Child Friendly Robotics

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Abstract— **A new discipline of greatest importance is introduced – Child Friendly Robotics. Its rich theoretical framework is beyond the scope of this paper, yet an excellent first glance at this revolutionary field is provided, by an in-depth analysis of a pioneer program to implement Child Friendly Robotics on a national scale.**

I. Introduction

Robots will be omnipresent and numerous - thousands or even millions per person. Every child will be surrounded by robots from birth. Most of the child environment will be robotic.

Robotic childhood, as well as huge advantages, could create many problems, among which are: child's understanding of robots and vice versa, influence of robots on the child, including various aspects: psychological, developmental, emotional, educational, social to name just a few.

Researching these problems and trying to solve them in the immediate future is vital. The need gave rise to a freshly created discipline of Child Robot Interaction (cHRI) built on other relatively new area of Child Computer Interaction.

One very basic, and maybe most fundamental, problem is that of a very young child, not yet mature or sophisticated, understanding robots, feeling confident around them and controlling them. Different but connected problem is the symmetrical mirror image of the first one – that of robots understanding the child, whose knowledge and behavior are very different from those of the grown-ups and is less predictable. This subject includes many different challenges, just some of which are: emotional, cognitive and pedagogical.

We introduce the discipline by presenting both theory and practice: an Organic Knowledge (OK) multidisciplinary paradigm, its implementation and applications.

The OK approach calls for immersing the child in an organically created and evolving intelligent knowledge driven environment - ecological system of children and robots (as well as other populations like adults, experts, knowledge systems and communications). The child, from the day of birth, is not only surrounded by robots, but is Montessori-encouraged to interact, learn about and control the robots. And vice versa, the robots are encouraged to interact, learn about and care for the child. And the crucially important aspect of this interaction is the friendship (which has special meaning in this case, somewhat different from friendship between humans).

As the child grows and his learning capacity evolves, the process becomes more intellectual and the learning includes more aspects of learning Robotics and Programming (RaP).

Over the past years we have used this approach to educate children from very young age (4-8) in robotics and programming. It has then been adopted on a larger scale - more than 1000 primary school students and hundreds of kindergarten students have studied robotics and programming in an OK environment created by us. The success has caused the Ministry of Education to adopt the approach on the national level. A national OK CFR program for robotics in kindergartens and primary schools is being implemented.

II. Child Friendly Robotics

The discipline evolved from research field of Human-Computer Interaction (HCI) [1], the newer Human-Robot Interaction (HRI) [2] and even newer Child-Robot Interaction (cHRI) [3]. Child Friendly Robotics (CFR) should be elevated to a discipline in its own merits. It is much more than cHRI. Its aims are more ambitious, its models are deeper and it is much more interdisciplinary. But the main difference is that CFR is both much more complicated and at the same time much more important.

What is a "friendly robot" and friendship in general when talking about child-robot interaction? It could have very narrow technical meaning e.g. robot not harming the child, or just a little more general meaning of Isaac Asimov's three laws of robotics. On the other hand it could have a much more ambitious meaning of being as close to friendship between humans as possible (as alluded in Isaac Asimov's Robbie in the I, Robot series).

The human friend is defined in Merriam-Webster dictionary thus:

- *… one attached to another by a feeling of liking and caring*
- *… one that is not hostile*
- *… one that is of the same … group*
- *… a favored companion*

The OK CFR described here is one robotic system paradigm that aims to facilitate all aspects of friendship including emotional aspects but also mutual understanding and knowledge and specifically learning robotics by the child and learning about the child by the robot.

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III. Organic Child Friendly Robotic Environment

A. Organic Knowledge

An Organic Robotic Environment is an Organic Knowledge System (OKS). Organic Knowledge (OK) systems are the newest generation of Knowledge-Based Systems (KBS), one of the major branches of AI.

Organic Knowledge (OK) is a Knowledge System paradigm that simulates and enhances through mutual learning the knowledge of both the IT and Robotics expert and the knowledge of the domain expert.

In a nutshell the organic approach is treating the problem and the solution process as evolution of different and frequently conflicting units of knowledge, algorithms and solutions. It is modeled after the growth and evolution of a living organism (or ecology of organisms if more appropriate) where different units of knowledge, algorithms and solutions are the organs [4].

The organic solution is like a child – in the beginning having no knowledge (except some basic mechanisms needed for evolution), and by process of feedback and Darwinian natural selection the solution gradually evolves, becomes better and better using its growing body of knowledge [5].

The most basic aspects of the paradigm are the especially massive body of organic knowledge and the organic life-cycle. Organic life cycle is somewhat reminiscent of the prototype cycle but it is much more sophisticated. It simulates the growth of human intelligence, creating solutions more and more plausible using mechanisms of feedback and learning [6].

B. OK Systems Implementation

Organic Knowledge (OK) systems are ICT systems incorporating human expertise. One would be tempted to describe them as Expert Systems (ES) "on steroids" transforming them into Knowledge Systems (KS). They are an ecological system of many different and sometimes contradictory experts called organs. OK systems are Turing's "child programs" [7] and Minsky's learning, evolving and non-algorithmic Society of Mind [8].

OK system is:

- intelligent
- evolving
- learning
- organized
- distributed
- dialectical
- having very big knowledge base

Each organ is simulating an independent expert, and includes:

- knowledge base (data, meta-data and procedures)
- feedback apparatus:
    - knowledge acquisition mechanism (interfaces and communication)
    - learning mechanism (inference of new knowledge and processing)
    - evolution mechanism (creating and changing organs in view of the new knowledge)
- interfaces:
    - environment (local)
        - subjective (user)
        - objective
    - communication (network)
        - with other organs (o2o)
        - with remote servers
        - with remote users (p2p)
        - with remote resources
- execution (proactive).

The Gestalt-Multiplex-Layering (GML) model [9] components are:

- gestalt – a deep model of the expert knowledge and reasoning process;
- multiplicity – simultaneous use and cooperation of different and conflicting approaches;
- layering – use of a hierarchy of independent layers of control and processing, through which the input and intermediate results are propagated.

IV. Montessori approach to Child Friendly Robotics

We are making available to the child a great variety of friendly robots and robotic activities. We encourage her to experiment through play. Gamification of robotics is an integral part of the OK approach.

Constant and very exact feedback allows putting in front of the child the optimal next stage activity allowing the games to evolve naturally into learning and forming very sophisticated robotic friendships.

This environment is the result of a century of research into the psyche of the child and her learning process, which produced almost a consensus about the way child's educational environment should be managed.

We will call this universally accepted approach and pedagogical toolbox, used by us and proposed as the preferred method for CFR, "Montessori pedagogy" after its first proponent – Maria Montessori.

Maria Montessori, educated as a physician and engineer, was the first not only to develop a scientific theory of childhood development and but also to implemented it as technological and engineering project.

Montessori approach pioneered feedback in education, gamification, educational technology and project based learning. Already in 1907 she designed and implemented an engineered environment for her students in the center of which was the best educational technology tools the technology of the day allowed her to build [10].

Her great success came when her students, who came from underprivileged families and some were even considered retarded, demonstrated unbelievable success in their studies. Most learned to read and write at four, and all of them at five, and they were winning mathematics competition against children in private schools. All this achieved while it looked like the children were left to do whatever they liked, instead of studying.

The teachers went to great length to create special toys which were in reality educational tools. Today we call it gamification [11] [12], and the toys are robots [13]. Students were closely watched and not allowed to just waste time. But there was no strict schedule, lectures or mechanical memorizing. Montessori was the first and most ardent child rights advocate. Her students felt totally different in her Home of Children compared to traditional school, as is evident from the next dialogs.

"Who has taught you how to write?", they were asked and a child looked up in wonder and answered, "Taught? No one has taught me".

"So, this is a place where you do what you like, is it not?" The child answered: "No, Madam, we do not do what we want, we want what we do" [14].

In 1938 John Dewey published his seminal work extensively describing his educational theory in the spirit of Montessori and since then it is known as constructivism [15].

Modern educational research, especially in robotics education, is a very rich field. But unlike many other disciplines, during the 20th century there was a convergence of approaches. Notwithstanding the great variety of different specific methodologies, the general consensus in this field could be well defined as a variation of the constructivist approach.

Some of the principles of constructivism: knowledge arises through a process of active construction, not a passive repetition; knowledge is constructed, not acquired. Knowledge construction is based on personal experiences and the continual testing of hypotheses. Each person has a different interpretation and construction of knowledge process, based on past experiences and cultural factors.

Among the many names given to constructivism inspired methods of robotics study are:

- Lab-based
- Project oriented
- Telescopic
- Individually customized
- Student centered
- Association driven
- Non-frontal
- Peer-oriented

V. OK Child Friendly Robotics

A unique large scale Child Friendly Robotics project using the OK paradigm and Montessori pedagogy has been so successful that it grew into a national robotics program.

The evolution of this OK CFR project went through several stages over the last 5 years:

1. Fundamental R&D – creating the infrastructure
2. Experiments with small groups of children 3-5 years old
3. Experiments with larger groups of 5-11 years old (avg=8)
4. Classrooms - taking the approach to real life primary schools classrooms (population = 1000 students)
5. Kindergartens nationally - applying the method in 30 kindergartens (pilot funded by Ministry of Education as a step in implementing it in all the kindergartens nationally)
6. Schools nationally – teachers of robotics in 300 primary schools are trained (pilot funded by Ministry of Education as a step in implementing it in all the primary schools nationally).

A. OK CFR Game Session

Game session is the basic unit of the system. It is also a lesson in robotics. Each game session lasts between 3 and 5 hours. A group of students is given access to a variety of robots, after some very short informal explanations and presenting the different games they can play with the robots (which are really learning projects of a very high standard).

They also have access to a great variety of resources such as tutorials, clips, books, samples, computerized and human help if and when needed. Some are local and many are distributed and online including tools to transfer general sources of information into excellent customized and adapted educational toolbox. Among others are YouTube, Google and Wikipedia.

The children are free to work individually or cooperate. Some sessions include as the final stage presenting the results to the group or even competitions between individuals and teams. A system of rewards and positive reinforcement is implemented.

During the session children are free to change their robots or the games. Feedback of all aspects by all participants plays major role in real time, and the session and future sessions are adapted following the feedback (which crucially is also added to the KB and improves the constantly evolving system for all future students).

On the one hand the children see it as a game and are in their eyes totally free to choose any game and play it in any way. However, in reality they learn, and the system, while adapting as much as possible to the individual child, proactively and surely directs and leads them towards achievement of the educational goal, by putting in their way the most appropriate game.

The OK CFR game (learning session) algorithm can be described thus:

1. Adding to KB, resources and robots
2. Updating KB, resources and robots
3. Making everything available to children
4. On Feedback – GOTO 2
5. Children Playing
6. On Feedback – GOTO 2
7. Child – KB and/or expert interaction
8. Reinforcement
9. On Feedback – GOTO 2

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10. Annealing – propose another game
11. GOTO 1

The main loop of session algorithm is presented in more details in Fig. 1 at the end of the paper.

B. OK CFR Environment

The environment includes such components, at all levels of complexity, as:

- Actors –
  - children
  - caretakers and parents
  - teachers
  - experts
  - IT professionals
- Various robot kits and robots
- ICT embodied in computers customized for the individual child, including various robotic programming environments
- Proactive OK system driving the process
- Knowledge base shared by all actors (including robots) of vast learning resources

All major platforms available were incorporated and children were exposed through them to different kinds of robotic environments. Among the environments used are:

- Lego MindStorm and Education programming
- Arduino robotic kits
- Makeblock mBot
- Intelitek ScorBot industrial robotic arm
- Meccanoid Personal Robot

The Meccanoid is the most anthropomorphic. It is 120 cm high and is intentionally modeled after human shape. It has voice recognition capabilities and over a thousand pre-programmed phrases, comments and witty comebacks, it can tell jokes and play games.

It can be programmed in 3 very young child friendly ways:

- Learned Intelligent Movement (LIM) technology - child can simply move robot's arms and head or speak to the robot and it remembers the commands
- Motion Capture - child can place a phone into Meccanoid's chest, activate the Motion Capture feature and Meccanoid recognizes the motion
- Swipe of the Ragdoll avatar in an app controls Meccanoid's 10 motors and moves its head, arms and feet

After much experimentation we designed and built our own robot: the OK*bot* with its child friendly environment. The OK*bot* and its unique programming environment are first especially designed CFR. Its main advantages:

- totally proprietary - including designing and self manufacturing (using 3-D printers) even of the chassis
- very lively, interesting and friendly
- easily built by child
- easily used by child
- easily modified by child
- cheap
- easy for child to program
- playful
- modular
- scalable to all ages and level of robotics

Among children's favored activities with OK*bot*:

- playing
- naming
- building
- humanizing
- learning
- teaching
- cooperating

And the result: they feel with robots happy, confident, and playful. In short – they become friends.

Very naturally the children evolve from players with friendly robots into builders and programmers of friendly robots. From pre-K age they start to build robots. Before they know how to read and write – they learn by watching and program in non-textual programming languages. After becoming literate they immediately and naturally evolve to text based languages and build and program with great enthusiasm and success even at such young ages as 7 and 8.

Even first graders already master robotics enough to successfully finish a project where they program in a standard programming environment an industrial robot to perform quite a complicated job.

VI. CONCLUSION

Friendly robots could become a positive reality tomorrow if today we invest in the right robotics education, familiarity and robotic environment for our children from a much earlier age. One such environment is the OK CFR described in this paper, which proved to be very successful and now is adopted on a national level. But this is only very basic first stage on which we should build.

In the next few years there is an urgent need to develop the CFR into well equipped toolbox of theory, technologies and applications. It should entail interdisciplinary collaboration and cooperation with parents, educators and governments. Vast resources should be invested in this discipline as it is a vital condition for the welfare of our children.

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1: R += ri // add resource ri to set of resources R
2: KB += ki // add rule ki to set of rules KB
3: D += di // add data di to be presented to children
4: For each CHILD from CHILDREN do
5: CHILD.KB = kj (kj in KB) // mapping knowledge about the child // to robots and games
6: CHILD.D = dj (pj in DxKB) // presenting initial data about the appropriate // robots and games
7: CHILD.R = rj (rj in RxKB) //making robots available
8: CHILD.P = pj (pj in PxR) end do // child playing and learning
9: IF pj > min
10: REINFORCE // reinforcements for success
11: IF pj > min_D_Feedback // if there is enough feedback that child needs // new data it is added
12: new dj= F(pj)
13: di = dj
14: GOTO 3
15: IF pj > min_KB_Feedback // if there is enough feedback to create new
                                   // knowledge about the child // the new rule based on the current play pj is created
16: new kj= F(pj)
17: ki= kj
18: GOTO 2
19: IF pj > min_R_Feedback // if there is enough feedback
                                  // that new resource is needed it is added
20: new rj= F(pj)
21: ri= rj
22: GOTO 1
23: IF pj>min_firing_kk // if a rule fired - an agent A proactively
                             // intervenes to change the game
24: pi=A(pk)
25: di= A(dk)
26: ri= A(rk)
27: GOTO 1
28: IF pj>min_Annealing kk=Random(RxDK) // once in a while annealing –
                                                // jump to another game to avoid local maximum
29: pi=pk
30: di=dk
31: ri= rk
32: GOTO 1
```

Figure 1. The basic session main loop algorithm