ARTICLE TITLE: COMPUTATION OF SUITABLE GRASP POSE FOR USAGE OF OBJECTS BASED ON PREDEFINED TRAINING AND REAL-TIME POSE ESTIMATION

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RESUME OF MUHAMMED TAWFIQ CHOWDHURY

- B.Sc. in Computer Science and Engineering, BRAC University, 2015
- M.Sc. in Computer Science and Engineering, University of Nevada, Reno, 2020
- Ph.D. in Computer Science and Engineering, University of Nevada, Reno (Ongoing)
- Lecturer, Department of Computer Science and Engineering, Northern University Bangladesh (September 2016-July 2018)
- Graduate Research Assistant, Department of Computer Science and Engineering, University of Nevada, Reno (August 2018-July 2019)
- Graduate Teaching Assistant, Department of Computer Science and Engineering, University of Nevada, Reno (August 2018-present)

OUTCOMES OF THIS RESEARCH

- Developing a system that can train a humanoid robot with different types of grasps
- Finding predefined grasp poses that would allow a robot to use tools such as screwdrivers, hammers, etc.
- Enabling the robot to grasp objects accurately from human hands
- Introducing a homography-based planar pose detection and estimation technique for objects that have complex shapes
- Implementing a color-based pose detection and estimation system using mathematical formulas for objects with linear shapes

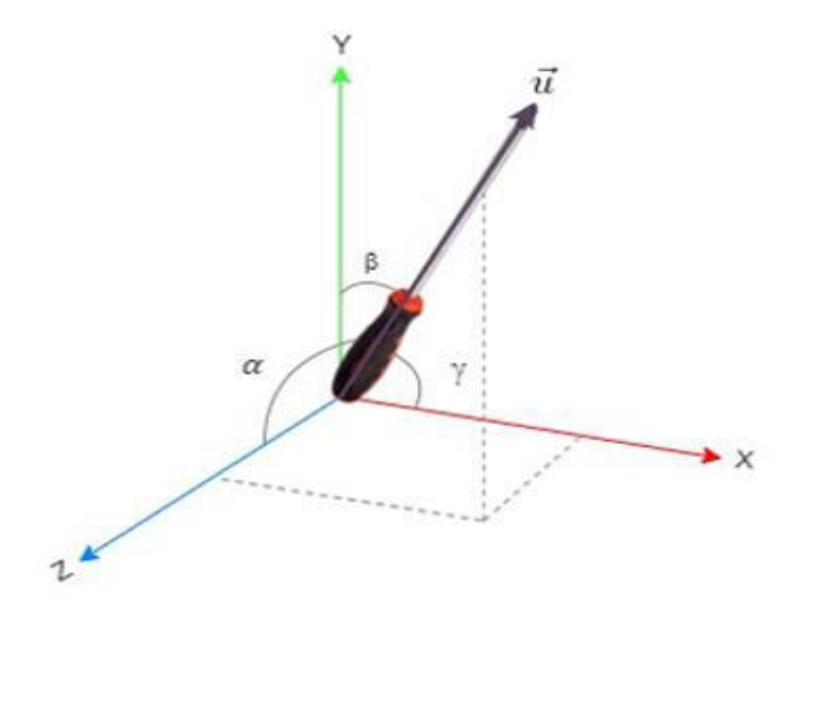
TYPES OF GRASPS

COLOR-BASED POSE ESTIMATION

- Color-based Pose Detection and Estimation

COLOR-BASED POSE ESTIMATION (CONTINUED)

Directional Cosine for Color-based Pose Estimation



$$\gamma = \cos^{-1}\left(\frac{\vec{u_x}}{|\vec{u}|}\right)$$

$$\beta = \cos^{-1}\left(\frac{\vec{u_y}}{|\vec{u}|}\right)$$

$$\alpha = \cos^{-1}\left(\frac{\vec{u_z}}{|\vec{u}|}\right)$$

PLANAR POSE ESTIMATION

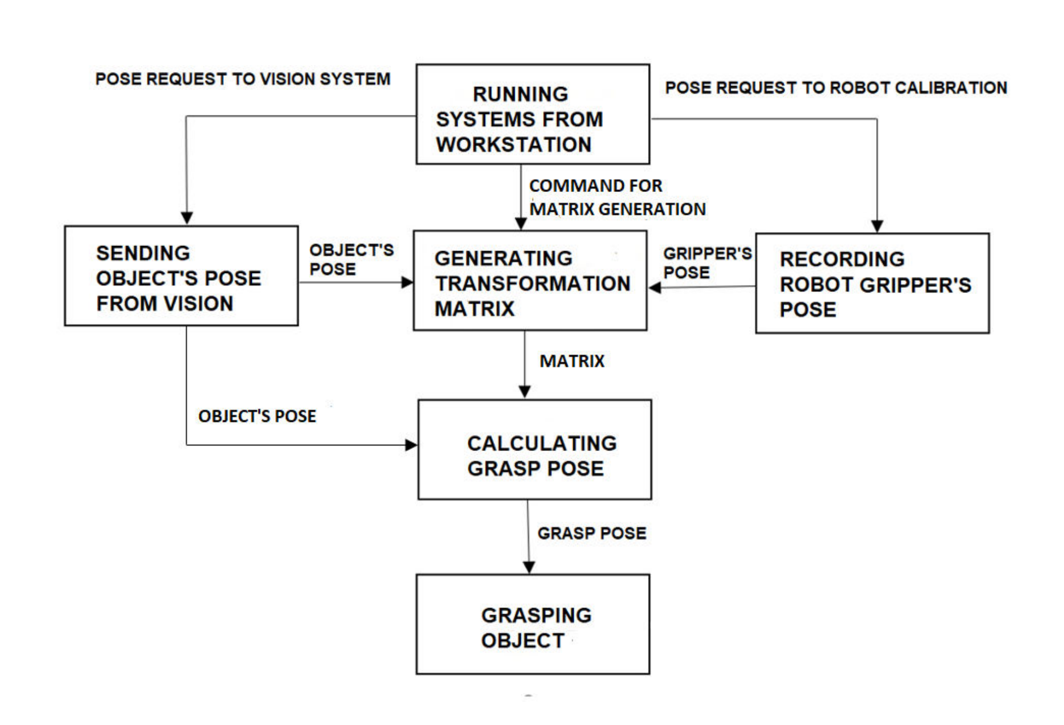
- **Homography Based Planer Pose Estimation**
- Estimate the pose in terms of a 2D planar representation of an object in 3D space employing the depth information from camera
- Extract features and match features found in the images from camera
- Perform Homography Estimation and Perspective Projection
- Find Directional Vectors on the object
- Compute Planer Pose

PLANAR POSE ESTIMATION (CONTINUED)

SYSTEM DESIGN (OVERVIEW)

- Place the gripper and object in relative poses
- Record the gripper's pose
- Record the object's pose
- Generate the transformation matrix
- Get a new pose of the object
- Grasp the object in the new pose

SYSTEM DESIGN (CONTINUED)



HOMOGENEOUS TRANSFORMATION (TRANSLATION AND ROTATION)

$$
{}^{A}T_B = \begin{bmatrix} \cos\alpha\cos\beta & \cos\alpha\sin\beta\sin\gamma - \sin\alpha\cos\gamma & \cos\alpha\sin\beta\cos\gamma + \sin\alpha\sin\gamma & x_t \\ \sin\alpha\cos\beta & \sin\alpha\sin\beta\sin\gamma + \cos\alpha\cos\gamma & \sin\alpha\sin\beta\cos\gamma - \cos\alpha\sin\gamma & y_t \\ -\sin\beta & \cos\beta\sin\gamma & \cos\beta\cos\gamma & z_t \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

HOMOGENEOUS TRANSFORMATION (CONTINUED)

$$
{}^{A}T_{B} = \begin{bmatrix} c_{11} & c_{12} & c_{13} & x_t \\ c_{21} & c_{22} & c_{23} & y_t \\ c_{31} & c_{32} & c_{33} & z_t \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

TRAINING

Side (Wrench) Top (Screwdriver) Side (Book)

COMPUTING THE MATRIX FOR TRAINING

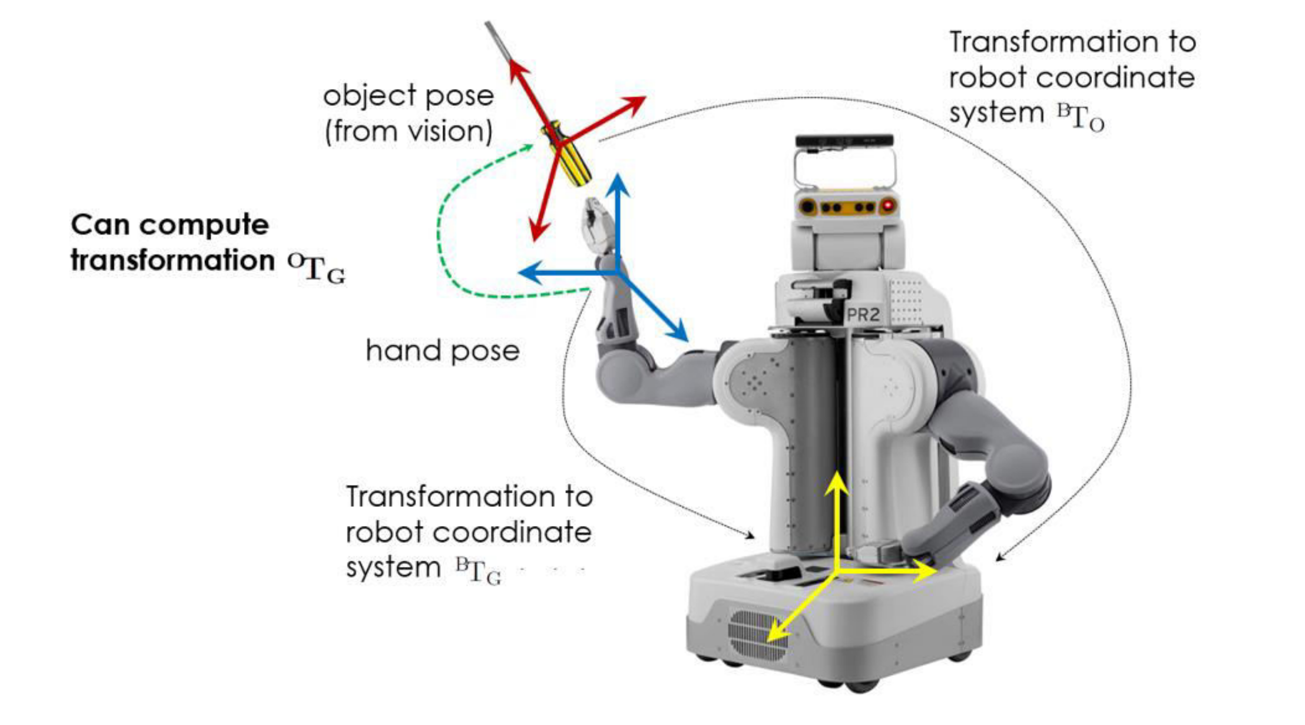
$$ {}^{O}T_G = {}^{O}T_B \times {}^{B}T_G \text{ where } {}^{O}T_B = ({}^{B}T_O)^{-1} $$

O refers to the object

B refers to the robot's base

G refers to the wrist of the robot to which the gripper is attached

COMPUTING THE MATRIX FOR TRAINING (CONTINUED)



GRASP POSE CALCULATION

$$ {}^{B}T_{G} = {}^{B}T_{O} \times {}^{O}T_{G} $$

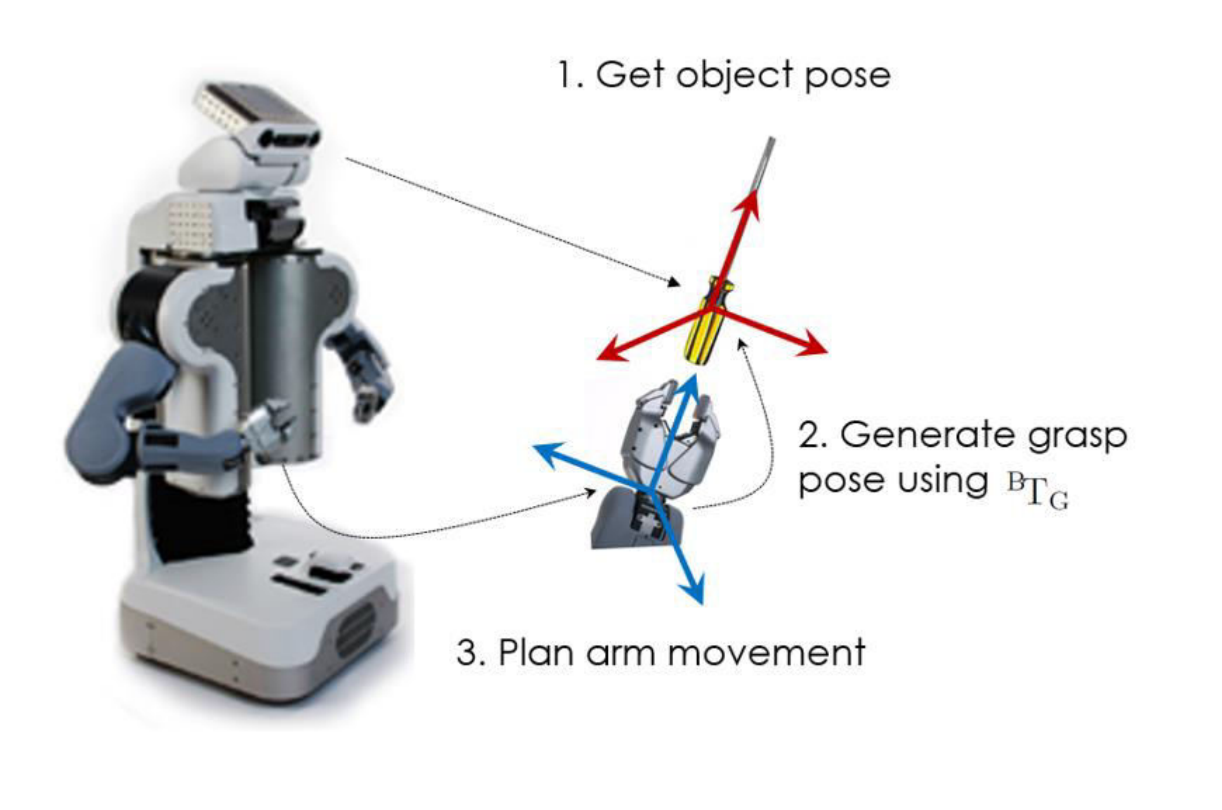
$$ \gamma = tan^{-1}(c_{32}/c_{33}) $$

$$ \beta = tan^{-1}(-c_{31}/\sqrt{{c_{32}}^{2} + {c_{33}}^{2}}) $$

$$ \alpha = tan^{-1}(c_{21}/c_{11}) $$

GRASPING FOR TESTING

- MoveIt Interface
- Robot Operating System



EXPERIMENTS AND RESULTS

General Validation Results

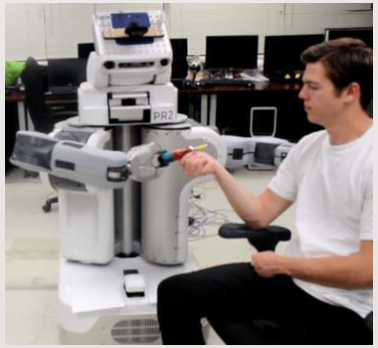
Objects	Top Grasp	Side Grasp	Successful Grasp (Top | Side)	Accuracy (Top | Side)
Wrench	12	24	12 | 22	100% | 91.67%
Screwdriver	6	N/A	6 | N/A	100% | N/A
Books	N/A	5	N/A | 5	N/A | 100%

Human Validation Results

Objects	Top Grasp	Side Grasp	Successful Grasp (Top | Side)	Accuracy (Top | Side)
Wrench	9	7	9 | 6	100% | 85.72%
Screwdriver	9	N/A	9 | N/A	100% | N/A
Books	N/A	5	N/A | 5	N/A | 100%

EXPERIMENTS AND RESULTS (CONTINUED)

Side grasp of the wrench using the right gripper



Top grasp of the screwdriver pointing towards the robot

Top grasp of the screwdriver pointing towards the human

Side grasp of the wrench using the left gripper

Side grasp of the sticker-book

Side grasp of the cartoon-book

FUTURE WORK

- A feature for dialogue with humans in the environment
- A feature for collision avoidance
- An automated trajectory