Ars Robotica: Robots in Theater

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INTRODUCTION

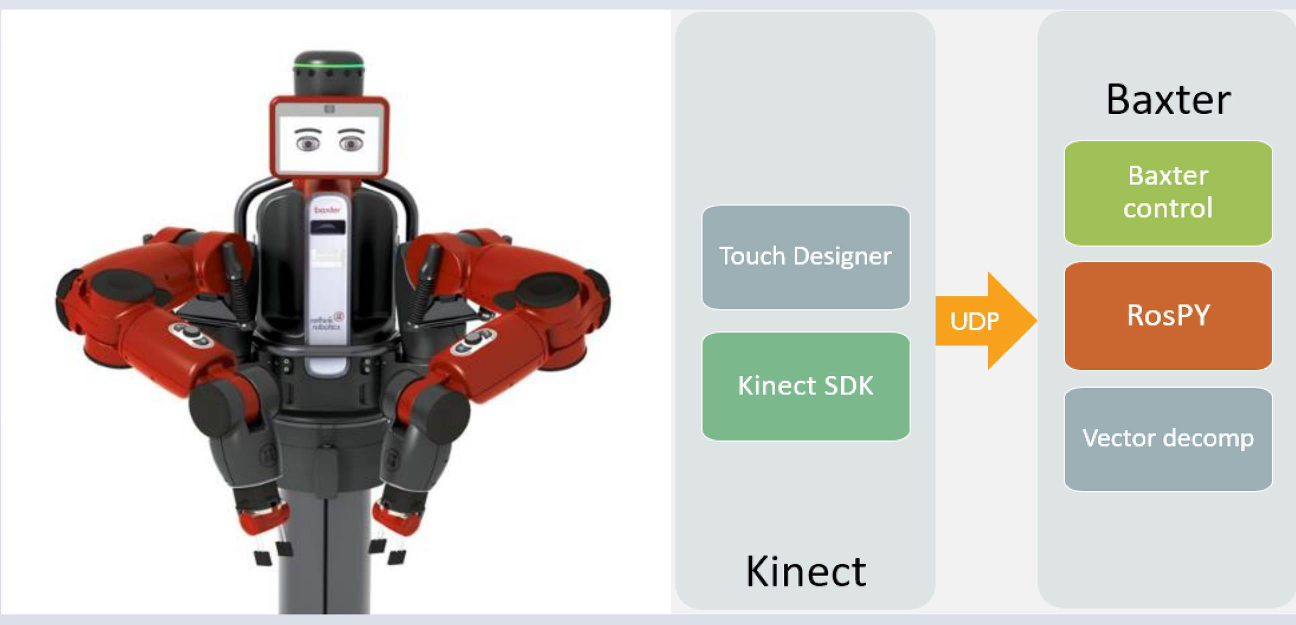
- Social robotics: focus on coordinated behavior, interactive moments and easy interpretation.
- We consider the question: Can we express movements at a higher level than classical descriptions such as angles, low level trajectories?
- How do we develop a structure to express terms such as fluidity, emotiveness and how they differ?

RESEARCH GOALS

- As the first step, we aim to develop a **movement framework for a robot that involves higher level descriptors and the possibility of modifications of aesthetic nature.**
- We have chosen theatrical performance as a test bed, aiming to view the robot as a performer in the midst of people. Advantages being continuous interaction with humans; and audience feedback, script conveyance etc. can be used as metrics.
- Goal of the research:
  - Define the applicability of human-like motion to robots.
  - Provide a framework to describe and construct a movement language for a robotic platform.
  - Define how metrics that are considered aesthetically significant can be added to the movements.

PART 1: HUMAN MOTION IMITATION

- Our first step was to determine if robotic movements can be enhanced using knowledge of human motion obtained through imitating it.
- Similar to the theater concept of a 'puppet'.
- Essential for understanding the limitations of Baxter, differences between the human domain of motion and the robot's.



- Kinect SDK integrated with Touch Designer, a software widely used for live performances.
- Joint positions were obtained as Cartesian coordinates and transmitted to the Baxter computer.

- Inverse Kinematics on Baxter: determines the joint angles necessary to achieve the given joint positions.
- We took a geometric approach to solve the IK problem, to avoid two main issues:
  - Solutions may not be unique.
  - Discrepancies in coordinate systems between human limb lengths and Baxter's.
- Problems with 'direct' imitation:
  - Kinect data corrupted with noise, contains lag etc.
  - Imitation might not preserve artistic nuances.
  - Occlusion problems with Kinect.
- On the other hand, better sensors are usually bigger, intrusive and could prove to be inapplicable for performance settings.

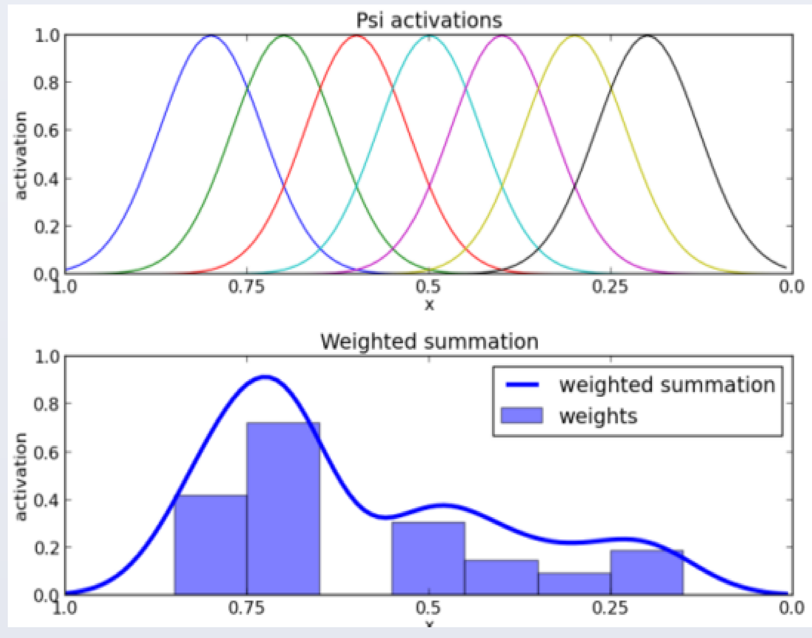
PART 2: MOVEMENT PRIMITIVES

We sought out to build a movement vocabulary for Baxter. Initially described using precise motion capture, these primitives would then be used as building blocks for complex movements.

- Trajectories obtained from noisy sensors can be replaced by the primitives' accurate versions.
- Accompanying rules specify aesthetics, intent etc. through modifications of the spatial and temporal structure of movements.

This allows complex movements to be interpreted and reconstructed by the robot. Our core idea is to describe movements to the robot how a script directs a performer. This was partly inspired from Laban Movement Analysis: a quantification of aesthetic behavior used by dancers.

Shoulder flex	S_F
Shoulder extend	S_E
Shoulder rotate	R_S
Elbow flex	E_F
Elbow extend	E_E
Humerus rotate	R_H
Wrist flex	W_F
Wrist extend	W_E
Forearm rotate	R_F



These movements were recorded using an Optitrack system to be stored as a dictionary for Baxter.

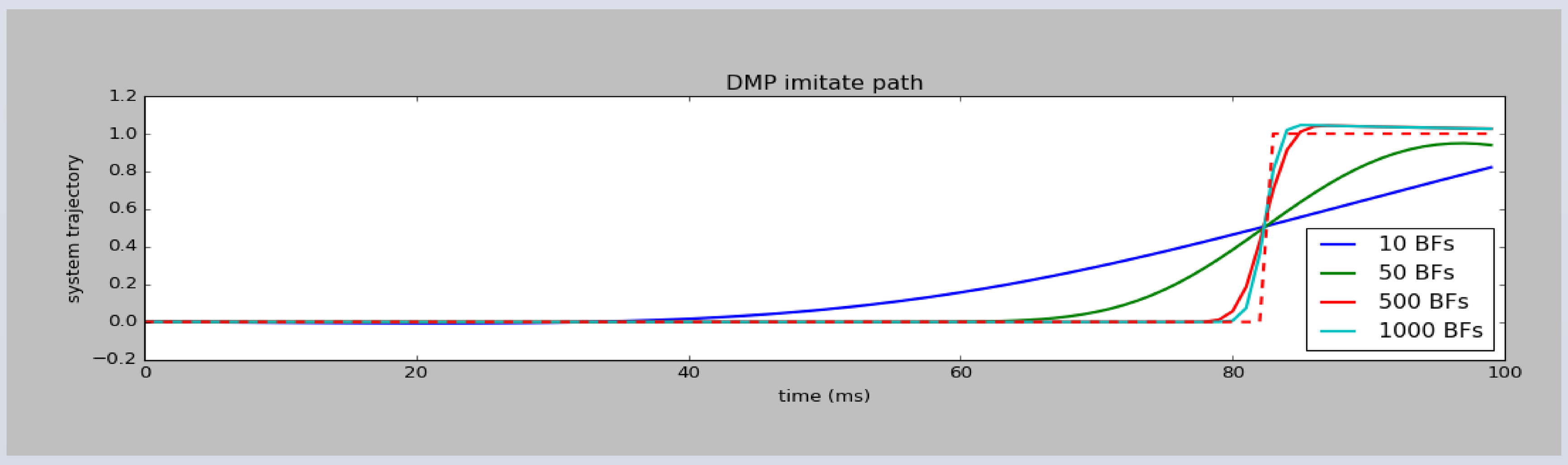
We use dynamic movement primitives to express movement primitives on Baxter. DMPs are advantageous for representing complex motor actions with real time adjustments without continuous parameter tuning.

The primitives can be combined to express more complex movements in an intuitive fashion, and the number of basis functions affects how 'smoothly' the motion is executed. .

Function approximation: $f(x,g) = \frac{\sum_{i=1}^{N} \psi_i w_i}{\sum_{i=1}^{N} \psi_i} * x(g - y_0)$ Spatial scaling

Trajectory profile: $\ddot{y} = \tau^2 * (\alpha(\beta(g - y) - \dot{y}) + f)$ Temporal scaling

Effect of basis functions on trajectories:



Able to differentiate between smooth and fast movements, specify time and extent of movement on the fly.

CONCLUSIONS AND FUTURE WORK

- Our work deals with the development of a generic language to express complex motions in terms of simpler movement grammar, as well as provide support to define qualifiers for the motions.
- Initial work focused on human motion imitation using Kinect, the current phase involves refining movement by dividing it into precisely articulated primitives and reconstructing it.
- We wish to conduct further validation of the described approach with considerable number of complex movements and possibly different styles of motion.
- Eventually, we would conduct evaluation and testing in a performance setting, obtain audience feedback etc.