Software Engineering Institute

Socio-Adaptive Systems Challenge Problem Workshop Report

Scott Hissam
Mark Klein
Gabriel A. Moreno

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Abstract

Socio-adaptive systems are systems in which human and computational elements interact as peers. The behavior of the system arises from the properties of both types of elements and the nature of their collective reaction to changes in their environment, the mission they support, and the availability of resources they use. The Software Engineering Institute (SEI) held the Socio-Adaptive Systems Challenge Problem Workshop in Pittsburgh, PA, on April 12-13, 2012. The workshop's goal was to identify the challenges associated with resource allocation for warfighters operating at the tactical edge, where networks are often unreliable, and bandwidth limited and inconsistent. This report presents a summary of the workshop findings.

1 Introduction

The Software Engineering Institute (SEI) is conducting research to achieve effective, mission-aware use of resources, such as sensors and networks, in environments where front-line soldiers must operate. In support of this effort, the SEI hosted a workshop with the intent to capture the challenges associated with resource allocation for warfighters operating at the tactical edge. We use the phrase *tactical edge* to describe mission environments where networks are often unreliable, bandwidth limited and inconsistent, and resources for performing mission tasks frequently scarce.

The Socio-Adaptive Systems Challenge Problem Workshop was held at the SEI in Pittsburgh, PA, on April 12–13, 2012. Participants included active duty Navy officers; researchers from the Army Research Laboratory (ARL), the Communications-Electronics Research, Development, and Engineering Center (CERDEC), and the Institute for Human and Machine Cognition (IHMC); and representatives from the defense industrial base.

This report presents a brief description of socio-adaptive systems and the findings of the workshop.

1.1 Socio-Adaptive Systems

Socio-Adaptive Systems are systems in which human and computational “elements” interact as peers. The behavior of the system arises from the properties of both types of elements and the nature of their collective reaction to changes in their environment, the mission they support, and the availability of resources they use.

Figure 1 shows a typical design problem in socio-adaptive systems. The humans in the systems require resources. To enable decisions about resource allocation, the humans provide information about their needs to a decision maker (either human or computational). Since the outcome of the decision affects the same humans who provide the information, they could have incentive to misrepresent that information to induce a more favorable decision outcome for themselves. The problem is that a resource allocation decision based on misrepresented information may lead to suboptimal allocation.

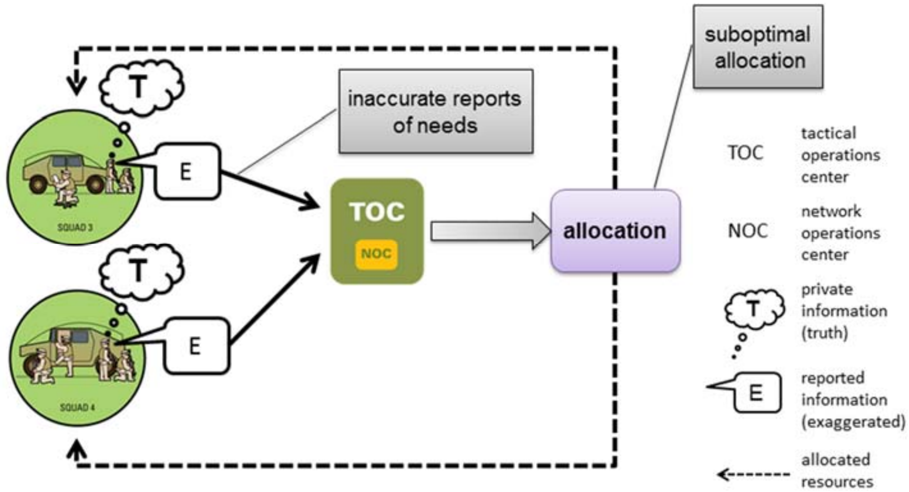

Figure 1: Socio-Adaptive Systems Design Problem

Tactical systems are socio-adaptive. The warfighters—the humans in the system—need resources to execute their missions. Based on their expression of those needs, resources are allocated. However, because of the scarcity of resources, and uncertainty and dynamism at the tactical edge, the humans in the system tend to exaggerate their requests as a means to ensure they get what they actually need when they need it. For example, units have requested recurring aerial surveillance of the same nearby targets day after day to make sure they have an unmanned aerial vehicle (UAV) flying close just in case they need it [Greenberg 2010]. In addition, systems are often designed to use resources greedily, without regard for what other systems need or for resource availability. These two problems lead to inefficient use of resources.

These challenges are also corroborated by the *Critical Code*, a recent National Research Council (NRC) report [Critical Code 2010]. The report identified the development of engineering practices for complex systems in which humans play critical roles as an important objective capability [Critical Code 2010, p. 9-10]. In the tactical environment, humans play an important role because they are the sources of information needed to effectively allocate resources. The report also calls for research and development in platforms that allow operators to aggregate QoS requirements, making it possible to formulate decisions, policies, and mechanisms to support global management in net-centric environments [Critical Code 2010, p. 135]. In addition, the overview to Chapter 6 of *Critical Code* describes this challenge:

> *Cyber-physical systems today often work well as long as they receive all the resources for which they were designed in a timely fashion, but fail completely under the slightest anomaly. There is little flexibility in their behavior, that is, most of the adaptation is pushed to end users or administrators. Instead of hard failures or indefinite waiting, what net-centric cyber-physical systems require is either reconfiguration to reacquire the needed resources automatically or graceful degradation if they are not available [Critical Code 2010, p. 134].*

The *Critical Code* report recommends research to accelerate the development of systems that can provide these kinds of capability in net-centric applications. The SEI's work on socio-adaptive systems directly contributes to that goal.

2 Workshop Findings

Most of the discussion during the workshop focused on the "socio element," that is, the humans in the system, and how their requests for resources affect the effectiveness of the system in supporting a mission. Participants most often presented network bandwidth as an example of a scarce resource. The adaptive quality of service technique to address the unpredictable and changing characteristics of the network was discussed briefly [Hansen 2010]. The following sections capture the major findings of the workshop.

2.1 Reasons for Requesting More Than Needed

There was agreement among the workshop attendees that misrepresentation (or requests for more resources than needed) occurs in military systems. However, workshop participants revealed many legitimate reasons for that observed behavior. These reasons include

- *lack of situational awareness to assess the real need for resources*. The lack of situational awareness translates into more uncertainty. Consequently, a warfighter may request more resources as a way to be prepared for the worst case within the perceived situation. With situational awareness, the warfighter would have less uncertainty about the situation and request resources according to that more accurate perception.
- *often receiving less than requested.* A warfighter who frequently receives fewer resources than requested may be inclined to ask for more, so that receiving less than requested brings the allocation closer to the real need. Success in compensating in this way may reinforce this behavior.
- *risk mitigation by requesting resources that may be needed later*. If there is some possibility that the warfighter may need resources later in the mission, he or she may mitigate the risk of not having the resources on time by requesting them in advance. This behavior is related to the next reason.
- *resource allocation approach not responsive to changes in needs*. If the allocation approach is not responsive to changes in needs, the warfighter will be inclined to request the resources that will be needed in a worst-case scenario.
- *local optimization.* Warfighters, trained to carry out successfully their parts of the mission, will try to do their best. If they can perform better, or have higher probability of success with more resources, they will request more resources. This behavior is related to the next reason.
- *lack of awareness of the impact of their use of a resource on others*. This is usually the case with divisible and abstract resources such as network bandwidth, where even if the warfighter is aware that others need it, the impact of sharing is not obvious. Even in the cases of indivisible resources, the warfighter requesting the resource is not in a position to evaluate whether the benefit he or she gets from using the resource is greater than the impact the lack of the resource has on others.
- *perception that there is no cost for using a resource*. With networked resources such as sensors, the warfighters largely ignore the fact that using those sensors consumes bandwidth.

Even if the warfighter keeps that fact in mind when requesting a resource, it is difficult for the warfighter to estimate the amount of network bandwidth needed.

2.2 Importance of Socio-Adaptive Systems

Regardless of the reason for its occurrence, misrepresentation can cause an inefficient use of resources. Currently, it is usually a human, such as a network manager, who resolves resource contention. However, considering the trends of increased network dynamism and availability of sensors, it is deemed necessary to have automated decision support for resource allocation.[1] When resource allocation is automated, the humans requesting resources become more relevant in the resource allocation aspect of the system, because no other human acts as a moderator. Therefore, it will become important to consider, at design time, the effects humans have on the efficiency of a system. Consequently, socio-adaptive systems are an important class of systems on which to work.

2.3 Dimensions of the Problem

Discussion participants identified several dimensions of the problem: the resource, people, decision maker, and timing of the decision. These dimensions will be useful for guiding the research in this area, since different solutions likely will be needed for different areas of the problem space determined by these dimensions.

2.3.1 Resource

Resources that are *shared and scarce* require special attention to their allocation. A shared resource can be either divided for simultaneous use (e.g., network bandwidth) or assigned for exclusive use during a time period (e.g., a UAV). A resource is considered scarce if the needs of those requesting the use of the resource cannot be satisfied with a uniform allocation of the resource. This definition of *scarce resource* includes the situation in which there is enough resource to satisfy the aggregate needs, but the allocation is not trivial. For example, if there are 50 Kbps of bandwidth available, and one unit needs 40 Kbps, and a second unit needs 5Kbps, a uniform allocation of the resource would fail to satisfy the needs.

Other relevant characteristics include the nature of the resource (its capacity, whether it changes over time); how long it takes to achieve the allocation (lead time); and resource-specific properties (consumable or not, preemptible or not).

2.3.2 People

Since the goal is to elicit accurate needs, there are two important characteristics in this dimension: how needs are expressed and the characteristics of the people (or their mindset) that would induce them to report inaccurately.

How needs are expressed concerns various aspects of the requests. Is the request implicit? There may be no explicit request for a resource; instead, the warfighter may simply try to use the resource. Is there a utility associated with the request (i.e., an indication of the utility that could be

1 It is also important to allow a commander to override a decision made by the system.

achieved with use of the resource)? Is the request flexible (e.g., different levels of resources can provide different levels of utility for the requestor)?

Warfighters might misreport their needs for various reasons, some of which overlap with the reasons mentioned previously. Warfighters may want to reduce risk. They may wish to optimize their own contributions to mission success, perhaps to enhance their own reputations. They may feel that they can achieve more with more resources; additional resources may also enable them to reduce risk.

2.3.3 Decision Maker

The decision maker is the element in the system (computational or human) that receives expressions of need from the humans and decides on a resource allocation. That is, it implements the rules for decision making. It is also responsible for the implementation of the means to ensure accurate reporting of needs (e.g., incentives for reporting accurately). This responsibility involves “incentivization,” enculturation, and their timing: whether these occur before, during, or after the mission.

Characteristics of the decision maker include being centralized or distributed and allocating across echelons and/or within an echelon.

2.3.4 When the Decision Is Made

The timing of the decision is important because it affects not only how responsive the system is to change, but also how the human element will behave (e.g., in the case of a static allocation, the human may require increased risk mitigation).

Characteristics in this dimension include static (one shot) vs. dynamic (changes over time) and made before or during mission (or possibly at both times).

3 Conclusion

Socio-adaptive systems, which involve humans interacting with computational elements, are important where military systems must be able to operate in environments that continuously change due to nature, the enemy, the availability of resources, and the movement of troops. When humans interact with computational elements in a way that can affect the efficiency of the system, special attention must be given to that interaction. The system must be able to adapt to its uncertain, dynamic environment. In order to do that, the local knowledge of the warfighters in the system must be aggregated to support decisions that best suit the aggregate needs. Mechanisms must be designed so that the aggregation of distributed information is not only possible, but also conducted in way that reflects the actual needs with the least possible distortion.

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