Within-hand Manipulation Planning and Control Approaches for Variable Friction Fingers

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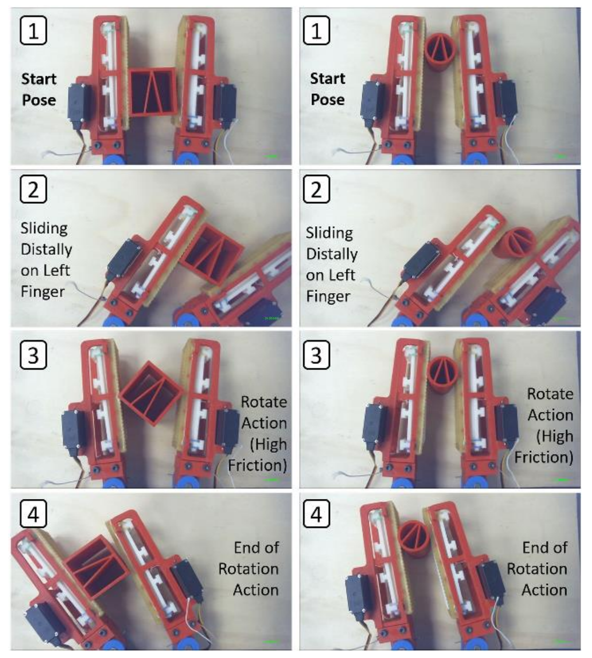
Abstract

The ability to conduct within-hand manipulation provides significant dexterity and flexibility advantages to robots operating in unstructured and constrained environments, as they can re-position and re-orient objects without regrasping. This is a challenging task even for an highly articulated robot. Here we propose different strategies to perform within hand manipulation of objects using Variable Friction(VF) Finger gripper system.

Background

VF Finger Gripper is a 2-DOF robot gripper that can change the effective friction of its finger surfaces with a simple actuated mechanism. It is a non-holonomic switching system which can slide and rotate objects within hand by varying the friction surfaces and the finger angles.

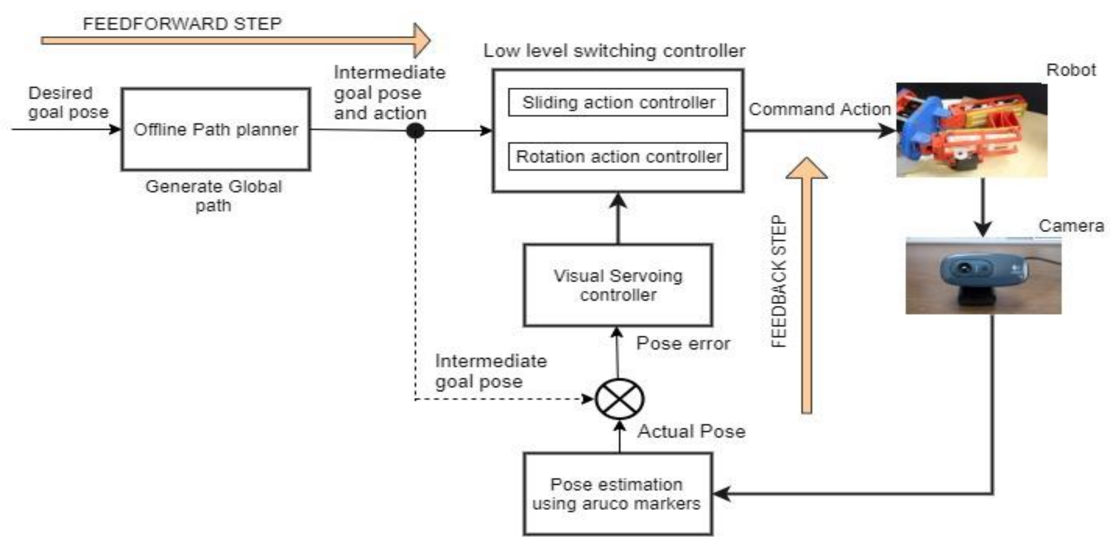


Project Objectives

1. Develop methods to solve within hand manipulation task.
2. Evaluate the methods based on path smoothness, accuracy and efficiency by testing on VF Finger Gripper system.

Methodology

1. Develop an Offline Motion planner.
2. Develop an Online Visual Servoing method.
3. Develop an Hybrid method integrating offline and online approaches.



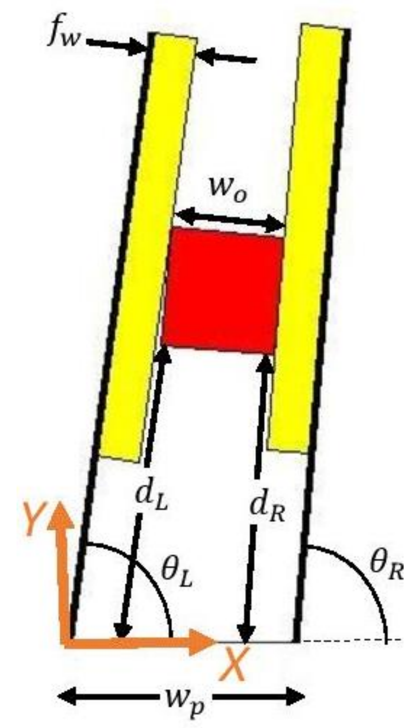
Operational Block Diagram

Modelling

Visual Servoing:

$$v_{ref} = -\lambda J_i^* e$$

$$\begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = \begin{bmatrix} -\left(d_L + \frac{w_0}{2}\right)\sin\theta_L + \left(\frac{w_o}{2} + f_w\right)\cos\theta_L \\ \left(d_L + \frac{w_0}{2}\right)\cos\theta_L - \left(\frac{w_o}{2} + f_w\right)\sin\theta_L \end{bmatrix} \dot{\theta}_L$$



Motion Planner:

Modified A* search

Cost Function Design:

$$f(s) = g(s) + \alpha h(s)$$

where $\alpha \geq 1$

$$h(s) = \beta h_a(s)$$

where

$$h_a(s) = h(s)_{position} + h(s)_{orientatrion}$$

$$\beta = \begin{cases} 0 < \beta < 1, & if\ a == Pa \\ 1, & otherwise \end{cases}$$

$a \rightarrow current\ action$

$P_a \rightarrow Parent\ action$

Kinematic Modelling Parameters

f_w – Finger Width

W_o – Object dimension

θ_L, θ_R – Left and Right actuator angles

d_L, d_R – Object Position in left and right finger

w_p - Width of palm

Experiments

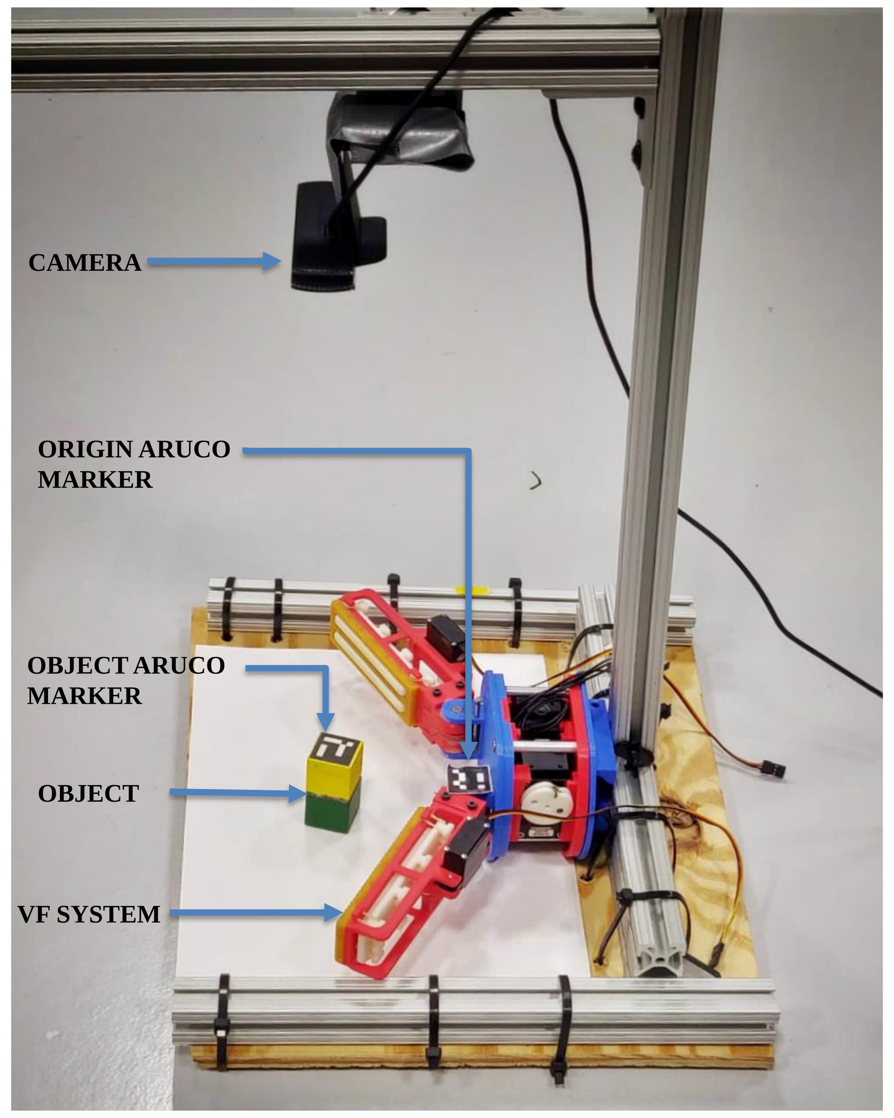
Each method was tested on 3 different tasks and 5 different start and goal positions.

<u>Tasks:</u>

1. Perform only position correction.
2. Perform both position and orientation correction.
3. Perform Position and orientation correction with modelling inaccuracy.

<u>Evaluation Metrics</u>

1. Accuracy
2. Time taken
3. Path length
4. Path smoothness



Experimental Setup

Results

Task Evaluation

a. TASK1: POSITION CORRECTION

	Accuracy (cm)	Time taken (s)	Path length (cm)	Switching actions
Visual servoing	0.14 ± 0.1	46 ± 22	38 ± 29	11 ± 3
Offline Motion planning	3.1 ± 2.3	10 ± 1	13 ± 3	2 ± 0
Hybrid	0.36 ± 0.2	27 ± 15	20 ± 3	6 ± 2

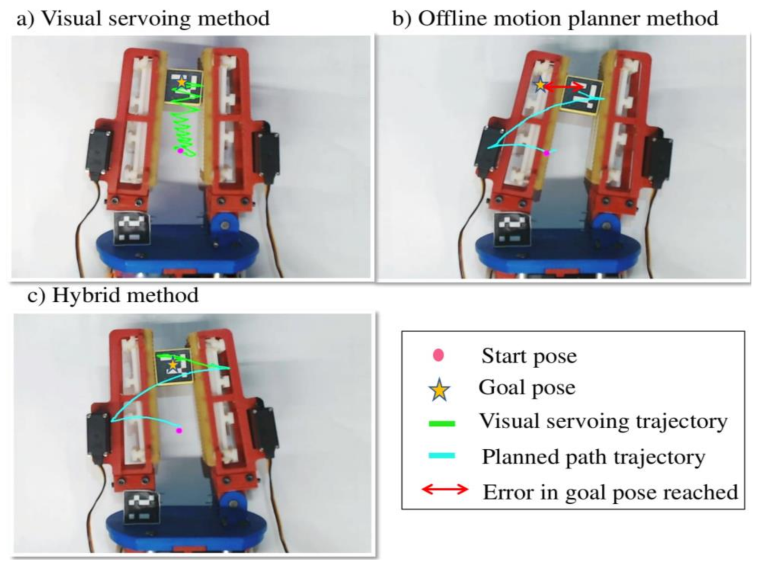
b. TASK2: POSITION AND ORIENTATION CORRECTION

	Accuracy (cm)	Time taken (s)	Path length (cm)	Switching actions
Visual servoing	0.35 ± 0.1	76 ± 50	90 ± 56	16 ± 11
Offline Motion planning	2 ± 1.8	28 ± 3	33 ± 5	4 ± 0
Hybrid	0.2 ± 0.1	54 ± 10	57 ± 9	12 ± 4

c. POSITION AND ORIENTATION CORRECTION WITH MODELLING INACCURACIES

	Accuracy (cm)	Time taken (s)	Path length (cm)	Switching actions
Visual servoing	0.2 ± 0.02	92.7 ± 14.74	82 ± 145	19 ± 8
Offline Motion planning	1.0 ± 0.8	20 ± 2.65	32 ± 5	5 ± 2
Hybrid	0.3 ± 0.2	37.3 ± 15.4	35 ± 10	7 ± 2

Experimental Trajectory



Trajectory tracked by the object from start pose (7,7,0) to goal pose (12,12,0) for different methods a) Visual servoing b) Offline motion planning c) Hybrid method

Conclusion and Future directions

1. Hybrid Method performs faster and gives smoother paths even with inaccurate models of the system as it combines the advantages of the pre-defined path from motion planner and online error correction from visual servoing.
2. In our future work, we propose to learn the policies to manipulate any object without modelling them explicitly.

References

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2. B. J. Cohen, S. Chitta, and M. Likhachev, “Search-based planning for manipulation with motion primitives,” in IEEE IntConf on Robotics and Automation (ICRA), 2010, pp. 2902-908.