Summer internship
Intelligence for a Social Robot in a Game

Bruno Alexandre Pires Henriques

Activities Report

Abstract—This report documents the work I have done during the summer internship at Intelligent Agents and Synthetic Characters Group (GAIPS) in 2014, with the subject "Building Intelligence for a Social Robot in a Game" using robot Baxter. The final project consisted in the development of a small scenario of object manipulation with four main components: Vision Manager responsible for image processing, Arms Manager responsible for generating and executing move/pick/place trajectories and another component named Emotion Manager responsible for representing human emotions. I developed partially the Arms Manager and I developed great part the Emotion Manager but my focus was making sure that the final architecture was flexible, scalable and had high quality. I also took part of the final presentation done on October 3rd 2014. All the required tasks were developed successfully and we exceeded the supervisors expectations. The report first will give an overview of the tasks completed during the period of the internship, then the results and the limitations will be discussed and analyzed with further detail.

Index Terms—GAIPS, INESC-ID, Research, Robot, Baxter, Presentation, Image Processing, MoveIt, BEA, Emotions, Vision, Motion Planning, Internship

Too Many! Only 5 or 6 relevant!

1 Introduction

THIS report documents the work I have done during the summer internship at GAIPS installations, Instituto Superior Técnico, TagusPark under the supervision of Professor Ana Paiva, Professor Francisco Saraiva de Melo and Eng. Tiago Ribeiro, researchers at INESC-ID. The internship's duration was two months from July 2nd 2014 (with a 10-day break in August). I also worked an additional week to prepare and present the project's end result in front of the supervisors and other researchers on October 3rd 2014 at Instituto Superior Técnico (IST) TagusPark.

The subject of the internship is "Building Intelligence for a Social Robot in a Game" using robot Baxter whose full name is Baxter Empathetic Agent (BEA). The final result consisted on a small game of object manipulation using a set of objects that required image processing algorithms, motion planning algorithms and some techniques for expressing human emotions using gestures and facial expressions.

The team was composed of four students: Rui Oliveira and Diogo Almeida have finished their Integrated Master Degree in Electrical and Computer Engineering (MEEC) at IST, Filipa Correia was still finishing her Master Degree in Information Systems and Computer Engineering (MEIC) at IST and me. At that time, I just finished my BSc's degree in Information Systems and Computer Engineering (LEIC) at IST. Most of the project was done unsupervised giving the team more autonomy and responsibility.

In the following sections I will describe without getting into technical details what was my role in the project, what I accomplished, what were the results and what were the project's limitations.

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What?

2 Project Overview

This being a big project, it was important to define the minimum value to be achieved at

	ACTIVITY					DOCUMENT						
(1.0) Excelent (0.8) Very Good (0.6) Good (0.4) Fair (0.2) Weak	Objectives x2	Options x1	Execution x4	S+C x1	SCORE	Structure x0.25	Ortogr. x0.25	Gramm. x0,.25	Format x0.25	Title x0.5	Filename x0.5	SCORE
	2	1	4	0.8	7.8	0.25	0.2	0.2	0.25	0.4	0.5	1.8

the end of the project and what were the supervisor's expectations. After a discussion with the supervisors it was decided that, at the end of the project, we should have a prototype that could detect and differentiate several different Lego bricks, pick one and finally place it at a specified place. The prototype's architecture should also offer great quality and flexibility acting as an example for future projects.

3 The Goals

The main activity objectives (and tasks) were:

- Arms Manager - Develop a component that generates and executes trajectories for moving, picking and placing objects;
- Vision Manager - Develop a robust image processing component capable of generating a virtual model of the world by detecting and mapping accurately different objects arranged on top of a table;
- Emotions Manager - Develop a component that is able to generate and represent human emotions;
- Bea Mind - Develop a component that integrates all the above components.

4 Exploring

July 2nd until July 11th

During this period, I explored Baxter Software Development Kit (SDK) [1] and some open-source tools made by others researchers working with robot Baxter. Most of the tools lacked documentation or were not fully integrated with robot Baxter so we had many difficulties integrating them on our project. I also explored the Robot Operating System (ROS) [2] and how it worked. In short, in ROS, each component can act as a client or a server and can share messages with other components by publishing information on public topics (e.g. the current angle of each joint).

During this period of time, I investigated a framework named MoveIt [3] that allows to generate and execute movement trajectories for Bea's limbs given the virtual description of the robot using Extensible Markup Language (XML). Additionally, I configured a version control tool in our project and explained how it should be used during the project.

5 Developing Arms Manager

July 14th until July 25th

During this period, me and Diogo, developed three components:

- Movement Controller - Responsible for moving the arms;
- Pick Controller - Responsible for picking objects;
- Place Controller - Responsible for placing objects.

5.1 Movement Controller

Using MoveIt [3] we managed to create, in short time, a component able to position Bea's hand anywhere given Bea's limitation and a maximum error for the hand's position and orientation. Then, we created a component that allows to add virtual objects in the virtual scene. Those objects were later taken into account by MoveIt when generating trajectories so, as a result, Bea would not collide with them. The motion planning was fast so the results were very satisfactory.

5.2 Pick Controller

For Pick Controller, we used a framework named MoveIt Simple Grasps [4] capable of generating and execute picking plans. Each pick plan contained:

1) The initial position for approximation;
2) The approximation vector;
3) The retreat vector;
4) The final position after retreating.

In one day, we developed a separate component responsible for generating several possible picking plans for a given object. The development of the component that executes the picking plan took longer than expected because we had many difficulties configuring Bea's hands XML description for collisions. The progress was slow as we tried to fix every bug. After researching, we noticed that most of the problems we were having were very similar to others mentioned on an online forum named "MoveIt Users" [5] created by MoveIt. Therefore, we shared our problems there and collaborated with other researchers working with Baxter, in order to find a solution.

Later, while Diogo kept on fixing Pick Controller, I focused on improving other aspects of the project:

- Cleaned up project structure;
- Removed outdated code;
- Configured installation scripts to ease the development cycle.

The results were excellent. It was easier to develop more software modules without breaking the existing code and I reduced to one the number of scripts needed to run the project (we had at least four). After Diogo managed to fix the existing problems with some limitations (section 5.4), I added hand gripping feedback and attached the object to the hand after picking allowing the generation of trajectories that took it into account avoiding impacts. Moreover, picking retreat vector had some issues using the generated picking plan so we choose to manually define one: vertically.

5.3 Place Controller

Finally placing the object (after picking) was trivial requiring only one day of work. We just reused Movement Controller (described in section 5.1) and manually opened the hand with the object attached.

5.4 Problems and Limitations

We had many problems with the XML description of the robot because it was very sensible to changes leading, or to slow generation of trajectories, or to collisions that were not supposed to happen (e.g. collisions between the neck and the head) and the lack of documentation did not help. As a solution, we established a minimum error tolerance in order to progress in the project. At the end of this period, the whole Arms Manager pipeline was done, but had some limitations:

- Virtual object's size is ten times smaller than reality;
- Lack of feedback when grabbing objects;
- Not integrated with Vision Manager.

6 Vision Manager

July 28th until August 1st

During the project's first three weeks, several algorithms were developed by Rui and Filipa, however, most of them lacked accuracy or efficiency. At the end, we all opted to discuss with professor João Costeira from Image Processing course. He suggested an algorithm (whose name is not mentioned intentionally) that can easily identify and locate objects in any angle using image patterns. Therefore we stamped zebra, leopard and fish patterns on top of the objects as shown in Figure 1.

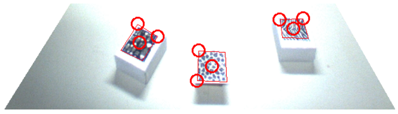

Figure 1. Computer generated image showing several objects located.

6.1 Optimizing Vision Manager

The obtained results were very accurate, but lacked speed and flexibility because most of the code was hard-coded so this component was far from finished. During one week, me and Flipa made some improvements:

- Made it work with any camera;
- Made it work with arbitrary number of different patterns;
- Removed irrelevant image features;
- Made it run in multiple threads.

These tasks were completed with excellent results. The component's performance was ten times faster, it allowed to use any camera available (one in the head and two for each hand) and allowed to use an arbitrary number of different patterns. It is relevant to mention that the more patterns this component is able to detect, the more variety of objects it is able to detect.

6.2 Integrating with Arms Manager

Me and Filipa developed a sub component inside Vision manager responsible for publishing, periodically, the list of objects available on top of the table using the head's camera. When picking, since the head's camera only gives a rough estimation of the object position and orientation, we had to use the nearest hand's camera to retrieve a more accurate one. For that purpose, we start by initially sending the Bea's nearest hand to a position exactly twenty centimeters above the rough estimation, with the camera pointing downwards to the object (Figure 2). Then, we re-analyse the image frame and retrieve a better estimation using the hand's camera. The result was great because we were able to estimate with negligible errors the exact position and orientation of the objects.

Figure 2. Bea using the hand's camera to estimate the object's position and orientation while showing a nervous face and following the hand with her eyes.

6.3 Problems and Limitations

Some limitations had to be tolerated in order to focus on the requirements that were more important. The main limitations are:

1) Table must be in a fixed position;
2) Object's position's height is constant;
3) The size of the blocks are not measured in runtime;
4) Cannot handle two blocks on top of each other.

7 Emotion Manager

August 4th until August 12th

While my colleagues, Diogo and Filipa, fixed bugs related with the integration of Arms Manager and the Vision Manager I helped a colleague of mine, Rui, that already had started developing several different faces to be shown on Bea's screen. However, as with Vision Manager, the code lacked flexibility and required re-factoring. For that purpose, with the help of Rui, we separated the face generator into four main stages:

1) Generation of the skin face;
2) Generation of the eyes;
3) Generation of the eyes brows;
4) Generation of the mouth.

Afterwards, I created several eyes behaviours and head gestures that allowed Bea to track her hands or the nearest person's face (using a component developed by Filipa in which I made small contributions) using her head and/or eyes. Then, I further expanded our work and made Bea able to nod "yes" and "no" with her head.

The final results were great because by separating the face generator into several different modules, we made this component very flexible and re-usable. I strongly believe that, with our efforts, we can integrate Emotions Manager in any project related with robot Baxter.

8 Bea Mind

August 13th

Filipa and Diogo finished wrapping up the Vision Manager and Arms Manager on August 12th and result were great. They developed the skeleton of the Bea Mind component that included the demonstration of our project.

I then integrated in the demonstration the Emotions Manager so that, during the demonstration, Bea would show several different facial expressions and gestures (using her eyes and head). For example, when Bea fails to pick the object, she nods "no" with the head and shows a sad expression and when she succeeded, she shows an happy face and nods "yes".

The final demonstration goes as follow:

1) Bea is idle until she detects a person's face;
2) Bea looks for objects (as described in 6.2);
3) Bea tries to pick the object;
4) If success, Bea places the object on the other side of the table;
5) Bea returns to idle.

[Too many "GREAT" classifiers]

write ?

9 Documenting

August 13th until August 15th

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During the last few days I made the Emotions Manager documentation using Latex without any difficulties. The final documentation was very complete and thorough.

10 Presentation

September 29th until October 3th

The project's supervisors invited the team to present the final work on October 3th to them and other INESC-ID researchers. However, only me and Filipa were able to attend the presentation so, during one week, we developed a set of slides and practised at home the presentation. The slides were as simple as possible to not deviate the researchers attention showing how we successfully accomplished the project's objectives. The results were great and at the end of the presentation, the supervisors asked many questions and were very happy with the things we accomplished during the summer internship.

11 Conclusion

To sum up the activity, during the internship:

- Developed the project's architecture;
- Improved Vision Manager;
- Developed most part of Emotion Manager;
- Integrated Emotion Manager on the demonstration;
- Documented Emotion Manager;
- Prepared and presented the project's end result to the supervisors.

Doing research work was an excellent opportunity to apply the knowledge I obtained during my BSc's degree in LEIC at IST. However, as described throughout the report, I faced many obstacles and difficulties developing the several components. Nonetheless, the whole experience of working at GAIPS was great and I learned tremendously about image processing, about ROS, about motion planning and how robots can express human emotions using their limited capabilities.

At the end, we suppressed the supervisors expectations (as told by them during the presentation) because we achieved great results in just one month and an half. Additionally, in my opinion, my contribution to the project was very important because I did not only focused on the individual components but also focused on the project's overall quality. With my contribution we managed to have a quality project with a flexible and a scalable architecture. Such a good result makes this project, as I wanted, a great example for future projects involving robot Baxter.

really ?!

I am very happy with the work I have done at GAIPS and I hope to join similar projects in the future.

Acknowledgments

I would like to thank:

- Professor Ana Paiva, Professor Francisco Saraiva de Melo and Eng. Tiago Ribeiro for giving me the opportunity to join GAIPS;
- Professor João Costeira for helping us developing Vision Manager;
- Filipa Correia, Diogo Almeida and Rui Martins for all the great work we have accomplished together.

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Bruno Henriques graduated from IST in 2014 with a BSc's degree in LEIC with a average grade of 17 out of 20. He is currently studying for a MSc's degree in MEIC at IST and he is an active volunteer in Motards Solidários. In the past, he studied English for two weeks in England, he did volunteer work in Refood and he did volunteer work in Natura Observa during two summers where he received three certificates for his performance.

Appendix
Statement of Execution

DECLARAÇÃO

Serve a presente para declarar ao Instituto Superior Técnico que Bruno Alexandre Pires Henriques foi Bolseiro no INESC ID Instituto de Engenharia de Sistemas e Computadores, Investigação e Desenvolvimento em Lisboa.

O vínculo acima descrito, teve início a 2 de Julho de 2014 e término previsto a 1 de Setembro de 2014.

Lisboa, 8 de Outubro de 2014

SIGN HERE

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