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Fuzzy optimization of acknowledged system of systems meta-architectures for agent based modeling of development

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Abstract

Acknowledged systems of systems (SoS) lie on a continuum between authoritarian central control and anarchy. The constituent systems are independent, with a life and purpose of their own. The systems require not only technical interfaces, but also social interactions, to create the SoS. A fuzzy optimization process may be used to select a desirable SoS configuration, but it may be unachievable due to the inability to persuade the systems to cooperate in the plan. Modeling the systems' internal decision processes could help understand how to design better SoS architectures. This research used generic, modular modeling processes to examine two proposed SoS architectures and the impact of degree of cooperation on the suitability of the achieved SoS.

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1. Introduction

One possible meta-architecture for systems of systems consists of the binary presence or absence of the potential participating systems, and their first order interfaces. An SoS manager's estimates of schedules and costs for developing interfaces, operations costs for systems, and performance indices for the systems are included in the model. Extra performance is presumed for the SoS if the system to system interfaces are used effectively. From the SoS manager's estimates and vision, a desired architecture in the form of requests to the systems for participation and development of interfaces is created. The SoS manager's vision includes a multiobjective optimization of the SoS architecture evaluated against several desirable attributes, with reasonable offers of funding and desired schedule to the individual systems that form the SoS. The main part of the model of this architecture is a simple, binary participation string[1].

In an acknowledged SoS, there is no enforceable mandate for the systems to cooperate in the SoS vision. Furthermore, each system may be assumed to be better informed on their own capabilities and problems than the SoS manager; they will likely have different concepts of the schedule and funding they will require, and performance they might be able to provide to the SoS. Using a variety of agent based negotiation models with a range of willingness to participate, different results for the achievable SoS architecture may emerge.

1.1. Acknowledged SoS

An acknowledged system of systems (SoS) consists of independent systems that cooperate for a higher purpose by contributing some of their capabilities to the SoS. The original missions and purposes of the systems usually continue, and the SoS purpose may have a lower priority than a constituent system[4]. However, the SoS could potentially deliver significantly higher performance than the systems could achieve by acting independently[4]. The SoS typically achieves this higher performance by improving the interfaces, or interoperability, between the individual systems[3]**.** Desired changes are minor, adding up to less funds or time than a new, dedicated system would require. If this were not the case, creating a new system would be the way to achieve the purpose. For a SoS where the interfaces between systems are achieved through communication links or transportation hubs, there is an additional feasibility constraint on the architecture. That is, both interfacing systems must have a common communication link or an ability to use a transportation hub. This commonality is so obvious that it is frequently ignored in system descriptions, or simply assumed not to be an issue[6].

2. SoS meta-architecture description

The meta-architecture is a string X_i of binary participation digits {0,1} for each of *m* systems and each pairwise combination of systems to indicate an interface as shown in Figure 1.

X_1	X_2	X_i	…	X_m	$X_{1\ with\ 2}$	$X_{1\ with\ 3}$	$X_{1\ with\ m}$	$X_{2\ with\ 3}$	…	$X_{i\ with\ j}$	…	$X_{(m-1)\ with\ m}$
Systems					Interfaces							

Figure 1. Meta-architecture, or chromosome, of system and interface participation

The representation in Figure 1 is exactly equivalent to the upper triangular matrix form shown in Figure 2a. In Figure 2a, the systems along the diagonal and the interfaces between system *i* and system *j* are located in the normal matrix location at the i^{th} row and j^{th} column; the interfaces for the system on the diagonal in the i^{th} row are also in the i^{th} row. The column of interfaces associated with that system have already been described by the lower numbered systems' rows. The advantage of the triangular representation in Figure 2a is that it is more compact, and interfaces are easier to find than in the linear string form.