Robotic Technology for Inclusive Education*

A Cyber-Physical System Approach to Pedagogical Rehabilitation

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ABSTRACT

The paper presents a novel cognitive architecture RELA - robot-enhanced learning architecture - intended to be implemented in inclusive education via a cyber-physical system for pedagogical rehabilitation. The specific aspect is that it aims to account for some cognitive deficiencies as seen in special education.

RELA is intended to help the learning process of children with various learning needs in inclusive education. It can account for both the need for technological support, as well as the need for teaching artistic performance as a learning method in the classroom. The paper presents the main features of RELA architecture.

CCS CONCEPTS

• Embedded and cyber-physical systems • Robotics • User characteristics

KEYWORDS

Inclusive education, Humanoid robots, Cyber-physical-systems, Pedagogical rehabilitation, Artistic performance

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1 Introduction

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Inclusive education is in a process of establishment in Europe and world-wide at the present moment¹. With the involvement of robots in the educational and instructional activities of inclusive education, and with the increased cognitive competence implemented in technology, people of different learning styles and educational needs will rely on a variety of sophisticated educational assistive tools, including robotic tutors, especially for cases of children, possibly vulnerable due to preexisting conditions [1]. Our approach to modelling the child-robot interaction in inclusive education is based on recent theories of social and cognitive development in the design of educational-assistive robotics, aiming at enhanced acceptability of this novel educational technology.

Educational-assistive robots will remain perceived by learners as sophisticated but limited computer periphery in the classroom unless they become adaptive to the learning situation and the individual learner. A useful operational definition of an assistive robot is proposed by David Jaffe (2013): "Assistive robot is a device that can perceive and process perceptual information and perform activities that are beneficial to children or adults with disabilities"². The proposed in the present context definition of a socially-assistive educational robot is adapted from the above as: "A socially-assistive educational robot is an electro-mechanical device with the designated software to receive and process perceptual information and perform activities that are beneficial to children and adults with special learning needs". When endowed with certain resemblance - physical or conceptual - to

¹ <https://www.unicef.org/education/inclusive-education>

² <https://web.stanford.edu/class/engr110/2013/07a-Jaffe.pdf>

the human, the robot becomes a complex physical, virtual and social stimulus, or a new 'robotology' [2]. A novel type of cognitive architecture is, therefore, needed, in order to be able to provide a realistic model of human cognition for a robot to be able to better 'understand' the cooperating learner.

Current robotic technologies are endowed with cognitive abilities - sensing, perception, reasoning, decision-making, follow-up relearning and generating new knowledge based on implicitly processed previous experience³. The adopted cognitive architectures rely on the existence of a short-term module, representing the memory involvement in the learning process. Our proposed cognitive architecture is similar to [3], however introducing long-term memory effects of implicit learning - a recollection module accounting for the so called "feeling of knowing" effect [4]. The expectation is a more realistic cognitive performance by the artificial agent and improved learner performance as a result.

A multi-agent system for teaching social skills to children with autism was designed and implemented in [5]. By agreeing on which task to jointly allocate to a set of Kheppera robots children, playing in pairs, learn to achieve better social skills, which are rewarded by robots performing as being told by the children. These and similar studies provide support to the pedagogical expectation about the wider application of robotic technology than just improving the problem solving or abstract thinking skills of children - towards understanding the complexity of the surrounding World, which is largely socially mediated [6]. The effect is being achieved in an implicit way, which relieves the burden on the child to self-control most of the time, which will help the education of children with limited cognitive resource in inclusive classes.

Our theoretical hypothesis (also included in the project CybSPEED⁴), is that the underlying processing of human-robot interaction possesses all the potential for triggering the *intrinsic motivations* of children, who face learning difficulties, resulting in efficient

compensation in education. This internal processing is the appropriate base for pedagogical rehabilitation via introducing robots as teacher assistants in schools and day centres. Robotic technology in schools, therefore, is a valuable part of the cyber-physical system framework towards inclusive education. The specificity of our approach is that we derive the conceptualisation of the elements of the CPS from recent studies of brain processing, underlying the social and cognitive behaviour in animals and humans [7], [8]. These studies serve as guidelines to translate outcomes from experimental research into directions for designing of improved and adapted-to-the-human technologies and interfaces to those technologies. A second, none less essential specificity is the inclusion of principles of artistic performance in defining the child - robot interaction process in a way, similar to the approach proposed in [9]. Educational scenarios are being proposed by a playwright and actors and then enacted with children.

Our conceptualisation is that robots - whether humanoid or abstract - play a socialising role and can be successful teaching assistants⁵. They can carry out routine and tiring activities, allowing the teacher to focus on working with children individually and developing their skills and talent. The theatre as an art can inspire the development of social robotics both technologically and aesthetically. The participation of children in educational theatrical performances, on the one hand, activates their intuition in the presentation of fictional characters, and on the other, young actors gain valuable implicit experience for future life situations. It is no coincidence that acting is being taught to students of preschool and primary school pedagogy.

The paper presents a novel cognitive architecture RELA intended to be implemented in inclusive education. The architecture is designed within an ongoing EU funded MSCA project CybSPEED: Cyber-physical systems for pedagogical rehabilitation in special education (2017-2021).

³ <https://phys.org/news/2017-12-importance-icub-standard-robotic-platform.html>

⁴ <https://cordis.europa.eu/project/id/777720>

⁵ <https://www.igi-global.com/newsroom/archive/can-robot-successful-assistant-teacher/3307/>

The paper is organised as follows: Section 2 describes the proposed brain-inspired cognitive architecture RELA for processing high-level (conceptual, gestalt-like, multi-analyser information) [10], [11]. The specific aspect is that it aims to account for cognitive deficiencies as seen in special education. By including them in the general cognitive architecture, it is supposed to help the learning process of children with various learning needs in inclusive education. Section 3 describes some considerations in relation to the inclusion of artistic performance as a method, complementing the entertaining aspect of technology in the classroom. The conclusion section outlines some future work.

2 Robot-Enhanced Learning Architecture (RELA) for Inclusive Education

The proposed architecture called RELA - robot-enhanced learning architecture - is inspired by the general anatomical structure of the neocortex of the human brain, following a similar approach, for example, of [12]. The main difference is in the current focus on the multi-sensory integration, especially when some of the sensor modalities are being underdeveloped (i.e. visual, auditory or tactile deprivation).

RELA's aim is to represent the process of acquiring new knowledge from a lesson, given by a human teacher assisted by a humanoid robot. The architecture operates on the level of modality-specific analysers and their interaction in the associative areas of the brain for providing the learner with conceptualisation of the learned material (Figure 1). Irrespective of the deprived sensor information, the higher-level logical concept is universal for all, due to the compensatory brain mechanisms for analysis, synthesis, analogy and abstraction. As we all know, an 'apple' is the same fruit and the same concept for all, irrespective of the sensor deficiency during learning of the essence of this concept. This understanding holds for higher-level concepts and underlies the present-day education philosophy. The novel aspect of RELA is the interplay of the intuitive and explicit knowledge in forming the concept, irrespective of the sensor deficiency (acquired or innate), as visualized in Figure 1. This level is higher

than the sensory integration modules of similar architectures, like IHA or EIHA, described in [3].

Previously, we designed a zoology lesson, given by a humanoid robot NAO, suitable for children at the age of 8 and above [8]. It provided information on appearance features of animals, their habits and their places of habitat, as well as of class belonging - e.g. a shark is a fish, whereas a dolphin is not a fish. This knowledge, understanding, idea, is formed in the child's cognition irrespective of the sensory channel - visual, auditory or tactile. The child can be deaf or blind, yet s/he will understand the essential aspects of the lesson irrespective of the sensor deficit. The conceptualisation of the learning process in RELA begins from the integration and complementarity of the modality specific analysers when acquiring high level knowledge during a lesson in the classroom.

Often, the interpretation is implicit, intuitive. This is obviated in cases of brain damage when the behaviour of the person clearly demonstrates previous encounter of an item (physical, verbal) without any recollection of this. A famous example by Korsakoff (1889) [14] is given in [15], called "eyeblick conditioning". The patient heard a sound, followed by a puff of air in the face. Subsequently, the patient blinked at the sound, without the puff of air (p. 252). This is a clear example that behavioural output from the interpretation block of RELA is possible without recollection of the learning episode, thus triggering the spontaneous reactions block of the behaviour module.

The Interpretation (I) and Behaviour (B) blocks are 3 dimensional at least, reflecting the brain mechanisms in the associative and executive areas of the brain. The processing is massively parallel and on two levels at least - intuitive or reasoning-based interpretation (I block) and spontaneous or rational actions (B block), being largely complementary as an outcome. This is the main mechanism of learning, bringing the biggest unpredictability of the acquired knowledge. The teacher uses the rational channel mainly and can have approximate expectation on the learning result in the child. RELA states this as an unexplored teaching focus.

Figure 1: Diagram of the proposed robot-enhanced learning architecture (RELA) for inclusive education

The behavioural output from the interpretation block of RELA is possible without recollection of the learning episode, thus triggering the spontaneous reactions block of the behaviour module. Yet spontaneous reactions need shaping, too. This is where the acting and the theater come into play in education.

Reasoning-based interpretation logically leads to rational actions based on the acquired knowledge, which the learner will use in the surrounding World. Yet another option is possible, when the learner experiences a state of “feeling of knowing” - which may or may not lead to recollection [4]. Numerous studies have demonstrated that the executive areas in the brain are being involved during this process, which justifies the effortful nature of the learning process [16]. A well-known example is the so called “tip-of-the-tongue” effect⁶, experienced by people in search for the name of the person, for example, when we meet them and cannot remember it. This is an effortful process, which may, or may not lead to successful recollection, yet it has to be accounted for in the proposed cognitive architectures of the learning process, guided by a human or a humanoid robot, or both.

In typical (standard) education, the teaching process heavily relies on the short-term/working memory module [17]. However, the repetition process is being reduced to a minimum in class and the next day the lessons move on to novel conceptual knowledge. Children with learning difficulties need a substantial amount of repetition and external help in learning how to transfer the acquired knowledge from the classroom to the external World. This is where the cyber-physical system, involving humanoid [18], social [19] and service robots [20], can play their unprecedented role in providing the learning support to each individual child. The CPS can define the cognitive states of the learner, whereas the robots can use this information to select the appropriate scenarios for rehearsal and practicing the newly learned knowledge.

The remembering of the study episode can be conscious, and the *self-analysis* serves the role of a feedback to the cognitive system, entering again the study loop at the

level of *perceiving* the stimulus. However, it is possible to encounter situations, when the child *cannot clearly remember* the study episode (the dashed line in Figure 1). Yet the teacher should not ignore the possibility for implicit learning that goes on as an internal feedback to the intuitive interpretation of the World. This process is observed in nonverbal children, who can acquire and master nonverbal skills - like dancing, or even chess playing. In this case the memory performance bypasses the conscious recollection linked to the short-term/working memory performance.

Therefore, the proposed RELA tries to account for many of the manifested symptoms in special education for the purpose of adequate learning support in the classroom, where children of different learning styles and needs have to communicate and cooperate in conceptual learning and social skills acquisition. The performance of the modules of the cognitive architecture will be simulated in WEKA and assessed statistically by applying an approach, similar to the presented in [21], [22]. The results of the evaluation of the novel architecture will be presented in future publications.

3 Artistic Performance as a Learning Tool, Complementing Technology

In [23] the role of robots in the theater is being analysed, especially focusing on the potential of the robot to perform like an actor. For this, one special feature of the agency, conveyed by an actor, is emphasized – the ability to add an extra dimension during performance on the stage. An actor makes the viewers not only believe in the emotions of the character, but also emphatically believe they *are* the character. The question is if a socially competent robot can become able to translate this triple *co-belief* (actor – character – viewer) in a manner, similar to the art of an actor?

It is expected that with the increase of the social interactive ability of RELA, i.e. with better understanding of the cognitive processing of the human counterpart during human-robot interaction, robots

⁶ <https://www.verywellmind.com/lethologica-tip-of-the-tongue-phenomenon-4154947>

may become valuable artistic partners of the actors on stage.

Figure 2: RELA approach to artistic skills learning in inclusive education

Currently, our understanding of the role of the robotic technology in shaping the artistic abilities of children in inclusive education is illustrated in Figure 2. The interacting Venn Diagrams represent the joint manifestation of the play as an interactive educational method, the Puppet theater as a well-known technology integrated in the theatrical art, and the socially-aware robots, being able to express positive and empathic attitude towards the child during the child-teacher-robot interaction in class [24].

Within the proposed RELA, the artistic performance, being instructed by actors and robots together, plays an essential role in generating the intuitive interpretation of the World. It helps in shaping the spontaneous reactions of the child similarly to Fleming's VARK model of learning styles (Visual, Aural, Read/write, Kinaesthetic) [25]. Moreover, it is possible that the artistic performance can support the mechanism of "feeling of knowing" so that this mechanism can bring to the explicit level a lot of the implicit knowledge. This hypothesis is planned to be tested in future studies by designing plays involving robots by Theater Tsvete - a beneficiary of the CybSPEED project.

4 Conclusion

The paper presented a novel cognitive architecture RELA for inclusive education via implementation of a cyber-physical system for pedagogical rehabilitation. It can account for both the need for technological support, as well as the need for teaching artistic performance as a learning boost in the classroom. Future studies will evaluate empirically the proposed cognitive architecture.

The societal implications of the present research will be in better understanding of the learning needs of children and provision of advanced technological support; better understanding of the professional needs of teachers and provision of advanced tools for individualised work with children; more entertaining learning environment for all children, expert system support to the teaching process, reduced number of tests in class and the respective stress level on children in inclusive education.

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