RESEARCH ON THE DEVELOPMENT OF A WINDOW CLEANING ROBOT

BRATU Robert-Sebastian[1], CHISELEFF Maria-Monica[1], DOICIN Cristian Vasile[2]
[1]Faculty: Industrial Engineering and Robotics, Specialization: Industrial Engineering, Year of study: II, e-mail: chiseleffmonica@yahoo.com
[2]Faculty of Industrial Engineering and Robotics, Manufacturing Engineering Department, University POLITEHNICA of Bucharest

ABSTRACT: Through the years, the evolution of technologies brought the world the opportunity to have new gadgets for ease living. Cleaning large windows on multi-story buildings is normally an extremely risky process even for those who are working in this domain, that is why robots have been developed to help or replace humans in such cases. The window cleaning robot is a smart device for those who are living in a multi-story building, or they are afraid of heights.

Key words: robot, window, cleaning, innovation

1. Introduction

Cleaning large windows on tall and multi-story buildings is a time-consuming and risky task. Outside, it can be done with hoisting machines and manual cleaning, or, in very rare cases, with sophisticated, complex, large, heavy, and very expensive automatic cleaning machines that are operated manually from the ground floor. [1]

A compact window-cleaning robot (WCR) was created specifically for use in a household setting. The robot climbs onto the surface of the window glass using suction cups and washes the surface with a revolving wiper at the same time. WCR is distinguished by its low weight and small size. The robot's navigation will be aided by the sensing system. This window robot will have 2 suction cups used as an adhesion system and it can travel independently around the surface of a building office window while cleaning and washing it thanks to the water spray nozzle that can spray it evenly on the glass. The robot will complete the work of window cleaning in a specified pattern helped of an app after it is attached on window. It can move freely on window surfaces indoors and outdoors, thanks to an internal vacuum motor, and a microfiber cloth. Because it is working on multi-surface, the robot can overcome small air leaks and move well on rough surfaces thanks to a vacuum pump that consistently supplies negative pressure. [2]

2. Current state

After we did short research to see what already exists on the market and what we must improve and innovate for our products, the two concepts were developed.

The assembly has three main objectives: to clean the window, to support and sustain the water for the cleaning process and to detect the window's edges.

Some parts will be fully 3D printed, while other components will be purchased to insure the motion of the assembly, as all the electronic components.

The first concept of the robot is composed of 5 different parts, while the second concept has 4 different parts:

1. Support
2. Main body
3. Water tank
4. Cover for the water tank
5. Pump with spray nozzle

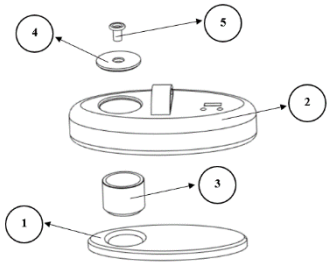

Fig. 1. First concept (sketch)

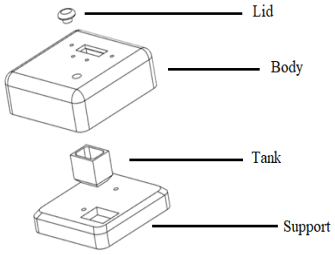

Fig. 2. Second concept (sketch)

The 3D design of the two concepts were designed in Autodesk Inventor Pro [8] and they are represented in Fig. 3 and Fig. 4.

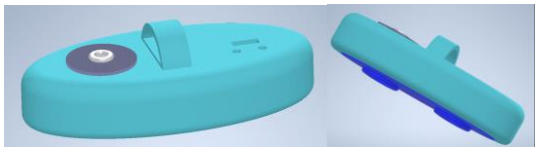

Fig. 3. 3D design of the first concept [6]

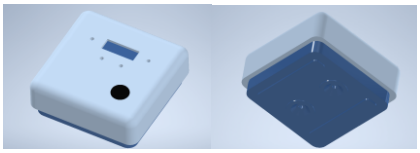

Fig. 4. 3D design of the second concept [6]

After designing the components, the additive manufacturing step must be completed in order to choose the best 3D printing machine [3]. We will utilize one of the 3D printing machines, which are accessible at the Industrial Engineering and Robotics Faculty, so in this case we do not need to utilize a complicated manufacturing process to print such components.

Fused Deposition Modelling (FDM) is utilized to print all the pieces and the material chosen for 3D printing is ABS (Acrylonitrile Butadiene Styrene) because it is lightweight and has good impact strength. Also, it is abrasion resistant and affordable [3].

BCN3D CURA [9] as software and SIGMAX as the main equipment and ZSUITE [10] as software and ZORTRAX M300+ as the main equipment will be used to compare the results.

Putting all components of the robot in one 3D printing machine, we will reduce the time of the printing. The main additive manufacturing principals which were used in the design of the parts are: supported walles, holes, connecting/moving pars and horizontal bridges [3].

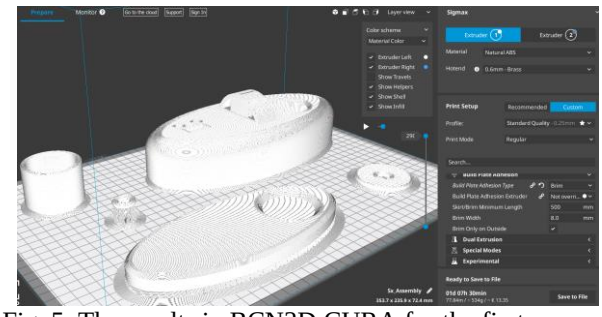

Fig. 5. The results in BCN3D CURA for the first concept

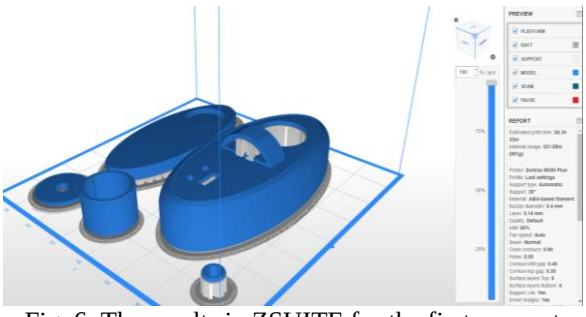

Fig. 6. The results in ZSUITE for the first concept

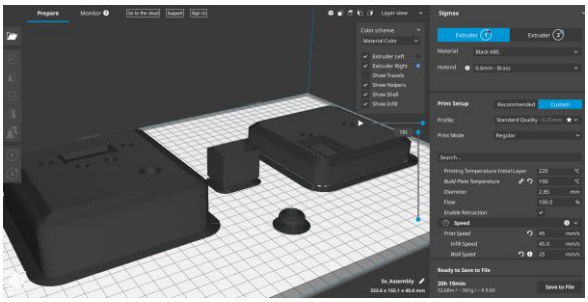

Fig.7. The results in BCN3D CURA for the second concept

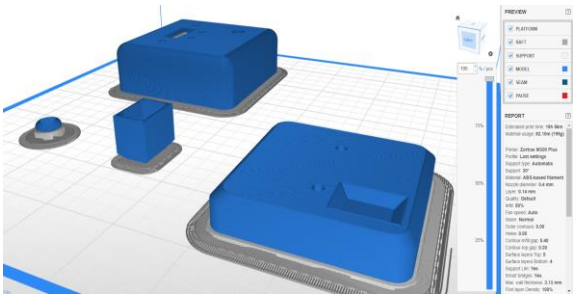

Fig. 8. The results in ZSUITE for the second concept

The data available in the figures show that the expected printing time is almost the same, the Sigmax material cost is chipper, but when it comes to material utilization, the Zortrax M300+ uses less material than the Sigmax.

As we can see, the Sigmax, will be choosen as the 3D printing machine for the first window cleaning robot designed and the Zortrax M300+ will be selected as the 3D printing machine for the second robot designed.

The following are the main steps in the manufacturing process for the parts of the first product that will be manufactured [4]:

1. The Autodesk Inventor software was used to design the parts.
2. The BCN3D Cura software was used to set the parameters for 3D printing.
3. The Sigmax 3D printer was used to print the parts.
4. Post-processing of the parts.
5. Assemble the parts.

The primary processes in the manufacturing process for the pieces of the second product that will be made are as follows [4]:

1. The Autodesk Inventor software was used to design the parts.
2. The ZSuite software was used to set the parameters for 3D printing.
3. The Zortrax M300+ 3D printer was used to print the parts.
4. Post-processing of the parts.
5. Assemble the parts.

The rest of the components will be purchased in order to insure the motion of the assembly, as all the electronic components. The main electrical components for the products are presented in Table 1.

Table 1: Components [2]

Name of the Component	Manufacturing technology	Price
Arduino Uno	Purchased	107.70 RON
Breadboard	Purchased	22.61 RON
DC Motor	Purchased	226.28 RON
Micro servo	Purchased	28 RON
Motor drive	Purchased	58 RON
Red Led	Purchased	0.73 RON
Green Led	Purchased	1.59 RON
Resistor	Purchased	7 RON
Ultrasonic distance sensor	Purchased	164.62 RON
LCD display	Purchased	51.67 RON

Potentiometer	Purchased	4.10 RON
Wires	Purchased	6.31 RON
H-bridge motor drive	Purchased	34.76 RON
Pushbutton	Purchased	14.34 RON
Suction cups	Purchased	206.77 RON
Vacuum pump	Purchased	141 RON
Pression sensor for vacuum	Purchased	15.20 RON
IR sensor and remote	Purchased	7.07 RON
Hobby gearmotors	Purchased	15.17 RON

The circuits of the two product concepts were designed in Autodesk TINKERCAD [11] software, where all the components are connected to each other [5].

For the first concept of the product is composed of 2 different circuits:

1. First circuit is for displaying different text on an LCD when you open the robot, then you have to choose which cleaning program do you want.
   The components used for this circuit are: Arduino Uno, two Breadboards, Wires, 220 Ω Resistor, two 10kΩ Resistors, two pushbuttons and a Potentiometer.

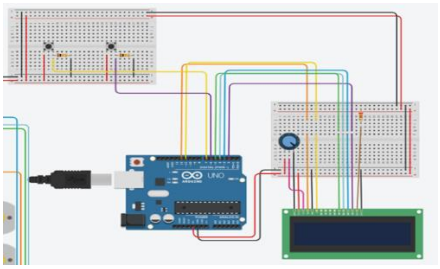

Fig. 9. First circuit [11]

2. The second circuit is for establishing the direction of the robot using an Arduino uno with a ultrasonic distance sensor, a potentiometer and micro servo for the angle, with 2 DC motors for the wheels connected by a H-bridge motor drive, a pushbutton with 2 Led in order to know when the robot is ON and OFF, 4 resistors of 220Ω and 10Ω resistor, wires and 2 breadboards.

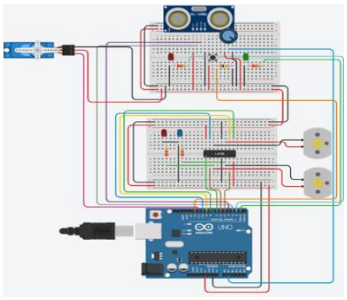

Fig. 10. Second circuit [11]

3. The two circuits are connected to each other with a GND wire and 5V wire (see Fig.3.4).

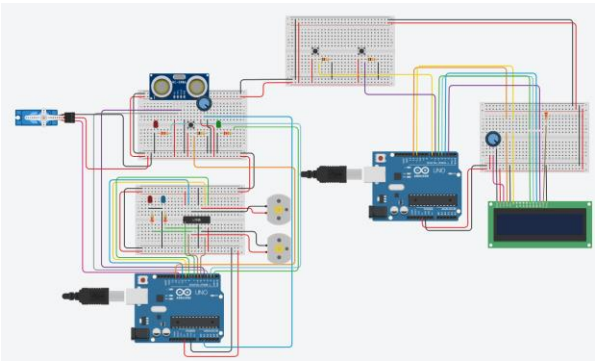

Fig. 11. The final TINKERCAD circuit [11]

For the second concept of the robot, an automated system for a cleaning robot will be designed. The robot can detect an obstacle with the help of the ultrasonic sensor, which automatically bypasses it to the left. The programs will be selected with an IR sensor and remote. It also, has an LCD display in order to show you different messages [6].

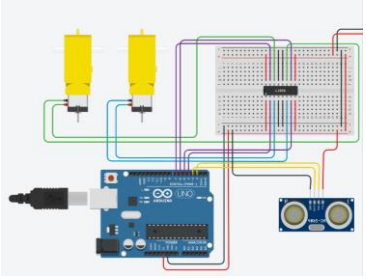

Fig. 12. The first circuit [11]

1. The first circuit represents the 2 gearmotors connected to the H-bridge motor drive and an ultrasonic distance sensor which calculates the distance between the robot and an object to avoid it.

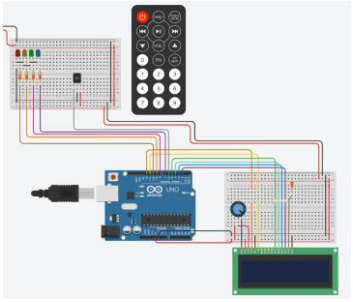

Fig. 13. The second circuit [11]

2. The second circuit is for the LCD display and the IR remote. The robot will be controlled by an IR remote having multiple comands.

3. The two circuits are connecting to each other in order to make the final circuit.

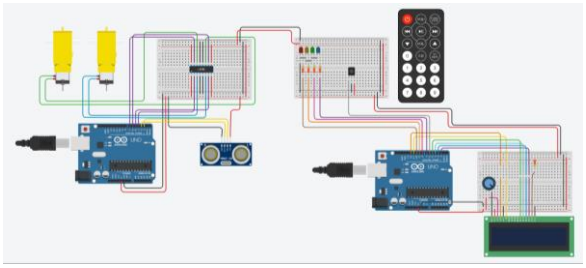

Fig. 14. The final circuit of the second concept [11]

3. Business plan

For our business we will have a registered company that will manufacture the products and sell them [6].

A. General data

1. Full name of the company: Cleannyhobo SRL

2. The location of the enterprise:

• Social headquarters: XYZ Street, No. 5

• Operational headquarters: XYZ Street, No. 5

• Working point: XYZ Street, No. 5

• Offices: XYZ Street, No. 5

3. Unique registration code: RO23456789

4. Legal form of incorporation: SRL (Limited liability company)

5. Date of establishment / Trade Register Number: J40/2233/2022

6. The main activity of the company and the related CANE code: Creative industries * - without CAEN code 6201

7. The value of the share capital: 10000 Lei

8. Contact person: Maria Monica CHISELEFF

9. Associates, main shareholders:

Table 2: Associates, main shareholders [6]

Physical person	Address and phone	Nationality	Capital shares (%)
Maria Monica CHISELEFF	ABC Street, No. 2	Romanian	50%
Robert Sebastian BRATU	DEF Street, No. 4	Romanian	50%

10. SME category: Micro

B. What is the mission statement?

• We are a new company founded by a young but ambitious team eager to make a difference by bringing technology closer to people with the goal of making their lives easier. Our products are for those who are living or have offices in multi-story buildings, or they are afraid of heights [6].

• The product is made up of two major components: an electronic component and a mechanical component. The mechanical component's primary function is to keep the supplies and electronic components running. The electrical component of the product ensures that the product moves correctly.

4. Process of selling the product

This part was done by using IBM WebSphere Business Modeler Advanced [12] to create business model [7].

Fig. 15 represents the process map starting from the moment the client places an order to the point where the order is delivered with all the steps involved along the way.

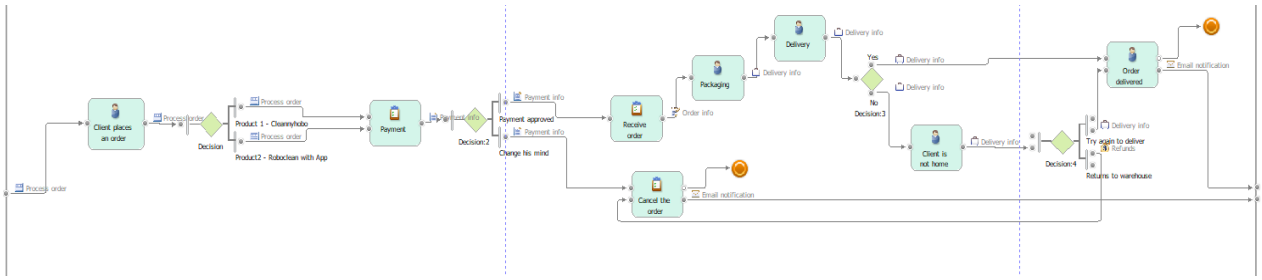

Fig. 15. Process map [12]

Because this program is as a database, different business items will be created (Fig. 16), resources and roles, shifts (Fig. 17 and 18).

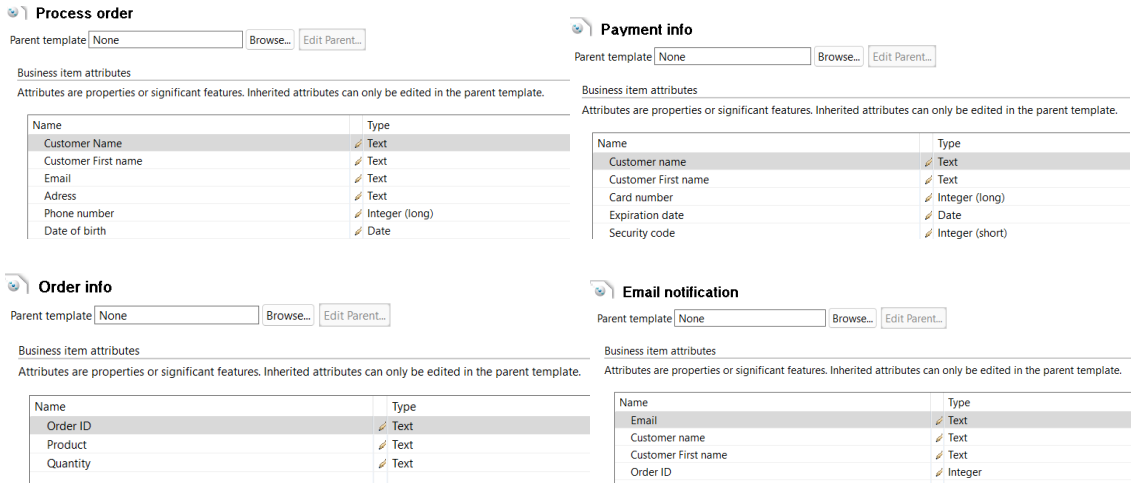

Fig. 16. Business items [12]

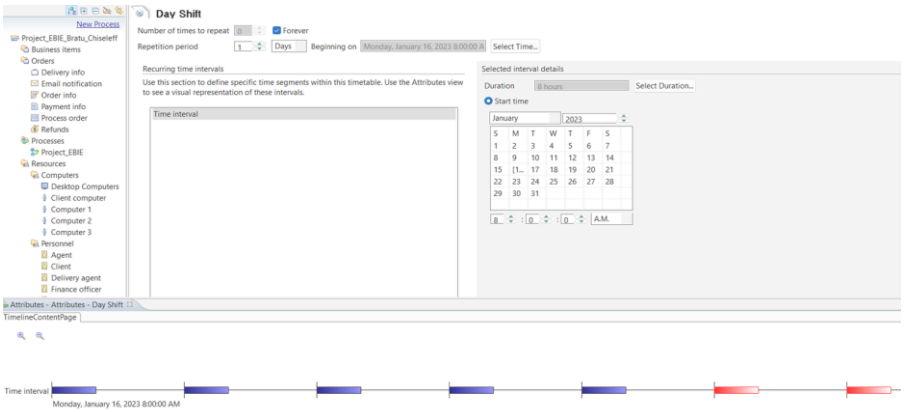

Fig. 17. Day shift [12]

5. Conclusion and future developments

To sum up, the two concepts of product were developed using the software Autodesk Inventor Pro [8], then the 3D printing machines were chosen to be the best for each robot to reduce time, money, and

material. Then a business plan was created because to sell and manufacture a product, a registered company must exist.

The future developments are as follows:

- Purchase the needed materials;
- Produce a prototype of each concept and test them;
- Make the right modifications (if needed) and test them again;
- Register the trademark, and the industrial design at the national and international level (OSIM and EUIPO) [1];
- Register the company and hire the right employees.

6. Bibliography

[1]. Author, BRATU R. and Author, CHISELEFF M. (2022), „RESEARCH ON THE DEVELOPMENT OF A WINDOW CLEANING ROBOT", Scientific Research 1, University POLITEHNICA of Bucharest, Bucharest.
[2]. Author, BRATU R. and Author, CHISELEFF M. (2022), "PRODUCT DESIGN AND DEVELOPMENT OF A WINDOW CLEANING ROBOT", Scientific Research 2, University POLITEHNICA of Bucharest, Bucharest.
[3]. Author, CHISELEFF M. and Author, BRATU R. (2022), "PROJECT ON DEVELOPMENT AND ADDITIVE MANUFACTURING OF A WINDOW CLEANING ROBOT", Project for Additive Manufacturing course, University POLITEHNICA of Bucharest, Bucharest.
[4]. Author, BRATU R. and Author, CHISELEFF M. (2023), " ANALYSIS ON THE IMPROVEMENT OF THE MANUFACTURING PROCESS OF A WINDOW CLEANING ROBOT", Scientific Research 3, University POLITEHNICA of Bucharest, Bucharest.
[5]. Author, Dugaesescu I., Mechatronics and robotics, course notes, academic year 2021-2022, University POLITEHNICA of Bucharest, Bucharest.
[6]. Author, BRATU R. and Author, CHISELEFF M. (2023), "BUSINESS PLAN CONCERNING THE PRODUCT WINDOW CLEANING ROBOT", Project for Technical Entrepreneurship for SME course, University POLITEHNICA of Bucharest, Bucharest.
[7]. Author, BRATU R. and Author, CHISELEFF M. (2023), "PROCESS OF SELLING A WINDOW CLEANING ROBOT", Project for E-business in Industrial Engineering course, University POLITEHNICA of Bucharest, Bucharest.
[8]. ***, Autodesk Inventor Pro, user manual and software.
[9]. ***, BCN3D CURA, user manual and software.
[10]. ***, ZSUITE, user manual and software.
[11]. ***, Autodesk TINKERCAD, user manual and software.
[12]. ***, IBM WebSphere Business Modeler Advanced, user manual and software.

7. Notes

The next notes are used throughout the work:
WCR = window-cleaning robot;
FDM = Fused Deposition Modelling;
ABS = Acrylonitrile Butadiene Styrene;
SME = Small and medium-sized enterprise;
OSIM = State Office for Inventions and Trademarks;
EUIPO = European Union Intellectual Property Office.