Applied Social Robotics - Building Interactive Robots with LEGO Mindstorms

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Abstract. Teaching Social Robotics is a requiring and challenging task due to the interdisciplinary of this research field. We think that it can not be taught in a solely theoretical manner. To help students to gain more interest in the topic and to foster their curiosity we restructured a paper club like lecture to create a bridge between a theoretical topic and practical applications. This paper describes our approach to create a lecture covering theory, methods and how to transfer those to applied informatics. Described is the given theoretical input and how students learn to transfer these to a robot they build on their own. We also evaluate how the new structure was accepted and what lessons can be learned for this lecture style.

Keywords: Social Robotics, Educational Toys, Applied Techniques

1 Introduction

In a not so distant future robots might be an integral part of our daily life. The commission for innovation and research of the German government has prognosticated that the consumer and service market will be the most growing economy in the next years [1]. Hence, there is a requirement for robots that are capable of interacting with people and working in domains that were up to now staffed by humans. Thus, engineers designing and building new robots need a broad knowledge from different disciplines (i.e. sociology, psychology, computer science). This interdisciplinary demand is currently brought together in the research on social robotics. However, there is no common curricula for students that are interested in this field of research yet. We see that early stage researchers coming from an engineering background have to struggle with many different theories, publications and methodologies.

In the past years we have offered courses to teach social robotics. Students read different publications connected to one of the sub areas of social robots. Those areas were i.e. robot design, emotion expression, anthropomorphism, applications and evaluation methods. The students were preparing on of the seminar sessions including a presentation of the publication, a discussion and a

[1] http://www.e-fi.de/fileadmin/Gutachten_2016/EFI_Gutachten_2016.pdf, visited 03/11/2016

handout. We encountered that the seminar sessions often did not match the actual details of the topics. Thus, the association between different topics and the general scope of the seminar were difficult to grasp for the students and obstructs students to continue with this line of research. We encountered that a theoretical approach to teach social robotics is not sufficient to understand the concepts and a more hands-on approach is needed.

To overcome the difficulty of the materials and the complex access to knowledge about social robotics, we restructured the seminar in a modern fashion. We have changed the seminar to a course that covers topics on social robotics in an interactive lecture like structure. Each lecture is accompanied by an exercise where a given technique or method is directly integrated into a practical hands-on part. A group project concludes the lecture part by applying all learned elements into one practical and functional social robot. Thus, we wanted to teach how the theoretical input can be explored using a practical approach.

For the practical part the LEGO© Mindstorms EV3[2] educational set is used, allowing students to easily create robotic systems that can act and be perceived as small social entities. The robot scenario is based on the Tamagotchi developed by Bandai. This small toy uses different needs and actions to mimic a small autonomously behaving pet the user has to care about. The idea for the project was to take basic elements and behaviors from the Tamagotchi and let the students understand and transfer those to a socially perceivable LEGO robot.

In this work we want to present our concept for teaching social robotics on a university level. We will present our lecture structure, content, and methods we have used. At last, we will give a discussion about our experiences teaching social robotics, the effectiveness of our lecture paradigm, and reflect on comments and feedback from our students.

2 Related Courses and Teaching Methods

In this section we want to describe how other universities are teaching social robotics. We have searched for courses using the keywords 'human-robot interaction', 'social robotics' and 'lecture'.

The social robots lab in Freiburg offers a seminar on social robotics[3]. Student's learn how to conduct a literature review, read papers, and learn about state-of-the-art methods. Finally, they give a presentation of their results during a block seminar and write a summary about a paper. The content of the paper were mostly tracking, motion, and path planning.

The GeorgiaTech has offered a course on HRI[4]. The lecture covers a wide range of topics on the emergence of social intelligence and the state-of-the-art on building systems with social intelligence (e.g. Anthropomorphism, Embodiment,

[2] education.lego.com/MINDSTORMS-EV3
[3] `http://srl.informatik.uni-freiburg.de/ss15seminarsocialrobotics`, visited 03/10/2016
[4] `http://www.cc.gatech.edu/~athomaz/classes/CS7633-HRI/`,visited 03/10/2016

Experimental Design, Intentional Action, Collaboration, Teamwork, Turn taking, Dialog, Emotional Intelligence, Social Learning, Telepresence, Assistance). The lecture is accompanied by a final group project.

The Indiana University offered a course on HRI Design[5]. Topics were Classifying HRI, Evaluating HRI, Autonomy and Perception, Interfaces, Enhancing Interfaces, Robot Teams, Museum Robot, and Search and Rescue. The lecture was followed by a final project. During the course, students had to complete readings, quizzes, and labs on how to design a HRI system. Prerequisite were programming knowledge in C and JAVA. The assignments were a discussion where students have to submit half a page summary of the class paper, pros and cons, and questions. Quizzes cover the reading material using multiple choice and true-false questions. Lab assignment were conducted on a mobile robot outside of class.

At last we want to mention the lecture Principles of Human-Robot Interaction from Carnegie Mellon University[6] . Topics are: Social Robotics, Multimodal, human-robot communication, Human-robot interaction architectures, Sensors and perception for HRI, Museum robotics, Educational robotics, Urban Search and Rescue, and Quality of Life Technologies. Students have to attend the course, read papers, answer questions related to the papers, and do a semester-long group projects.

All presented courses, except the seminar taught at the University of Freiburg, have a similar structure and similar topics. However, the description of the topics for the course are still a bit broad. This makes it hard to compare the content of i.e. 'Autonomy and Perception' to "Sensors and Perception for HRI". The difficulty to distinguish the different topics of social robotics reflects the interdisciplinary of this research field. Hence, all lectures use different books or publications as the reading material for the students (there is only one publication that all of them are using as a reference: [1]). This leads to the fact that students studying at different universities will read different references for the same subjects. We do not think that every seminar should have the same content at every university. The diversity on topics is important to give students the choice to think about to which university they apply. However, we see a demand to define a core set of topics that should be taught in a introduction course on social robotics.

Therefore, we want to report how we went from a reading-based seminar to a lecture based-hands-on course. Using this process we generated ideas how to capture the different topics of social robotics into a new curricula.

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[5] `https://www.rose-hulman.edu/~berry123/Courses/HRI/HRI%20Syllabus.pdf`,visited 03/10/2016

[6] `http://www.cs.cmu.edu/~illah/ri899.html`,visited 03/10/2016

3 Previous Courses

In the past years we offered several courses for students to start gathering knowledge in the field of social robotics. Most of the courses were held in a paper club style to introduce to the different subtopics of social robotics.

Throughout the lecture each student had to prepare a given topic and to present it to its fellow students. To fulfill the course the topic had to be documented in a written style and handed in at the end of the term. In the first session of the course details on the structure of the lecture as well as a basic introduction on the topic of social robots were provided. Afterwards the different subtopics got briefly introduced and distributed between the students. The common topics used for the paper club lecture can be seen in Table 1.

Table 1. Topics covered in the paper club on the topic of social robotics.

Topic
Anthropomorphism [2]
Forms and Function of Robots [3]
Uncanny Valley [4]
Relations between Forms and Robots [5]
Perception of Behaviors [6]
Attitudes towards Robots [7]
Mental Models for Robots [8]
Socially Assistive Robotics [9]
Evaluation of HRI [10]
Long-Term Interaction with Social Robots [11]
Emotion Models [12]

Each student prepared their topic themselves and presented it in the paper club. The presentation concluded with a discussion allowing fellow students to ask questions on the topics or to discuss possible conjunctions with following topics. Afterwards the students wrote a short documentation for their topic to be handed in at the end of the term. The documentation was the main element to successfully complete the course. There was no written or oral exam due to the fact, that the course was part of an individually chosen block of the students study regulations.

One big problem with this structure was the decreasing motivation to participate in later presentations, especially for those who had already presented their topic. The seminar started with around 14 students in the first sessions. Throughout the term this number decreased to about five to six students being present for the last presentation.

Another problem was the lack of fortification of knowledge and the transfer to other topics. Due to the fact that the presented information where not prompted afterwards in an exam style, many students did not tend to foster their interest.

4 The Idea with a Goal: Applied Social Robotics

Based on the experiences from the previous course, we decided to change the structure for the next term and to help students in finding more meaningfulness. We wanted to foster the transfer of gathered information and knowledge into a more practical approach.

To achieve this we decided to build a new course structure around a project in which students themselves build small social robots. Because the course is open for Bachelor students that had just started their university career as well as for Master students that already had come in contact with more complex topics, we decided to use the LEGO Mindstorms platform. This technology allows, even without deeper technological understanding, to easily create small robotic systems. Nevertheless it also offers a wide range of exploration and artistic freedom for users with more expertise.

Fig. 1. The Tamagotchi device. A small child's toy capable to mimic behaviors to foster engagement. It can request attention and care due to visual and audio feedback.

To provide a base scenario we decided to let the students create robots behaving equally to the Tamagotchi toy pet(see Figure 1). These small devices mimic behaviors of pets by demanding attention and care (see Section 5.1). Hence, our teaching idea was to help students understand how the Tamagotchi can be seen as a social entity, how its behaviors can be described, and how such elements can be transfered to small robots build with LEGO.

Our overall goal was to evaluate how students deal with the new structure. We proposed that creating a conjunction between a dry theory and a practical approach can help students to gain an easier access to such a topic. Additionally, such a course structure can promote creativity and result in an interesting outcome concerning the created robots.

5 Structure of the Course

For the structure of the course we decided to use three different parts: a lecture on topics of social robotics, an exercise to introduce the technological part and give some transfer ideas between topics and technology, and a project in the end of the term with focus on applying learned elements into a real robot behaving in a social manner.

The first part is a lecture. Throughout each session the lecture covers a given topic (see Table 2) that is presented by a lecturer. At the beginning of a new topic the last topic is shortly reviewed and students have to solve simple tasks like answering questions. To keep the students interested we used some interactive teaching methods that should encourage students to directly work with the knowledge. For example we use a method called *Mumble Time*. This method helps students to exchange their knowledge on the current topic with a partner and to collect ideas for a discussions with the whole group. Students that don't like to discuss in a broad group can exchange ideas with the partner and let them forward these to the group. The techniques used are based on smaller and bigger groups and work as well as working with shared contents of the presented topics. At the end of each lesson the topic is summed up and a discussion to ask questions, on possible ideas on how to apply the topic, or how the conjunction to a follow up topic can be is started. The lesson concludes with an impulse outlook for the following exercise and the upcoming topic.

The second part is the exercise. These exercises mostly cover how the technology of the LEGO Mindstorms can be used to create small robotic devices. Here the programming part gets explained as well as direct practical realizations by the students. As programming language we selected JAVA and the LEJOS[7] API. This API allows to develop control algorithms for the LEGO EV3 control brick with easy to understand elements. Throughout each exercise students work together in groups with up to three people and try to solve given tasks. These tasks cover building small moving vehicles or more complex tasks like creating emotions with the given parts.

The third and most practical part is the group project at the end of the term. Each group consists of up to four students. For every group a complete LEGO Mindstorm education set is issued to create their own robot. As project goal we defined that each robot needs to include behaviors according to those of the Tamagotchis. For the full project every group has time span of six weeks. Throughout this time frame the group has to create their own robot, program its behaviors, and to create a documentation of the project process. In the last session of the term, the groups have to present their robot by providing information on their idea behind their robot, how they build and developed it, and give a prospect about possible enhancements or additions.

[7] http://www.lejos.org/

Table 2. Topics to be covered in the lecture part of the seminar. Each topic is presented by a lecturer. Throughout the lecture students use group work to discover and discuss the different topics.

Topic	Content & Lecture	Teaching Method
Introduction to the Course	Information about the lecture, exercise and the group project	-
Introduction to Social Robotics	Outlook on Research, Platforms, What makes a robot social?[1], [13]	Mumble Time, Open Discussions
Social Agents and Control Structures	Introduction to Agents, Models for Agents, Definition of Control Structures[14]	From Mumble Time to Group Presentations
Anthropomorphism and Social Actors	What means Anthropomorphism? How do humans perceive robots and agents? What means "to act socially"? [2], [15]	Group Work and Cross Presentation
Form and Design for Robots	From technical to human-like robots? Design choices for robots, Examples of research platforms[4], [5]	Mumble Time and Collection/Discussion of Good, Bad, Ugly Designs
Internal Models and Emotions	How to model behaviors, Controlling internal states, How to express emotions? [12], [16], [17]	Hands on: How to build Emotional Elements for Robots
Applications for Social Robotics	Information on ongoing research, Already applied robotic systems	Group Posters and Presentation
Studies: How to for Evaluation	Basics about evaluations, What is a research question?, How to create a study?[18], [19]	Group Discussion about what to evaluate based on the upcoming project

To fulfill the course each group has to prepare a documentation containing the information provided in the final presentation as well as a documentation of the building and programming process.

5.1 Tamagotchi: Behaviors of a Small Toy

To provide a scenario that defines a broad range of behaviors but leaves space for individual ideas, we decided to use the Tamagotchi toy device and its features as basis.

The Tamagotchi published by Bandai in the 1990th is a small digital toy that was created in Japan by Akihiro Yokoi. The small egg like toy has a digital display and three buttons. The toy is programmed to mimic behaviors of a small pet. With the buttons the user can manipulate and interact with the digital pet. The pet itself is based on simple wishes and desires. It needs to be *fed with different food, cleaned, disciplined, cheered*, or *cared about* in case it got ill. With the different buttons the user can initiate different actions according to the needs of the pet. The goal is to understand the different needs and to satisfy them. If not cared about correctly the pet may die and a new pet needs to be bred.

Throughout the lecture the Tamagotchi is used to compare topics of social entities with the behaviors of the toy. For this students got introduced to the Tamagotchi and were advised to understand how the digital pet works. Our goal was to teach students how to transfer the Tamagotchis behaviors into ideas for a social LEGO robot. Based on understanding the toys background the students should reverse engineer the behaviors and then transfer them to their robots. For the project and the transfer we focused on the behaviors concerning *feeding, cleaning, cheering*, and *taking care*.

Each group could themselves decide how such behaviors are expressed with the available parts of the provided set. We only advised each group that their ideas should be understandable by other persons that only interact with the robot, but who had not programmed the behaviors themselves.

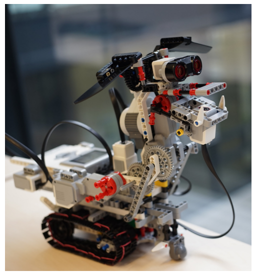
5.2 The Group Project and the Results

For the project phase a total of six weeks was determined. In these weeks the student groups should think about how they could create the Tamagotchis behaviors, how to build their robot, and how to program the control mechanisms. Each team was free to explore how the given LEGO elements can be used and how their ideas could come to life. Every group was advise to document the steps taken from starting with ideas until the final robot was created. This should help to generate content for the documentation to be handed in afterwards.

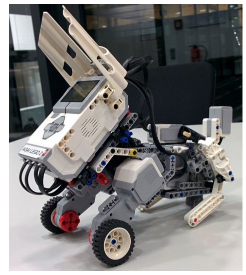
Four student groups with up to three students were formed for the project phase. Each group got one full set of LEGO Mindstorms. The sets could be taken home and there was no need to bring them in or to only work in predefined slots. This allowed the groups to work freely on their own behalf. Before the final presentation all groups were randomly visited by the course supervisors to get an idea on how the groups come along. Also each group was free to ask the supervisors for help.

For the final presentation each group created a small digital presentation mentioning the ideas on how they approached the project, how they build their robot, and how they implemented the requested behaviors as well as their own. Additionally they should mention what problems occurred throughout the free working time. After all groups had presented their LEGO robot, the different robots were demonstrated between the project groups. In this live demo the different behaviors were shown and fellow students could test the robots themselves and asks questions.

The resulting robots were quiet impressive and fully functional. Every group was able to create robots that showed the intended behaviors. Some groups focused on more complex technique robots while other focused more on simple movements with most impact on understanding the behaviors. To give an example one group created a robot that looks like a duck (see Figure 2a). The robot is capable to move its ears up and down. This feature is used to show the emotional state of the robot. Whenever the robot is sad the ears are moving down. For the predefined states this feature is used to support the robots needs, for instance if the robot feels dirty and needs to be cleaned. This emotional state is supported by using audio files in the corresponding situation. The behavior of feeding / eating is supported by opening the mouth and by chewing whenever a given item is placed inside the mouth and therefore above the placed light sensor. In total the robot duck was programmed by using a subsumption architecture. Needs and beliefs are predefined and get selected according to values stored in



(a) The Robot Duck



(b) The Little Dog

Fig. 2. Two examples of the different robots created by the project groups. Image (a) shows robot duck with ears to show emotions. Image (b) shows a dog like pet with eyes presented on the display.

the background. The designed and implemented behaviors are understandable to users and fulfill the course definitions. The second example is a dog like robot called little dog (see Figure 2b). It can turn around, move its head, and use audio files to express its mood. One interesting feature of this robot is the cooperation needed with the human. For example if the robot gets tired, it uses audio and head rotation paired with eyes shown on the display to announce this state. The user then needs to flip the robot to the side. By using the gyro sensor this state gets detected and the robot starts sleeping and snoring. A video showing the behaviors of the little dog can be found at the CITEC video channel[8].

5.3 Evaluation of the Course

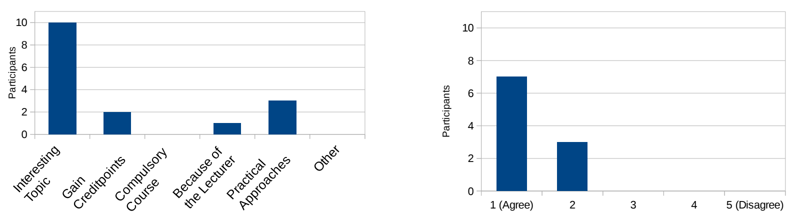
The Technical Faculty of Bielefeld University offers an evaluation for each course by providing questionnaires. These can be handed out to the students and will be evaluated by staff from the faculty itself. The results can then be compared between all provided courses. Unfortunately these questionnaires are optional and were not conducted for the previous lecture style. Nevertheless from colleagues we were assured that the amount of students decreases until the last sessions and that the motivation was not that high.

For our new lecture we handed out the questionnaire on the date of the presentation session. In total eleven students participated in the evaluation. We had three bachelor students, five master students, and three PhD students.

The results showed a positive response to the new designed course structure. One question concerns why students visit the course (see Figure 3a). For this question multiple answers were possible. Ten students marked their interest on the topic as a reason to participate. Three students liked the idea to work in a more practical manner. Nearly all students participated in every session until the final presentation. This shows that we could keep the students interested on the

[8] CITEC, https://www.youtube.com/citecbielefeld

topic. For the lecture part the slides used were marked as detailed and interesting (see Figure 3b). Nevertheless an additional script would be appreciated and could help foster the transfer of gathered knowledge.



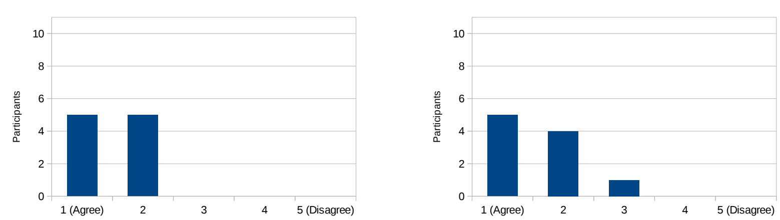
(a) Why do you participate?

(b) Did the provided material support the content of the lecture?

Fig. 3. Evaluation results provided by the Technical Faculty.

We tried to apply now teaching methods to help those students that normally would not discuss in larger groups. This commitment was positively assessed by the students group (see Figure 4a).

For the practical part the votes showed that students liked to be creative and to transfer the topics to the LEGO robot. The results also show that the new structure fosters interest on the topic of social robotics beyond the course (see Figure 4b).



(a) The Lecturers are interested in teaching the topic

(b) Students are actively involved

Fig. 4. Evaluation results provided by the Technical Faculty.

Additionally to the questionnaire we conducted an open discussion round at the end of the presentation session. We used a method called *Five Finger Feedback*, allowing students to give one feedback concerning a scope matching a finger of the hand: *What was good?* (thumb), *What needs to be enhanced?*, *What was not good?*, *What do you take with you?*, and *What was too short?* (little finger).

From the verbal feedback we can conclude that the new structure is very helpful to transfer theories to practical applications. It helps students to understand the associations between topics. Students reported that they liked to get a psychological point of view on computer science which was new and interesting for them. For ourselves we learned, that we need to provide more time for the exercises to foster creativity. Also we may need to hand out a script with more details on the given topics. Another point mentioned was the wish to deploy more LEGO sets to allow smaller groups and therefore to build more robots.

6 Lessons Learned

Retrospective we are happy with the new structure and we are glad we switched to the more practical part. This was our first approach to this new type and we learned much about what else could be enhanced. We will work on the parts mentioned in the evaluation and given by the students feedback to make the seminar more interesting and understandable. Also we will extend the number of LEGO sets to increase the number of further students. Additionally, we will define some criteria to rate the results and to evaluate if the provided lecture style and the given specifications match the outcome.

In general for teaching a topic that is complex and that combines many subtopics, the idea to create a bridge between theory and practical applications offers a big benefit for both, students and lecturers. With the direct transfer from lecture to exercise students can more easily adapt to gathered knowledge. Also the connection between subtopics becomes more clear. At some point for our teaching method this conjunction resulted in interesting discussions. This also helps us, the lecturers, to question the theory ourselves.

Nevertheless a practical part can help to understand theory more easily, the lecture part should also offer a good proportion of knowledge. This lecture part should also offer some impulses for the students to employ themselves even more and to create more transfer ideas for the practical parts and even other related topics.

7 Acknowledgement

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