MAVI: Measuring Assistant for Visually Impaired

Final report Engineering Design (4WBB0)

October 26, 2020

Group no: 075	
Name	**Student ID**
David Becker	1464116
Ruud Erens	1440780
Jeroen Hellenbrand	1414844
Bob Keulers	1451332
Raf Leclaire	1465341
Noah van Rossum	1446681
Rik Tieben	1453637

1 Group effectiveness

The group consisted of two people from Mechanical Engineering, one from Computer Science and Engineering, one from Industrial Engineering, one from Biomedical Engineering, one from the Built Environment and one from Applied Physics. This gave our group a very diverse background. While the people from Mechanical Engineering, Biomedical Engineering and the Built Environment had a lot of practical knowledge, the people from Computer Science, Physics and Industrial Engineering had a lot of theoretical and programming knowledge. This diversity made it easier to divide tasks in the group, as most people would volunteer for tasks they know they are good at. The capability of the group is visualised per major in Figure 1. As you can see, all important capabilities for this project are covered by the group. In the radar chart, it is visible that the strengths of the group are working in a team and writing a report while the weakness of the group is creativity.

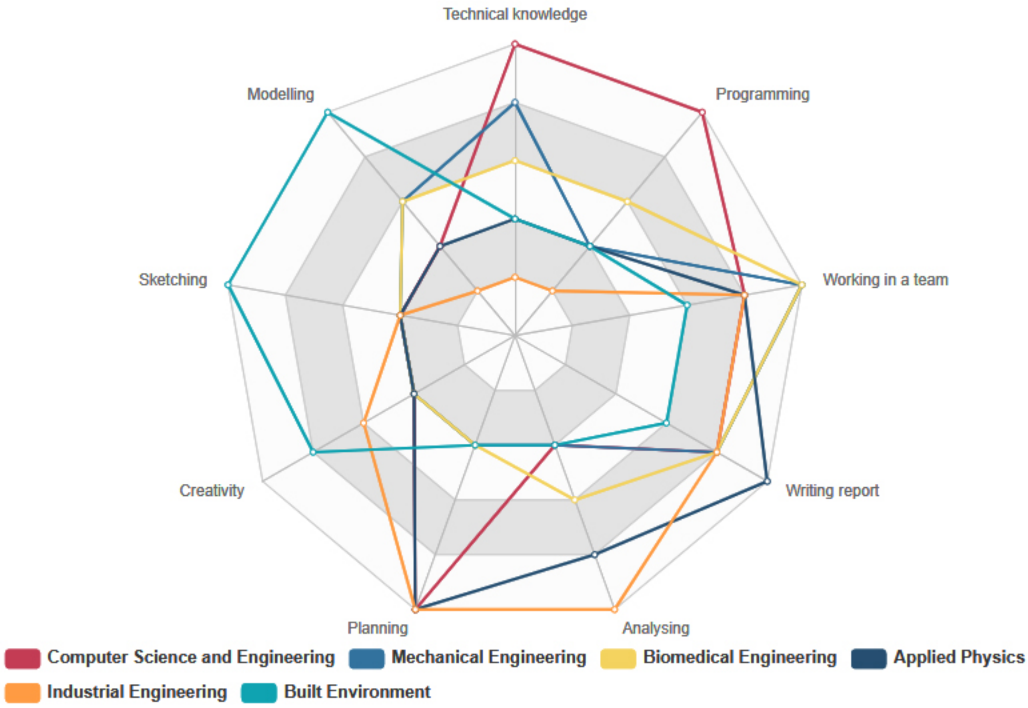


Figure 1: Capabilities of the group visualized in a radar chart

One of the strengths of the group during the start of the project was that every team member was very motivated to work on an aid for personal, in-house use, for people with an impairment or disability. After deciding on the final product, every group member supplemented the emerging problems of the product with solutions, which constantly improved the idea. The group did this with nearly every problem to maximize the result. This process led to the best possible design for the product. Another strength of this group is that every single person excels in the subject he is working on. Besides, every group member finished the work on time, so the process would not get stuck. During the project, the team got to know each other's abilities, strengths and weaknesses. This resulted in a more efficient task distribution.

The group meetings were structured and well organized. This is due to the fact that everyone has been present, on time and prepared for every meeting. Each meeting was lead by the chairman, who created an agenda of the most important topics that should be discussed during the meeting. Every member had to become chairman at least once, and everyone took this task seriously. Each meeting, one team member was assigned as secretary. The secretary had to take notes during the meetings and make sure that every important decision was written down. The task of chairman and secretary was alternated every meeting. For each meeting, everyone had to do a Self Study Assignment (SSA) in which they noted down what they have done and their findings. Each SSA of every team member was done with care and was very comprehensive, which made the progress of the project go rapidly. During the meetings, everyone in the group could speak about their tasks and share their findings. After someone was finished, the fellow students could comment and ask questions about the findings. All the things mentioned by any student is respected by the other students. For example, when one person was talking, the others listened without interrupting. Any comments on the topic would be discussed after the person had finished talking. In this way the group builds trust and respect for each other.

As a group, cooperation was strength during the project. The communication was organized not only in the meetings, but also online via a group chat. Furthermore, whenever there was a task which had to be done by multiple people, the communication between these people was great. Voice calls were frequently used to communicate with each other while working on a task, documents were shared through a mutual Google-drive, which enabled everyone to work cooperatively.

A possible weakness was that every group member trusted each other blindly, which could lead to mistakes being overlooked. This is because every team member had their own strengths, and therefore picked the tasks which they felt confident doing. Because of this, other group members didn't get the opportunity to master the task. For example, the group trusted the Computer Science and Engineering student to program the Arduino Nano since this person had the most experience in programming. However, since the others had no programming experience whatsoever, mistakes in the code could be overlooked. We resolved this by assigning another student to this specific task. This student would learn how to program a micro controller in C++. By doing this, possible mistakes were less likely to be overlooked and the other student could learn new things, namely programming in C++. As one of the major goals in this project was to learn new things, this was very important. The fact that the group members were confident to trust each other was also one of the greatest strengths of the group.

At the start of the project, the group had struggles with dividing the tasks such that everyone can learn new things, as every person in the group does the task which fits their skill. This is obviously effective, however it might lead to less gain of knowledge in this project. The only way too gain more knowledge about certain subjects is to do things out of your comfort zone. This issue was brought up during our midterm evaluation, during which we discussed how to tackle this matter in the best way possible. After some consideration, we decided to alter the tasks in such a way that the group members who previously worked on the report would focus more on testing and error analysis, whilst the people who worked out the preliminary design would continue working on the report. This way there would be more variation in the tasks and ensures that every member of the group is involved in every aspect of the project, which enabled everyone to work outside of their comfort zone, maximizing the experience and knowledge gained from this project.

2 Design goal

During the first meeting, all members of the group brought up ideas on an aid that people with a disability could help with their in-house problems. After hearing and discussing all ideas, it became clear that the majority of the group had ideas on how to help blind and/or visually impaired people. Vision impairment is a decreased ability to see to a degree that causes problems not fixable by usual means, such as glasses, with a visual acuity of worse than either 20/40 or 20/60. The focus of the next meetings was on the visually-impaired audience. During these meetings the question arose: what do visually impaired struggle with the most? This is why daily tasks, which seemed normal to us, were taken a closer look at. How do visually impaired people do these tasks without any help? Eventually, the group decided to create some aid that would help people with a visual impairment to cook since this is an essential task which creates happiness for a lot of people [6]. After taking a look at existing cooking related aids for visually impaired people, a measuring cup that can easily be used by visually impaired people and a device in the form of a glove that detects heat from a distance that would prevent burning ones hands were investigated. After comparing the feasibility, usability and market potential of both designs, the measuring cup was chosen to be the design goal.

A member of the group had a conversation with someone who is visually impaired. Questions such as "how do you measure a specific amount of water?" were asked. The conclusion was that this person had a hard time using a measuring cup without assistance. Instead of a measuring cup, this person used multiple small cups with different sizes which all can contain a different amount of water. This was not convenient since the person would be restricted to these amount of water. For example, this person has cups of 100mL, 200mL and 500mL. When this person would want 350mL, it would be very difficult. The visually impaired will be restricted while cooking or baking , this results in them feeling more dependent of others while they actually want to feel independent.

It is clear that is very hard for visually impaired people to measure a specific quantity of a liquid. The inability of visually impaired people to use such a kitchen gadget increases the struggle to cope independently [7], while kitchen gadgets designed for visually impaired people increase their confidence and independence [9]. This made it very interesting to design a measuring cup. A measuring cup can have several functions, is realistic to design within 8 weeks and will fit within the budget of €70,-. As we had students in the group who had experience with 3D printing, students with technical knowledge and a student who had programming knowledge, we felt capable of designing such a measuring cup. The idea was set in motion.

Research was done on the existence of a measuring cup designed for the visually impaired. There exist braille measuring cups with a fixed (low) capacity. However, this is not useful for specific amounts as discussed previously. Besides these small cups, there exists a measuring cup for the visually impaired that can hold up to 700mL. This measuring cup, designed by Jason Yore [22] and shown in Figure 2, works with a float mechanism in which an indicator outside the cup will move to the corresponding volume. Because of this, visually impaired people can measure more specific amounts up to 700mL.

Figure 2: Measuring cup for the visually impaired, designed by Jason Yore [22]

However, the user could not specify an amount of water beforehand, and could only know the volume by finding the indicator with his/her hand. This can be dangerous when using hot liquids. Besides, the design of this measuring cup seemed impractical for visually impaired users as the handle of the cup was weirdly placed. These shortcomings resulted in an innovative idea to create a measuring cup in which the user can input their desired amount and hear a sound if this amount has been reached. The cup will have several utilities as it can be used for cooking but also for other things such as measuring drinks. The idea is innovative since the product stands out from the competitors and will make the lives of the visually impaired easier. After pitching the idea to someone who is visually impaired, it seemed that the aid would be helpful to that person and they would be inclined to buy the aid for themselves.

To summarize, the group had a preference and interest in helping visually impaired people. The project assignment stated that the tool should help in the household, as a group the preference quickly went to a measuring cup with adjustable values that one can choose. This cup will allow visually impaired people to be a lot more independent when cooking, baking or even making a cup of tea.

3 Functional design and solutions

To create a clear overview of the vision in mind for this project, a list of functions and RPC's (Requirements, preferences and constraints) were created with their possible solutions. The functions were prioritized using the MoSCoW method [1]. After the functions, the RPC's were given with its own solution encyclopedia, since these were very important in the designing phase to improve the final design.

Functions:

1. Measure water level
2. Giving a signal
3. Get input from user

Solutions for the functions:

1. Measure water level:
   - Water level sensor.
   - Multiple moisture sensors.
   - Floater sensor.
   - Funnel with flow sensor.
   - Floating part with a distance sensor.
2. Giving a signal:
   - Sound signal.
   - Vibrating signal.
   - Light flash.
   - Speaker calling out the amounts in the cup.
   - Use a servo to push a bar along the handle as sign of how full it is.
3. Get input form user:
   - Multiple pressure sensors as keypad.
   - Matrix keypad.
   - Microphone with voice detection.
   - Make a sensing strip along the cup so people can put their finger on the height of the liquid they want. (This is not for exact amounts)
   - Make a slid along the handle where people can slide up a part of which the height will be measures as input of how high the liquid should be.

General Musts:

- Relatively small (for reasons of practicality): it must fit in a box of 0.34 x 0.23 x 0.31 m.
- Fit in budget of €70,-.
- Have a combination of sensor(s) and actuator(s) embedded.
- Built from parts that do not have a complete function.
- Function autonomously or by interaction with the user.
- Safe to use.

[1] The MoSCoW method is used to classify both functional and technical specifications. MoSCoW is short for: must have, should have, could have, won't have.

Product specific
Should:

- Have a clear alarming system for when the required volume is reached.
- Be precise.
- Easy to use.

Could:

- Be light.
- Have an easy to use shape.

Won't:

- Be visually the nicest.
- Have a voice signal output.

Solution encyclopedia
Musts:

- Let the volume of the measuring cup be at most 0.5 L.
- Use cheap materials.
- Buy materials outside the Netherlands / Europe, preferably from China.
- Place sensors inside the measuring cup and put activators are outside the cup as a speaker.
- Combine sensors and activators yourself to create a complete function.
- Immediately activate when the sensors are in contact to water.
- Let the user press a button to start measuring.
- Use materials that won't leak any harmful substances when water gets in contact with it. (I.e. don't use plastics with BPA's)
- Add rubber to the edges to make sure the product won't break when falling.

Should:

- Use multiple (small) speakers.
- Make use of a vibration motor.
- Have a clear/neutral voice.
- Use multiple measurement methods. (Weight and volume)
- Use precise sensors.
- Use multiple sensors in the cup to cancel out errors.
- Add a button which will play an audio instruction on how to use the product.

Could:

- Limit the electronics.
- Use lightweight materials such as magnesium.
- Add a handle.
- Add a spout.

4 Design concepts

The three design concepts that met the design goal differed from each other by the method of measuring the amount of liquid since every design concept used different sensors for measuring the liquid. The design of the cup was nearly the same for all three design concepts as a traditional design of a measuring cup is used.

4.1 First design concept

The first of the three design concepts was the concept with the floater sensor as shown in Figure 3. When the water level rises, the sensor would move along the pole. As soon as the sensor reaches a certain level, the signal would be changed and the actuator would be turned on.
The sensor would be placed standing up in the cup as visible in Figure 4. To make the design waterproof, the cables would be led through the bottom of the cup, because the screw of the sensor is waterproof. This creates a perfect possibility to make a second department underneath the cup to store all the electronics. Besides, the keypad is visible on the side where the users could put in the desired amount of liquid.

Considering a 1L measuring cup with a 10 cm long sensor, the cup would need an inside diameter of 11.2cm according to Formula 1, which would make enough space for a 18x45mm Arduino Nano and a 30x40x9.5mm buzzer. The second department of the measuring cup would need a height of approximately 2cm to store all the electronics. On the outside of the cup, a small braille keyboard will be attached to enter the desired amount of liquid.

$$V = h * \frac{1}{4} * d^2 * \pi \tag{1}$$

Figure 3: Float sensor

Figure 4: Prototype 1

4.2 Second design concept

The second design concept was to create a measuring cup with multiple water detecting sensors lined up to measure the water level. The cup with the sensors and the hollow handle for the cables is visible in Figure 5. Together they measure the quantity of the liquid and this would give a value for the amount of liquid in the cup. The sensors would collaborate. On the top of the handle, a keyboard would be attached to set the preferred level of the liquid.

As mentioned before, the design of the measuring cup itself will be nearly the same for all three design concepts. Just as the first design, the second design used a second department underneath the cup as well as visible in Figure 6. The cables would go through the handle of the cup to the bottom of the cup. This makes it different from the first design.
A problem is to make the design waterproof because this design has no screw or something else which is already waterproof. The cables would be led to the bottom, through a hole in the cup, so this implies that the model will not be waterproof.

Figure 5: Prototype 2

Figure 6: Bottom view

4.3 Third design concept

The third design concept was to create a measuring cup with a long strip visible in Figure 7, this strip would be attached from the bottom of the cup to the top of the cup, to measure the level of the liquid at any given time. A small keyboard would be attached to the cup, to set the desired level of the liquid. This keyboard would be suitable for blind people, by attaching a braille dot on the 5. By attaching this dot, blind people could navigate and would be able to enter the desired level of liquid needed. This is sufficient as blind people are used to navigating on such a keypad by using pin terminals.

Just like the other design concepts, this concept had a second department underneath the cup. This department is very useful to store all the electronics (visible in Figure 8), such as the Arduino and the batteries. The cables will be led through a hole to the Arduino and the batteries.

For this design concept the same problem as the second design concept existed. There needed to be a hole in the design for all the cables, however the liquid is not allowed to reach the electronics. So, the problem was again that the device is not waterproof. This could be solved by using rubber or something else, to close the hole and make the design waterproof.

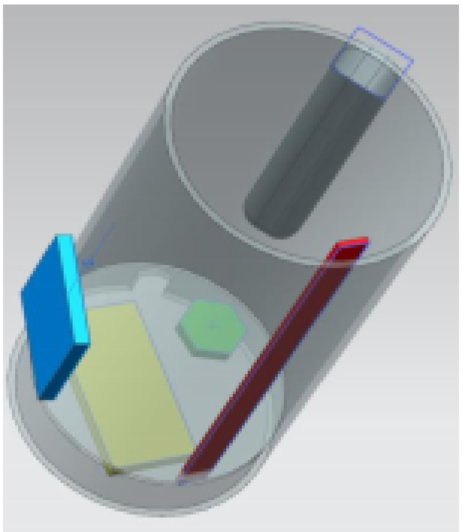


Figure 7: Prototype 3

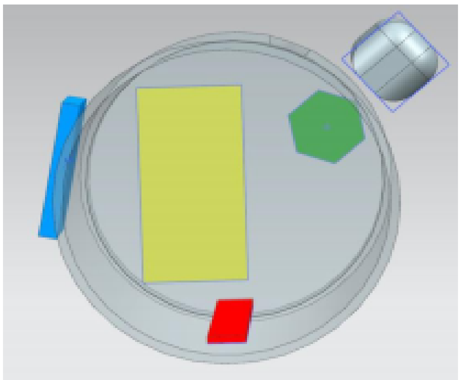


Figure 8: Top view

5 Final design concept

After the three possible design concepts were presented, the third one was chosen (see Section 4.3). This was the most practical design with the best sensor. The first design had a sensor which was very unpractical and the second design was too imprecise. The preliminary design is shown in Figures 9, 10 and 11. The water level sensor is clearly visible in the top view with the cables running through a double-wall towards the bottom compartment, which would be closed off with glue to make sure the device would be waterproof. Also, the cables of the keypad on the front view are running toward the bottom compartment with the rest of the electronics in the bottom view.

The design meets the functional specification and also meets the RPC's from Section 3. The sensor can measure the water level within a 5mm accuracy which will result in a 50mL accuracy for the cup. The signal is given by a buzzer and the user can give their requested amount of liquid as input via the matrix keypad.

The product will be very user-friendly with the braille keypad to give input. It also will get a pleasant handle to hold grab it and an easy way to poor water with a pouring spout. Of course, making it very user-friendly creates challenges such as making the keypad usable for blind people by adjusting it to braille keys. Also, making it a pleasant to handle product is challenging, the best and cheapest way to design it is by 3D printing. This needed a lot of developing time in CAD since it needed to be very precise to be as watertight as possible and made all the electronics fit. The product is innovative because of the possibility for the blind people to give their requested amount of liquid as input.

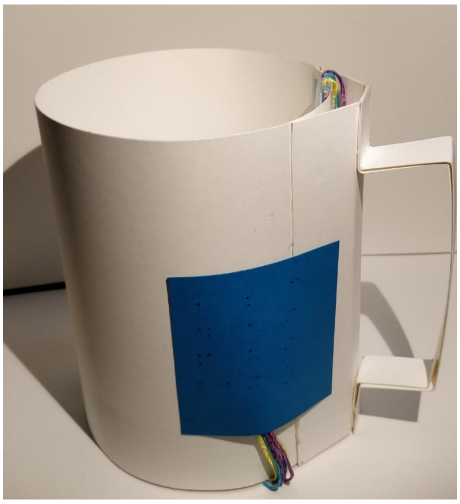


Figure 9: Front view.

Figure 10: top view.

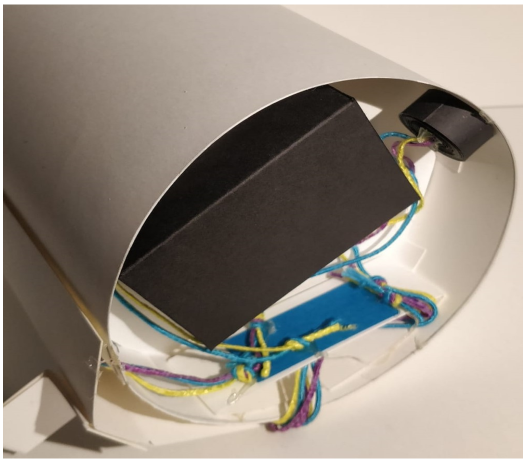


Figure 11: Bottom view.

6 Technical specification

The product should have certain technical specifications which are defined below using the MoSCoW prioritization method. To achieve these functions, the most convenient components were chosen and described.

Musts:

- The maximum absolute difference between the measured value and the real value should be less than 25mL.
- The speaker is loud and clear. A minimal volume of 70 decibels. (A little less than typical alarm clocks)
- The speaker can output multiple frequencies.
- Function autonomously or by interaction of the user.
- Function with temperatures up to 100°C. (To be able to function with boiling water)
- The electronics have to be protected from the liquid to make sure there will not be any short-circuiting.

Should:

- The aid should work on batteries. (To remove moving restrictions and danger for short-circuiting)
- User should be able to define a requested amount of liquid.
- The speaker should give live feedback on the amount in the cup.

Could:

- Have a charging pad.

Won't:

- Be dishwasher safe.
- Have a voice signal in-/output.

In order to meet the technical specifications the following parts were collected:

Board:
The board needed to have at least 14 pints to be able to connect to a speaker, sensor, keypad and battery. Besides, it should be able to connect to any laptop to be able to program the board. This was the case for any board. Since the board needed to fit in a small component and the project is bounded by a budget, the Arduino Nano as shown in Figure 12 was the best pick with dimensions of 18 x 45 mm and cost between €7 and €20 depending on the chip used. The board also needed to have headers to be able to connect cables to the board easily, these headers were sold separately or already soldered to the board. There were 2 variants of the Arduino Nano in which the only difference is the chip used. As the measuring cup won't need extra RAM or extra functions which the ATmega4809-chip provides [11], the cheaper version of the Arduino Nano with the ATmega328P-chip [5] should be sufficient.

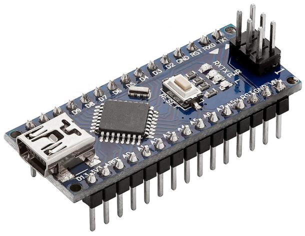


Figure 12: Arduino Nano

Sensor:
The water level sensor needed to be long and be able to function in different temperatures. As defined in the must, the sensor had to be precise. After researching multiple sensors, the Grove Water Level Sensor [13], as shown in Figure 13, was the best pick. This was because it has an accuracy of 5mm (which means 50mL in a 1L cup of 10cm long) and a length of 10cm, while other sensors were way smaller. The sensor is waterproof and can function in temperatures from -40°C to 105°C. To attach the sensor to the Arduino Nano, a conversion cable from Grove 4 pin to male jumper was needed and the 4 cables to the GND, SCL, SDA and 5V pins should be connected as shown in A.1.

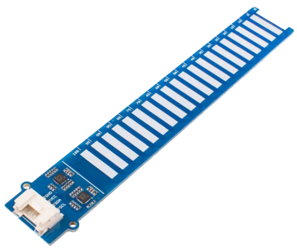


Figure 13: Grove Water Level sensor

Figure 14: Piëzo buzzer

Speaker:
As described in the technical specifications above, the speaker needed to be loud, clear and be able to output multiple frequencies. To keep costs low, the speaker used is a simple buzzer without any chip and thus with only two cables. It is a GLOGLOW piezo buzzer as visible in Figure 14. The buzzer has a volume of 85dB and can output multiple frequencies [4]. However, the buzzer is not waterproof, so this will be taken into account when placing it in the cup.

Battery:
To power the Arduino Nano and remove moving restrictions, 3 x AA (or AAA) alkaline cells (4.5v) are required. For this a battery holder and the batteries were needed. The battery life has been calculated to be 39.5 hours.

Keypad:
To enable interaction with the user, a keypad has to be added. The keypad lets the user define a quantity of liquid to his/her desire. The keypad needs to have 12 keys: 10 numbers in the range 0 till 9 and an accept/reject button. The 3X4 flexible matrix keypad [10], as shown in Figure 15,is used as it satisfies the conditions. It can be stuck onto the cup very easily because of the self-adhesive backing. To make the keypad useable for blind people, braille numbers will be added on top of the keys.

Figure 15: 3X4 flexible matrix keypad

By using these components for the final product, all 'musts' and 'shoulds' of the technical specification list and function list were satisfied. The defined 'won'ts' were unrealistic to realize in the given budget and are therefore not taken into account.

7 Detailing

In this section, the taken steps in the detailing process will be described. In particular, the design of three key components will be elaborated on. These key components are the sensor, the in/output and the 3D printing of the cup.

The sensor

In the detailing phase of the design process, a lot of testing was involved to gather information to optimize the design and the function of the design. Testing of the water level sensor was a very important factor because this is the most important part of the product. The sensor gave a signal in the form of the percentage of the sensor which was underwater. The sensor had a length of 10 cm so 1% would be 1 mm which would mean 10 mL according to the measurements used which are given in section 4.1. When the given value was not in line with the real value, the measuring cup was not working as it was supposed to be. Hence, testing of the sensor was very important for the optimization of the design. To optimize the design it was important to know the error of the sensor. To get this error, the sensor was tested on different amounts of water. These tests were done multiple times to get the most accurate results. The results will be shown at a later stage in Section 9. When the error value is known, the programming can be changed to get the right amount of value. When the error is consistent, a specific value could be added or subtracted in order to obtain the real value. In the case of the Grove Water Level Sensor [13], a systematic error was measured to be exactly 50mL. Therefore, 50mL is subtracted from the measured value in the code.

The in/output

Another important part for the optimization of the design was the input and output of the measuring cup, as blind people should be able to use the device easily.

To make sure blind people can use the keypad, the corresponding braille marking has been added to the number 5, the OK and delete key. To get the user input from the keypad, the program constantly checks if the user pressed a key. If this is the case, that particular key gets added to an array. As soon as the user presses the # key (OK), the array, containing the desired value, will be sent to the Arduino Nano which will constantly check if the measured value is equal to the array. To get out of this loop, the user can simply press any key. If the user made a mistake when pressing a key, he/she can simply remove this number by pressing the ∗ key (delete). This section of the code is given below.

```
void loop(){
  char customKey = customKeypad.getKey();
  if (customKey){
    if (customKey == '#') {
      tone(BUZZER_PIN, 2400, 100);          // Turn on buzzer
      Value = atoi(Data);                   // Convert the data array to Value
      check();                              // Pass the data to sensor
      clearData();                          // Clear the data
    } else if (customKey == '*') {
      Data[data_count] = 0;                 // Delete the last entry
      data_count --;                        // length of number decreases by 1
      tone(BUZZER_PIN, 2100, 100);          // Turn on buzzer
    } else {
      Data[data_count] = customKey;         // Save entry on the array
      data_count++;                         // Increase the length of the number
      tone(BUZZER_PIN, 4000, 100);          // Turn on buzzer
    }
  } else {
    digitalWrite(BUZZER_PIN, LOW);          // Turn off buzzer
  }
}
```

A lot of tests were conducted involving the optimization of the buzzer, the output of the product. The buzzer has to be loud enough for the user to hear. To be more precise, the buzzer has to be at least 6 dB louder than the sound of the water from the tap. Because of this, the buzzer needs to produce a sound of at least 80 dB. This is why the GLOGLOW Piezo Buzzer [4] has been used. As blind people are very dependent on sounds, the buzzer will produce a sound whenever the user presses a key, or when the desired amount has been reached.

Additionally, a kind of park system was created to optimize the design. When the amount of liquid gets closer to the required value, the buzzer starts making a sound. The closer the amount of liquid is to the required amount of liquid, the faster the buzzer start zooming. This was a very suitable feature to implement in the design because with these system blind people know when to turn out the tap in order to receive the required value. This was an important step in order to optimize the design and to achieve the design goal. The code that made this work is given below.

```
void alarm(int mV, int V, uint8_t trig){
    if (mV < V){
      if( (0.5*V-30)<= mV & mV <= (0.5*V+30)){
      tone(BUZZER_PIN, 2800, 100);
        } else if( (0.75*V-50)<= mV & mV <= (0.75*V+50)){
            tone(BUZZER_PIN, 2800, 100);
            delay (500);
            tone(BUZZER_PIN, 2800, 100);
        } else if ((0.90*V-50)<= mV & mV <= (0.90*V+25)) {
            tone(BUZZER_PIN, 2800, 100);
            delay (250);
            tone(BUZZER_PIN, 2800, 100);
            delay (250);
            tone(BUZZER_PIN, 2800, 100);
        } if ((0.95*V-25)<= mV & mV <= (0.95*V+50)){
            tone(BUZZER_PIN, 2800, 100);
            delay (125);
            tone(BUZZER_PIN, 2800, 100);
            delay (125);
            tone(BUZZER_PIN, 2800, 100);
            delay (125);
            tone(BUZZER_PIN, 2800, 100);
        }
       else{
        digitalWrite(BUZZER_PIN, LOW);
       }
    }
}
```

3D printing

To produce the cup, a 3D-printer was used. Since the cup is quite big, it was printed by one of the group members who has a 3D-printer at home. There were two possible materials to use: PLA and PETG. As the specifications of PLA and PETG do not differ that much, the decision was made to use the cheapest material, namely PLA.
PLA can resist heat up to 55°C [20], which is not very high. This temperature is not sufficient when the user wants to measure boiling water. When water with a higher temperature is poured into the measuring cup, the PLA will melt which will be dangerous for the user. So the use of material might be a problem for our design process because it needs to resist higher temperatures than 55°C. PETG can resist heat up to 68°C [17], which is higher than PLA, but not high enough to use boiling water in combination with the measuring cup.
PLA and PETG are both made from natural products, nevertheless, the chemicals involved to give the material its colour and the chemicals of the printing machine could be dangerous if realised into the liquid. However, the chemicals will not be released when using the measuring cup for water, so the safety of the material would not be a problem for our design process. [14] [16]
Within the cup design, it was important to make sure the lower compartment with the electronics is waterproof. To ensure this, all parts are closed off with hot glue and electrical/isolation tape. The bottom part and the top part were made separately and fitted on top each other by pins and then were glued together. The cables of the sensor are led through the shaft in the wall to the lower compartment. Once everything was in place, this shaft was also be closed off with hot glue, just as the hole where the cables for the keypad go through. In the bottom of the cup, there is a hole for the battery-holder in order for the user to switch the batteries when the batteries run out of power. The battery-holder is kept in place by hot glue which directly makes it watertight. The entire bottom compartment is closed off from water in the end.

8 Realization

After discussing multiple ideas for this assignment, a measuring cup was the most suitable idea, since it was possible within the budget and highly demanded. Since our design is made for a specific audience, blind/visually impaired people, usability is highly important. This is actually the most important factor in our design. To achieve a usable product for visually impaired people, there are many steps which need to be taken to create our final product which will be called the MAVI, the Measuring Assistant for Visually Impaired.

Figure 16: Logo MAVI

Technical and Functional specifications
While realising the product, the specifications are highly important. The design should be based on these specifications. With every decision in the design, these specifications have been taken into account. So also in every step in the realization, the focus is on the specifications.

Preliminary tests
Before the final design could be built, preliminary tests had to be performed. Individual components had to be checked for water resistance and compatibility with the Arduino. One of the electronics did not work as planned, so this product has to be re-ordered. Since the group worked in a structured way, there was enough time for this. Furthermore, the dimensions of the component had to be measured, in order to ensure everything fits into the cup. For all the separate kinds of parts, different tests were made. Finally, for the final product, a few tests were made.

3D printing
First all the components of the cup needed to be 3D printed separately. It is actually split into 3 parts, the bottom part, the actual cup and the handle which will be attached to each other. The bottom part is where almost all of the waterproof electronics will be placed and the keypad is on the side of the cup. To make sure the battery holder (which will be accessible at the bottom of the cup) will not be in the water when the cup stands on a wet surface, an extra ring with a height of 1cm is added under the bottom compartment.

Tests for 3D printed parts:

- ☐ Is the device waterproof without the electronics included (the cup itself)?
  - ○ Fill the cup with water for at least 24 hours.

Electronics
All electronics which were listed in section 6 were ordered. First, all the separate components were tested on the Arduino Nano with basic code for these components. These tests were conducted by connecting the components directly to the Arduino through the header pins, no breadboard was used. Also, a few physical tests were conducted to the electronics to make sure what the best way to put them in the device would be.

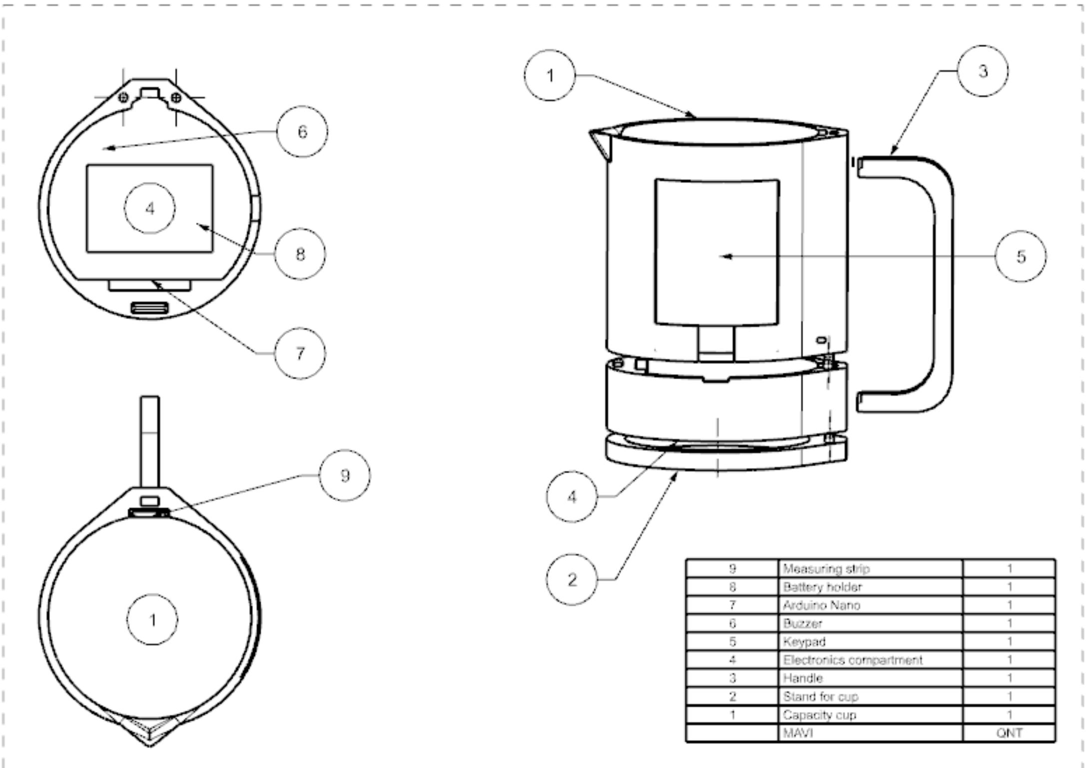
Tests for electronics:

- ☐ Are the sensors waterproof?
  - ◦ First check description on the internet, if not waterproof no further test is needed. If waterproof, confirm it by placing the sensor in the water and see if it transmits any output.
- ☐ Speaker is waterproof
  - ◦ First check description on the internet, if it is not waterproof, no further test is needed.
- ☐ Do the electronic components connect to the Arduino?
  - ◦ For every component, run a basic code in order to check if the component is compatible.
- ☐ Does the speaker produce noise?
  - ◦ Write a code for the speaker, and check if it produces noise.
- ☐ Does the sensor register water levels?
  - ◦ Write a code for the sensor, and check if it is working and registering water levels.
- ☐ Does the keypad register input?
  - ◦ Write a code for the keypad and check if it is registering the input correctly.

Assembling
All the components went through the tests, after which the keypad had to be re-ordered. Also, the sensor was found to not be waterproof at the connection part and the buzzer was waterproof. This lead to the final decision to make the speaker not visible to the outside world and tape connections of the sensor with isolation tape to make it waterproof. (These decisions were already the idea, now they were confirmed)
The final device was assembled according to the blueprint visible in figure 17. As well as the test plan in section 9, the following tests were conducted on the final device.

Tests assembly:

- ☐ Does everything fit into the cup?
  - ◦ Place every component, and see if the compartment closes. If the compartment can be easily closed, it will be a sign that everything fits. (Figure 18)
- ☐ Is the cup easy to hold?
  - ◦ Take the cup in your hands and try to see if it is easy to hold it without any liquid inside. Repeat this step again, but this time make sure that the cup is full.
- ☐ Is the device waterproof with the electronics included? (Is the entrance for the cables waterproof)
  - ◦ Fill the cup with water for another 24 hours, but now with the electronics integrated.



9	Measuring strip	1
8	Battery holder	1
7	Arduino Nano	1
6	Buzzer	1
5	Keypad	1
4	Electronics compartment	1
3	Handle	1
2	Stand for cup	1
1	Capacity cup	1
	MAVI	QNT

Figure 17: Blueprint MAVI

Results of tests

According to the fit tests we can conclude that everything functions well and the cup is easy to hold in your hands with and without liquids in it. The electronic components connect well to the Arduino, the speaker produces the right noise and the sensor registers the water level. Also, the keypad registers input. So all the components are working well on their own and together. The final design is visible in figure 19 and 20.

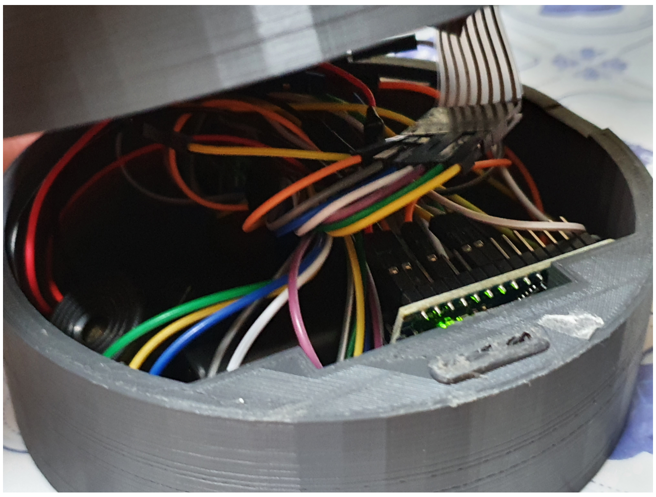


Figure 18: Fit test of the components in the final product

Figure 19: MAVI

Figure 20: MAVI

Plan for Production

The 3D printed parts were self-manufactured, which needed some time to do it right. All measurements needed to be exactly right and the cup needed to be sturdy to be able to hold the weight of the electronics and the water. Also, the cup needed some user-friendly appeal, it had to be nice to use in order to be a good aid. Therefore the following steps were followed:

1. Make a sketch of the cup with the correct measurements for a 1L cup in Siemens NX12. This was done according to the measurement stated in section 4.1. To make sure the cup was sturdy enough, a wall thickness of 5mm was chosen on test printed parts. (already existing prints used to feel how sturdy it was) The cup height was extended with a few centimetres to make sure the cup would not overflow when 1L was in it. The bottom compartment was made as small as possible, but still with enough room for all the electronics. This lead to a height of 3cm for the 2cm high battery holder with 1cm extra for cables.
2. Next all the exact spaces for the electronics were implemented, this included the slid for the sensor, the double-wall for the cables of the sensor, a hole for the battery holder to be accessible from the outside and a place to hold the Arduino Nano in place. Also, a space was carved in the outside wall for the keypad to make sure it would be glued to the right place on the cup.
3. Finally the parts were formed to be user friendly and easy to assemble. A handle was made along with a ring which would act a stand to make sure no water would flow into the battery holder whenever the cup stands on wet surfaces. Also, a poor spout was added to the cup to make the cup nice to use. Holes and pins were created on components to make them click into each other to make the assembly easy.
4. All components were printed by one of the group members with PLA filament.
5. Added with the electronics all components were assembled by clicking them together and glueing it to make it waterproof.
6. The very last step was making braille keys to put on the keypad, these were made on small pieces of cardboard and put on the according keys with double-sided tape.

Bill Of Materials

Product (*brand*/name)	**From**	**Cost**	**Shipping costs**	**Total cost**
Arduino Nano (ATmega328P-chip) [5]	Amazon	€7,70	€1,61	€9,31
Grove Water Level Sensor (10 cm) [13]	Kiwi Elektronics	€8,50	€0,83	€9,33
3D printing job	Rik Tieben	€12,00		€12,00
Battery holder [2]	AlleKabels.nl	€1,99	€1,98	€3,97
Grove Conversion Cable (5 pack) [12]	Kiwi Elektronics	€3,50	€0,83	€4,33
GLOGLOW Piezo Buzzer [4]	Amazon	€4,69	€1,61	€6,30
Adafruit 3x4 Flexible Matrix Keypad [10]	Kiwi Elektronics	€4,50	€0,83	€5,33
Varta 3x AA batteries [3]	AlleKabels.nl	€1,49	€1,98	€3,47
Velleman 40 Jumper Wires [21]	Amazon	€2,55	€1,61	€4,16
			Total	€58,21

9 Test plan and results

To make sure the device is functioning properly, without restricting the user, several aspects of the devices needed to be tested. This allowed the group to get a clear overview of its functions and this helped the team members to see what needed to be improved. The test plan included several tests targeted towards specific areas; the waterproofing of the device, how do the separate parts fit together, and how well everything works as it is supposed to.

Final system test

For the final system test, the technical aspects needed to be tested. Does everything work as it is supposed to do? These tests were very important for the final design, because the product needed to work without any restrictions, which became clear during the testing of the final system.

Must:

- ☐ The used sensor is precise (5mm precision)
  - ∘ Check using a known amount of liquid and compare it to the amount the sensor detects.
- ☐ The measured quantity should be correct.
  - ∘ Measure a quantity with the final design, and remeasure this amount with an existing measuring cup. The maximum absolute difference between the measured value and the real value should be less than 25 mL.
- ☐ The speaker is loud and clear
  - ∘ Check the sound of the speaker. (Sound pressure level and frequency.)
- ☐ The speaker can output multiple frequencies
  - ∘ Check which frequencies the speaker can produce.
- ☐ Function autonomously or by interaction of the user
  - ∘ Check if the users input changes the output of the Arduino/speaker.

Should:

- ☐ The aid should work on batteries to remove moving restrictions
  - ∘ Check if the Arduino works well with the batteries.
- ☐ The speaker should give the right information
  - ∘ Check if the speaker is giving the information at the right moment, by filling in an amount and see if the speaker produces noise when the amount is reached.
- ☐ Gives a signal at 50%, 70% and 90% and 100%
  - ∘ Fill the cup with water and check whether different output signals are given at 50%, 70% and 90% and 100% relative to the requested amount.
- ☐ User should be able to define an amount
  - ∘ Is the keypad user-friendly, especially for blind people, and are people able to define an amount? Ask someone to fill in an amount and see if the keypad has registered it correctly.
- ☐ Blind people could use the keyboard
  - ∘ Is the keyboard provided with a braille dot?

Could:

- ☐ Have a touch-pad such that the user can define an amount
- ☐ Have a holder to put the measuring cup in to charge it

Sensor testing
Measurement:
A cup was filled until the sensor gave a certain value and then it was measured what the real value was. Instead of measuring different values once, two values were measured multiple times (minimum of 10 times). The results of this test were processed using MATLAB. See the appendix [A.2] for the test results and the MATLAB code. The summary statistics are shown in Table 1.

Input value (mL)	Mean (mL)	Standard deviation (mL)
250	249.4	1.5
375	376.4	10.8

Table 1: Final statistical values of the sensor test.

From the statistical data, it is seen that the final systematic error is neglectable. The accuracy of the measurements varied a lot when comparing the measurements of 250 mL to 375 mL. This was expected because the sensor was programmed to measure in steps of 50 mL, therefore, an input value of $n\times$ 50 mL would result in a precise measurement, whereas an input value in between two multiples of 50 mL would result in the most imprecise measurement. So the final advice is to use the MAVI mainly to measure liquid quantities which are a multiple of 50 mL.

Table to rate the tests

In the table, found in the appendix [A.2], every single test was rated from very poor to very good. In this way, it was clearly visible if something was functioning well, or if it needed to be improved. An explanation of the categories used to rate the functions:

- Very good: Nothing has to be changed
- Good: Nothing has to be changed, but improvements could be made
- Sufficient: Depends on the test if it is OK or not. (Improvements are up for debate)
- Poor: Improvement has to be made
- Very poor: A drastic change has to be made to the component/function

When the test results were compared with the technical specifications the following could be stated:
The maximum absolute difference between the measured value and the real value should be less than 25 mL and the measured accuracy was in fact $\pm$ 11 mL, so this goal was reached. The speaker also had the desired sound pressure level and frequency domain. During the tests, the interaction between the MAVI and the user was very smooth. The cup was also waterproof enough to ensure that during normal use no damage could be done to the components. The only goal in the technical specifications that were not reached is that the material could not resist high temperatures.

10 Design evaluation

Critical step
The most critical step in our design was to make sure that all components that could be damaged due to water were placed in a waterproof area of the cup. These are the following components:

- The Arduino.
- The batteries.
- The top of the water level sensor.
- The cables connecting the electronic components to the Arduino.
- The switch to turn the MAVI on and off.
- The buzzer which warns the user if the required amount of liquid is reached.

In order to make sure no water could reach these components, the following measures were made:

- The Arduino and the buzzer are placed in a separate component in the bottom part of the MAVI.
- An elevation was implemented, to lift the bottom of the cup from the surface it was standing on. This was done in order to keep (most of) the water away from the batteries and the switch when the surface would be wet.
- The connecting part of the sensor needed to be made waterproof with isolation tape as well as hot glue. The rest of the sensor is covered in conformal coating.
- The cables are placed inside of a double-wall so they do not come into contact with the water, the inlet where the cables go into the wall is covered with hot glue to make it waterproof.

So in the end the most critical step was implemented well. It is of the highest importance that the electronic components are being kept away from the water and in the final design, this is the case.

Possible future improvements

The material from which the cup is built in this design process cannot resist high temperatures. The material used for the measuring cup is PLA which could resist up to 55°C. This could cause a problem because if blind people are working with hot water, the material can melt which is very dangerous. So, for applications which would involve boiling water, the current cup is not suitable.
A second problem of the material used is its safety. PLA is made from natural products, however, the chemicals involved to colour the material or the chemicals of the printing machine can be dangerous when working with food or liquids. Therefore the material can release chemicals into the water, which can be dangerous. However, it seems to be safe when working with natural water.
A possible solution for the above-mentioned problems is epoxy. When there is a layer of epoxy over the PLA, the measuring cup is safe to use in the food industry [1] and can also resist temperatures up to 177°C. [15] So, this would be a possible improvement in the future, because to cover the measuring cup with a layer of epoxy was not possible within the given budget and time constraints. This improvement can be implemented after the measuring cup is printed and before all the electronic parts and sensors are placed into the cup.

The bottom compartment of the cup is not completely waterproof. If the cup was to be placed on a significant layer of water, the water would reach the batteries and this would possibly create a short circuit. The bottom of the cup is not waterproof due to the battery compartment, which should be accessible from the outside to change the batteries whenever they are empty. This battery holder is not waterproof, which can cause danger when the water reaches the batteries.
A possible improvement would be to buy a battery holder which is waterproof. However, these battery holders are more expensive than the battery holder used in this project. So, a battery holder which is waterproof could solve this problem.

The sensor is not very accurate. When someone needs to measure a very precise amount of liquid, e.g. for baking, the measuring cup would be useless. The sensor consists of 20 sensors, which implies that every sensor

represents 5% of the total amount of the measuring cup. This implies that every sensor represents 50ml when the total amount of the cup is 1000ml. Every amount of liquid which is a multiple of 50 will be measured precisely, but with every other value, the sensor will not be very accurate.
A possible improvement to this problem is to use a better and more accurate sensor. However, these sensors are quite expensive and due to the given budget, it was not possible to use a sensor which is more precise than the one used. So, a better and more accurate sensor would be a good improvement for the future.

Another problem with the cup is the safety of the sensor. The sensor is unsuitable for the food industry since it does not have the CE marking. Therefore it is not safe to use in combinations with liquids one would consume because the sensor could release chemicals into the water.
Another problem of the sensor is the splashing water when filling the cup with a tap. When a drop of water hits one of the twenty sensors the measurement result can be influenced when this is a sensor which represents a higher value of liquid than the requested amount of liquid. When the drop of water hits a sensor representing less than the requested amount this is not a huge problem, except there is a chance the buzzer will start to beep because a certain percentage of the requested amount is reached. As a consequence filling the cup will take more time because the tap is turned down.
A possible improvement for the future is to buy a sensor which has the CE marking and which does not react on a splashing drop of water on the sensors. However, these sensors are more expensive than the sensor used in this design project, so the purchase of this kind of sensor was not possible due to the given budget for this design project.

The possible improvements of the sensor and the battery holder should be implemented when ordering everything required to design the cup. To safe money and time, the correct parts should be ordered. This could be best implemented when the technical specifications of the cup are determined.

Another possible improvement for the future is to attach a switch to the batteries which is waterproof to switch on and off the batteries and the batteries can be replaced at the same time. This is very useful because in this way the measuring cup will have enough electricity for months, and when this switch is not attached the measuring cup is on all the time or when the batteries cannot be replaced due to the switch this can cause several problems for the users. The batteries can provide electricity for 40 hours, so this implies that the measuring cup will need new batteries every two days without a switch. So a possible improvement would definitely be a switch, which is waterproof, to turn on and of the batteries. This possible future improvement should be implemented when everything is attached to each other.

11 Special topics

As a group, the following special topics were explored during the project: design sketching, human factors design, CAD design, error analysis and curve fitting.

1. Design Sketching

Design sketching was important in the design process, in order to gain insight about the materials it was necessary to sketch/build a preliminary design. This is useful in order to be time and budget efficient. The materials on the Canvas page were studied.

For this course, Sketchdrive was used. Sketchdrive gives multiple lectures and examples which all focus on different parts of drawing products. Linear and cylindrical products both have their own course. Since our product will be a measuring cup, the course of cylindrical products was most relevant. In this course, the process which needs to be taken while sketching a cylindrical product is explained. Before drawing, other cups were used as a reference to get a clear idea of how it could look like. In the beginning, you need to start with the shape of the product. The cup at the bottom starts with a smaller circle which gets bigger and bigger until the top of the cup.

While sketching it was important to show the most important parts of the idea. It was important to have an idea of where the sensors would be located, where the wires would go, and where the other elements should be placed. This is why more than just one perspective was used; one top view and one side view. Since it was just a sketch, it did not have to be detailed, it just had to be easy to understand.

Before the sketch was made, it was not clear yet which sensors would be used. Therefore, multiple sketches, as shown in Figure 21, were made with different sorts of sensors. The first one is with a sort of strip and the second one is where there is a floating element within the measuring cup. The orange part in the sketch is the temperature sensor which we decided not to use anymore. The drawing was based on a hand-drawn sketch. The sketch was further elaborated in Photoshop where lines were erased and added to make it clearer.

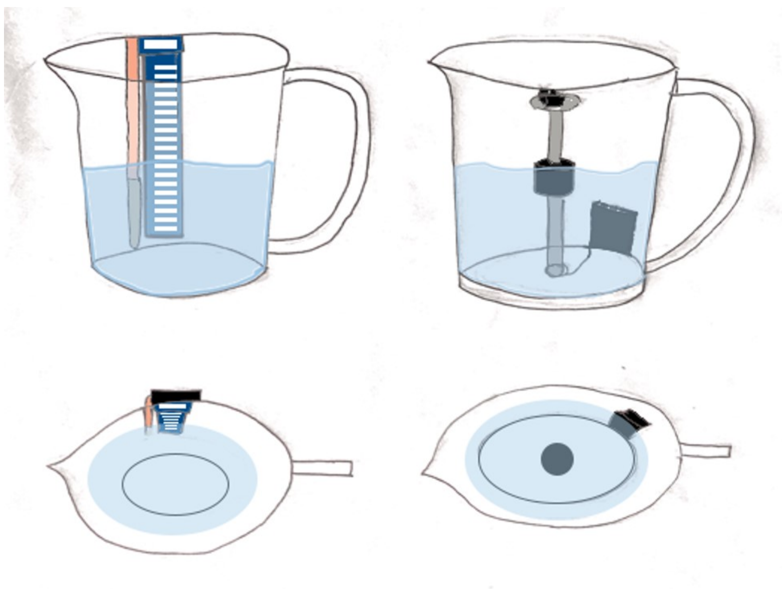


Figure 21: First sketch of the measuring cup

2. Human factors design for elderly and people with functional limitations.

This special topic was needed to design an aid that was useful, usable, safe and desirable. It was a useful special topic to discover the human factors of blind people. It was useful to apply the human factors of blind people to the design in order to make the design more effective. Thanks to this special topic, the design of a product could be enhanced to better address the limitations, capabilities, expectations and needs of the targeted users.

2.1 User Test/Usability Test

A usability test was performed on our design.

User profile:

The user profile of the test subject was described using the following categories:

- *Physical characteristics*
- *Mental state*
- *Senses*

Test scenario

The test subject was told to measure a certain amount of liquid (100/200/300 mL).

Procedure

Introduction.

The test subject was welcomed and informed what he/she had to do. Also, the user profile was made.

Task performance

The test subject had to follow the test scenario.

Post task activities

The test subject had to rate his experience on a scale of 1 to 5 using standard SUS usability questionnaires. How good our design is was based on the mean value and standard deviation of this measurement.

Results

Physical characteristics

Age	70	20
Agility	45%	80%
Handedness	0%	30%
Voice	80%	100%
Fatigue	45%	90%
Gender	Man	Woman
Body and body part size	Moderate	Moderate

Mental state

Attention span	Low	High
Use of drugs (both prescription and illicit)	Yes (blood pressure pills)	No
Long-term memory (includes previous experience)	No	Yes
Short-term memory	Yes	Yes
Work schedule	Retired	Student

Senses

Auditory acuity	60%	100%
Tone perception	40%	100%
Tactual	80%	100%
Visual accommodation	0%	20%
Visual acuity	0%	20%
Colour perception	0%	50%

SUS item	Strongly disagree (1)		Disagree (2)		Neutral (3)		Agree (4)		Strongly agree (5)	
I think that I would like to use this system frequently					X			X		
I found the system not unnecessarily complex							X			X
I thought the system was easy to use							X			X
I do not think that I would need the support of a technical person to be able to use this system					X			X		
I found the various functions in this system were well integrated							X			X
I thought there was not too much inconsistency in this system							X			X
I would imagine that most people would learn to use this system very quickly									X	X
I found the system not very cumbersome to use							X			X
I felt very confident using the system									X	X
I did not need to learn a lot of things before I could get going with the system							X			

Table 2: Table with the results

The results were processed using MATLAB and the found mean value was equal to :
4.4 ± 0.7

So this means the measuring cup was found usable enough.

2.2 Analysis of potential bad human factor issues.

In phase one of the Human Factors special topic, every team member had to come up with potential bad human factor issues and suggested improvements for these issues. "The Handbook of Human factors and ergonomics" [18] was used for this. Here are the most important ones according to the group members:

2.2.1 Age-related response time difference of 1.5s

Description

Reaction time will be a bad human factor when filling a measuring cup with an amount of liquid. The response time is age-related, which means when a person becomes older, the response time will decrease. Between young adults and the elderly the response time difference can be 1.5s which is very high, especially in for example the driving environment. However, this could also be a problem when a specific amount of liquid is needed, because the reaction time between switching on and off the tap could have an influence on the amount of liquid in the measuring cup. Thus, this is associated with the device, because the device is a measuring cup for people with visual impairments and the response is very important because otherwise the correct amount of liquid is not obtained.

Analysis

This seemed like an example of bad human factors because response time has a massive impact on human life. When one is in the driving environment and the response time is very slow, this could cause accidents or even something worse. It will not be functionally meaningful when searching for information on the internet, however, this age-related difference could thus be critical in the driving environment or when responding to a medical emergency in a home where delayed responses could lead to serious consequences. This is also the case when blind or elderly people fill a measuring cup with hot water for thee or something else, when they do not respond in time, the hot water will burn their hands, which could have serious consequences.

2.2.2 Unnoticeable whether a button is pressed

Description

A possible problem of with keypad is that the user presses the keypad but they do not know if they really pressed it. It is unnoticeable whether it worked or not. Eventually, they might press a button twice by accident and the amount of water will be way higher than the person wanted since there will be an extra digit.

Analysis

There should be a signal when you press a button. For a visually impaired person to be independent, it is important to know when something is happening. There would be a lot of stress in the person's mind when they do not know what they are actually doing. So a signal for every button on the cup is recommended.

2.2.3 Sound pressure level is too low

Description

A potential human factors problem that can be encountered when designed a measurement cup for blind people is that the sound which should warn the user could be barely noticeable. The greater the sound pressure level of the masker (background noise), the more the increase in the masked threshold of the signal. A general rule of thumb is that the S/N ratio at the listener's ear should at a minimum be about 15 dB above the masked threshold for reliable signal detection (Sorkin, 1987) [19]. Sound Pressure Levels of +95db can be very dangerous for the user. Of course, the MAVI should not form a threat to the users in the form of causing noise-induced hearing loss (NIHL).

Analysis

In order to minimize the annoyance and risk due to the warning signal from the MAVI, the sound should ideally exceed the masked threshold by more than 15 dB. The masked threshold would be the average sound level from the environment while filling the cup, so this would be the sound level of the user's tap. This means that the final sound that is produced by the buzzer on the MAVI should be louder than 88dB.

2.2.4 Frequency is inaudible or disorientating

Description
Another human factors problem which could be encountered in our design according to chapter 23 of the "Handbook of Human Factors and Ergonomics, Fourth Edition" [18], is that the frequency of the produced sound is not ideally chosen, which could lead to disorientation or detection loss for the user. The final conclusion was that the frequency of our warning tone should be between 3000 and 4000 Hz. Also, the produced tone should not be a harmonic of the masking tone, in this case, the water tap.

Analysis
Preferably, the signal should contain energy in the most sensitive range of human hearing, approximately 1000-4000 Hz, unless the noise energy is intense at these frequencies (Sorkin, 1987) [19]. See Figure 22 [8].

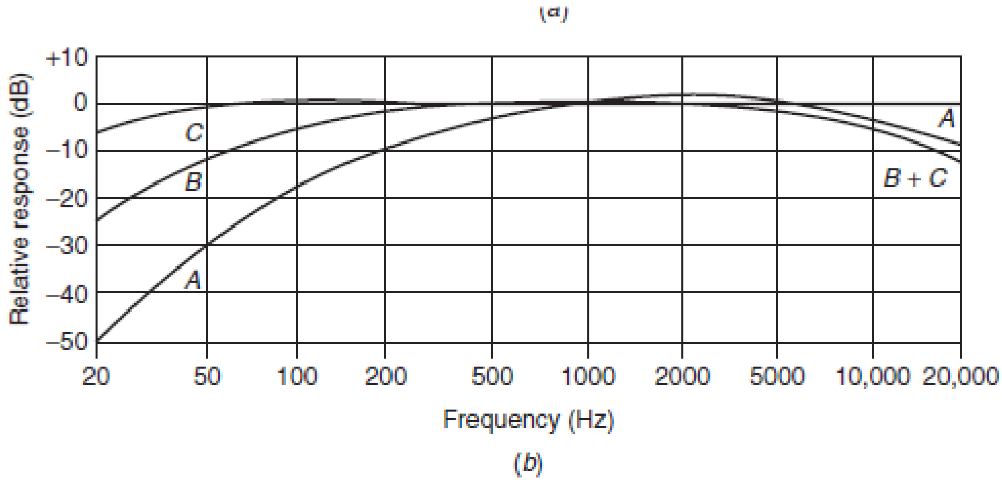


Figure 22: Relative response (dB) per frequency (Hz)

When a signal must be localized, it is advantageous to include signal energy content below 1000 Hz and above 3000 Hz to maximize one's ability to locate the signal, taking advantage of both interaural time and interaural level differences, respectively. So in the end the ideal range is 3000-4000 Hz. The average frequency of the noise produced by the tap is higher than 4000 Hz, so we did not need to worry about the harmonics of the tap.

2.2.5 Size and contrast of warning signs

Description
Warning signs are generally used to improve safety. The example used was color as it attracts attention more effectively. Another concept used in warning signs is size and contrast, a bigger sign is generally better. An increase in print size and contrast against the background show benefit to subsequent recall. What is important is not just the size of the warning, but also its size relative to the other information on display. A bold warning on a product label with many other informational items in a larger print is less likely to notice as compared with the other labels.

Analysis
The visual impaired person does not orientate themselves via a means of visual sense. They use their sense of hearing, smell and touch. In the first two instances, a warning sign generally does not make any sound or noises instructing the user of potential danger. It also does not secrete any smells for the same person. The warning sign can however stand out as a means of a sense of touch, but this is limited for the user has to be in physical contact with the sign for this to happen, which is not preferable, as the sign might be located in a hard to reach place or a place which is susceptible to drastic temperature changes. This is another example of a bad human factor.

2.2.6 Difficulty with typing on keypad

Description
Many people, especially older people, have problems typing on touchscreens and small keyboards which can lead to problems for them using the product. This is since the innovative part of our product is using a keypad to let people give their requested amount of liquid as input.

Analysis
When people age their bodies start wearing down, they get problems with joints and getting lumps of skin on places. When this happens in the hands of people, they might have problems using them to push in buttons without 'fat fingering' the buttons around the button they want to press. From experience, elderly people tend to have problems with for example typing on a phone, we had to make sure the buttons were not too small and they will not be 'fat-fingered' in the process of giving input.

2.3 Conclusion.

The results of the usability test and the bad human factor issues analysis were taken into account for the final design.

3. CAD design

Two group members explored CAD designing via the Training Technical Design Skills course. In this course, the software of Siemens NX12.0 was used to design 3D shapes and combine them to later be printed by a 3D printer.

Both group members followed the course which helped them make full models of the product needed. The main learning goals were making models of the individual parts and later make them into a full assembly. For the 3D designing of the parts the full home taskbar needed to be used, thus the group members had to thoroughly understand all features and use those features to their maximum extent. To learn all these features of NX, a few models were made which included most of the functions. Two of these models are shown in Figure 23 and Figure 24. To eventually make the loose parts into one big product, the assembly taskbar needed to be well understood and used. This was not only needed to make one product out of it but also to make a printable file. For 3D printing, the basics of 3D printing were also important to learn. In the printable file, all the parts needed to be on the same level as the side they will be printed on. Also, there was no possibility for big overhanging edges or small overhanging edges with perpendicular corners to prevent the parts from collapsing on themselves during the printing since the plastic was hot when printed and was not very strong yet.

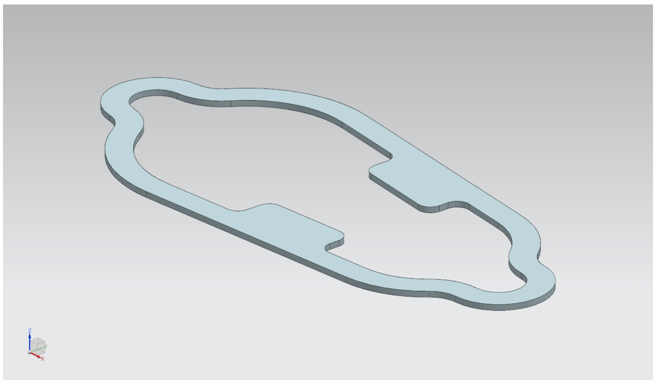


Figure 23: exercise model 1

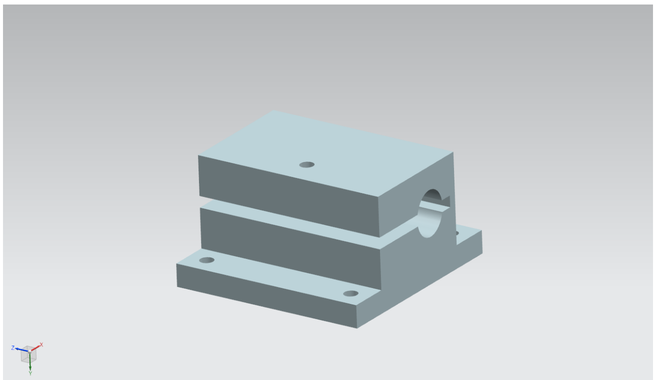


Figure 24: exercise model 2

3D printing was very helpful in this project, all the components were easy to make in a way the electronics would fit right in. Besides, 3D printing was a safe way to make a product, the risk of human errors in shaping the product (for example make a slip up with a fretsaw) is low. Even if mistakes were made during designing, fixing them is easy by just adjusting the part in the computer and print the part again. There was no need to start all over again. Only the costs of printing were slightly higher than adjusting already existing parts bought in a low-cost shop.

The group members luckily already had a bit of an advantage in the CAD designing course since they already had some experience with CAD, making it easy to start early with designing the product. This special topic was implemented a bit in the conceptual phase to make quick sketches of the possible version of the product. But this special topic was most importantly implemented in the final concept, the detailing and the realization parts of the project. All parts outside of the electronics are CAD designed and 3D printed with a printer someone within our group has at home. This also made it easy to get the parts and reprint them when needed.

4. Error analysis and curve fitting

Error analysis and curve fitting was a very functional special topic because it was necessary to check the functioning of your design. It was useful in the testing and evaluation phase of the project. It was important to show that all technical specifications were satisfied and also for optimizing the settings of the controls and adjusting parts or connections.

All the group members contributed to the test and evaluation phase of this design process. The material of the special topics was not explored by all of the group members. Two group members studied the material of the special topic. The other group members were involved in this special topic by executing the test and communicate the test results to the group members which studied these materials.
This special topic helped to improve the design process by analyzing the tests and alter the things that need to be improved based on the test results. This helped to create the best possible design at this moment in these time constraints. To get the best out of this product, this special topic was very useful. Because the executed tests gave insight into what aspects of the design needed to be improved and what things already worked well.

Both group members followed the course and studied the materials which helped them to create and develop a test plan for this design process. This special topic was also very useful when processing the obtained test results.
The main learning goal of this special topic was to get to know more about statistics because statistics is a very important subject in this special topic. Both group members develop the skills of: "experimental design", "data exploration and error analysis", "regression analysis and curve fitting". The skills of "experimental design" consist of the systematic and the random error and the confidence intervals in statistics. Another skill developed during this special topic was to report the measurement results. The skills developed in the "data exploration and error analysis" section was to make calculations such as the mean and the standard deviation, this is part of the standard normal distribution. Furthermore, the skill to plot the results using MATLAB in different kinds of plots was studied during this special topic. In the last section of this special topic, the group members studied the material of "regression analysis and curve fitting". The main learning achievement of this section was to know how to execute a regression analysis. This all together were the main objectives of this special topic.

The material studied during this special topic was implemented in Section 9 of this report: "Test plan and results". The test plan has been created with the information gained in this special topic. The results of the tests have been analyzed with the material of this special topic, so statistics were involved when analyzing the results. See the appendix [A.2] for the MATLAB code.

References

[1] Food safe epoxy, https://epoxycountertopdiy.com/food-safe-epoxy/#:~:text=Epoxy%2C%20when%20cured%2C%20is%20generally,with%20the%20FDA%E2%80%99s, author = DIY countertop epoxy,.

[2] Allekabels. 3x aa batterij houder, https://www.allekabels.nl/batterij-houder/1062/1281616/3x-aa-batterij-houder.html.

[3] Allekabels. Aa batterij - set van 4 batterijen, https://www.allekabels.nl/aa-batterij/4570/1217527/aa-batterij.html.

[4] Amazon. Gloglow 12v 85db elektronische zoemer, https://www.amazon.nl/dp/B07F5LB8K9/ref=cm_sw_r_wa_apa_fab_zqACFbFV4PJ18.

[5] AZDelivery. Arduino nano v3.0 ch340 chip, https://www.amazon.nl/AZDelivery-Nano-gesoldeerd-verbeterde-V3/dp/B01MS7DUEM/ref=sr_1_1?__mk_nl_NL1.

[6] M. Blades. Food and happiness. *Nutrition & Food Science*, 39(4):449–454, 2006.

[7] E. Brady, M. R. Morris, Y. Zhong, S. White, and J. P. Bigham. Visual challenges in the everyday lives of blind people. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI 13*, 2013.

[8] J. J. Earshen. Sound measurement: Instrumentation and noise descriptors. *Noise and Hearing Conservation Manual*, 1986.

[9] R. Hewett, G. Douglas, and S. Keil. Young people, visual impairment and preparing to live independently. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI 13*, November 2015.

[10] Kiwi-Electronics. 3x4 flexible matrix keypad, https://www.kiwi-electronics.nl/3x4-flexibel-matrix-keypad&search=keypad&description=true.

[11] Kiwi-Electronics. Arduino nano every, https://www.kiwi-electronics.nl/arduino-nano-every-with-headers?search=arduino%20nano&description=true.

[12] Kiwi-Electronics. Grove - 4 pin female jumper to grove 4 pin conversion cable - 5-pack, https://www.kiwi-electronics.nl/grove-4-pin-female-jumper-to-grove-4-pin-conversion-cable-5-pack?search=grove%20conversion&description=true.

[13] Kiwi-Electronics. Grove - waterlevel sensor, https://www.kiwi-electronics.nl/grove-water-level-sensor-10cm-for-arduino.

[14] D. Malony. Plastics: Petg, https://hackaday.com/2019/01/29/plastics-petg/#:%7E:text=PETG%20is%20resistant%20to%20many,great%20choice%20for%20outdoor%20applications.&text=And%20PETG%20is%20considered%20a,it%20in%20contact%20with%20food.

[15] J. J. Morena. *Advanced Composite Mold Making*. Krieger publishing Company, 2006.

[16] B. Obudho. Is pla food safe?, https://all3dp.com/2/is-pla-food-safe-what-you-really-need-to-know/.

[17] pmcplastic. Petg resin, https://www.pmcplastics.com/materials/petg-resin/.

[18] G. Salvendy. *Handbook of Human Factors and Ergonomics*. John Wiley and Sons, Inc, 2012.

[19] R. D. Sorkin. Design of auditory and tactile displays. *Handbook of Human Factors*, 1987.

[20] E. Tyson. How to anneal your 3d prints for strength, https://rigid.ink/blogs/news/how-to-anneal-your-3d-prints-for-strength#:%7E:text=PLA%20heat%20resistance%20is%20low,178C%20(343F%20to%20352F).

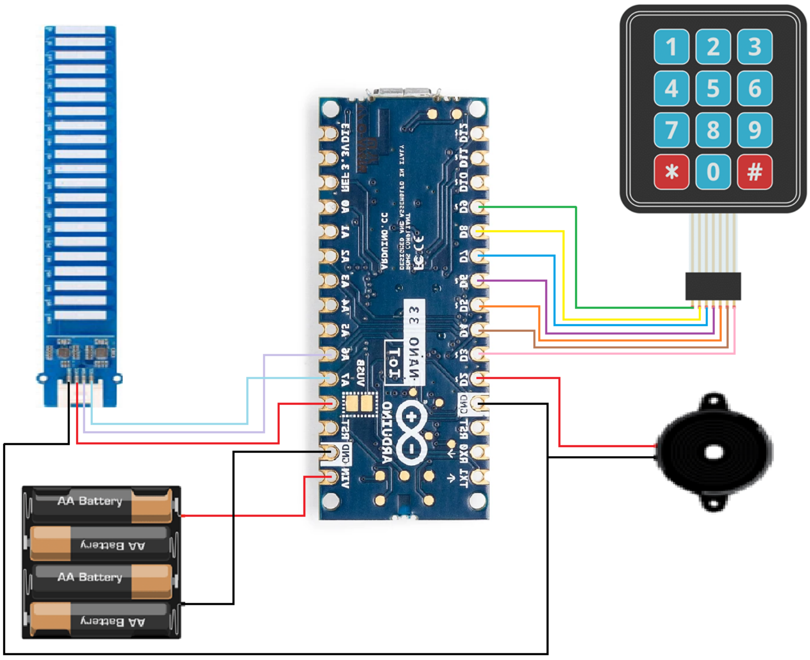
[21] Velleman. Velleman vma415 40 pins female to female flat cable jumper wire, https://www.amazon.nl/dp/B01MYGGDBP/ref=cm_sw_r_wa_apa_fab_8yBCFbJXAP7YW.

[22] J. Yore. Measuring cup for the blind, http://cargocollective.com/jasonyore/measuring-cup-for-the-blind, 2011.

A Appendices

A.1 Chapter 6

Board:
Pin diagram:



A.2 Chapter 9

Table to rate the tests:

	Very poor	Poor	Sufficient	Good	Very good
Waterproof cup itself?					x
Waterproof with electronics?				x	
Sensors are Waterproof?			x		
Speaker is waterproof	x				
Does everything fit into the cup?				x	
Easy to hold?					x
Does the electronics connect to the Arduino?					x
Does the speaker produce noise?					x
Does the sensor register water levels?					x
Does the keypad register input					x
Sensor is precise?					x
Speaker is loud and clear?				x	
Speaker gives right information					x
Speaker can produce multiple frequencies					x
Aid works on batteries					x
Gives a signal at 50%, 70% and 90% and 100%					x
User is able to define an amount					x
Blind people could use the keyboard?				x	

An explanation of the categories used to rate the functions:

* Very good: Nothing has to be changed
* Good: Nothing has to be changed, but improvements could be made
* Sufficient: Depends on test if it is OK or not. (Improvements are up for debate)
* Poor: Improvement has to be made
* Very poor: A drastic change has to be made to the component/function.

Table with the sensor test results:

Value sensor (mL)	Real value (mL)	Absolute error (mL)	Relative error
250	248	2	0.008
250	249	1	0.004
250	249	1	0.004
250	249	1	0.004
250	251	1	0.004
250	252	2	0.008
250	247	3	0.012
250	249	1	0.004
250	251	1	0.004
250	249	1	0.004
375	384	9	0.024
375	376	1	0.003
375	388	13	0.035
375	368	7	0.019
375	395	20	0.053
375	360	15	0.04
375	364	11	0.029
375	380	5	0.013
375	373	2	0.005
375	376	1	0.003

Matlab code used to perform statistical analysis on the sensor test results

```
T_data_250= [248 249 249 249 251 252 247 249 251 249];
T_data_375= [384 376 388 368 395 360 364 380 373 376];

StD_250 = std(T_data_250);
StD_375 = std(T_data_375);

M_250 = mean(T_data_250);
M_375 = mean(T_data_375);

disp(M_250)
disp(StD_250)
disp(M_375)
disp(StD_375)
```