Interim Design Report

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Summary

A need exists for an easy to use, mobile and safe Automated Teller Machine (ATM). Thus, the scope of this project is to design a fully functional and mobile ATM machine with a simple user interface. This report highlights the entire design process that went into designing the ATM, namely the criteria and constraints on the project alongside the overall design decision.

Constraints on Design:

- Time: Design should not take more than 4 weeks to complete
- Human resources: Design should not require more than 4 people to meet the deadline
- Project resources: Design should not require more than the given resources that were provided for the project by the employer (niversity of Waterloo)
- Budget: Design should not cost more than $20 for external resources

Criteria for Evaluation:

- Stability of system
- Efficiency of money dispensing
- Storage of bills in system
- Safety

Design Options:

- Design 1 – A pin-entering mechanism is placed at the front of the robot and money is dispensed through the back of the robot
- Design 2 – A pin-entering mechanism is placed at the front of the robot whereas money is dispensed through the side of the robot
- Design 3 – A pin-entering mechanism alongside a storage component is placed at the front whereas money is dispensed through the side of the robot

Design Decision:

Using a decision matrix and the weights set for each criterion, Design 1 achieved the highest overall result due to it being the safest and most stable system.

Introduction

"An automated teller machine (ATM) is an electronic banking outlet that allows customers to complete basic transactions without the aid of a branch representative or teller" [1]. ATMs are popular due to their convenience, operation at virtually all hours and lack of lines and human interaction. For instance, in 2016, 107 billion cash withdrawals were conducted on ATMs globally [2]. However, there are a few problems with ATMs that prevent future growth in their usage; the increasing complexity of ATM user interfaces and the lack of mobility and flexibility of ATMs prevent the technology from being more widely used.

Firstly, the increasingly complex menus and graphical user interfaces (GUIs) used by ATMs have a negative impact on the user who are stakeholders of the ATM. For instance, according to a survey done in India by S. Bhargavi, cash withdrawal accounts for 78% of all ATM usage, yet the most common ATMs nest this option behind 3 to 4 menus [3]. Furthermore, S. Bhargavi's surveys also illustrate the negative impact of increasingly complicated menus and interfaces of ATMs that often cause users to seek human help, prolonging the time spent at the ATM and perhaps making it more inconvenient than going to a local bank [3].

Moreover, the size and weight of ATMs, which is on average 150-250 pounds for a regular sized ATM, make them stationary and inflexible [4]. Lack of movement is an issue to certain stakeholders such as users, clients and customers. Lack of mobility is a problem for some users because they may not be able to or find it inconvenient to drive or walk to an ATM to withdraw money. Clients and customers could find the immobility of ATMs to be a source of extra expenses and wasted time as the ATM could not easily be moved from its initial installation position.

Thus, by creating an fully functional mobile ATM with a simple and understandable user interface, the needs of the stakeholders for a simpler and more flexible ATM would be satisfied.

Scope

As an ATM machine, the robot must maintain the basic functionality of an ATM, in addition to the improvements. Thus, to accomplish the task of creating a mobile and simpler ATM, the robot must have the following capabilities:

- Security: Must ensure that only the account owner has access to their account and the balance associated with their credit card. This is necessary to prevent illegal transactions [5].
- Storage of Account Information: The ATM must store the information of all the accounts and credit cards that are to be used with the ATM. This includes but is not limited to: the name of account owner, the current balance on account, the colour of credit card and the PIN associated with the account.
- Transaction Processing: Once the card has been authenticated with the correct PIN associated with the account, all transactions update the account balance respectively.
- Human Interaction: The ATM robot should allow users to access and modify their account balance without much complication through the use of a simple menu with easily understandable options.
- Physical Operation: The ATM robot must withdraw and deposit cash of the correct value.
- Mobility: Should be able to move safely and freely on a two-dimensional space.

To satisfy the functionalities mentioned above, the ATM robot must implement various method inputs. The table below illustrates the types of input, what they will measure and the purposes they will serve to satisfy the functionalities.

Input Type	Measurement	Purpose
Touch Sensor	1 or 0	Detects if credit card has been inserted. Also used for powering off the robot.
Colour Sensor	RGB values	Distinguishes between various coloured cards, each of which are associated to a certain account. A colour sensor will also be used for detecting the value of money deposited into the ATM machine.
File	String and integers	For storing and updating user information.
nMotorEncoder	Numerical value from the rotation of the motor shaft	Used for account PIN entry and selection of amount of money to transfer.
EV3 Buttons	1 or 0 from the press of a particular button	Used for majority of user input and option selection

Table 1. Implementation of ATM inputs and the purpose they serve.

As this ATM robot is mobile, it is crucial that it interacts with its environment in a safe manor. Two continuous Tetrix motors are to be used to allow the robot to move on a two-dimensional plane. A gear reduction has been applied to the motors to increase torque but decrease speed, allowing the wheels to move the relatively heavy ATM robot while also preventing it from moving too fast. For safety reasons, it is important that the robot does not move faster than the average walking speed of a human being. As the motors are from a Tetrix kit while the other components are connected to the EV3, due to design constraints, the robot's movement will be controlled remotely.

As mentioned earlier, the main tasks of the robot revolve around making the account transaction process as simple as possible. Thus, once turned on, by powering on the EV3 and Tetrix components, the ATM will remain on and be ready to operate on a user's account until a power off button is pressed. This button will be implemented through the EV3 buttons or through a touch sensor depending on future testing.

The success of this mobile and simple robot ATM machine will be measured by its ability to complete the tasks required and meet the design criteria and constraints. The final product should have all the functionalities mentioned in the list found under the Scope section. The final product must also be programmed in a way that meets the specified requirements.

Criteria

Criterion Name	Measurement	Preference	Weight Factor
Stability of system (quantitative)	The time in minutes the ATM can drive without requiring any human intervention	A greater time is preferred	2
Efficiency of money dispensing (quantitative)	The number of bills the ATM can dispense in one minute	A greater number of bills is preferred	1
Storage of bills in system (quantitative)	The number of bills the ATM can dispense before having to be reloaded	A greater number of bills stored is preferred	1
Safety → Speed of robot's drive and control of robot (quantitative / qualitative)	Centimeters driven / minute How much control does the robot have (On a scale of 1-10, with 1 being that the robot has no control, and 10 being the robot is fully controlled.	Lower numbers are preferred for the speed Higher numbers are preferred for the rating	3

Table 2. Criteria for comparing various designs.

Description of Criteria

Stability of system: Due to the interactive nature of the design, it is important that the system is stable in its movement. The ideal design would be for the robot to drive on its own without any human intervention (excluding remote controlling) to ensure that the parts of the system are intact. This aspect also ties into the safety criterion, as it is essential that the parts of the system do not fall off, especially when a user is in contact with it. This criterion is given a weight factor of 2, to ensure that the system is able hold the weight of its components and perform its main task.

Efficiency of money dispensing: The efficiency of the ATM's money dispensing is also important as it reduces the wait time for the user. A greater number of bills dispensed per minute is preferred to reduce the wait time for the user, which in turn contributes to a better user experience.

Storage of bills in system: The number of bills the ATM can dispense before having to be refilled is important to once again reduce human intervention. A greater number of bills is preferred as it will reduce the number of times the ATM will have to be refilled. This is extremely important to ensure a good user experience by reducing the amount of the times an ATM would need to be closed for it to be refilled.

Safety: Considering the interactive nature of the design, it is important that the system does not pose an unsafe environment. Alongside the stability of the system, the safety of the system's surroundings will be ensured by the speed of the robot and the control that the designers have over the robot. In terms of velocity, a lower speed is preferred to ensure that the robot has sufficient time to react to its surroundings. Furthermore, it is preferred that the owners of the system have full control over the system. This may include the system being remote controlled or programming the robot's sensors to react to its surroundings. This criterion is given the highest weight factor of 3 as the entire project revolves around the idea of a safe and easy-to-use system.

Constraints

Constraint Description	Reason for Constraint
The design must not take more than 4 weeks from the start date to build.	The Demo Day for the entire Mechatronics Class of 2023 is on November 23rd, and hence the project should be ready for viewing and grading purposes by this date
The design must not use more than the following resources: ▪ 4 EV3 motors ▪ 4 rubber wheels ▪ 2 touch sensors ▪ 3 color sensors ▪ 1 ultrasonic sensor ▪ 1 Tetrix kit ▪ 1 Lego pieces kit	These are the only resources we were provided with, and therefore the design must use at most the resources listed.
The design should not require more than 4 people to meet the deadline	The class has been divided into groups of fours and hence the design should be feasible enough to meet the deadline with 4 people.
The budget for purchasing external resources (such as fake currency) should not exceed more than $20	As most of the resources have been provided with, the only external resource required is fake currency, which should not exceed $20.

Table 3. Constraints on the design of the ATM.

Design Options

Design Option 1

[Refer to Figure 1 in Appendix Section]

For this design option of the ATM, the user will first insert their card in the card reader slot. Next, they will enter in the pin by spinning the motor encoder wheel and using the Lego EV3 brick display. Once the setup is complete, the ATM will spin 180 degrees so that the money dispenser is facing the user. The user will collect the money and the process will be complete. This design meets all constraints as it is simple enough to build within the given timeline and does not use any more parts than the resources given. As for criteria, this design is the most stable since it is the lowest to the ground, having the best centre of gravity. Since it is very stable, it is safe as well since the ATM is less likely to tip over, but since it is the lightest option, it could move faster than desired, which is a concern. This option has more storage space for bills than other designs as they are stored at the back of the ATM where there is more unoccupied room. The downfall for this design is that the 180-degree turn is not as fast as the other options, so the user will have a longer wait time.

Design Option 2

[Refer to Figure 2 in Appendix section]

The second option follows the same set-up procedure as the first. The difference in this design is that after the setup, the ATM only needs to spin 90 degrees which makes the overall process significantly faster and more efficient. This option meets all constraints as well. In terms of criteria, the design shares the same levels of safety/speed and stability. The only major difference is how fast the user will collect his/her money. A concern for this option is that since the storage component for the bills is closer to the front where all the other components are, the amount of bills stored within the ATM will be significantly less compared to the other design options.

Design Option 3

[Refer to Figure 2 in Appendix section]

The third design option follows the same setup and money dispensing procedure as the second option as it also only turns only 90 degrees. The difference in this is that there is an extra level added to the front of the ATM which allows the components of the ATM to be spaced out more. This is beneficial for the storage component because it allows for more room for bills to be stored. Since there is an extra level added, it will make this option the heaviest and in turn will give the lowest moving speed. However, the extra level adds a concern because it decreases the overall stability of the ATM. The front of the ATM will be more likely to tip over as it is higher up and adding weight to one side. A solution can be to add a counterweight, but this could result in the ATM becoming too heavy, which may cause the machine to be unable to move.

Design Decision

The following is a table comparing the three different design options with the criteria.
The category weights are defined as:
1 - Efficiency
1 - Storage of bills
2 - Stability
3 - Safety

The criteria weights are defined based on importance. In terms of safety, it is the most important criteria, so it will be worth twice everything else. Stability is the second most important, so it is worth one and a half, storage is worth just one, and lastly, efficiency is worth the least, giving it a half.

	Design 1	Design 2	Design 3
Stability (rating)	9/10 (3*1.5)	6/10 (2*1.5)	3/10 (1*1.5)
Efficiency (seconds)	90 (1*0.5)	45 (3*0.5)	45 (3*0.5)
Storage (number of bills)	100 (3*1)	50 (1*1)	70 (3*1)
Safety (rating)	8/10 (3*2)	7/10 (2*2)	2/10 (1*2)
Overall results	14	9.5	8

Table 4. Decision matrix for comparing the three designs.

The results from the decision matrix indicate that the first design option is the best as it achieves the highest overall result. This is mainly due to the fact that it is the safest and most stable option.

Project Plan

The major milestones of the project are as follows:

Design	
Team Creation	Oct 12
Initial Design Brainstorming (needs/requirements etc.)	Oct 12 - Oct 22
Project Idea Formulated	Oct 22
Design Sketches and Functionalities Determined	Oct 22 - Nov 2
Project Pitch Presentation	Oct 26
Hardware Request	Oct 29
First Design Revisions	Nov 2 - Nov 9
Second Design Revisions	Nov 9 - Nov 23
Preliminary Design Report	Nov 12
Project Demo	Nov 23
Final Design Report	Dec 3
Building	
Chasis	Nov 2 - Nov 9
Card Detection Mechanism	Nov 2 - Nov 9
Mechanical System Presentation	Nov 9
Housing	Nov 2 - Nov 14
Cash Deposit	Nov 12 - Nov 14
Cash Withdrawal	Nov 12 - 18
Coding	
Card Detection Mechanism	Nov 13 - 14
Software Design Meeting	Nov 13

User input	Nov 13 - 14
Deposit and Balance Update	Nov 14- 17
Withdrawal and Balance Update	Nov 17 -18
Testing	
Stability and Mobility Test	Nov 10
User Input Mechanism Test	Nov 12
Money Deposit Test	Nov 14
Money Withdrawal Test	Nov 14 - Nov 20
System Test	Nov 17 - 22

Table 5. Project schedule and deadlines.

See Graph 1 in the Appendix for a graphical interpretation of the project timeline.

In terms of roles, Sarim Ali and Kyle Tam are primarily responsible for the mechanical and structural components of the project while Dhruv Manani and Mahad Zaryab are primarily responsible for the software components of the project. All team members are equally responsible for the overall design. Throughout the duration of the project, team members either all work together or split into pairs based on their responsibilities.

The Gantt chart depicted in Graph 1 is structured to demonstrate the importance of each task. Sections like Design come before sections such as Coding because tasks in Coding are dependent on tasks in Design to be completed before they can begin.

Some of the tasks that were allocated more time in comparison to other tasks include the following:

- Manufacturing of the housing and cash withdrawal
- Coding of the deposit and withdrawal functions
- Coding of the main program
- Testing of the deposit and withdrawal functions
- Testing of the entire system

This was done as each of these tasks is expected to be difficult to accomplish or will be time-consuming. In addition, as some of these tasks (such as the manufacturing of cash withdrawal) are difficult to allocate an amount of time. This is due to the fact that these designs are concepts that have not been tested and may be subject to multiple revisions.

Conclusion

In conclusion, design #1 was chosen due to a combination of its greater stability, storage and safety as compared to the other design options.

References

[1] Investopedia, “Automated Teller Machine - ATM,” *Investopedia*, 03-Aug-2018. [Online]. Available: https://www.investopedia.com/terms/a/atm.asp. [Accessed: Nov. 9, 2018].

[2] “ATM cash withdrawal volume grows 6 percent in 2016,” *ATM Marketplace*, 15-Dec-2017. [Online]. Available: https://www.atmmarketplace.com/news/atm-cash-withdrawal-volume-grows-6-percent-in-2016/. [Accessed: Nov. 9, 2018].

[3] S. Bhargavi, “User experience and ATMs,” *YourStory.com*, 04-May-2017. [Online]. Available: https://yourstory.com/2017/05/user-experience-atms-neglected-issues-affecting-bank-customers-india/. [Accessed: Nov. 9, 2018].

[4] “ATM Installation,” *ATM Depot*. [Online]. Available: https://www.atmdepot.com/resources/how-atm-machines-work/atm-installation-training/. [Accessed: Nov. 9, 2018].

[5] K. Al-Saleh and S. Bendak, “An Ergonomics Evaluation of Certain ATM Dimensions,” *International Journal of Occupational Safety and Ergonomics*, vol. 19, no. 3, pp. 347–353, 2013. [Accessed: Nov. 10, 2018].

Appendix

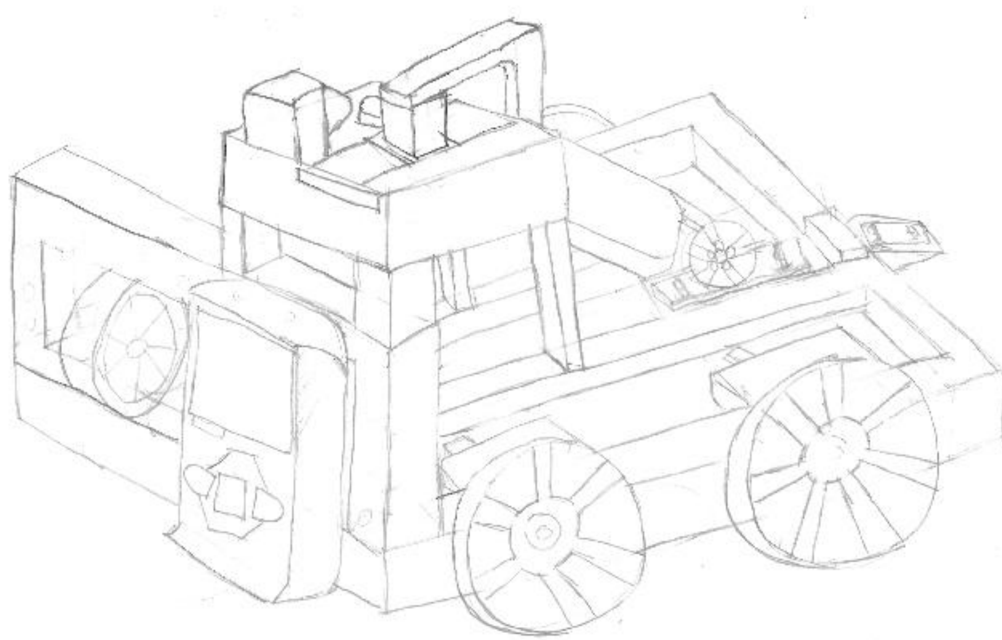


Figure 1: Sketch of Design Option 1 which implements the cash withdrawing system on the opposite side of the user interface for greater storage and weight distribution and thus also stability and safety.

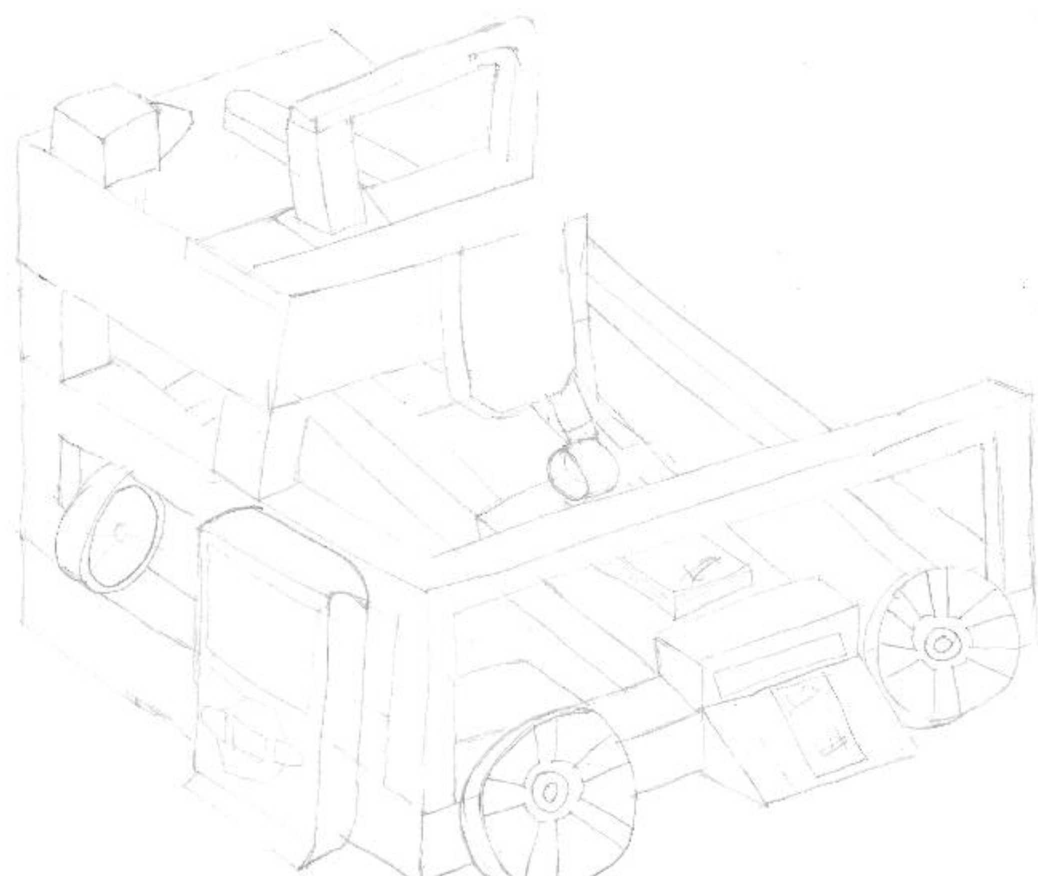


Figure 2: Sketch of Design Option 2 which implements the bill dispensing mechanism to the right of the user interface, allowing easier access for the user, but occupying more internal storage space.

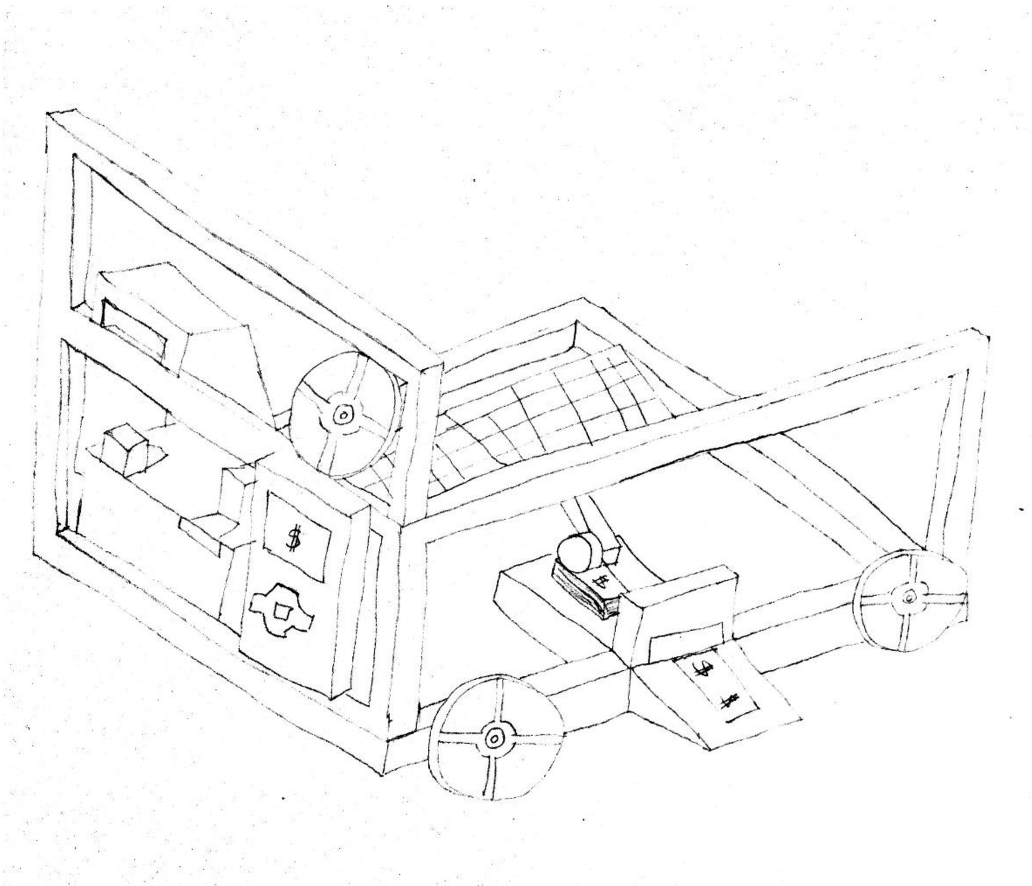
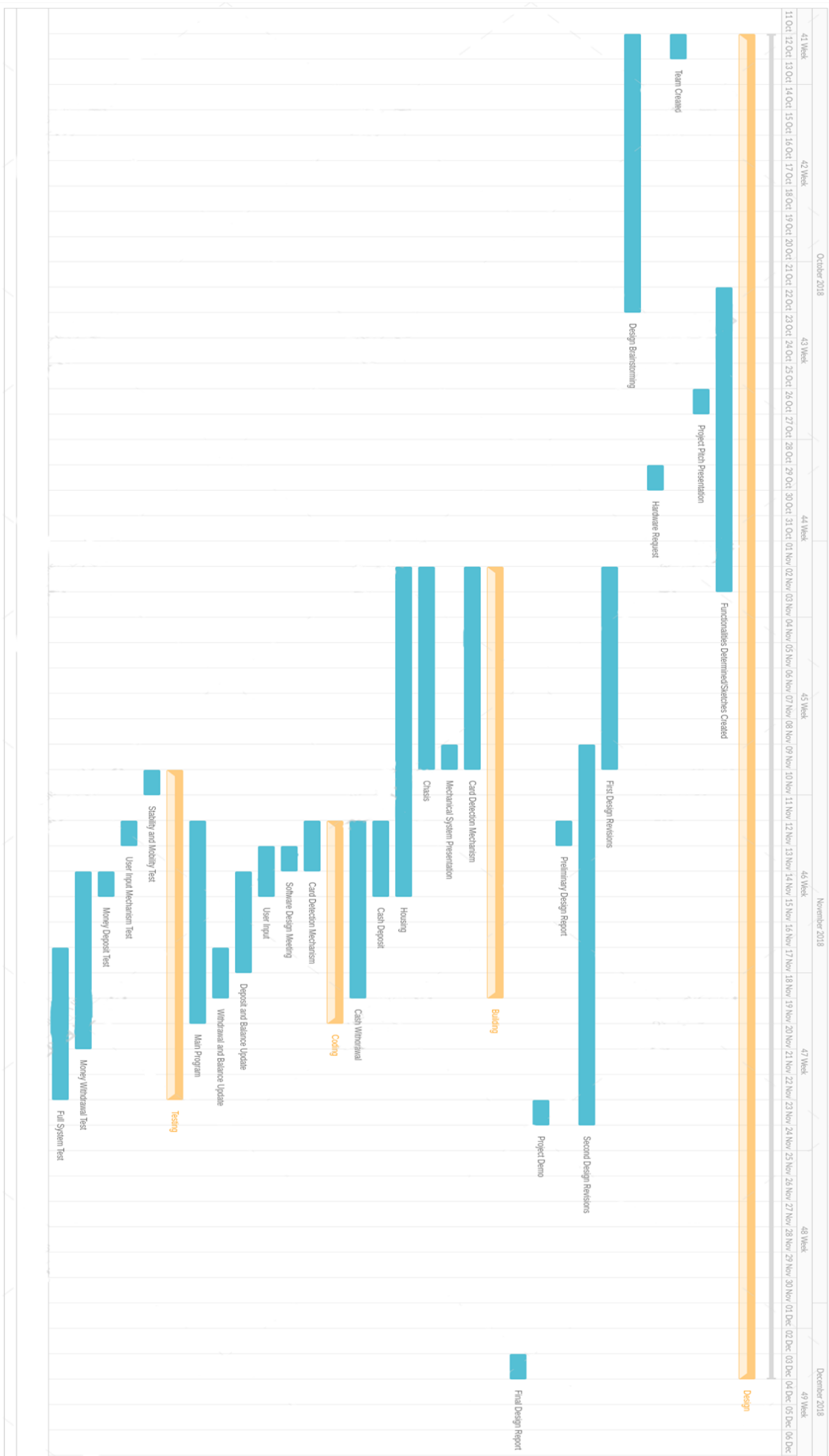


Figure 3: Sketch of Design Option 3 which, similarly to Design Option 2, implements the cash withdrawal system on the right side of the robot, but adds a second layer on the front side for more component space.



Graph 1. Gantt chart of the timeline of the project (Rotated for larger text size)