Towards Algorithms for Effective Stabilization and Situational Awareness for Humanoid Robots

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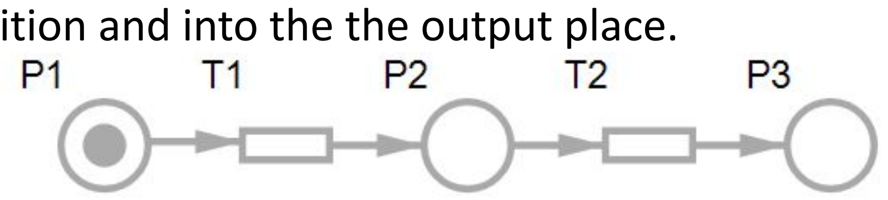
Abstract

Algorithms and operating systems are continually being evolved in need to develop more equipped and reliable robotic systems capable of performing in many real-world dynamics. The NAO robot is used to observe the ability of robots to perform specific tasks and the accuracy and reliability in the robot's performance. The robot is tasked with stepping onto a scaled platform, maintaining stability when pushed, and accurately identifying object distances. Algorithms modeled using Fuzzy Petri nets, a graphical simulation and demonstration tool, are made to improve these efforts leading to effective stabilization and situational awareness, which can effectively lead to a more independent model.

Petri nets

<u>*Definition*</u>: A graphical tool used for modeling and simulating various complex systems. Petri nets include places (circles), transitions (squares or rectangular bars), and arcs (arrows). These represent states, operations, and connections within a system. Tokens move through the net and represent the current state of the system.

<u>*Firing Rules*</u>: A token may only fire when a transition is enabled. A transition is enabled when the place preceding the transition is marked with a token and arc weight conditions are satisfied. When a token is fired, tokens from an input place fire through the transition and into the the output place.



Fuzzy Logic

<u>*Definition*</u>: Uses fuzzy set theory to describe, analyse, and process qualitative or imprecise data

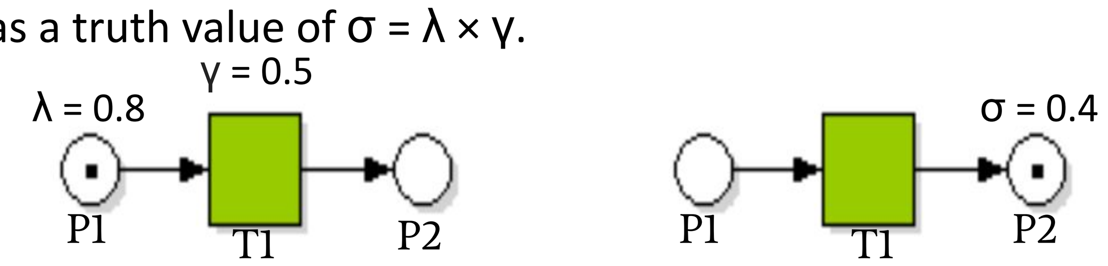
<u>Crisp Set</u>: A set that only allows full membership, where 0 is false and 1 is true. $\phi_x : X \rightarrow \{0,1\}$

<u>Fuzzy Set</u>: A crisp set with a membership function that defines the truthfulness of a set. It allows partial membership where 0 is false, 1 is true, and decimals between 0 and 1 indicate a degree of truth. $\mu_x : X \rightarrow [0,1]$

Fuzzy Petri nets

<u>*Definition*</u>: A Petri net that incorporates fuzzy logic. Fuzzy logic makes decisions based on levels of truth and can make conclusions on qualitative situations that do not have precise reasoning.

<u>*Firing Rules*</u>: Tokens are assigned a certainty factor (λ) and transitions are assigned a threshold value (γ). A transition is enabled when λ > γ. Once the enabled transition fires the token has a truth value of σ = λ × γ.

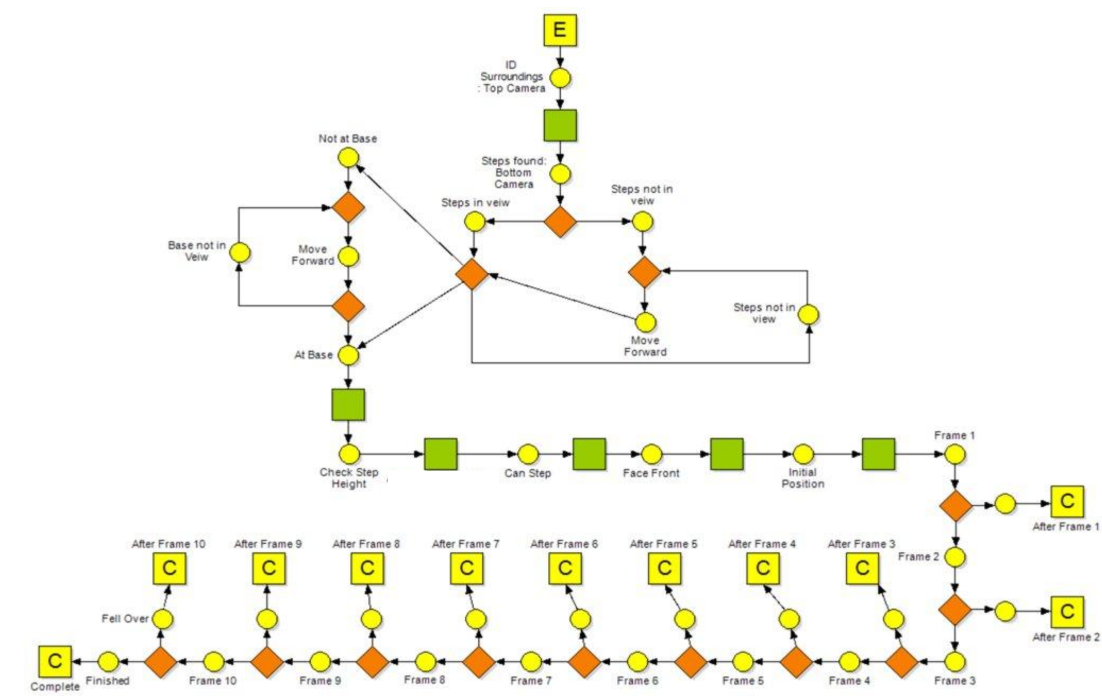


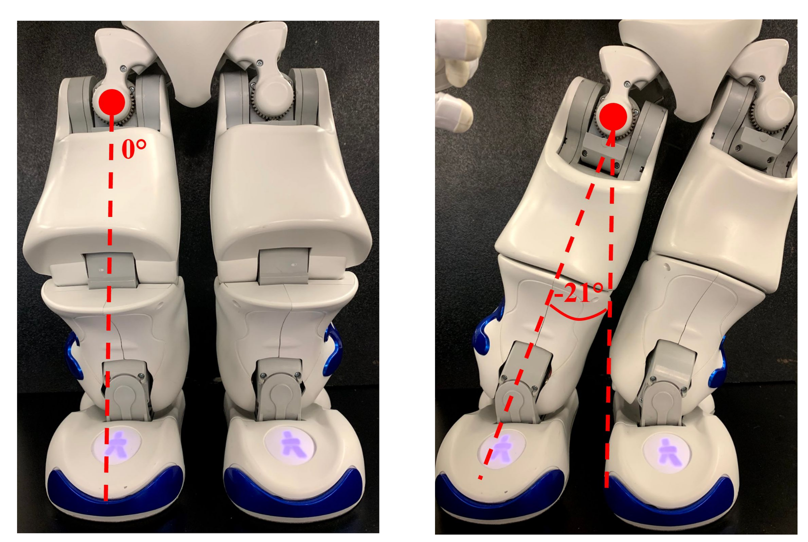
Stabilization: Stepping onto a Platform / Push Recovery

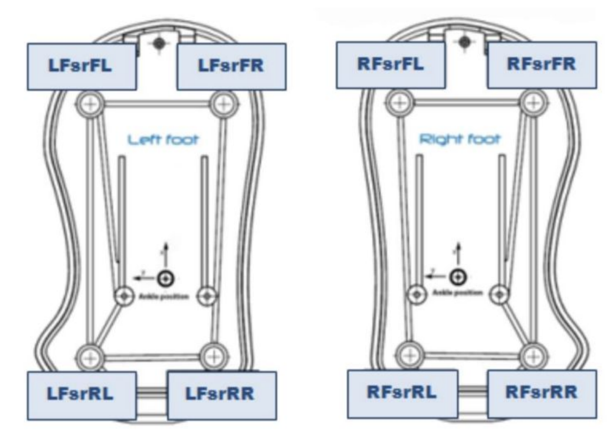
The NAO robot is tasked with stepping onto a scaled platform and maintaining stability when pushed. The self-learning algorithms use fuzzy logic to make decisions about the NAO's stability.

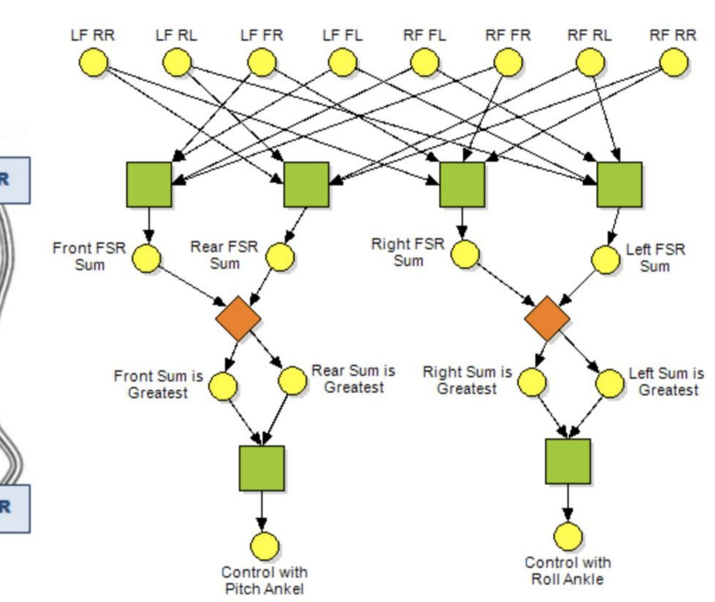
Ten key frames have been developed in Choregraphe to optimize NAO stability for stepping onto a platform. The RHipRoll actuator values are tracked using the self-learning algorithm and modeled by the Fuzzy Petri net to create simplicity.

FSR sensor data is retrieved through choregraphe from the NAO robot and is analyzed. The self-learning algorithm recognizes an external push and uses the ankle actuators to correct the detected push and remain stable.









Situational Awareness: Object recognition/ Distance calculation

The NAO robot bottom camera takes multiple photos from varying angles of a checkerboard print out. After running these images through a calibration algorithm, a camera calibration matrix (K) as shown in (1) is produced, providing the camera's focal length in pixels (an average of fx and fy values).

$$K = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \quad (1)$$

$$d = \textit{distance from camera to object} = \frac{\textit{real object width (mm)} * \textit{focal length (pixels)}}{\textit{object width (pixels)}} \quad (2)$$

$$x = \textit{actual distance from robot to object} = \sqrt{d^2 - (h-r)^2} - r \quad (3)$$

The NAO robot bottom camera then takes photos of a red ball of diameter 100 mm at calculated distances (x). The images are passed through the created Reduction Filter method, which involves converting the RGB image to HSV to eliminate colors out of the red range from the image.

With only the red ball remaining in the image, a Hough Circle Transform circle is created, outlining and calculating the ball's radius in pixels.

The distance from the camera to object can then be calculated by using (2). Finally using the Single Camera Distance Ranging Method, the actual distance from the robot to the object (x) is calculated in (3), using the Pythagorean theorem where h is the height of the camera to the ground and r is the radius of the ball in mm as shown in Figure 1.

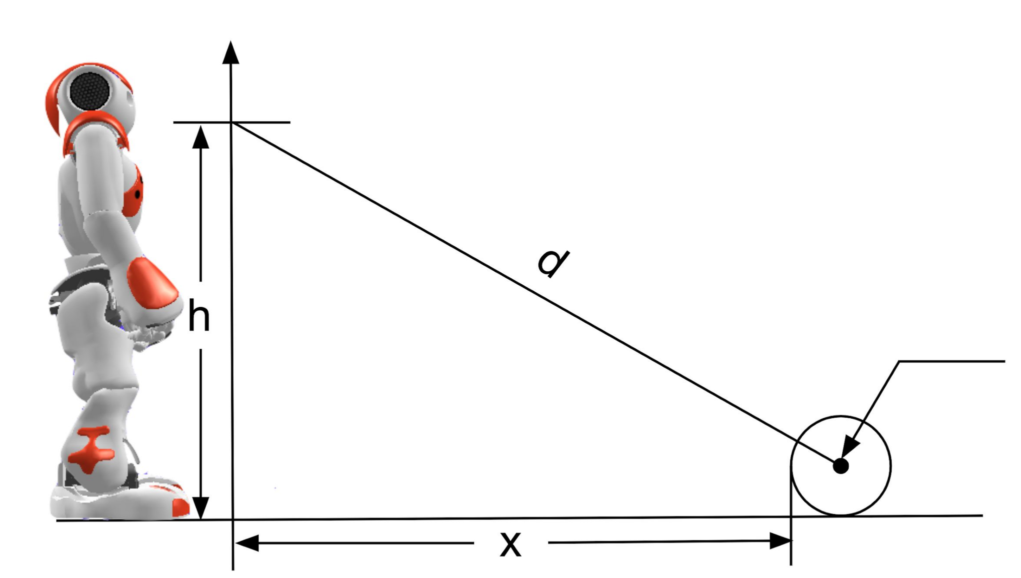
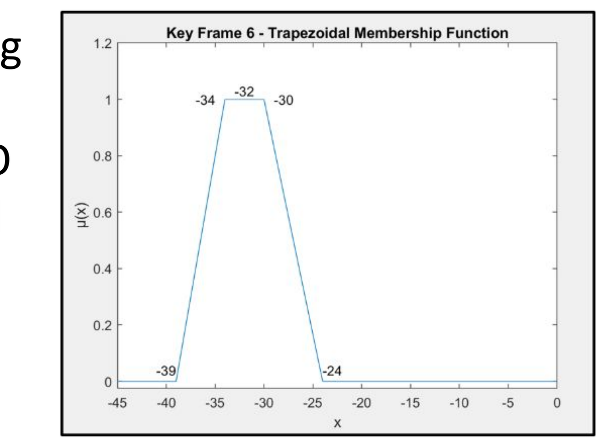


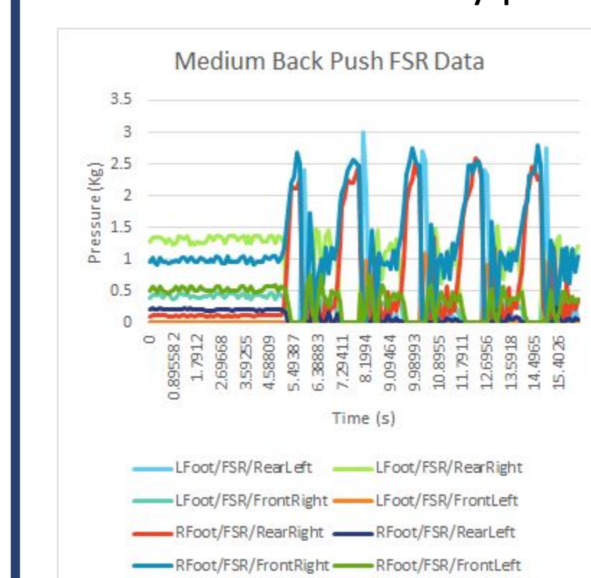
Figure 1. Single Camera Distance Ranging Method

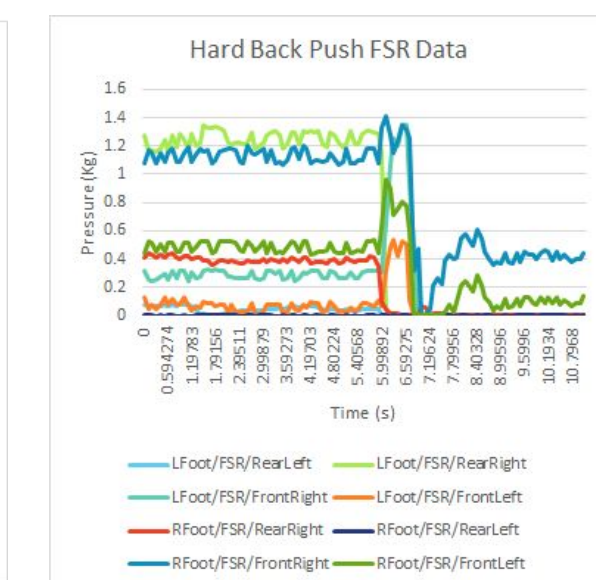
Results

A trapezoidal membership function was developed using the data collected from the RHipRoll actuator of the NAO robot. This data will be used to define the self learning-algorithm responsible for maintaining NAO stability while stepping onto a platform.



Push recovery data was collected using NAO's FSR sensors. When implemented using fuzzy logic, the NAO will be able to identify pushes and recover without falling.





The Optimized Distance Detection algorithm was finalized after multiple trials resulted in precision and accuracy. Creating the Reduction Filter method in collaboration with accurate camera calibration matrix data allowed for reliable results as shown in Figure 2. This algorithm can easily be altered to include a dual camera ranging method, which will create optimal tracking capabilities for the NAO robot and allow for better functionality.

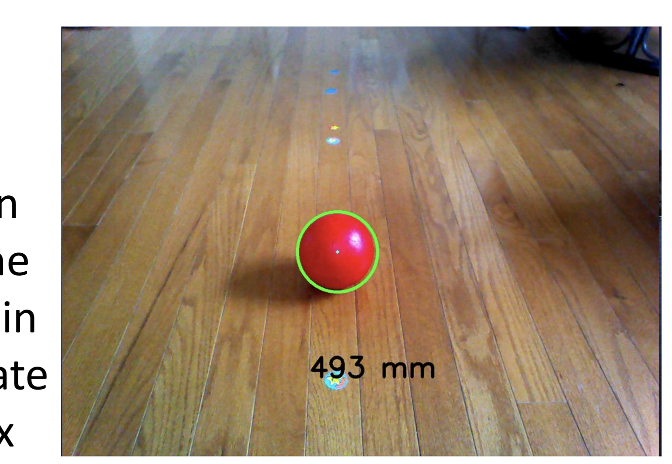


Figure 2. 500 mm distance from robot

Conclusion & Future Work

To merge the tasks of stabilization and surrounding realization and implement the algorithms on a team of NAO robots to participate in ROBOCUP. It is important for the NAO robots to maintain stability while performing a variety of actions such as kicking the ball and field navigation. While situational awareness is crucial for avoiding opponents, tracking the ball, and precision of its movements. These skills will improve NAO performance in ROBOCUP.

Acknowledgement

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