

Generative AI in Engineering Applications

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Agenda

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- 2 Engineering with Knowledge Modelling and GenAI**
- 3 Hybrid Approach: Joining GenAI and Engineering Automation**
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Introduction and Motivation

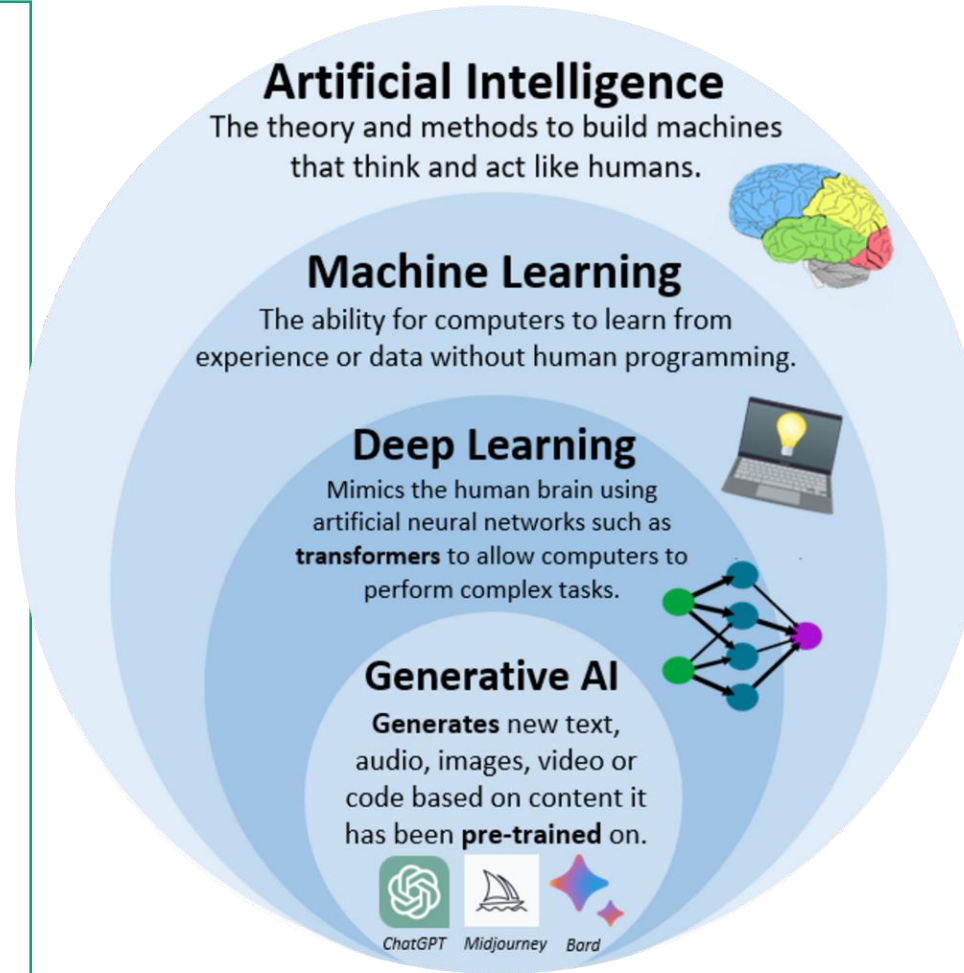
Definitions

Digitalization:

- Intelligent, networked components and systems
- Communication and cooperation between these and people

Artificial intelligence:

- Technologies to supplement/enhance human abilities in analyzing, deciding and acting [1]
- Automation of intelligent behavior and machine learning [2]



Added value

Digitalization:

- Self-organization and optimization of circular value creation networks across all phases of the product life cycle

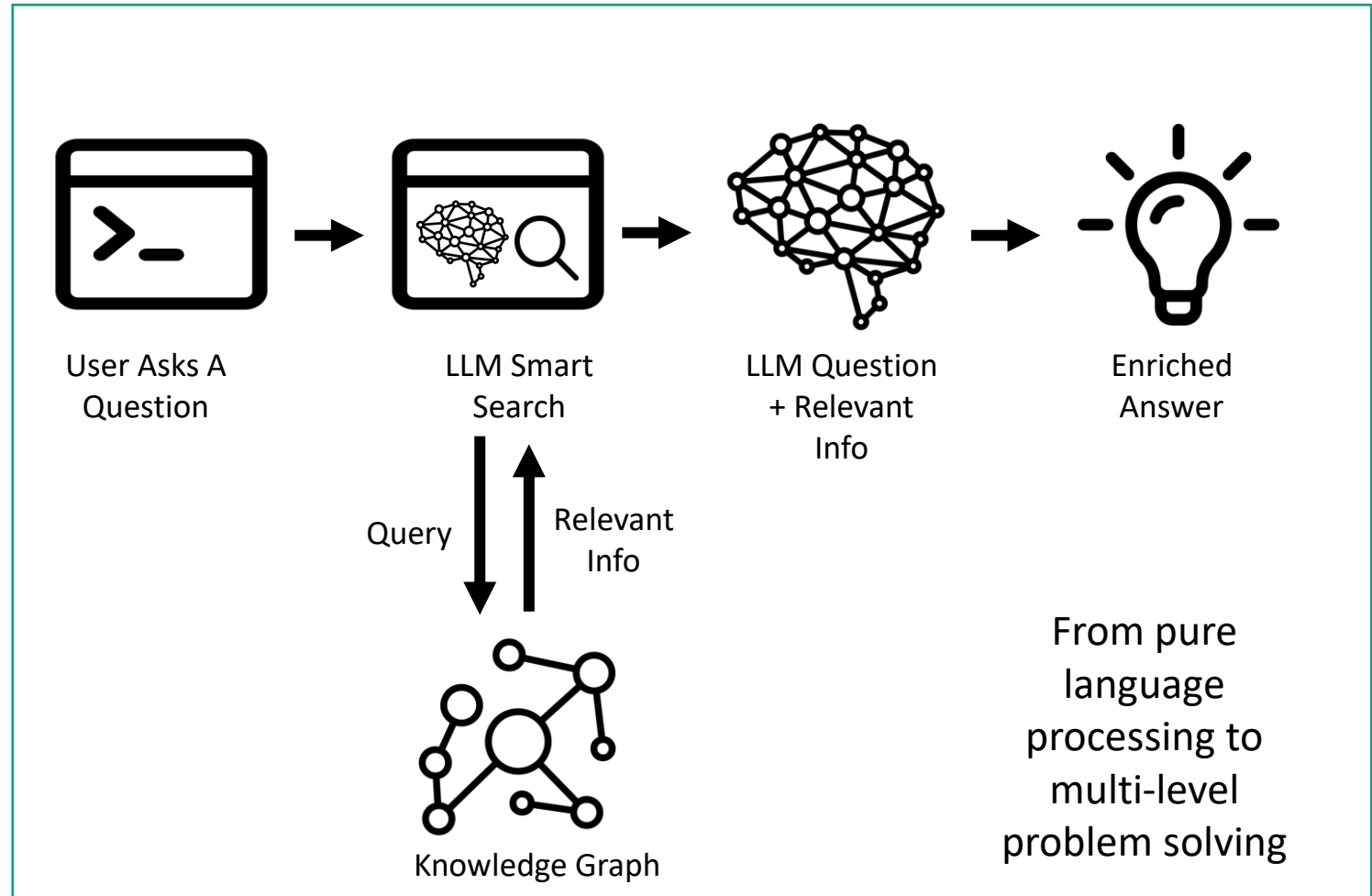
Artificial intelligence:

- Ability of (technical) systems to:
- human-like and intelligent behavior [3]

Introduction and Motivation

RAG with knowledge graphs

- Use of existing specific knowledge from knowledge graphs
- Further processing of relevant information from knowledge graph after query by LLM
- Expl. Knowledge representation and reproducible query
- Interface to all graph technologies (ontologies, reasoning, ...)



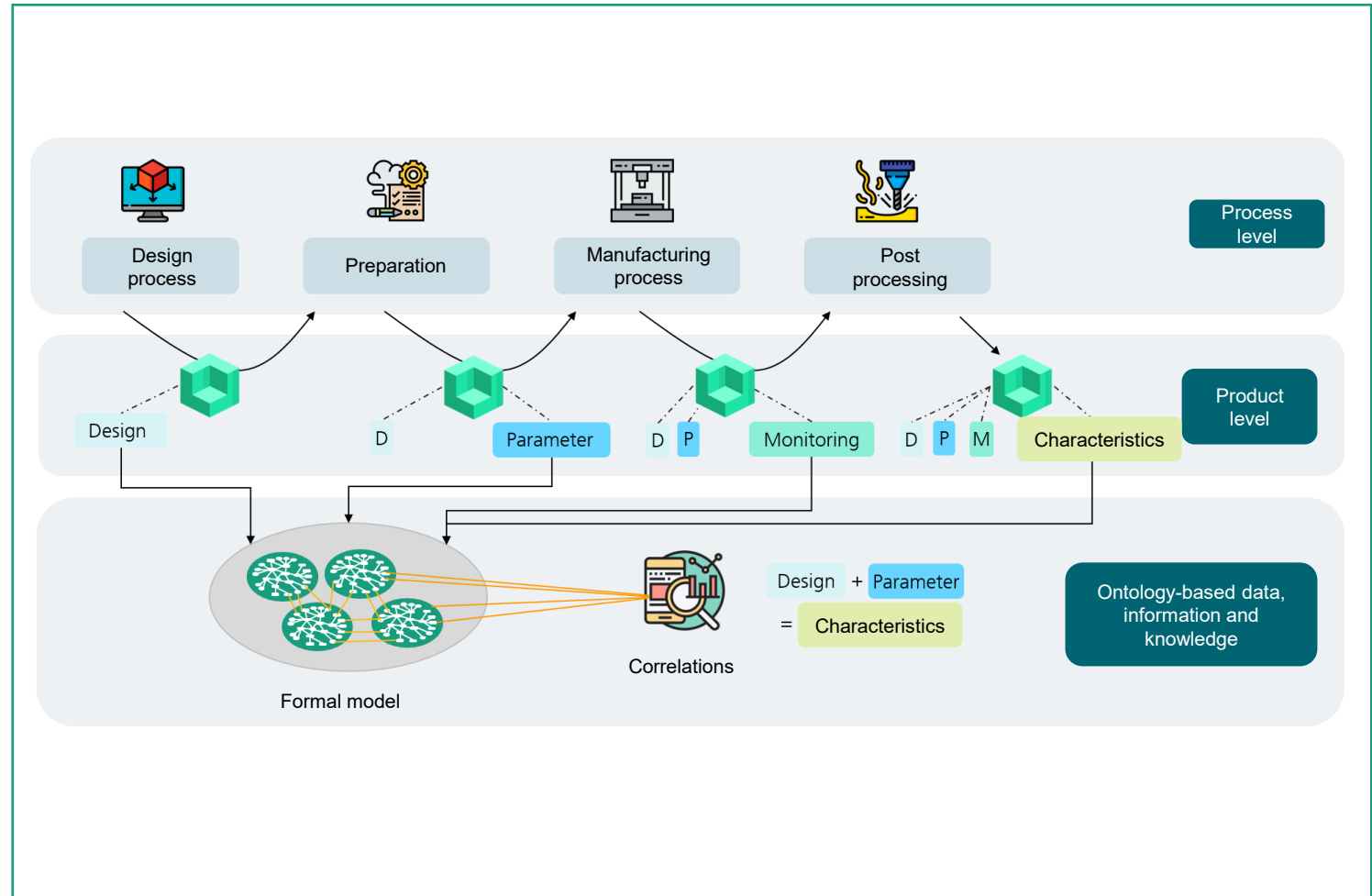
Source: according to Maximilian Holland 2023, Fraunhofer IGCV

RAG: Retrieval Augmented Generation
LLM: Large Language Model

Engineering with Knowledge Modelling and GenAI

Knowledge Graphs

- Used to formalize heterogeneous sources of information.
- Analyzed by humans due to its semantics and by computers due to its data structure
- The formalized data/information/knowledge can be retrieved for specific use cases (e.g. machine learning)



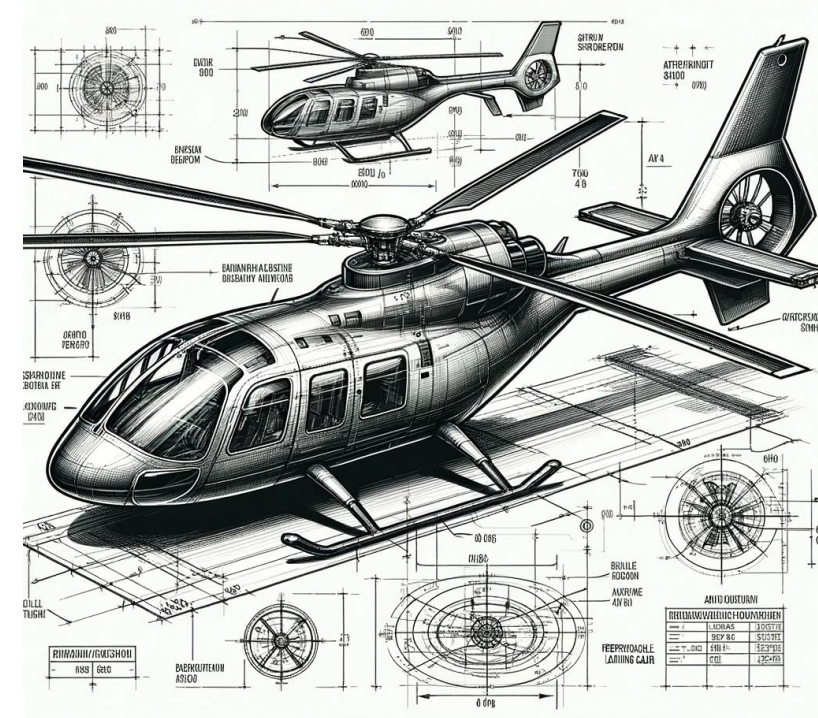
Engineering with Knowledge Modelling and GenAI

Prompt: "Let's design a helicopter for a 800kg payload. Calculate the main parameters of a possible design configuration. Make assumptions where necessary."

AeroPulse HX800

Key Aspect	Description
Payload and Range	Maximum payload of 800 kg; range of 400 km (max payload) to 560 km (no payload)
Rotor System and Size	Four-blade main rotor; rotor diameter of 10.5 meters
Engine and Power	Engine with approximately 433 horsepower
Airframe and Aerodynamics	Lightweight, robust design; streamlined fuselage with retractable landing gear
Operational Versatility	Suitable for cargo, medevac, and passenger services; versatile for various environments

generated with SkyMaster AerospaceGPT / GPT-4, **data not verified**.



generated with SkyMaster AerospaceGPT / DALL-E

- Generative models can create **text, images** and **other data** based on **prompts**
- Results are based on **patterns** learnt from **training data**

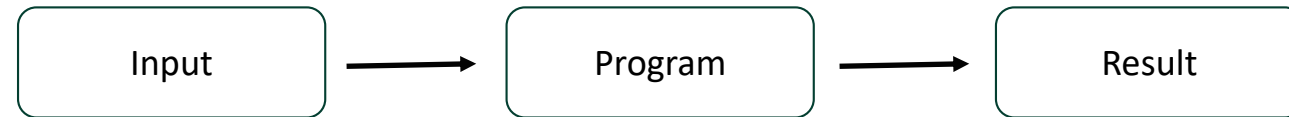
Hybrid Approach: Joining GenAI and Engineering Automation

Agent-based Planning

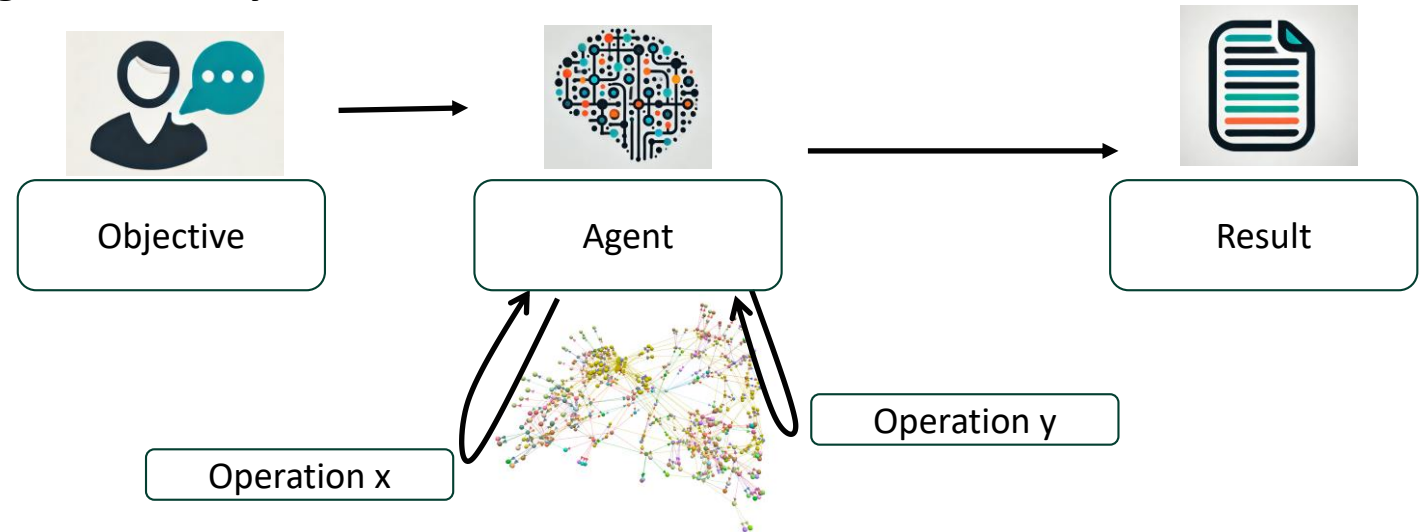
Large Language Models (LLM)

- (Appear to) have reasoning capabilities and intuition
- Can act as agents, executing multistep solutions
- Powerful LLMs have become available since end of 2022, led by OpenAI

Process planning software



Agent-based systems



Hybrid Approach: Joining GenAI and Engineering Automation

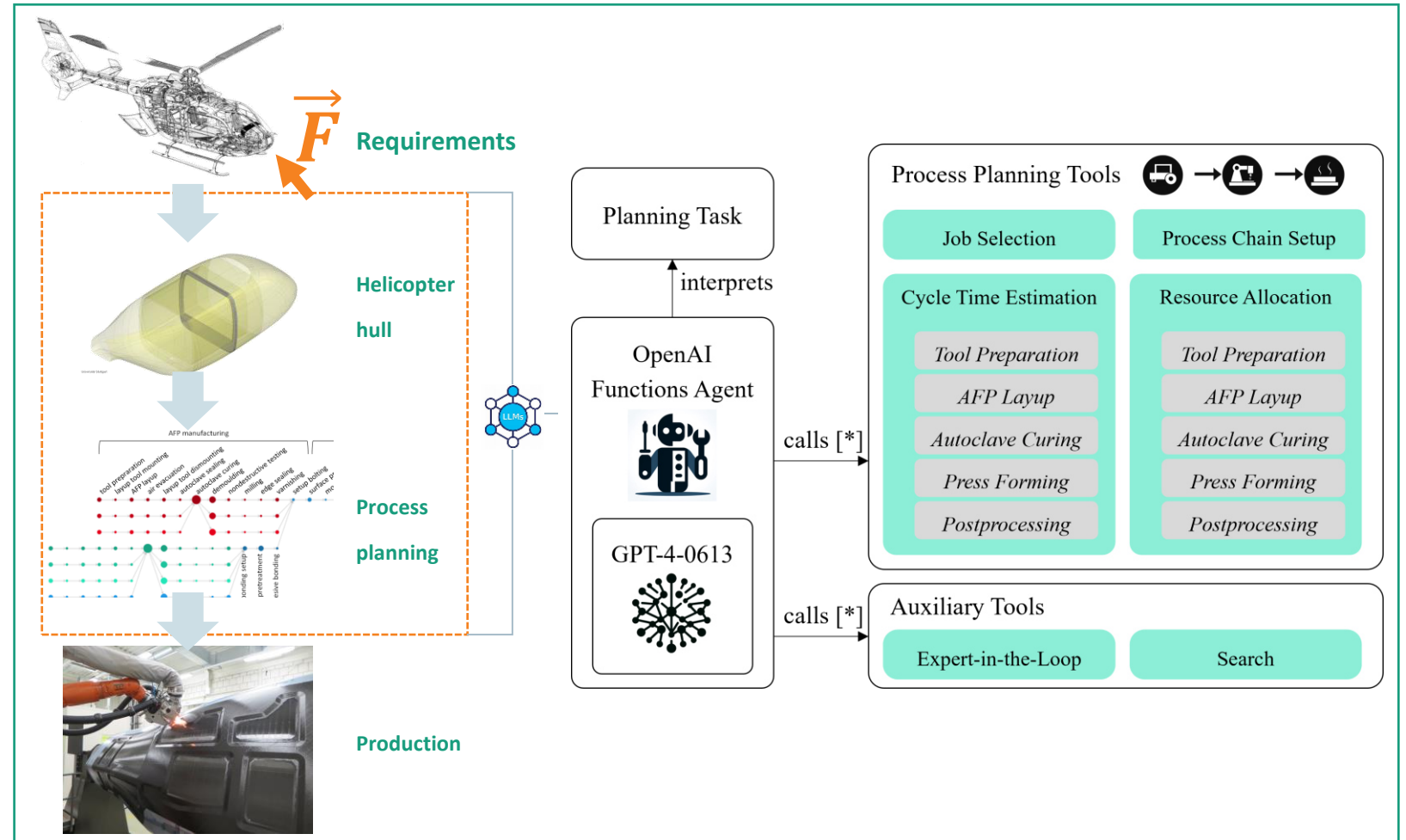
Agent-based Planning

OpenAI Functions Agent:

- Agent implementation in the LangChain framework
- Can use different LLMs (e.g. GPT-4-0613)

Process Planning Tools

- Implementation of process planning knowledge
- Perform individual steps of process planning
- Implemented in python



AFP: Automated Fibre Placement

Source: Holland, M. et al 2023: Model-driven Approach for integrated Design and Process Planning of Fiber Composite Aerostructures, Konferenzbeitrag, SAMPE 2023

Hybrid Approach: Joining GenAI and Engineering Automation

Use Case – Expert-in-the-Loop / Web Search

Agent-based Planning

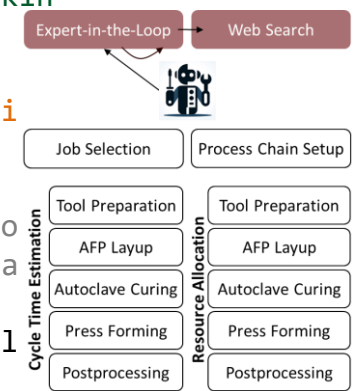
- Agent gathers missing information from the user and web
- After completing the required information, process planning tools are executed
- Increases adaptivity and robustness of the planning system

Task: How long does it take to manufacture a 3x2m composite skin panel? Search for missing information.

Agent: What is the thickness of the laminate for the composite
User: The laminate consists of 8 plies of M21 prepreg. Ply thickness is publicly available.

Agent: Invoking: `web_search` with `{ 'query': 'M21 prepreg ply thickness' }`
Return: “...The studied material in this research is a unidirectional HexPly® M21/34%/UD194/IMA-12K, made of M21 epoxy resin and carbon fibers with a nominal cured ply thickness of 0.184 mm...”

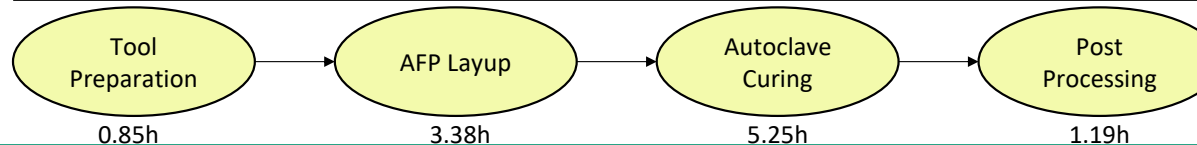
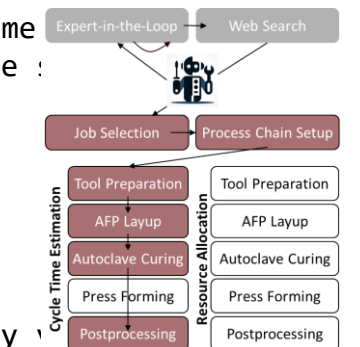
Agent: What is the average fiber orientation of the laminate plies?
User: 0°.



Agent: [...] (calls job selection, process chain_setup, cycle time estimation, resource allocation)
Agent: The total estimated time to manufacture a 3x2m composite skin panel is approximately:

- Tool Preparation: 0.85 hours
- AFP Layup: 3.38 hours
- Autoclave Curing: 5.25 hours
- Post Processing: 1.19 hours

This gives a total of approximately 10.67 hours. Please note that these are estimated times and actual times may vary.



AFP: Automated Fibre Placement

Hybrid Approach: Joining GenAI and Engineering Automation

Use Case – GPT & Design Language

Agent-based Planning

- Using LangChain framework, LLM and Design Language (e.g. DC43)
- Creating a CAD model and variations (e.g., 5 rotors)

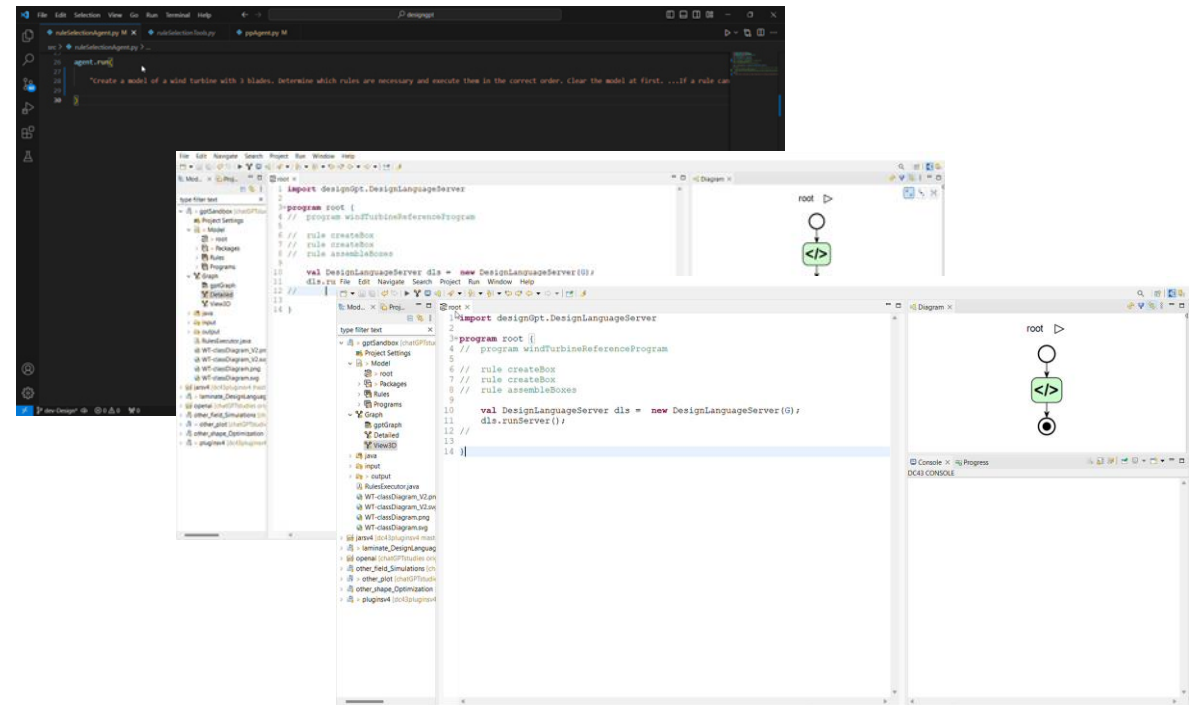
Prompt

Large Language Model

controls

Design Cockpit 43

“Create a model of a wind turbine with 3 blades. Determine which rules are necessary and execute them in the correct order. Clear the model at first. ...If a rule cannot be executed, you have to execute another rule first. Exit after calling 10 tools at maximum.”



Conclusion

GenAI in Production

- Generative AI creates text, images etc. based on user prompts
- Off-the-shelf models (e.g. ChatGPT) offer basic engineering skills
- Combination of GPT engineering techniques (e.g. Design Cockpit 43) is promising
- Solution space is defined by providing certain rules/tools
- Domain-specific models, e.g. CAD/FEM, can be generated.



Outlook

- Limitations to problem complexity (apart from computational power)?
- Combining AI-based knowledge extraction & knowledge execution?
- What portion of the workflow is left to the LLM?
- What about creating a dedicated Engineering Transformer model?
- Will the unseen pace of innovation continue?