

RLACS: Robotic Lab Assistant Cognitive System for interactive robot programming *

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Abstract

Integration of robotics system is challenging task and requires specific skills including domain area knowledge, programming, and robotics engineering experience. Programming process could be improved with advanced interfaces, for instance Mixed Reality device or cognitive dialog system. Our previous work related to interactive robot programming with mixed reality HoloLens device. To achieve the goal of efficient interactive robot control, the scope of the project should be extended to cognition system of the robotics system. Efficiency could be achieved by improving autonomy of the system. To develop the system, which unifies cognition and human-computer interaction we should define strong requirement to the artificial cognitive system. In this work we define requirements for cognitive properties such as perception, anticipation, adaptation, motivation, knowledge representation, and autonomy of the system. In addition, we propose high-level architecture of cognitive system which represent the relationship between inner modules of the robotics system.

1 Introduction

Our task is to develop a cognitive robot for an industrial process laboratory. Lab processes include a lot of various tasks. Developing a lab helper is a complicated task which possibly could involve activity from helping with providing and processing information to acting, for example connecting related components. The main goal for the lab robots is usually performing the same actions which human already performed. Such robot can perform common tasks more quickly and safely than its human counterparts. Furthermore, some work could be dangerous for human (toxic chemicals or radiation), thus performing such work with robot is reasonable.

Artificial cognitive systems theory covers high-level architecture of complex intellectual systems. Cognition, both natural and artificial, is about anticipating the need for action and developing the capacity to predict the outcome of those actions [1]. This theory covers embodiment, autonomy, anticipation, adaptation and other aspects of cognitive systems. The goal of our work is to develop cognitive architecture for intellectual robotics lab assistant system and provide interconnectivity overview of required components.

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Our cognitive agent could be a general-purpose industrial manipulator or set of manipulators which will perform requested tasks. Task could be formulated with gestures as we or with natural language voice commands. Hoenig, Wolfgang, et al. [2] demonstrated the potential of mixed reality for robotics application. In our previous work, we developed interactive programming system which combines industrial robot and Microsoft HoloLens Mixed Reality device to provide direct robot control with intuitive gestures (Figure 1) [2]. In addition, we developed a system for exploration of obscured environments [3] which allows to control hidden robot which generate mixed reality knowledge representation of environment for HoloLens device and provide egocentric view of environment for human.

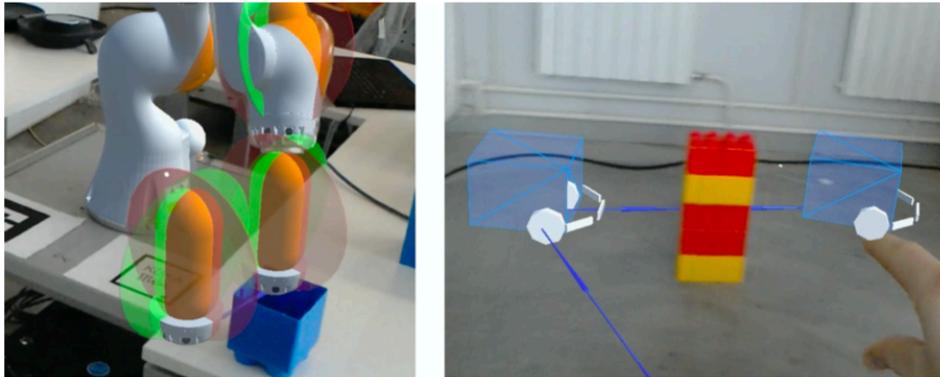


Figure 1: Mixed Reality Robots paths example

Below, we present the list of desiderata for our robotic cognitive assistant.

1. Natural language processing. For example, if scientist or engineer work with some project and performs experiments, it will request required robot in real time and performs some action immediately.
2. Utilization of online resources and services. The utilization of online component databases and combining those knowledges with lab inventory will provide ability to give to robot high level command capabilities. Robot will analyze equipment and will perform required task without explicit human guidance.
3. Anticipating the need for action. If human performs possibly dangerous operation with robotic system, artificial assistant should prevent those operation to keep human and inventory security.
4. Learning from human actions. Command should be not only formally specified but robot should generate executing plan and formalize human action to provide editable repeating routine based on previous human interaction with equipment.

Desiderata's serve as a good starting point for discussing the possible implementations and application scenarios of lab assistant.

2 Overview of the cognitive architecture

The RLACS (Robotic lab assistant cognitive system) is an autonomous hybrid system, overview architecture provided in Figure 2.

3 Functional characteristics of components

Here we describe components from the point of view of goals, in contradiction to agent's activity and computations. Input and output components of the system compose interaction system. All functional characteristics except nature of knowledge representation are given not only for specific task, but for any reasonable application.

Inputs are given in symbolic representation and may be entered by means of:

1. Entered through software interface between laboratory computer and the cognitive system
2. Recognized through agent's vision system
3. Received voice commands
4. Perceived by gestures

At the finishing tasks the system sends message to the laboratory computer through software interface about completing the tasks with laconic appropriate version of log.

Through all processing detailed log is recorded. Firstly, computational system (inference mechanism) are run. Then data about how exactly move physical elements of the system are taken from procedural memory. Then physical actions are performed with checking expected values taken from semantic memory, with actual values received from sensors.

There is planner that connects input, semantic and episodic memory, and executor. There is also executor that connects actuators with executor and procedural memory. Finally, there is judgement that connects sensors, semantic memory and actuators for precision in performing physical activity.

4 Review of the cognitive architecture

We provide excessive review on cognitive architecture properties in Table 1. In addition, we provide interaction abstraction diagram in Figure 3.

Table 1: Characteristics of the cognitive architecture

Criteria	Presence	Justification
Embodiment	+	System has sensors and actuators to perform actions and analyze results of its actions. This is done by physical components, which are obviously a part of the system.
Perception	×	System gets data from sensors, and receives tasks by interaction system. That gives system an ability to understand its tasks, current progress and its success by understanding what exactly this data means.
Action	×	RLACS is designed to make actions, it is expected to make lab operations, which it should do with success, however, if it makes mistakes, it should be able to find the possibility to fix it, or at least try not to repeat it again.
Anticipation	×	Machine leaning models and knowledge database give the system ability to predict future events. System can perform statistical analysis to anticipate future task, and neural network computation can also give it some information about the future.
Adaptation	+	Data from sensors, compared to expected values stored in knowledge database give the system ability to make judgments and adapt to current situation in order to perform better and achieve better results.
Motivation	+	When system doesn't succeed in the task, it tries to find the solutions and succeed next time. It also tries to improve its performance as it gets new knowledge, which gives it additional ways to solve problems.
Autonomy	+	If system faces missing of the knowledge, it tries to use data search in order to fulfill its knowledge database, other autonomy property is that it verifies its results by itself, as it has stored expected values for many final states.

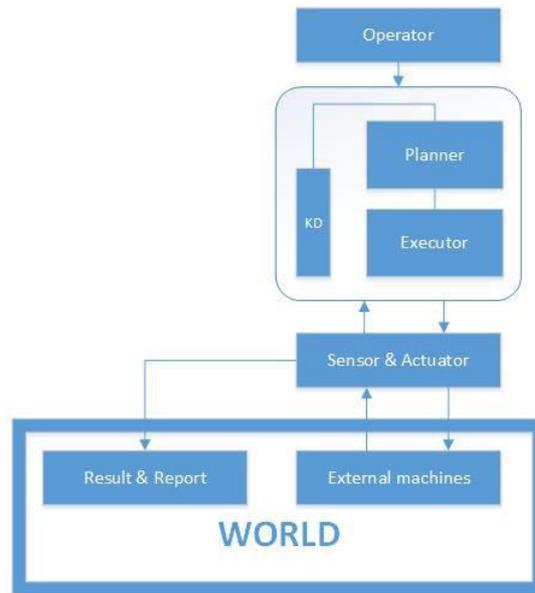


Figure 3: A diagram showing the interaction in the abstraction level

5 Conclusion

In this work we covered requirement to our project from cognitive system theory. In order to provide intuitive and intelligent interface to robotics system, this system should have the properties of anticipation and cognition. The degree and strength of autonomy is crucial for the system to improve the efficiency of operator. We provide excessive architecture of the system with components description and interaction diagrams. We covered properties of embodiment, perception, anticipation, adaptation, motivation and autonomy in the context of robotics system. This architecture allows us to continue our development with further integration of different interaction mechanisms, data sources and data processing algorithms to achieve cognitive behavior of our system. Source code of our project available on GitHub [6].

References

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