2. Robot cognitive architectures based on quantum computing

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Description:

Formalisms inspired by quantum theory have been used in Cognitive Science for decades. Indeed, quantum-like approaches provide descriptive features which are inherently suitable for perception, cognition, and decision making. With the free availability of quantum computing backends, such as the IBM Quantum Experience [1], it is now possible to start developing software applications taking advantage of this new computational paradigm.

In the past year, we conducted preliminary studies on the feasibility of quantum-like perception models for robots with limited sensing capabilities [2]. These preliminary studies have been extended to multi-sensory inputs with the aim of generating a 3D, quantum-like, multi-dimensional representation of the robot environment directly based on sensor readings [3]. In particular, it has been shown how quantum-like cognitive models provide a compact and elegant representation, embodying features which are extremely useful to model uncertainty, and define operators to inspect any world state, which quantifies the robot's degree of belief in that state.

The goal of this PhD research proposal is to design and develop a complete, quantum-like, cognitive architecture for robots. It is envisaged that the students will carry out the following activities:

1. Design an appropriate quantum-like formalisation to express robot cognitive processes related to perception, knowledge representation, reasoning, and action.
2. Starting from a framework developed in the last year [4], design and develop a novel, quantum-like, general purpose cognitive robot architecture allowing a robot to perceive its environments, maintain a set of beliefs about it, and perform goal-oriented decision making.
3. Perform validation on a selected number of use cases, possibly related to robot navigation and manipulation, with the aim of benchmarking with respect to existing models.

The resulting cognitive robot architecture will be the first of its kind.

The PhD student will work within an engaging, stimulating, and multi-cultural environment. He or she will be involved in the activities carried out by the TheEngineRoom team. This will involve also helping the teams supervise MSc students in their thesis work, most notably students from the UniGe's Robotics Engineering program. To conduct research activities, the PhD student will use state of the art dual arm manipulators (a Baxter robot from Rethink Robotics and Tiago++ from PAL Robotics), a network of RGB-D devices, motion capture systems (two combined OptiTrack systems), as well as advanced computational machinery.

Requirements:

- Software development in C/C++/Python.
- Knowledge of quantum computing principles is a nice plus.

References:

[1] https://quantum-computing.ibm.com/.
[2] D. Lanza, P. Solinas, F. Mastrogiovanni. A preliminary study for a quantum-like robot perception model. arXiv:2006.02771, 2020. Available: http://arxiv.org/abs/2006.02771.
[3] D. Lanza, P. Solinas, F. Mastrogiovanni. Multi-sensory integration in a quantum-like robot perception model. Proc. 17th Int. Symposium on Experimental Robotics (ISER), Anywhere on Earth, 2021.
[4] http://www.quantum-robot.org/.

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