The Development of a Smart Kitchen Cabinet in Order to Reduce Food Waste

Wettbewerbsarbeit SJF

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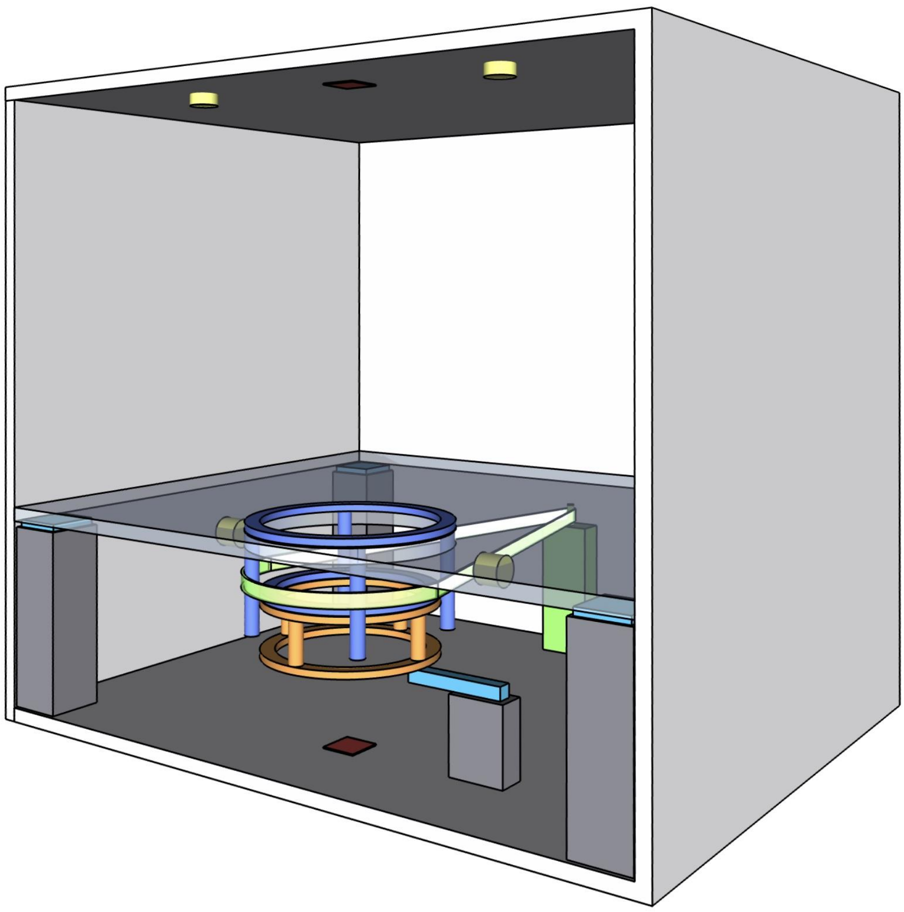

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1. Abstract

The object of this paper is to describe the development of a smart kitchen cabinet with the aim of reducing food waste. To tackle this task, a system inspired by the concept of the Internet of Things was set up. All items entered in the cabinet are placed on a rotating platform and scanned. The product is photographed from every angle and the images are evaluated. The expiration date is extracted using Optical Character Recognition (OCR). In addition, the item is identified using its barcode. All data collected is saved in a CSV file. In a further step, the user is reminded when a product is about to expire.

First, the reader is introduced to the components and a draft of the project to gain an overview. Afterwards the processes are described more precisely. 20 items are scanned in order to determine in how many cases the scanner is able to extract the correct barcode and expiration date. Reasons for the lower recognition rate in expiration dates than in barcodes are discussed. In addition, the cameras are exchanged and the experiment is repeated. As a result, the accuracy of the recognitions rises significantly. To conclude, further steps are named.

2. Introduction

2.1 Food Waste

In Switzerland, 2.6 million tons of food is wasted every year, two thirds of which would still be edible. With a share of 28 %, nutrition contributes significantly to the overall environmental impact of Switzerland. This is due to the high land and water consumption, CO_2 emissions and the loss of biodiversity. In addition, food waste has economical consequences for the private households, agriculture and the food industry. [1]

This project will focus on the food waste generated by private households. They are the main producer of food waste in Switzerland with approximately one million tons annually. According to the Federal Office for the Environment, there are three main causes for the high food waste production by private households (see next page). [1]

Main causes for food waste in Swiss private households:

1. The general lack of awareness of the waste generated and of the value of food
2. Insufficient knowledge about shelf life and storage
3. Insufficient knowledge about ways to make use of leftover food

The smart kitchen cabinet aims to increase the knowledge about the shelf life of the stored products. In a further step it will suggest ways to utilize items, which are about to expire.

2.2 The Internet of Things (IoT)

The IoT is the concept of connecting everyday objects to the internet and collecting data using their integrated sensor. The data is then gathered on an IoT platform and filtered. Important information is used to optimize processes. A printer connected to an IoT platform could for example measure how much paper is left and automatically order more when it is running low. [2]

IoT has already established a high presence in homes. Many gadgets are available for the kitchen but they mainly focus on increasing productivity such as automatic shopping list creators or ovens, which can be controlled by a smartphone. However, no products have been found on the market, which aim on reducing food waste. This project therefore attempts to explore the possibilities and identifying problems of a smart home device focused on sustainability.

2.3 Leading Question

How can a kitchen cabinet be optimized to reduce food waste by integrating an IoT system?

2.4 Hypothesis

An intelligent kitchen cabinet can analyse food items after entering and prevent food waste by reminding the owner of the expiration date. However the accuracy of the scans will not be sufficient for the owner to rely fully on this system.

3. The Development

3.1 Components

Hardware:

- Raspberry Pi 3 Model B V1.2 equipped with a SanDisk Micro SD Card (32 GB)
- 2 Raspberry Pi Zero W V1.1 equipped with one SanDisk Micro SD Card (16 GB) each
- Raspberry Pi Camera Rev 1.3
- 2 Raspberry Pi Zero camera (Model RPIZ CAM2 5MP)
- 1 Load Cell (supporting up to 10 kg with an accuracy of 1 g)
- 4 Body Load Cells (supporting up to 50 kg each with an accuracy of 1 g)
- 2 HX711 Load Cell signal amplifier modules
- 5 Osram LEDs (100 lm each)
- Power Distribution Board
- SPT4412LV-360 Continuous Rotation Servo
- 4 x 5V power supply and 1 x 12V power supply
- Jumper wires and breadboard
- White decorative chipboard, screws, plexiglas and tools for the construction

Software:

- Python 3.7
- Thonny (Python IDE available on the Raspberry Pi)
- OpenCV
- Tesseract and Pytesseract
- Zbar and Pyzbar
- CSV
- MQTT
- Node-RED

In the following, the most important components will be described furthermore.

Raspberry Pi

The Raspberry Pi is a pocket-sized computer, which is designed for children to explore coding in Scratch and Python. It is an ideal device for this project due to its low energy consumption, the small size and the available GPIO pins. In addition, the Raspberry Pi 3 B is equipped with a 1.4GHz quad core processor, which is strong enough to handle basic tasks in the field of computer vision. [3, 4, 5]

Zbar

Zbar is an open source barcode-decoding library originally developed on Sourceforge. It is well suited for this project as it offers high-speed barcode readings. Pyzbar is used as a wrapper to enable the usage through Python. [6]

Tesseract

Tesseract is an optical character recognition engine, which is used to extract text from images. This is needed in order to recognize the expiration date. Pytesseract was used as a Python wrapper.

Continuous Rotation Servo

Unlike a regular servomotor, a continuous rotation servo is not limited to a certain angle. The PWM impulse does not correspond to a position but to the direction and speed of the continuous rotation. Servomotors are a popular choice due to their precise control over the PWM signals. [5]

Python 3.7

Python is a high-level, cross-platform programming language. It is the original programming language of the Raspberry Pi and was therefore used for this project. Its syntax is close to the English language, which makes it easy for beginners to understand. [5]

MQTT

In order to establish a connection between the Raspberry Pis, MQTT was installed. It is a messaging protocol, which is often used for IoT systems as it is lightweight. Before communication is possible, a channel has to be set up between the publisher and the subscriber. A channel can be used by more than two devices, which is convenient, as the communication has to occur between three Raspberry Pis.

Node-RED

Node-RED is a tool used to wire components with the object of forming an IoT network. It features Nodes which can be dragged and dropped on a canvas and connected. Each Node has different functionalities such as receiving messages over MQTT or read and write to the GPIO pins of the Raspberry Pi. In combination with the Node-RED-Dashboard, it is possible to create a user interface, displaying the data gathered by the connected components and interacting with them.

3.2 Project Draft

It is important to have an overview of the setup in order to follow the processes. Figure 1 shows a CAD draft, which was created prior to the construction. It displays the final installation of the cupboard. On the left side, the colour code is explained.

Yellow:
5 LEDs
Red:
3 cameras
Dark Blue:
Scanning platform
Orange:
Scanning base
Light Blue:
5 Weight sensors
Green:
Servomotor and the strap connected to the scanning platform

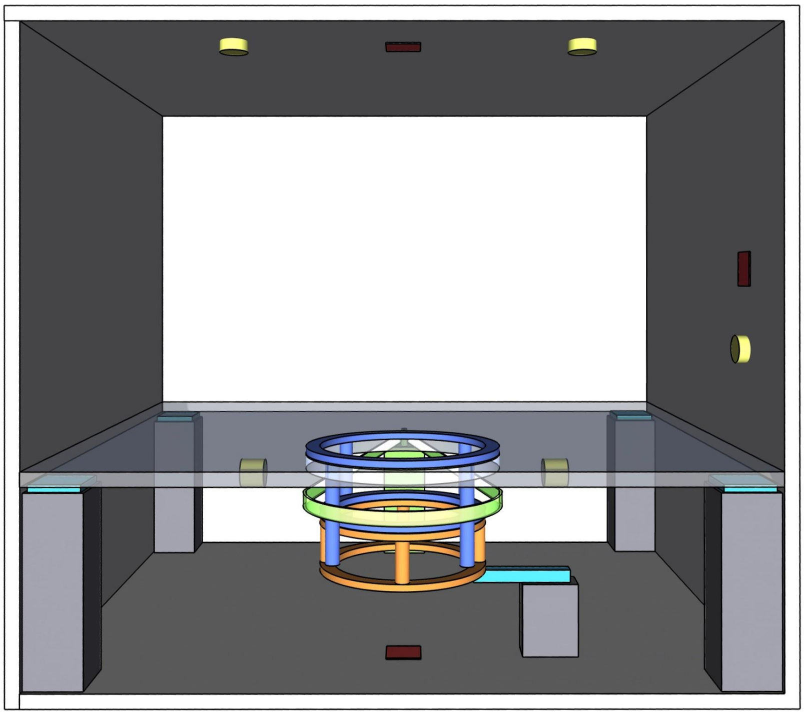

Figure 1: CAD draft of the final installation

One of the conditions that had to be fulfilled in order to construct a working prototype was to place the cameras in a way that they would at some point of the rotation face towards every angle of the item. The scanning platform has a diameter of 12 centimetres. The Raspberry Pi camera has a horizontal field of view of 53.50 degrees. Therefore the camera has to be at least 11.90 centimetres below the platform in order to photograph all of it. However, this is the only distance that could be calculated due to the different sizes of the items.

As seen in Figure 2, all Raspberry Pis are connected to one camera each. In addition two HX711 modules and one servo motor are controlled by the Raspberry Pi 3B+. Load Cell 1 is placed underneath the scanning platform whereas Load Cells 2 to 5 are located underneath the storage shelf. As Load Cells 2 to 5 are connected to the same HX711, their measurements are accumulated, resulting in the total weight of all items placed on the self.

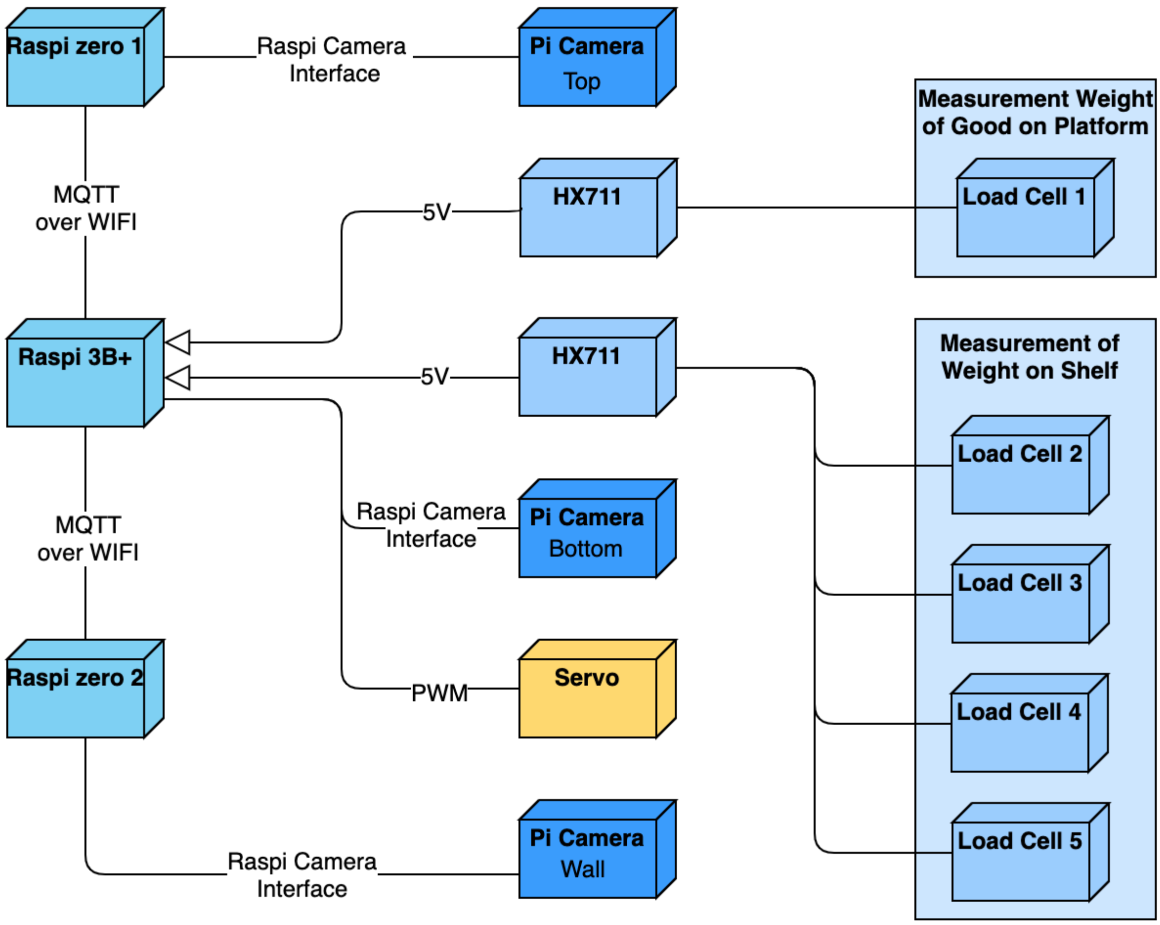

Figure 2: Connection of the Hardware Components

3.3 Rotation, Cameras and Lighting

Each product in the kitchen cabinet has to be scanned to extract the expiration date and barcode. The initial aim was to place the item directly on the shelf in order to eliminate any additional user input. A camera would be placed on each wall of the cupboard to scan the products. This approach would work well, if only one item was stored in the cupboard. However, as soon as there are multiple items, they block the camera view and no item can be scanned from every side. Therefore the accuracy of the barcode and expiration date recognition decreases.

With the goal of providing a full scan of each item but keep the user input minimal, the following solution was developed.

Every item entered in the cupboard is placed on a scanner. Cameras are located underneath, above and on the right side of the item. Figure 3 shows the scanning platform (dark blue) and the scanning base (orange). The scanning base is fixed to the weight sensor (light blue). The product is placed on the scanning platform, which is connected to the continuous rotation servo. It is turned in 7 intervals starting at 0 and ending at 315 degrees. Therefore 45 degrees are added with every interval. In between intervals, the servo stops and one picture is taken from each camera. After the scanning process is completed, the scanner is returned to the starting position (0 degrees). The lower part of the scanner does not turn.

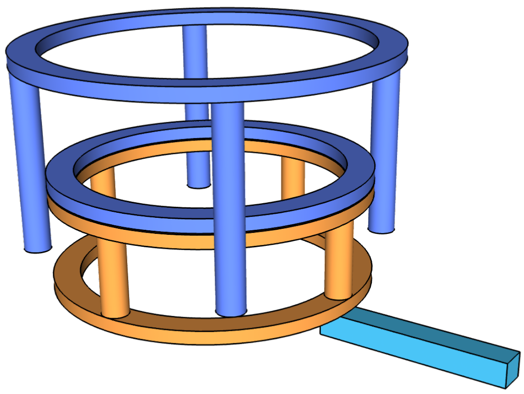

Figure 3: CAD of the scanner

Five LEDs are attached around the cameras and lit as soon as the product is placed on the scanner. This leads to a better image quality. In addition, the scanner can also run while the cupboard is closed. This solution minimizes the user input, because all processes are automated after the product is placed on the scanner. There is no need to wait until the scan is completed, as the item does not have to be removed until the next product has to be scanned.

3.4 Communication between the Raspberry Pis

A Raspberry Pi is equipped with a maximum of one camera port. There are adaptors on the market, which make it possible to connect more than one camera to the Pi. However, they are unreliable. Therefore 3 Raspberry Pis have to be used in order to integrate 3 cameras. The Raspberry Pis have to be connected in order to take pictures at a synchronized time and exchange data. MQTT was chosen as a way to communicate and 2 channels were set up (see figure 4).

Channel 1:

The scanner is started when a weight difference is detected by the load cell underneath the scanning platform. The load cell is connected to the Raspberry Pi 3B (RP1). A time 1.5 seconds from now is calculated and sent to the subscribers (RP2 and RP3). Therefore all cameras can take the first picture at a synchronized time. The following images can be taken in intervals of one second.

Channel 2:

To save costs, two Raspberry Pi Zero W (1GHz single core processor) were used instead of the stronger Raspberry Pi 3 B (1.4GHz quad core processor). It was intended to evaluate the pictures on the Raspberry Pi they were taken from. However, the workload of extracting the expiration date and barcode from the images was too big and the Raspberry Pi Zeros eventually shut down. To solve this problem, channel 2 was set up to send the images as a byte array to the Pi 3 B, where they can be evaluated. [3]

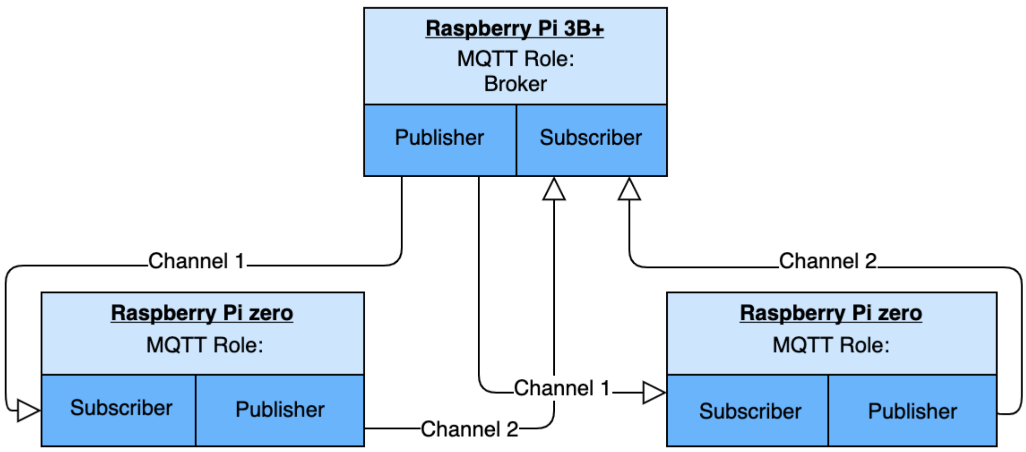

Figure 4: Connections between the Raspberry Pis

3.5 Barcode Recognition

In order to recognize the product, a barcode scanner is implemented. The scanner is able to identify both one-dimensional barcodes (such as the UPC) and two-dimensional barcodes (QR Codes). However most food items are marked with the UPC. It differs from the two-dimensional barcodes in terms that it usually only holds between 6 and 13 numeric digits.

A barcode is designed to be easily readable by a machine. Every one-dimensional barcode is enclosed by guard lines. They indicate the beginning and end of the code. There is a fixed number of spaces depending on the type of barcode, each of which can either be coloured in black or white. A black space codes for 1 and a white one for 0. The digits are appended and form a binary code, which can easily be red by a machine.

When a barcode is decoded it has to be interpreted using a database. It usually contains the complementary product names and in some cases other attributes such as the weight, brand or price. Yet the expiration date cannot be included in the UPC.

In this project, the barcode is recognized using the decode function imported from pyzbar. Because a total of 24 images are analysed, it is possible that multiple barcodes are detected. In order to find the correct barcode, they are appended and the one, which occurs most, is chosen. In the following, it is interpreted using a CSV file containing 25 barcodes and their complementary product name, weight when full and brand. There are large databases including multiple millions of barcodes. However, they are only available through a paid subscription. The small database is sufficient for testing and can be exchanged with a large one if needed.

3.6 Expiration Date Recognition

The expiration date cannot be displayed in the barcode and therefore has to be recognized separately. To solve this task a deep neural network was considered in order to recognize the expiration date directly from the image. However, to achieve a reasonable accuracy, a dataset including thousands of images is required. No such dataset was available and therefore this approach could not be used.

Optical Character Recognition (OCR) was considered as an alternative. All characters in the picture would be converted into a string and the expiration date could then be extracted from there. This is achieved by using Tesseract and OpenCV. Tesseract is already pretrained and therefore no dataset was required.
First, the input image is converted from RGB to grayscale. This reduces the number of colour channels from three to one, which is easier to interpret. Afterwards it is resized.

10 images were evaluated to determine the frame size with the highest recognition rate. Each image was tested with six different widths (500, 1000, 1500, 2000, 4000 and 6000 pixels) and the corresponding height so that the dimensions remained unchanged. The results of the experiment are stated in figure 5. It was determined, that a width of 2000 pixels offers the highest recognition rate for both barcode and expiration date.

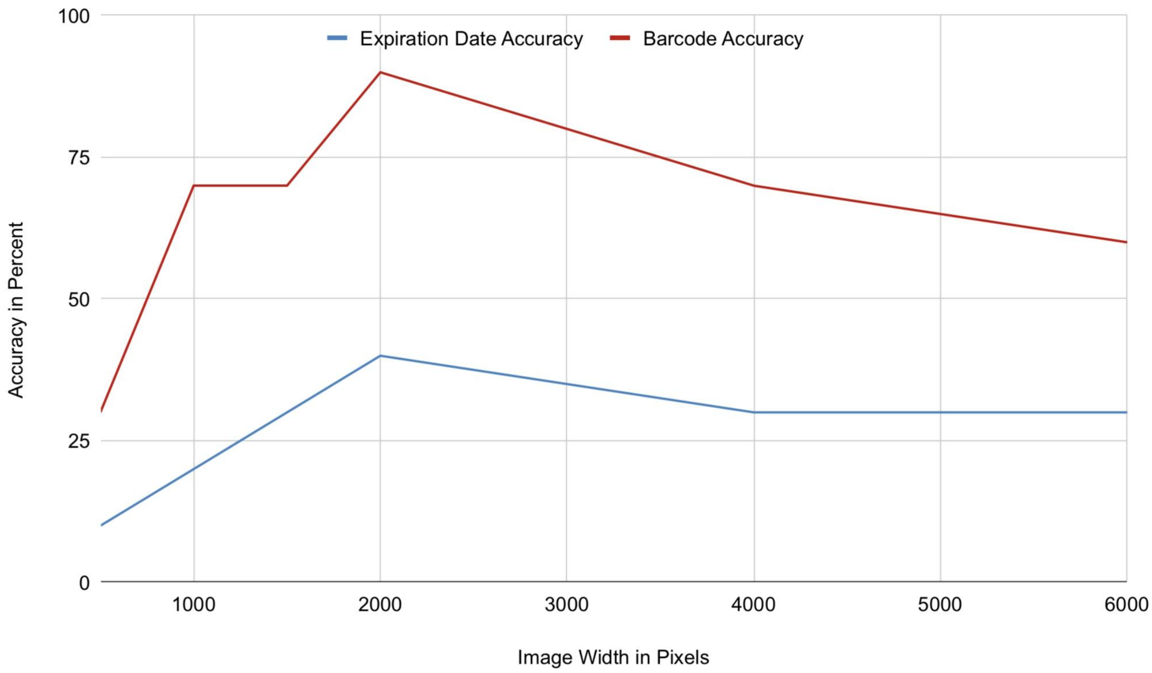

Figure 5: Recognition rate of the barcodes and expiration dates

Furthermore, the time effort of each frame size was measured. This is an important factor, as 24 pictures will have to be evaluated per scan. As seen in Figure 6, the time effort shows a exponential growth depending on the image width. With three seconds per picture, the width of 2000 had a reasonable time effort. This frame size was therefore put to use.

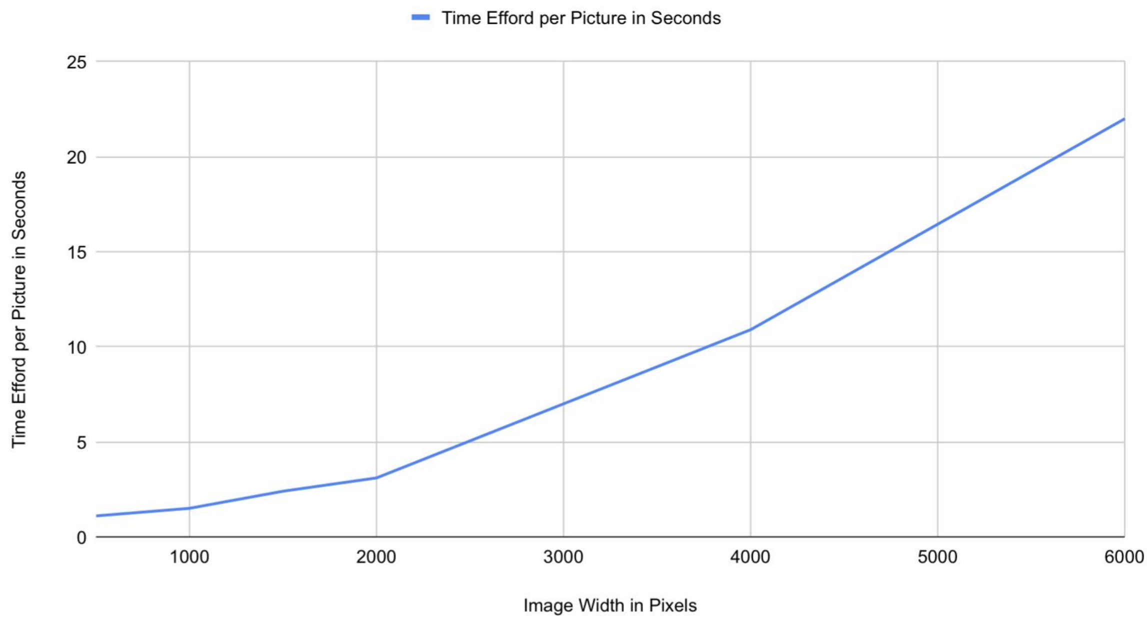

Figure 6: Time effort of the image processing depending on the image width in pixels

After editing the image, pytesseract is applied to convert the image to a string. Conditions were set up to filter out the expiration date from the string. However, as there are no official regulations regarding the display of expiration dates, they come in various different formats. This prototype is limited to four formats (dd.mm, dd.mm.yy, dd.mm.yyyy and mm.yyyy). A backslash, a hyphen or a period are accepted as a separator.

One filter was programmed for each format. They all start with finding punctuation marks in the text. When a backslash, a hyphen or a period is found, the digits around it are analysed. For example the first digit of a month can only be equal to 0 or 1. When the date has fulfilled all conditions of a certain format, it is rearranged to dd.mm.yyyy. However, some speculation has to take place, as not each format holds all the necessary information. Especially the dd.mm format is tricky, as no year is given. In order to determine the year it was assumed, that no products that have been expired for over three months are scanned. Based on this assumption, the year can be added.

As a final step, the date is checked for its validity. As errors can occur during the image to string transformation, dates that lie more than 10 years in the past or in the future are not accepted. This additional filter can prevent errors in three of the four supported formats.

3.7 Weighing System

When the barcode and expiration date are identified they are saved in a comma separated value file (CSV). In addition, every item is assigned a check in number which is also saved. In a next step the weight has to be registered. There are two weighing systems integrated in the cupboard.

The first one is measuring the weight of the item on the scanning platform. Its weight is saved for further operations. In addition, the scanner is started when a weight greater than 20 grams is detected.

The second weighing system measures the weight of all products placed on the storage shelf. 4 load cells are situated underneath the shelf and each one of them has a range of 50 kg with an accuracy of 1g. Therefore a total of 200 kg can be measured. When an item is extracted from the kitchen cabinet, the load cells detect a weight difference. Based on that weight difference, the corresponding item can be identified using the weight saved by the first weighing system. Its check in number is set to zero.

Every minute an update is carried out. The object of the update is to calculate the time remaining until a product will expire. The number of days is saved in the CSV file. Furthermore, all rows with check in numbers equal to zero are deleted from the file.

By detecting the weight difference and deleting the corresponding item, a second scan to check the item out can be avoided. In addition the weight can be used to indicate the fill level of each product as the weight when full is given using the barcode database.

3.8 Notification

This chapter will elaborate on how the user is reminded of soon to be expired products. There are two notification systems which the user can access. They will be described in the following.

The Email Reminder:

The smtplib module was used to define a SMTP client session object which can be used to send emails. Moreover, a gmail account was set up to use as an email dispatcher.

Every day at 6am, the CSV file containing all items currently located in the cupboard is updated. Afterwards all products are sorted by their expiration dates. In a further step the list is reduced to items which will expire in 2 days or less. If the list is not empty, it will be edited and sent to the users email. If there are no items expiring during the next 2 days, no email will be sent. By doing so, the user can be reminded of the most pressing items without being lavished by emails.

The Node-RED Dashboard:

In order to have real time access to the content of the cupboard, a Node-RED Dashboard was developed. It offers a more convenient way to view the data as well as a platform to add more features such as a search function or a shopping list creator. The dashboard can be viewed by typing the IP-address of the Raspberry Pi 3B+ and :1880/ui into a web browser. However, it is currently only accessible if the device is located in the same WIFI as the cupboard.

As described in chapter 3.7, the CSV file is updated every minute. After each update all items are sorted into the following three categories:

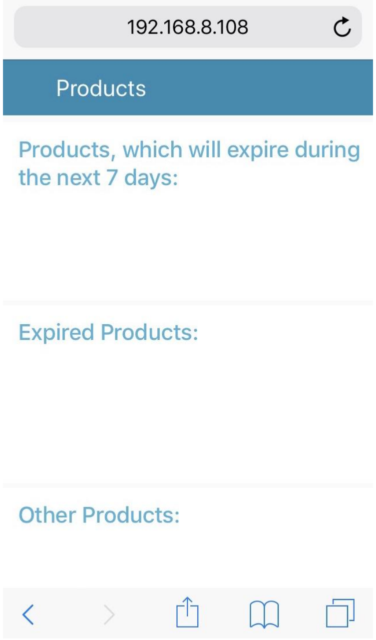

Figure 7: Dashboard on Mobile

1. Products which will expire during the next 7 days
2. Products which have already expired
3. All the remaining products

A MQTT channel is set up to send the sorted items to Node-RED. The string will be edited on Node-RED and posted on the dashboard in three separate text boxes representing the categories listed above.

3.9 The Smart Kitchen Cabinet in Context

The Smart Kitchen Cabinet aims to reduce food waste in private households. The prototype only includes one scanning platform and one storage shelf. However, to create an effective system, all storage shelves in the pantry as well as the in fridge should be equipped with weight sensors.

The whole process starts at the grocery store. The user does the shopping as usual. As most shoppers have an account at their local grocery store, purchases are saved on a platform such as Cumulus. In the future, that account could be paired with the Smart Kitchen so the item would not have to be scanned at home. However, in order for this to work, the store has to incorporate the weight of a product including its packaging in the interpretation of the barcode. Therefore the item could be identified by its weight when placed in the cupboard. Nevertheless, the expiry date is not scanned at the store. Bearing in mind that the goal of the Smart Kitchen is to reduce food waste, the expiration date is essential to the system. As a result, this option will not be explored furthermore.

If the user returns home after grocery shopping it is likely that there are multiple items to be scanned. To speed up the process, there should be multiple scanning platforms available. After the scan, the item can be placed anywhere in the kitchen as long as it is above a weight sensor. When an item is extracted, it is assumed that it will not have the same weight when it is re-entered so it needs to be

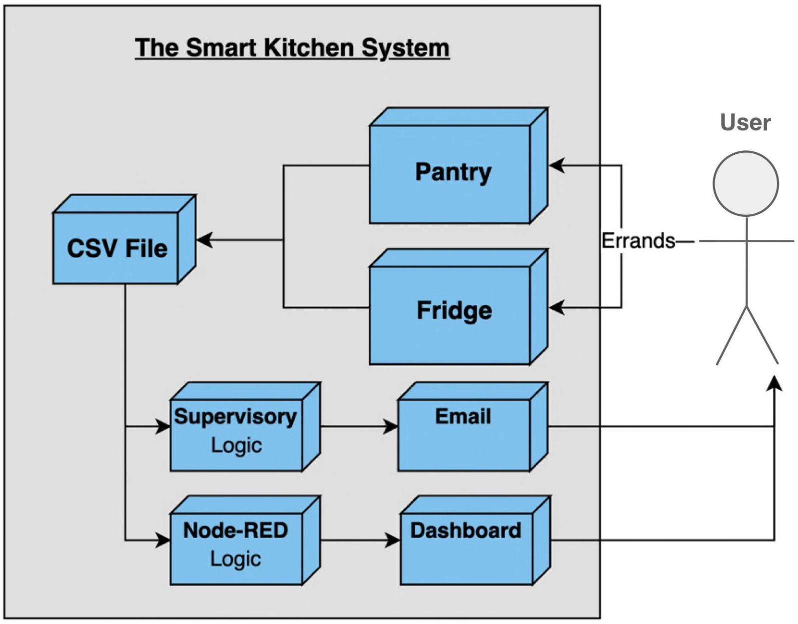

Figure 8: Use Case Diagram of the Smart Kitchen System

scanned again. All the data will be centralized in one CSV file (as seen in figure 9). As there is usually one WIFI network per family, every member of the household can access the Node-RED dashboard and sign up for the email reminder.

```
check in/out,current weight in g,barcode,expiration date,product name,weight when full in g,brand,expires in
1,47,70177118518,02-03-2022, Kamillentee, 25, Twinings of London,727
1,110,5000159498746,26-02-2020, Balisto Nuts Getreideriegel, 156, Balisto,-8
1,346,7610848046615,31-08-2020, Espresso Bohnen Kräftig, 500, Coop Qualité & Prix,179
1,211,7610900047079,0, Pfirsich Vanille Jogurt, 175, Cristallina,no expiration date found
```

Figure 9: CSV File Including 4 Items

4. Results

To determine how accurate the scanning system operates, 20 items were tested. 10 items showed a strong contrast between expiration date and background (black on white or white on black). The other 10 showed expiration dates with lower contrasts (e.g. white on yellow). The barcode was always printed in black and displayed on a white background. The results are stated in table 1.

	High Contrast	Low Contrast	**Total**
Correct Barcodes	5 / 20	-	25 %
Correct Expiration Dates	3 / 10	0 / 10	15 %

Table 1: Recognition rate of 20 scans using the Raspberry Pi cameras

When evaluating the above experiment, it became clear that all expiration dates and barcodes, which were recognized, were printed on the lower surface of the item. This is the only side photographed by the Raspberry Pi Camera (Rev 1.3).
The experiment was repeated in order to determine the impact of the image resolution. The Raspberry Pi cameras were dismounted. Instead two smartphones and one tablet (iPhone SE, iPhone 8 and iPad Pro) were attached. No other changes were made to the setup.

	High Contrast	Low Contrast	**Total**
Correct Barcodes	19 / 20	-	95 %
Correct Expiration Dates	8 / 10	1 / 10	45 %

Table 2: Recognition rate of 20 test scans using smartphone and tablet cameras

A selection of the images taken during the test scans are illustrated in the appendix.

5. Discussion

This project resulted in a prototype, which is able to recognize items and their expiration dates. All components communicate efficiently in order to generate images in a short time frame. Nevertheless, the recognition rate is too low to rely on the smart kitchen cabinet. Therefore the hypothesis has been proven true.

5.1 Accuracy

After replacing the cameras, the number of correct recognitions rose significantly. This is due to the higher resolution of the images. Figure 10 shows a comparison between the cameras. It shows the Raspberry Pi zero, Raspberry Pi 3 B and the iPad Pro camera from above to below. The first image is blurrier than the others and neither the text nor the barcode could be extracted. On the contrary, the text and barcode recognition was successful using the Raspberry Pi 3 B and the iPad Pro camera. It has been established, that there is a strong connection between the image quality and the recognition rate. Nevertheless, as cameras can easily be exchanged, this is not a factor that would lower the usability of the design.

Figure 10: Camera comparison

After conducting the second experiment, the recognition rate of the barcode remained higher than the one of the expiration date. A barcode is generated to

be easily readable by a machine. It is always displayed in black on a white background and therefore shows the highest possible contrast.
Unlike a barcode, the expiration date can be displayed in different fonts, colours and on any background. It is designed to be readable by humans, not by a machine. Nonetheless progresses in AI also imply progresses in character recognition. 80% of the dates showing a high contrast could be recognized. It can therefore be stated, that the character recognition engine offers a high accuracy when a clear distinction between fore- and background can be made.

5.2 Challenges

The main challenge of this project was the under regulation of the expiration date display. Not only are there no restrictions regarding the format of the date, but the date can be displayed anywhere and in any size, font and colour. This implies that a more extensive scanning process has to be conducted to find the date.
For example, if the expiry date would always be displayed on the bottom of the item, only one camera and no rotating platform would be needed. Therefore the time and the processing power needed to find the date would be significantly lower. Furthermore, if the expiration dates were displayed in a more machine readable form (e.g. QR code), a higher accuracy could be guaranteed.
Another challenge was to keep the prototype as low cost as possible. The resources were limited and therefore, components had to be used which are not ideal for the setup. For example, depending on the weight of the item, the servo motor cannot achieve a full rotation in the timeframe given. The torque obtained by the motor is too low. In addition, no machinery was available and therefore all wooden parts are handcrafted. This results in inaccuracies, which have an impact on the rotation.

5.3 Differentiation to Existing Solutions

In the following, two smart kitchen systems will be evaluated and compared to the Smart Kitchen Cabinet.

The Samsung Family Hub:
The Samsung Family Hub is one of the most famous smart fridges currently found on the market. The refrigerator features a 21.5 inch touchscreen

including apps to manage food items and to offer entertainment while cooking. Samsung claims that the fridge reduces food waste because it reminds the user of soon to be expired items. The fridge is equipped with a camera which takes a picture each time the fridge is closed. Afterwards, the user has the possibility to view the image and label different items. The refrigerator therefore depends on the user to add information such as the expiration date and even the name. In comparison, the Smart Kitchen Cabinet is more self-sufficient, as less user input is required. In general, it can be said that the Family Hub lays a stronger focus on the user experience than the reduction of food waste as proven by the variety of entertainment options offered by the Family Hub. [7]

Ovie Smarterware:

The Ovie Smarterware is a storage system consisting of food containers and pins. They are equipped with LEDs that light up in green, yellow and blue. When a new food item with a high risk of expiring is purchased, the user can attach a pin and tell Alexa the name of the new item. It then calculates the average shelf time and changes colors based on the age of the item. Additionally, the user is reminded on an app when an item changes its color.
The central aim of Ovie Smartware is to fight food waste, which can be achieved on a small budget. However, an Alexa needs to be present for the system to work and the expiration dates are unspecific as some products are sold shortly before their expiration date. Nevertheless, using an average shelf life is an effective way considering that many expiration dates cannot be identified using OCR. [8]

Generally, it can be said that both alternative systems require more responsibility from the user. The consumer has to be informed on how much food waste is generated and which items are at risk so he can set up a reminder. However, such responsibility cannot always be anticipated which is why the Smart Kitchen Cabinet strives towards reducing any user input.

6. Further Steps

Even though the main goal of the smart kitchen cabinet is to recognize items and their expiry dates, there are countless features, which would improve the setup and user friendliness furthermore. Some of the enhancements that are are described below.

6.1 Recipe Proposition

One of the reasons for food waste in the Swiss households is the lack of knowledge about ways to utilize leftover food. In order to embark on this problem, a recipe proposition could be implemented. A database containing numerous recipes is required. Recipes including as many available items as possible can then be posted on the Node-RED Dashboard. Items, which are close to their expiration date are prioritised. Therefore ways to utilize leftover food are suggested and the user might be able to avoid going to the supermarket on some days.

6.2 Specifications of the Expiration Dates

In Switzerland, many items are marked with either a „zu verbrauchen bis‟ or a „mindestens haltbar bis‟ sign. If a product is marked with the „zu verbrauchen bis‟ sign, the item should be used before the expiration date. Those items are often health threatening if they are consumed after their expiration date. On the other hand the „mindestens haltbar bis‟ signifies that the quality of the product can only be ensured until the expiration date. However, consuming it after the expiration date does in most cases not have an impact on the health. Currently, the scanner does not recognize those signs. Nevertheless, their distinction can offer more information about a certain product. When an item marked with a „mindestens haltbar bis‟ sign expires, it can be stated that the item might still be edible. As a result, the user is sensitised and motivated to use the human senses in order to determine whether the product is still safe to consume.

7. Conclusion

A functional prototype was constructed, which can remind the user of the expiration date and therefore prevent food waste. When a strong contrast between the expiry date and the background is given, the scanner is able to identify most expiration dates and barcodes. However, when the contrast is low, only few dates are recognized. As a result the user cannot rely fully on this system until regulations addressing the expiration date display are introduced. Therefore the hypothesis has been proven true.

To conclude it shall be said, that even though the expiration date gives information about whether a product is safe to consume, it cannot replace checking the item with the human senses. Canned items can in many cases be consumed years after their expiration date. Hence the smart kitchen cabinet does not aim on replacing the human senses but offer a tracking system to prevent items from being forgotten.

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Table of Figures

Appendix

Images of expiration dates taken with smartphone cameras.

Image 1: Not Recognized

Image 2: Recognized

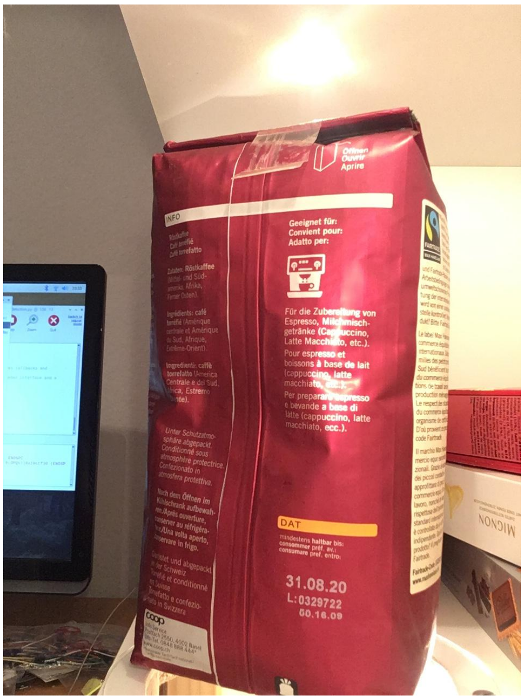

Image 3: Not Recognized

Image 4: Not Recognized

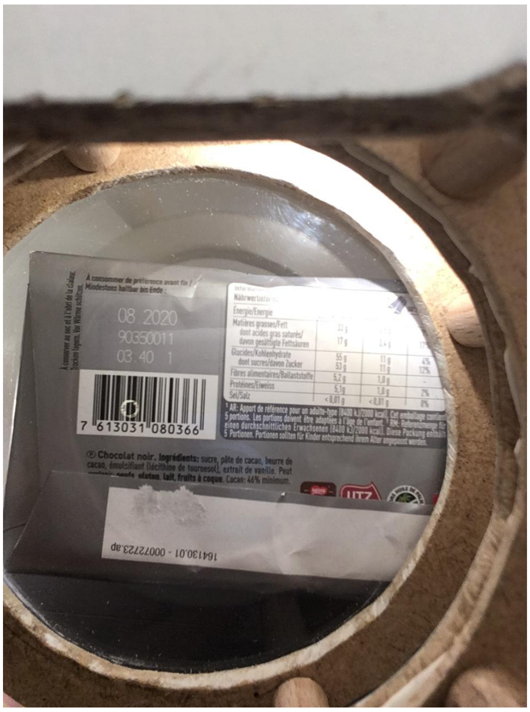

Image 5: Recognized

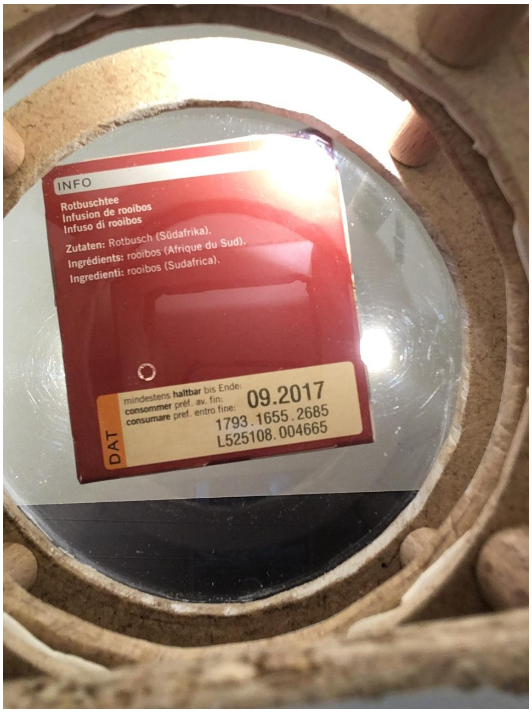

Image 6: Not Recognized

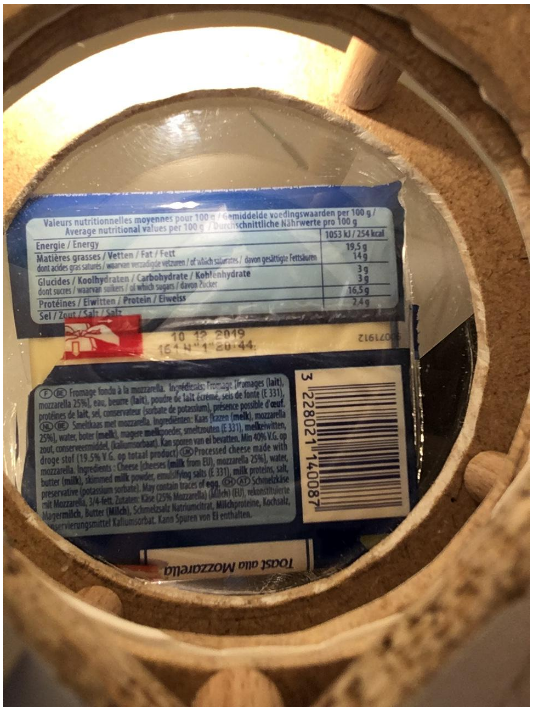

Image 7: Recognized

Image 8: Not Recognize

The Final Product: