Developmentally Learning the Support Affordance of a Platform

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1. Introduction

The concept of support is important for solving a variety of tasks. Humans can easily determine whether an object is supported in a given position. However this is not a concept that is understood by machines. For that reason, this research aims to learn the concept of support through exploration of a platform. By learning the properties of this experimental platform, it is anticipated that these properties can be expanded to form a broader support model.

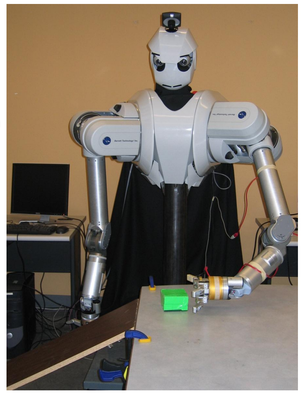
2. Motivation

- This research is primarily motivated by the principles of developmental robotics. In particular, support cannot be learned through programming alone, it must be learned by the robot in order to perform tasks intelligently.
- Humans begin to understand the concept of support at an early age. By detecting "visual cliffs" humans are able to operate safely when in close proximity to these unstable conditions. If robots are to operate safely in a similar manner, it will be necessary for them to have a similar understanding.
- The goal of this research is to gain insight into support through developmental learning and exploration. Human infants naturally learn this concept through observation and direct experimentation.
- More complex problems (such as stacking) arise from understanding object support. It is anticipated that understanding the fundamental concepts of support will lead to a solution of these more complex tasks.

3. Experimental Setup

Upper-torso Robot

- Two 7-dof Barrett WAMs
- Two Barrett Hands
- Logitech Quickcam Pro 4000
- Vibrotactile fingertip sensor
- Zcam 3D camera

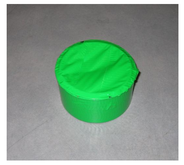


Additional Equipment

- Horizontal Platform
- Adjustable Ramp

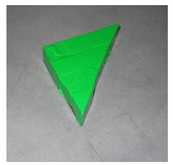
Object Shapes

Circle



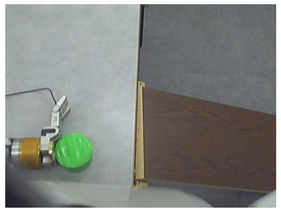
Square

Triangle

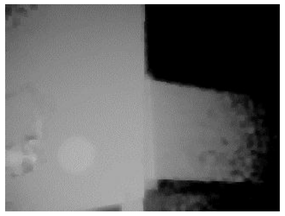


Objects as seen through the viewpoint of the robot:

Color Image



Depth Image



Behaviors for Data Collection:

- 3 separate pushing trajectories.
- 4 ramp configurations {horizontal, vertical, steep incline, and no ramp present}.
- Exploratory poking behavior.
- 10 trials collected for each object and configuration.
- Total of 390 trials collected.

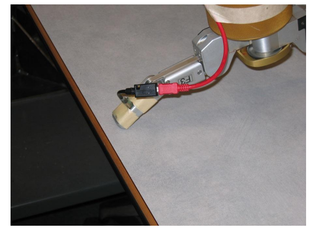
4. Methodology

Edge Detection and Visual Mapping

Several different modalities were used to explore the boundaries of the platform. Depending on the configuration of the platform, either the vibrotactile sense or vision served as the primary indicator. For vision, the OpenCV computer vision library was used for object tracking. After tracking, the data from vision and the associated data from the other modalities could be analyzed for interesting events.

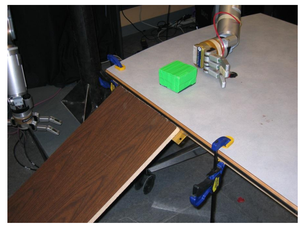
Poking Exploration

The vibrotactile sensor detected the edge while exploring the top of the platform. Accelerometer data showed a strong change whenever the edge was crossed.



Horizontal and Incline Ramp Exploration

The object and robot hand were visually tracked as the object moved across the platform and onto the ramp. Once moving down the ramp, the object began moving at a faster speed and showed the point at which the edge became apparent.

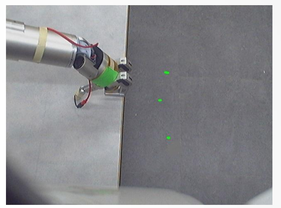


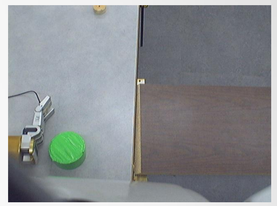
Vertical Edge Exploration

In addition to horizontal and inclined positions, the ramp was also oriented perpendicular to the table. This allowed for an object to be pressed against the ramp in order to detect the edge of the platform. When the object first made contact, the robot continued to push until meeting its torque limits. This increase in torque was considered to be a detection of the edge and was recorded as such.

5. Results

Visual Point Clouds of the Edge





From top left to bottom right: Poking, Horizontal, Incline, and Vertical Exploration point clouds.

The green points above are generated as objects meet the edge criteria for a given exploration. Because points are superimposed onto an image, they may be offset from the actual edge. However, they consistently cluster in a manner consistent with the platform edge.

6. Conclusion and Future Work

- The properties surrounding the edge of edge of a platform have been explored using varying sensory modalities. From these senses the edge's properties can be extracted and mapped into visual space.
- The next stage of this research will focus on clustering the properties of platforms given changes in depth. For this stage, the depth data collected in the dataset will be used. Ultimately this research seeks to build a conceptual model of support. This study, is the first stage in that ultimate goal.