The Epoch Syncopation Framework: Analyzing System Change Options in Cost and Schedule Domains

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Motivation

The early phases of tradespace exploration require careful consideration as they will propagate a significant impact to the ultimate success or failure of the system. Planning for uncertainty, both in needs and in context, as early as the tradespace exploration stages allows designers to create a system that provides value in a multitude of epochs at a cost and schedule that meets their constraints.

Goal

The goal of the research team is to create a framework that allows for analysis in both the cost and schedule domains that can identify valuable designs, path enablers, and decision strategies. The ESF will be able to scale to handle new tradespaces, epoch variables, distributions of epoch variables, decision strategies, and the output of new metrics.

Initially, the ESF will be demonstrated on a familiar data set, the orbital transfer vehicle (a.k.a. "Space Tug"). Additional studies will look at applying the ESF to other data sets, including systems of systems (SoS).

Concept Demonstration: Space Tug Case Study

Design Space

<table>
<thead>
<tr>
<th>Design Variables</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manipulator Mass (kg)</td>
<td>[300, 1000, 3000, 5000]</td>
</tr>
<tr>
<td>Propulsion System</td>
<td>Storable BiPropellant, Cryogenic, Electric, Nuclear</td>
</tr>
<tr>
<td>Fuel Mass (kg)</td>
<td>[30, 100, 300, 600, 1200, 3000, 10000, 30000]</td>
</tr>
<tr>
<td>DfE (% Mass Penalty)</td>
<td>[0, 20]</td>
</tr>
</tbody>
</table>

Epoch Variables

- Technology Level
  - Future Tech or Present Tech
  - Mean change time: 5 years
- Decision Strategies
  - Strategy 1: Change to highest utility design at all times
  - Strategy 2: Change anytime utility falls below predefined threshold
  - Strategy 3: Change only if below threshold at predetermined points in time

Results

- Lifecycle cost
  - Decreased as change threshold decreased, decreased as generation length increased
- Time-weighted accumulated utility
  - Increased as change threshold increased, decreased as generation length increased

Next Steps

Expand Scope

- Addition of a budget variable, the size of which determines available (and allowed) transitions
- Develop more decision strategies for analysis
- Output more metrics and indicators concerning performance
- Expand stochastic options in Markov probability era constructor
  - Look at options beyond Poisson random variable
  - Consider having the transition matrix become a function of time elapsed between changes

More Case Studies

- Maritime Security SoS case application
- Satellite Radar System, X-TOS, and other existing data sets

For more information, please visit: http://seari.mit.edu