Department of Mechanical Engineering
Dynamics and Control section

Impact-Aware Learning From Teleoperation for Fast and Versatile Robotic Manipulation

Master thesis

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Abstract

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Nomenclature

Groups, algebras, and sets

$\mathbb{C}$	The set of complex numbers
$\mathbb{R}$	The set of real numbers
$\mathbb{R}^+$	The set of non-negative real numbers

Roman symbols

t	Global time
x	State variable

Greek symbols

Δt	Time interval of a time-step
δ	Dirac delta function
δ_k	Kronecker delta function

Subscripts and superscripts

$\dot{(\cdot)}$	First time derivative
$\ddot{(\cdot)}$	Second time derivative
$\hat{(\cdot)}$	Estimated or approximate variable
$\bar{(\cdot)}$	Mean or expected value

Chapter 1

Introduction

In logistics, robots are not yet able match humans in versatility and speed when it comes to object manipulation. Consider a conveyor belt with packages to be picked up: while humans inherently have the ability to handle packages of various geometries and inertias, significant engineering effort on a case-to-case basis such as modeling the package or generating a reference is required for robots to perform the varying picking tasks – occasionally to the point where the usage of robots becomes infeasible. Furthermore, while a human's bodily structure and sense of touch allow for careful yet swift grabbing of objects, robots for object manipulation are still lacking on this front. In an impact, i.e., a change in velocity due to collision between two objects, the contact force peaks. This peak is more pronounced for higher velocities. Therefore, to prevent disruption or damage to robots and packages, the control approach in a picking task often involves slowing down prior to making contact. Not slowing down would increase productivity of a robot, but requires adequate hard- and software.

Chapter 2

Background

2.1 Hardware for compliant robots

Historically, stiffness has been an important aspect for robots. Stiffness allows for an easy method to reject disturbances such as friction or hindering objects. To achieve a high stiffness with limited actuator force or torque, robots typically use drivetrains with high gear ratios. Once disturbances become large, high gear ratios become problematic. These drivetrains tend to have a low backdriveability; applying a force at the linkside of the drivetrain generally causes a lot of friction and little force transmitted to the motorside. This friction makes the drivetrain susceptible to breaking. Furthermore, tracking with high a stiffness results on large contact forces being exerted on heavy objects that block the path.

It can be concluded that stiff robots with non-backdriveable gearboxes are not suitable for high-velocity impacts with objects whose location is uncertain or unknown. Instead, the robot must be compliant have a high backdriveability. One way to improve backdrivability is to use torque sensors combined with flexible elements between the drivetrain and the linkside. Even if the drivetrain blocks when a torque applied on the linkside, the flexible element still allows for some compliance. Furthermore the torque sensors is used to in closed loop so that the motor rotates until the desired torque is achieved. This method allows robots with non-backdrivable gearboxes, such as the KUKA LBR or Franka Emika Robot, to be backdrivable. Another method

Chapter 3

Conclusion and recommendations

3.1 Conclusion

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3.2 Recommendations

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Appendix A

Appendix A Title

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Appendix B

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