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DR 7.5: A curiosity driven self-extending robot system

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In this deliverable we present the curiosity driven self-extending robot system George that is capable of interactive learning of visual concepts in a dialogue with a human tutor. We present representations and mechanisms that facilitate such continuous interactive learning. We present how beliefs about the world are created by processing visual and linguistic information and show how they are used for planning the system behaviour with the aim at satisfying its internal drives - to respond to the human and to extend its knowledge. We describe different mechanisms that implement different behaviours leading to a coherent compound behaviour that facilitates different kinds of learning initiated by the human tutor or by the system itself. We demonstrate these principles in the case of learning conceptual models of objects and their visual properties.

Executive Summary

In this report we present the final CogX reincarnation of George, the curious robot. It is based on the systems we presented in the previous years; it is, however, more robust and is able of a wider range of behaviours. These behaviours are also better integrated and enable more coherent operation of the system. We increased the robustness of the system by improving the two-layered attention-driven visual subsystem, which is based on more robust RGBD sensor. We fully integrated object learning and recognition into the system, so the robot can now also recognise and talk about object types. In addition, we also reformulated the belief system and introduced merged beliefs as the final result of the information fusion and abstraction; they contain as reliable information about the perceived objects as possible and as much information about them as available. We also better structured the goals the robot is aiming at and introduced three priority levels for drives that generate goals. We assigned the highest priority to the interaction drive as the robot should always try to respond to the human as promptly as possible. On the second level we placed the extrospection drive that generates goals to understand and explore the scene and to learn as much as possible from this information. We assigned the lowest priority to the introspection drive, which tries to improve its models by introspection. This prioritisation together with the planning mechanism is supposed to lead to smooth transitions and appropriate switching between different behaviours leading to an efficient and natural mixed-initiative learning dialogue.

Role of a curiosity driven self-extending robot system in CogX

George tries to understand what it is certain about and what it is not, what it knows and what it does not know. Based on this, it tries to get the missing information (also by interacting with the human tutor) to fill the detected knowledge gaps. Therefore, through curiosity-driven extrospection and introspection the robot tries to extend its current knowledge, which is the major research topic in CogX.

Contribution to the CogX scenarios and prototypes

George is one of three scenarios that we have been addressing in CogX. We have designed this scenario to monitor and show progress on the development and integration of various competencies needed for interactive continuous learning. This scenario has been designed as a use case for guiding and testing system-wide research and for demonstrating methods developed in WP 5, WP 2, WP 1, WP 4, and WP 6 in a working system. Moreover, George also shares a great part of the code with Dora; the main functionalities in both scenarios are based on the same principles and implementation.

1 Tasks, objectives, results

1.1 Planned work

This deliverable mainly tackles the problems addressed in Task 7.7 of Workpackage 7:

Task 7.7: Integration for full curiosity driven extension system.

As such, it is addressing the following objectives as specified in the Technical annex:

11. *A robotic implementation of our theory able to complete a task involving mobility, interaction and manipulation, in the face of novelty, uncertainty, partial task specification, and incomplete knowledge. [WPs 2,3,6,7]*

12. *Within the same implementation the demonstration of the ability to plan and carry out both task driven and curiosity driven learning goals. [WP 1,7]*

The main goal for the final year of the project was to increase the robustness of the system, as well as to wider the range of different behaviours and to better integrate these behaviours into a coherent compound behaviour. Our objective was to demonstrate that a cognitive system can efficiently acquire conceptual models in an interactive learning process that is not overly taxing with respect to tutor supervision and is performed in an intuitive, user-friendly way.

1.2 Actual work performed

In the last year of the project we substantially extended the George system that was developed in the previous years [6]. We reformulated and re-implemented some of the functionalities (such as the belief system and the prioritisation of the main motivation drives), we added several new functionalities (such as object learning and recognition), and we robustified some of the functionalities (such as attention-driven visual processing), as well as the operation of the system as a whole.

In Annex 2.1 we attach the technical report describing the George robot from the component and from the system point of view; all the individual competencies are briefly described, and also the entire system is shown, focusing on mechanisms that implement different behaviours. It presents how George learns and refines conceptual models of visual objects and their properties, either by attending to information deliberately provided by a human tutor (*Tutor-initiated interaction*: e.g., H: 'This is a Coke can.') or by taking initiative itself. In the latter case, the robot can learn by *extrospection*, i.e., by analysing the objects in the scene and using the acquired information for updating the knowledge, either automatically, or after asking the tutor for additional information about the objects when necessary, e.g., R: 'Is the elongated object yellow?'. George can also initiate learning by *introspection*, i.e., by analysing its internal models of visual concepts and asking questions that are not related to the current scene, e.g., R: 'Can you show me something red?'. Our approach unifies these cases into an integrated approach including attention-driven visual processing, incremental visual learning, selection of learning goals, continual planning, and a dialogue subsystem. By processing visual information and communicating with the human, the system forms beliefs about the world, which are exploited by the behaviour generation mechanism that selects the actions for optimal learning behaviour. George is therefore a curiosity-driven system that aims at understanding where its own knowledge is incomplete and that takes actions to extend its knowledge subsequently.

The attached technical report will be, when completed, submitted for a journal publication. The journal submission will also include a thorough evaluation of the robot system that is currently being performed and will be completed by the end of the project.

1.3 Relation to the state-of-the-art

In this section we discuss how our work is related to, and goes beyond the current state-of-the-art.

Interactive continuous learning using information obtained from vision and language is a desirable property of any cognitive system, therefore several systems have been developed that address this issue (e.g., [5, 7, 1, 2, 8, 4, 3]). Different systems focus on different aspects of this problem, such as the system architecture and integration [1, 2, 4], learning [5, 7, 4, 3], or social interaction [8]. Our work focuses on the integration of visual perception and processing of linguistic information by forming beliefs about the state of the world; these beliefs are then used in the learning process for updating the current representations. The system behaviour is driven by a motivation framework which facilitates different kinds of learning in a dialogue with a human teacher, including self-motivated learning, triggered by autonomous knowledge gap detection. Also, George is based on a distributed asynchronous architecture, which facilitates inclusion of other components that could bring additional functionalities into the system in a coherent and systematic way (such as navigation and manipulation).

2 Annexes

2.1 Skočaj et al. "An integrated system for interactive learning in dialogue with a tutor"

Bibliography D. Skočaj, M. Kristan, A. Vrečko, M. Mahnič, M. Janíček, GJ M. Kruijff, M. Hanheide, N. Hawes, T. Keller, M. Zillich and K. Zhou: "An integrated system for interactive learning in dialogue with a tutor". To be submitted for journal publication, 2012.

Abstract In this paper we present representations and mechanisms that facilitate continuous learning of visual concepts in dialogue with a tutor and show the implemented robot system. We present how beliefs about the world are created by processing visual and linguistic information and show how they are used for planning the system behaviour with the aim at satisfying its internal drives - to respond to the human and to extend its knowledge. We describe different mechanisms that implement different behaviours leading to a coherent compound behaviour that facilitates different kinds of learning initiated by the human tutor or by the system itself. We demonstrate these principles in the case of learning conceptual models of objects and their visual properties.

Relation to WP The paper describes the final version of the George system, so it is directly related to WP 7. It also briefly describes the individual functionalities of the system that have been developed in other workpackages, namely in WP 5, WP 2, WP 1, WP 4, and WP 6.

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