Recognition and Catching of a Throwing Ring Using High-speed Visions

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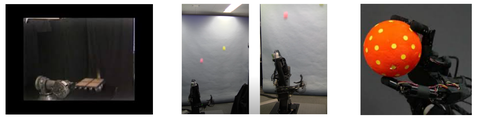
Introduction

A. Related Research


paddle juggling

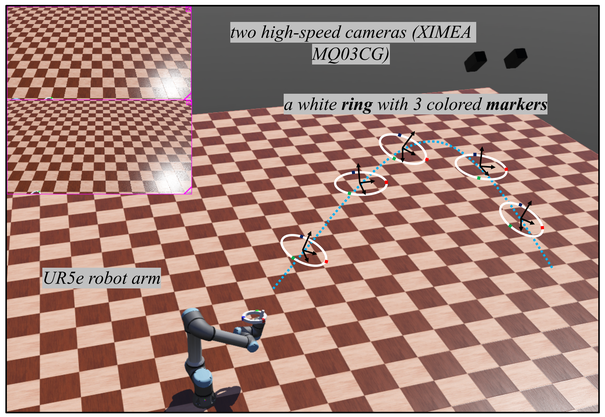
two ball juggling

ball catching

We want to challenge a larger universality and rapidity of object manipulation

B. Task

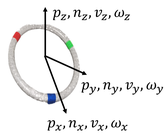
Catching of a Throwing Ring



C. Challenge

Specialty of Ring:

- *Position (p) and Orientation (n), SE(3)*
- *Linear velocity(v) and angular velocity(ω)*
- *Phenomena of Nutation*

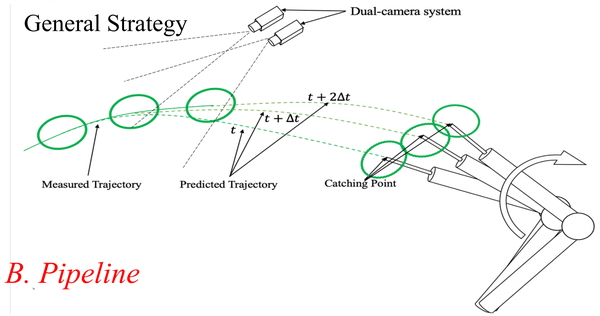


High Speed of Task:

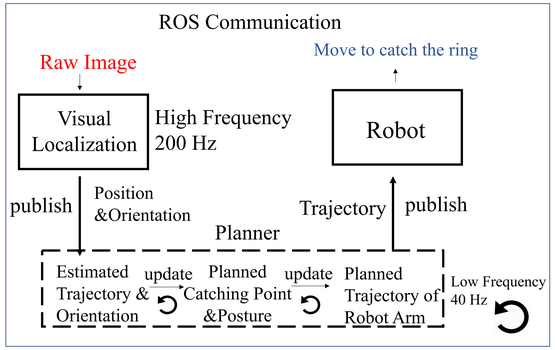
- *Appearance duration in the view of camera is less than 1 second*
- *Preparation duration from appearing in view to catching is less then 1.5 second*

Methodology

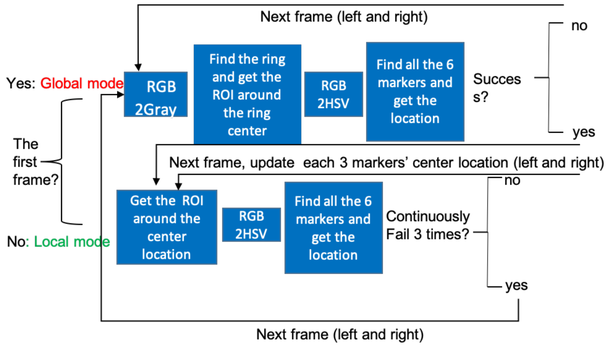
A. Overall



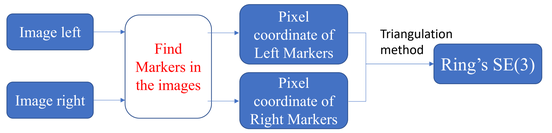
B. Pipeline



C. Visual Localization



Methodology



Performance:
Speed: Global mode 50 Hz Local mode 200 Hz
Ratio of local mode: 97.1%
Successful rate of find all markers: 89.7%.

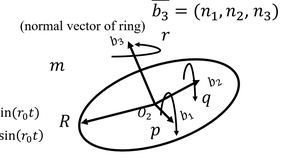
D. Trajectory Prediction

Reason: Motion planning and execution needs time

Dynamics analysis

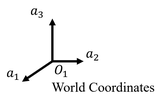
$$m\begin{bmatrix}\ddot{x}\\ \ddot{y}\\ \ddot{z}\end{bmatrix}=\begin{bmatrix}0\\0\\-mg\end{bmatrix} \Rightarrow \begin{aligned} x &= x_0 + v_x t \\ y &= y_0 + v_y t \\ z &= z_0 + v_z t - \frac{1}{2}gt^2 \end{aligned}$$

$$I\begin{bmatrix}\dot{p}\\ \dot{q}\\ \dot{r}\end{bmatrix}+\begin{bmatrix}p\\q\\r\end{bmatrix}\times I\begin{bmatrix}p\\q\\r\end{bmatrix}=0 \Rightarrow \begin{aligned} p &= p_0\cos(r_0 t) + q_0\sin(r_0 t) \\ q &= q_0\cos(r_0 t) + p_0\sin(r_0 t) \\ r &= r_0 \end{aligned}$$



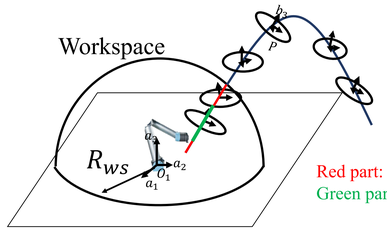
Trajectory Model:

$$\begin{aligned} x &= \theta_0 + \theta_1 t \\ y &= \theta_2 + \theta_3 t \\ z &= \theta_4 + \theta_5 t + \theta_6 t^2 \end{aligned} \qquad \begin{aligned} n_1 &= \theta_7 \sin(\theta_8 t + \theta_9) \\ n_2 &= \theta_{10}\sin(\theta_{11} t + \theta_{12}) \\ n_3 &= \theta_{13}\sin(\theta_{14} t + \theta_{15}) \end{aligned}$$



To catch the ring, its position and its normal vector is considered

E. Catching Point Planning



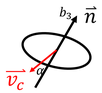
Red part: Position Condition
Green part: Orientation Condition

$Position\ of\ ring = (x, y, z)$
$Normal\ vector\ of\ ring = (n_1, n_2, n_3)$

Methodology

1. Position Condition:

$$P_{catch} \in Working\ Space \Rightarrow \begin{cases} (x - x_{robot})^2 + (y - y_{robot})^2 + (z - z_{robot})^2 < R_{ws}^2 \\ z > z_{robot} \end{cases}$$



2. Orientation Condition:

$$\langle \overrightarrow{v_c}, -\overrightarrow{b_3} \rangle < \alpha_{threshold}$$

This condition guarantees the orientation of ring and its velocity is close.

Experiment

Due to the COVID-19, we are sorry that we cannot conduct experiments in the laboratory. Instead, we conduct the experiment in the simulation.
View our demonstration at this website: https://youtu.be/sY5x89v5OrQ