Application architectures for neurosymbolic A.I. systems

Summary

The goal of the planned research is to develop and test experimental neurosymbolic systems for specific application areas. The systems should be able to understand rules and facts given in natural language in the application area context. It is expected that they should use a large language model (LLM) for creating symbolic knowledge which is usable -- for example -- for database queries, API calls, search algorithms, reasoning engines and external tools, and based on these, give answers to questions posed in natural language, so that the answers are explained, verifiable and have confidence estimations attached. The main technologies to be explored and combined are different types of machine learning, existing LLMs, databases, API-s and specialized automated reasoners.

Research field:	Information and communication technology
Supervisors:	Prof. Dr. Tanel Tammet Priit Järv
Availability:	This position is available.
Offered by:	School of Information Technologies Department of Software Science
Application deadline:	Applications are accepted between June 01, 2024 00:00 and June 30, 2024 23:59 (Europe/Zurich)

Description

Large language models (LLMs) like the GPT family are a breakthrough technology in natural language understanding and commonsense reasoning. However, they appear to exhibit primarily intuitive “system one” reasoning and are severely lacking in deliberate and logical “system two” reasoning. LLMs typically give estimated answers based on the overall material they have been trained on, often resulting in incorrect answers: the so-called “hallucination” phenomenon. LLMs have low capabilities when performing long chains of dependable inference, more complicated computations and calculations, and retrieving answers from databases. It is often hard to detect contradictions in their reasoning. LLMs cannot be effectively controlled and it is hard to give them substantial amounts of new information and remove some of the old information.

All of this makes it hard to use them as a natural language interface to software systems where the data and/or business rules often change and the answers provided must be trustworthy. On the other hand, classical logic-based reasoning systems, when employed in a similar human-dialogue context, cannot cope with nontrivial natural language, cannot handle contradictions and uncertain knowledge, require unrealistic amounts of human-produced common-sense rules, suffer from brittleness and combinatorial explosion exacerbated in reasoning over large knowledge bases.

Altogether, the research area of combining LLMs with tool use, including reasoning systems and databases, is growing very quickly.

The main objective of this research is to enhance the state of the art in neurosymbolic systems for specific application areas, combining machine learning, particularly LLMs, with symbolic reasoning and tool use. The context of this research is building natural language user interfaces to software systems. As noted earlier, it is important to be be able to build systems able to understand rules and facts given in natural language without additional learning, use databases and APIs, and based on these, give answers to questions posed in natural language, so that the answers are explained, verifiable and have confidence estimation attached. We are also aiming at building experimental systems which could be used as prototypes for core technologies for building natural language user interfaces in the domains of business processes, e-governance and e-commerce.

The research will also focus on the algorithmic aspects of neurosymbolic systems. As the amount of symbolic knowledge acquired from natural language and databases grows, it becomes crucial to employ efficient algorithms for storage, retrieval, reasoning and question-answering over this knowledge. The ultimate goal is to identify a combination of techniques that can scale seamlessly with increasing amounts of data and users, enabling the deployment of neurosymbolic systems in demanding real-world settings.

Applicants should fulfil the following requirements:

- a master’s degree in computer science or analogous specialty
- a clear interest in the topic of the position
- good programming skills
- a clear interest and demonstrated experience in experimental computer science
- some experience in using machine learning systems as parts of a larger system
- excellent command of English
- strong and demonstrable writing and analytical skills
- capacity to work both as an independent researcher and as part of a team

The candidate should submit a research plan for the topic. The candidate can expand on the research questions, objectives and tasks, and propose both theoretical and experimental lenses to be used.

We offer:

- 4-year PhD position in one of the largest, most internationalized and leading computer science research centers in Estonia with a large portfolio of ongoing pan-European and national projects.
- The chance to do high-level research in the context of the freshly created Estonian Centre of Excellence in Artificial Intelligence (EXAI) in cooperation with the Tartu University and Cybernetica AS.
- Excellent opportunities for cooperation with joint AI projects with both industry and public administration.
- Opportunities for conference visits, research stays and networking with globally leading universities and research centers in the fields of public administration, innovation studies and digital government

About the department

The Department of Software Science is a part of the School of Information Technologies of Taltech. We focus on both the applied and theoretical computer science. The mission of the Department of Software Science is to advance internationally and nationally relevant state of the art in research and apply it in bachelor, MSc and doctoral education in the areas of computer science, information systems, data science, artificial intelligence and cyber security with the goal to solve problems the society is facing and support sustainable development. When creating and renewing study programmes, we work in close cooperation with both the public and private sectors to ensure that study programmes are up to date and unique e-Estonia needs are covered. The Department offering with an modern and motivating environment that supports acquiring a valuable degree in every level of university education.

(Additional information)

For further information, please contact Tanel Tammet tanel.tammet@taltech.ee and Priit Järv priit.jarv@gmail.com

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