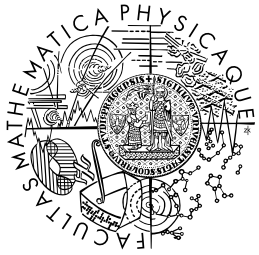

FACULTY
OF MATHEMATICS
AND PHYSICS
Charles University

MASTER THESIS

Lada Kudláčková

Manipulating Objects through Deictic Gesture Recognition

Department of Theoretical Computer Science and Mathematical Logic

Supervisor of the master thesis: RNDr. David Obdržálek, Ph.D.

Study programme: Computer Science

Prague 2024

I declare that I carried out this master thesis on my own, and only with the cited sources, literature and other professional sources. I understand that my work relates to the rights and obligations under the Act No. 121/2000 Sb., the Copyright Act, as amended, in particular the fact that the Charles University has the right to conclude a license agreement on the use of this work as a school work pursuant to Section 60 subsection 1 of the Copyright Act.

In ..... date ....

Author's signature

Dedication.

Title: Manipulating Objects through Deictic Gesture Recognition

Author: Lada Kudláčková

Department: Department of Theoretical Computer Science and Mathematical Logic

Supervisor: RNDr. David Obdržálek, Ph.D., Department of Theoretical Computer Science and Mathematical Logic

Abstract: Use the most precise, shortest sentences that state what problem the thesis addresses, how it is approached, pinpoint the exact result achieved, and describe the applications and significance of the results. Highlight anything novel that was discovered or improved by the thesis. Maximum length is 200 words, but try to fit into 120. Abstracts are often used for deciding if a reviewer will be suitable for the thesis; a well-written abstract thus increases the probability of getting a reviewer who will like the thesis.

Keywords: gesture recognition, object manipulation, autonomous control

Název práce: Manipulace s objekty pomocí rozpoznávání ukazovacích gest

Autor: Lada Kudláčková

Katedra: Katedra teoretické informatiky a matematické logiky

Vedoucí bakalářské práce: RNDr. David Obdržálek, Ph.D., Katedra teoretické informatiky a matematické logiky

Abstrakt: Abstrakt práce přeložte také do češtiny.

Klíčová slova: rozpoznání gest, manipulace s objekty, autonomní řízení

Contents

Introduction

1 Task Analysis

1.1 Theoretical Background

1.1.1 Basic Definitions

Definition of key words: gesture recognition, object manipulation, autonomous control

1.1.2 Human-Robot Interaction (HRI)

brief description of HRI;
remote vs. proximate interactions;
roles of humans and robots in interaction: Supervisor, Operator, Mechanic, Peer, Bystander, Information consumer, Mentor (taxonomy from paper: M. A. X. Goodrich and A. C. Schultz, "Human-Robot Interaction: A Survey," Foundations and Trends R© in Human- Computer Interaction, vol. 1, no. 3, pp. 203–275, 2007.);
areas of application: industrial, search and rescue, medical, social, ...

1.2 Task description

1.2.1 Pick and Place Task

Performing 'Pick and Place' using pointing gestures:

Pick:

- Determine a object that was selected with a pointing gesture
- Navigate close to the object
- Identify the object and compute its exact coordinates
- Pick the object

Place:

- Determine a target location from a pointing gesture
- Navigate close to the location
- Place the object to the location

1.2.2 Task Specification

Requirements and restrictions:
gesture recognition based on image processing (available sensors - depth cameras), proximate robot control by single user, no interaction with other robots or humans, static indoor environment (robotic lab), safe manipulation with objects, safe navigation (obstacle avoidance without unnecessary emergency braking), ...

1.3 Goals

1.3.1 Implementation of Mobile Manipulator

Design and implement a mobile manipulator that performs 'Pick and Place' tasks according to the given requirements;

1.3.2 Comparison of deictic gestures types

Metric: the distance between the correct coordinates (of the selected object or location) and the intersection of the pointing ray and the floor.

Experiment with different ways of using deictic gestures:
- a pointed ray calculated from a pair of skeleton coordinates (head - hand, elbow - wrist, shoulder - wrist)
- pointing with or without visual feedback (pointed ray shown in rViz)

2 The state of the art

2.1 History of Gesture Recognition

Summary of gesture recognition techniques; historical development of sensors;

2.2 Localization and navigation with deictic gestures

Deictic gestures for multi-robot systems

Paper:
B. Gromov, L. M. Gambardella and G. A. Di Caro, "Wearable multi-modal interface for human multi-robot interaction," 2016 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR), Lausanne, Switzerland, 2016, pp. 240-245, doi: 10.1109/SSRR.2016.7784305.

Use of the pointing gesture for localization

Paper:
B. Gromov, L. Gambardella, and A. Giusti. Robot Identification and Localization with Pointing Gestures. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2018, pp. 3921–3928 https://people.idsia.ch/ gromov/repository/gromov2018robot.pdf

3D Motion planning with pointing gestures

Paper:
B. Gromov, J. Guzzi, L. Gambardella, and A. Giusti. Intuitive 3D Control of a Quadrotor in User Proximity with Pointing Gestures. IEEE International Conference on Robotics and Automation (ICRA), 2020 https://people.idsia.ch/ gromov/repository/gromov2020intuitive.pdf

2.3 Interpretation of gestures

Papers:

Chaudhary, A (2018). Robust Hand Gesture Recognition for Robotic Hand Control. Springer. ISBN 978-981-10-4798-5 https://doi.org/10.1007/978-981-10-4798-5

Alikhani, M., Khalid, B., Shome, R., Mitash, C., Bekris, K.E., Stone, M. (2020). That and There: Judging the Intent of Pointing Actions with Robotic Arms. AAAI.https://ojs.aaai.org//index.php/AAAI/article/view/6601

2.4 Object detection with pointing gestures and speech recognition

Li-Heng Lin, Yuchen Cui, Yilun Hao, Fei Xia, Dorsa Sadigh (2023). Gesture-Informed Robot Assistance via Foundation Models. https://arxiv.org/abs/2309.02721

A. Ekrekli, A. Angleraud, G. Sharma, R. Pieters (2023). Co-speech gestures for human-robot collaboration. https://arxiv.org/abs/2311.18285

3 Design of Robotic Manipulator

3.1 Robot Model

3.1.1 Mobile robot manipulator

Overview of main components: mobile base, robotic arm with gripper.

3.1.2 Sensors

Depth camera for gesture recognition and objects detection.
LIDAR for navigation and objects detection.

3.2 Software

Robot Operating System.

3.3 Control

Pointing gesture for object selection.
Gesture for confirmation.

4 Hardware

4.1 Mobile vehicle

4.1.1 Neobotix MP-500

4.1.2 Laser Scanner SICK

4.2 Manipulator

4.2.1 Robotic arm UR5

4.2.2 Gripper

4.3 Visual system

4.3.1 ORBBEC Astra camera

4.4 Computers

5 Visual system

5.1 Gesture detection

5.2 Object detection

5.3 Stream switching

5.3.1 Problem - SDK vs. libs

5.3.2 Solution - switching by ROS msgs

6 Autonomous movement

7 Gesture based robot control

7.1 Gestures

7.2 Deictic gesture

7.2.1 Recognition

7.2.2 Object selection

8 Object manipulation

Conclusion

List of Figures

List of Tables

List of Abbreviations

A Attachments

A.1 First Attachment