Learning Systems Engineering

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INTRODUCTION

This chapter presents a project proposal, which defines future work in engineering the learning systems. This proposal outlines a number of directions in the fields of systems engineering, machine learning, knowledge engineering, and profile theory, that lead to the development of formal methods for the modeling and engineering of learning systems. This chapter describes a framework for formalisation and engineering the cognitive processes, which is based on applications of computational methods. The proposed work studies cognitive processes, and considers a cognitive system as a multi-agents system of human-cognitive agents. It is important to note that this framework can be applied to different types of learning systems, and there are various techniques from different theories (e.g., system theory, quantum theory, neural networks) can be used for the description of cognitive systems, which in turn can be represented by different types of cognitive agents.

BACKGROUND

Traditionally multi-agent learning is considered as the intersection of two subfields of artificial intelligence: multi-agent systems and machine learning. Conventional machine learning involves a single agent that is trying to maximize some utility function without any awareness of existence of other agents in the environment (Mitchell, 1997). Meanwhile, multi-agent systems consider mechanisms for the interaction of autonomous agents. Learning system is defined as a system where an agent learns to interact with other agents (e.g., Clouse, 1996; Crites & Barto, 1998; Parsons, Wooldridge & Amgoud, 2003). There are two problems that agents need to overcome in order to interact with each other to reach their individual or shared goals: since agents can be available/unavailable (i.e., they might appear and/or disappear at any time), they must be able to find each other, and they must be able to interact (Jennings, Sycara & Wooldridge, 1998).

Contemporary approaches to the modeling of learning systems in a multi-agent setting do not analyze nature of learning/cognitive tasks and quality of agents' resources that have impact on the formation of multi-agent system and its learning performance. It is recognized that in most cognitively driven tasks, consideration of agents' resource quality and their management may provide considerable improvement of performance process. However, most existing process models and conventional resource management approaches do not consider cognitive processes and agents' resource quality (e.g., Norman, Preece, Chalmers, Jennings, Luck & Dang, 2003). Instead they overemphasize the technical components, resource existence/availability problems. For this reason, their practical utilisation is restricted to those applications where agents' resources are not a critical variable. Formal representation and incorporation of cognitive processes in modeling frameworks is seen as very challenging for systems engineering research.

Therefore, future work in engineering the learning processes in cognitive system is considered with an emphasis on cognitive processes and knowledge/skills of cognitive agents as a resource in performance processes. There are many issues that need new and further research in engineering cognitive processes in learning system. New/novel directions in the fields of systems engineering, machine learning, knowledge engineering, and mathematical theories should be outlined to lead to the development of formal methods for the modeling and engineering of learning systems. This article describes a framework for formalisation and engineering the cognitive processes, which is based on applications of computational methods. The proposed work studies cognitive processes, and considers a cognitive system as a multi-agents system.

This project brings together work in systems engineering, knowledge engineering and machine learning for modelling cognitive systems and cognitive processes. A synthesis of formal methods and heuristic approaches to engineering tasks is used for the evaluation, comparison, analysis, evolution, and improvement of cognitive processes.

In order to define learning processes, cognitive processes are engineered via a study of knowledge capabilities of cognitive systems. We are not interested in chaotic activities and interactions between cognitive agents (since cognitive tasks require self-managing activities/work), nor interested in detailed tasks descriptions, detailed steps of tasks performance and internal pathways of thoughts. Rather, we are interested in how available knowledge/skills of cognitive agents satisfy required knowledge/skills for the performance of the cognitive tasks.

The proposed research addresses the problem of cognitive system formation with respect to the given cognitive tasks and considers the cognitive agent's capabilities and compatibilities factors as critical variables, because these factors have an impact on the formation of cognitive systems, the quality of performance processes and applications of different learning methods.

It is recognised that different initial knowledge capabilities of the cognitive system define different performance and require different hybrid learning methods. This work studies how cognitive agents utilise their knowledge for learning the cognitive tasks. Learning methods lead the cognitive agent to the solution of cognitive tasks. The proposed research considers a learning method as a guide to the successful performance. That is, initial knowledge capabilities of cognitive agents are correlated with learning methods that define cognitive processes. An analysis of impact of different cognitive processes on the performance of cognitive agents is provided.

This work ensures support for a solution to resource-based problems in knowledge integration and scheduling of cognitive processes to form a capable cognitive system for learning the required tasks.

AIMS AND OBJECTIVES

The aims of the project are to develop a formal method for the modelling and engineering of cognitive processes. Capability and compatibility factors have an impact on the formation of cognitive systems, the performance processes and define different learning methods. Therefore this work studies cognitive processes and knowledge capabilities of cognitive systems to ensure the required level of the learning and performance of the cognitive systems. In order to support the formation of a cognitive system that will be capable of learning the required tasks within the given constrains, this work addresses problems of the knowledge integration and scheduling for cognitive system modeling, taking into account critical capability and compatibility factors. Study of learning conditions in cognitive systems defines an important task of the proposed project.

The individual measurable objectives are:

- Evaluation of knowledge integration and scheduling approaches in cognitive systems.
- Evaluation of existing machine learning approaches in cognitive systems.
- Determination of the impact of capability and compatibility factors on the formation of cognitive systems.
- Development of knowledge integration metrics.
- Development of knowledge integration models for the formation of the cognitive systems.
- Development of scheduling models for learning of cognitive systems.

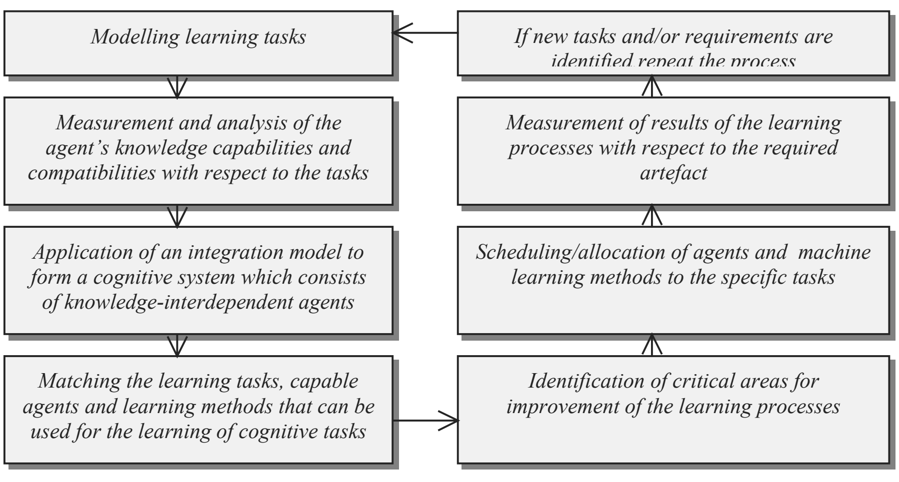
METHODOLOGY AND JUSTIFICATION

In order to identify the best learning processes we analyze the cognitive processes. A scenario for engineering the cognitive processes is based on the following steps (Figure 1).

The methodology of the proposed project is based on the following new theoretical basis (Plekhanova, 2003).

Profile Theory and Machine Learning: For formal modeling of complex systems we utilise the profile theory (Plekhanova, 1999a). A profile is considered as a method for describing and registering multifaceted properties of objects. There are important practical applications of the profile theory (Plekhanova, 2000a, 2000b). For instance, internal properties of the system elements such as capability and compatibility factors are critical variables in modeling, design, integration, development, and management of most

Figure 1. A scenario for engineering the cognitive processes



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