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# Restoration and PLC control of a robot cell compatible MP-11 industrial manipulator platform

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**Abstract.** The designing and usage of newer and newer tools and devices is an unavoidable part of industrial development. The robots employed this way either replace human work, or replace previous, obsolete robots. This advancement might cause otherwise functional robots to be discarded, or otherwise lost. Such robots might still be in usable condition after a suitable refurbishing, and their limitations can be alleviated by integrating these devices into a robot cell. In my project, I have set the goal to restore such a machine, which goal includes the full mechanical and electrical overview of the device and replacing its missing controller. The robot itself and other various resources necessary were provided by University of Debrecen, Faculty of Engineering, department of mechatronics.

## 1. Introduction

The robotics lab can be found University of Debrecen, Faculty of Engineering, department of mechatronics, where the subject of robot technology is taught to the students of the faculty. In this laboratory, numerous industrial devices can be found [1]. The goal of the laboratory is to have a collection of devices assembled and programmed in a way, that the students can find their way in any industrial environment where assembly lines are present. The MP-11 industrial manipulator can also be found in this room. I have chosen its restoration as my topic. During this work, the goal was the restoration and improvement of the manipulator, including its integration to the robot cell.

## 2. The robot's structure

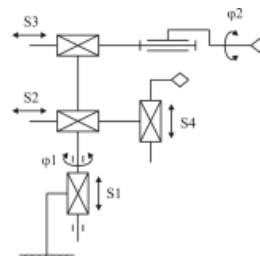
The MP-11 manipulator, based on its first 3 axes of movement, can be categorised as an RTT work area manipulator, in other words, its work area is cylindrical. The work area itself is the curve of the cylinder, changing the curve's properties requires mechanical change. The pneumatic actuators' function is made possible by monostable, spring return, 3/2 electropneumatic valves. The manipulator is also equipped with hydraulic end-stop dampeners. The manipulator consists of three main parts: the first, is the body. This is where the valves are, and on the back panel of this part can the electrical and pneumatic connectors be found. The second, is the tower. This part is responsible for the translational, and rotational movements, meaning, that this part is able to rotate around, or move along its axes. This is where the movement limits can be set, by moving the end-stop bumpers, and the limit switches. The third part of the manipulator is where the two arms can be found. These are secured on top of the tower, and execute horizontal, translational movement. The limit switches are activated by magnetised bumpers found on the arms. After loosening the tightener screws, they are freely movable along the pistons' axes,



to the desired position. This first bump against the dampeners, and only later against the limit switches, so the dampeners' proper condition is crucial. On the second figure, the manipulator's kinematic structure can be observed. This specifies the amount of degrees of freedom. The first is a rotational direction of movement, around the "Z" axis. This is achieved by the tower's rotation. The second one is the translational (vertical) movement of the arms, along "Z" axis. The third movement is given by the movement of the arms themselves. The direction of these varies, as the angle between the two arms is adjustable. Another fact to note about the working of these axes, is that they always move in the same direction, as both cylinders and controller by the same valve. Both arms can be equipped with one gripper each, which have different properties. The first one is able to rotate in 180 degrees, along one axis, which axis is parallel with the axis of the arm's translational movement. This can be useful for rotating the workpiece by a desired amount, as the bumpers can be adjusted to adjust the rotation's amount.



**Figure 1.** MP-11 manipulator



**Figure 2.** kinematic diagram [2]

The other gripper is able to do translational movement, perpendicular to its arm's axis. This can be used to lift out, or precisely move the workpiece. The magnitude of the movement can be similarly adjusted by moving bumpers. These grippers require jaws to grip the desired object. In this case, they are made from sheet metal. The heads are adjustable, depending on if we desire normally open, or normally closed functions. On the inside, a small piston can be found, which is returned to its starting position by a spring. As the head is entirely symmetrical, by rotating the piston and moving the spring to the other side, the gripper's resting state can be altered. These can be useful for lowering the load on the compressor, if multiple valves are operated at the same time.



**Figure 3.** Normally closed gripper



**Figure 4.** Normally open gripper

Every actuator's end position, except the grippers, is sensed by reed-sensors. These sensors are placed in small, wooden sockets. In one half, the reed-relay can be found, while in the other, a spring-loaded bumper. When the bumper moves, the magnet of it approaches the reed sensor, closing the electromagnetic contacts, sensing the actuator's state. The advantage of the reed switch is its long lifetime, its insensibility to dirt and grime. Their maintenance is simpler than mechanical switches: in event of malfunction, the fix is to simply switch out the broken relay for a functional one.

### 3. Inspection and restoration

#### 3.1. Maintenance

The first task was to inspect the manipulator's movements. After carefully moving the axes, it was found that not every actuator can reach its limits, as some cylinders were partially stuck. By thorough cleaning and lubrication this problem could be solved and has not returned later. The next task was to map the electronical connections. After removing the back panel, the 12 valves became visible, which control

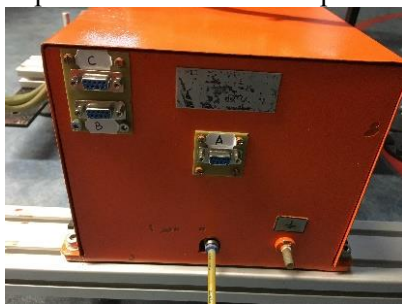
the actuators. On them, it can be seen that they operate at a voltage level of 24 volts, however, no additional information was available concerning their power consumption. By using a bench power supply, by carefully and gradually increasing the current limit, I have found that the valves reliably open at 0,5 A. This was followed by the check-up of the limit switches, with the help of a digital multimeter's continuity mode. This process was greatly sped up by the fact, that near the connector, the same number is shown as near the limit switches. By the end of this test, every sensor seemed functional, except one, where the internal soldering was faulty. This was later fixed.



**Figure 5.** Valve

### 3.2. Improvements

The first upgrade was to improve the mobility of the manipulator. For this, four wheels (equipped with brakes) were placed at the bottom of the manipulator. As these wheels were not enough to provide necessary stability during operation, additional stands were added to the structure. The old connectors, which were used to connect the old controller, were damaged. As a replacement, three 9-pin D-SUB connectors were used. These connectors were fastened to plastic PCB panel material. These were then later cut to size and prepared in a way to allow the connector to fit through and be fastened by screws. The chosen PLC's output voltage is 24 V, however, it cannot operate two valves at the same time, as its total power is not high enough to do so. To overcome this problem, a device to switch logic power to a much higher power was created. In it, 12 TIP120G transistors were built in, using them as a switch. The PLC opens and closes these transistors, which are supplied by a power supply which is able to satisfy the power demands of multiple valves at the same time.



**Figure 6.** New connectors

In this device, galvanic separation was also added. The importance of this, is that the PLC and the manipulator are now completely separated, so in case of a valve's malfunction, the created power spike cannot damage the PLC. The device has a separate power supply. To connect the manipulator and the amplifier device, it was necessary to determine which connector is which, and what purpose they fulfil. This is when the connectors were given the names "A", "B", and "C". These names were used to identify every pin, using the actual pin's number on the connector. For example, the first pin of connector "A" is called A/1. These connections were somewhat simplified within the amplifier device. Thanks to this simplification, the numbering of the PLC's outputs and inputs match the device's input and output numbering.

## 4. Control of the manipulator

### 4.1. PLC

To control the manipulator, a Schneider Modicon M340 modular PLC was chosen. The device was assembled on a BMXXBP0840 type rack. The power supply has its specific place on the rack, which is

a BMXCPS2000. The processor must be placed at slot zero of the rack. The used processor is BMXP342030 [3], version 0.1. This processor is able to communicate via Ethernet, CanOpen, and USB networks. In the first and second position of the rack a BMXDDI1602, in third and fourth slots a BMXDDO1602 input and output modules were placed.

For PLC programming the Unity Pro S program was used. With this program, first the PLC itself must be assembled, using a graphical interface. The used modules must be chosen: the rack, the power supply, and the processor. After the processor is added, the rest of the modules can be freely added. Afterwards, the network itself must be created. The P342030 is able to communicate via Ethernet, as such, there's no need for a separate network module. After validating, the network is ready to use.

This is followed by the program's creation. The program was written in ladder diagram. During the addressing of the discrete I/O modules, care must be taken that four pieces of information must be given. The first is defining if a given pin is an input, or output. In case of input, the letter "I", in case of output, the letter "Q" is used. Afterwards, three numbers, separated by dots must be entered. The first number is only necessary if we use multiple PLCs within the same network, which was not the case in my project, so that number is 0. The second number is the module's slot on the rack. As the processor always goes to slot 0 in the first rack, the I/O modules are placed into slots 1-4. The final number is the number of the pin itself.

#### 4.2. Human-machine interface

To faithfully represent an industrial environment, an interactive terminal (Schneider Magelis XBTGT7340) has also been used during a project. This is a touchscreen HMI, which can send to and receive data from the PLC. Vijeo Designer was used during its programming.

For the interactive terminal's use, it was necessary for it to be on the same network as the PLC. In Vijeo Designer, the HMI was given the IP address of the PLC. TCP/IP Ethernet network was used in this case as well. Registers had to be defined to be shared between the PLC and the HMI. The variables themselves may be named anything, but they must be of the correct format.

To control the PLC, the only required task is to use the created register variables on both the HMI, and the PLC. The HMI may function as an output (to show the PLC's states), or as an input (to command the PLC to do certain task, not unlike a pushbutton or switch). The created control panel has two uses. First, it's able to operate the valves separately, while also gives visual feedback, if they reached their end states. This can be useful during the creation of a new task. It might be time-consuming, or dangerous to run the entire program, so by using this method, the different states can be tested by the user beforehand. The other use is starting the automatic program.

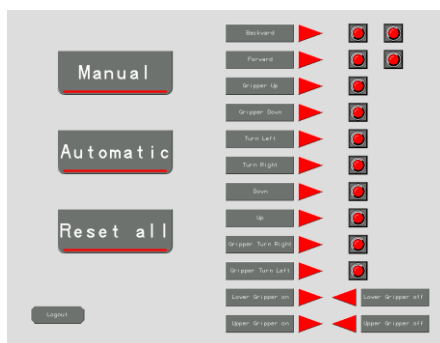


Figure 7. HMI

#### 4.3. Automatic program

The manipulator's automatic control makes it possible for it to execute a task without further commands. The chosen task was the material handling of workpieces, modelled by steel cubes.

The program's "Start" function is activated when the HMI's "automatic" button is pressed. After that, the program continues, and sets the "HOME" position on the manipulator, by ordering three of its actuators to move. It moves upwards, left, and retracts the arms. This step has no additional conditions,

as this position must be possible to reach from any other position. In every step, registers are used for the sequential control.

In the next step, the manipulator extends its arms. For this, the Y1 valve must be turned off, and Y2 valve must be turned on. In other words, set command is sent to output %Q0.3.2, and reset command is sent to output %Q0.3.1. The condition of this movement is that the manipulator must be in a lifted position, rotated to the left, and the R2 must be active. Every row also has an "A" register. This indicates the "automatic" switch's state on the HMI. If it's active, the program is running, if not, it stops. When later restarted, the PLC continues the program from the point where it earlier stopped. After the arm extends, the gripper grabs the cube. The gripper has no limit switch, so we cannot use this movement as condition in the next step. Because of this, a TON timer is used in the next step, which delays the execution of the following step, giving enough time for the gripper to successfully grip the handled material. Following the same logic, the manipulator retracts its arms, turns right, drops the cube, extends, grips another cube, retracts again, turns left, and drops the cube.

The program works cyclically, thus at this point, it jumps back to the beginning, after every register except R1 has been reset. The manipulator is in HOME position in the last step, so that particular step needn't be repeated. From this point, the program repeats until the "automatic" button is pressed on the HMI. For a completely clear state, the "rest all" button must be pressed. This resets every register and output to "low" state, and the system is no longer under load.

## 5. Conclusion

The restoration of the MP-11 manipulator was successful. The machine is mechanically intact. Its mobility was improved by wheels, but it's also possible to secure it with stands, during operation. Suitable modifications were made to make it compatible with modern PLCs. The new D-SUB connectors and the transistor device enable the system to use a wide variety of controllers. During testing, even an Arduino Nano could drive the manipulator. It can be stated that the manipulator is suitable for educational purposes, because it's easy to follow the functioning of the manipulator, the programs are easy to upload using a PC via Ethernet, and they receive adequate feedback from the manipulator. As a potential upgrade, colour sensors or barcode scanners could be employed, which would enable the manipulator to sort products into two categories, based on this sensing method.

## Acknowledgement

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