Carnegie Mellon

Andy Project

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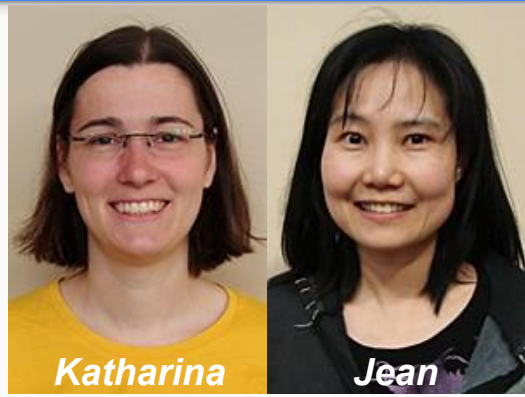
NREC
National Robotics Engineering Center

Mentors

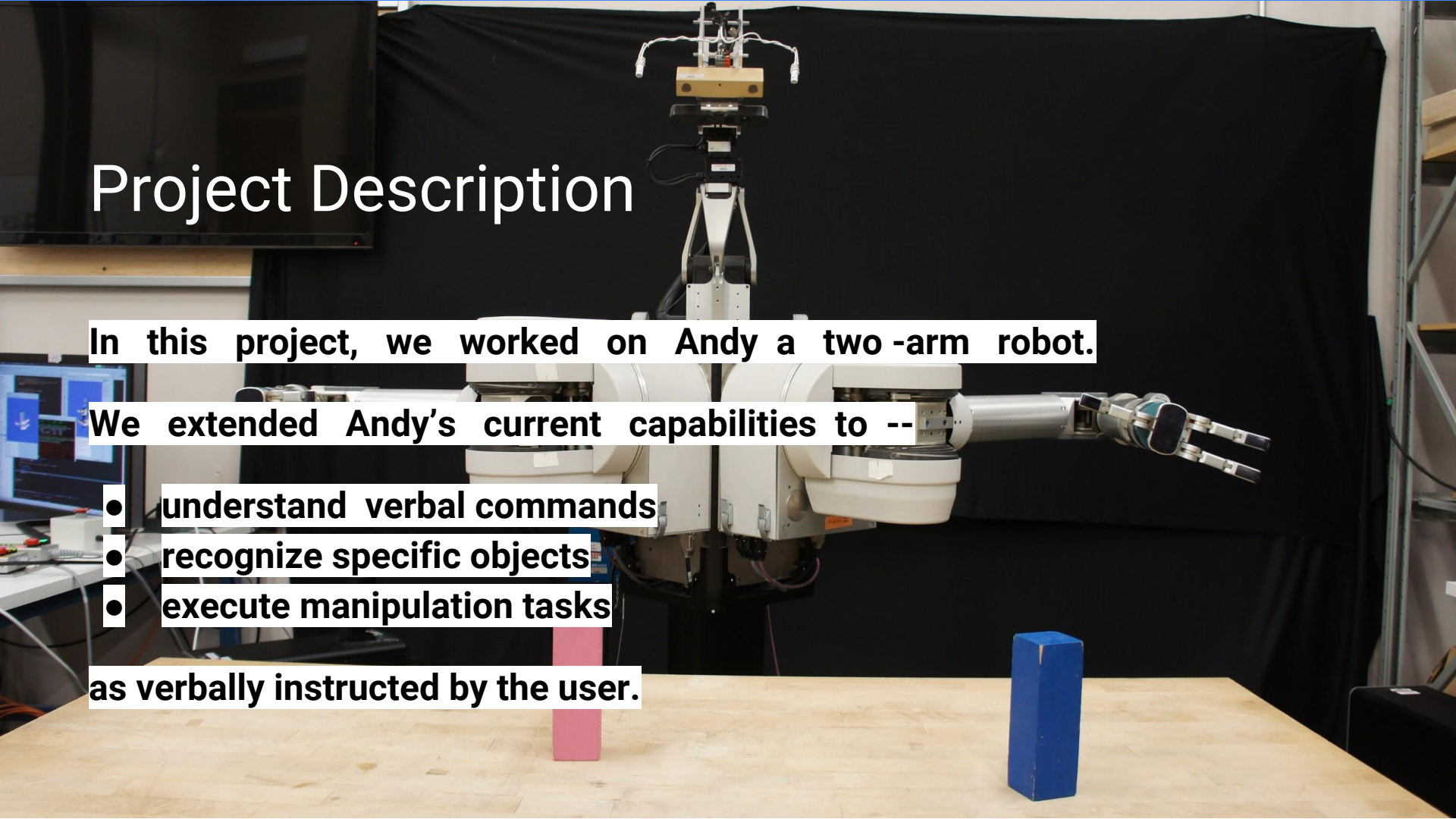
Special thanks to our mentors --

- Jean Oh -- Project Scientist, NREC
- Katharina Muelling -- Project Scientist, NREC



Autonomous Robotic Manipulation Lab, NREC

Project Description



In this project, we worked on Andy a two -arm robot.

We extended Andy's current capabilities to --

- **understand verbal commands**
- **recognize specific objects**
- **execute manipulation tasks**

as verbally instructed by the user.

Subsystems of the Project

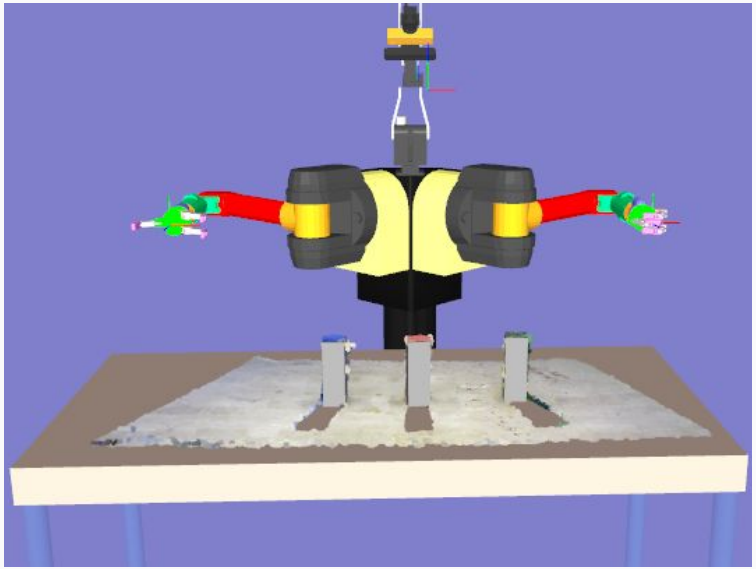
- Perception
- Speech/Language
- Manipulation

- *User Study*

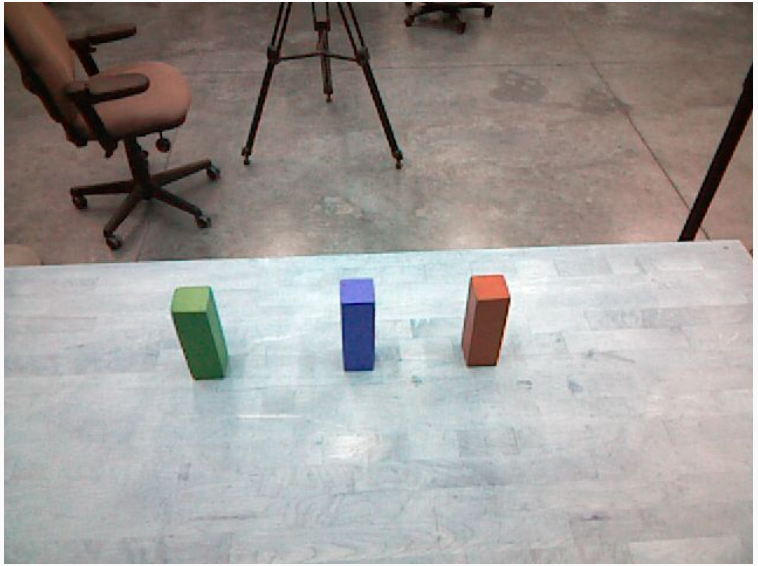
Perception Subsystem

Asus Xtion Pro Live

Block Detection

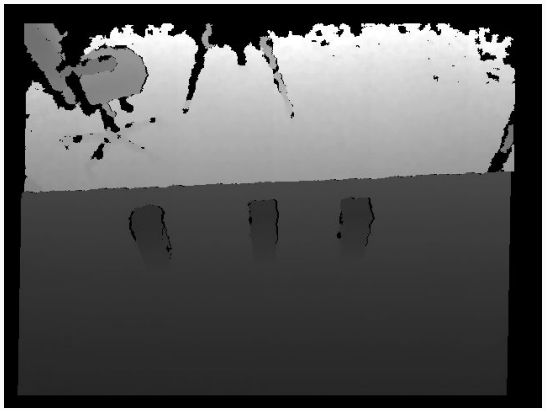


Visualization of the blocks in the GUI



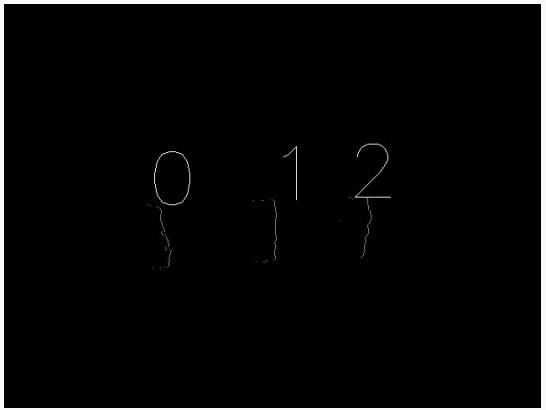
RGB Camera Image

Block Detection



Depth Map

Contour Detected

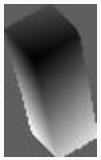


Labelled Blocks

Color Detection

To detect the average color of each block --

- Calculate the enclosing contour for each image as shown below --
  - OUTPUT



- Calculate the average across all the 3 channels --
  - OUTPUT
    [R, G, B] = [34, 203, 43]

Color Reasoning

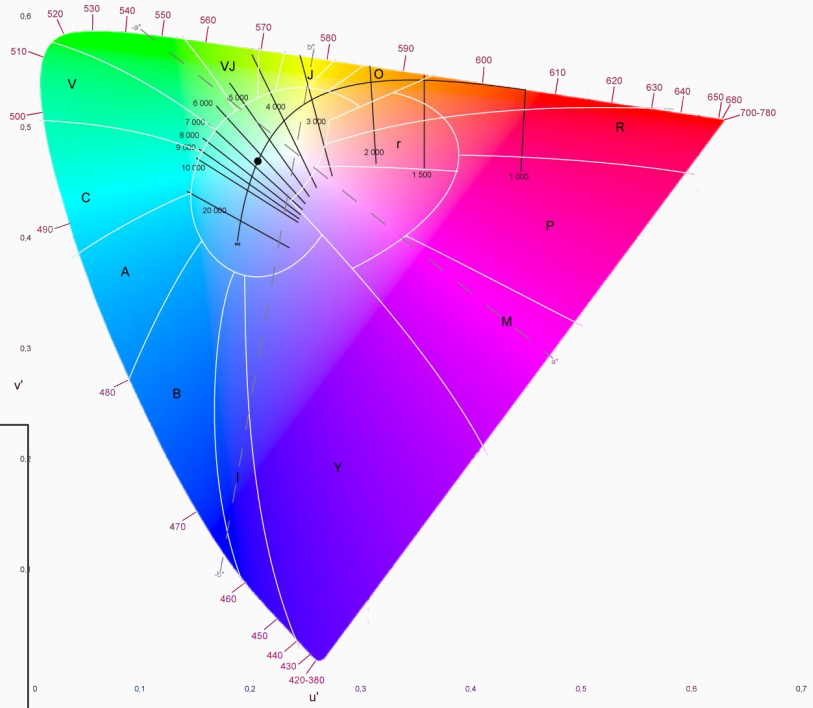
Convert the average color to from RGB color space to CIE Lab color space and rank based on Euclidean Distance from the desired colored block.

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$$

OCCAM'S RAZOR

Why not just keep in RGB color space?

Although RGB values are a convenient way to represent colors in computers, we humans perceive colors in a different way from how colors are represented in the RGB color space.



CIE COLOR SPACE

Language Subsystem

Andy + Alexa = Awesomeness :)

Amazon Echo


amazon
echo


Volume ring
Reflex port
Enhances the woofer's output for deeper sounds without distortion
2.5 inch woofer
Delivers deep bass response
2.0 inch tweeter
Crisply hits the high notes
9.25 in
amazon
3.27 in
Light ring
Action button
7-microphone array
Microphone off button

ROS + Amazon Echo Integration

We wrote a package to integrate ROS with Amazon Echo.

amazon echo + ROS

HTTP
PULL
UBUNTU

ROS

We will be soon open-sourcing the code at **github.com/auto-pirates.**

We love Open Source !!

We used and **extended capabilities** of the

TBS-Parser

written by Jean

“The Best Code is No Code At All”

High Level Idea

VOMA = (**Verb**, **Object**, **Mode**, **Adverbial**)

Modes are "quickly", "a little bit", "more" etc.
Adverbials are "to the left", "up", etc.

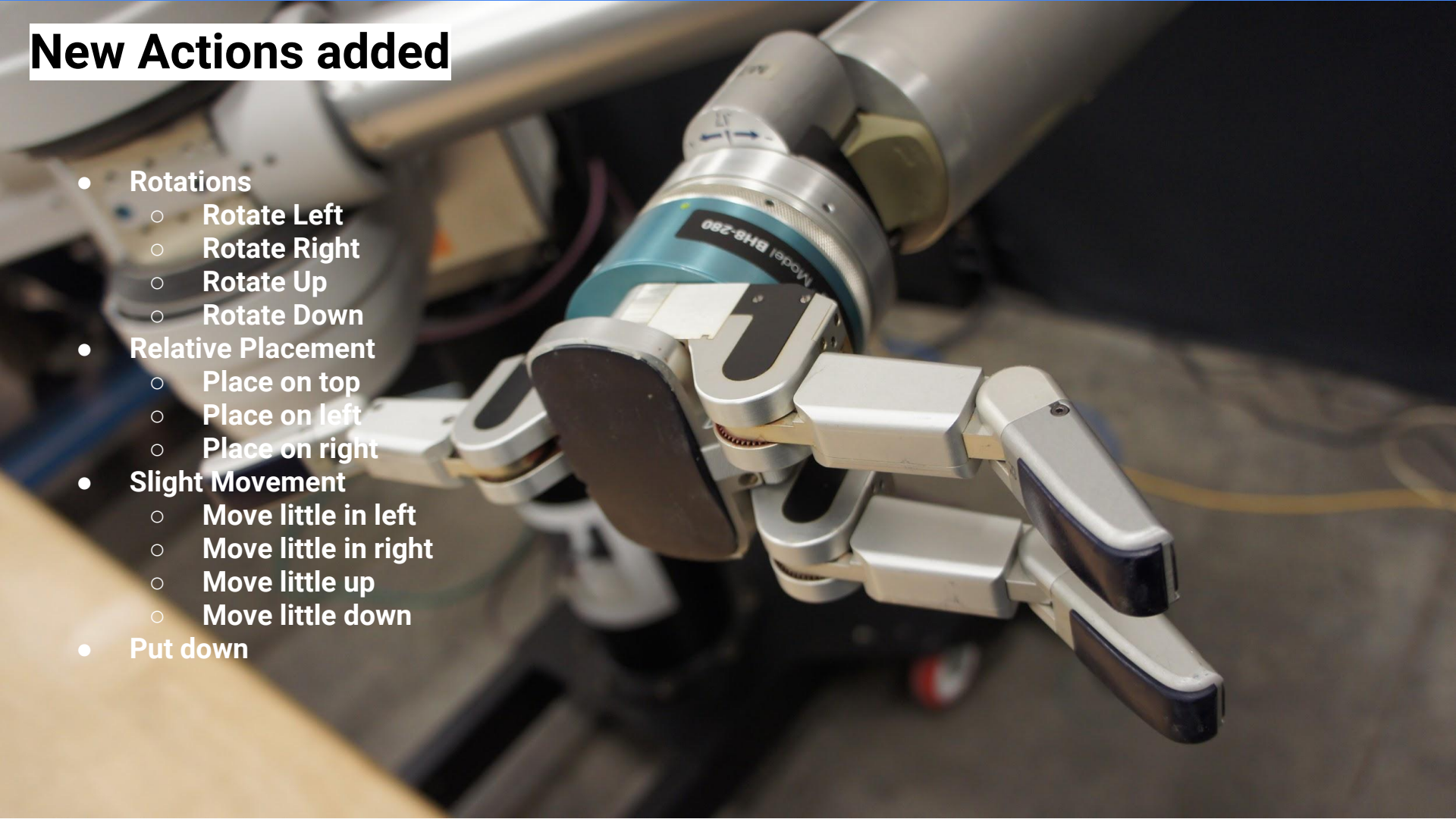
Examples:
Rotate your right arm a little bit forward.
Move your left arm more to the right.

Tactical Behavior Specification (TBS) language in BNF

```
<tbs> ::= <action><direct-obj>[<mode>][<action-constraints>]<goal>[<goal-
constraints>]
<action> ::= navigate | search | observe | grasp
<direct-obj> ::= <named-obj>
<goal> ::= [ <relation> ] <landmark-object>
<goal-constraint> ::= <constraint-list>
<action-constraint> ::= <constraint-list>
<constraint-list> ::= <constraint-term> | <constraint-term> { <operator>
<constraint-term> }
<constraint-term> ::= [not] <relation> <named-object> [<constraint-list>]
<mode> ::= "quickly" | "covertly" | "safely"
<relation> ::= "to" | "left" | "right" | "behind" | "front" | "around" |
"near" | "away"
<landmark-object> ::= <named-object>
<operator> ::= and | or
<named-obj> ::= "Robot" | "Building" | "Wall" | "Door" | "Grass" | "Asphalt"
| "Concrete" |
"Person" | "TrafficBarrel" | "Car" | "GasPump" | "FireHydrant"
```

Manipulation Subsystem

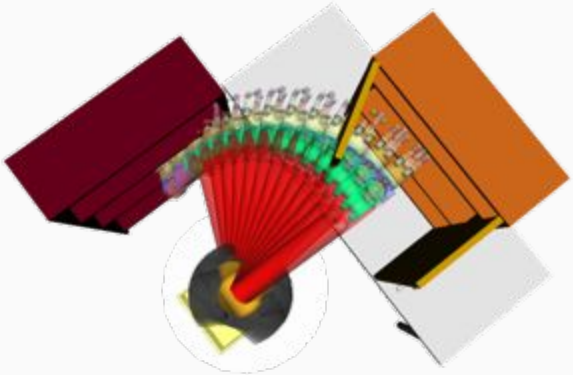
New Actions added

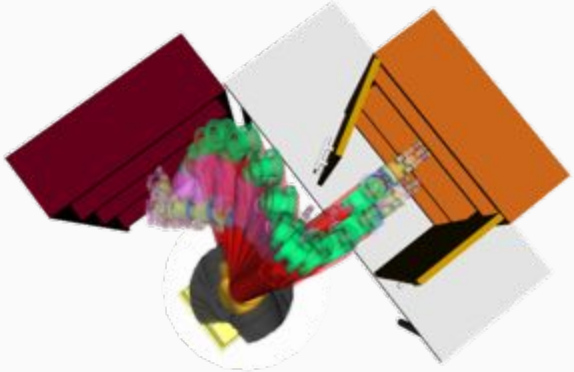


- Rotations
  - Rotate Left
  - Rotate Right
  - Rotate Up
  - Rotate Down
- Relative Placement
  - Place on top
  - Place on left
  - Place on right
- Slight Movement
  - Move little in left
  - Move little in right
  - Move little up
  - Move little down
- Put down

Motion Planning

- For motion planning, we used **Covariant Hamiltonian Optimization for Motion Planning(CHOMP)**.
- The advantage of CHOMP over other sampling based planners is that it very smooth trajectories.
- **Smooth motion makes the robot's actions look more natural to the people around it.**





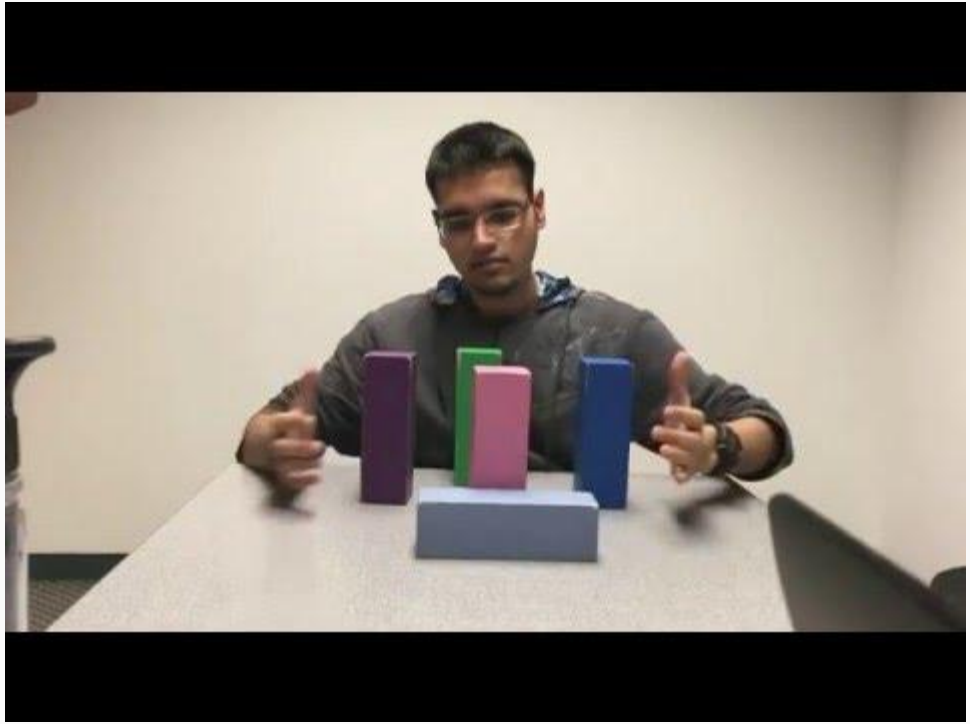
Co-authored by our very own SID :)

User Survey

User Survey

Thanks for participating folks; We really appreciate it :)

Shivam attempting the survey !! [VIDEO]



Inference

SAMPLE USER COMMAND

1. Pick the blue block, place it vertically with the side with the **largest surface area** facing yourself.
2. Pick the green block. Place it vertically with the side with the largest surface area towards yourself, along the blue block **just beside it** with the corners touching each other.
3. Now move the green block until the contact is just about to be removed.
4. Now pick the pink block and **do the same thing** on the other side of the blue block.
5. Move the pink block back so that the edges are changed, touching some other side of the blue block. **Do it again.**
6. Now pick the purple block and place it next to the green block, just touching it.
7. Place it vertically **facing yourself**.
8. Pick up this one. Put it **just** touching the pink in line with the purple and blue block. Vertically with the largest surface area facing yourself.

INFERENCE

1. There was a lot of **intuition** involved.
2. Confusing actions (Actions not necessary, because can be expressed otherwise or hard to code):
    a. Bring
    b. Use
    c. Separate
    d. Leave
    e. Stack = Put on top of
3. Synonyms:
    a. Shift: Push
    b. Take : Pick up
4. Repeat:
    a. Repeat: Do the same thing
    b. Undo the previous
    c. Do it again
    d. Repeat the same thing
    e. Once more

Andy in Action !! [VIDEO]