Hochschule
Bonn-Rhein-Sieg
University of Applied Sciences

b-it Bonn-Aachen International Center for Information Technology

R&D project defense

Exploiting contact constraints in robotic manipulation tasks

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Wing Ki Lau

Advisors

Prof. Dr. Nico Hochgeschwender, M.Sc. Sven Schneider

Introduction

Human vs robot

(a) Picture of human writing [1]

(b) The example of robot performing writing [2]

Current work

- Articulated Body Algorithm (ABA)
  - Solve forward dynamics problem hierarchically [3]
  - Does not support partial task specifications for bias force
- Recursive Newton-Euler algorithm (RNEA)
  - Solve inverse dynamics problem recursively [4] [5]
  - Require task specification in all 6 directions when defining constraints

Current work

Popov-Vereshchagin hybrid-dynamics (PV) solver

- Exploite the defined constraints,robot model, joint angles, joint velocities, feed forward torque and external forces to compute the required joint torque and joint accelerations [6]
- Allow to use task definitions directly as input [7]:
  1. Cartesian Acceleration constraints : $\alpha_N^T \ddot{X}_N = \beta_N$
  2. The virtual and physical external force acting on each segments: F_{ext}
  3. The feed-forward force τ acts on each joint
- Not widely noticable in academia
- Lack concreate application [8]

Current work

PV solver - Cartesian Acceleration constraints

The structure of Cartesian Acceleration constraints

$$\alpha_N^T \ddot{X}_N = \beta_N$$

- Manage physical interactions with the environment
- Deal with artificial constraints

$$\alpha_N = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad \beta_n = \begin{bmatrix} 0 \end{bmatrix}$$

(a) Number of constraint = 1

$$\alpha_N = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}, \quad \beta_N = \alpha_N^T \ddot{X}_N$$

(b) A full contraint

Robot architecture

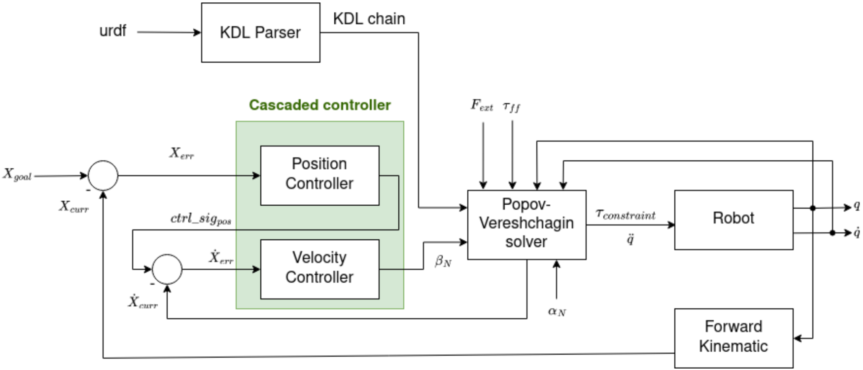


Figure 3: A generic robot system architecture

Extension of Robif2b

- A robot control interface wraps the session creation, connection establishment and communication between actuator, base and client side [9]
- Uncapable to retrieve the voltage and current status of the gripper actuator

```
struct robif2b_kinova_gen3_nbx
{
  double *act_cur_msr;  // [A]
  double *act_vol_msr;  // [V]
  double *gripper_pos_msr;
  const double *gripper_pos_cmd;
}
```

Listing 1: Code snipnet of new command

Experiement and evaluation

Three experiements was performed:

1. Grasp object by sliding motion along surface
2. Perform writing task
3. Resting elbow manipulation

Experiement and evaluation

Grasp object by sliding motion along surface

- A proof-of-concept task
- Energy efficiency and joint torque will be evaluated

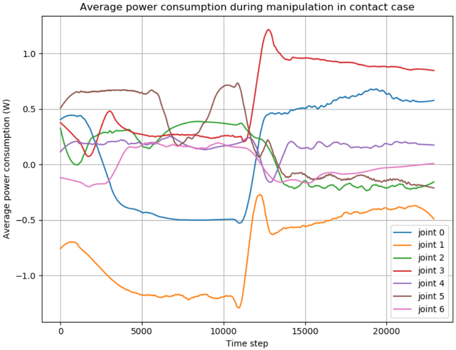
Hypothesis

The energy efficiency increases and joint torque decrease in contact case

insert demo video

Experiement and evaluation

Grasp object by sliding motion along surface



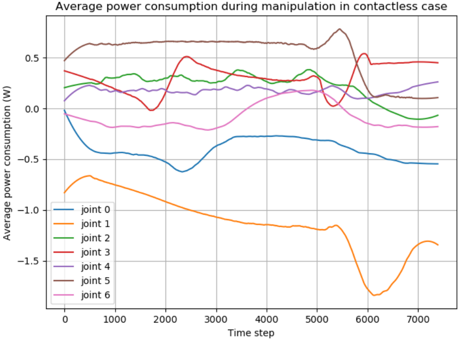


Figure 4: Average power consumption during manipulation in contact case

Figure 5: Average power consumption during manipulation in contactless case

Experiement and evaluation

Grasp object by sliding motion along surface

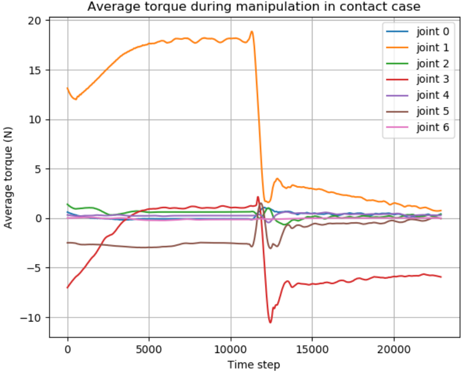


Figure 6: Average torque during manipulation in contact case

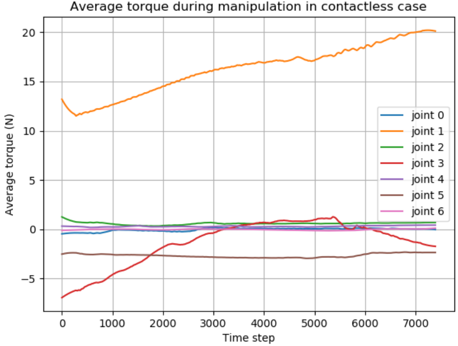


Figure 7: Average torque during manipulation in contactless case

Experiement and evaluation

Perform writing task

- Compare the trajectory
- Accuracy is the maximum displacement in linear y direction

Hypothesis

The accuracy will be increase, and the trajectory will be more stabile in contact case

insert demo video

Experiement and evaluation

Perform writing task

	maximum displacements(m)	average displacements(m)
Contact	0.00211145	-0.00120878
Contactless	0.00089509	0.00034292

Table 1: Table of the average displacement, and maximum displacement in contact and contactless case

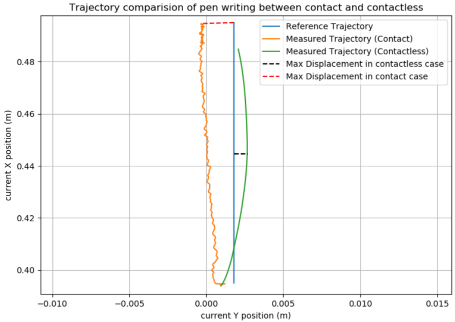


Figure 8: Average torque during manipulation in contactless case

Experiement and evaluation

Resting elbow manipulation

- A potential increase in energy efficiency by allowing certain joints of the manipulator to rest on a supporting surface

Hypothesis

The energy efficiency increases and joint torque decrease in contact case

Experiement and evaluation

Resting elbow manipulation

Figure 9: The initial position of the robot arm in use case 3 where the elbow joint is resting on a book

Figure 10: The final position of the robot arm in use case 3 where the elbow joint is resting on a book

Conclusion

- Background of related works on dynamic solver were introduced
- A cascaded controller is being implemented
- The Robif2b library is extened to retrieve voltage and current status of each joint
- Three experiements were conducted
- Average energy consumption and joint torque of most of the robot's joints decreased
- The accuracy of motion in contact scenarios was found to be lower

Future work

- Study on how different tasks and contact surface affect the energy consumption of the robot manipulator
- Fuse force/torque sensor on the robot manipulator

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