

# Human-Supervised Deep Generative Design Framework for Conceptual Design of Product Shapes

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## Background

- **Deep generative design (DGD) methods** using deep generative models (e.g., GANs)
- The **emulative learning behavior** of DGD methods could **essentially hinder creative designs**
- Current methods focus on **special neural network architectures**
- **Human inputs** are **less emphasized**

Artificial Intelligence  
Creativity  
Human

## Research Questions

- How to **integrate human factors and intelligence** in a DGD process?
- With the establishment of the human-supervised DGD framework, what could the **co-evolution** of design creativity between **humans and AI** look like?

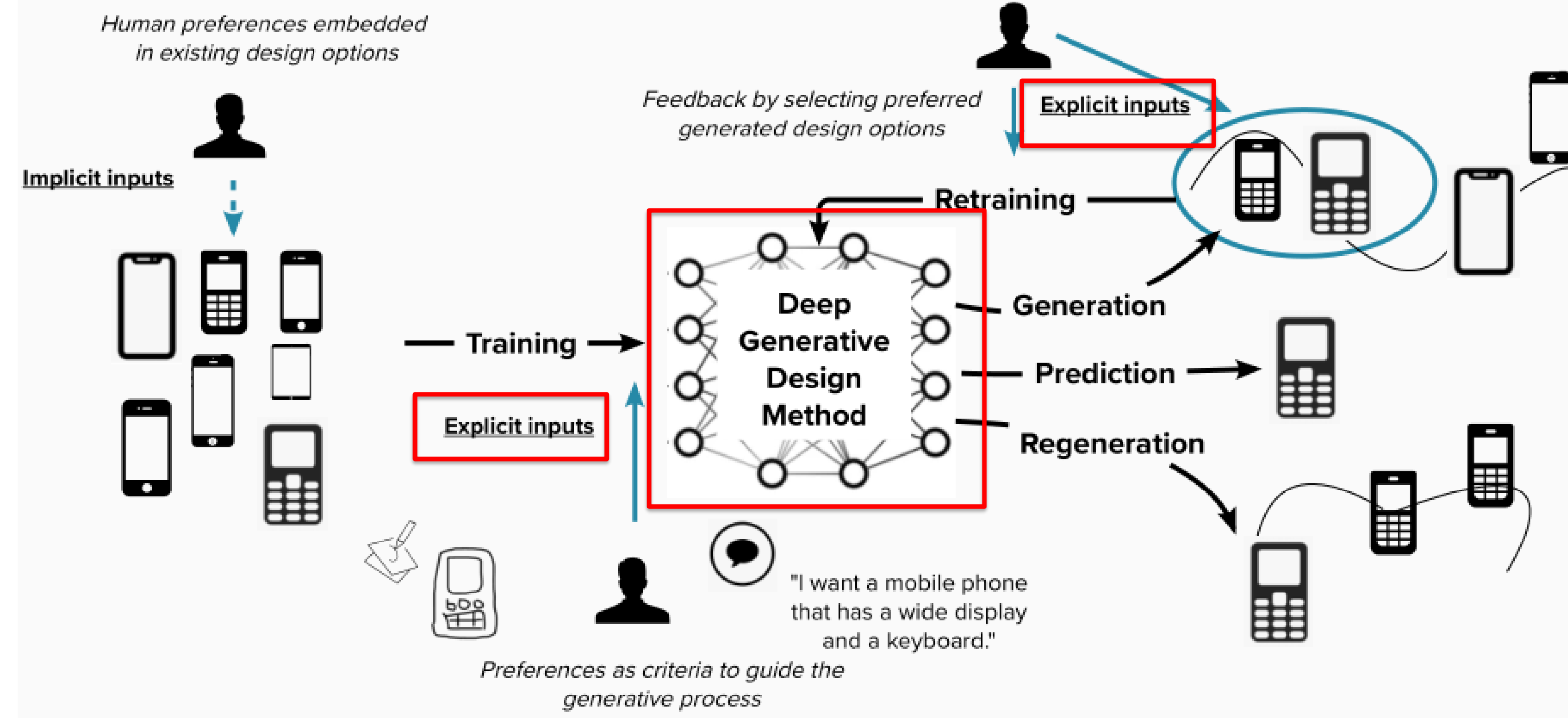
## Research Objective

To build a **DGD framework** to **encourage design creativity** by

- constructing **special neural network architectures**
- by **explicitly taking human factors and intelligence** (e.g., needs and aesthetic preferences) in the loop

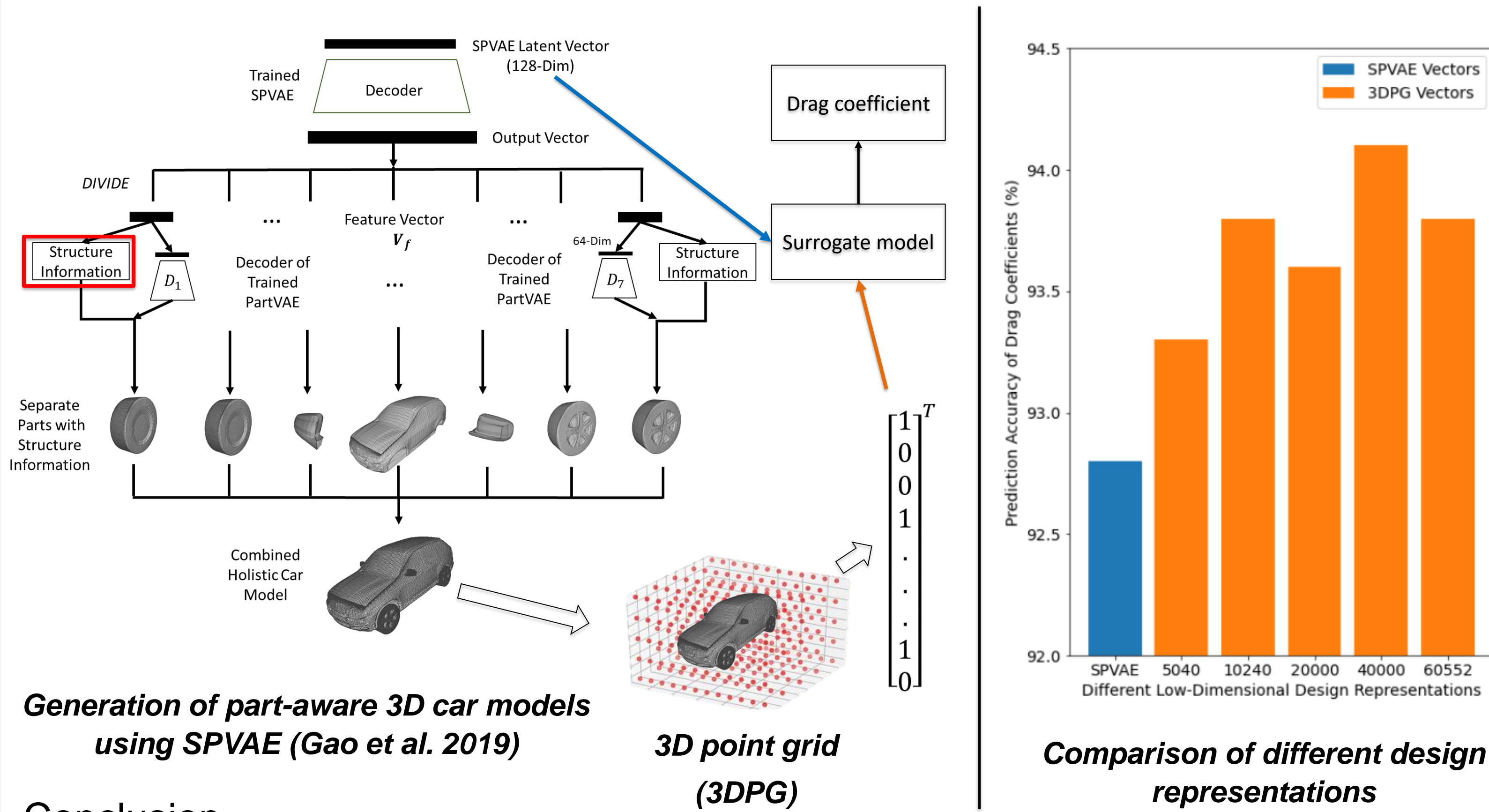


Human-AI  
collaboration



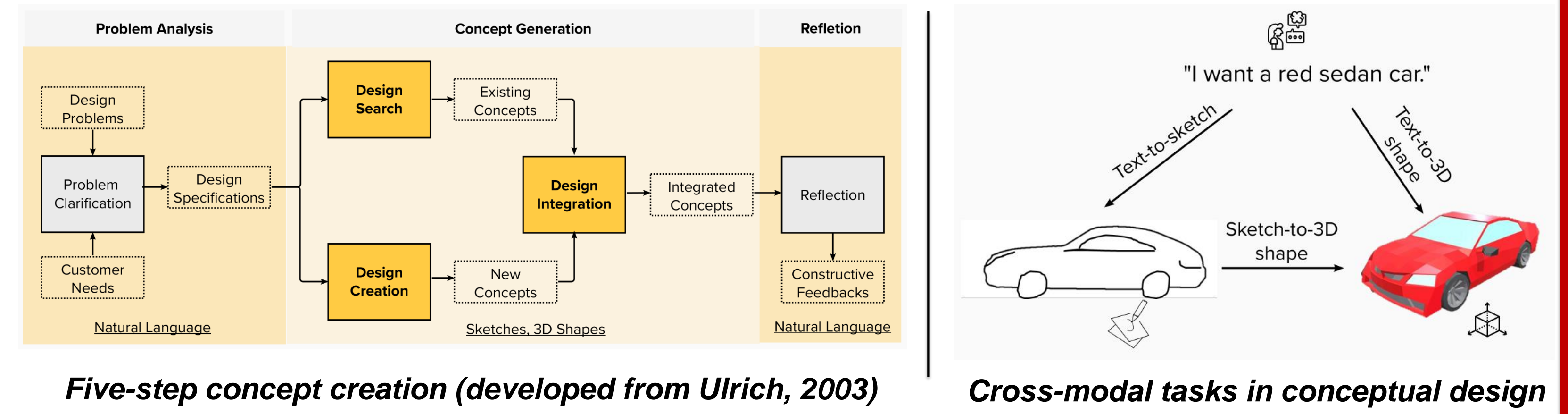
The human-supervised deep generative framework for conceptual design

## Major Activity 1: Data-Driven Drag Prediction of 3D Shapes in Part-Aware Deep Generative Design



- Conclusion
- **Structure information** in the latent vectors can **affect their usage** for drag prediction.
  - Alternative ways, such as **3DPG vectors**

## Major Activity 2: Deep-Learning Methods of Cross-Modal Tasks for Conceptual Design of Engineered Products: A Review



Five-step concept creation (developed from Ulrich, 2003)

Cross-modal tasks in conceptual design

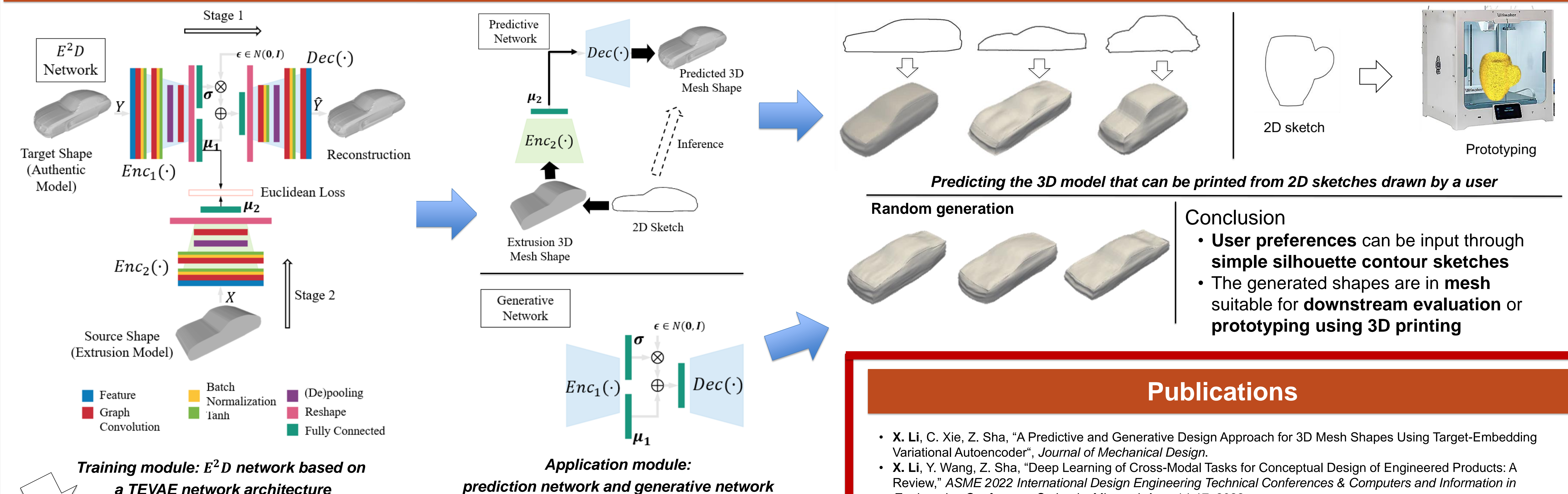
Cross-Modal Tasks	Article
Text-to-3D shape retrieval	2
Text-to-3D shape generation	6
Text-to-sketch generation	4
Sketch-to-3D retrieval	19
Sketch-to-3D generation	18
Cross-modal design integration	5

Reviewed articles

Conclusion

- Opportunities: **incorporate human inputs**
- Challenges
  - **Datasets: engineering performance and manufacturability**
  - **Complex system design**
  - **3D representations**
  - **Generalizability**

## Major Activity 3: A Predictive and Generative Design Approach for 3D Mesh Shapes Using Target-Embedding Variational Autoencoder (TEVAE)



## Publications

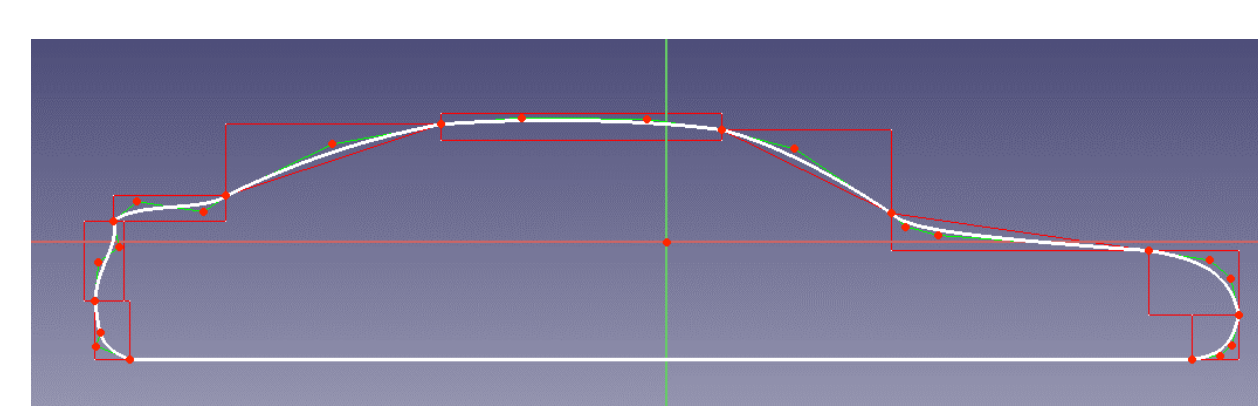
- X. Li, C. Xie, Z. Sha, "A Predictive and Generative Design Approach for 3D Mesh Shapes Using Target-Embedding Variational Autoencoder", *Journal of Mechanical Design*.
- X. Li, Y. Wang, Z. Sha, "Deep Learning of Cross-Modal Tasks for Conceptual Design of Engineered Products: A Review", *ASME 2022 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference*, St. Louis, Missouri, Aug. 14-17, 2022.
- X. Li, M. H. Goldstein, O. Demirel, Z. Sha "Exploring Generative Design Thinking for Engineering Design and Design Education," *2021 ASEE Midwest Section Conference*, Virtually hosted in Fayetteville, AR, Sep. 13-15, 2021.
- M. H. Goldstein, J. Sommer, N. T. Buswell, X. Li, Z. Sha, O. Demirel, "Uncovering Generative Design Rationale in the Undergraduate Classroom," *2021 IEEE Frontiers in Education Conference (FIE)*, Lincoln, Nebraska, Oct. 13-16, 2021.
- J. Clay, X. Li, M. H. Rahman, D. Zabelina, C. Xie, Z. Sha, "Modeling and Profiling Student Designers' Cognitive Competencies in Computer-Aided Design," *The 23rd International Conference on Engineering Design*, August 16-20, 2021, Gothenburg, Sweden.
- X. Li, C. Xie, Z. Sha, "Part-Aware Product Design Agent Using Deep Generative Network and Local Linear Embedding", *The 54th Hawaii International Conference on System Science (HICSS)*, January 5-8, 2021, Kauai, HI.

## Acknowledgment

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## Future Work

- Develop an interactive **user interface** for sketch-to-3D generation by allowing simple sketch input
- Explore **text-related cross-modal design methods** using natural language processing techniques
- **CAD data**
- Conduct **human subject experiments** to better understand human-AI interaction
- Build and disseminate **cross-modal design datasets** with **engineering performance and manufacturability**



A preliminary user interface using Bezier curve based on FreeCAD Python API