The Use of "Tell me, show me and let me do it" in Teaching Robotics

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Abstract

The summary of our experience conducting a hand-on course, titled "The Introduction to Robotics" with a Lego-based laboratory, is given here. We discuss the importance of using video clips, live demo, lab visits, and regular competitions in teaching robotics. Our experience showed that through a combination of teaching and hands-on lab, the students acquire system design skills and improved understanding of important physical concepts, algorithms, and coding methods that apply to the vast field of engineering.

Introduction

The new generation of students is not easy to be entertained and looses its focus easily. The harder the topic, the harder to keep the students interested and focused on the subject. Consequently the engineering topics are the primary field which suffers from student retention. On the other hand, the same generation has used many new intelligent toys and played with computer games. Thus, they have a good memory about technology and engineering. To take advantage of this good memory, a hands-on course will definitely improve the student retention and helps them understand the subjects better. We, at the University of Southern California, have implemented a hands-on introduction to robotics course which allows the students to enjoy the beauty of engineering topics while they learn robotics.

It is well said that "Tell me and I will forget. Show me and I will remember. Let me do it and I will understand." We implemented our Introduction to Robotics [1] course based on the same approach. In other words, the students listen to lectures to start learning about robotics, they see actual robots demonstrated in the class or by video clips to remember the topics, and they actually build mobile robots in the lab to fully understand the concept. The descriptions of the lectures followed by the labs are discussed below.

Course Material

The course is based on the following books:

- "The Robotics Primer" by Maja Mataric
- "Robotic Explorations: An Introduction to Engineering Through Design" by Fred Martin

The first book in used totally in the class. The second book is used partially in the class and mainly in the lab. We used to use the book by Ronald C. Arkin titled "Behavior-based Robotics". Although it was very informative, however it was hard for the main stream undergraduate students. The replacement, "The Robotic Primer", is very nicely written which makes it very easy for students to follow it. Nonetheless, a book in between the two would be a great addition to teaching robotics to undergraduate students. The "Robotic Explorations" is very hand-on book and very well written tailored for working with the Handy Board, the single board computer used in the lab. A companion set of slides to this book can be found at http://www.ee.washington.edu/class/462/aut01 that covers the same set of topics in a presentation form made by Dr. Linda Bushnell. The extra information needed for the course that has not been covered in any of these books has been provided through our own slides.

Another source of material especially for the lab is the books related to Lego Mindstorm, a kit similar to Lego Technic kits with less computation power. Since Lego Mindstorm has been used widely among the hobbyist, there are many books written to do projects with it that can be similarly used in the lab. Also, there are many web sites describing projects related to the Lego Mindstorm. We have listed several on these useful resources on our class website.

Lectures

The lectures, which are 1 hour 20 minutes long, are organized to start with a brief history about robotics and continue with the robot's mechanical parts like wheels, motors and gear boxes. Then shifts to discuss sensors and electrical hardware needed to build a robot. In the next step, the control theory behind the robots is discussed by looking at the classical feedback control followed by the discussion on the 4 robot architectures: reactive, deliberative, hybrid, and behavior-based. More advanced topics such as learning, group robotics, and humanoid robots are discussed afterward. The detailed syllabus is as follows:

1. Defining robotics
2. Historical context
3. Robot components
4. Effectors and actuators
5. Locomotion
6. Manipulation
7. Sensor basics
8. Simple sensors
9. Complex sensors
10. Feedback control
11. Control architectures
12. Representation
13. Reactive control
14. Hybrid control
15. Behavior-based control
16. Behavior coordination
17. Emergent behavior
18. Navigation
19. Robot learning
20. Group robotics
21. Humanoid robots
22. Advanced topics/robotics today and tomorrow

In each of the above topic, beside the books, we use extra resources mainly from the web to discuss them. For instance, in the lecture about the history of robotics, the old images and movies would be very interesting to the students. For example, Hans Moravec's work has been very well documented at his own web site [2].

The lecture about the manipulators has been improved by using VRML (Virtual Reality Modeling Languages) models. For instance, the model for Puma 560, Manutec, and Kuka KR6 can be found at the German Aerospace Center [3]. These models let the students to get a more realistic feeling about the manipulators especially when they do not have a chance to physically use them.

During the discussion about the sonars, we use the work done for the handicaps at the University of Michigan to demonstrate the important of such sensors [4].

Beside the normal lectures, we use the following methods and tools to improve discussion and to avoid boringness:

1. Video clips

To avoid lectures of becoming boring and to increase the discussion on the topics, one or two video clips are used throughout each lecture. It is important to choose clips that are related to the topics under discussion. One of the best sources for video clips is the ICRA, the International Conference on Robotics and Automation, video proceedings. However, more video clips can be downloaded from web by simply searching based on the topic.

2. Live demo

We have also used live robot demo in the class to better explain the topics. Cheap, off-the-shelf robots such as RoombaVac [5] have been used to show how the sensors are incorporated in a robot and how a robotic architecture has been implemented. This close contact with robots allows the students to better understand the robotic/engineering issues and feel more confident by seeing/touching a robot. Furthermore, we have invited people from the research community or the industry to come and give short talks about the use of robotics in their field of interest. We have been eager to invite people who can bring actual robots or very informative video clips to make the presentations as useful as possible. For instance, the use of demining robots, which is a hot topic after the war in Afghanistan and Iraq, was discussed by the president of the Society of Counter-Ordnance Technology, Mr. Bottoms [6].

3. In-class quizzes

It has always been a problem to introduce a topic and start a useful discussion among all the students, especially the more theoretic the topic the harder to get the whole class into the discussion. We have used in-class quizzes to further improve the discussion in the class. The students are given some questions to answer in 2-5 minutes followed by a discussion on the question. If the questions are selected appropriately, then the quiz greatly increases the student's understanding about the subject. Moreover, it makes all the students to think about the topic and the instructor can get a feeling of how much of the topic has been understood. A good source for in-class quizzes is the previous exams which attract more students into the discussion.

However, some may question using quizzes in every lecture due to its difficulty of grading. To avoid the burden imposed by grading the in-class quizzes, there is no official grading for the in-class quizzes. Nonetheless as long as a student participates in the quiz, he/she earns the extra credit assigned to it. It was interesting to see that the students' attendance has been increased, above 75% throughout the semester, since they saw a great impact of the in-class quizzes in their understanding. Moreover they were interested to earn the extra credit.

Figure 1 shows an example of an in-class quiz in which we wanted to show the students the difficulty of image processing and object detection. It is very hard to tell the students how hard and time consuming it is to find objects in an image. However, by asking them to do the image processing by hand, they felt the difficulty of the image processing and the amount of time needed to do it. Moreover, they realized the steps involved in using cameras for sensing the environment.

4. Lab visits

Many students were curious to see what goes in different robotic labs on campus to make a connection between the subjects discussed in the class and real world research. Moreover, they want to make a decision on what to do before/after graduation. One method is to give a short talk about each lab and their activities. However, the better approach is to have a live lab visit. We conducted some lab visits and the students had a close contact with the corresponding faculty, even some started working for them. It is very important to have the faculty responsible for the lab to do the presentation since the students get a better understanding about the lab and its activity. Also they feel respected by having direct contact with the research faculty.

5. Detailed Examples

Like all other engineering topics, a detailed example greatly facilitates the students' education. In robotics, there are many topics from different fields like Mechanical Engineering and Electrical Engineering that some of the students may not be familiar with them. Consequently, a detailed example greatly helps the students to better understand the topic under discussion. For instance, we use a very simple example to demonstrate the steps involved in controlling the speed of a car using feedback control. In this example we show the result of using the Proportional, Proportional Derivative, and Proportional Integral feedback controls.

Laboratory

The lab is almost half of what the students are going to do for this course. It is designed so that it will provide the students with an educational environment both academic and fun. In groups of 3, the students gradually grasp the fundamental concepts of robotics through the first half of the semester and then will use them to prepare for their final project. They learn how to use different kinds of sensors, what issues are important in designing the body (hardware) of a robot, and how they can practically implement the robotics concepts into actual programs.

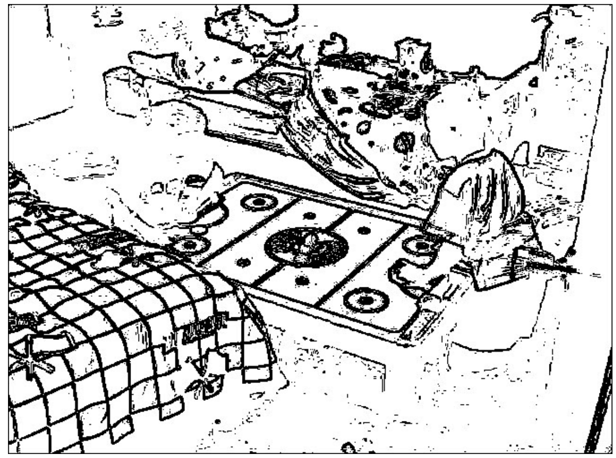

Figure 1: A sample quiz "find the objects in this picture."

Their performance in the labs is judged based on whether they achieve the objectives of each lab, how much they participate in design and implementation, and how well their robot will perform in the final contest. The lab structure and equipment is summarized as follow and more information can be found on the lab web site [7]:

1. The structure of the labs

The lab sessions are weekly, each 3 hours. We have 3 lab sessions each week and they usually contain 12 to 16 students, grouped in teams of 3 (and sometimes 2). Students are encouraged to choose their friends as teammates and stick to them throughout the semester. It is important to mention that we use groups of 3 due to lab size and the number of available kits. However, the perfect group size is 2 since all the members get a fair amount of exposure.

The semester is divided into two parts: In the first half of the semester, they will learn how to work with different sensors, such as photo-resistors and contact sensors, and how to program their robots to do simple tasks. During this period, they basically use the same design for their robots and mostly focus on the programming part (except for the labs involving gears and speed).

Each lab of the first half of the semester begins with an introduction made by the lab assistant about what they are supposed to do in that session. The introduction contains a brief explanation about the sensor that they will use in that lab, the requirements of the job, the concepts underlying the lab and some tips and suggestions on how to do the lab more effectively. They are also provided with handouts that provide them the necessary information about their lab in addition to the book.

The difficulty of using complex sensors, like ultrasound sensors and vision (camera), has made us to dedicate two labs to these sensors. The students are shown the basics of these sensors and they are given clear steps to use them.

Unfortunately, the single board computer, the Handy Board which we are using on our robots, has limited resources like limited power and memory. Consequently, these sensors are not used widely in the lab. For instance, when we requested the students' feedback on using ultrasound sensors, the immediate response was that it is not accurate since the Handy Board's battery discharges very fast using sonar. Thus, the reading is not accurate.

2. Competitions

In order to make the environment more competitive, the labs are designed so that the objective of each lab is achieved through a contest. For instance, in order to learn the concept of speed and torque, gears and movement, the corresponding lab contains a speed contest in which their robots will compete and the fastest robot will become the winner. This encourages the students to work harder to improve the performance of their robots and grasp the material more efficiently during the process. Each of the contests requires a different setting for the lab to provide the suitable platform for their robots. The contest platform is prepared by the lab assistants prior to each lab.

3. Lab reports

Students are required to turn in lab reports about each lab which should contain their design (both hardware and software), the problems they encountered, how they solve them and the problems they were not able to solve (and why). In addition to this, they are occasionally supposed to take quizzes which are about what they have done in the labs.

4. The final contest

The second half of the semester is dedicated to preparing for the final contest. In this period, the students are on their own and will design both hardware and software of their robots according to the requirements of the final contest. At the end of the semester, the final contest will be held in which their robots will compete with each other and the best robot (the winner of the game) will be announced. The winner team, the team with the best mechanical design, and the team with the most innovative design receive certificates for their achievement.

Figure 2 shows the structure of the field used for the contest. It is a simulated soccer field with some obstacles to avoid. The goals are marked with IR emitters and the filed does not have sharp corners to avoid robots getting stuck in the corners. We used both balls and cubes since the ball are harder to be controlled when picked up.

There are some technical issues in making the competition field and conducting the contest:

- The walls should be dark and not shiny. Otherwise they will reflect the IR waves very well resulting in misbehaviors in robots.

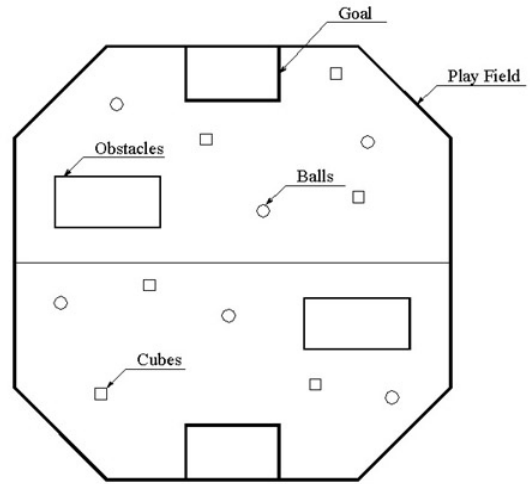

Figure 2: The competition field is a simulated soccer field. Balls, cubes (in some cases), and obstacles are lying on the field to be collected and avoided by the robots. The goals are marked using IR emitters. The robots should pass the goal line and leave the collected balls in the goal area.

- The filed should be very smooth or the robots get stuck since the line detection sensors should be placed very close to the ground.
- It is better to conduct the competition in a room with multimedia facilities so the competition can be shown live on a big screen. This will resolve the students' congestion around the competition field.
- A double elimination competition is much better than a single elimination since it gives a second chance to the students to find and fix their problems.

5. Equipments

We are using the Handy Board [8], a 68H11-based controller, to control the robots. The robots are built of the Lego Technic kits [9], which are the improved version of the normal Lego kits to tolerate more pressure and they are stronger. The sensors and extra accessories for the robots can be purchased from Acroname [10] and the robot store [11]. Sensors such as photo-resistors and contact switches can be purchased from any electronic shop such as All Electronics [12]. We decided to use normal contact switches rather than the switches provided by Lego since they are cheaper and can be manipulated more easily. We are also planning to replace the photo-resistors with other light sensors since photo-resistors are very sensitive to the ambient light resulting into students' frustration.

To develop the code, each group needs a workstation (PC, Mac, or Linux) to write their code and upload it into the Handy Board. Each workstation is equipped with Interactive C (IC) version 4, an Interactive C version with graphical user interface [13], to write the code in C for the Handy Board. The graphical user interface of IC4 makes it better than the old versions but it has some limitations such as it cannot run more than 4 processes simultaneously. These types of restrictions/problems can be further discussed at the following discussion lists:

- http://groups.yahoo.com/group/handboard
- http://news.lugnet.com/robotics/handyboard

Further information about the Handy Board and related sensors can be found at:

- The Handy Board project at MIT [14]
- Gleason Research [15]

Future work

We are constantly working on improving the labs and add more features to it. We recently fixed a problem to effectively use the Polaroid sonars for the Handy Board. We are working on making a lab for vision processing using CMUcam. Finally, we have started some studies to use PocketPCs rather than the Handy Boards since they have more features and can be programmed more easily.

We also conducted extra projects with some of the students to remotely control a robot over web. The next step is to make the robot more intelligent. The advantage of these types of projects is the inclusion of two popular topics in computer science: robotics at one end and web programming at the other end.

Conclusion:

There is no doubt that teaching robotics along with a lab is very effective, fun and entertaining for the students, and appealing to the university. Our experience shows that including the all three elements of teaching; tell me, show me, and let me do it, are necessary in a successful teaching. Finally the web is a good resource for finding examples, demos, video clips and simulations that can be used in the class.

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