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FACULTY OF ELECTRICAL ENGINEERING, AUTOMATICS, COMPUTER SCIENCE AND BIOMEDICAL ENGINEERING

DEPARTMENT OF AUTOMATICS AND BIOENGINEERING

Master of Engineering Thesis

Design and development of the system for data acquisition and analysis for the mobile platform with a set of two manipulators.

Projekt i wykonanie systemu akwizycji i analizy danych dla mobilnej platformy z zespołem dwóch manipulatorów

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Introduction

The aim of this work is to design and implement a mobile manipulation robotic platform with a basic vision system for object recognition with a three dimensional camera. This work is a part of a project named "Mobile set of manipulators on a wheeled chassis". The project was realized in a three person team, as part of the Second Edition of ABB Students Scientific Association programme organized by ABB Corporate Research Center in Cracow.

In the first chapter, a design of the robotic system is presented. General concept of mobile manipulation is described and possible application areas are mentioned. Subsequently, design requirements, selected hardware components, and implemented software architecture is described. The second chapter provides information about modern depth map acquisition techniques, including stereo, time-of-flight and structured light cameras. For each method, its operation principle basics and general advantages and disadvantages are provided. The third section is focused on modern methods of depth image analysis. Concepts of point clouds and point descriptors are introduced. Moreover, general object-recognition pipeline is provided.

The final section presents an implementation of selected object recognition method. Test results in the real environment are provided. Possible future improvements to the algorithm are also mentioned.

1. Mobile manipulation system design

1.1. Project background

A mobile manipulation system (MMS) is a robotic system that is capable of both manipulating objects and locomotion. Typically, the system is composed of a robotic arm based on a robotic mobile platform. Such configuration enables the manipulator to operate in an unlimited workspace, thus providing great application opportunities.

Typically, mobile manipulators are designed to relieve people in hostile situations. They are, for example, widely used in the field of chemical, biological, radioactive or nuclear (CBRN) defense. Explosive materials and other hazardous substances can be disposed without exposing operators to any danger. Another example is space exploration, where manipulation systems are used in planetary rovers in unmanned exploratory missions on other planets. Substitution of human operators in such expeditions significantly reduce their expenditure and risk.

Augmenting the MMS design with a certain degree of autonomy, brings the possibility for the robot to be used as a human-assistant in the household. Most of current applications in this field refer to pick up and delivery services, that have the potential to improve lives of the elderly, injured and disabled people []. Furthermore, typical service robots in human environments are dedicated to accomplish only a single task, such as vacuum cleaning, lawn mowing, pool cleaning, window washing. Their operation is achieved by adjusting existing domestic appliances with a degree of autonomy. With a multi purpose robotic system such as a mobile manipulator, it is potentially possible not to replace existing devices but to replace the human operator. Autonomous gripping and transportation could also be used in the industry for designing flexible factory plants and intelligent warehouses, as discussed in [].

One of the most promising applications is the PR2 robot from the Willow Garage company. The PR2 robot has already proven successful in such dexterous experiments as opening doors, folding towels and serving beverages to people.

In MMS robots, the unstructured environment and additional degrees of freedom complicate the control task. Furthermore, the workspace of a manipulator is often shared with people and other vehicles. Such work environment renders many potentially hazardous situations. Therefore, it requires a highly sophisticated control system, with vision based feedback.

1.2. Design requirements

Design requirements:

1. The robotic system should consist of two cooperating serial manipulators, based on a wheeled robotic platform.
2. The whole construction should be made of easily accessible components, preferably available on the consumer market, as it would ease the maintenance of the equipment in the future.
3. Both serial manipulators should be equiped with grippers for general object manipulation.
4. Their reachable workspace should allow to reach objects located on the ground.
5. The workspace of each manipulator should also intersect, to allow collaboration on manipulation tasks.
6. The steering mechanisms of the MMS chassis should be kept simple and convenient to control.
7. The platform is expected to move only on flat surfaces at indoor areas.
8. The MMS robot should possess a control server, that is expected to provide a web interface, developed in a commonly used and well supported standard.
9. That interface is required to provide methods for setting positions on manipulator joints, for setting speed of achieving those positions, and for setting velocity and direction of platform movement.
10. Processing power of the computing unit should be sufficient to analyse camera images in an online fashion.
11. The whole system should be powered by a source that could withstand at least an hour of continuous work.

1.3. Hardware components

Mechanical structure:

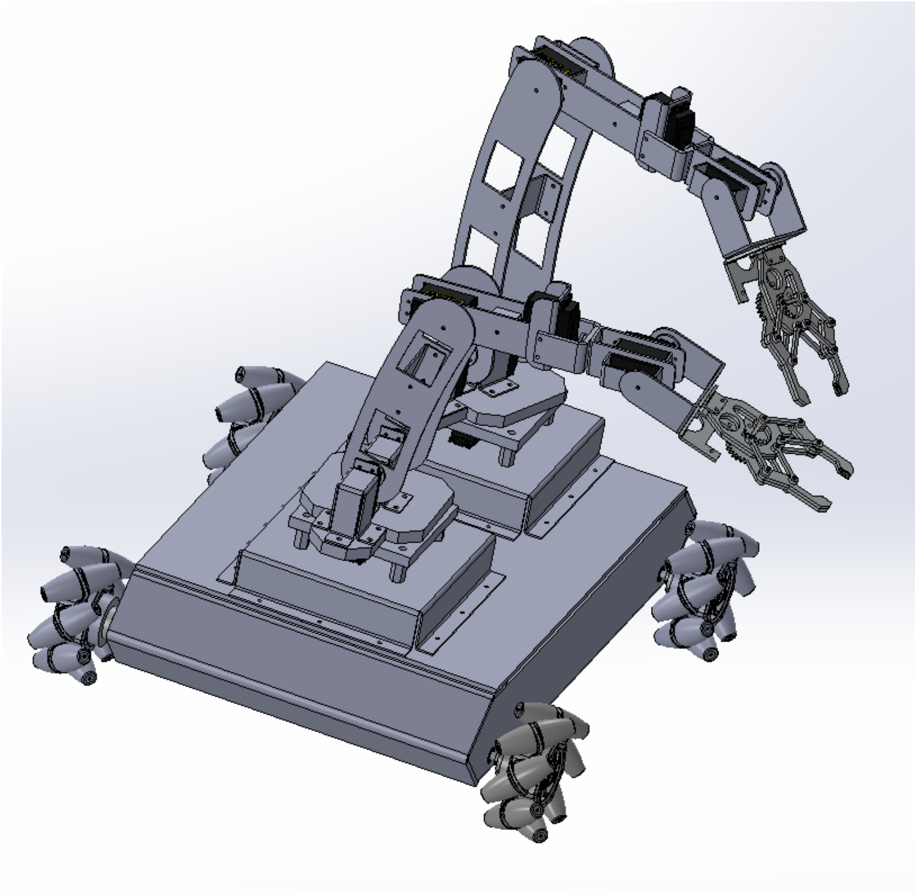

Figure 1.1: Model

The MPTM robot consists of two robotic arms based on a simple four-wheeled mobile platform. Both of robotic arms have 5 degrees of freedom and are in articulated structural configuration. To avoid complicating the mechanical design of the chassis with a steering mechanism, a special kind of wheels were used. Mecanum wheels, as they are called, are equipped with a set of rollers attached to their circumference, which allow a vehicle to move in any direction without turning the wheels.

By alternating wheels with left and right-handed rollers, in such a way that each wheel applies force roughly at right angles to the wheelbase diagonal the wheel is on, the vehicle is stable and can be made to move in any direction and turn by varying the speed and direction of rotation of each wheel. Moving all four wheels in the same direction causes forward or backward movement, running the wheels on one side in the opposite direction to those on the other side causes rotation of the vehicle, and running the wheels on one diagonal in the opposite direction to those on the other diagonal causes sideways movement. Combinations of these wheel motions allow for vehicle motion in any direction with any vehicle rotation.

Another advantage of such design is increased stability of the platform.

Basic components:

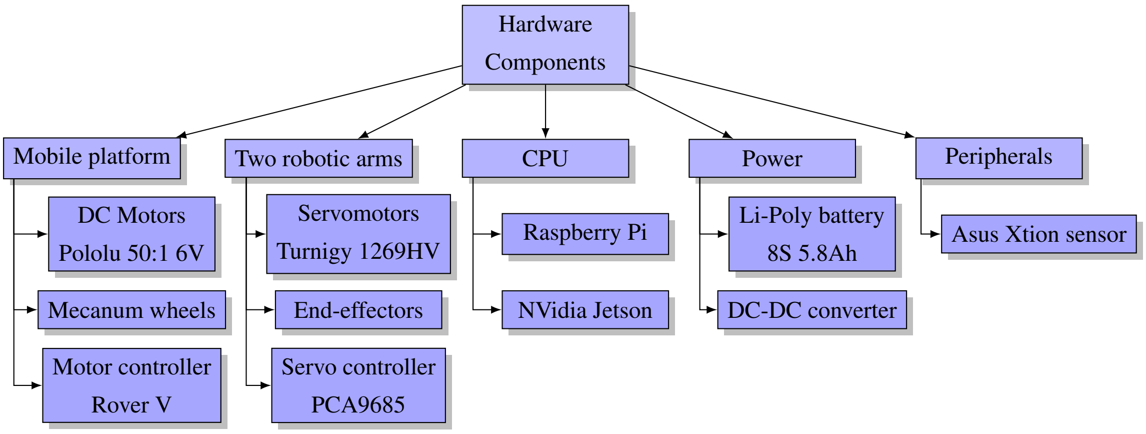

Figure 1.2: Components

The MPTM robot utilises two types of actuators, 4 DC motors for the mobile platform wheels and 12 servomechanisms for manipulator joints. All DC motors have 50:1 metal gearboxes. They achieve 200 RPM of no-load speed and 12 kg cm of stall current. Additionally, they possess 64 CPR encoders, which multiplied by the gear ratio provide 3200 counts per revolution.

Servomechanisms used are Turnigy 1269HV, with operating speed of

Actuators are driven by PWM signal generated by MSP430G2553 microcontrollers, one for each of manipulators and one for the mobile platform.

End effect:

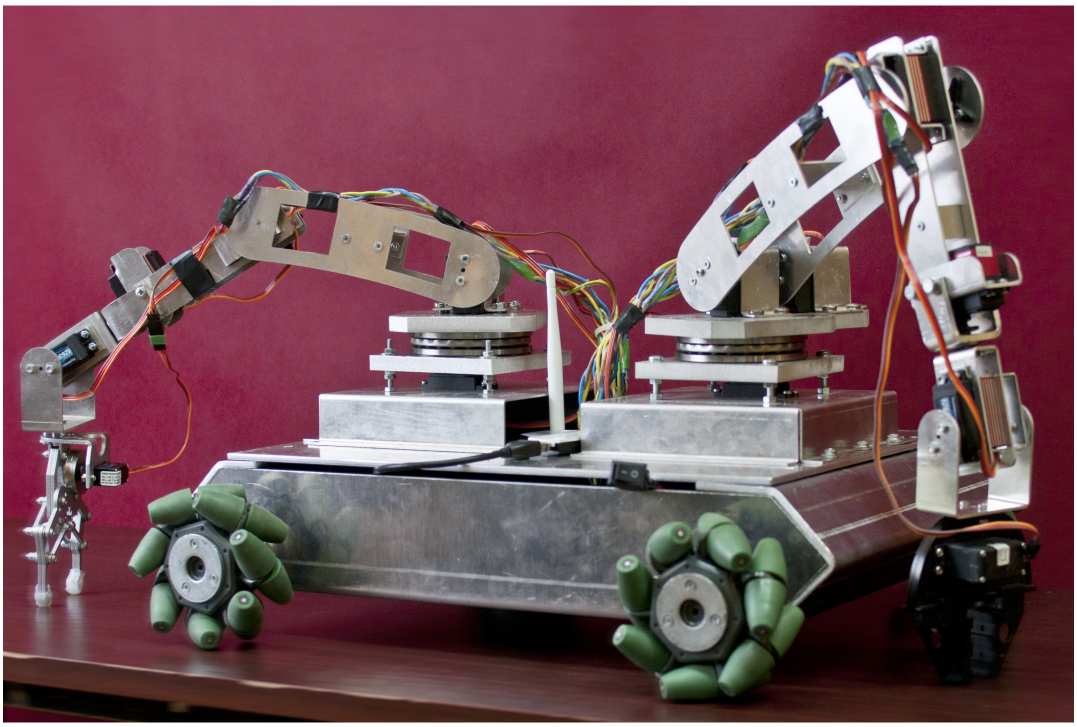

Figure 1.3: Construction

1.4. Software architecture

2. Depth data acquisition techniques

Why use 3D data? Applications in robotics! In computer vision, a depth map is a type of image, where each pixel value represents distance to the corresponding point in the scene. Just as in the grey scale image, it typically takes the form of a two dimensional array and it is the simplest way of representing and storing depth measurements from a scene.

The first depth-map acquisition techniques emerged as a replacement for a contact-based coordinate measuring machines (CMM). CMMs were used in the industrial quality control applications and worked by recording the displacement of a probe tip sliding across a solid surface. Such method was time consuming and inadequate for fragile objects. Modern, contact-less 3D scanning apparatus overcome those limitations by using light to interact with the environment. The new technology had also extended the application area of 3D scanning to the field of robotic perception.

Methods of 3D data aqcuisition are classified by the light source they utilize to measure depth. Passive techniques rely only on the ambient light, whereas active ones operate by projecting illumination onto an object and recording the reflected beam. In the following sections, examples of both categories are presented, with a brief description of their principles of operation and a discussion of advantages and disadvantages.

2.1. Stereo vision

Passive method. Based on human vision - biological process of Stereopsis. Depth info acquired using two or more images concurrently captured from displaced cameras. Processing steps: image acquisition, camera modeling, feature extractions, correspondence analysis and triangulation. Simple, low-cost hardware, but processing computationally expensive. Features? Correspondences? Triangulation with picture.

2.2. Laser LIDAR

2.3. Time-of-flight

2.4. Structured light

3. Analysis of depth data

A point cloud is a set of data points in some coordinate system. In a three-dimensional coordinate system, these points are usually defined by X, Y, and Z coordinates, and often are intended to represent the external surface of an object.

Point clouds may be created by 3D scanners. These devices measure a large number of points on an object's surface, and often output a point cloud as a data file. The point cloud represents the set of points that the device has measured.

3.1. Point cloud processing

3.2. Descriptors for object recognition

3.3. Object recognition pipeline

4. Implementation and testing

4.1. Algorithm implementation

4.2. Testing in the real environment

Summary

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