95p

Robot Design Lab
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Group: 09

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Worksheet 6

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20p 1 Quiz on Mechanical Design [20%]

1. **The construction process is divided into 3 main parts: specification, principle solutions and design. Please explain what is meant by each of these parts. (6%)**

   Specification is used as a guideline and documentation, you record along with timestamps for example through writing or pictures on what is definitely necessary to fulfill the objective, like a list of requirements, what would be nice to carry out the objective in a well, convenient way and who does which task, making it very obvious and clear what is mandatory. The more "ambitions" you are able to fulfill the better the system will be in the end. By getting the specification you have the simple task to fulfill which means for example locomotion, modify or manipulation tasks. And for that you are searching for principles.

   If you are have the requirement list, you start with the solutions. It is ideal to document ideas systematic, quick and unbureaucratic. One possibility for the principle solution is the "morphologic box". It divides the whole system you would like to build up into different functions, where you write everything you need down with multiple possible solutions for realizing your ideas and discuss it with the people. You also make sketches of how you think it could work. What would be a good solution or not. And then for example you can add lines to connect which solutions will be used for which functions and so on. The morphologic box is great because it brings all the solutions from before together in one piece of paper and enables you to do the decisions that are necessary to get the first impression of a theoretical system that could be build.

   The core concept of design is to promptly draw your ideas on paper which also assures easier discussion with your team. Additionally you have to process this to someone who manufactures it, so you need to have a good protocol.

   In design you have to consider three main topics: qualitative design, quantitative design and modeling & drawing. Qualitative design involves the elements of the machine. There are sometimes more than 20-30 kinds of solutions on how you can manufacture a single joint or screws alone for instance, which is why you need a lot of information on the materials to make sure the machine parts compatible like if the parts are purchasable, affordable, robust, have the correct size, have the correct amount of weight, etc. The more variations you considered, the better the construction becomes. You need to follow the rules of design, make it simple, clear, safe, weldable, manufactureable, etc. If you have to calculate to much on the object to much, it's probably not a good construction (quantitative design) so you need to observe proportions. You should be roughing calculations and have survey orders of magnitude. In this step you also built models and prototypes to testing. Modeling and drawing is the basis of the technical documentation. Nowadays Computer Aided Design is becoming increasingly more common especially for 2-dimensional representation of 3-dimensional components by projection.

So that means the construction process should have a basic manufacturing process, basic machine elements and include a basic understanding of the mechanical manufacturing process.

2. **What is the main difference between additive and subtractive manufacturing? How do additive and subtractive manufacturing compare in terms of speed, complexity and robustness? (8%)**

   As the names suggests, the main differences between these two manufacturing methods is the fact that the additive manufacturing can create new shapes or objects because it adds bit by bit to the manufactured subject by using material such as plastics or a combination of different materials. the additive manufacturing process is becoming cheaper and the quality is good and the material is flexible, but you have to make sure the structure itself has enough support often needing support material. The subtractive manufacturing creates new objects by altering and/or removing parts from an already existing object. You can cut up very robust materials like metal, stone, glass or wood.

   An example for additive manufacturing is the 3D printer, because it involves a process that creates something new by using and adding materials while laser cutting would be categorized as subtractive manufacturing because it cuts and in some way damages the to be manufactured object. The additive manufacturing process in comparison with subtractive manufacturing is a lot more complex than their counter part and can be rather slow depending on which kind of additive manufacturing is being executed.

3. **What is biomimetics? How can robotics design benefit from it? Give two examples of a biomimetic design in robotics. (4%)**

   The basic principle of biomimetic is to observe and learn from nature for technology. Bionik is an artificial word made out of BIOloge and TechNIK. The approach is that plants and animals have already solved many problems in the course of the past evolution and engineers use these as inspiration for inventions to make new technical progress.

   Example: Flying You have vortices if you fly with a plane and this causes a problem, because if you land behind the plane you are likely to fall upside down. The fins, the arching feathers from the birds wings, reduce this. Using the birds wings as a role model, engineers implemented winglets.

   You can use this when building a flying robot.

   Example: functional surfaces

   The Salvina keeps a permanent layer of air under water which repulses water. The effect is called "salvinia effect".

   This could be used in robotics for machines that act on the water surface to reduce drag.

4. **What are the two main design principles used in biomimetics? (2%)**

   The basic principle of biomimetic is to observe and learn from nature for technology.

   Bottom-up-process:

   In the bottom-up-process you find for instance the "salvinia effect" and observe and learn on how it works. Then you do an abstraction and you have a technical solution and can discover problems that can be solved by it.

   BASIC Research → principle understanding → abstraction → technical implementation

   Top-down-process:

In the top-down-prozess we have a problem, we look how nature solves it, learn it, and we have solutions which were transferred from biology that we can use to solve different kind of problems.

Technical problem → role model in biology → understanding of principles → abstraction → patent specification

25p 2 Quiz on Actuators [25%]

1. **What is the difference between a stepper motor and a DC motor? (4%)**

   The DC motor is the most common actuator, is very affordable in terms of money and is highly efficient with up tp 98% efficiency. DC-motors do not always need a motor controller. Like in case of the Brush motor it has 2 connectors and you can simply change the polarity of the used battery to reverse the revolution motion that turns bit by bit. There are many kinds of DC-motors such as the brush motor, brushless motor, inner rotor motor, external rotor motor, which creates significantly larger range of possibilities in comparison to the stepper motor.

   You drive stepper motors by revolution steps. The step amount can be configured partly by the motor controller. Unlike the DC-motor you can make it drive a specific number of clockwise or counterclockwise steps and define on your controller definition. The disadvantage in stepper motors is that they don't have any sensors which means that if a force occurs that causes more force to the axis than the motor itself it, the motor will still try to make the steps and it will lose it's position, because it locates it's location by counting steps.

2. **Describe the advantages and disadvantages of brushed and brushless motors.(4%)**

   Brush motor:

   The brush motor has been around since the 1870 and thus is considered mature technology. It Is very affordable money wise. It has up to 98% efficiency and has 2 connectors and by changing the polarity of the battery you can switch the way it turns without the need of an controller.

   The disadvantage of the brush motors: Because it's coal elements, leading the electrical flow, it is not as good controllable as the brushless motor and while in use they create sparking and because of the friction of the carbon brushes, therefore it can't be used in certain applications. It also means that the Life span of the motor compared to other DC motors is shorter, since the brushes are being slowly reduced in operation.

   Brushless motor:

   It is efficient and because it's brushless it creates less friction and therefore less heat and wear. It has more power per weight compared to the brush motor. They have good control, high performance (movements) and a lot of data feedback. That means it has many use potentials.

   Disadvantages: It is more expensive in comparison with the brush motor. The brushless motor requires a motor controller, because it has 3 poles which have to be addressed at the right time. You need some sensors on the system to activate the right cause and the right time, making the operation of these motors more difficult.

3. **What is the difference between an inner rotor motor and an outer rotor motor? Name two optimal uses for these two types of motors. (5%)**

   The difference between an inner rotor motor and an outer rotor moter is the position of the arrangement of the rotor, stator and the shaft.

   The inner rotor has low mass on the shaft and the permanent magnets are inside and the heavy coils are on the outside. This structure provides high speeds and high performance level.

   If you need a motor that needs to perform a lot of movement and build up not a lot of load, the inner rotor would be a favorable choice, because it has less weight on the axis and can change the speed direction reasonably fast.

   The outer rotor has higher weight on the shaft, because the heavy coils are located inside and the permanent magnets are positioned outside. It has high torque and overload potential at low speeds. That is why it has constant running behavior.

   A optimal use for the outer rotor would be a rc plane that has a propeller at the front, since it should have a consistent and stable rotation speed and is build for more permanently speeds. That's because it has considerably more mass on the axis through the arrangement of the parts.

4. **What is a motor characteristic curve? What is it used for? (5%)**

   The motor characteristic curve illustrates the motor performance in form of a graph and it's abilities. It shows the torque M [mNm] (X axis), the rotation speed N per minute [rpm] (Y axis), the current consumption and the efficiency of the motor.

   It's important to know what kind of characteristics a DC motor has to ensure maximum efficiency and lifespan. For example it shows the quantity of rotations. The information is useful because it can be used to avoid damage to the motor caused by the heat of the rotations.

5. **Give two examples of bio-inspired actuator designs. (2%)**

   - Artificial muscles (mcKibben actuators):

   As the name suggests the bionic design is inspired by muscles. They have a flexible chamber, which you are able to drive with pneumatics. The shape of the inflation is determined by the net-structure over it.

   - IFAM spider-robot:

   Based on the half fluidic actuation system of a spider. Combines muscles and fluid-actuators (pressure pads) and integrates pneumatic cells within the 3D printed structure using multiple materials.

6. **What is the working principle of hydraulic cylinders? (5%)**

   Hydraulics are actually a gear type, they normally don't have any position feedback (you have to add it manually) and they change power to different movements.

   In case of the hydraulic cylinder, the piston part creates linear movement by converting the hydraulic energy back to a mechanical movement. You put energy in some type of pressure tank called reservoir and a filter element, where the medium gets pumped from through a control valve. The medium for the hydraulic transmission is generally oil or air with oil.

   If you have one container and you apply pressure on one piston, the rod pushes out and consequently pushes the force out and therefore as the pressure comes to the second piston

a counter motion occurs which makes the rod as well as the force retreat. For that reason it also works if you do it in reverse, where you get the oil back to the reservoir.

The pressure which is being put on the piston determines the force. The pressure is put on it in Newton per square millimeter times to the piston surface in square millimeter, thus making it very powerful.

22% # 3 Quiz on Electronics

3.1 Explain the Pulse Width Modulation (PWM) concept and name two practical applications. (3%)

... coding an analog signal in digital form.

3% PWM is a technique for digitally and efficiently controlling the average Voltage to an electrical component by sending a digital signal with a fixed period and modulating the ratio of low and high state. This results in minute on and of flickering of the powered component which is visually unnoticeable for humans due to the high frequency.

The two most common applications are controlling either a motor for e.g. wheels and the brightness of LEDs

3.2 Calculate the PWM duty cycle [in %] of a signal with the period T = 20ms and the active time Ton = 4ms. What is the frequency f of the signal? (3%)

1.5%

$$100 \div 20 = 5$$
$$5 \cdot 4 = 20\%$$

The frequency of this signal is

$$20ms \cdot 2 = 40ms$$
$$1s \div 40ms = 25hz$$

f = 1/T = 1/20ms = 50 Hz

6.5p

3.3 Explain the components, working principle and usage of the H-bridge. Moreover, please provide a schematic representation of the current flow in the H-bridge circuit in the two operation modes for motor control. (8%)

The H-bridge is a simple circuit consisting of just four switches (in integrated circuits usually solid-state not mechanical. In the lecture about electronics the H-bridge is depicted in great detail, even the solid-state switches are depicted as structures of transistors and diodes. For simplicity's sake they are depicted as regular switches, in reality those would be controlled by the micro-controller and just regulate the flow from an external power source.) used to switch the polarity of the energy being fed to an electrical component, usually a motor, which enables it to easily change direction of operation.
This is achieved by routing the energy on either side to opposite inputs of the motor, e.g. connect the positive terminal of the DC energy-source through S3 1 to the positive terminal of the motor and the negative terminal of the energy-source through S2 1 to the negative terminal of the motor will result in the motor spinning forward and if we switch S3 and S2 off and S1 and S4 on we get a backwards spinning motor

The current directions are incorrect.
Please refer to the slide 27 of the Electronics lecture.

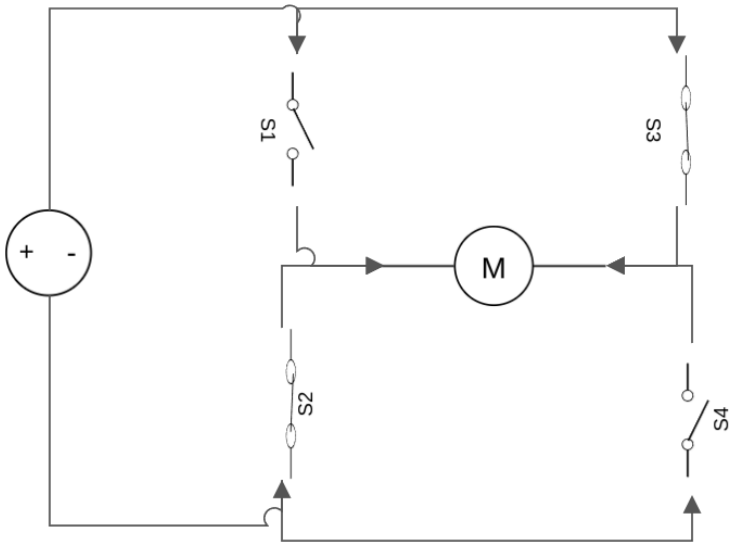

Figure 1: H-bridge positive voltage

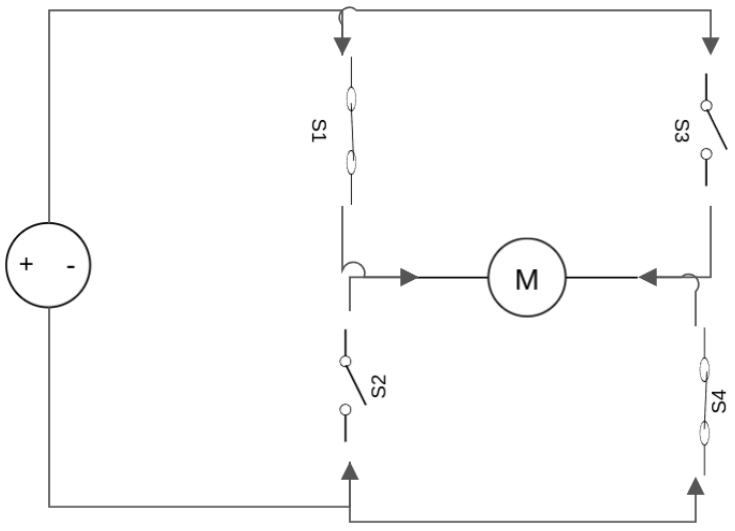

Figure 2: H-bridge negative voltage

6%

3.4 Describe the following data communication protocols and name an use case for each of them: (6%)

3.4.1 Serial Peripheral Interface (SPI)

SPI is as the name says a serial protocol. It is Synchronous limiting transmission speeds and usually has one master chip which can individually address multiple slave chips. Due to its master-slave-architecture it is capable of full-duplex communication which means that each chip can receive and send signals at the same time.
Due to its short range of operation it is usually used for chip to chip communication in an integrated circuit.

3.4.2 Universal Asynchronous Receiver-Transmitter (UART)

UART is an asynchronous protocol meaning the clocks of the communicating chips don't need to be synchronized. The transmission of bits can't be arbitrary however, the chips need to agree on a fixed transmission-speed (baud rate) and the start and end of transmission are signalled by special start and stop bits.
This enables flexible transmission speeds for different devices and in combination with the ability to switch between serial and parallel modes makes it useful for communication to peripheral devices like keyboards and printers.

3.4.3 Inter-Integrated Circuit (I2C)

I2C is a synchronous serial protocol which uses just two wires (clock and bidirectional data) which are used in a master-slave setup to let the slaves know when data is transmitted and if the slave should send or receive. Due to its simple construction I2C is a half-duplex protocol and only one device can send data at any moment.
Due to its sensitivity to interference it is only effective over short distances leading to it usually only being used for communication between components on the same board, e.g. a microcontroller querying the temperature from an onboard temperature probe.

5%

3.5 Consider you want to measure a voltage with an Analog-to-Digital Converter (ADC). You configured your ADC to a resolution of 10bit. The voltage reference for the ADC is a high precision 2.048V source. After reading the ADC result, you got a value of 0X00F7. What is the measured voltage? (5%)

$$2.048V \div 2^{10} = 0.002V$$
$$0.002V \cdot 247 = 0.494V \qquad (0X00F47 = 247)$$

19/20

4 Robot Hardware-Software Architecture

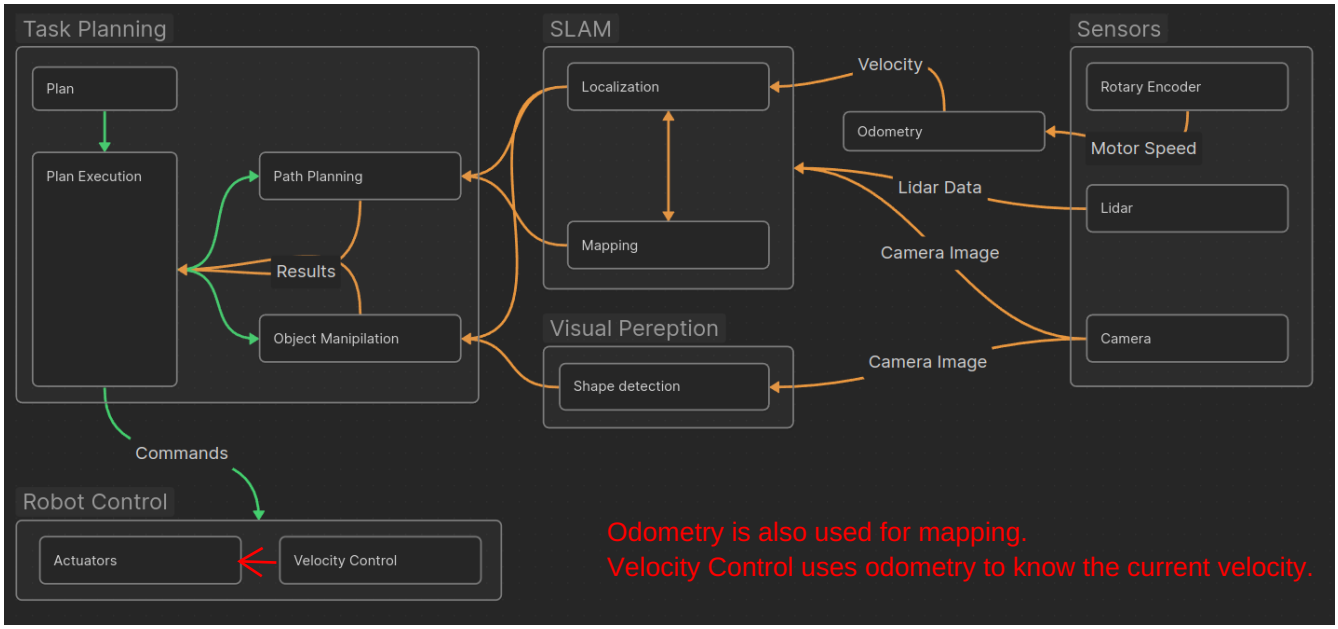

Figure 3: Diagram showing the data and control flow of an robotic system.

Excellent work!

- Green arrows symbolize control flow connections.
- Orange Arrows symbolize data flow connections.

4.1 Description of the Diagram

First of all I designed an only data flow oriented Diagram. The basic Idea is that data is passed from the sensors to some control logic. This control logic produces commands for the motors an actuators, that move the robot. With the knowledge we learned over the semester, we know that there a a few systems that make up the control logic of an robot.

There is an mapping Algorithms that takes the Lidar and maybe even the Camera data and calcuales a map of the environment. There is an localization Algorithms that is twined with the mapping Algorithms to estimate the postion of the robot in the map. This System is called SLAM. ~~In some cases~~ it also uses the Odometry of the motors to aid in the localization of the robot. Odometry is needed for mapping as well.

The Camera data is also parsed to a Visual Perception System. In this System the Camera Images a evaluated and for example shape detection is performed. This shape detection Data can for example be used to manipulate Objects. Like Picking up a Box. Because if we want to able to pick up a Box we first off all need to detect the Box. The we are able to use our own position to calculate to position of the box in the world. Very good!

The map and the positions estimation is also used by an path planning Algorithms. This Algorithms like the Object Manipulation is part of the Task Planning System. In this System Controls essentially what the robot will do. It has a Plan that is executed. This Plan contains instructions that define how the robot will react to the position, map and shape detection data. The plan execution then produces command for the motors and actor of the robot to essentially move the robot.

9p 5 Perception on Robot

You should also provide the circle detection output for the images with polygons, such that we can verify there are no outliers. Similar for the polygon detection applied on the image with circles. (-1p)

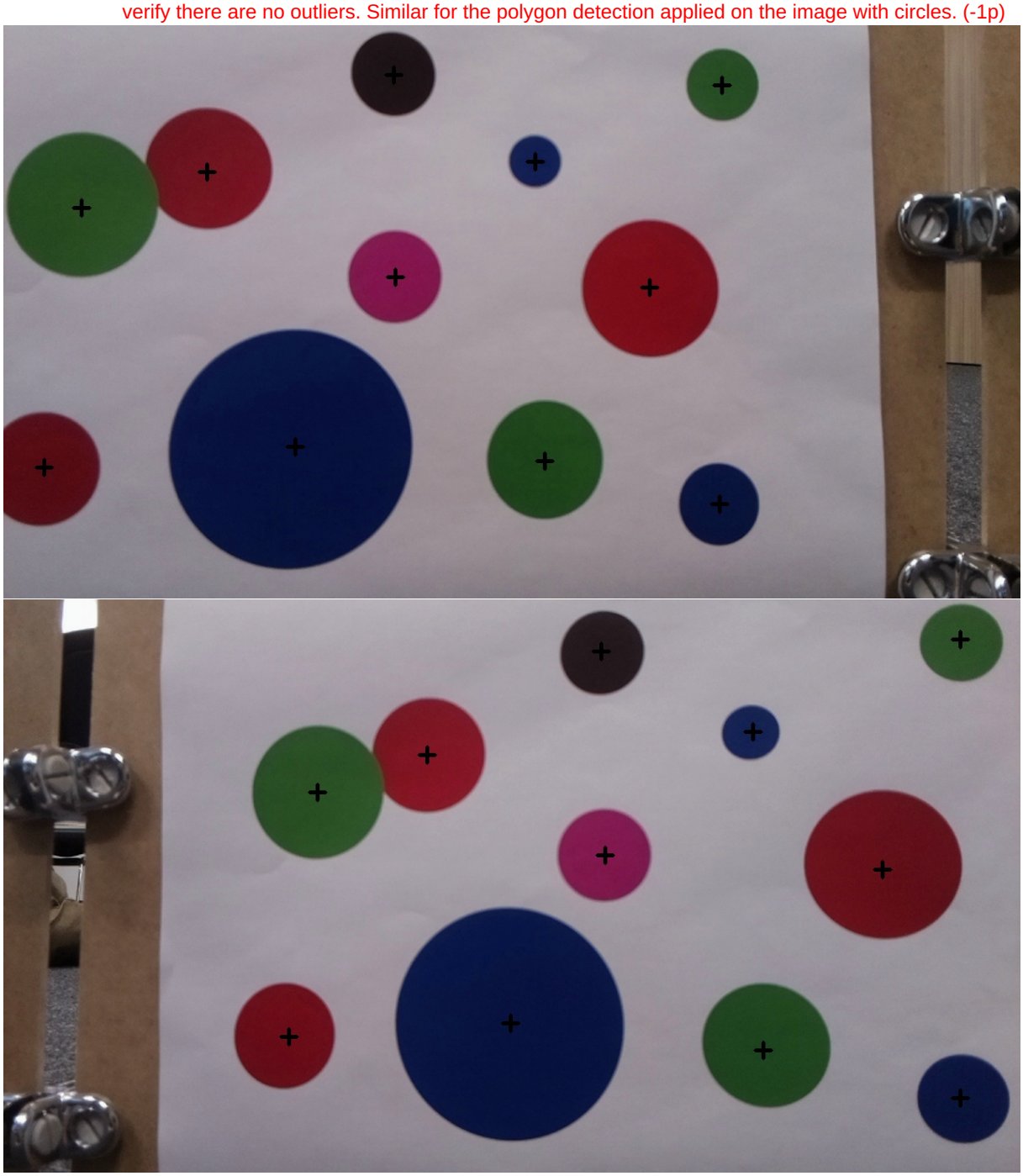

Figure 4: Circles

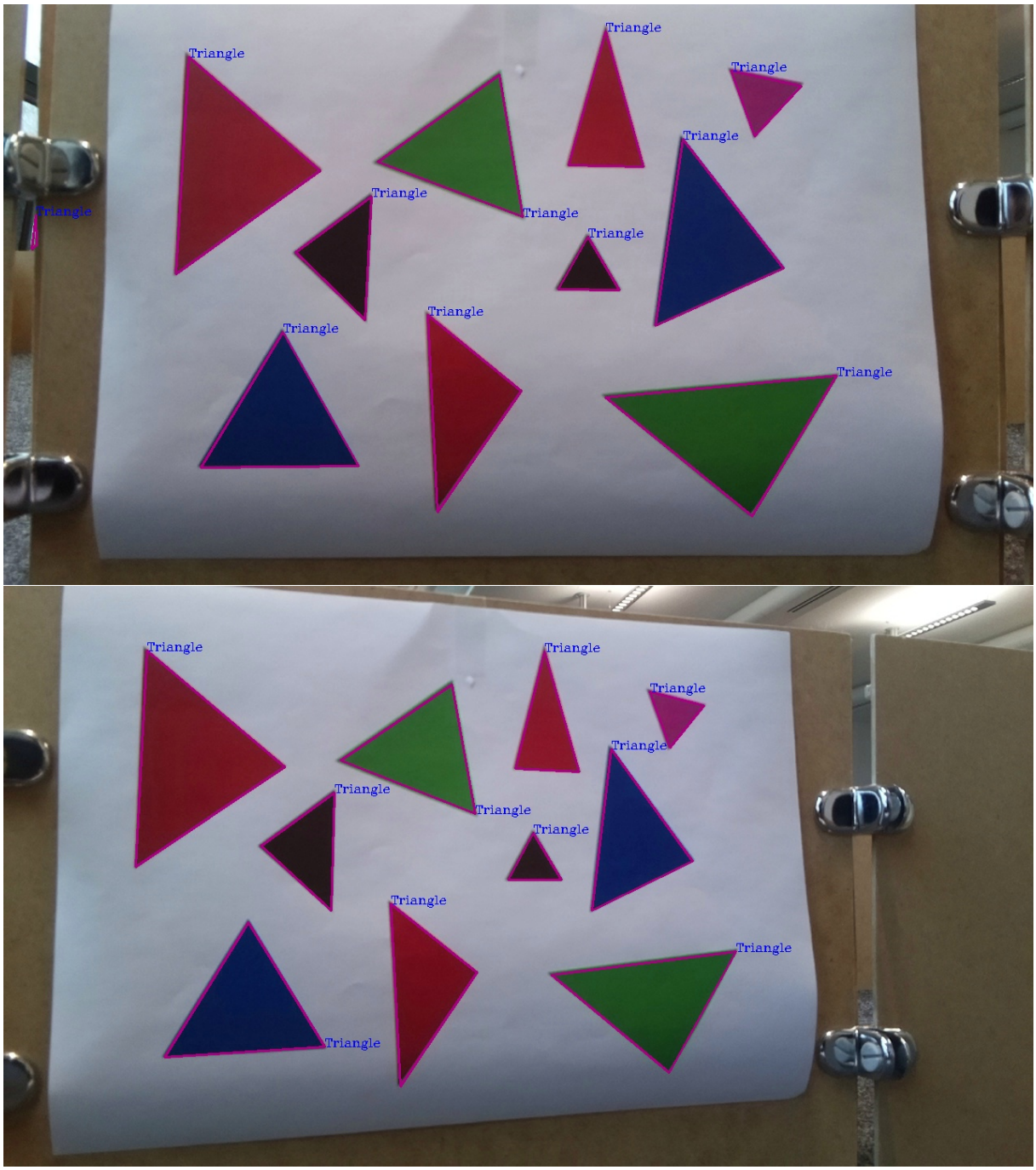

Figure 5: Triangles

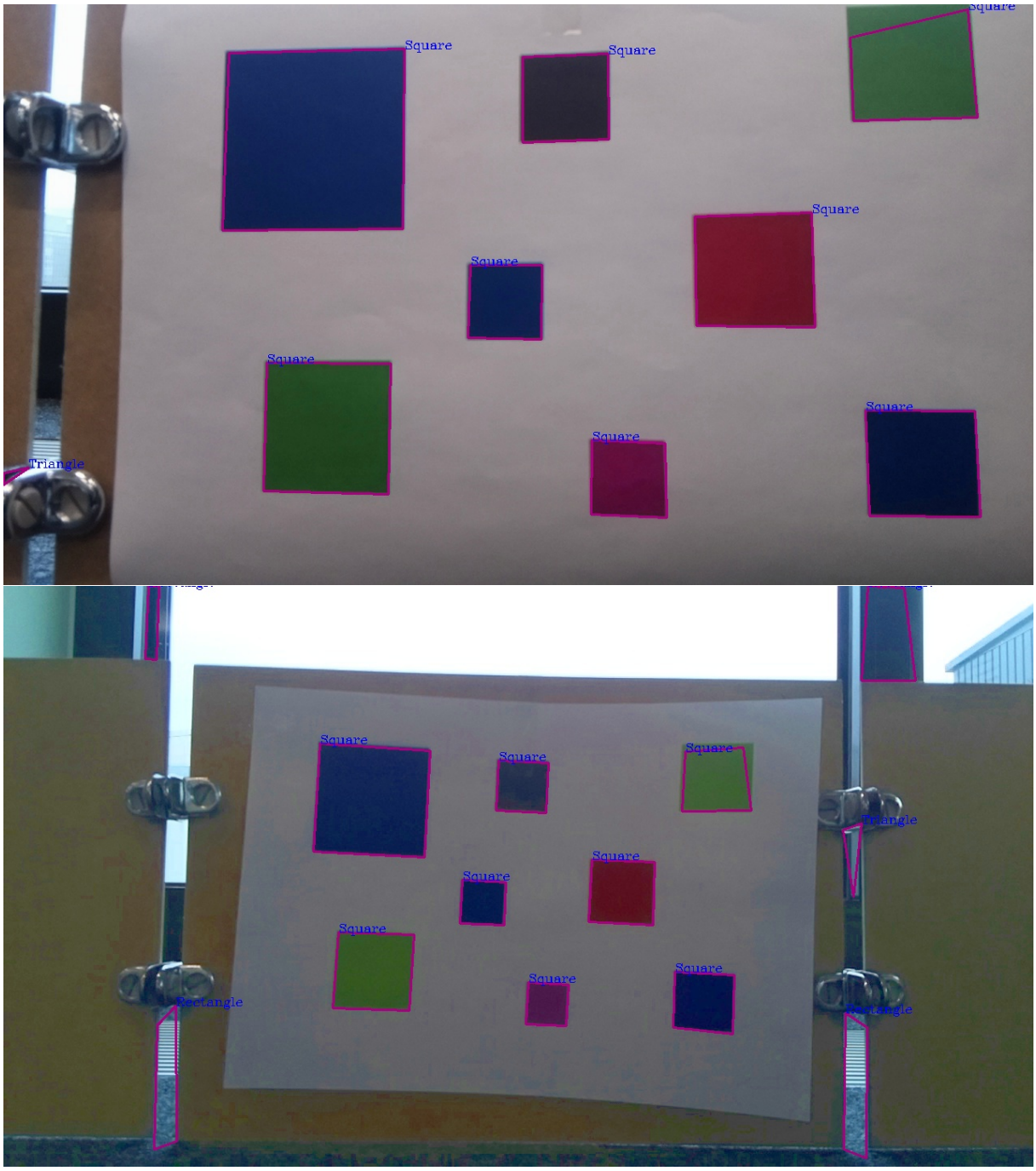

Figure 6: Squares

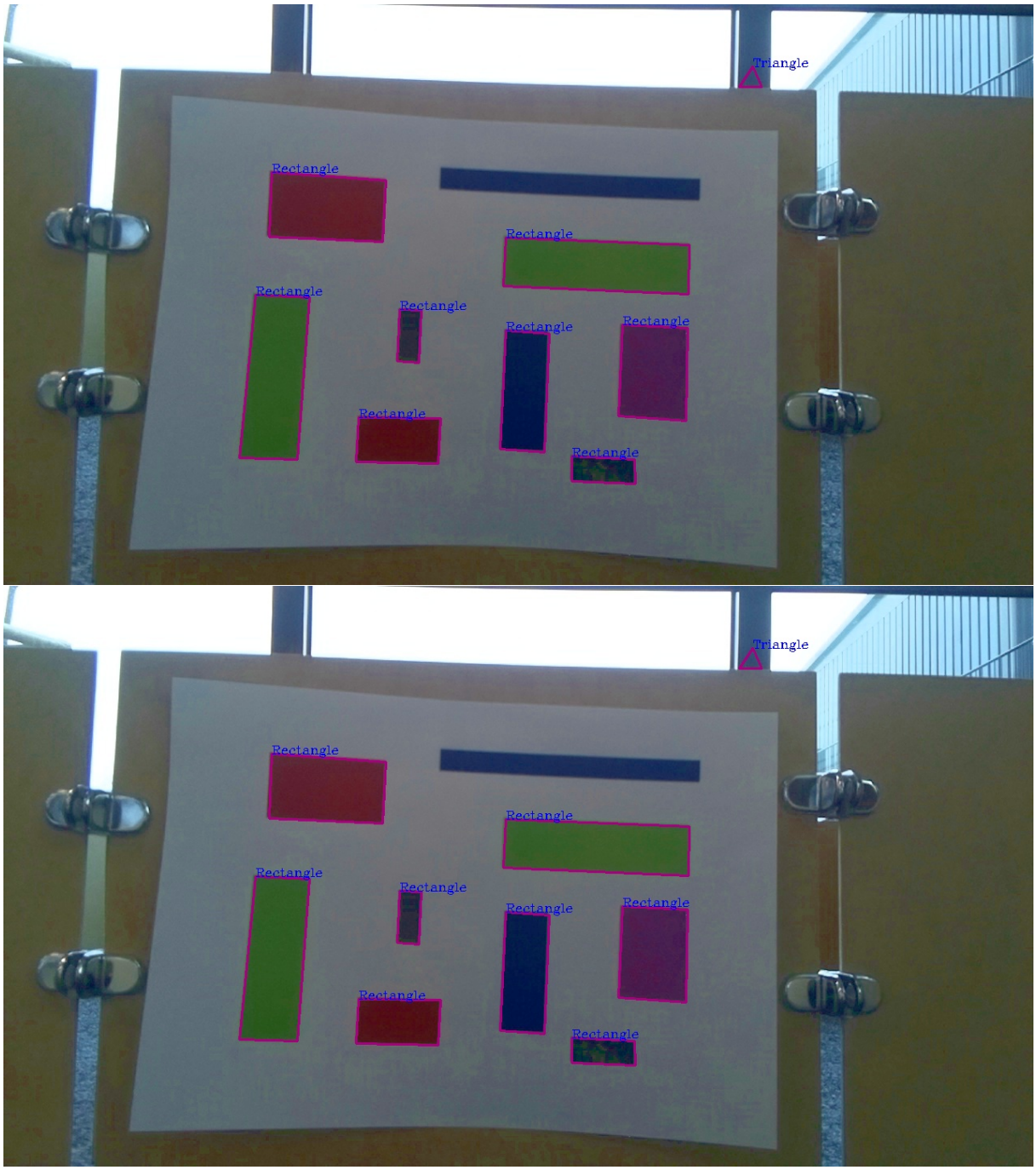

Figure 7: Rectangels