THE BENEFITS OF INTEGRATING LEGO MINDSTORMS INTO DESIGN EDUCATION. COURSE "MEDIA SYSTEMS"

Constanze Langer, Christine Strothotte
Institute of Industrial Design, Magdeburg, Interaction Design Group

ABSTRACT
Nowadays, the LEGO Mindstorms Robotic Invention System is known as an established component of the education at many universities and has become accepted at schools and universities. Faculties of computing and electrical engineering, in particular, commonly use LEGO Mindstorms. In contrast, the use of this technology for the education of designers is more the exception rather than the norm.
Likewise, we have been using LEGO Mindstorms Robotics for teaching at the Industrial Design Institute at the University of Applied Sciences Magdeburg since 2000. This paper presents the course "Media Systems" as part of the Bachelor's programme in Industrial Design. The course introduces students to the basic principles of computerised systems pertaining to hardware and software, which should enable them estimating the impact and the potential of modern information technology. The acquired technical expertise will be of value for incorporating aspects of information technology in the design of future products.
Developing robots and working with LEGO Mindstorms Robotics creates an awareness of the very close relationship between software and hardware: manipulation of one has a strong impact on the other. This perception is essential for developing intelligent products successfully. We suggest that components of a product ought to be developed in a synchronised process where the designer focuses on both, the hardware as well as the software.

Keywords: LEGO Mindstorms, Media Systems, Computerised Systems, Information Technology, Hardware Design, Software Design, Product Design Process

1 INTRODUCTION

LEGO Mindstorms Robotics were developed as an ambitious toy by the well-known manufacturer in 1998. Seymor Papert, serving on the LEGO advisory board for many years, is one of the driving forces for enabling children to learn playfully with the help of technology. Even the brand "Mindstorms" was derived from his book named "*Mindstorms: Children, Computers and Powerful Ideas*" *[1]*. The main focus of the LEGO Mindstorms project was to create a learning environment that enables "learning by making". Papert introduced this catchy phrase for representing the idea of constructionism [2].
The LEGO Mindstorms System consists of a collection of user-programmable components, electric motors, sensors, and LEGO-Technics bricks. A proprietary operating system can be easily controlled from a conventional PC. Furthermore, it is

also possible to extend the provided components by integrating them with traditional LEGO bricks.

2 LEGO MINDSTORMS: PART OF THE CURRICULUM

Within our Bachelor's programme on Industrial Design at the University of Applied Sciences Magdeburg, we teach "Media Systems" as part of the "Technologies" Module. One of the most challenging tasks to teach the first year students is to handle the complexity of modern products as well as the complexity of the design process itself. A robot can be seen as a complex industrial product containing micro-electronics, such as sensors and micro-chips. The inter-dependability of hardware and software is an essential challenge and insight for the students.

In the tradition of constructivism, we do not talk much about the basic concepts of interaction design at the beginning of the course, but let the students just experience the dependability of software and hardware. At the end of the term the students are able to reflect and draw conclusions on the basis of their own findings, much more effective than information passively absorbed in traditional lectures.

The development of solutions takes part in groups of 2-4 students. The deadline is usually one week. Part of the task is always the presentation of the robot and its functionality as well as the documentation of the solution. Students usually spend 4-6 hours per week on this course and earn 2 credit points.

3 PLAYING WITH THE ROBOTS

3.1 Typical challenges

The tasks are chosen in order to present different challenges for the students to explore. We will introduce some of them within the following chapter.

The first task is to become familiar with the LEGO system. Very typical for this phase is the creation of a robot that can follow a line on the ground by using a light sensor, or the moving of a robot by exactly one metre. These first tasks are not restricted to any kind of hardware or software limitations, as this is reserved for some of the later tasks. The goal is to integrate a primary sensor and to become familiar with the programming editor. Other examples of tasks are building a drawing robot (see Chapter 3.2.2), building a moving robot out of as few parts as possible (see Chapter 3.2.1) or enabling the robot to change its hardware while working. One example for the last challenge is "Mind the gap". The robot firstly has to recognize the gap, then it has to use some kind of folding mechanism to overcome the gap.

All tasks we have referred to so far posed real challenges to the students, but at the end we were surprised over and over again. The results were completely different in most cases and this variety of solutions encouraged us to follow up.

3.2 Examples of completed tasks

We will go into more detail for three examples of exercises and their results in the following chapters. Details of the ideas behind the exercises can be explored by examining these tasks and the results.

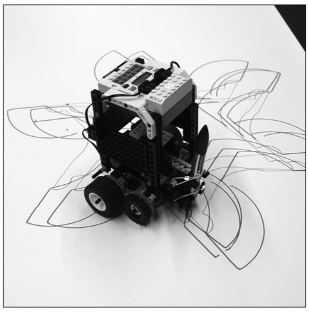
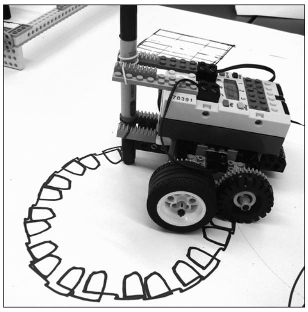
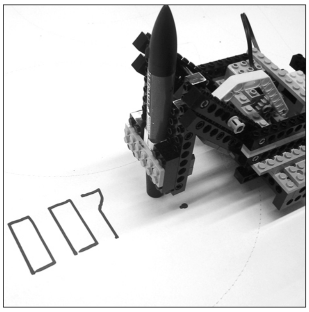
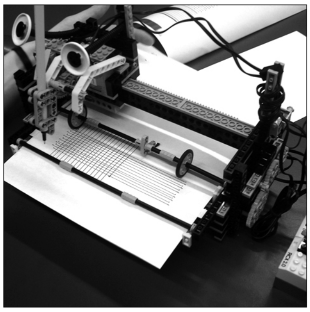
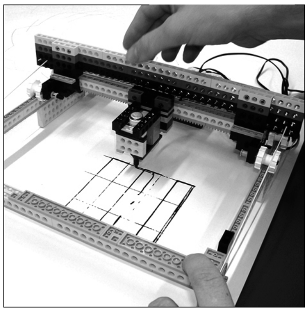
3.2.1 The Minimalist

Designers often have to deal with special agreements and restricted terms in the design of products for their future working life. Because of that it is useful for the students to get used to handling such situations and creating high creative output, hence some

exercises are assigned with restrictions. For example, we arrange the competition of creating a moving robot which turns exactly to the right after one metre by using the smallest number of parts as possible.
The most surprising result was a robot with only one motor and therefore moving both wheels synchronously, but blocking one wheel exactly after one metre and therefore turning the robot. The winner used only 11 components. All other groups had used two motors to control the wheels separately.

3.2.2 Drawing Robots

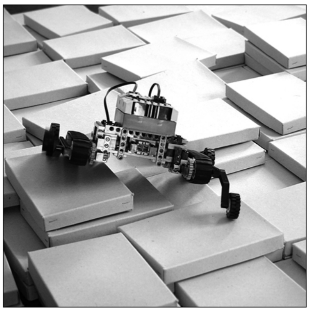
This task is the construction of a robot that draws a geometrical pattern on a maximum area 2x2 metres. The first step was to draw continuously on paper with a fixed pencil, whereas the second task was incorporating a liftable pencil into the drawing robot. The pencil ought to be placed at the centre of rotation of the robot in order to guarantee drawing an exact right angle.
There are several further exercises possible in the field of drawing robots, like writing sentences or visualising the metaphor of chaos and organisation.

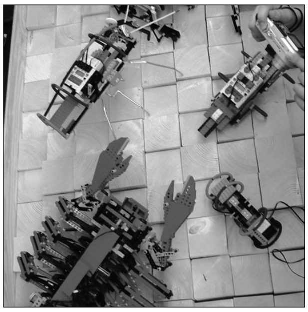
It is obvious that there are several ways to achieve a satisfactory result. To provide an example: one team might build a robot which acts as a LEGO-printer drawing exact straight lines; however, their robot is limited in drawing chaotic structures or curves. If the robot itself is mobile, it will be able to draw very interesting but its ability to draw a straight line is impaired.
Besides different hardware design coding different programme scripts for controlling the robot enables more variations too. It can solve different tasks by using a single hardware design but multiple software designs. Playing with these possibilities enables the students to derive different variations, a typical approach in the design process. Our intention is that the students should recognise that there are several ways of looking at a problem and hence make a decision that leads to success.

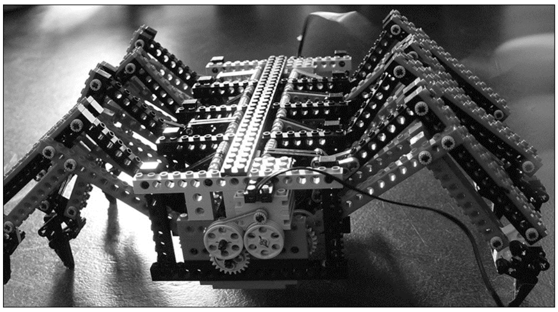
3.2.3 Imitation of animal motion in a rough environment

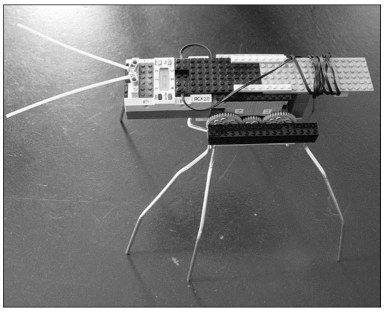
A specific challenge is the building of a robot that imitates the motion of an animal and can also move in a flat as well as a rough and unknown environment.



There are several questions of interest, like:
_What is the typical appearance of the animal?
_How does the animal move in detail?
_What kind of kinematics is transferable when using LEGO Mindstorms?







Obviously there is a high variety of methods of constructing animal robots. The crab, for example, combines a high degree of complexity by using multiple motors and a lot of bricks. The imitation of movement was almost life-like, but somewhat clumsy because of the heavy weight. Other teams decided to choose a light construction that enables faster movement. One group achieved a fantastic result, with which it was possible for the robot to move in a rough environment while imitating a stick insect.

3.3 Integration of related sciences

Design History and Industrial History are commonly regarded as very theoretical, in the worst cases even dull, subject areas. This course provides the pleasurable opportunity of integrating these sciences – and indeed other related sciences – into the robot development, in addition to the courses included in the normal curriculum. The integration of History, Visualisation and Documentation Techniques in a suggestive way is the topic of the next two sub-chapters.

3.3.1 History

In addition to the performance of the robot solution, lectures are held every week. For example, topics range from the history of robotics [3] to the evolution and usage of robots in industry [4], service robots [5], humanoid robots [6], war robots, and the influence of robots on science-fiction movies and books or vice versa. To offer experience here as well as in building robots we screen classics such as “Metropolis” or “2001: A Space Odyssey” – the discussions afterwards are very compelling, especially because the students are enthusiastic about the films while at the same time they are so far away from their normal viewing habits.

3.3.2 Techniques of visualisation and documentation

In addition to the elaboration of the robot each exercise also includes techniques of visualisation and documentation. Several techniques are applied during the term, so that various techniques can be compared at the end of the term. It is interesting for the students to ascertain which technique is useful for communicating which kind of information. The process of the development of the robot or the experimentation of the best solution for the assigned task can be documented, e.g. in written form, with or without the help of pictures, or by creating infographics without using any kind of text, or verbal explanation, or by using pictures, movies, and providing mindmaps.

3.4 Feedback of students

We ask our students for feedback at the end of every term, which is essential for developing and improving the course in a continuous way. Feedback is gathered by means of evaluation forms as well as personal interviews and correspondence via e-mail.

It is possible to say with certainty is that team-working takes place very well and social cohesion of the groups was confirmed over the course. Students often emphasise that solving a problem did not feel like a problem and or like hard work, when offset by the amusement provided by playing with LEGO bricks together in a team.

It was confirmed that the development of hardware and software took place in parallel and were considered of equal importance, and that every student worked on the hardware as well as on the software at least once.

4 DISCUSSION

Although it is always a fun project, our “Media Systems” course is equally an essential module of the basic curriculum of teaching Interaction Design. The structure of the course, with new tasks almost every two weeks and presentations almost every week, enables the development of at least 4-5 different robots and presents the teams with a new challenge every second week. This approach enhances the motivation significantly although it limits the possibilities for complexity. This course provides an introduction and an overview – students’ knowledge can be deepened in one of the full projects in

cooperation with students from electrical engineering. The aim of this course, however, is to explore the wide variety of robots.
As you can read from the feedback of the students, the team-building process during the term is highly appreciated and is obvious to the teachers. Depending on the team and the experiences and skills of the team members, the teams achieve results by using simple hardware but by balancing it with a high level of complexity in software design, or vice versa.
To date, we have worked with the LEGO Mindstorms Robotic Invention System, however, we have already tested the new LEGO Mindstorms NXT. The variety of new sensors opens up new possibilities for the hardware part of the tasks, and the open source software makes the software part more flexible. On the other hand, our first experiments with NXT have showed us quite plainly that the new form concept (i.e. the deviation from the classical brick form) makes NXT much less flexible. To combine both systems could be an attractive solution, with which we plan to experiment during the next term.

REFERENCES

[1] Papert, S.: *Mindstorms: Children, Computers, and Powerful Ideas.* (Perseus Books, 1999).
[2] Papert, S. and Harel, I.: *Constructionism* (Ablex Publishing Corporation, 1991).
[3] Cecaarelli, M. (Ed.): *International Symposium on History of Machines and Mechanisms* (Springer, 2004).
[4] Miller, A.: *Industrial Robot Handbook: Case Histories of Effective Robot Use in 70 Areas* (Van Nostrand Reinhold, 1989).
[5] Schraft, R. D. and Schmierer, G.: *Service Robots* (AK Peters, 2000).
[6] Hornyak, T.: *Loving the Machine: The Art and Science of Japanese Robots* (Kodansha International, 2006).

Acknowledgements
The authors gratefully acknowledge the participation of all of our highly motivated students and teachers from the Industrial Design Institute.

[1]Constanze LANGER
Institute of Industrial Design
Department of Engineering and Industrial Design
Interaction Design Group
University of Applied Sciences Magdeburg-Stendal
Breitscheidstrasse 2, Haus 9
D-39114 Magdeburg | Germany
contact@constanze-langer.de
www.design.hs-magdeburg.de
00 49 (0) 391 8864 242