Intellectual Output_O2:
EMERALD e-toolkit manual for digital learning in producing biomimetic mechatronic systems

Toolkit 6
3D Printable Robotic Arm

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EUROPEAN NETWORK FOR 3D PRINTING OF BIOMIMETIC MECHATRONIC SYSTEMS

E-toolkit for teaching purposes, basic knowledge about realizing biomimetic mechatronic systems

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1. INTRODUCTION

This toolkit presents construction, programming, assembly and tests of a 3D printable robotic arm that can be used as a haptic device.

The robotic arm was constructed as a project realized by University of Agder lecturers and students, as an educational example on how to construct and program simple robotic grippers.

It has been used during the EMERALD project summer school in year 2022, by students of all universities involved in the project consortium.

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2. 3D PRINTED PROGRAMMABLE ROBOTIC GRIPPERS

2.1. Introduction to 3D printed robotics

Robotic arms have been an integral part of industrial automation, healthcare, and various other domains. The convergence of 3D printing technology with robotics has given rise to programmable robotic arms that offer enhanced versatility, cost-efficiency, and customization.

Various parts of robotic arms can be 3D printed, including joints, grippers, and even end-effectors. The ability to customize these parts to suit specific tasks is a notable advantage of 3D printing in robotics.

Figure 1. Robotic arm parts 3D printed using low-cost FDM technology

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2.2. Programming Robotic Arms using Arduino Platform

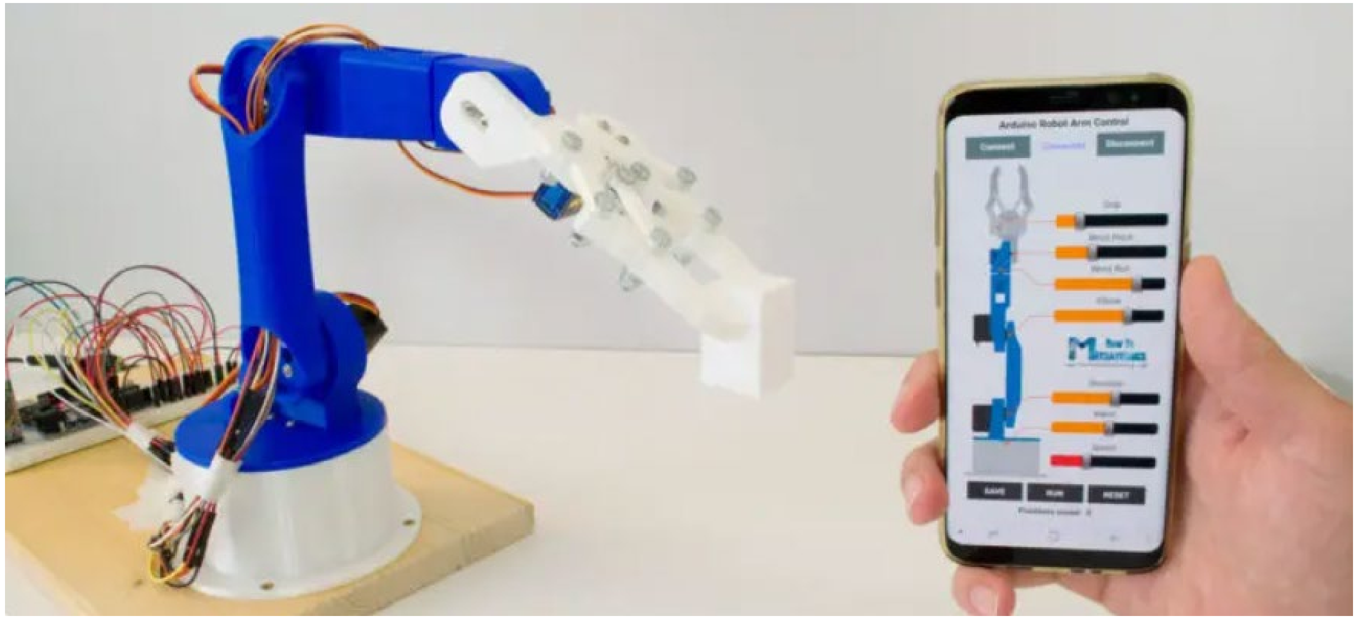

Figure 2. Use of Arduino in a “do-it-yourself” project for 3D printable robotic arm

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2.3. Design and 3D printing of robotic arms

Current technology allows to use various 3D printing technologies in construction of low-cost robotic arms.
Many designs can be used as DIY projects, to create home-made or school-made robotics.
Students and researchers interested in this topic may easily find many suitable projects, along with customization possibilities.
Fused Filament Fabrication (FFF) is a versatile additive manufacturing method used to create 3D-printed robotic arm components, including grippers and whole arms.

2.4. Use of robotic arms as haptic devices

Haptic devices, which provide users with tactile feedback in virtual environments, have gained significant attention in various fields, including virtual reality, telemedicine, and robotics.
Robotic arms, with their ability to simulate touch and force interactions, have emerged as valuable tools for creating immersive haptic experiences.

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3. BIOMIMETIC 3D PRINTABLE ROBOTIC GRIPPER

Figure 3. The robotic gripper 3D design

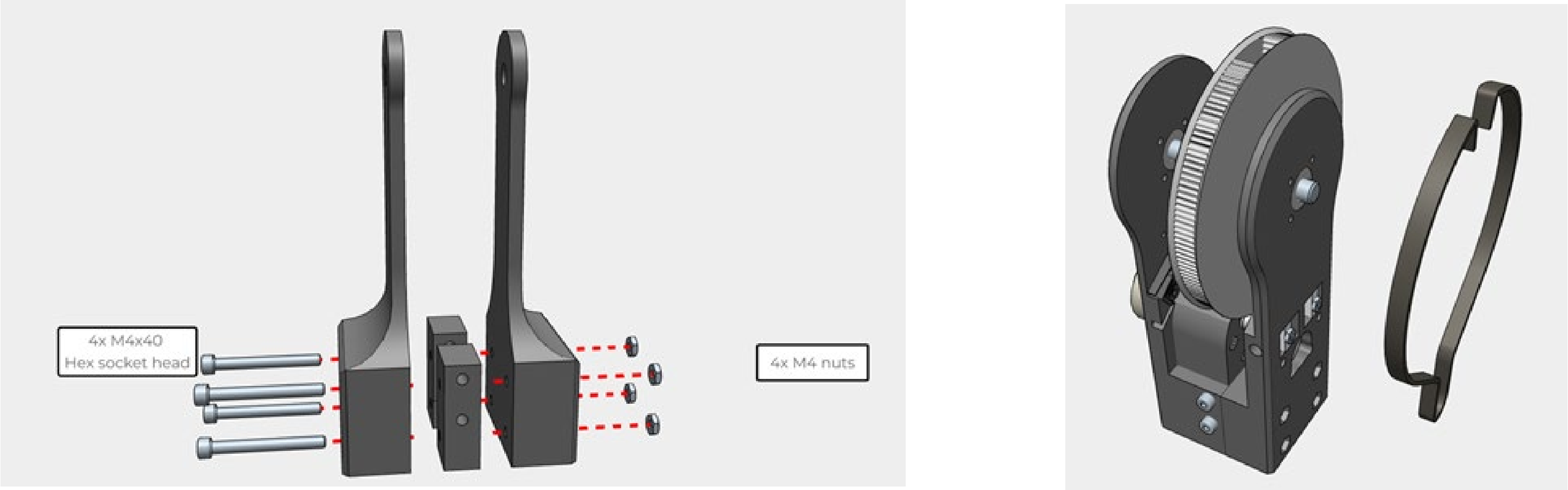

Figure 4. Disassembly instruction of the robotic arm

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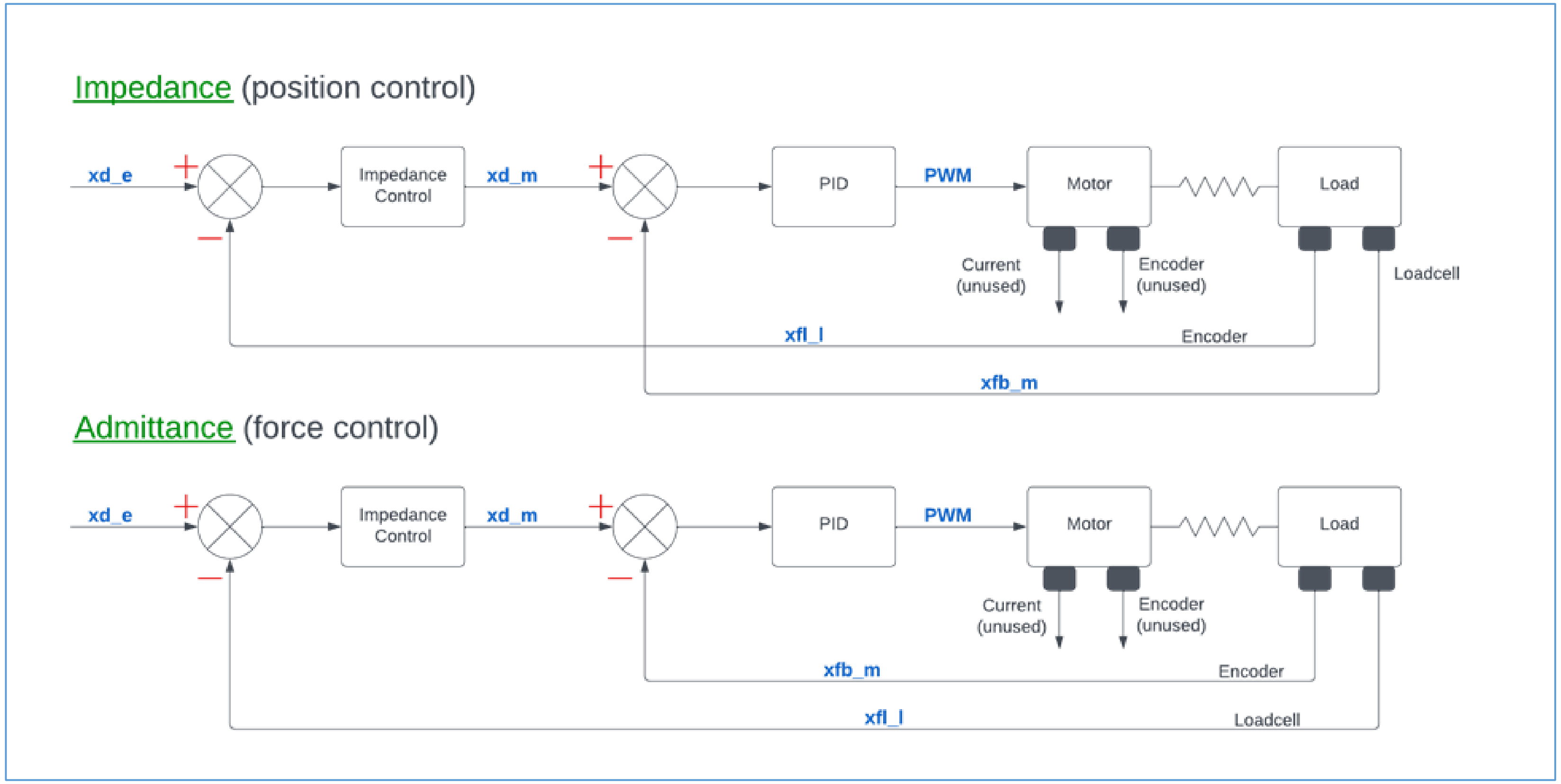
CONTROL STRUCTURE OF THE HAPTIC ARM



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THE SOFTWARE was built to be as modular as possible, aiming to ensure the easy operation of the robotic arm for users with varying programming backgrounds.

The software comprises five classes.
The AS5600 library, provided by Seed-Studio, facilitates the easy retrieval of data from the absolute magnetic encoder. Additionally, three low-level classes—PID, pwmMotor, and HapticSensor—are dedicated to data retrieval and the hard-coded control of the haptic arm.
The final library, HapticArm, offers a variety of control methods based on control theory, utilizing the aforementioned classes for arm control.

The AS5600 library is created and distributed by Seed-Studio, which is the producer of the encoder used in this project.

The PID class are made for easy implementation of PID loops.

The PID constructor is used to initialize the PID object. The constructor take Kp, Ki and Kd as input and a single PID object are intended to be used for a single PID loop.

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CALCULATE (FLOAT VALUE, FLOAT TARGET)

The PID equation used are the standard European method

$$u_d(k) = K_p e(k) + K_i(u_{i-1} + e(k) \cdot dt) + K_d \frac{e(k) - u_{d-1}}{dt} \quad (1.1)$$

BACKCALC (FLOAT VALUE, FLOAT TARGET, FLOAT BACKVAL, FLOAT SATUTAIONMIN, FLOAT SATURATIONMAX)

$$u_d(k) = K_p e(k) + K_i(u_{i-1} + (e(k) + \frac{e_p(k) - u_{d-1}}{T}) \cdot dt) + K_d \frac{e(k) - u_{d-1}}{dt} \quad (1.2)$$

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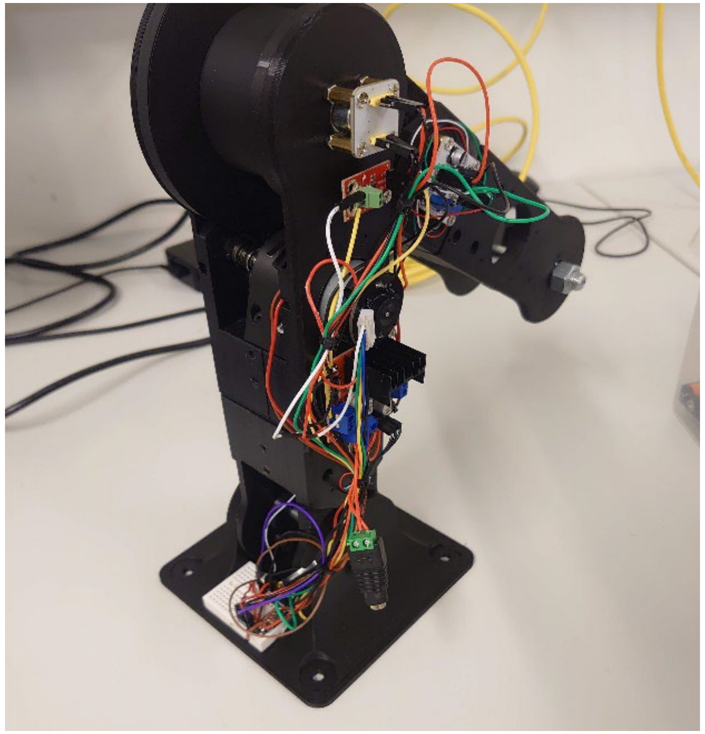
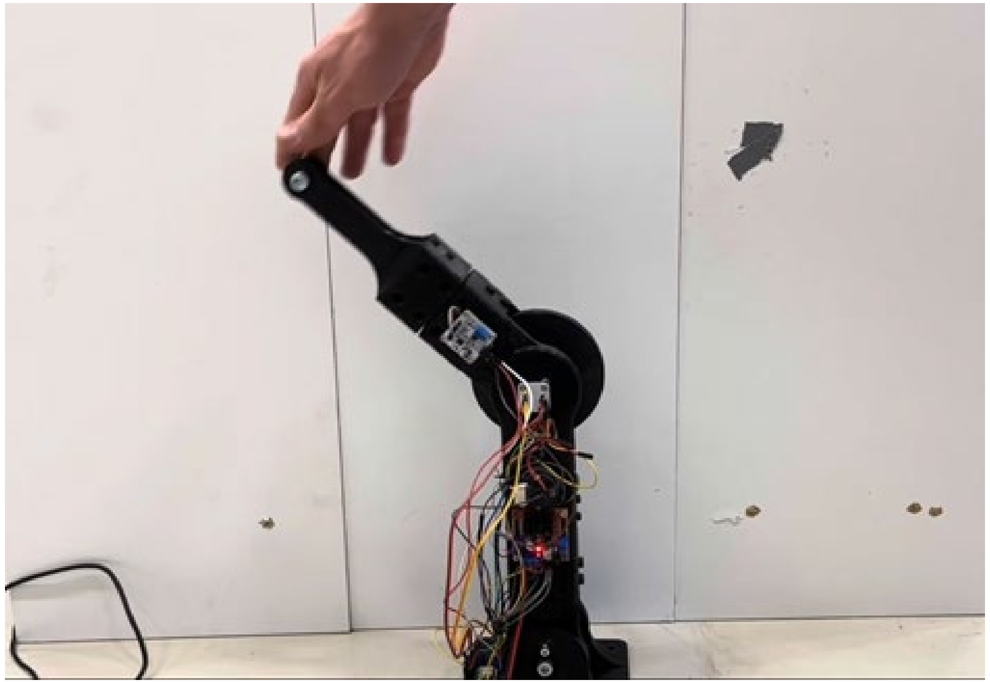
3. MANUFACTURING AND TESTING



Assembled robotic arm made of 3D printed components



Haptic arm tests

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4. SUMMARY

In this toolkit, a concept of a simple robotic arm usable as a haptic device was presented.

The device was designed, 3D printed, programmed and tested using widely available technologies and low-cost components.

The whole project was made freely available as an educational asset for the interested students and researchers worldwide through the GitHub platform.

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