Report on the DeMeMech- EU-Japan exchange program 2005/2006

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2. Executive Summary:

The title of the research I did in the Arai laboratory at the University of Tokyo was „Strategy design of behavior of autonomous agents (ROBOCUP)“.
Therefore I was part of the RoboCup 4-legged league team „Araibo“ which competes in the international robot soccer competition „RoboCup“ which has the goal of establishing a robotic soccer team that can beat the human WorldCup champion until 2050.

All teams in this league use the „Aibo“, a robot dog manufactured by Sony“ and write the control programs for this.
My initial goal was to use Artificial intelligence methods to automatically develop RoboCup control programs, more specifically Genetic programming, an method that automatically develops generations of computer programs which then undergo a simulated evolution and therefore evolve into better solutions over time. This is similar to the Genetic algorithm although this method is supposed to be more powerful because the solutions to a problem are actual executable programs and allow unexpected solutions whereas in Genetic algorithm the form of the solution is has to be prespecified, that is the solution space is predefined.

My first months I spend with modifying a simulation of the Robocup for my needs so that the evolution of programs could be done in finite time because usually a generation of programs consists of thousands of programs which have to be individually evaluated for their fitness which would not have been possible to do in reality.
The solutions found this way corresponded to very simple manually programmed solutions since I didn’t evolve the already existing movements that were created by my group.
But the amount of time needed to evolve large populations over long periods of time proved to be too big since the simulation also simulated the physics of the real-world including the physical properties of the camera which was especially computing power intensive.
My research became more and more theoretical as I began to realize that the method I was using was good for finding solutions to nonanalytical problems but the solutions derived had a maximum complexity which would equal 200-300 lines of manually programmed code.
The research I did after that was to extend the Genetic programming paradigm to create more complex solutions which I tested for less complex tasks than deriving a robot control program.

Apart from the research I had time to get to know Japan better and met a lot of interesting people, Japanese but also the foreigners who lived in the same dorm as I did. The dormitory created the opportunity to get to know people from diverse fields and I not only could learn about many different cultures but also about other fields and the research that is going on in those fields.
I also didn’t have any problems with the Japanese which I mainly attribute to my Japanese language abilities which made life much easier than for my fellow foreign students.

Overall the 6 months in Japan were not only very fruitful for my professional life, getting to know the japanese way of working and thinking, but also for my personal since I not only learned very much about the mentality and thinking of Japanese people but also of other cultures like Chinese, Russian, African, Indian etc.
I can only recommend this experience to everyone willing to learn about new cultures, ways of thinking, meeting interesting people and who is open to experience all this without prejudice because it can also be a shock for people who expect Japan to be similar to the Western culture.

3. Travel schedule

22. 09.2005	Hamburg	-	Frankfurt am Main	(Lufthansa)
	Frankfurt am Main	-	Tokyo Narita	(Lufthansa)
December 2005	Trips to Nikko and Hakone			
January 2006	Trip to Osaka			
09.04.2006	Tokyo Narita	-	Frankfurt am Main	(Lufthansa)
	Frankfurt am Main	-	Hamburg	(Lufthansa)

4. Technical report:

The first month I spend with searching for an interesting research topic since in Japan you are expected to come up with a research topic on your own and don't get help from the professor or the assistant.
Since I was very interested in Artificial Intelligence methods and their application to complex tasks like the robotic soccer that was being researched in the work group that I was assigned to I decided to research the applicability of Genetic programming to that field.
Genetic Programming is a AI method that searches for solutions to a given problem by means of evolution. It produces solutions in form of computer programs or algorithms that are able to solve the problem in question.
My initial goal was to use these means to derive control programs for the Aibo robot because after examination of the exisiting code of the „Araibo"-team code I found it to be suited to be used as components of the algorithm.
Since my team had a Robocup-simulation that realistically modelled the Robotic environment including uncertainty of position after movement and a realistic model of the camera image and the camera properties, my initial goal was to speed up this simulation which ran in real-time so that meaningful evolution of computer programs could be made.
After my topic had been accepted by the professor I started to read the existing literature and so-far conducted research in this field and started to modify a Robocup simulation that my group had written before so that the development of the control programs would be possible in finite time.
The modularity of the code already written allowed me to use the components as basic modules in the evolutionary algorithm.

Genetic programming

The basic genetic programming algorithm is a method that automatically creates computer programs that are tested with a fitness function and are, according to how well they perform the given task, assigned a fitness value that also reflects the probability of the program to reproduce in the next generation of programs.
More specific, Genetic programming creates a generation of programs that have a tree structure. Depending on the computing power available a generation has up to a few thousand programs as members. These programs or trees are randomly created out of a before predefined set of so-called functions and terminals which represent the nodes and leafs of the trees.

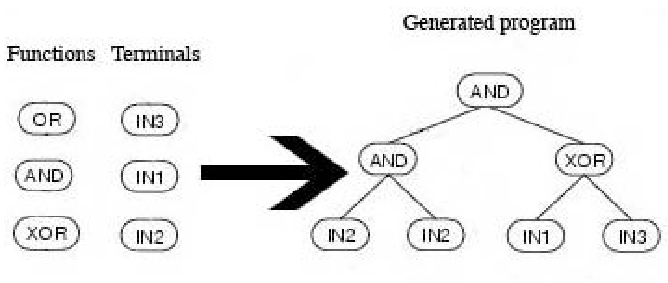

Figure 1:Creation of a program by Genetic programming

Then a manually-implemented, problem-specific fitness function tests those randomly created program and assigns a fitness value according to how well they perform.
The next step is to create a new generation of programs based on the information of the parent generation.

Therefore we have several devices.
First would be a simple copying of a solution to the next generation but if we only use that device we wouldn't be able to produce any better solutions than those of the initial generation.
Second is the so-called cross-over operation. It takes two parent programs and exchanges sub-tree between them as can be seen in figure 2.

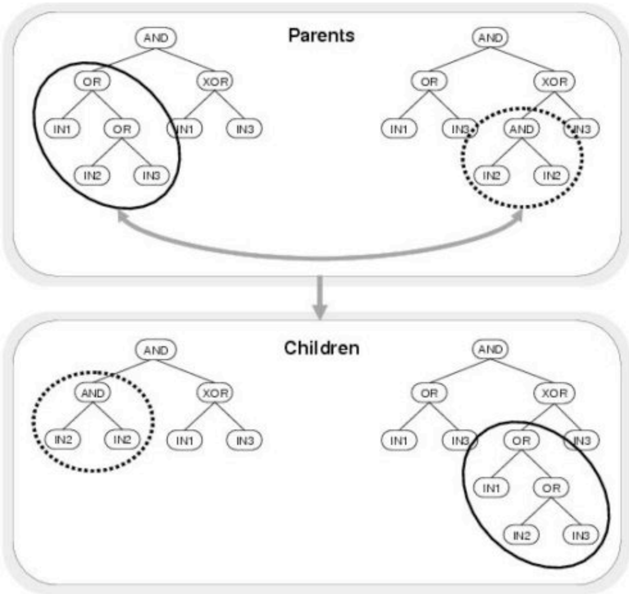

Figure 2:Creation of children by cross-over

The third operation that is used to create programs of the child generation is mutation. This operation either just alters one node or whole subtrees of the parent and therefore creates a new program.

Usually of these three operations the percentage of programs created by simply copying the parents or by cross-over is the highest although new research shows that cross-over and mutation are equally powerful and indeed create child programs that are equally strong as opposed to older views that only scarcely used mutation.

In my experiments usually the new generation consisted to 5 percent mutation, 40 percent cross-over and 50 percent copying. The rest of the generation was randomly new created programs or also copying, although those new programs could be considered as a form of total mutation.

Genetic programming had before been used in the Robocup simulation league to derive new programs but it also showed the flaw that this method had:
The maximum complexity of the programs was limited, meaning that the functionality of those solutions never exceeded the complexity of manually-coded programs more than 100-200 lines.
In this problem field it leads to solutions that are so-called „kiddie-soccer" solutions meaning players evolved would follow the strategy of running towards the ball and then if in ball posession would try to go near the goal and shoot themselves. This was not the solution I was looking for since I was looking for cooperation strategies that were more complex than that.

My analysis of the Genetic programming showed the following problem areas that could need modification in order to produce more complex programs:

1. Terminal and function set
2. Fitness function
3. Construction of the programs

I tried to work on point 2, the fitness function. My idea was to combine learning and Genetic programming: Make a flexible fitness-function that assigns fitness to the programs on how close they are to human solutions. In this particular field it would involve imitating the behavior of a manually controlled robot. This is done by creating a very big initial population in the beginning which is decimated during the fitness evaluation by simply deleting programs whose behavior was too far away from the desired example solution.

The problem with this approach was the lack of a metric that could evaluate the closeness of two programs just from the structure which would have been much faster.
Instead I compared the output of the example program and the created GP-programs if given the same input. I modified an exisiting GP-system and tried this approach with a much simpler, less-complex problem, a symbolic regression problem which is one of the standard problems to test Artificial intelligence methods.
Unfortunately this approach proved to be unfruitful and results didn't show improvement to normal GP.

My next idea was to analyse the process of construction of programs and why that leads to less complex programs.
I came to the conclusion that after a certain size of programs, large parts of the code become Junk-code, meaning that it doesn't contribute to the functionality of the programs but is just useless. But the bigger this Junk-DNA is, the higher the probability of this particular program surviving through the generations because if Cross-over operations or mutations are performed their destructive aspect, which means that if for example two parents with a high fitness value perform cross-over the children can have very poor performance, has less influence because if performed on Junk-code it doesn't alter the performance and therefore ultimately programs with large parts of Junk-code are more likely to stay throughout the evolution.

To overcome this I thought of a system where the programs would behave like molecules, and the terminals and functions would therefore be the atoms. If you put together a set of atoms that ultimately form a molecule they try to establish a form that minimizes the energy needed for a stable state.
My idea was to assign binding energies to certain combinations of terminals/functions and then a program would only be the set of those terminals/functions which would then at runtime create the minimal representation, the actual program. Crossover then would only be an exchange of members of the set and the new programs could look totally different, but still meaningful if the binding energy assignments were meaningful.
I think this approach could lead to very interesting results but unfortunately my time in Japan was not enough to actually implement the system and test my idea.

5. Exchange student life

The life in Japan is very different from life in Germany. It takes some time to get adjusted to it but once one accepts and embraces the differences it is a very big opportunity to broaden one's horizon.

First I had to get used to the spatial limitations of the accomodation provided by the university.
I had a small room in Komaba, a quiet part of Tokyo very close to Shibuya, where the undergraduate and the research campus of the University of Tokyo is located.
The room was in the Komaba International Lodge, a dormitory exclusively for foreign students and researchers of UT, and apart from being extraordinarily cheap provided everything necessary for life. The usage of space is optimized which means that everything can be folded away: desk, bed and even the shower/toilet combination is a clever construction to save space.
The room even included a small kitchen with a sink and one hot plate which isn't really enough to cook a meal but that also forced you to cook with other people together and then combine everything in one room to enjoy it together.

Upon arrival I organized a dinner for the people in the lodge since the lodge office planned to do something similar but in december and I thought that many new people who just arrived would like to meet the others in the lodge. This event was very well perceived and in this way I met people who would later become my friends.
I also actively participated in the lab life since I practically spend all of my time there.
Japanese students spend most of their time in the laboratory, usually they would come at 1 or 2 pm and stay very late until 1 or 2 am. Not all of the time is dedicated to working so I had many opportunities to practice my English skills. Japanese students have a decent level of written English but when it comes to spoken English their skills are limited and because of their mentality they rather say nothing than saying it with mistakes. This was a problem for many other foreigners who would then only have close contact to other foreigners which I don't recommend because I think in this way they rob themselves of the unique opportunity to gain insight in the very different japanese way of thinking.
The lab members spend a lot of time together which includes lunch and dinner every day but also sports. I could motivate some of them to start a sport called „Sports Chambara" with me which is a very funny martial art where you fight each other with soft swords and other weapons.
Lab members also sometimes go out drinking which is also a very good way to get to know the people better since then they are able to relax more and are also more open.
On these occasions it is also very popular to do Karaoke and it is even a blast if you can't sing at all.

The only downside of Japan, especially Tokyo, that I have found is of course the number of people that live there. Especially hard for me was the daily 1-hour-commute to university and back in crammed subways where sometimes people would be pushed into the wagons by the station personal. Public transportation in Tokyo is certainly nothing for people with claustrophobia nor for people who have problems with being pushed against other people all the time. In the first month the train rides make very aggressive but one can get a little used to it(although I don't think I'll ever be ok with it)

6.Summary:

All in all I can say that this was a fantastic experience and I really regret not having done the 10-months-exchange instead of the 6-months because I think it is a very short time and I had the feeling that time flew by. As soon as you have adjusted to the life in Japan, found some friends, get to know the city, found interesting research, you have to go home. But I can say that I learned a lot of new things for my professional as well as my personal life and I am now really thinking about doing my PhD in Japan. I can recommend this program for everybody with interest in mechatronics since the resources at the university are much better than in Germany who is open for new stuff.
A lot of students go to Japan and are overwhelmed with the country. They usually got homesick and didn’t have a lot of fun so this program shouldn’t be done by those people. It can really be hard on those people and Japan is very far away from Europe but for everybody else this program is a jackpot.