Automatic Design of Reliable Systems by Cooperation of Numerical Optimization and Logic

Our research
- We achieved **automatic & efficient discovery** of reliable gas turbine system designs
- **Without mathematical re-modeling** of the system, our method directly uses a realistic (black-box) simulators as a model
- The key enabler is the **logical structure** of requirement specifications

Advantage
- Design process is automated and the result is **comparable to a manual tuning by human expertise**, in our case study
- The method is generally applicable to black-box control systems. Expected to be useful in **various fields of system design** such as autonomous driving

Background & Goals

**Background**: Quality assurance of black-box system

Finding an input such that the corresponding output satisfies all of requirements

![Input-output relationship](image)

- Often there appears trade-off, so careful balancing is required

**Goals**: Exploiting domain knowledge to effectively find a desirable design

By quantifying how “nearly satisfying” the output is, system design is translated into numerical optimization.

To solve it in realistic time frame, we need to adress:
1. Broad search space (30 dim)
2. Stuck in local optimum or plateau

Method

**Multiple constraint technique**
- We treat some of violation degrees as “constraint functions”
- Each violation degree is seperately evaluated in scale-invariant way

**Area modality**
- Counterintuitively, these signals are equally valued in conventional framework of STL formula evaluation
- We introduced new modality into STL system to reflect the time-and-value violation degree

Result

Our method automates the design process that costs 7 person-days of manual tuning

<table>
<thead>
<tr>
<th></th>
<th>Quality</th>
<th>Automation</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Manual</td>
<td>+</td>
<td>no</td>
<td>—</td>
</tr>
<tr>
<td>Existing tool</td>
<td>—</td>
<td>yes</td>
<td>+7(7 person-days)</td>
</tr>
<tr>
<td>Our method</td>
<td>++</td>
<td>yes</td>
<td>+3(3 hours)</td>
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![Manual vs. Our Method](image)

The resulting behavior is comparable to the one by human expertise