Robot Autonomy Project
Auto Painting

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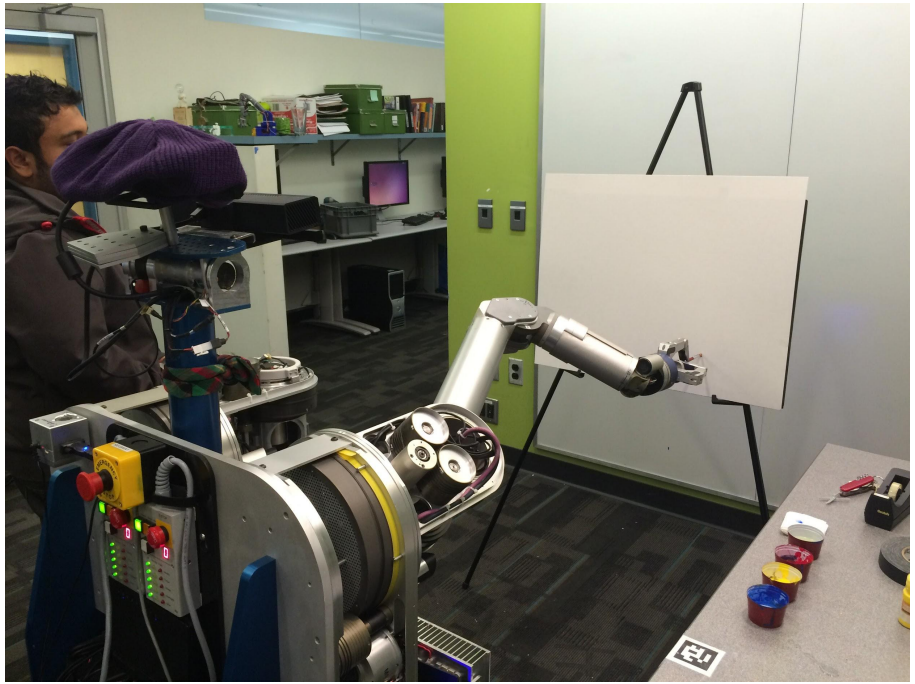
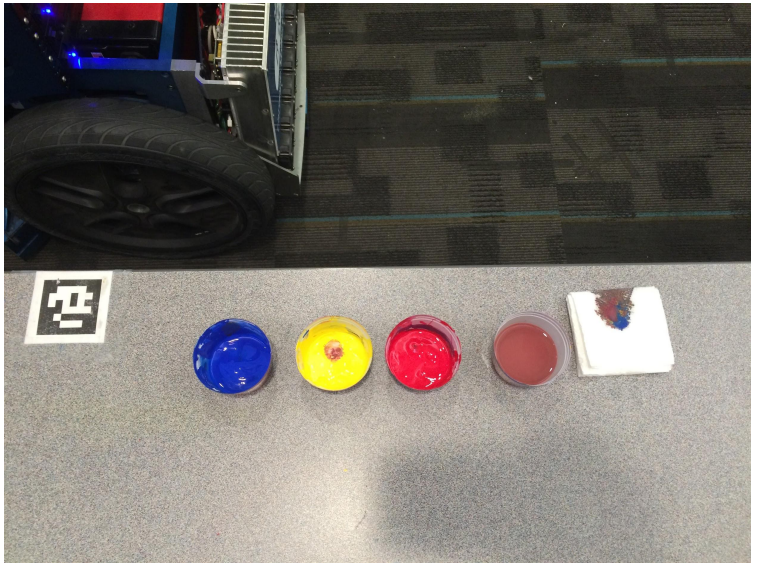
Goal -Get HERB to paint autonomously



Overview

- Initial Setup of Environment
- Problems to Solve
- Paintings:HERB, RRT, All Paintings images - Geometric + others
- Issues Faced
- Future Scope
- Final Video

Initial Setup of the Environment



Problems to solve

Holding the paintbrush

Localizing Herb to the canvas

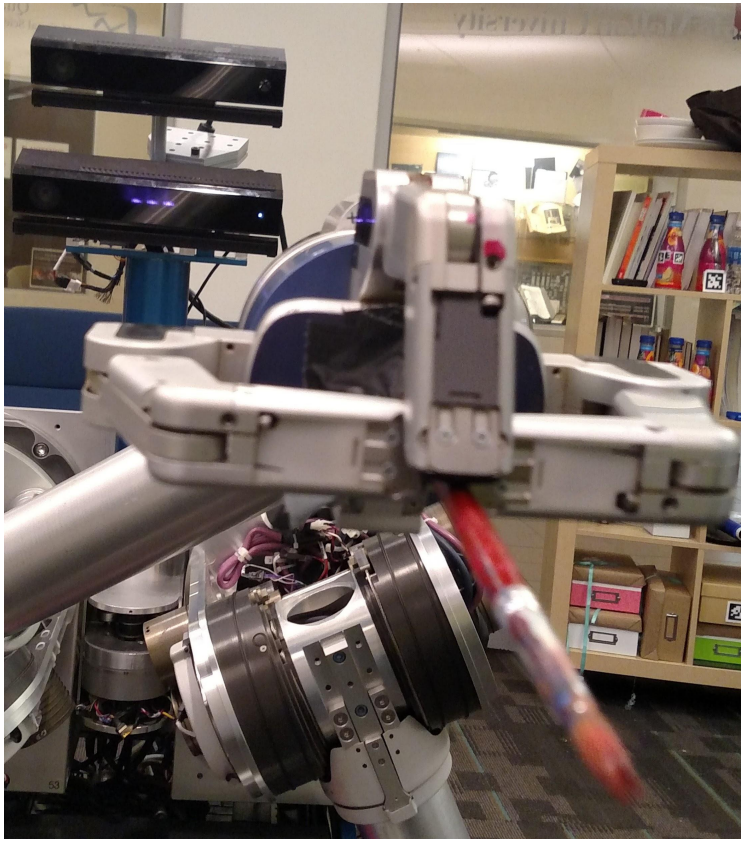
Planning the painting movements

Gathering the Color

Avoiding objects in environment

Holding the Paintbrush

- Herb's hand held onto the middle of the paint brush.
- Simply set palm DOFs to Close configuration.
- Tape was used to attach the back of the paint brush to the palm
- This made the paintbrush rigidly attached to the arm.



Localizing Herb to the Canvas

Find 3 points on the Canvas

- Manually move Herbs hand close to the canvas when the robot is not Stiff
- Make Herb Stiff so that Herb can make sure that his palm pointed directly in front of him.
- Then use a set of controls to move the paintbrush in Herbs hand onto the canvas until the brush hit the canvas
- This also configured the bottom left corner of the canvas

Planning the Movement of the Arm

- The Goal
  - Draw a set of 2D points as a single connected line on the canvas.
- Planner
  - We used the Personal Robotics Lab herbpy PlanToEndEffectorOffset function to plan along a unit vector which was along the plane of the canvas.
  - To find the unit vector the 2D points were transformed into 3D space then the difference between current point and the next point was used to find the vector in 3D space to plan along.

Constrain Movement of the Arm to the Canvas

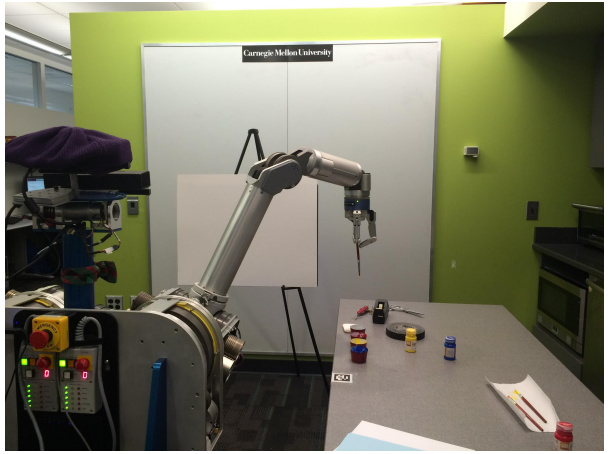
- The procedure
  - Move the arm to the preconfigured canvas position
  - Rotate the wrist so the palm, and therefore paintbrush is pointed directly away from the robot
  - Move the arm to the corner of the canvas at point 0,0 and 5cm off of the canvas
  - Move the arm to the initial position
  - Next move the paintbrush along the normal vector of the canvas to touch the canvas
  - Now move along the set of 2D points
  - Move away for the canvas

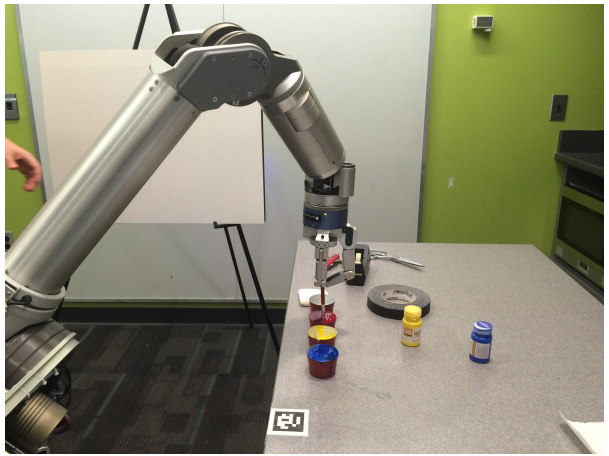
Constrain Movement of the Arm to the Canvas

- Optimizations
  - Use a virtual robot to help make fluid movements
    - This meant that there was no pausing from the start of going onto the canvas until leaving the canvas
    - This was also used so that the robot did not have to move to the 0,0 point on the plane ever, it was just done virtually, and then the final DOF values were sent to the robot

Gathering the Color

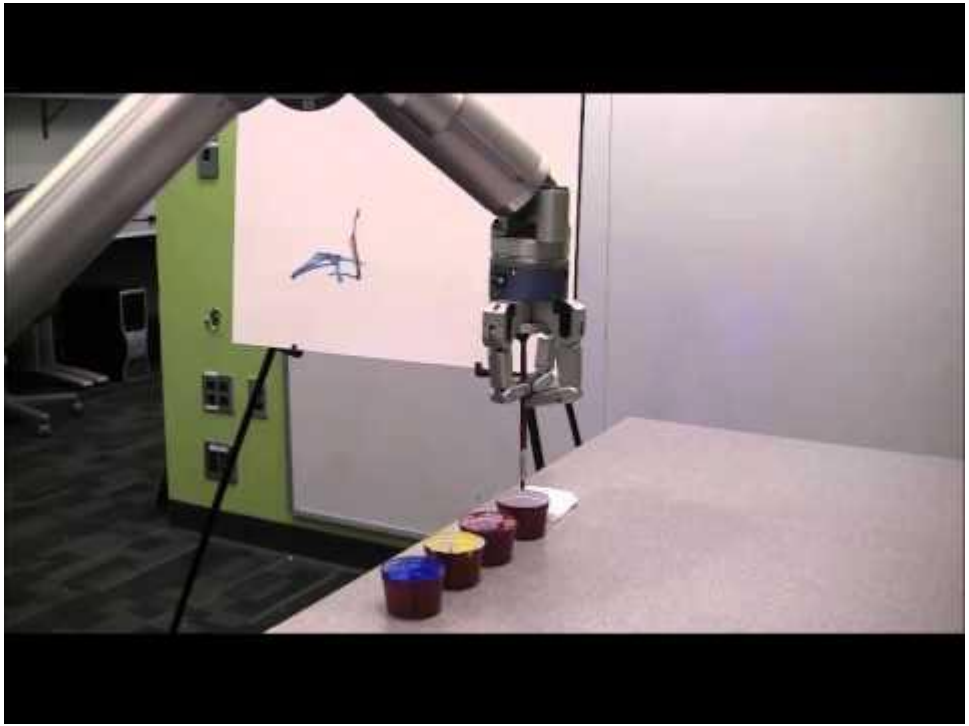
- Why
  a. Allow Herb to paint longer than just a single full brush of paint
  b. Allow Herb to get different colors
- Manually move hand to each position
- The following positions
  a. Red
  b. Yellow
  c. Blue
  d. Clean
  e. Dap
  f. Pre Color
  g. Canvas





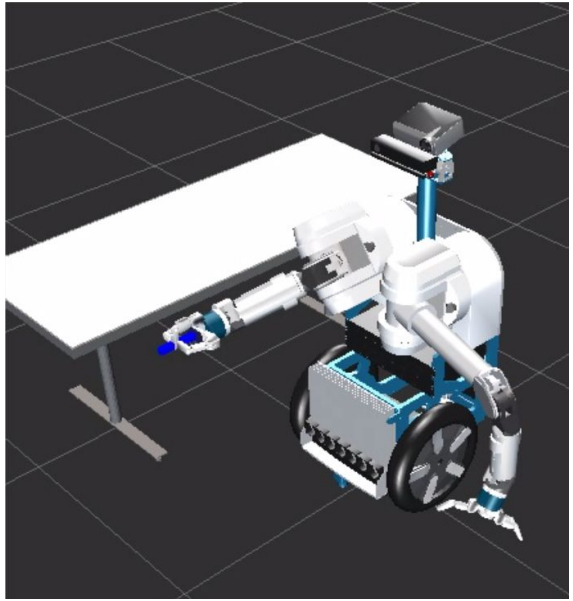
Performing the Color, Clean and Dabbing Positions

1. Move to the pre-color position that is above the color and cleaning areas
2. Move to the color
3. Go down into the color
4. Spin the brush to collect the color
5. Go up out of the color
6. Go back to the pre color position



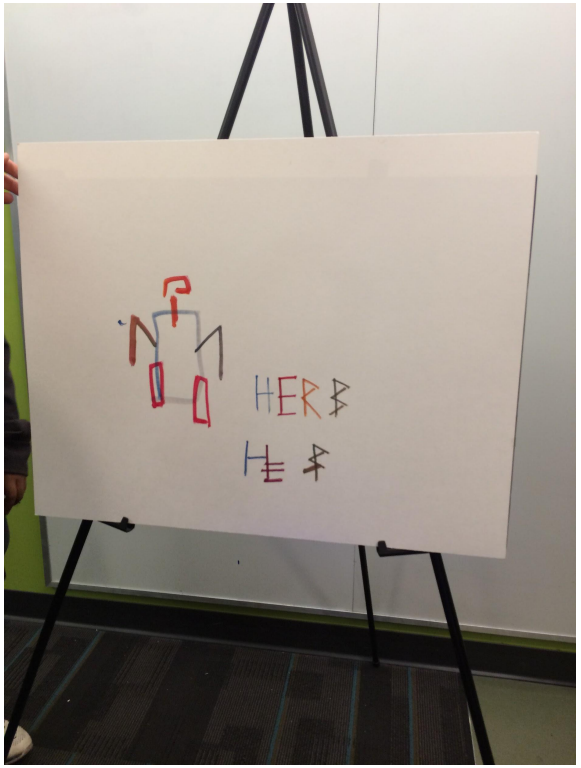
Avoiding Objects in The Environment

- The objects in the Environment were table and canvas
- Table (To Herb’s right side)
- Canvas (in front of Herb)
- Vessels containing colors placed on the table.



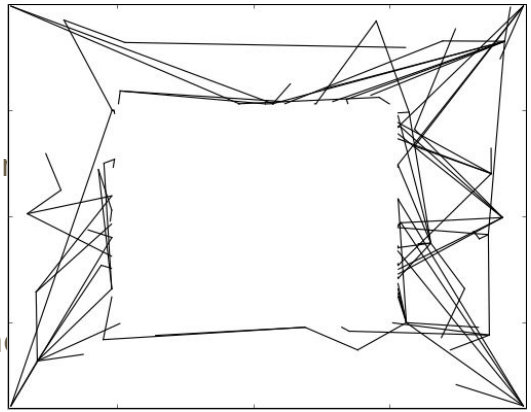
Paintings

- HERB
- RRT
- Geometric shapes.

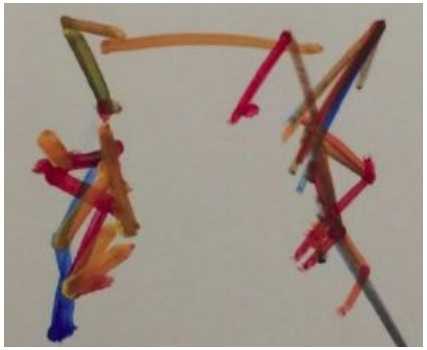


Random - Planned Art using RRTs

- **The Thought:** Randomness v/s determinism in art
- **The Algorithm:** Parallel drawn with rando motion planning
  - "What HERB wants to show" is defined as obstacles in a costmap.
  - Soften and bloat and then determin costmap gradients.
  - Coverage v/s detailing
  - Alter the underlying probability distribution from which RRT samples to **control Voronoi properties.**
  - Wait an eternity for the masterpiece !
- **Advantages:**
  - Easy to extend to relatively abstract and complex ideas.
  - Easy to apply on a real robot (accuracy, movement etc.)
  - Coverage v/s detailing allows for faster computation

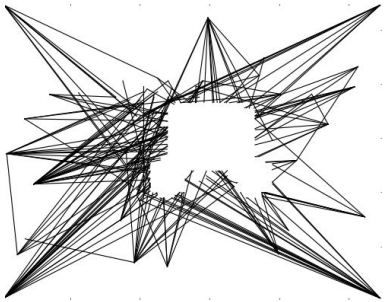


What we aimed at



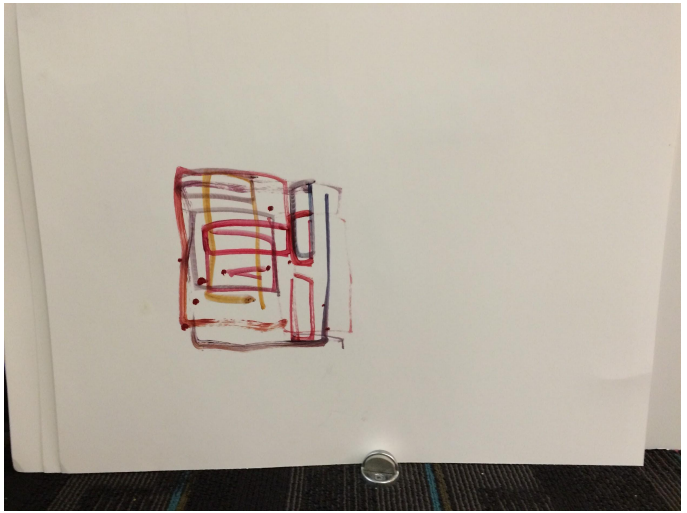
What we had the patience for

Another Simple Example:



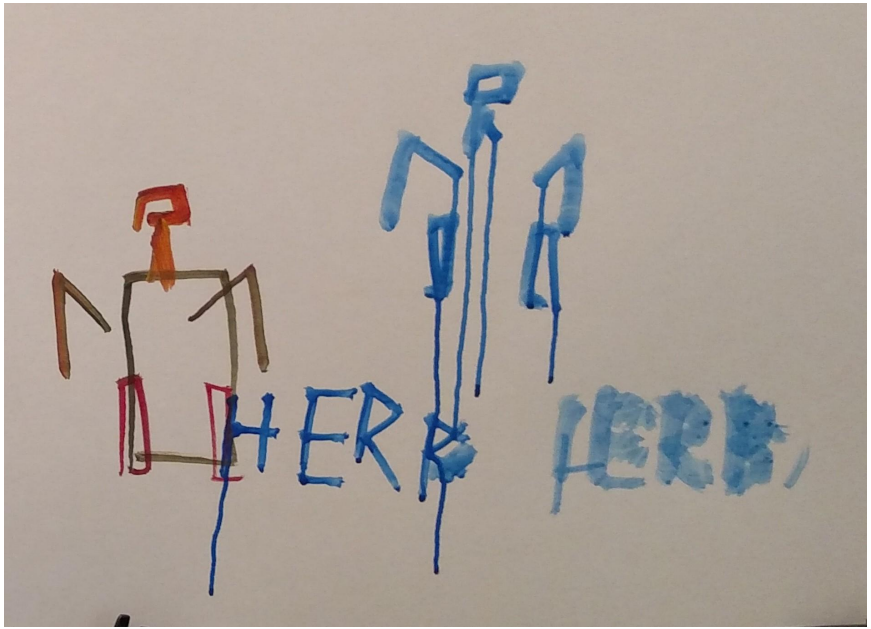
Herb's lower body


HERE



Issues Faced

- Hitting the plane
  - Developed a procedure to find the plane
- Dripping
  - Perform a single dab after gathering paint
- Failing to plan
  - Catch the exception and continue on.
- Inaccuracies occurring due to no perception (open loop system)



Future Scope

- Drawing on a curved surface, like a curved ceiling
- Using perception to determine when the paint brush hits the canvas.
    - There were cases where the inaccuracies of the arm would make the arm above or below the intended position. Sometimes the arm would also either be too far in or too far away from the canvas
- Mixing colors to get an expected color
- Autonomous grasping of the paintbrush

Final Video

Acknowledgements

- Siddhartha Srinivasa for teaching the class
- Laura Herlant for sponsoring and mentoring this project
- The group at the Personal Robotics Lab for making and maintaining Herb
- Herb (Of course)