Motion Learning for Emotional Interaction and Imitation of Children with Autism Spectrum Disorder

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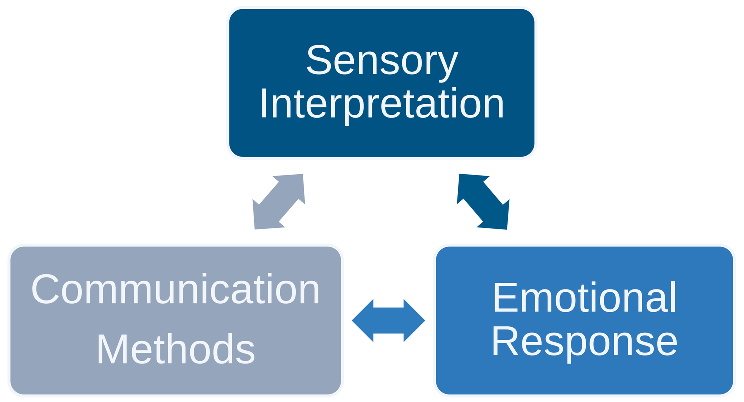
MOTIVATION

Children with autism spectrum disorder (ASD) often display difficulty with social interaction. We aim to improve their emotional communication skills through the use of an assistive robotic framework, which will identify and dynamically respond to emotion-revealing body language detected through multimodal inputs.

INTRODUCTION

Children with ASD may differ from neurotypical children in areas such as:



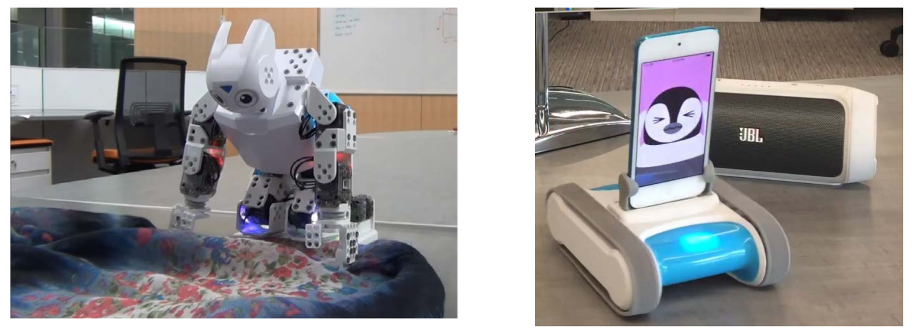
As a result, children with autism may have difficulty interacting with their peers. Studies show that the incorporation of robots, music, and imitation techniques into therapy sessions all promote the child's level of interest in interacting with others.

PURPOSE OF THE SYSTEM

We propose the use of an autonomous social robot to identify emotional movements, and to reciprocate them through imitation, in order to form empathy with the child and encourage engagement. This will be accomplished by using multi-dimensional motion learning of dynamic movement primitives.

Previously conducted preliminary study:

- Demonstration-based behavioral game – "Five Senses Game"
- Combined musical interaction and sensory-evoking activities to stimulate emotional responses and develop behavioral skills
- Introduced participants to robot companions



The two robots used in the preliminary study: a Robotis Mini (left) reacting positively to tactile feedback, and a customized Romotive (right), reacting negatively to auditory feedback.

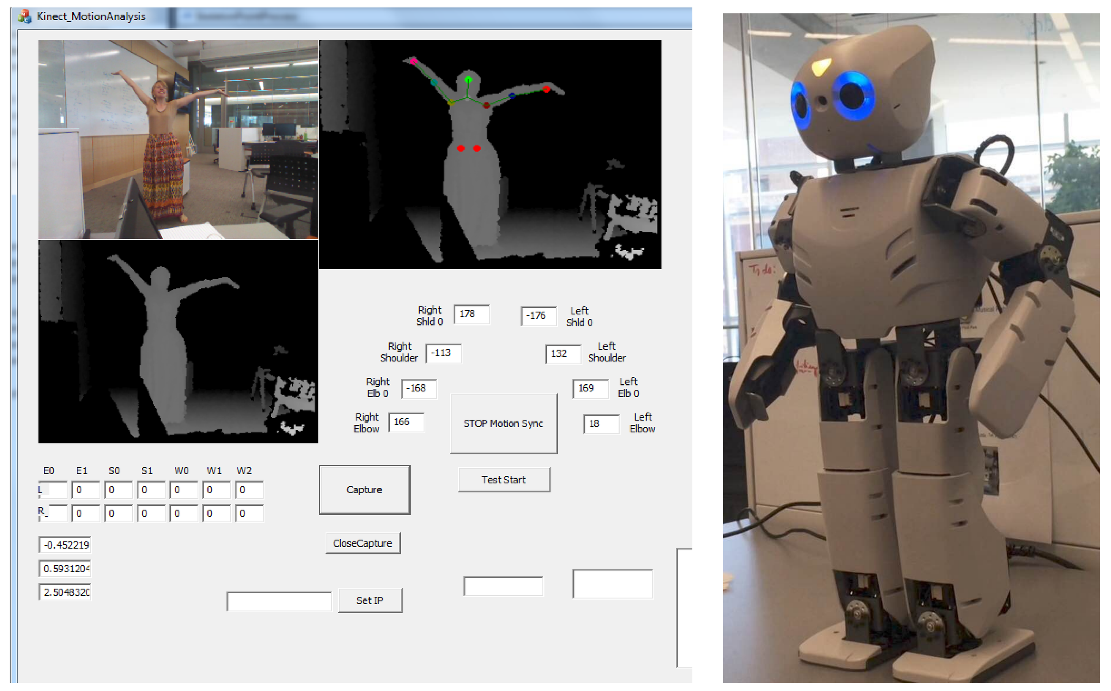
DYNAMIC MOVEMENT PRIMITIVES

$$\begin{bmatrix} \dot{z} \\ \dot{y} \\ \dot{x} \end{bmatrix} = \begin{bmatrix} \alpha(\beta(y^g - y) - z) + x * f(x))/\tau \\ z/\tau \\ -\alpha_x x/\tau \end{bmatrix}$$

Equation for DMP – a PD control signal with temporal scaling and forcing terms for producing a modified trajectory.

- A **dynamic movement primitive** (DMP) is a generalized task with specific position goals and end points joined in a sequence to create a scalable movement.
- Robots utilize DMPs to reproduce core movements in variable settings.
- Emotional body language will be stored as DMPs.
- The equation set above is for calculating a DMP in one dimension. To generate multi-dimensional trajectories, the equation set is run multiple times, simultaneously. These are all linked by providing identical phase functions to each dimension.

ROBOTIC SYSTEM



Left: Custom developed graphic user interface of the Kinect tracking system. Right: ROBOTIS-OP2, the robot that will utilize the motion learning algorithm.

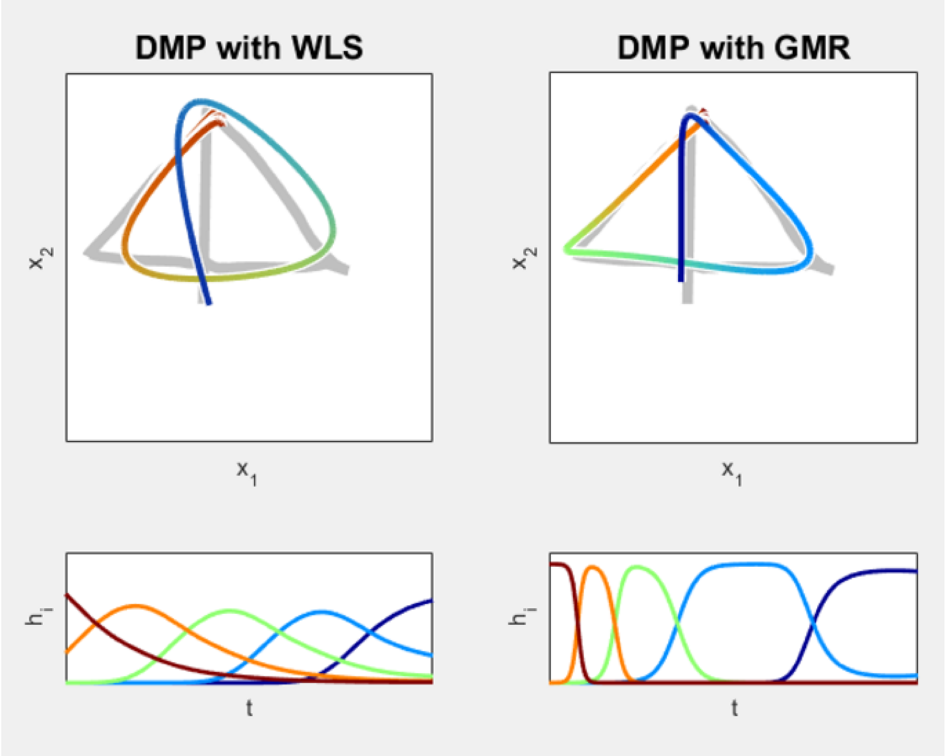
Skeletal tracking:

- RGB-D based motion analysis using Kinect
- Continuous observation and tracking of participant
- Velocity, acceleration, and angles of joint s measured to determine emotional state and estimate social engagement

ROBOTIS-OP2:

- Capability for more advanced interaction than the preliminary study robots: visual tracking, higher processing power, greater mobility

COMPARISON OF METHODS

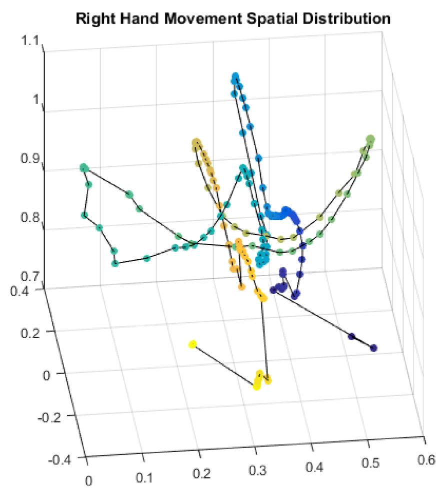


Top: Original figure, in grey, mimed by participant and recorded by Kinect. Computer replication using each DMP method overlaid in color. Bottom: Activation function firing and duration.

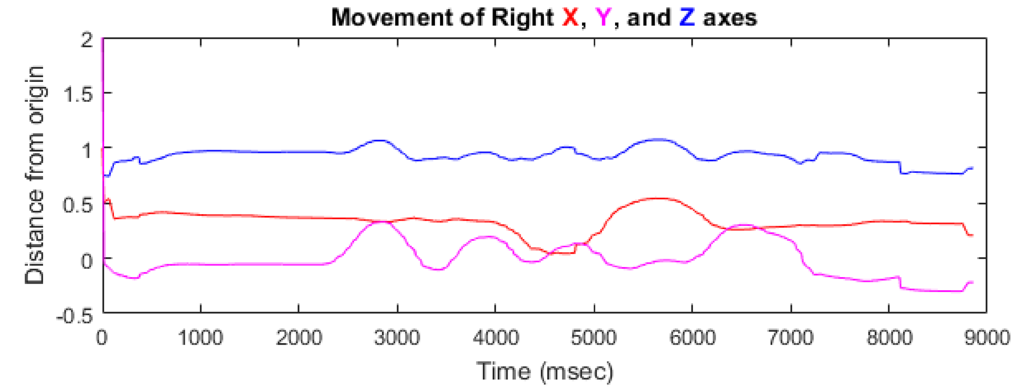
For standard DMP techniques, such as DMP with weighted least squares (WLS), the duration, position, and intensity of the activation weights are preset. Usually, they are evenly distributed across the duration of the movement. For DMP with GMR, the span and placement of the activation functions are modified as the motion is learned.

PRELIMINARY RESULTS

After analyzing the two motion learning techniques, more complex movements were recorded using the Kinect – this time in 3-dimensional space.



The DMP with GMR algorithm will be modified to reproduce changes in movements along all 3 axes.



Top: 3D spatial representation of the right hand moving in a "conducting" motion. Progression of time is represented with a color gradient, from yellow to purple for start to finish. Bottom: Tracking the user's hand movement over time, over all 3 axes.

PRELIMINARY ANALYSIS

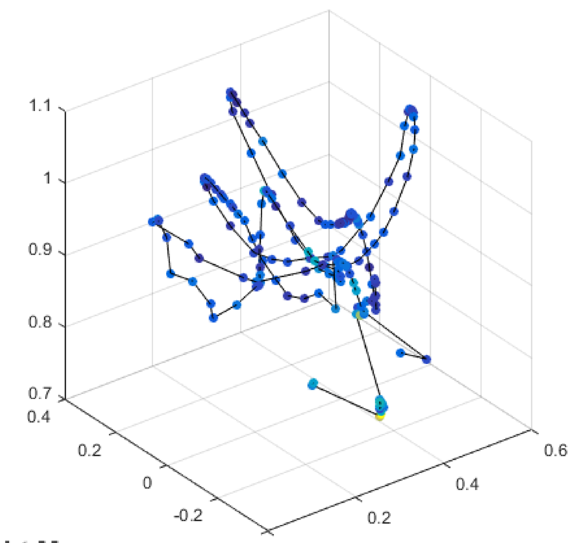
DMP with GMR is a better method for computer replication of human movements (motion learning) than traditional DMP methods due to its capability for producing more accurate simulations while using the same number of activation states.

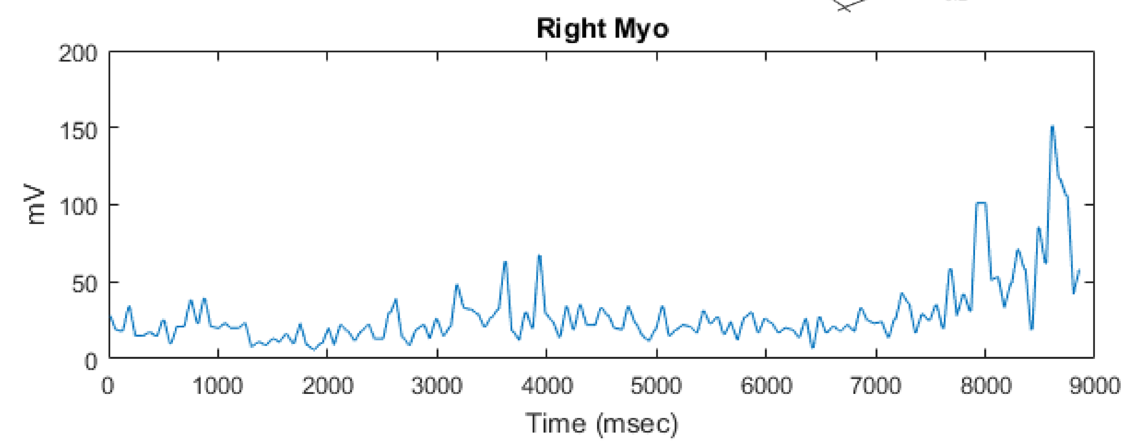
Our current work can successfully detect the user, generate a skeletal framework, and track, record, and replicate movements in a 1D trajectory.

We can record and generate 3D representations of the user's movements, and are working towards 3D replication and testing next.

FUTURE WORK

Right:: The same 3D spatial representation of "conducting" movement, this time with color gradient overlay representing levels of EMG activity. Bottom: Comparison of EMG levels over time.





- Utilize electromyogram (EMG) signals in motion learning and emotion detection, using wearable sensors
- Incorporate a kernel function to smooth movements

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