Integrated Online Perception of Articulated Objects for Manipulation [Martin, 2014]

Jia Guo, George Kontoudis

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Mechanical Engineering Department, Virginia Tech

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Outline

Background

Problem:

- Grasping and manipulation in unstructured environments
- Identify object's shape, pose, and kinematic structure
- Visual perception techniques cannot be solved online

Solution:

- Utilization of Recursive Bayesian Estimation (RBE) techniques
- Allocation to sub-level algorithms

Objective

Identify kinematic structure of objects and environment w/ visual perception

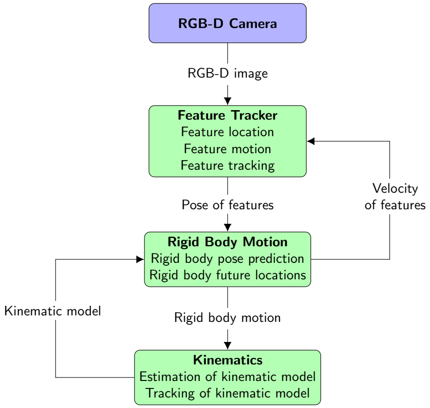
- Estimate joint axis
- Estimate type of joints
- Motion with uncertainty

Autonomous grasping in unstructured environment

Kinematic Structure Identification

Estimation of kinematic structure using an RGB-D camera

1. The feature tracker is based on KLT algorithm [Tomasi, 1991]
2. Rigid body motion achieved w/ EKF
3. Kinematic model obtained w/ EKF



Stochastic Models

Motion model of EKF

$$x_k^t = f^t(x_{k-1}^t, u_{k-1}^t) + w_{k-1}^t, \tag{1}$$

where $w_{k-1}^t \sim \mathcal{N}(0, \Sigma_{w_{k-1}^t}) = \mathcal{N}(0, Q_{k-1}),\ Q_{k-1} \geq 0$

Sensor model of EKF

$$z_{k-1}^t = h^t(x_{k-1}^t) + v_{k-1}^t, \tag{2}$$

where $v_{k-1}^t \sim \mathcal{N}(0, \Sigma_{v_{k-1}^t}) = \mathcal{N}(0, R_{k-1})$ with $R_{k-1} > 0$

Integrated Visual Perception

Jia Guo

Developed/Implemented Detection Technique

Jia Guo

RBE for Rigid Body Motion - 2*nd* Level

Inputs: Feature's pose (1*st* level), Rigid body velocities (3*rd* level)

Sensor model of 2*nd* level EKF

$$z_k^t = h^t(x_{k-1}^t) + v_{k-1}^t = \begin{bmatrix} T(p) f_{k-1}^1 \\ \vdots \\ T(p) f_{k-1}^m \end{bmatrix} + v_{k-1}^t, \tag{3}$$

where $v_{k-1}^t \sim \mathcal{N}(0, \Sigma_{v_{k-1}^t}) = \mathcal{N}(0, R_{k-1})$, $R_{k-1} > 0$, and $T(p)$ homogeneous transformation of the feature's pose

Output: Rigid body motion (3*rd* level)

RBE for Kinematics Structure

Input: Rigid body twist ($2nd$ level)

Sensor model of $3rd$ level EKF for prismatic joints

$$z^t_{pr,joint} = \begin{bmatrix} q_p \hat{o}_p \\ 0_3 \end{bmatrix} + v^t_{k-1}, \tag{4}$$

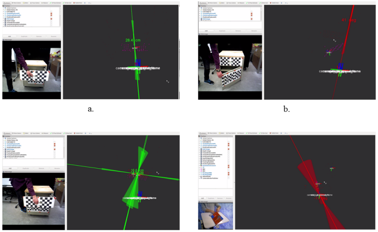
Sensor model of $3rd$ level EKF for revolute joints

$$z^t_{rev,joint} = \begin{bmatrix} (-q_r \hat{o}_r) \times p_r \\ q_r \hat{o}_r \end{bmatrix} + v^t_{k-1}, \tag{5}$$

Output: Kinematic Model ($2nd$ level)

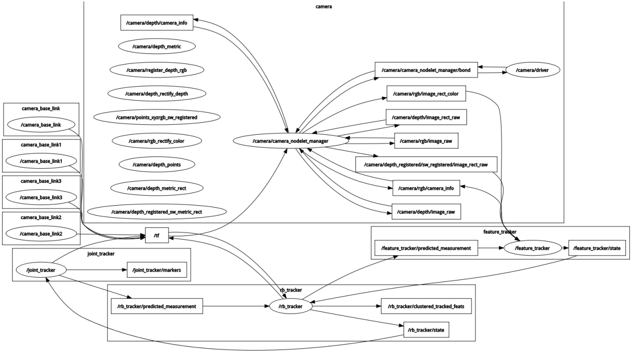
Implementation in ROS

- Simulations and experiments were conducted in ROS
- With .bag files we check the validity of the proposed methodology
- RGB-D stream utilized for experimental kinematic structure identification
- Uncertainty of the estimation is also studied



a. b. c. d.

ROS Computation Graph



- **RGB-D camera**
- **Feature tracker**
  I: RGB-D image
- **Rigid body motion**
  I: Feature's velocity
  O: Pose of features
- **Kinematics**
  I: RB motion
  O: Kinematic model

Experiments

https://youtu.be/weG94fqyQpY

Conclusions and Future Work

Conclusions

- Method is valid for online kinematic structure identification
- Includes 3 sub-level recursive estimation models
- Shape-based tracker to refine the outcomes of feature tracker
- Simulations and experiments conducted

Future Work

- Utilization of contemporary ft (KLT [Tomasi, 1991])
- UKF instead of EKF might provide better results
- Incorporate online perception technique to our robots

References

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Thank You!