AI in Children's Play with LEGO Robots

Henrik Hautop Lund

LEGO Lab
The Danish National Center for IT Research
University of Aarhus, Aabogade 34, 8200 Aarhus N., Denmark
http://www.daimi.aau.dk/~hhl
hhl@daimi.aau.dk

Abstract

We have made a number of robot applications as children toys. The design principles behind these applications are based on different artificial intelligence techniques. One of our main principles is to go away from the traditional play scenario of two intelligent agents such as child and "intelligent" computer game to a physical reality of the second intelligent agent. Hence, the game consists of a child playing with a physical robot that can be manipulated to different performances. For instance, we constructed a physical model of the old, popular computer game Pacman, where the child is to navigate a semi-autonomous LEGO Mindstorms robot around in a labyrinth while avoiding two fully autonomous "ghost robots". In other cases, we extend the games to include three intelligent agents: child, robot, and computer game, and in some cases, we even have four intelligent agents to interplay: child, robot, computer, and "intelligent" room.

Introduction – Educational Argument

In the LEGO Lab, we are interested in how to apply artificial intelligence techniques in children's play with LEGO robots. We find it essential, that the children have a physical entity to play and interact with, in contrast with the traditional computer games with which children interact with a virtual reality. Our attachment to the use of physical entities stems from our educational experiences with the use of robots. We find that children can learn about the real world (including math, physics, engineering, real world systems) by working with robots when using a constructionism approach (Papert 1980), especially when using a *guided constructionism* approach rather than the unguided constructionism approach (Lund 1999). In the guided constructionism approach, lectures/guidance and hands-on experience is combined in order to allow the students to learn about a subject. In general, the constructionism approach puts emphasis on the hands-on experience, and it is believed that children can obtain a tool to think about an artifact by playing with/constructing the artifact. Here, we believe that it is important that the artifact is physically represented. Our educational experience shows us that if the artifact is virtual, then at least in a number of cases, students tend to use abstraction about different characteristics of the artifact – abstractions that have no validity in reality! (Lund 1999) — see also (Miglino, Lund, & Cardaci 1999). Therefore, we believe that some subjects need to be taught in a way that puts emphasis on the child/student interacting with a physical entity.

When we are making toys for our children, we should be very aware of the positive or negative educational impact that these toys may have on our children. Therefore, we should also take it serious if research on students' use of abstractions shows that the abstractions lead to unrealistic views of real world systems. This should tell us that even though abstractions (and hence virtual realities) might be good in numerous circumstances, they might have a negative effect in other circumstances. We are trying to make a number of toy applications that allow children in a better way to ground their knowledge about artifacts in the real world.

Experiments – LEGO Robot Games

In the LEGO Lab, we have made a number of experiments that investigate the use of robots in children's play. In the autumn of 1998, during the Danish National Science Festival, we had 190 school classes with approximately 4,000 pupils of the age 7-15 to play with different interactive LEGO Mindstorms robots developed at the LEGO Lab. The robots include both wheeled and legged LEGO robots – among these an 8-legged LEGO spider robot with a layer of autonomous behaviour (walking, obstacle avoidance, etc.) which functionality can be overwritten by the child when controlling the robot's behaviour with a LEGO joystick. In this sense, the control system of the LEGO spider robot is a behavior-based system (Brooks 1986). Young children have great joy in observing, touching and steering the LEGO robot spider, and often use a lot of time to investigate the walking behaviour. The wheeled robot models include a LEGO fire engine that children can steer towards a house and have to spray water into.

Further, in order to allow children to play with the concept of facial expressions, we built a "humanoid" LEGO robot that will respond with different facial expressions depending on the colours of the LEGO bricks that the children feed to the "humanoid".

Figure 1: Some children playing with the LEGO spider robot. ©H. H. Lund, 1999

In order to allow young children to build their own robots, we have developed *modular LEGO robots*. Modular LEGO robots consist of a control unit with one or more fixed control programs. The children can build different functionalities of a robot by changing the morphology of the robot, rather than by changing the control program of the robot. This is radically different from traditional robotic approaches that normally consist of developing the control system of the robot. However, programming robot control systems might be difficult for children, because it demands knowledge of the syntax and semantics of the programming language, and it is necessary to go through a tedious debugging process. Our experience with children tells us, that they find changing the morphology of the robot simpler, and it allows the children to immediately observe the effect of their changes in the physical reality. Initially, we have implemented a couple of Braitenberg-type (Braitenberg 1984) controllers as the fixed control programs, and provided the children with around 6-10 different hardware modules that they can combine in order to develop new behaviours for their robot. The modules include a motor module, a back wheel module, a bumper module, an afraid-of-light module, a seek-light module, a labyrinth module, etc. We have observed children down to the age of 3 enjoying playing with the most simple of these modular LEGO robots, and a bit older children fascinated by building their own robots in the matter of minutes.

Another way to allow children to develop their own robots is by the Toybots approach (Lund *et al.* 1998). The Toybots approach is an evolutionary robotics approach that develops robot controllers through an interactive genetic algorithm. Here, we allow children to "program" by selecting which robots should reproduce among a population of robots that are shown graphically on the computer monitor. There is no need for knowledge about robot programming in order to enter into this process. The children simply points on the robots that have a characteristics that they might like, and through the evolutionary process, the robots are gradually modified in the direction that the individual child prefer. After the evolutionary process, the controller that the child has developed is downloaded to the physical LEGO robot. More details about this approach can be found in (Lund *et al.* 1998).

All these approaches put emphasis on the play with a physical model, either through the construction of models or by interaction/play in order to understand the functioning of the physical models. However, the fastest growing toy over the last couple of decades has been the computer game, which does not have a physical reality, but is a virtual reality. A reason for making virtual realities rather than physical realities is that one can make whatever kind of "reality" that one likes in the virtual world. It is possible to introduce agents (monsters, ghosts, heroes, etc.), actions (10 meter jumps, flying, shooting with extremely powerful weapons, etc.) and worlds (ancient worlds, planets from other galaxies, fairy tale worlds, etc.) that have no parallel in the "real" reality. This facilitates the story-telling in the virtual worlds, and allows the computer game industry to make appealing games. The games are, like most cinema films, appealing because they allow the user to flee away from the "real" reality into a virtual world in which the user does not have to question the reality but simply go with the (virtual) reality. However, this point becomes serious if we are interested in making games educational as well as entertaining. It is important that we educate our children to be active participants and to question the mysteries of the "real" reality. But since the computer games are so appealing, as developers of toys, we can ask ourselves if some aspects of these games can actually be transferred from the virtual reality to the "real" reality. As a first study of this, we have developed the LEGO Pacman game.

The LEGO Pacman game consists of three LEGO Mindstorms robots: two red ghost robots, and a yellow Pacman robot. The robots can move around in a white labyrinth with black lines as "walls". The labyrinth measures approximately 2m*2m. The control systems of the robots are behaviour-based with layers of behaviours. The ghost robots have a simple line-avoidance behaviour that allows them to move around in the labyrinth. The Pacman robot also has the line-avoidance behaviour, but on top of this, the user can steer the robot with a LEGO joystick that (via infra-red communication) sends commands to the Pacman robot. The goal of the game is to steer the Pacman robot into the centre of the labyrinth without the red ghost robots bumping into the Pacman robot. Children immediately recognises that this is the physical reality of the famous computer game, but are then also astonished that some functionalities are not included in the physical game, because they simply are too difficult to implement in reality. Initially, the children might have an unrealistic view of the robots, but they soon accept the robots with the functionalities that the robots have and play with these functionalities. The children accept the "real" reality as it is, and probably this will help the children in thinking about the "real" reality – what is possible and what is not?

Tournaments is another game concept that we have explored with LEGO robots. In the autumn of 1998, the LEGO Lab arranged the FIRST LEGO League pilot project, in which Danish school classes were to compete against each other in a friendly competition. Each class of pupils (aged 12-14) was handed out four LEGO Mindstorms robot kits, so that groups of 4-5 pupils could project, build, and program their own robot. The robots were to compete against another robot in a race on an arena that contained lines, obstacles, a ramp, etc. The robot that would move the longest way in the shortest time would win the race. The final between two schools from different Danish cities was held as a big event, and there were prizes to most teams (we wanted it to be a friendly competition).

LEGO Robot Soccer

For another competition, namely the RoboCup'98, which was held in France during the World Cup 1998, we made a robot soccer model using LEGO Mindstorms robots. For the robot soccer model, we constructed a stadium out of LEGO pieces, including stadium light, rolling commercials, moving cameras projecting images to big screens, scoreboard and approximately 1500 small LEGO spectators who made the "Mexican wave" as known from soccer stadiums (for more details, see (Lund *et al.* 1999). These devices were controlled using the LEGO Dacta Control Lab system and the LEGO CodePilot system that allow programming motor reactions which can be based on sensor inputs. The wave of the LEGO spectators was made using the principle of *emergent behaviour*. There was no central control of the wave, but it emerges from the interaction between small units of spectators with a local feedback control.

RoboCup is an international initiative to promote artificial intelligence robotics and the task of robot soccer as a landmark project (Kitano *et al.* 1997). As a landmark project, RoboCup differs from earlier artificial intelligence landmark problems, such as constructing an artificial chess player. One of the main differences is that robot soccer players have to play in the real world, where the chess play can be viewed as an idealised world, in which there is no need to address the problems of perception and noise in the real world. Essentially, the differences are similar to the differences between a simulated model of emergence and a real world model.

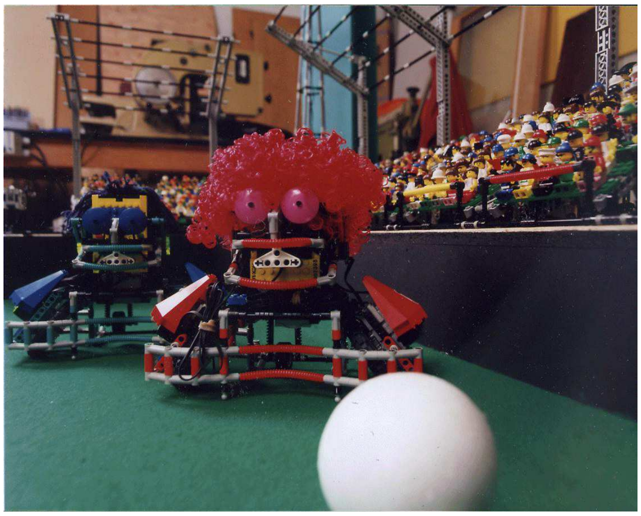

Figure 2: Two LEGO Mindstorms robot footballers. ©H. H. Lund, 1999

Each team of LEGO robots consisted of one goalkeeper and two field players. The goalkeeper was controlled with a LEGO CodePilot, while the two field players were constructed around the LEGO Mindstorms RCX (Robot Control System). Each player had two independent motors to control two wheels to make the robot move around on the field, and one motor to control movement of the robot's mouth (so that it could "sing" the national anthem and "shout" when scoring a goal). A player had three angle sensors to detect the motion of wheels and mouth. All parts of the robots except for batteries and coloured hair to indicate the team were original LEGO elements (LEGO Dacta, LEGO Mindstorms, LEGO Technic).

The coloured hair allowed a vision system connected to a camera above the soccer field to track the players (it also tracked the white ball). The vision system consisted of a neural network in hardware that could be trained to recognise the different colours. The information from the hardware vision system was sent to a host computer that processed it and could send information to the LEGO robots via infra-red transmitters.

In order to put the robot soccer play into a stimulating context, we built a whole LEGO stadium. The stadium had light towers (with light) in each corner, and these towers also hold infra-red transmitters that could transmit information from a host computer to the

RCXs. In one end, there was a scoreboard that could be updated when a goal was scored via an interface with the LEGO Dacta Control Lab. Over each goal, there was a rolling commercial sign that held three commercials that were shown in approximately 30 seconds each before the sign would turn to the next commercial. The control of the two rolling commercial signs was made with the LEGO CodePilot. A camera-tower with a small b/w camera was placed in one corner. The camera (controlled from a CodePilot) could scan to the left and the right of the field, while displaying the image to the audience on a large monitor. Another camera was placed over the sideline on one side and should scan back and forth following the ball. Also this camera image was displayed on a large monitor, and its control was made from LEGO Dacta Control Lab.

Essentially, the robot soccer set-up was made to be an entertaining event. Indeed, it was so, and a large number of television companies (including CNN, Sky, Columbian National Television, Reuters, AP, Azteca, Danish Television, etc.) came to film the event. It was broadcasted to estimated 200-250 million television viewers world-wide. In order to make the game interactive, we have now made a radio control for one of the teams, using LEGO CyberMaster, so that children are now supposed to play in teams of two against the team of autonomous robots. In this way, children can compete against AI controlled agents. Essentially, the concept of children playing with the radio controlled LEGO CyberMaster against the team of AI controlled autonomous LEGO robots is the same as in the LEGO Pacman game. We are taking a traditional computer game set-up with two intelligent agents interacting – child and AI controlled virtual agent(s) – and transfer one of the agents (the AI controlled virtual agent) to a physical reality.

At the moment, we are investigating how to make the interaction in games with three different kinds of intelligent agents, namely the child, the robot, and a computer game with AI controlled agents. Here, the computer game could be represented on the Internet and allow children to upload and download between the game and the physical agent (robot).

Conclusions

The above has presented a series of experiments in developing LEGO robots as an entertaining toy for children. The experiments range from models with a fixed structure to models that can be manipulated, from single robot games to multi-robot games, and from single user games to multi-user games. In all cases, the educational purpose has been emphasised (in some cases to a larger degree than in other).

Such physical games will have impact on the game industry – at least as a construction toy. The games should appeal to the increasing group of concerned parents who wants to provide their children with toys that apart from being very fun to play with also have an educational purpose – especially toys that prepare the children for the technological information society of the next millennium.

Acknowledgments.

The LEGO Mindstorms robot models were built by students from the LEGO Lab. Rene Schalburg built the LEGO robot spider. Esben Østergaard, Jesper Blynel, and Kasper Støy built the LEGO Pacman. Mikkel Kjær built the modular LEGO robots. Jakob Fredslund built the Humanoid LEGO robots. Jørgen Ilsøe built the LEGO fire engine. Henrik Madsen participated in making the Toybots, which is also a collaboration with Orazio Miglino, University of Naples, and Luigi Pagliarini. Jens Aage Arendt, Jakob Fredslund, and Luigi Pagliarini participated in making the LEGO robot soccer. Ole Caprani headed the FIRST LEGO League pilot project.

For photos, videos and further details, please refer to the LEGO Lab web-site:
http://legolab.daimi.au.dk

References

Braitenberg, V. 1984. *Vehicles: Experiments in Synthetic Psychology.* Cambridge, MA: MIT Press.

Brooks, R. A. 1986. A robust layered control system for a mobile robot. *IEEE J. Robotics and Automation* RA-2(1).

Kitano, H.; Asada, M.; Kuniyoshi, Y.; Noda, I.; Osawa, E.; and Matsubara, H. 1997. RoboCup. a Challenge Problem for AI. *AI Magazine* (spring):73–85.

Lund, H. H.; Miglino, O.; Pagliarini, L.; Billard, A.; and Ijspeert, A. 1998. Evolutionary Robotics — A Children's Game. In *Proceedings of IEEE Fifth International Conference on Evolutionary Computation.* NJ: IEEE Press.

Lund, H. H.; Arendt, J. A.; Fredslund, J.; and Pagliarini, L. 1999. Ola: What Goes Up, Must Fall Down. In *Proceedings of Artificial Life and Robotics 1999 (AROB'99).* Oita: ISAROB.

Lund, H. H. 1999. Robot Soccer in Education. submitted to Advanced Robotics journal.

Miglino, O.; Lund, H. H.; and Cardaci, M. 1999. Robotics as an Educational Tool. *Journal of Interactive Learning Research.* Forthcoming.

Papert, S. 1980. *Mindstorms: Children, Computers, and Powerful Ideas.* New York: Basic Books.