Contents

LIST OF USED ABBREVIATIONS

I2C – Inter-Integrated Circuit

PWM – Pulse-Width Modulation

INTRODUCTION

The modern drive towards the development of automation in manufacturing processes and the growth of automated factories has led to an increasing set of requirements for sorting systems and robotic process systems.

In addition, the desire to miniaturise the parts and components of each system is forcing the development of new methods to improve the efficiency of the process , taking into account the size of the parts. To solve the problem, it is necessary to choose the smallest solutions,Solutions must be simple, cheap and efficient components of the complex.

The problem of moving small parts is very important. In many areas, process improvements contribute to the reduction of system parts and components. Therefore, it is necessary to manipulate small parts in the manufacturing process, to place them in the right places at the right angle. Unfortunately, a large number of small parts in production and assembly lines are handled manually these days.

For tasks that require automated movements, robots are great, but robot arms are more logical. Smaller robotic arms that can be placed on a table can be used, but they require a large amount of space. This increases the space required for the task, so it is not quite reasonable to use these robots. It is also worth considering the table robots were developed to work with large objects, for accurate movement and location of small objects is not always possible due to the existence of backlash and the complexity of turning the long axis at a small angle. To increase the efficiency and reduce the size of the manipulator robot, it is necessary to develop a minirobot that will meet the above parameters. The development of any robot arm is a complex task that involves the interaction of complex systems. It is necessary to take into account the subtleties of design, hardware and software.Due to the complexity of the overall development of the theme of the bachelor’s thesis will be concerned only with the control system of the mini robot manipulator itself.

The aim of the bachelor’s thesis is a control system for a mini robot manipulator.

In order to achieve the set goal of the bachelor’s thesis, it is necessary to:

- Determination of technical parameters, functions and modes of operation of an industrial minirobot
- Development of mechanical designs of industrial minirobot
- Determination of technical parameters, functions and modes of operation of the minirobot control system

- Development of the structural scheme of the minirobot control system
- Development of functional and circuit diagrams of the minirobot control system
- Development of algorithms and control programmes for the minirobot control system
- Testing of the minirobot control system

1 ACTUALITY OF DEVELOPING A CONTROL SYSTEM FOR A MINI-ROBOT

1.1. Purpose and classification of robot arms

Industrial robots, and in particular manipulating robots, have a wide range of applications in a variety of sectors and offer many advantages, including increased productivity, accuracy and safety. Certain types of robots may be better suited to a particular application than others.

- Welding
- Material Handling
- Assembly
- Painting and Coating
- Packaging
- Inspection and Quality Control
- Machine Tending

Figure 1.1. Indusrial robot arm

One of the main characteristics of any robot arm is the number of degrees of freedom(DoF), which is characterised by the set of motion axis parameters that the robot has. It describes the freedom of movement of the robot arm or manipulator in its workspace. The degrees of freedom of a robot arm are determined by the number of joints it has, each of which provides a specific axis of motion.

The degrees of freedom of the robot arm can be classified in one of two possible ways:

- Linear Motion (Translational DoF)
- Rotational Motion (Rotational DoF)

Manipulator robots can be classified on the basis of their structure and movement capabilities. Each type is suitable for each application, rotating joints and often the preferred choice for tasks that involve reaching, grasping and positioning objects, as they allow for more flexible movement in a variety of directions. In scenarios where precise linear motion is required, such as assembly lines where components need to be moved in a straight line, prismatic couplings can be used. But it is not uncommon to use two types of motion in a robot design and they have become widespread.

There is no strict dependency on which type of robot arm should be used in a particular case. The choice of robot arm will still get the job done, but the right robot is necessary to maximise productivity and cost savings.

1.2. Disadvantages of existing robotic arms

The understanding of robots is something universal that can be applied to different tasks, in fact it is so that there are not so many special different variants in architecture among robot arms, the main differences lie in the different technical characteristics and technical implementation of these robots. It is possible to be overwhelmed by the sheer number of different robot models when studying them. In order to get acquainted with robotic manipulators, two models have been chosen that can be analysed in detail and from which a conclusion can be drawn.

MyCobot

Among the models that are not very expensive, **myCobot** works occupies an honourable place, this robot spreads in the low price segment, in this and stood interest what possibilities developers offer to the user of this device. , some of them can be considered really small in size and suitable for the requirements. Certain disadvantages exist that are often found in existing models of robot manipulators.

Figure 1.2. MyCobot 280

One of the popular models that is available on the market and can be available is the **myCobot** model robot, shown in the picture 1.2, as well as technical specifications of the robots represents in the table 1.1.

Table 1.1

Specifications MyCobot Robot Arm

Parameter ame	***Value***	***Units***
DOF	6	-
Payload	0.25	kg
Weight	0.8	kg
PRepeatability	± 0.5	mm
Power Voltage	DC 12	V
Power Current	5	A
Gear type	-	Steel
Shell	-	Metal
Max. reach	280	mm
Cost	800	Euro

In most cases, one of the main factors in this type of robot is the use of more low-cost actuators that drive the robot's axis. This may be the use of more low-cost gearboxes and motors that greatly reduce the cost of the entire robot, but the lifetime of these systems is relatively short.

In the process of testing the basic specifications that was explained that with not all the parameters that are presented in the table **??** data are not all reliable, the accuracy of movement is highly dependent on the load at the end of the 6 axis of the robot. Thus, the repeatability of the robot movement was not within ±**0.5 mm**, but could reach deviation around **5 mm**. As shown in figure 1.3

Figure 1.3. Robot repeatability measurement example

In fact, the servomotors used in hobbyist versions of robotic manipulators, such as the one shown in figure 1.4, are significantly less accurate and reliable than those used in their industrial counterparts. One of the main reasons for this is that these types of servos are typically designed with cost-effectiveness and basic functionality in mind, rather than high accuracy or durability. This can lead to inconsistent performance, frequent failures and a shorter overall life.

Figure 1.4. Hobbyist Servo Motor

In addition, the lightweight construction of these servomotors can make them more susceptible to physical impact and other environmental factors. This lack of robustness often results in frequent maintenance, which can lead to increased downtime and reduced productivity.

Hobbyist servomotors often have less sophisticated control systems, which may not provide the advanced features required for precise control in complex applications. Based on all of the above factors, we can conclude that this type of robot is not suitable for the task due to the lack of rigidity and accuracy of the design itself, as well as deficiencies in the actuators of each axis.

Kawasaki

On the other side of the available robot arms are serious systems from reputable manufacturers, an example of such robots available for review is from the Japanese corporation Kawasaki - Robot Arm FS03N, the appearance can be seen in the picture , , according to the data sheet look at the table 1.2 you can see the main characteristics of the robot, this robot has better accuracy of movement, repeatability and weight of the travelling load, the main disadvantage of this robot is the redundancy of all the characteristics for tasks related to the movement of small objects. This choice of robot reduces the efficiency of technological production.

Figure 1.5. Kawasaki FS03N

Table 1.2

Specifications Kawasaki Robot Arm FS03N

Parameter ame	***Value***	***Units***
DOF	6	-
Payload	3	kg
Weight	20	kg
Repeatability	± 0.02	mm
Power Voltage	AC 230	V
Max Power Current	9	A
Gear type	-	Steel
Shell	-	Aluminium
Max. reach	620	mm
Cost	12 000	Euro

1.3. Rationale for creating a miniature robotic manipulator

Nowadays the use of mini robot manipulators in modern production is rare and most of any small works are created manually or it is necessary to create machines for a specific task, which takes more time to develop on a more universal basis. And the use of human resources is a human factor and quality is reduced in pursuit of quantity.

The problem can be solved by creating a new robot manipulator that will be suitable for interaction with small objects, as well as more cost-effective in the process of exploitation.

1.4. Concept of systems development

This bachelor thesis will deal with the creation of a control system for a mini robot. The control system will include algorithms and control board, motor control board for the robot's axes. The principle is to create a modular design of the control system, which allows to increase or remove the motor boards, without any special modification of the robot itself.

2 TECHNICAL PARAMETERS OF MINIROBOT

2.1. Brief information about the robot arm

This chapter will provide a short description of the development of the minirobot control system.

The comparative characteristics of existing robot types are shown in the table 2.1.

Table 2.1

Various types of robots and their characteristics

	Speed	Accuracy	DoF
Robot Arm	Low	Middle	**High (6)**
Scara	Middle	**High**	Middle (4)
Delta	**High**	Low	Middle (4)

For the implementation of the robot control system was chosen ”Robot Arm” type because of the high degree of mobility of this type of robot, which contribute to a more convenient movement of objects in space.

2.2. Kinematic structure of the robot arm

The design of a robot manipulator can usually be divided into many parts. It is divided into several structural elements that perform different functions and movements: the base, the body, the mechanical arm, the gripper. The latter, depending on the production requirements, is performed by: a gripper, when something needs to be moved, held or assembled; a welder - directly for welding products; a suction tool - to hold or move an object. From the base to the gripper, the robot is made up of links forming a kinematic chain. Two adjacent links form a kinematic pair. The distance from one link to another is called the link length. The distance from one degree of freedom to another is called the link distance.

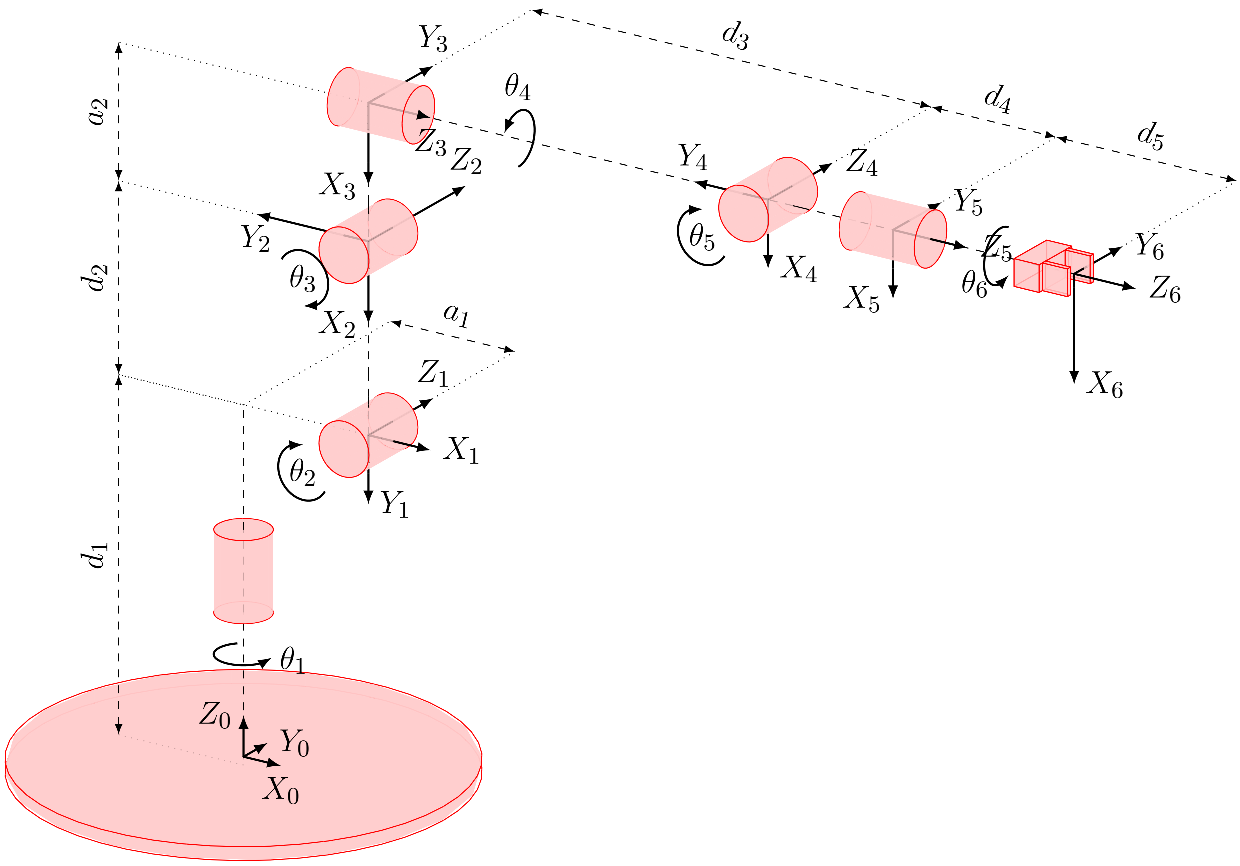

Figure 2.1. Kinematic structure of robot manipulator

Kinematic diagram of the manipulator robot presented in figure 2.1

d_1, d_2, d_3, d_4, d_5 - Link distances

$\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6$ - Link angles

a_1, a_2 - Link lengths

X_0, Y_0, Z_0 - Base coordinates

X_6, Y_6, Z_6 - Tool coordinates

Table 2.2

Denavit Hartenberg table of kinematic parameters of the robot

Joints	θ_i	d_i	a_i	a_i
1	θ_1	d_1	a_1	-90
2	$\theta_2 + 90$	0	$-d_2$	0
3	θ_3	0	$-a_2$	90
4	θ_4	d_3	0	-90
5	θ_5	d_4	0	90
6	θ_6	d_5	0	0

On the basis of the design proposal, Table 1 shows the DH pa parameters of the robot arm. (Siciliano et al. 2010) Using the parameters from Table 1, the following forward kinematic kinematic equation for the determination of the transformation matrix of the robot arm can be of the connecting rod:

$$
{}^{0}A_1 = \begin{bmatrix} \cos(\theta_1) & 0 & -\sin(\theta_1) & a_1\cos(\theta) \\ \sin(\theta_1) & 0 & \cos(\theta_1) & a_1\sin(\theta) \\ 0 & -1 & 0 & d1 \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

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2.3. Industrial minirobot arm modes

3 MECHANICAL DESIGNS OF MINIROBOT ARM

4 FUNCTIONS AND MODES OF OPERATION OF THE MINIROBOT CONTROL SYSTEM

5 DEVELOPMENT OF THE STRUCTURAL SCHEME OF THE MINIROBOT CONTROL SYSTEM

6 DEVELOPMENT OF FUNCTIONAL AND CIRCUIT DIAGRAMS OF THE MINIROBOT CONTROL SYSTEM

7 DEVELOPMENT OF ALGORITHMS AND CONTROL PROGRAMMES FOR THE MINIROBOT CONTROL SYSTEM

8 TESTING OF THE MINIROBOT CONTROL SYSTEM

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