Decomposition-based Optimization for Complex Systems
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Introduction

- Many products involve various knowledge in different disciplines. They are too complex to be addressed by a single designer or even a single design group.
- One approach for solving the complex problem is to divide the product design task into smaller and more manageable design problems, which is called decomposition.
- Decomposition process consists of two steps:
  1. Partitioning a system into smaller elements that can be designed autonomously
  2. Coordination of individual elements towards an optimal and consistency system

This research focuses on making decomposition-based optimization of complex system more accurate and efficient.

- An illustrative example:

![Diagram](Image)

For this example, we tried:
- 4 partition methods: decom1, 2, 3, 4
- 3 coordination methods: Augmented Lagrange Coordination: ENMOM, INMOM, ADMOM

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Partition

Traditional: Discipline based partition

Component based partition

Proposed: hybrid partition

Coordination

w – penalty weights used to drive the inconsistency between different sub-problems to zero

Traditional:

\[ w_i = \begin{cases} w^+ & \text{if } |\mathbf{f}_i| > |\mathbf{f}_j| > 1 \\ w^- & \text{if } |\mathbf{f}_j| > |\mathbf{f}_i| > 1 \\ 0 & \text{if otherwise} \end{cases} \]

where \( w^+ > 0 < w^- \)

w is always increasing

Proposed:

\[ w^+_i = \begin{cases} w^+ & \text{if } |\mathbf{f}_i| > |\mathbf{f}_j| > 1 \\ w^- & \text{if } |\mathbf{f}_j| > |\mathbf{f}_i| > 1 \\ 0 & \text{if otherwise} \end{cases} \]

where \( w^+ > 1 > w^- \)

w can either increase or decrease

Numerical tests

Test problem:
- Optimization objective: the footprint area A
- Constraints: design requirements in the four disciplines
- Design variables: Geometry & circuit variables
- Reference solution: Through solving the problem as a whole, without decomposition

More experiments have been conducted on other engineering problems, such as portal frame design and Golinski's speed reducer design problems

Conclusions

1. Explored the effects of different partitions and coordination on optimization.
2. Proposed two kinds of hybrid partition.
3. Solved two hybrid partitions with good solution accuracy.
5. Verified the efficacy of the proposed update strategy.

Future work

1. Study the convergence property of the proposed update from the mathematical perspective.
2. Extend the proposed weight update to other coordination methods.

Flow chart:

Initialization

Solve sub-problem 1

Solve sub-problem 2

Solve sub-problem n

Update

Converged

Yes

End

Proposed partitions:

<table>
<thead>
<tr>
<th>Optimization(mm²)</th>
<th># of Iters</th>
<th>Max_vari_error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid 1 90%</td>
<td>Min</td>
<td>459</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>538</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>769</td>
</tr>
<tr>
<td>Hybrid 2 90%</td>
<td>Min</td>
<td>367</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>434</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>589</td>
</tr>
</tbody>
</table>

Proposed coordination:

<table>
<thead>
<tr>
<th>Traditional</th>
<th>Proposed update strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective(mm²)</td>
<td># of Iters</td>
</tr>
<tr>
<td>Max</td>
<td>0.0891/10.7%</td>
</tr>
<tr>
<td>Mean</td>
<td>0.0901/11.6%</td>
</tr>
<tr>
<td>Min</td>
<td>0.0910/12.8%</td>
</tr>
</tbody>
</table>

Results:

Future work:

1. Study the convergence property of the proposed update from the mathematical perspective.
2. Extend the proposed weight update to other coordination methods.