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Retrieving Memories from a Cognitive Architecture using Language Models for Social Robot Applications

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A social robot obtains real-world data via an LLM or VLM and

- sends it to a cognitive model of the **Adaptive Control of Thought-Rational** (ACT-R) cognitive architecture for processing according to the model's procedural memory,
- retrieves content (recollections) from the **declarative memory** of the ACT-R model and
- uses the model's findings as instructions for action (e.g. prompt augmentation for an LLM).

Cognitive Architecture ACT-R

Cognitive architectures refer both to a theory about the structure of the human mind and to a computer-based implementation of such a theory. They attempt to describe and integrate the basic mechanisms of human cognition. Their formalized models can be used to react flexibly to actions in a human-like manner and - when used in a robot - to develop a situational understanding for adequate reactions. **Adaptive Control of Thought-Rational** (ACT-R) is a well-known and successfully used cognitive architecture.

For **human-robot interaction** (HRI) applications that use an LLM to generate speech and/or a VLM to recognize image content, a cognitive model can help to provide facts and context of a specific scenario for the language model.

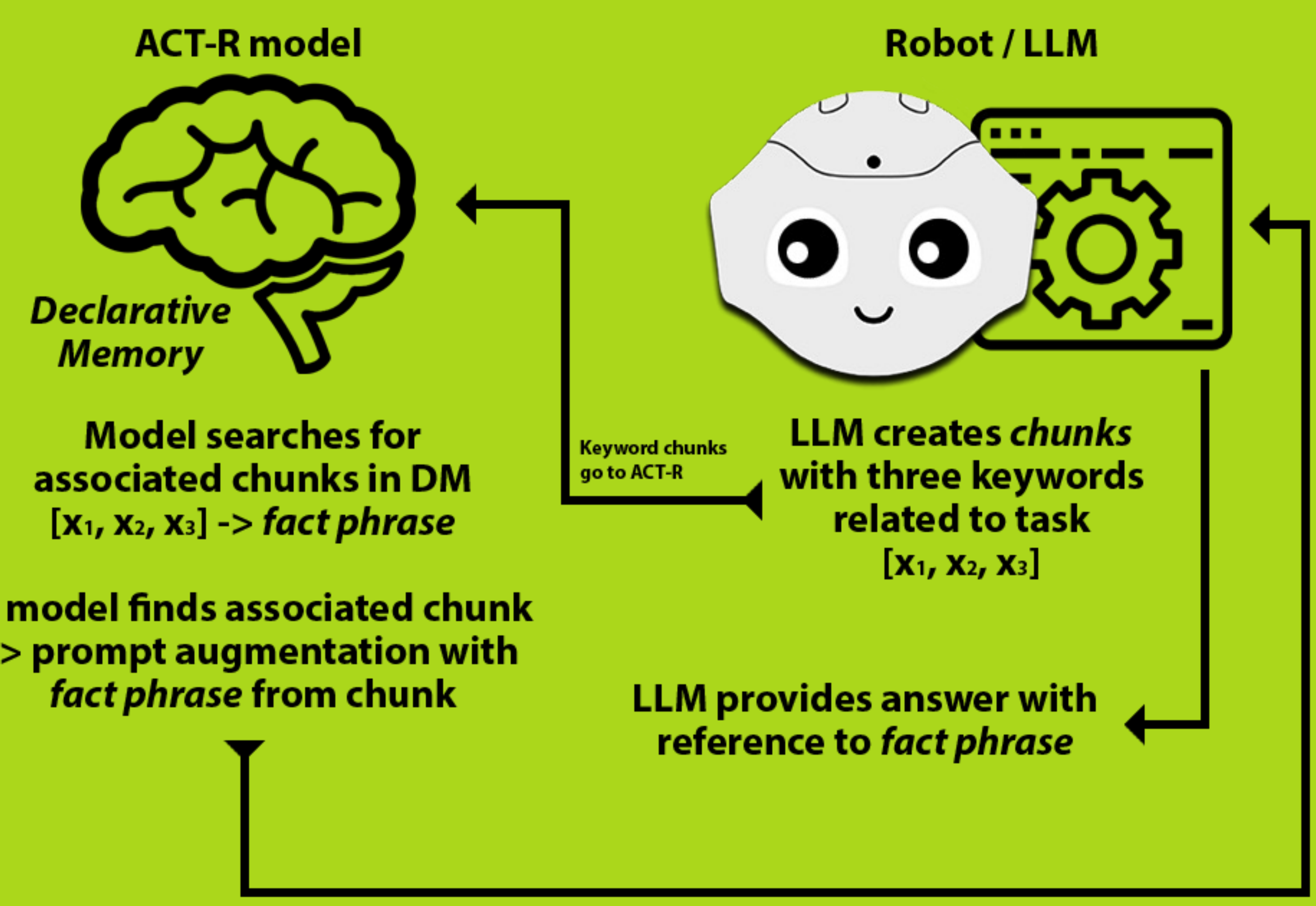
Using **prompt augmentation**, conclusions of a mental model can be taken into account in instruction generation for the LLM and thus reduce weaknesses such as ignorance of current individual facts and thus hallucination when relevant facts are unclear. Furthermore, language models are good at fast automatic reasoning, but less capable of high-level cognition to enable complex mental operations and "slow thinking" following the dual process theory of human cognition.

ACT-R comprises a **declarative** and a **procedural memory**, whereby the declarative memory supports lexical knowledge by encoding, storing and retrieving semantic knowledge, while the procedural memory enables the learning of habits and skills.

Using the ACT-R chunk and memory system to store and process facts and impressions and utilizing knowledge from the procedural memory of the cognitive model allows an LLM to incorporate these facts, **opening a path for a more reliable and evidence-based application of LLMs for individual HRI scenarios**.

Retrieval of memory content for prompt augmentation

In ACT-R, declarative knowledge is represented in the form of chunks. The cognitive model receives chunks with keywords from the robot and checks whether corresponding chunks for these keywords already exist in the declarative memory. These chunks also contain a "fact phrase". This could be a remembered fact from a previous interaction related to similar keywords and can be used to augment an LLM system prompt.



1. Three task-related keywords generated by LLM are given to ACT-R model as **chunk**
2. Search in ACT-R's **declarative memory** for associated chunks
3. Possible **prompt augmentation** with fact phrase from chunk
4. Chunk with keywords and fact phrase based on human-robot interaction is stored in declarative memory, ready for recollection

Conclusion

Cognitive architectures enable the incorporation and study of cognitive principles and processes in combination with a social robot and LLMs and can add a human touch to robots in HRI.

References

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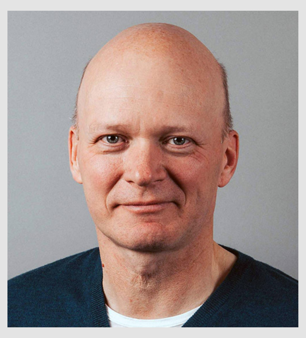

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Social robot Pepper

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