Deep Co-design: Streamlining the Electro-Thermal Design Process for Future Automation

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INTRODUCTION

- Design teams are increasingly facing complex problems necessitating highly-integrated and interdisciplinary collaboration
  - Example: thermal solutions for power electronics needed to meet the demand for electric vehicles (EVs) and consumer electronics
- Electro-thermal practitioners have employed a “co-design" approach [1]
- Traditional co-design falls short of the ideals of simultaneous collaboration and rich communication between disciplines

OBJECTIVE

Draw on collaboration principles from design and systems engineering to propose a new concurrent design framework:

"Deep Co-design"

	Traditional Co-design	Deep Co-design
Nature of Collaboration	**Collaboration happens sequentially [2]** • Infrequent sharing of domain information • Sequential optimization of sub-systems • Freezing of design architecture of one domain to inform the other	**Collaboration happens simultaneously** • Frequent sharing of domain information • Concurrent optimization of sub-systems • Co-development of design architectures
Fidelity of Domain Models	**Low fidelity models** • Geometric constraints imposed [3] • Late iterations cause high costs [4]	**High fidelity models** • No geometric constraints • Integrated models reduce costly iterations

RESULTS

Traditional Co-design

			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Electrical	Electrical specifications determined	1													×	×
	Analytical calculations of electrical system	2	•		•	•	•			×				×	×	×
	Simplified electrical models to determined system losses	3		•		•	•								×	×
	Designing of printed circuit board (PCB)	4			•		•								×	×
	Determine distribution of components on the PCB	5				•		•							×	×
Thermal	Select appropriate thermal management system	6					•								•	×
	Generate CAD of system architecture	7						•	•	•	•	•	•	•	•	×
	Import CAD into Spaceclaim, design modeler, or COMSOL	8							•		•	•	•	•	•	×
	Generate computational fluid dynamics (CFD) ready CAD	9								•		•	•	•	•	×
	Import electrical CAD into thermal model	10									•		•	•	•	×
	Multi-physics simulation setup	11										•		•	•	×
	Solve simulation	12											•			
	Post process and evalulate results	13												•		
Build	Fabricate system and test	14													•	

Deep Co-design

			1	2	3	4	5	6	7	8	9	10	11	12
Integrated Electro-thermal	Electrical specifications with consultation	1												
	Construct numerical model of electrical system and assess preliminary results	2	•		×				×			×		×
	Designing of printed circuit board (PCB)	3	•	•					×			×		×
	Design thermal management system	4	•	•	•				×			×		×
	Generate optimized thermal design in 2D	5	•	•	•	•			×			×		×
	Generate CAD of system architecture in 3D	6					•		×			×		×
	Conduct 3D high-fidelity simulation of thermal design and assess results of simulation	7						•				×		×
	Incorporate high-fidelity thermal model into electrical model	8							•			×		×
	Solve electro-thermal simulation until the desired design criterion is met	9								•		×		×
	Post process and evalulate results	10									•			×
	Parallel electrical and thermal system build	11										•		×
	Test system, validate simulations	12											•	

FUTURE AUTOMATION

Categorize the integrated (electro-thermal) design tasks into the five design stages

Identify the role/contribution of designers and computational supports in each category

Select, develop and implement apt automation method to further reduce time-to-develop at the category/task-level

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