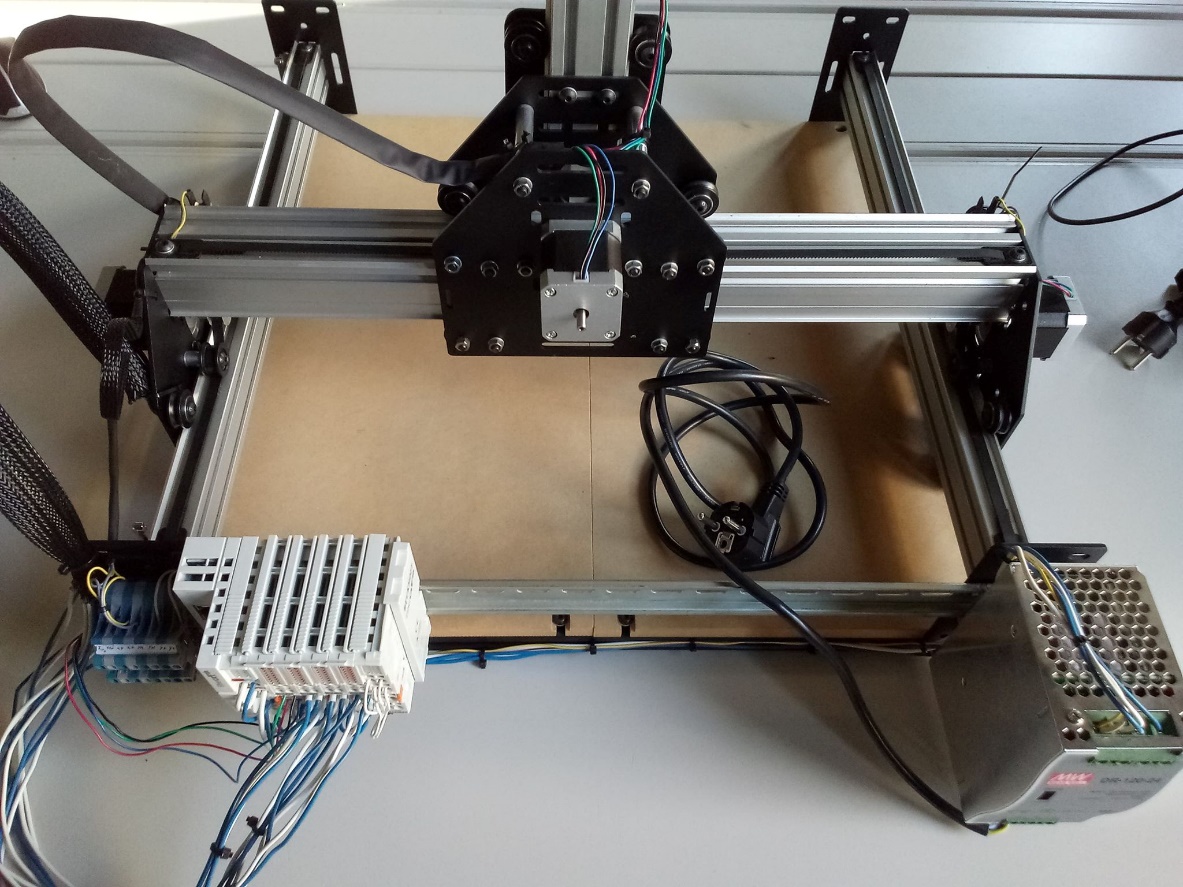
TC Robot

Multi-purpose, voice controlled automated cartethic robot



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# Over all goal

## Goal describtion

The cartesian robot is a Shapeoko 2 device, that is controlled by a programmable logic controller (PLC). This machine will be fully controlled by voice. De voice commands are received through a MQTT connection with the Raspberry Pi. A movement or a certain program will be executed with these commands.

The goal of the project is to create a cartesian PLC construction that can be programmed in TwinCAT. The construction will eventually have multiple functionalities. Its processes will be automated and started using voice commands.

An example of a functionality is Analyzing a object from a picture and obtaining it’s contours which are then converted into g-code. This g-code is sent to the plc and the contours are retraced.

The part that are talked about in this report are:

* *Vision:* In this section 2D snapshot cameras and 3D line sensors are compared to see which is best to use in this setup.
* *Speech-to-text*: This section describes how voice commands can be converted into text to communicate with the plc.
* *Cartesian robot*: this section describes the specifications of the setup.

## 

## Applications

* The possibilities are endless but here are some useful and obtainable applications :

Applying glue / soldering paste using a extruder using ether a servo motor or a pump to push the liquids out. When using the pump, the pressure will have to be calibrated depending on what liquid is being used. When using a servo motor, a certain volume can be extruded.

Sorting coins using a electromagnet.

Picking and soring cards using a suction cup and vacuum pump.

Edging / drilling using a Dremel tool.

Picking up parts using a servo motor claw mechanism

|  | hardware | price | difficulty |
| --- | --- | --- | --- |
| #1 | Gleu/soldering paste | 4-15 € |  |
| #2 | Electro magnet | 3-10 € |  |
| #3 | Suction cup | 15-20 € |  |
| #4 | Drill / dremel | 15-20 € |  |
| #5 | claw | 10-20 € |  |

The prices of the electromagnet or servo motor depend on how powerful they need to be. A small electromagnet that can lift 2.5Kg will cost about 4 euros. Stronger ones that cost up to 25 euros can lift 25Kg.

To test the limitations of the tools, stress tests can be performed. To test the limitations of the Dremel or pen, the max speed can be looked for before the result is inaccurate.

Prices of different parts that can be used to create the different tools have been looked up on amazon to do an estimation of the costs.

. [1]

[Link Elektromagneet](https://www.amazon.de/BQLZR-Metall-Elektrohubmagnet-Halten-Elektromagnet/dp/B00EQ1XGO6/ref=sr_1_4_sspa?__mk_nl_NL=%C3%85M%C3%85%C5%BD%C3%95%C3%91&keywords=elektromagnet&qid=1565710141&s=gateway&sr=8-4-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyRDJJNThZT0FTM1NUJmVuY3J5cHRlZElkPUEwNzYwMTYwUkhZOENMTkhGN1ZXJmVuY3J5cHRlZEFkSWQ9QTA0MDY0MDQyQ0lWRFZVMDFSOENNJndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==)

[Link DC-Motor](https://www.amazon.de/sourcing-map-STK-Elektromotor-Rundschacht-Spielzeuge/dp/B07L8DN584/ref=sr_1_1_sspa?__mk_nl_NL=%C3%85M%C3%85%C5%BD%C3%95%C3%91&keywords=DC-Motor&qid=1565710267&s=gateway&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyRlBOQ09HSzZFWlpQJmVuY3J5cHRlZElkPUEwMjkxOTcxMkpJT1JISVNBQlNOQyZlbmNyeXB0ZWRBZElkPUEwODY2NzQ3MlExRjFWUVE0MFo0MyZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=)

[Link DC-motor](https://www.amazon.de/s?k=servo+motor&__mk_nl_NL=%C3%85M%C3%85%C5%BD%C3%95%C3%91&ref=nb_sb_noss_2)

[Link Drill set](https://www.amazon.de/Metabo-Bohrerkassette-Spiralbohrer-rechtsschneidend-627151000/dp/B00239S7QK/ref=sr_1_13?__mk_nl_NL=%C3%85M%C3%85%C5%BD%C3%95%C3%91&keywords=bohrersatz&qid=1565710526&s=gateway&sr=8-13)

[link Dremel set](https://www.amazon.de/Heimwerker-TwoCC-Elektrisch-Schleifer-Geschwindigkeit/dp/B07W3ZPXYQ/ref=sr_1_1?__mk_nl_NL=%C3%85M%C3%85%C5%BD%C3%95%C3%91&keywords=dremmel+tool+heads&qid=1565710709&s=gateway&sr=8-1-spell)

[Servo claw CAD-file](https://grabcad.com/library/gripper-with-servo-motor-1)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **equipement** | **object** | **differences** | **Task** |
| **Sort** | magnet, suction | coins, cards, components, sluitringen | size, color, shape | Place difference 1 at xy coordinates |
| **Drill** | drill | Points  circles | none | drill holes |
| **Trace** | draw,  gluing, milling | card(boards), lids, pcb's  (WORKING AREAS ) | files on ftp (gcode+json) | place file 1 inside objects (scale if needed) |

There are 3 main categories of applications: sorting, drilling and tracing.

Sorting can be either done with a magnet or a suction cup. The Vision system will detect differences in size, color or shape in the different objects such as coins. Each set of similar objects is pointed to a XY coordinate on the surface and each object in its category is placed in its respective location.   
(Place difference N at “X, Y” coordinate).

A drill is used to drill holes at marked locations. The locations are marked by points or circles and detected by the Vision system. In this application there are no differences to be detected.   
 (Drill Holes).

Tracing can either be done with a pen/pencil, Glue dispenser, rotary tool. The vision system detects a drawing or written text and create 2 files on an ftp server. The XYZ robot will retrace the drawing or text inside a newly marked and scanned (working)area such as lids, cards/boards and PCB’s. If a scanned drawing or text must be placed in multiple smaller areas, the image must be rescaled.   
 (Place file X inside objects)

The vision system creates a Json and g-code file on an ftp server which can be filtered by the user. The XYZ table will point to an object or difference and the user will validate if the object is valid or if 2 differences are similar. The filtering is done by voice commands.

# Component vision

The vision part is necessary to scan object end send the data to the PLC. This data is needed to control the cartesian robot and to automate the processes.

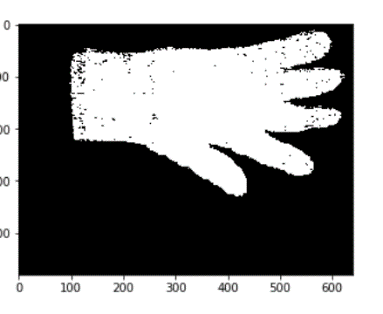
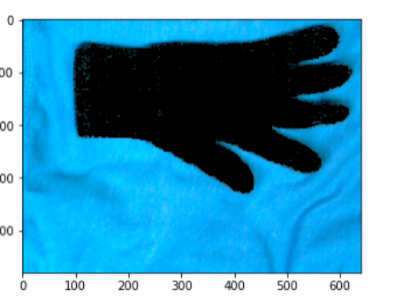
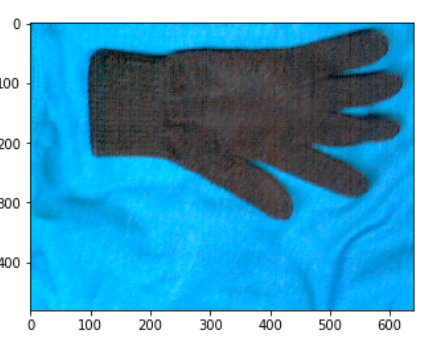
There is a choice to be made. Either a 3d line sensor or a 2d snapshot camera will be used. The specifications (resolution/accuracy) and possibilities of the different cameras.

## 2D vs 3D

3D compared to 2D allows to scan object at low contrast with its background since there’s a Z coordinate which can be filter with instead of filtering on colour differences with the background. This Z position is also needed in some applications, for example, when it is needed to apply glue to a raised surface.

**TARGET**

The purpose of this part of the project is to take a photo of an object and to extract the alignment for this object using a python script. The aligned image is then converted to g-code and then sent to the plc.



**RESEARCH VISON CAMERA’s**

Research was done on vision camera’s the prices of the vision cameras are between 100 and 200 €.

***cognex in-sight 2000***

link: <https://www.cognex.com/applications/customer-stories/electronics/ease-of-use-vision-system-helps-connector-manufacturer-achieve-zero-defects>

*• Pressure gauge parts to check critical dimensions and / or to measure components for sorting and classification processes*

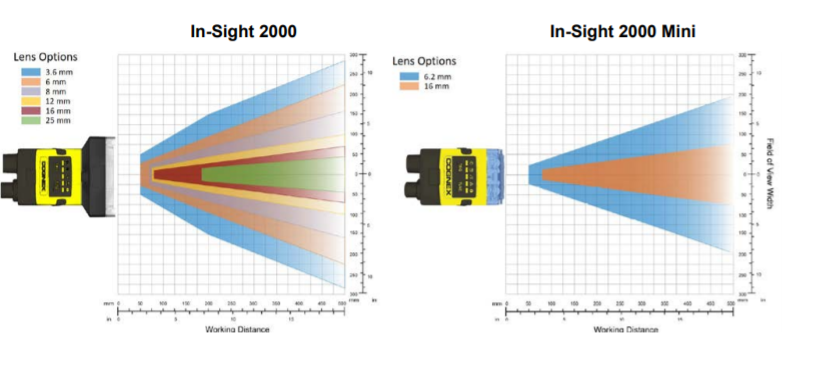
*• Can be connected to PLC*

*• Delivery time can last up to 6 months*

*• No large field of view*

*• Using easybuilder*

*• Request price via email*



***SENSOPART | V10-RO-A3-C-2***

Link: <https://shop.fortop.be/be_nl/catalog/product/view/id/50820/s/sensopart-v10-ro-a3-c-2-st502753-vision-sensor-robotic-advanced-c-mount-631-91082/category/1667/>

* Field of view 800-600
* communicatie via Ethernet IP, Ethernet (LAN), PROFINET, SensoWeb

***USB2.0 Camera***

Link: <https://www.vision-camera.nl/5MP-USB-Camera-OnSemi-MT9P031-MER-500-7UC-L>

* Goedkope industriële camera
* -Resolutie van 2592x1944 (verkrijgbaar in meerdere resoluties)
* begint met een prijs 98€
* Programmable Control (features) : Image size, gain, Exposure time, trigger polarity, flash polarity, etc.
* daheng Imaging kunt u alleen aansturen met de SDK van Daheng Imaging.

***Adimec Q-12A65***

Link: <https://www.adimec.com/cameras/machine-vision-cameras/quartz-series/q-12a65/>

* Functions & features (welke zijn interessant voor ons)
* Region of interest
* Burst mode
* Flat Field Correction
* Programmable I/O
* HiQ mode (image averaging)
* High dynamic range mode
* Mirroring
* Internal & External triggering
* Video LUT

***keyence***

Link: <https://www.keyence.com/ss/products/vision/visionbasics/use/inspection03/>

* Measuring maximum/minimum dimensions of parts or products
* Measuring maximum/minimum/average inner or outer diameters or center coordinates of O rings
* Te korte afstand
* -geen product gevonden op de site

***Imprex T484016 MP CCD Camera***

Link: <https://www.imperx.com/ccd-cameras/t4840/>

The camera provides 4864 x 3232 resolution

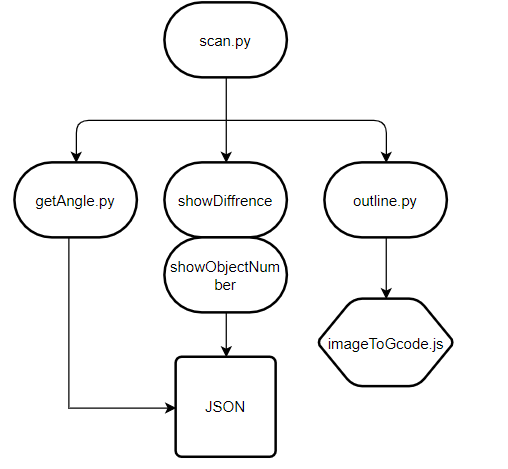
***Alibaba EX130MS Machine Vision Mono Rolluik USB C-mount Camera***

Link: <https://dutch.alibaba.com/product-detail/ex130ms-machine-vision-mono-rolling-shutter-usb-c-mount-camera-1627817894.html?spm=a2700.8699010.normalList.1.539f77a3c92Nbj&s=p>

* prijs van 120 tot 150 dollar
* sensor CMOS
* ondersteund VB, VC, C#
* software DSHOW, TWAIN, OSX, SDK, Labview
* geen info over afmetingen

**Vision commands**

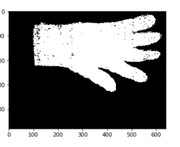
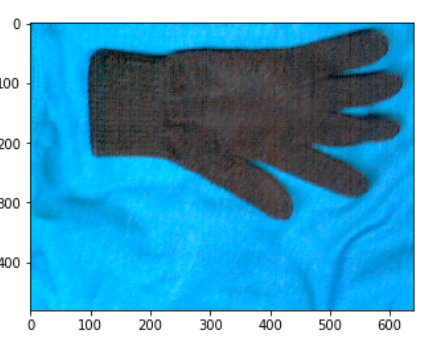
The commands to call up the python and node files are shown below



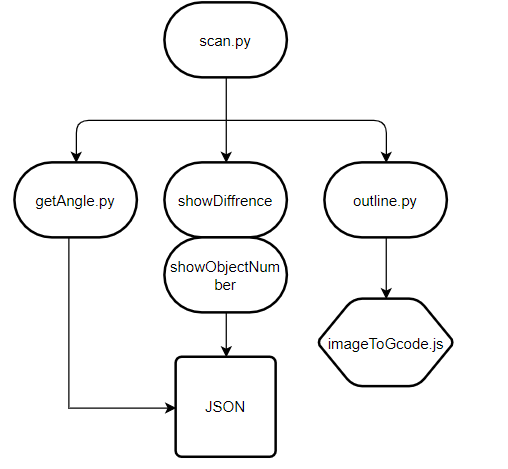
|  |  |  |  |
| --- | --- | --- | --- |
| Commands Rpi | Remarks | reply voice | reply command |
| scan | Takes pictures in python | Picture made | show foto (opens scanfoto.jpg) |
| outline | Python porgram that gets the outline of the picture | Picture outline made | Show outlineGcode  (Opens outlineGcode.jpg) |
| Create gcode | Node js program that generates gcode | GCode file generated | / |
| Objectdetect | Detects objects and saves them in a array | Objects and 4 corner points + x objects found | show JSON |
| Change angle  (in progress) | Rotate objects  (easyer to find simularities of objects) | X items rotated and measured | / |
| Show all commands | Shows all the commands | List with  Scan, outline, Create Gcode, Objectdetect, Change angle | / |
|  |  |  |  |

**PROGRAM**

In This Code a photo is made of an object. This is done on a blue background so that we can filter the object out using the color filter. The photo is converted to black and white and then saved as a .png file and later as a gcode file. The incidence of light is very important for an accurate end product.

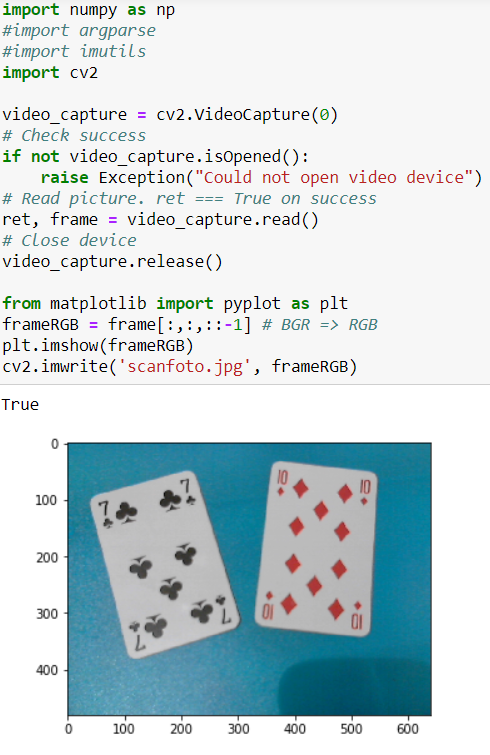


**CODE**



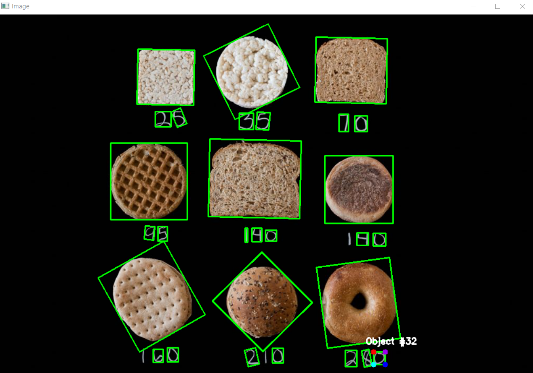
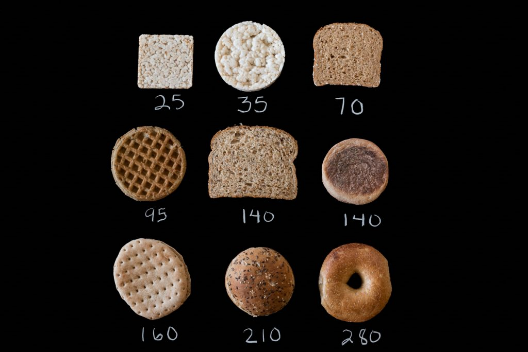
**Scan.py**

In the scan function we use the videocapture function to get a picture of our objects. We use this in a separate file so we can use the picture of the objects in multiple .py files.



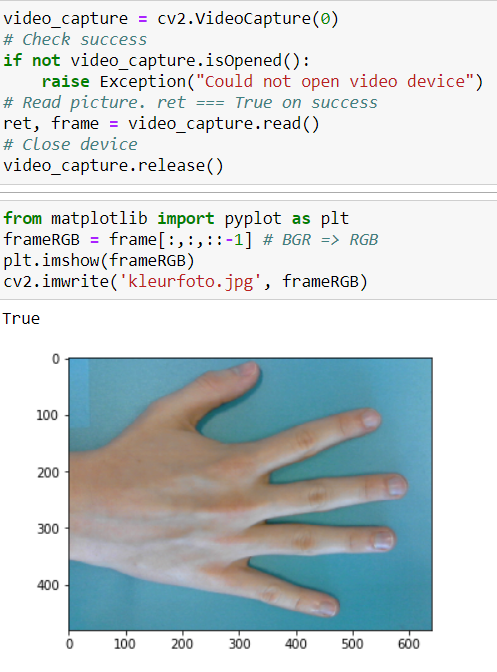
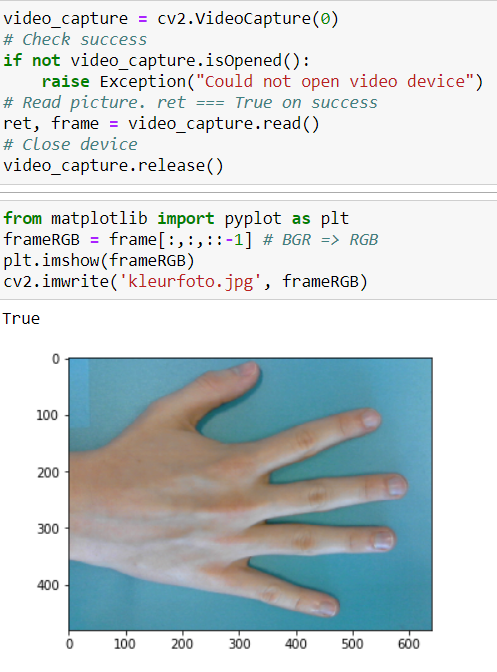
**Oblectdetect.py**

In the program we include scanfoto.jpg from the scan.py. In the program we scan for objects and put a bounding box and give the coordinates of the four endpoints of the square. In the program all the objects will also be numbered so it will be easier to remove a objects if we don’t want to use it.



**Get outline.py**

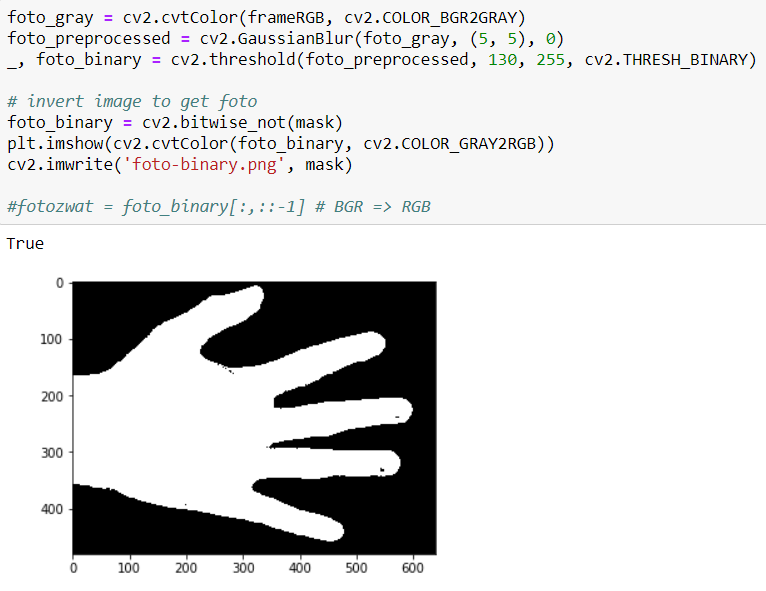
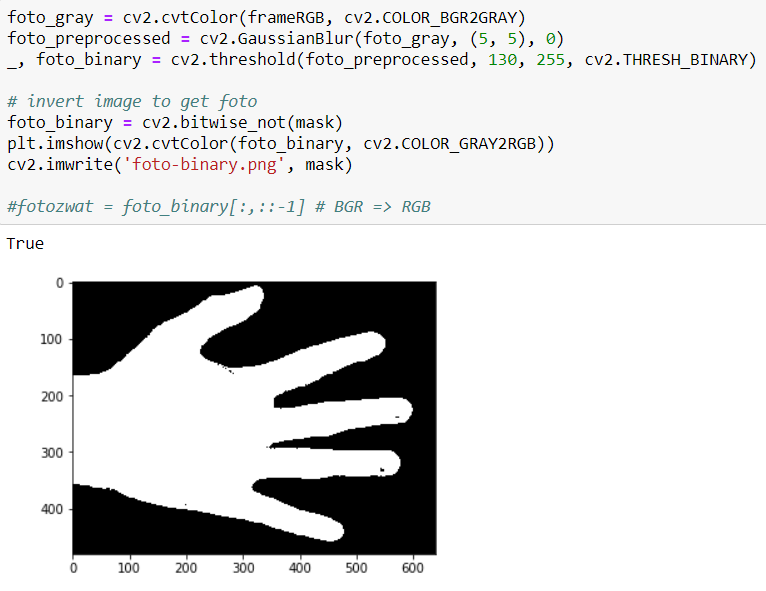
We call up scanfoto.jpg from the scan.py function and use it to go further in this program



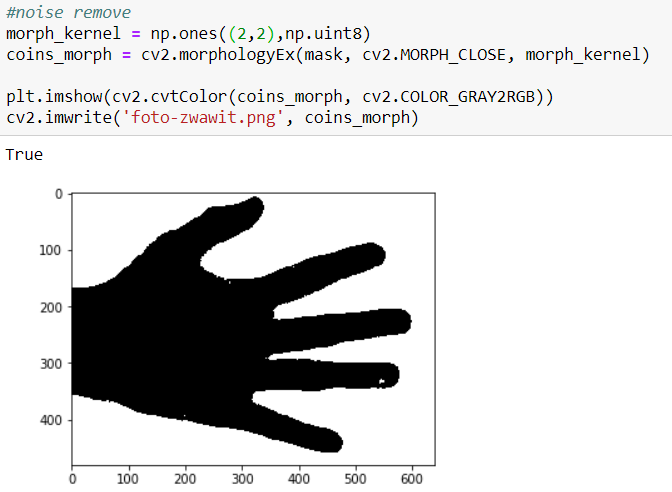
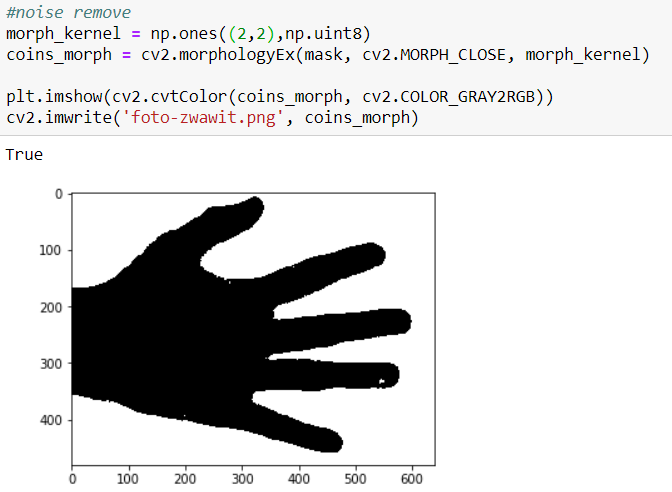
The colorfilter is then applied where only the blue colors remain. This ensures that all objects that are not blue turn black. Attention must be paid here to the exposure, because shadows or the reflection of light may cause parts to be displayed incorrectly.



The photo is then set in black and white to make it easier to edit.



The photo is now inverted, and part of the noise is also filtered out here, this is then saved as "foto-zwawit" we use the canny function to get the edges of the item. we save the picture as outline.jpg and use this picture in the nodeJS image to Gcode converter.



## Line sensors

* A line sensor creates a 3d image of an object by measuring the Z distance to the object line per line. This creates a profile of the object which is needed for application where a precise Z coordinate makes a difference.

To be as efficient as possible the camera must at least scan half of the surface (16 cm) at once, which means the line sensor must be at least 16cm wide. Table 1 has an overview of the different options for line sensors. Only the line sensors for which a price was found are given since price played a big part in deciding which camera to use for the vision component.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | Clearance | measure range | Resolutie x | Resolutie z | repeataility µm | field of view | scan rate | Prijs |
| 2x scan |  |  |  |  |  |  |  |  |
| Gocator 2440 | 183 | 210 | 0,09 | 0,037 | 1,2 | 194 | 170 - 5k Hz | 11.453 euro |
| Gocator 2340 | 190 | 210 | 0,095 | 0,037 | 1,2 | 194 | 170 - 5k Hz | 8.894 euro |
| Gocator 2140 | 190 | 210 | 0,19 | 0,037 | 1,2 | 194 | 170 - 5k Hz | 5.407 euro |
| 1x scan |  |  |  |  |  |  |  |  |
| Gocator 2350 | 300 | 400 | 0,15 | 0,06 | 2 | 365 | 170 - 5k Hz | 8.893 euro |
| Gocator 2151 | 300 | 400 | 0,3 | 0,06 | 2 | 365 | 170 - 5k Hz | 5.407 euro |

The Gocator sensors can communicate through various protocols. Most discussed and recommended protocols are CANopen and ethernet/IP. To use these protocols the right plc terminal must be provided. For CANopen the BC500 terminal is required and ethernet the BX9000

<https://www.beckhoff.de/bx9000/>

<https://www.beckhoff.de/bx5100/>

Online specifications gocator line sensors:

<https://lmi3d.com/gocator/product-selector?product_movement=MovingLine&part_width=180&part_height=&part_length=>

The prices are obtained over e-mail or over the phone from LMI technologies representatives.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| COGNEX | Clearance | Measure range | Resolutie x | Resolutie z | repeatability µm | field of view | scan rate | Prijs |
| DS1300 | 180 | 725 | 0.101 - 0.457 | 0.016 - 0.265 | ? | 410 | up to 10 Khz | ? |
| DS1100 | 135 | 220 | 0.079 - 0.180 | 0.01 - 0.051 | ? | 161 | up to 10 Khz | ? |

Info about COGNEX sensors:

<https://hogeschoolpxl-my.sharepoint.com/personal/20003024_pxl_be/_layouts/15/onedrive.aspx?id=%2Fpersonal%2F20003024%5Fpxl%5Fbe%2FDocuments%2FDocumenten%2FAutomation%20en%20electronics%2FIndustrial%2FTC%20Robotics%20and%20Vision%2FPOZ%201819%2FcognexDS1000%2Epdf&parent=%2Fpersonal%2F20003024%5Fpxl%5Fbe%2FDocuments%2FDocumenten%2FAutomation%20en%20electronics%2FIndustrial%2FTC%20Robotics%20and%20Vision%2FPOZ%201819>

With these sensors comes a open source SDK for configuration and real time 3D visualization. This software can be used for third party processing and communication with PLC’s.

Another brand that was considered is BASLER but for these camera’s there is no obtained pricing data and they had to sensors that had a whide enough scan area.

## Line sensor or snapshot camera ?

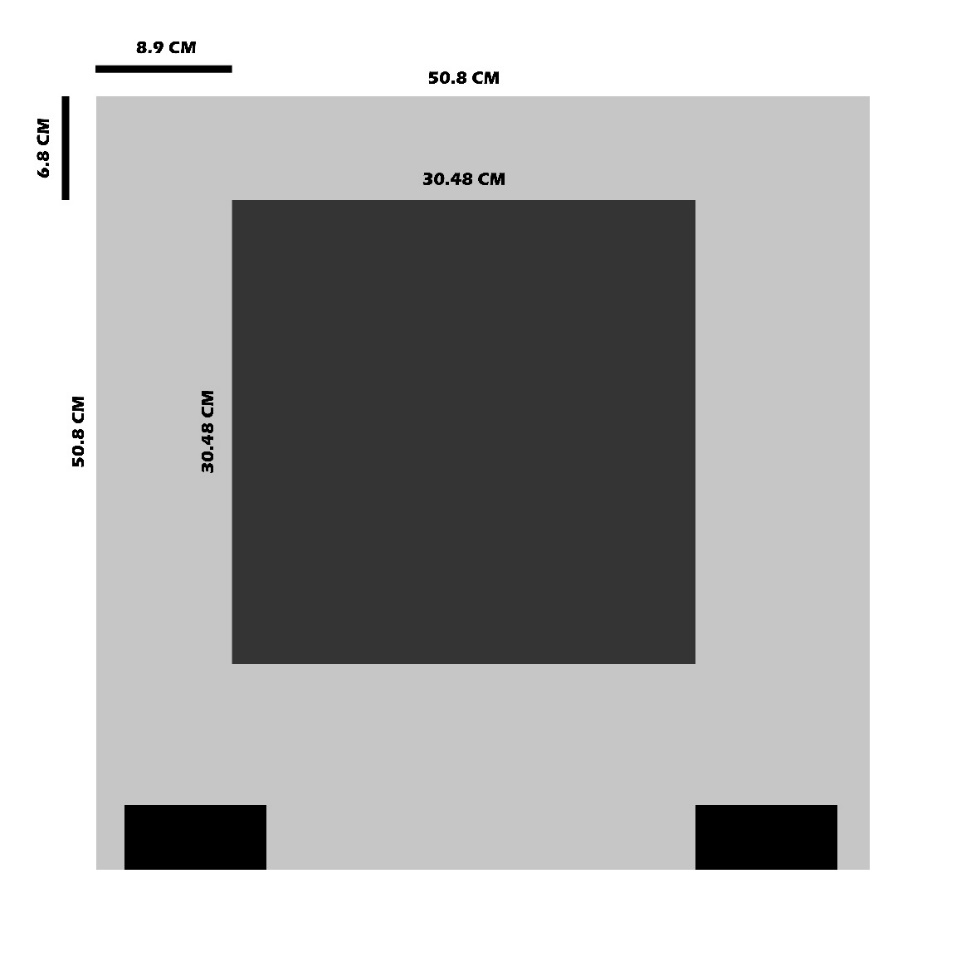
For most applications the snapshot camera is good enough. Since The price difference is so big it is best to start with a simple snapshot camera since the price to benefit ratio for the line sensors is so bad.

Component

# cartetische robot

The robot consists of 3 axes, an X, Y and Z axis. Each axis has a stepper motor (SM42HT47-1684B) to accurately determine the location. The Y-axis consists of two stepper motors instead of one, like the other axes. All these motors are individually connected to a stepper motor terminal (EL7031). The EL7031 EtherCAT Terminal is intended for the direct connection of stepper motors in different sizes. The slimline PWM output stages for two motor coils are in the EtherCAT Terminal together with two analog inputs.

The EL7031 can be adapted to the motor and the application by changing just a few parameters. 64-fold micro-stepping ensures particularly quiet and precise motor operation. [1] To determine the exact locations and to perform a homing, there are end-to-end contacts on the X and Y axes, which are connected to the digital input terminal EL1008. The entire system is powered by the DR-120-24 power supply. This power supply has an output voltage of 24 V DC that is needed for the terminals and the stepper motors. The setup surface of 50,8 on 50,8 cm, but the work surface is   
only 34,8 on 34,8 cm.



Everything is controlled by an industrial Beckhoff C6930 PLC. Beckhoff implements open automation systems based on PC Control technology. The product range covers Industrial PCs, I/O and Fieldbus Components, Drive Technology and automation software. [2]

This PLC has a windows version and can be programmed in   
Twincat 3. Due to the text-to-speech that happens on the raspberry PI, commands are sent to the PLC. These commands then ensure that a certain movement will happen or that a program will be executed, for example a G-Code. All of this makes the cartesian robot multifunctional and allows the user to sort parts, drill, glue, etc.

This part of the cartesian robot is fully programmed in Twincat 3. Twincat is a software program made by Beckhoff, that makes it possible to program the PLC. This program is used to program the motion control for this device. The program consists of various functions from the motion control references. The functions make it possible to do the movements and the location determination. One of the important functions is mc\_home, this one is needed to calibrate the robot for further movements. The movement that will happen depends on the command that the PLC receives from the Raspberry Pi. The robot can move to a certain position and perform an operation, can perform various operations one after the other with the information that is noted in a JSON file or even execute a G-Code. The G-Code or JSON files can be sent to the PLC through an FTP connection between the Raspberry Pi and the PLC.

***All of this together makes this robot a multifunctional cartesian robot.***

# **Component** **Speach-to-text**

This part will discuss the part of speech-to-text in the project. Hereby there will first be a short discussion about the different possible speech-to-text programs that are available. It will state what the advantages and disadvantages for each program is. This is then followed by a brief decision about which speech-to-text program has been chosen and why. The part that follows will elaborate on the chosen speech-to-text program. What are the functions that it has, the communication between the speech-to-text and the PLC and other aspects?

## DIFFERENT SPEECH-TO-TEXT

Various speech-to-text programs have been investigated and compared with each other. The various pros and cons will be discussed below.

### Snips (.ai)

Benefits:

* Works offline/embbeded
* Has its own broker
* Possible to make personal assistant
* Easy to install

Drawbacks:

* Is not available on a windows device

### Daialogflow

Benefits:

* Chat bot
* Possible to make personal assistant

Drawbacks:

* Only available on internet applications
* Needs an internet connection in order to work properly

### Google cloud speech-to-text

Benefits:

* Only translates .wav files, with speech, to a string

Drawbacks:

* Needs an internet connection in order to work properly
* There are limitations with the sound file it can convert
* Is only free for a limited time. Trial period 60 minutes

### Deepspeech (git):

Benefits:

* Only translates .wav files, with speech, to a string
* Available for free
* Possible to make personal assistant

Drawbacks:

* Only available on certain internet applications
* There are limitations with the sound file it can convert
* Difficult to install
* Not available on every system

## DECISION SPEECH-TO-TEXT SELECTION

Out of all the different speech-to-text applications, Snips (.ai) merged as the best option for the current project. In contrast to the other applications, it has less disadvantages that would influence the performance of the speech-to-text. Furthermore, Snips (.ai) has many advantages that benefit the current project. One of these has to do with the personal assistant and how it works and that it has its own MQTT broker. Which makes it possible to communicate with the PLC.

**Installation and tutorials Snips (.ai)**

Installation tutorial for Snips (.ai) on a raspberry pi 3. (Snips (.ai), at this point, only works on Raspbian Sketch. It does not work on Raspbian Buster. This is because Snips (.ai) was built to work on Sketch but has not been configured to work on Buster.)

<https://docs.snips.ai/getting-started/quick-start-raspberry-pi>

Tutorial for making a Snips (.ai) assistant and extra.

<https://www.hackster.io/matrix-labs/voice-control-your-lights-with-snips-ai-and-a-matrix-device-9c54ce>

## OPERATION OF SNIPS

In this section the different steps for the communication between Snips (.ai) and the PLC will be discussed.

Snips (.ai) is, as mentioned before, a speech-to-text program. Which makes uses of mqtt for communication with other programs or devices. This communication protocol is also used for communication between Snips (.ai), on the Raspberry Pi, and the PLC.

The operation/communication between Snips (.ai) and the PLC will be discussed step by step in the following point.

*· When starting the Raspberry Pi, the Snips (.ai) assistant, including the broker, also starts up.*

*· To give a command, the "wake word" must first be said. In this project it has been kept default to "Hey Snips".*

*· After the "wake word" is spoken, a sentence can be spoken that contains the different commands. Some of these commands are:*

* + Scan
  + Show object
  + …

*The section that follows will go more in depth on the different commands.*

*· When one of more commands is detected, the Snips (.ai) program will send a json string to the broker, with the different commands in it. This json string will then be received by the PLC.*

*· The PLC has a program running that listens to the broker for possible json strings that can be sent.*

*· Wanneer het PLC-programma zo een json string ontvangt zal deze verder in het programma ontleed worden voor enkel het commando uit te hallen. Dit wordt dan gebruikt om de juiste functie op de PLC en xyz tafel uit te voeren.*

*· When the PLC (program) receives a json message, it will analyse it for the different commands it contains. The different commands are then used to preform different task with the cartesian robot.*

## POSSIBLE PROBLEMS

*There have also been some problems showing up while using MQTT on the PLC (cartesian robot). The mayor problem that has occurred, is that the MQTT code (/program) that handles the communication between the PLC and broker, only works on the latest version of the system. In older versions, of the operating system of the PLC, the libraries about MQTT are not integrated. The system while therefore not go into the "run mode", making it impossible to run code.*

# Result smart robot

In dit deel zal er een kort besluit getrokken worden van de verschillende delen van het project van PLC.

## Keuzen Vision Camera of Vision Line Sensor

Uit het onderzoek van vision is er uiteindelijk gebleken dat de vision camera de beste optie is. Dit is vooral door de hoge prijs van de lijn sensoren en omdat de meeste van de toepassingen verwezenlijkt kunnen worden met een vision camera.

## Keuzen Speech-to-text

Uit de verschillende opties is er uiteindelijk besloten om gebruik te maken van Snips (.ai) als speech-to-text voor dit project. Snips (.ai) is gekozen met dat deze de meeste voordelen heeft in vergelijking met de nadelen. Maar het belangrijkste is vooral dat deze offline werkt en een eigen broker bezit. Snips (.ai) maakt gebruik van mqtt waardoor communicatie tussen Snips (.ai) en de PLC zeer simpel is.

## Cartesisch Robot

Bij het onderzoek van de Cartesische Robot zijn er verschillende ondervinding gedaan. Zo zijn er limitaties gevonden. Zo heeft de xyz tafel maar een beperkt oppervlak waarin het kan werken, de snelheid van de motors, de kracht van de motors. Bij het maken van de code voor het aansturen van de xyz tafel is er altijd plaats voor uitbreiding. Er kunnen verschillende koppen bevestigd worden en afhankelijk hiervan kan de code aangepast of gemaakt worden.

## algemeen

De verschillende delen werken apart. Er kan een object gescand worden waarvan de randen omgezet kunnen worden in g code. De plc ontvangt de juiste voice commando’s en de plc kan G-code gebruiken voor de aansturing van de robot.

Naar volgend jaar toe kan alles worden samen gezet zodat het één geheeld wordt. De verschillende koppen kunnen gemaakt en getest worden en de verschillende onderdelen geperfectioneerd.

“Het werkt”