric, system, and domain.

In practice, we support this layered perspective by means of a platform for system articulation and construction (SOLACE1) and a tool for system observation and instrumentation (DISCERN2).

1 www.soclab.bth.se/practices/solace.html
2 www.soclab.bth.se/practices/discern.html

In order to identify requirements of the platforms and tools involved, we have investigated a prototype for trustworthy and sustainable operations in marine environments (TWOSOME3) as a joint effort between Blekinge Institute of Technology and Kockums. At the core of this prototype is the development of a multi-agent system, where interacting and coordinated entities come together in a physical setting; in order to perform a particular assignment under dynamic and hostile conditions. From a methodological perspective, we have focused this investigation and prototype development on online engineering of open computational systems. Specifically, we consider the involved systems to be of such a complex nature that the traditional approach of software engineering to analyze, design, implement, and deploy some particular system is no longer applicable. Instead, we argue that systems have to be continuously articulated, constructed, observed, and instrumented in an ongoing online process of adaptation.

2. Scenario

The prototype involves two interrelated aspects — attacker and defender — focused on creating and removing physical threats at some particular environment location. In essence, this state of affairs renders itself as a game of deception where one party continuously tries to outsmart the other by means of information fusion, coordination, and reasoning. If an entity at any point in time should fail to fulfill either one of these capabilities the game is lost.

An attacker — a smart mine — is deployed in the environment and set to detonate whenever the presence of a particular vessel is identified in its surroundings. Correspondingly, we assign three coordinated defenders — autonomous vessels emanating acoustic and magnetic signatures — the role of sweeping different environment locations and, consequently, aim at removing potential

3 www.soclab.bth.se/systems/twosome.html
attackers by means of making mines detonate in a harmless way. The goal of a team of defenders is to outsmart the mine by means of providing fake signatures of real vessels. In practice, according to the overall system quality of sustainability, this exercise involves the continuous adaptation and reconfiguration of roles and resources. In the particular case of TWOSOME, we identify the following roles and resources.

- **Sensor** — the sole purpose of sensor entities is to acquire information concerning their surrounding environment and pass it forward in an appropriate format to those entities that are dependent on such information in order to fulfill their particular goals, e.g., an operations center.

- **Operations centre** — an operations center gathers intelligence and is responsible for the overall safety of some physical environment. In practice, we can achieve this role by means of continuously delegating orders, based upon newly acquired intelligence, to other entities under the operation centre’s control.

- **Defender** — a defender emanates different acoustic and magnetic signatures in order to exhibit characteristics similar to those of general naval vessel properties, e.g., propeller cavitations and engine acoustics. In doing so, the defense vessel has the ability to trigger the detonation mechanisms of artifacts such as mines. A team of defenders can, by means of coordination technology, form combinations of complex signatures as well provide for self-organization.

- **Transporter** — in the present scenario, we use multi-purpose vessels, e.g., a corvette class vessel, to transport a group of defenders from one location to another and subsequently delegate a defense order to the transported entities upon arrival.

- **Attacker** — we make the role of an attacker operational by means of a mine. The sole purpose of this mine is to detonate when it identifies certain acoustic and magnetic signatures — corresponding to targeted vessel types — in its surrounding environment.

In the particular case of TWOSOME, an attacker (an active mine) is created somewhere in the physical environment and thereby triggers observations by two different sensors. We forward this information to an operations centre that sends out a transporter carrying a number of defenders, i.e., autonomous vessels emanating deceiving acoustic and magnetic signatures. At some particular location, estimated by the operations centre and based on the information given by its sensors, the transporter deploys the defenders and travels back to its origin. It is at this point that we can start to understand the opportunities and challenges with trustworthy and sustainable operations in marine environments.

Each defender has the capability to navigate and cooperate with other defense vessels and thereby provide a potential attacker with more or less complex and deceiving vessel signatures. That is, a team of defenders can produce a complex vessel signature that is very difficult to distinguish from that produced by the actual vessel class threatened by an attacker. However, the coordinated structure of this efficient number of defenders is also very sensitive to perturbations in the surrounding environment.

Since the quality of the coordinated team of defenders corresponds to their effectiveness in deceiving some potential attacker — making it detonate and thereby removing the threat — it is essential that each defender produce an appropriate complex signature at the appropriate location. In order to do so, each entity must be able to observe and instrument its current context with respect to the given mission. For example, if we downgrade a particular defender’s service of producing some specific signature or completely remove it, we have to reorganize the whole team. However, by means of self-organization, the team of defenders is capable of reconfiguring and reusing its currently available services and resources in order to provide for a particular complex signature at all times.

3. References
