Mission-Oriented Optimization

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A major challenge present when evaluating or inferring the success of a given mission is a set of metrics and measures that are general enough to be easily understood while being specific enough to adequately discriminate subtle changes in mission parameters. Unfortunately, there is no metric, nor set of metrics, that are both general enough to encompass all possible types of mission parameters yet specific enough to adequately represent the human elements that contribute to potential mission success or failure. The following abstract for a proposed presentation at "NATO Specialist Meeting on Mission Assurance of Autonomous Unmanned Systems" summarizes some of our efforts and lesson's learned to get closer to a set of metrics and measures. Specifically, our goal is to converge on a better methodology for evaluating mission state, whether online, or pre-planned, with the intent to infer how well the network assets and requirements will support mission success.

The approach begins with the specification of Information Exchange Requirements (IERs). IERs specify sets of assets, capabilities of those assets, product types, their requirements, along with information producers and consumers. From there the system management tools compute all mission relevant configurations (Theater plans, Data plans, Asset definitions, Capability definitions, zone definitions, etc.). Once IERs have been specified we can then formalize the other mission relevant elements. The first area of concern is the definition and description of mission critical objectives along with a timeline of relevant events. Several open architectures exist which describes a mission as a set of tasks across the communication and mission plans. Within these plans each task describes the relevant activities and required capabilities. The second area of concern correlates the IERs with the open architecture plans. This connection provides a formal connection between the (1) mission activities, (2) relative priorities of individual information exchanges, and (3) competing objectives of those exchanges. The third area of concern describes all network assets, their configuration and capabilities.

Presumably, with these 3 areas described in a formal way, one can then correlate and compute whether or not the allocated network assets will be able to sufficiently support the described mission. However, with the many degrees of freedom in each area, along with the vast complexity of an even moderately sized mission (not to mention the human element) this computation quickly becomes intractable. Instead, emulation or simulation of the given mission, its elements and applications along with systems under test provides a log of the performance of each individual information exchange.

The challenge now is the construction of metrics and measures that will indicate how well the mission needs were met, along with indication of increased or decreased performance of subsequent emulation with different mission parameters. One such metric is the IER Success-Rate (ISR). The ISR provides an aggregate or instantaneous metric on (0,1) that measures the rate to which mission relevant information exchanges are meeting their specified requirements. Additional supporting measures like Traffic efficiency, SA accuracy, Update Delay along with others have served as excellent indicators of the underlying factors that lead to a measure ISR.

To provide a bit more color, we will now describe how ISR computes the level to which information exchanges are meeting their specified requirements. ISR uses these a set of aggregated metrics to provide a library of *metric utility components (MUC)* denoted u_j^X with $X \in \{E, R, C\}$. MUCs quantify how well an aggregated performance metric adheres to a preferred operating criterion. In general, we assume that a MUC is a mapping between an aggregated performance metric formed by functional composition to a real number between 0 and 1. That is,

$$u_j^X = \mathrm{SIG}\left(m_j^X(\mathbf{d}, \mathbf{r}); \theta_j\right) \quad \textbf{(1)}$$

where $\mathrm{SIG}(\cdot)$ is a sigmoid function whose shape is defined by θ_j. The MUC shape is determined by the preferred operating criteria of the corresponding information exchange performance metric.

For example, consider a file transfer, a MUC will consist of a log-scaled linear line between a best-case and minimum required goodput. The resulting MUC curve becomes piecewise logarithmic when plotted in linear scale. These bounds are derived from a maximum tolerable delivery time, a best-case preferred delivery time, and the size of the file being transferred.

ISR then asserts, $\mathcal{U}_k \ \forall k \in \{1, \ldots, M\}$, across all information exchanges using collections of MUCs with specific shape parameters. This function is composed of the product of the corresponding MUCs, parameterized by information exchange instances at each timestep, and has the following form.

$$\mathcal{U}_k(\mathbf{d}, \mathbf{r}) = \prod_{j \in \mathcal{J}} u_j^{(x_j)} \left(m_j^{x_j}(\mathbf{d}, \mathbf{r}); \theta_j\right) \quad \textbf{(2)}$$

Given this formulation, we have a metric that provides at a high-level indication of how well information exchanges are succeeding and where mission needs were met or not. While at the same time organized in a hierarchical manor that allows for investigation of the cause of mission, task, or information successes or failures.