Trajectory planning with humanoid robots

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Introduction

During SHINE I have worked in Professor Schaal's Computational Learning and Motor Control lab (CLMC). My mentors were Zhe (Harry) Su and Giovanni Sutanto.
The objective of the research conducted at CLMC is programming more intelligent robots through different ways, such as reinforcement and imitation learning.
While working here I have learned several ways to plan trajectories (Flash & Hogan 1985; Schaal, Pastor, et a 2013) and how to make use of inverse kinematics, both of which constitute the basis of robotics.

Objective & Impact of Professor's Research

Dr. Schaal's research focuses on making robots move in a smooth, human-like fashion by using Dynamical Movement Primitives, and improving their intelligence by enabling them to learn similarly to humans, for example by mimicking movements (imitation learning), or by reinforcing good behaviors (reinforcement learning).

Harry and Giovanni are working on a method which would allow the robot to interact with the environment in a way closer to ours, reacting for example to obstacles, thanks to sensory information (like touch sensors) and then planning its motion accordingly, while also making it easier manipulate objects like we do.

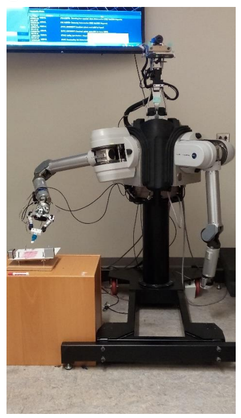


Figure 1. Barret – WAM robot used by Giovanni and Harry for their research. PC: Luigi Massacci

Skills Learned

Trajectory planning: one of the most basic and yet essential skills in robotics, trajectory planning aims to get a robot to its objective in the smoothest possible way. This is done by calculating the velocities and accelerations needed to get to a point in a given time. I have learned two different ways to plan trajectories (using a Dynamical System or a spline), and solved various issue tied to trajectory planning, as well as implementing them in C++ for use on the robot.

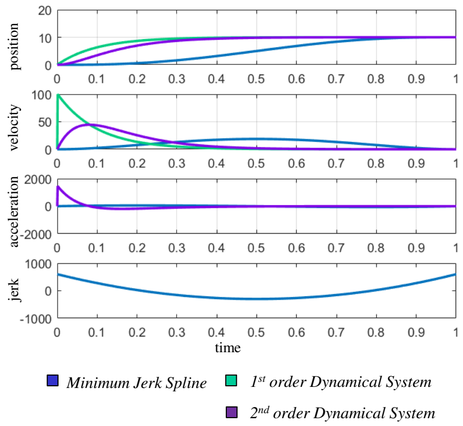


Table 1. MATLAB graphs displaying three methods to plan trajectories. PC: Luigi Massacci

Inverse & direct kinematics: Inverse kinematics is needed to convert coordinates between the joint space (joint angles, joint angular velocities…) and the operational/Cartesian space (Cartesian distances, velocities…). It allows the programmer to develop tasks for the robot in straight lines, while at the same time being far more accurate.

MATLAB (Matrix Laboratory):
Matlab is an all purpose programming language, especially designed to be both type-light and powerful. It is highly useful to make graphs, simulations, and models of physical systems, as well as serving as a scientific calculator. As the name suggests, it is particularly adept at working with matrixes, thus making it an excellent tool to implement all the linear algebra I have learned to use during my time here.

How This Relates to Your STEM Coursework

Matlab will be highly useful in physics and math classes, to easily make graphs and model physical systems as well as Computer Science classes, since it's given me a broader understanding of interpreted languages.

I have also strengthened my knowledge of C++, one of the most useful and popular programming languages.

The physics and linear algebra I have learned will also be invaluable in the next few years of high school (I approached for the first time subjects such as derivatives, matrixes and differential equations). In particular, I leave with a much brighter view of how math defines the world, and what a good job it does at it!

$$\dot{q}_d = \alpha\left(q_f - q_d\right)$$

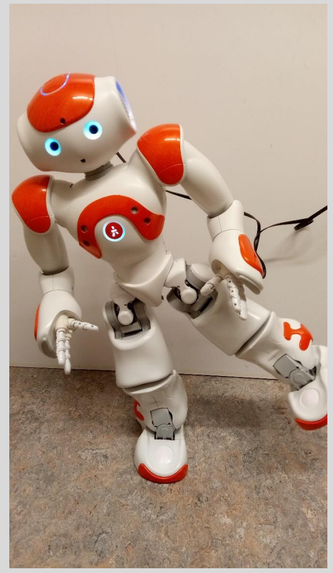
Speed Target

Differential equation for trajectory planning (Dynamical System)

I have also inadvertently learned more about the human body than I expected, especially around the concept of balance, and how extraordinary and complicated the most common movements we do every day actually are.

Furthermore, I have gained a better understanding of how physical systems (robots and humans alike) relate and react to the world around them.

SHINE as also given me a better, and more practical understanding of scientific research, and how it should be conducted, as well as some insight on this growing field of engineering and computer science.



Gilbert, the NAO robot I have used during the summer. Even though it's only 58 cm tall, NAO is an advanced, interactive robot. Its appearance is humanoid, with 26 DoFs (Degrees of Freedom), which allow it a roughly humanlike motion. It is one of the most widespread humanoid robots (there are over 10'000) and it has recently become the standard platform for RoboCup (an international robotics soccer competition), as well as a receptionist in a Japanese hotel.

PC: Luigi Massacci

Next Steps for You

I intend to apply all that I have learned to the Robocup competition, and share it with my teammates. And who knows, perhaps even do it as a roboticist in the future.
My advise to future SHINE students is to ask as many questions as you can, since it helps a lot when you feel out of your depth (which to me happened often enough). Trust me, it will make life a lot easier.

Acknowledgements

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References

- The coordination of arm Movements: an experimentally confirmed mathematical model (Flash & Hogan,1985);
-Dynamical movement Primitives: learning attractor models for motor behaviors. (Pastor, Schaal, et a, 2013)