Master Thesis Description - Songhua Zou

Topic: **LLM-Powered Behavior Tree Generation for Intuitive Robot Task Planning**

Description:

The aim of this work is to design and implement a system that allows a user to instruct a robot using high-level, natural language commands (e.g., "Assemble the gearbox" or "Bring me a coffee mug") and automatically generates an executable, robust, and adaptive Behavior Tree (BT) to complete the task. The project will leverage the reasoning and planning capabilities of Large Language Models (LLMs) to translate ambiguous human instructions into a structured, hierarchical BT plan. The system must be able to handle environmental changes and failures by dynamically expanding the generated BT, enabling the robot to perform tasks robustly in unpredictable environments.

Motivation:

Programming complex, long-horizon tasks for robots is time-consuming and requires expert knowledge. While Behavior Trees offer excellent modularity and reactivity, creating them manually is effort-intensive. Simultaneously, LLM's have shown remarkable ability to understand intent and reason about tasks but often struggle to produce reliable, executable plans for dynamic environments. This project bridges this gap by combining the strengths of both: using LLMs as intuitive, high-level planners and BTs as robust and reactive execution frameworks. The goal is to create a system that democratizes robot programming, allowing non-experts to command robots through simple language while ensuring the resulting plans are reliable, verifiable, and adaptable to disturbances.

Tasks:

- **Comprehensive literature review:** Conduct a literature research on LLM-based robot task planning, Behavior Tree synthesis, and existing hybrid methods (e.g., LLM-BT, LLM-as-BT-Planner).

- **System Design & Core Algorithm:** Designing the core pipeline from natural language command, through LLM-based reasoning to produce a task outline, to the automated generation of an initial Behavior Tree. The central challenge is designing the reactive expansion algorithm that dynamically modifies the BT during execution to handle failures and disturbances.

- **Implementation & Testing:** Build a functional prototype in a robot simulation environment (e.g., MuJoCo, Isaac Sim). Implement a set of benchmark manipulation tasks to serve as a test-bed.

- **Evaluation & Analysis:** Evaluate the system's performance. The key metrics are Success Rate on pristine tasks, Adaptability/Robustness to injected disturbances, and the Logical Quality of the generated plans.

- **Documentation and Code:** Compile the work into a final report and presentation and upload the implementation/code on TUC cloud (link will be provided).
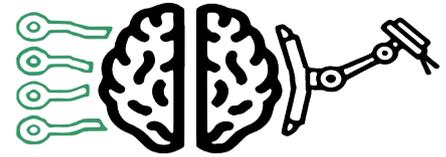
Further Links:

- LLM-BT: Performing Robotic Adaptive Tasks based on Large Language Models and Behavior Trees - https://arxiv.org/abs/2404.05134
- Behavior Tree Generation using Large Language Models for Sequential Manipulation Planning with Human Instructions and Feedback - https://arxiv.org/abs/2409.09435
- Automatic Behavior Tree Expansion with LLMs for Robotic Manipulation - https://arxiv.org/abs/2409.13356

Requirements:

- Fundamental knowledge of Robotics
- Proficiency in Python programming
- Basic knowledge of Linux
- Good to have – prior practical experience in NLP.