The Potential of Generative AI for Systematic Engineering Innovation

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This research explores the use of generative AI for systematic engineering innovation, employing Multidirectional Prompting (MDP) to enhance idea generation and evaluation. While AI tools like ChatGPT and Claude boost productivity and diversity in solutions, they often overestimate feasibility and show biases. The study underscores the importance of human-AI collaboration and calls for improvements in AI self-evaluation and interaction frameworks for practical engineering applications.

1 Introduction

Key research areas currently include:
- Development of Generative Models for creative output.
- Human-AI collaboration in complex innovation tasks.
- Integrating AI with TRIZ and other innovation methodologies.
- Prompting Techniques for enhanced creativity.
- Practical implementation for engineering applications.
- Assessment and selection of robust and promising ideas by AI.

2 Objective

Explore generative AI's role in enhancing **engineering design problem solving** and innovation

Applications of AI for inventive problem solving in engineering design compared to other types of problems are characterized by:
- need for high precision of generated solutions, and for a wide range of scientific and technical knowledge areas,
- rigorous validation and selection of useful solutions,
- detailed documentation of solutions, ideally drawings in CAD,
- practical constraints like manufacturability and economic feasibility, novelty and sustainability etc.

3 Methodology

- **Interactive Problem Formulation**
  Define the problem collaboratively with the AI.

- **Multi-Directional Prompting**
  Random: Applying multiple solution principles simultaneously.
  Systematic: Sequentially applying selected solution principles.
  Collaborative: Using multiple AI tools to enhance solution diversity.
  Multi-problem: Addressing prioritized sub-problems.

- **Inventive Concept Development**
  Combine ideas into comprehensive solutions.

4 Results

Autonomous Solution Concept Created by Generative AI

- A somewhat human-like behavior: AI-generated ideas and concepts often diverge from given elementary solution principles.
- Unexpected: ideas (e.g., magnetic or thermal concepts) appeared despite prompts lacking those principles.
- Insight: AI struggles with combining multiple ideas into comprehensive solutions without guidance.
- Not Invented Here Effect: AI rates its own concepts higher in novelty and usefulness than those from other LLMs or humans.

Key Observations and Recommendations

- Bias and Overengineering: AI shows hidden biases, may create too complex solutions, and often overestimates its own ideas.
- Mixed AI Teams: Different AI tools (e.g., ChatGPT, Gemini) can complement each other.
- Technical Drawings: Current AI capabilities struggle with generating precise technical drawings for practical use.

5 Analysis

Nr.	Survey question: How do you rate the following aspects in application of generative AI …	Mean values 17 participants
1	contribution of AI to increasing your personal inventive CREATIVITY?	7.1
2	performance of AI in terms of the ideas USEFULNESS?	6.1
3	performance of AI in terms of the ideas NOVELTY?	6.7
4	performance of AI in terms of the ideas FEASIBILITY?	4.7
5	overall performance of AI in the solution concept development phase?	6.1
6	level of detail of the solution concepts proposed by the AI, so that designers can quickly implement a solution?	4.7
7	accuracy of the evaluation of solution concepts by AI?	4.2
	Scale: 1 (very low) – 10 (very high)	

Survey on the performance of generative AI

- Positive Impact on Creativity:
  AI effectively enhances creativity among participants.

- Moderate in Usefulness and Novelty:
  AI performs reasonably well in idea usefulness and novelty.

- Challenges in Feasibility and Evaluation Accuracy

6 Conclusion

- Generative AI and MDP: Multi-directional prompting (MDP) effectively boosts idea diversity and innovation potential in engineering design.
- Strengths and Challenges: While AI enhances creativity and generates novel ideas, it struggles with feasibility and self-evaluation accuracy, necessitating human oversight.
- Importance of Human-AI Collaboration: Combining AI's generative capabilities with human judgment is key to achieving practical, viable solutions.

7 Future Research

- Focus on refining AI models to improve self- assessments of ideas and solution concepts
- Development of frameworks for better human-AI collaboration
- Enhancing models' capabilities to produce technically precise solution concept designs