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Adaptive Robotics in the Entertainment Industry

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Abstract

In this paper, I discuss the market for adaptive robots in the entertainment industry, and some of the most promising avenues for the future development of this field. A United Nations report forecast an impressive 800% growth of this industry within 2-3 years. However, there are many issues that have to be considered when entering this field/market. Most notably, robotic toy systems can be developed to become either closed or open systems. Here, I promote open systems based on different psychological considerations, and I describe a few systems that we developed to enlighten the possibilities for open systems.

1. Introduction

Over the last decade, robots have entered to a large degree into the entertainment industry. Here, I will concentrate on a specific sector, namely robots as toys for children. In recent years, robotic toys have entered into the commercial market (see the following section).

In a recent survey, the United Nations forecasted that the entertainment robotic market sector will experience an impressive growth in number of units from 155,010 in the year 2002 to 1,202,000 in the year 2005 [1]. The UN forecast makes this field a very attractive business sector for many companies, and there should be vast possibilities for companies in the entertainment robotics field in the near future. However, it is also important to understand the underlying mechanisms of this market and especially to understand how the field may develop in the future in order to better understand the possibilities in this growing field.

Apart from the obvious business potential, as outlined above, there are some important issues regarding the value of the robotic systems as toys for children that need to be considered. Many robotic systems developed for the toy industry were developed with a main focus on the product price, meaning that little or no investigation of children's use of the robotic systems was performed. Essentially, the driving force has, in many cases, been the enhancement of a known product simply by adding a micro controller, a couple of sensors, and/or a couple of actuators. Whether such enhanced systems actually provide a qualitative increase in the joy of play remains unknown, as little structured investigation were performed.

Some robotic games for children were developed by putting emphasis on an educational approach, in which the children are allowed to learn about technology in Piaget's manner. However, we find that it is not enough just to promote this kind of learning. Suitable tools will have to be available for teachers and children, so we propose user-guided approaches based on adaptive systems techniques. These may include user-guided behavior-based systems, user-guided evolutionary robotics, user-guided co-evolutionary robotics, and morphological development. The techniques should be applied to allow children to develop their own robot behaviors in a very easy and fast manner. At the same time, the techniques should be so simple that most children and adults will have no difficulties in understanding and using them.

However, it should be realized that the autonomous systems approach also might introduce an educational problem. Often, in autonomous systems research, the goal is to achieve fully autonomous robots, both in the development and the behavior. This is highly desirable from a theoretical point of view and in some fully autonomous systems applications, but sometimes, in other applications, it may turn out to be less desirable. For instance, in entertainment that involves construction, the user would like to be able to direct the development of the system, and in production systems, the worker in a production hall might want to re-configure the robot for flexible production. We try to solve this problem by introducing the user-guided approaches.

It is important to note, that there are significant differences in between the different robots emerging on the market. In some cases, the robots are fully autonomous both in development and behavior (e.g. Furby) and so give *no* possibility for development by the user, in some cases there are *limited* possibilities for development by the user (e.g. I-Cybie, AIBO), and in other cases there are *extensive* possibilities for development by the user (e.g. LEGO MINDSTORMS, FischerTechnic robot). In our own work, we will concentrate on the latter kind of robotic systems, since we view these systems to best facilitate an educational approach in applications for children (though, initially, we have explored all three kinds in order to create the best possible basis for the future work).

2. Robotic tools as toys

The entertainment/edutainment sector has during the last couple of years tried to introduce artificial intelligence (AI) to children through various more or less intelligent toys. The study [2] presents a survey of these systems. One of the first AI based toys to hit the market (in November 1996) was the Tamagotchi from Bandai. Later, in 1998 Tiger Electronics released the Furby and LEGO released the LEGO MINDSTORMS. SONY released the first AIBO in 1999. Since then, a number of larger (e.g. Hasbro, FischerTechnik, K'Nex) and smaller companies have released numerous robotic products for the toy market.

Especially, numerous, cheap clone products with less AI capabilities than their more expensive inspiration products have hit the market. In most cases, these cheap clone products perform a repetitive behavior or a behavior based upon a very simple sensor-action coupling. The repetitive behavior may be changed slightly due to timing or simple reactions to sensory input. From the producers, this is often taken as evidence for claiming 'intelligence' in the robotic product. Though from a research point of view, this would by no means be enough to claim 'intelligence'. Indeed, it also results in products that seem to have a very short life span among the users. The interest wears off quickly because the behavior is discovered to be repetitive and not 'intelligent'.

Let us take the Furby as an example, since it is well-known to most readers. The Furby has sensors that react to light, sound, touch and physical orientation (standing or upside down). The infrared sensor, which looks like a third eye, allows Furbys to communicate among themselves, and even transmit colds that result in sneezes. The Furby can also communicate with humans using its "Furbish" language - the toy gradually learns some English words, too - and body language, including winks, ear twitches, and wiggling.

Seen from an AI point-of-view, the Furby has some very clear limitations. Everything the Furby is "taught" during its life is already pre-programmed and activated by the level of attention and caring it receives. Therefore it can principally not be called intelligent, as it has not got the ability to learn anything by itself.

Figure 1. The Furby toy robot.

It is quite characteristic for many of the cheap robotic toy products at the market that they are pre-programmed, and do not allow for much or any learning during the product life. Hence, the robotic behavior may become predictive and somewhat boring to the user.

Another limitation amongst many of the existing robotic toy products on the market is the lack of possibilities to allow the user to be creative in his/her interaction with the toy. Most systems are closed in their physical construction, so that the user is presented with a predefined robot structure with which it is possible to interact only in terms of manipulating the control or the sensory input. However, as described above, in many cases it is not even possible to manipulate the control, since it is pre-programmed. However, a few exceptions exist such as the LEGO MINDSTORMS, FischerTechnik, WonderBorg and CyberK'NEX that all allow construction of both the physical aspects of the robot and their control.

Some robotic toys are made for edutainment, and most of the current literature, when evaluating the educational power of robotics, refers to two main theories: Piaget's Constructivism [3, 4] and Papert's Constructionism [5, 6]. However, we should consider how edutainment robotics implements Vygotsky's idea of viewing knowledge as a process, which basically depends on technological and cultural scaffolding [10]. Nevertheless, we would believe that there is also something else that contributes to making edutainment robotics successful, though we cannot present a fully elaborated theory. The experience [7,8,9,10,11] tells us something more about learning mechanisms. First of all, we should bring fun within a learning context. That is something more than simply manipulating: it is to enjoy manipulating. Secondly, the first approach to the game/interaction is relevant. The game/interaction should be easy to discriminate, recognize and understand. The younger the children are, the more important that aspect becomes. At the very first sight, children should know what the game is about, how much fun they might get out of it and, loosing no time for understanding new rules, they will engage themselves in having the robots doing what they want them to do. As a side effect, parents/educators will feel comfortable with the game in the very same way. That is important, too, since parents' or teachers' motivations, drives and, oppositely, stresses might be directly reflected on to the children's ones.

A concern regarding the autonomy of autonomous robots is expressed in "Tech Toys. How are they affecting your child?", Child Magazine, February 2001, in which it is questioned whether the new technological toys may in fact "be dumbing down our children's play: stunting their intellectual growth, stifling creativity, shortening attention spans, undermining relationships, and, on top of it all, proving to be a huge waste of money, because the novelty of these high-tech toys can wear off long before their batteries die." A problem arising from this is that we may see an increase in the number of children who have trouble playing cooperatively, who lack empathy, and who crave nonstop entertainment, and David W. Willis, M.D., a developmental-behavioral pediatrician in Portland, has expressed "The problem is that without enough opportunity for open-ended play like building with blocks or engaging in pretend games, children may not learn the kind of logical thinking and persistence that help them develop problem-solving skills."

This is one of the reasons that in our future entertainment and edutainment robotic work, we will work towards the development of new technological tools that support the open-ended play, and try to develop technological building blocks (intelligent artifacts).

3. Development

In order to explore some of the issues mentioned above, we recently engaged in different activities of both developing robots with limited interaction (humanoids), context (RoboCupJunior 2002), new control for re-configurable robots (CONRO robots), and new construction kits for facilitating play with re-configurable robots. Further, the we engaged in an Italian State project on 'Educational Robotics' together with psychologists from University of Palermo, University of Naples II, and University of Cosenza, which supports the work on development of new technological tools in our work by providing a psychological basis and tests for the development of the new tools.

Viki Humanoids

In some work, we are promoting a new understanding of the way to build complex, electronic artifacts derived from modern artificial intelligence focus on bottom-up approaches. We wanted to investigate how this general approach of designing electronic artifacts bottom-up could lead to new ways for designing humanoids for edutainment. In contrast to the top-down approach of equipping a humanoid with as many sensors, motors, power, etc. as possible, we developed a bottom-up approach to the construction of humanoids. The approach is shown with the development of the Viki humanoid that won the RoboCup Humanoids Free Style World Championship 2002. For the development of the bottom-up approach we looked at the correspondence and interrelatedness between material, electronic hardware, energy use, and control. By finding the right balance and relationship between these components of the system, it becomes possible to develop biped walking and other humanoid behaviors with much simpler hardware and control than is traditionally envisioned for humanoids. Indeed, the Viki humanoid robots were able to win the world championship though they include much less sensors, motors and energy use than their competitors.

We developed our humanoid robots by first showing that one motor is enough to achieve straight walking and turning [12]. Later, we increased the number of motors when more flexibility in movement was desirable. So the humanoids use 5 motors. Two motors are used for leg turning, one motor for hip movement, one motor for body balance, and one for arm swinging. The humanoid is app. 25cm of height.

For the RoboCup 2002, the Viki humanoids were developed to dance and performed in an autonomous manner. Hence, in that implementation, they can be viewed as belonging to the class of entertainment robots with no or limited interaction possibilities (as Furby, AIBO, etc.). Currently, we are developing user-guided behavior based interaction systems for the Viki humanoids in order to increase the interaction possibilities. Another important experience with the user-guided behavior based approach is described in the following.

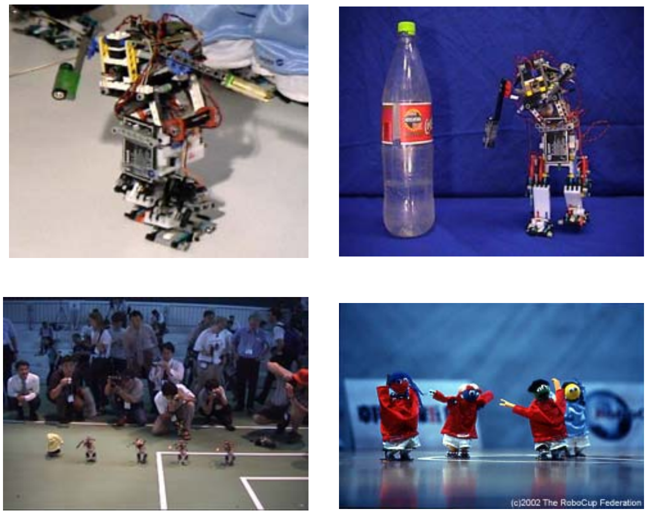

Figure 2. The Viki humanoid robots that we developed to explore the principle of coupling between hardware, software, material, and energy use. The Viki humanoid robots won the RoboCup Humanoids Free Style World Championship 2002. The RoboCup 2002 had 117.000 visitors in Fukuoka Dome in June 2002.

RoboCupJunior 2002

For the RoboCupJunior, we developed the game to allow children to get hands-on experience with robotics, and for this purpose we set up a LEGO MINDSTORMS robot soccer game for children. In Fukuoka, Japan, 70 teams of children from 16 different countries participated in the RoboCupJunior tournament. Before the RoboCupJunior 2002, we arranged a local tournament in Denmark in order to investigate the suitability of different tools that we developed for edutainment robotics – see http://www.adaptronics.dk/Projects/RobotFodbold/. We developed the *user-guided behavior-based approach* [7] in order to allow non-expert users to develop their own robots in an easy and fast manner. Indeed, using this approach, children of the age 7-14 were able to develop their own LEGO MINDSTORMS robot soccer players to play in nice and friendly tournaments with 60-90 minutes of development time! The winner of the local tournament was a small boy of 7 years of age, who won the trip to RoboCup 2002 in Japan, sponsored by the RoboCup Federation.

In a user-guided behavior-based system, it is the system developer who takes care of the difficult robotic problems, while the end-user is working on a higher abstraction level by making the coordination of primitive behaviors. So the programming environment for the LEGO MINDSTORMS RoboCup Junior was made with emphasis on allowing children (between 7 and 14 years of age) to develop their own robot soccer players. We found the behavior-based approach to be an excellent inspiration for achieving this. Especially, we used the concepts of low and high levels of competence, or primitive behaviors and arbitration. We, as developers, provide the primitive behaviors to the children, while they work (play) on a higher level with the arbitration of the primitives. Hence, the difficult task of designing low level primitives that includes sensor interpretation is done a priori by the programmer (so the children get to do the easier and funny part of coordination rather than doing low level programming). For instance, the interpretation of analog values on the input channels is done in the primitive behaviors, which might provide the user with a behavior such as ``Find the Ball''. The designer of the system programs the motors to allow the robot to, for example, turn around and stop when receiving values such as 618 and 355 on two of the input channels. But the user is simply coordinating the primitive behaviors.

Figure 3. The robot soccer tournament for children that we developed and held in Odense in May 2002.

Towards edutainment with reconfigurable robots

During the past year, our Ph.D. student Kasper Støy from the Maersk Institute collaborated with Shen's group at Information Sciences Institute, USC on developing control algorithms for producing locomotion in self-reconfigurable robots (and so focused on introducing the basic HYDRA foundation of modern artificial intelligence in the CONRO work and on the use in a demonstrator that gives indication to the possibility of using reconfigurable robots in edutainment). The idea is that an appropriate locomotion pattern can emerge depending on the way in which the modules are connected. This is appropriate for entertainment, because the child can change the way the modules are connected and the robot will automatically pick an appropriate locomotion pattern. For instance, the child can connect the modules in a chain and the robot will move like a snake. Later the child can make a quadruped walker and have it walk. This idea is demonstrated in Figure 4 and is reported in [13].

Figure 4. The robot first moves using a sidewinder gait (left). The robot is then manually reconfigured into a quadruped walker (middle). Finally the robot walks (right).

The simple software building blocks that make up role based control could be represented by different modules and the child could by connecting different modules produce different gaits. Overall this work represents some initial ideas about how to use self-reconfigurable robots in edutainment.

Intelligent Artefacts

The survey of existing edutainment robot systems tells us that there currently exist three categories of such: those with no construction possibility, those with little construction possibilities and those with extensive construction possibilities. Based on the input from psychologists, we currently engage in development of tools for the latter category, since such tools seem to provide the best basis for valuable edutainment for children.

Some important ideas about such new edutainment tools are presented in [14] on *intelligent artefacts*. With the development of intelligent building blocks it becomes possible to ‘program by building’. The construction with intelligent building blocks results not only in the development of a physical structure, but also in the development of a functionality of the physical structure. So construction of functionality can happen with physical building blocks that each contains computational processing and communication.

This allows us to work on some of the most important issues for the future robotic entertainment industry, namely the flexibility, creativity and user interaction. Indeed, we are able to use inspiration from embodied artificial intelligence to create these new robotic entertainment systems, because of the focus on a balanced approach between morphology and control (or in other terms, between body and brain). Hence, we focus on the integration of morphology and control, and thereby allow the user to be creative in designing both the physical aspect and the control of the artifact. And this happens as an integrated approach, in which the physical construction results also in the construction of the overall behavior (functionality) of the artifact.

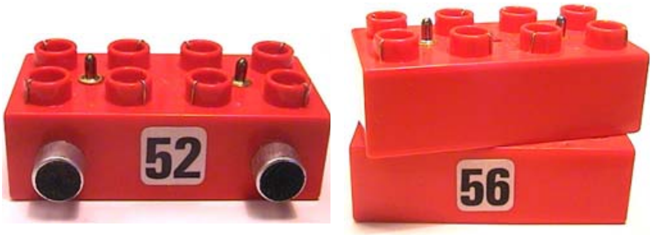

Figure 5. An example of intelligent building blocks implemented in LEGO DUPLO. In this implementation, there are two connectors on the top and two on the bottom of each neural building block. On each stud, there is connection for power transfer. Left: sensor building block that contains two microphones. Right: motor building block that contains a servo motor that allows the top element to turn. © H. H. Lund, 2002.

In order to exemplify the concept of ‘programming by building’, we developed a series of intelligent building blocks. Each intelligent building block contains processing power and communication capability. When two building blocks are physically connected they can communicate to each other and process the received information from neighbours. The building blocks can take various forms and be implemented in various materials, but for simplicity and for better visualisation of the concept, here they are housed in LEGO DUPLO bricks[1] (see Fig. 5).

Each building block is equipped with an electronic circuit containing a PIC16F876 40-pin 8 bit CMOS Flash microcontroller and a number of serial two-way connections (Fig. 6). In the case of rectangular LEGO DUPLO, each building block contains four serial two-way connections, two connections on the top and two connections on the bottom of each brick. In other implementations, there may be more or less connections, for instance there may be six connections (one on each side) in a cubic building block.

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[1] LEGO and LEGO DUPLO are trademarks of LEGO System A/S.

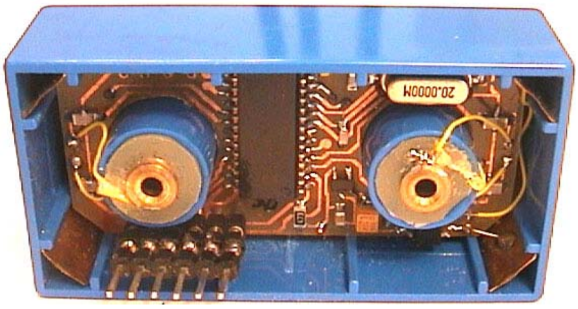

Figure 6. A building block with micro processor and communication channels. © H. H. Lund, 2002.

When two building blocks are physically connected together, they may communicate with each other over the serial connection(s). In the sending building block, signals are sent to one of the connectors, and the attached connector in the receiving building block receives these signals. In a typical set up, each building block will receive input on its communication channels, process this input, and then send the output of the processing procedure as output to the communication channels. A construction of such building blocks will have functionality defined by the physical construction (i.e. the topology), the input, the processing procedure in the individual building blocks, and the communication scheme. If input, processing, and communication are pre-defined, the user of such a system can decide the functionality of the system exclusively by manipulating the physical structure. However, it also is desirable to allow input to be decided at run-time, for instance through the inclusion of sensors in some building blocks.

All building blocks include the standard functionality of being able to process and communicate, but some include additional hardware, so amongst others, we developed input and output building blocks (see Fig. 5). Further, we developed battery building blocks (e.g. for rechargeable battery, standard 9V battery and small back-up batteries). It is possible to construct a number of other building blocks not included in table 1, e.g. building blocks with digital compass, sonar, accelerometer, etc.

With the intelligent building blocks, it is possible to construct a huge variety of physical objects with various functionalities. The processing in the physical construction is distributed among all the building blocks, and there is no central control opposed to traditional computerised systems (e.g. traditional robots). The distribution of control is obtained by allowing processing within each individual building block.

We the user is attaching the intelligent building blocks together in different configurations, he/she will create different behaviors. The behavior of the assembled artefact will depend on the physical configuration (i.e. the construction), the sensory stimuli (i.e. the interaction with the artefact), the processing in the intelligent building blocks (i.e. the control mechanism).

For the control, we implemented both arithmetic building blocks, behavior building blocks, and various kinds of neural building blocks, and other control methods can easily be implemented in intelligent building blocks. Arithmetic building blocks contain arithmetic operations such as addition, subtraction, division, multiplication, and children can therefore perform mathematical exercises by building physical structures with the intelligent building blocks. The behavior building blocks contain primitive behaviors that can be executed according to a schedule in the building blocks. For instance, they may be executed in a sequential manner according to their position in the physical construction, or extensions may lead to a behavior-based system with parallel execution of primitive behaviors and arbitration in the actuator building blocks.

One of the most interesting possibilities with the intelligent artefacts is the implementation of neural building blocks [15, 16]. The building blocks become neural building blocks by the specific implementation of artificial neural network processing in the PIC micro controller of each building block. In the simplest form, the individual processor reads the input (activation) on each input channel (connector), sums up the activation, applies a function (e.g. sigmoid or threshold) and sends the result to the output channels (connectors). So, the individual building block works as a simple artificial neuron, and the connection of a number of building blocks can work as a traditional artificial neural network with input, processing and output.

It is also possible to implement spiking neural networks in the neural building blocks (see Fig. 7). In this case, in a neural building block, action potentials build up towards an activation threshold, and when reaching the threshold the neural building block may be able to fire action potential to other connected neural building blocks.

The user can build artificial neural networks by assembling the building blocks, and afterwards train the artifact to obtain a specific behavior. The training can, for instance, happen through Hebbian learning in the neural building blocks, as shown in [16]. So the user is building a physical construction and afterwards trains it to obtain a specific behavior. This all happens with the building blocks alone – and, importantly for the entertainment experience, no use of an external host computer and no use of traditional programming languages.

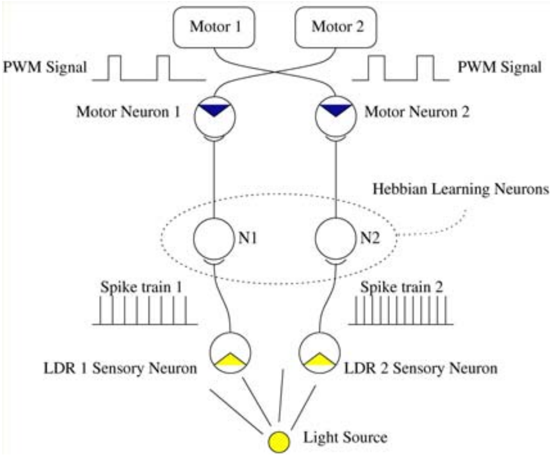

Figure 7. Spiking neural network with Hebbian learning in the building blocks. Taken from [16]. © J. Nielsen and H. H. Lund, 2003.

4 Discussion and Conclusion

In our collaboration with Italian psychologists in the Educational Robotics project, we try to quantify the positive and negative aspects of using robotic tools in education [17, 18] in order to study the impact of using robotic toys with children.

Not having the quantified data, we can however say that our extensive experience tells us that we need to go towards open systems in order to allow for more creativity and interaction, in order to keep children's interest with the robotic tools. Therefore, we are developing the intelligent artifacts (building blocks) that allow children to both manipulate the physical structure and the functionality of the artifact that they construct.

Also, together with the Danish playground company, Kompan, we are investigating how to apply adaptive robotics techniques to the development of future playgrounds in the project called Body Games. This may open a whole new market sector for adaptive robotics in the entertainment industry.

Figure 8. The test playground for assessment before the Body Games project. The test playground is enhanced with sensors, loud speakers, touch screen, etc.

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