Final Report

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1. Executive Summary

Our Autonomous Container Delivery System aims to safely and quickly transport an egg between two unknown points, whilst avoiding obstacles that are in the way. Our device is automated and centralised through the use of an Arduino UNO, which controlled the DC motors for the physical movement, as well as the ultrasonic sensor in order for the pulley system to be accurate when picking up and delivering precious cargo. The physical components of our design involved machine cut wood that constructed the main body, while the electrical components were secured to the body through the use of glue, screws and soldering.

Through this design, there are significant advantages to each of the component design for every function. The DC motors utilised for both vertical and horizontal provided sufficient torque, while the ultrasonic and audio sensor allowed for precise measurements of variables within the operation of the device. Thus DC motors were used to maximise speed, while fishing line was used for its high tensile strength in order to maximise safety and robustness of the system. However, there is a major disadvantage to having such a cohesive unit; the physical movements of the device could not be relayed to the Arduino, and a response could not be made in return. For example, a wheel is falling out of its socket; due to the lack of connectivity between the physical component and the Arduino board, the device will continue to run with 3 wheels, thus altering its horizontal movement significantly.

A key resource utilized for the device were the electrical components involved in creating the autonomous system with the Arduino UNO. The majority of these components came from the Arduino Kit obtained from the UNSW Create store, including the Arduino board, the ultrasonic distance sensor, motors and the motor driver. Pieces of wood including boards and dowels were needed to construct the body of the device and were collected from MakerSpace.

During final testing, the device performed very well, being able to carry the egg over on our first attempt. However, the issue mentioned before, arised once again during the final testing, the pulley was stuck due to the mechanical error, thus when it fell the increased force caused the clamp system to fail, resulting in the failure of the two egg test.

2. Introduction

Background

Autonomous delivery systems present an exciting, new way to revolutionise transport of goods. In areas such as manufacturing, autonomous devices are already being used to quickly mass produce products which are of consistently high quality. By taking humans out of the equation, manufacturing can be streamlined, reducing the chance of error and improving customer satisfaction. This can also be applied to the delivery of goods. Such delivery is usually time consuming and monotonous, which can be taxing to people. This problem is compounded by the fact that places such as ports and mines must operate 24 hours a day, seven days a week, requiring a large workforce to keep goods flowing in and out. If we are able to replace these workers with autonomous systems, more people are able to be put towards more technical roles where humans have much more use, rather than physically demanding jobs. Robots also minimise the error and time spent during delivery, being able to learn the optimal route of travel immediately, compared to a human worker. Current autonomous transport systems also contribute to a significant decrease in energy consumed, with some designs travelling faster with less fuel consumed (Graham, 2019). They also minimise time spent waiting to drop off and deliver goods. The device that we design may be a potential prototype for forthcoming autonomous devices.

Problem Definition

With the problem condition presented, it was firstly properly defined and construed so that every aspect of the overall problem is clearly understood by every member.

The problem was defined as: The design and creation of an autonomous, mechanical system that is able to move fragile cargo from unknown pickup and delivery locations, which are wirelessly communicated through control modules. It will also be required to automatically detect the heights of both pickup and delivery points and needs to be able to raise and lower the cargo to avoid damage through collisions with potential obstacles.

Design brief discussion

The Autonomous Container Delivery (ACD) system involves designing an autonomous system so that it can communicate with a control module to accurately move cargo between initially unknown pickup and delivery locations.

The specific design objectives for a prototype of such system firstly includes a need to move efficiently through the course, responding to the heights of the obstacles in its way, without damaging the package throughout the process. In terms of movement, it must travel at a speed fast enough to complete the course quickly but keep the egg safe in transit. The device must also be able to stop accurately so that it is able to retrieve the egg. To communicate with the control module, the device must be able to emit an infrared light to trigger the module's speakers as well as be able to recognise and respond to the sound emitted. It must be able to detect two different frequencies in order to complete the required task. To be able to detect the height of the pickup and delivery points, the device must be able to use a type of ranging technology to pinpoint the distance between itself and these points, so that it knows where to execute its lifting mechanism. To pick up the egg, the device must have a mechanism to firmly grasp the egg without breaking it. This mechanism must also be raised and lowered so that it can both adapt to the varying heights of the pickup and drop off locations as well as dodge any obstacles in its way. The speed at which it is being raised and lowered must be controlled in order to prevent damage.

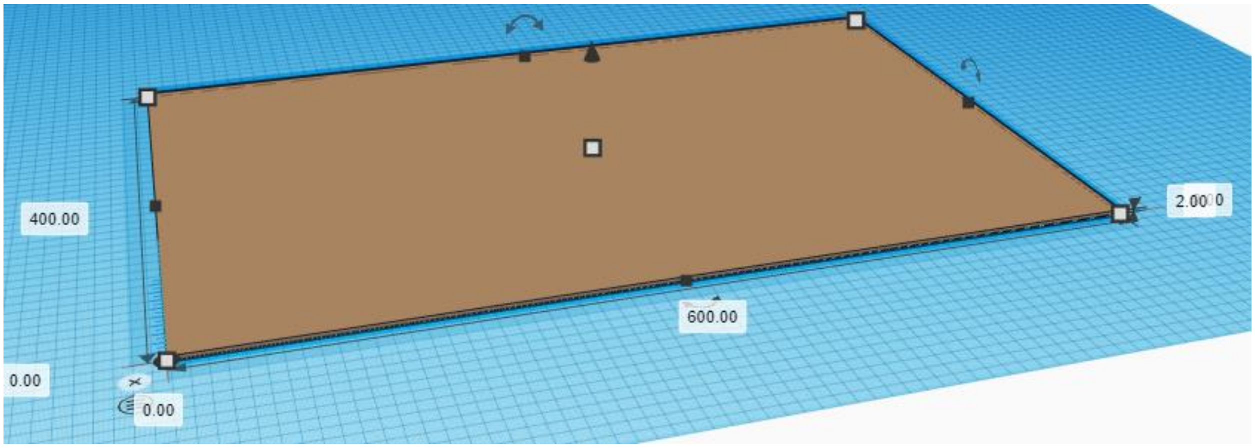
The design brief of the system raises a few issues. Firstly, there will be several obstacles present in the path of the device. A potential solution for this is raising the egg above the maximum height of the obstacles and then lowering it to the point of delivery. In addition, the egg must be delivered safely. This places some constraints on the top speed of the device, as well as the design of the pickup mechanism. Furthermore, the control module is depicted as being 30 cm away from the inner edge from the guide rails. This could present a problem as it may be too far away from our device to be detected if we decided to go with a compact design. It may be necessary to build an extension arm on which the microphone is placed.
During development, a key problem was the design of the pickup mechanism. We went through several designs, ranging from simple to complicated in their implementation. It was only after rigorous discussion that we decided on the final design of the mechanism. Another issue arose during testing, which was the robustness of the device. This was due to a lack of care when connecting wires, resulting in them being tangled and often disconnecting.

In this report, all the concerns mentioned above will be addressed. This will be accomplished via an outline of each individual component of the design, namely its movement, the pickup mechanism, object detection system and communication system. In addition, the required knowledge to construct each component will be demonstrated, including not only what current knowledge we hold, but also what further research has to be done. Finally, we will discuss the logistics of our system, which include the risks faced by it during final testing as well as a detailed project plan for our construction and testing.

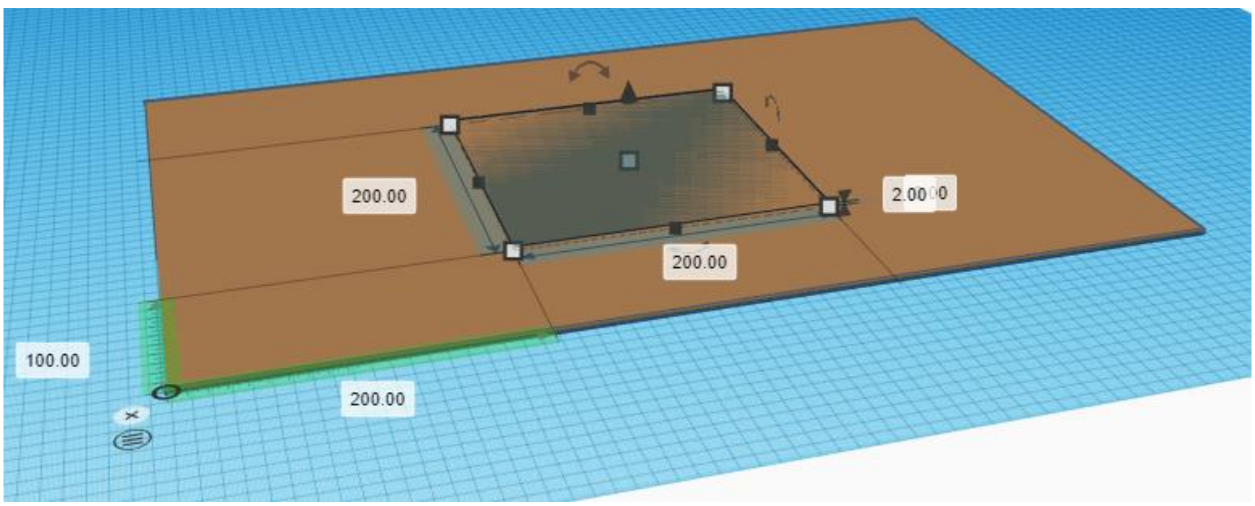
3. Final Design and Implementation

Mechanical Body

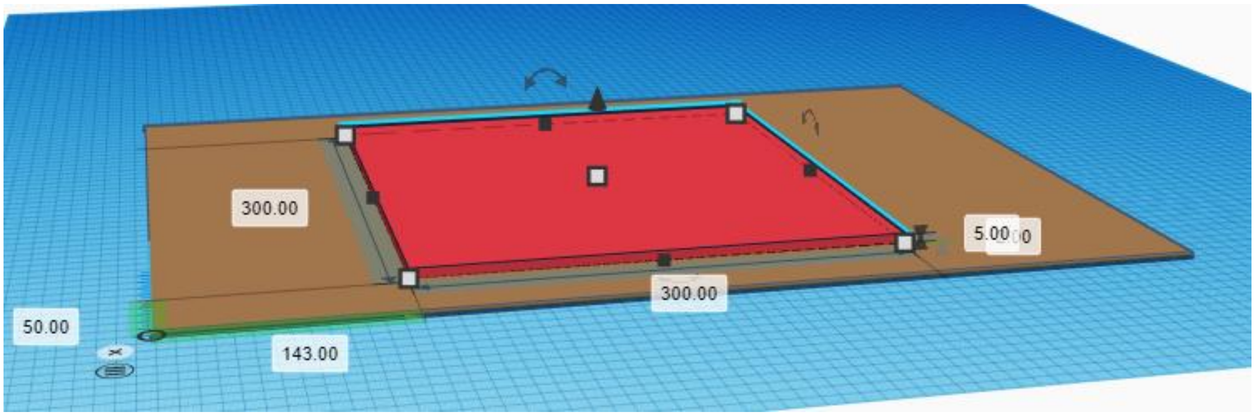
The main platform of the device consists of a wooden plank of dimensions 60 cm by 40 cm by 5cm. These sizes were selected mainly to fit the guide rails, as well as to provide enough surface area to hold the electrical components. The material used was pinewood which was picked due to it’s high tensile strength being able to withstand the weight of the pulley and components on top, as well as being light enough to allow for faster horizontal movement.



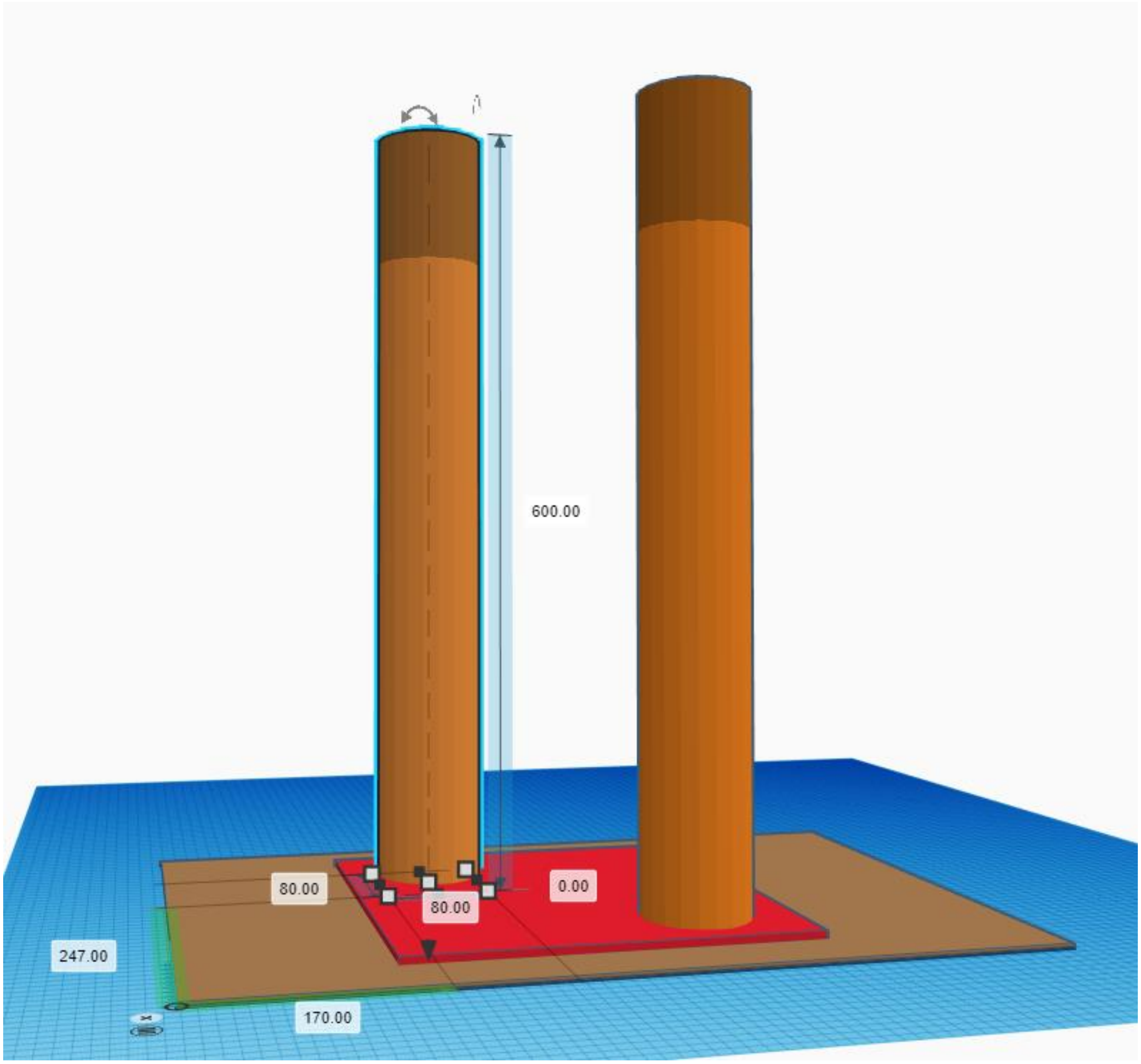
Within the middle of the main platform lies a hole of dimensions 20cm x 20cm, positioned 20cm away from the sides and 10cm from the front/back as below: This hole is cut to fit the track and allow the placement of the pulley system as well as dowels for maintaining balance for the system.



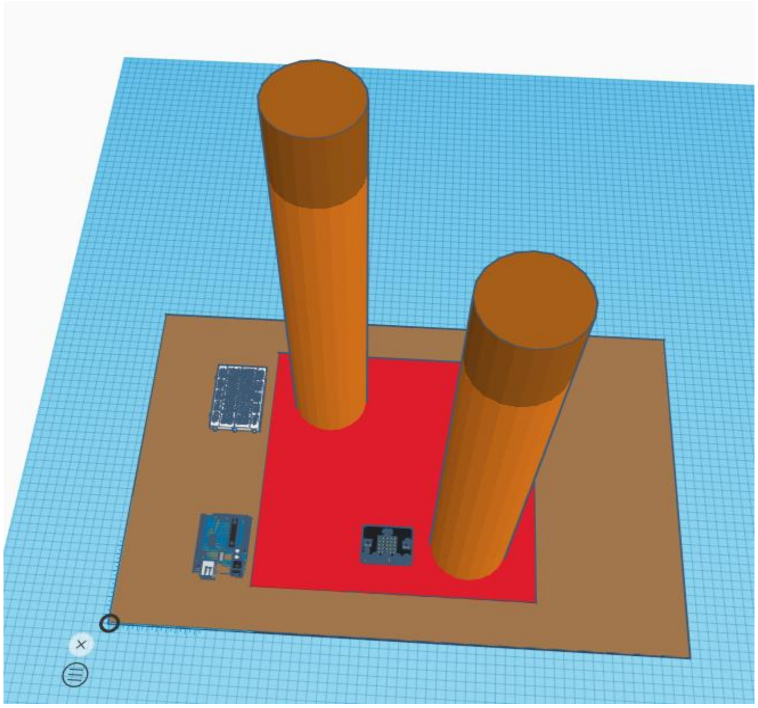
On top of the main platform, there is another thick plank of dimensions (25cm by 25cm by 5cm) to serve as a guide for the dowels (dimensions given later) to be lowered and raised smoothly as well as perpendicular to the surface of the platform. The plank also serves to minimise flexion of the main platform, especially during the pulley operation as the high rotational velocity of the DC motors can cause alot of vibrations.



In the two opposite corners of the wooden plank, a hole of diameter 9cm is drilled through the red coloured wood. Through this, a dowel of diameter of 8cm is placed through each corner. The length of the dowels was chosen to be 60cm to allow the pulley system to be lowered completely. The hole diameter was selected to be slightly larger than the dowel diameter such so that there is no physical contact between the dowels and the plank to minimise friction and thus, allow for a smoother lowering/raising of the clamp.These holes allow the dowels, which are connected to the clamp, to travel vertically and prevent too much swaying during the pulley operation.

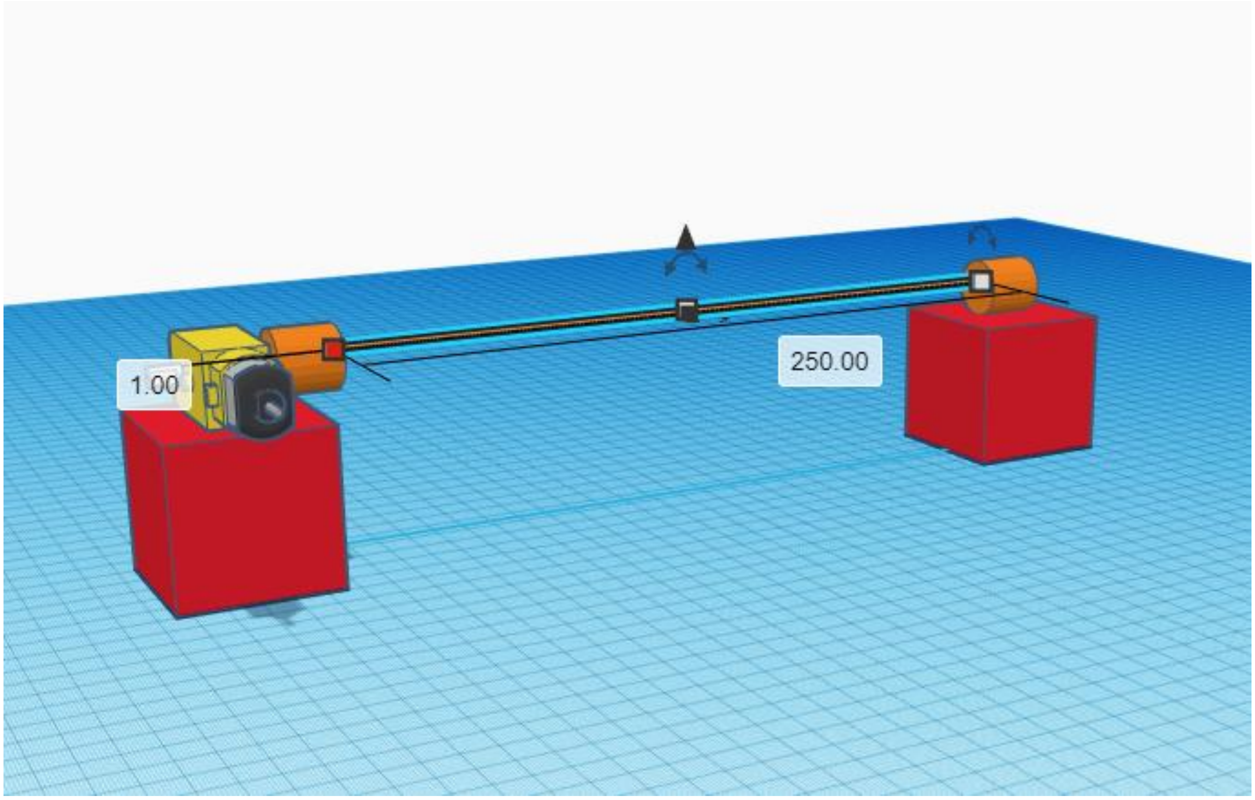


The breadboard (low pass filter) and the Arduino Uno are mounted on the left edge of the platform, making room for the pickup mechanism which is centrally located on the platform. These positions were selected so that the audio/IR sensor could be closely placed to the side of the main platform and can easily interact with the control module which will be on the side of the device. They are then tied down with cable ties as well as screwed into the board through the holes available on the Arduino board. The direction and rotation in which the boards were put also serves a purpose; the USB port was specifically put towards the outside rather than inside to allow for easier access, as well as the breadboard was put close to the Arduino board to minimise wiring requirements.

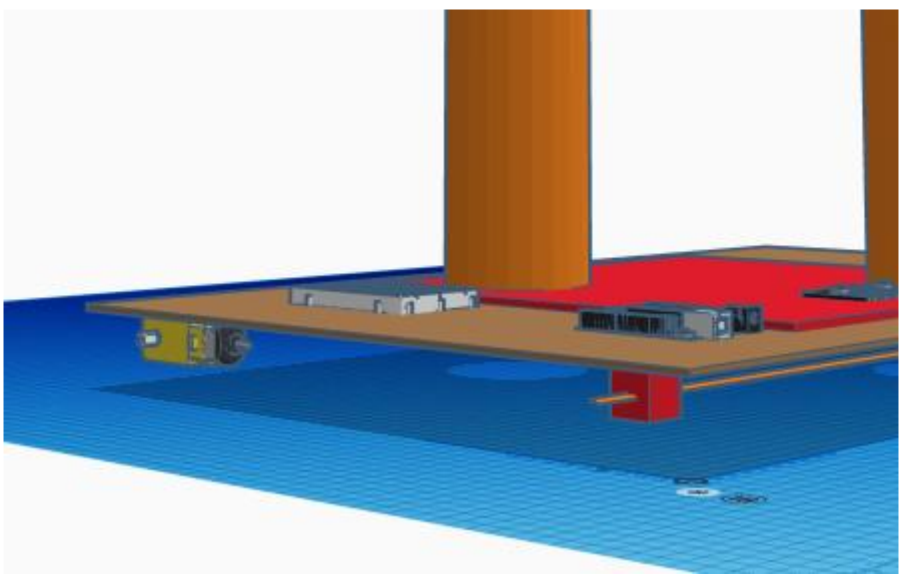


The motor used to raise and lower the container is mounted onto a small cube of 10cm on the right edge of the raised platform to ensure that it has enough room to properly raise and lower the container. Glue was used to secure both the motor onto the cube and the cube onto the plank.

Attached to the motor was a cylinder of diameter 10 cm, used purely as a rotator for the dowel used to wind up the string and also as a contact surface for the motor and the dowel used to wind up the pulley. Another thin dowel, diameter of 1cm, is then attached to the larger cylinder, secured through a drilled hole and glue. The other end is secured to another cylinder of diameter 10 cm but is only placed through the hole, rather than glued.



The two motors used to drive the rear wheels is mounted on the underside of the top left and right corners of the main platform, with the wheels directly attached to the motors themselves. To provide additional stability, several wooden standoffs were glued to the bottom of the front edge of the main platform. Through the standoffs, holes were drilled so that an axle could be placed through them. Then, on the ends of the axles, another wheel was placed on each end. The wide wheels provided some additional stability. Also connected to the breadboard was an emergency stop switch.

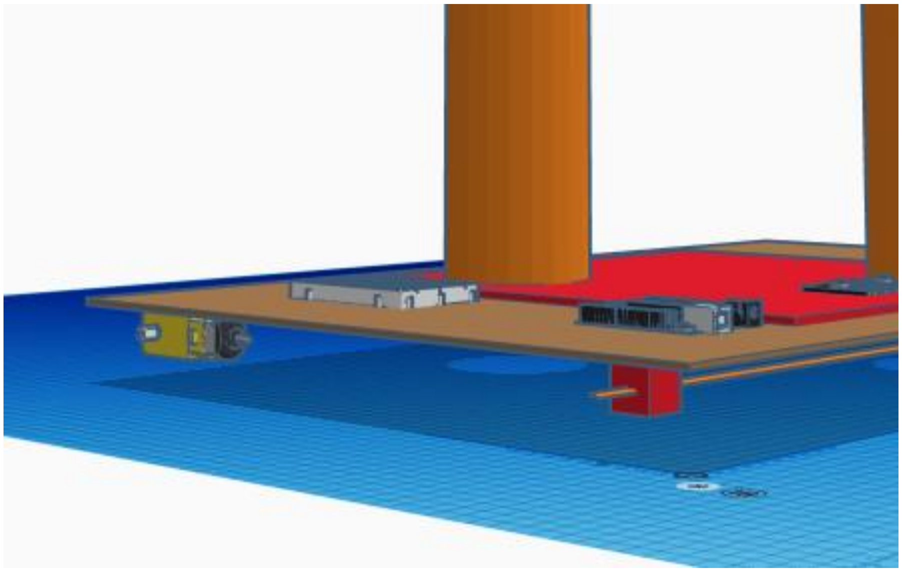


Pickup Mechanism

The pickup mechanism involves a container which is able to be opened and closed, and also able to be moved up and down to avoid obstacles. It is engaged after the sound signal from the control module is detected. The container is a piece of PVC pipe attached to a board and attached to it is a base connected to a servo which controls the movement of the lid. The lid is a circular piece of wood big enough to completely cover the bottom of the pipe. The servo is glued near the bottom of the rim of the pipe, so that when closed, the lid is flush with the bottom of the pipe This servo is able to slide the lid open and closed, securing the egg in the container. To raise this container, a piece of cord is attached to the board and tied to a shaft. The shaft is spun by a motor so that the container can be raised. To fasten the shaft to the motor, a wooden cylinder was crafted with a hole through it so the motor shaft could be put in one end and the shaft of the pickup mechanism could be put in the other end. The cylinder is 2cm in diameter and 3cm high. This securely linked the motor to the shaft to prevent slipping. On the other side was a block with a hole drilled into it to fasten the other end of the shaft. As mentioned, two wooden dowels are attached to the container, which run through two holes in the main platform, to guide the path of the container. The dowels are glued to the board on which the pipe is mounted, on the top left and bottom right corner, exactly below the holes drilled into the main body so that they can move perfectly vertically. Furthermore, as the container is raised or lowered, a speaker was installed to generate a beeping sound.

Horizontal movement

The motors used for both the device’s movement and the movement of the container are connected to a L298N motor driver. This motor driver made running the motors much easier to do. Two motors drive the front wheels of the device, both connected in parallel, while another drives the pickup mechanism. The two motors used to drive the rear wheels of the device are connected in parallel, so that they can be driven together. The motors used for movement are triggered when the on button is pressed. Upon detection of the control module’s signal, the motors will stop to quickly halt the movement of the device. Then, after the container is raised, the motors are engaged again to move the device forward, until the second signal is detected and the procedure is repeated.



Ultrasonic Distance Sensor

The model of sensor we used is the HC-SR04. This sensor is used to establish the distance from the device to the cargo below. The sensor was mounted on the underside of the board, adjacent to the container, so that it is able to send and receive a clear signal, increasing accuracy of measurement. To connect the sensor to the Arduino board, the sensor's ground pin was connected to the ground of the Arduino, the VCC pin to the 5V pin of the Arduino, then trig and echo are connected to any digital I/O pin on the Arduino. A schematic of the circuit and the code used can be found in the Appendix (Figure 1 and 2 respectively). In essence, the trigger pin is set to HIGH to send a burst of sound over 10 microseconds to the object, then the echo pin is read to determine how long the sound took to reflect back. Then, distance can be calculated by dividing the time by two and multiplying it by 0.034, which is the speed of sound in cm/μs. When the signal from the control module is detected, the sensor is engaged along with the pickup mechanism. Once the sensor detects that the container has touched the ground (since the height of the container is known), the servo motor will be engaged to close the lid, securing the egg. Then, the container will be raised, until the acceptable height of x cm from the ground is reached, well above any potential obstacles

Sound Detection

To detect the sound emitted by the control module, an infrared LED and a KY-038 sound sensor was used. This were directly connected to the breadboard, close to the edge of the device so that it can be as close to the control module as possible. The LED was used to trigger the control module's sound. It was placed so that its height would be level with the infrared receiver on the control module in order to reliably trigger the module. The sensor was placed so that it would be the same distance away from the LED as is the speaker is from the receiver on the module. This would ensure that once the LED is moved directly in front of the module, the sensor would also be directly in front of the module's speaker. This sensor was connected to a low-pass filter which was used to eliminate the noise from the signal, allowing us to more clearly detect the sound. After the sound was detected, the pickup mechanism and ultrasonic sensor will be activated at both the pickup and drop-off points.

Evolution of Design

Overall, the main change from the design proposal was the pickup mechanism. We adopted this change because our original design, although it seemed to work well on paper, was too hard to implement, requiring too many motors which simply couldn't be plugged into the Arduino board. For compliance testing, we were able to get forward movement, the ultrasonic sensor and sound sensor working well, hence the only thing we had to concentrate on was the pickup mechanism. Hence, after compliance testing, we simply modified the main platform so that the newly designed pickup mechanism was able to be fitted on, namely by drilling two holes through it. We already realised that the pickup mechanism had to go in the middle of the board, so we organised all the components on the breadboard and the motor driver and put them towards the edges of the main platform, allowing us to make easy changes to adapt to the pickup mechanism.

In total, the cost of our final prototype was around $60.
Note: Majority of the materials used for the body was freely obtained from MakerSpace.

4. Evaluation of the Design

After the first prototype was constructed for compliance testing, the initial tests that we did were used to established that our ACD system worked. This involved checking each component, such as being able to detect audio signals, powering the motors which drove the wheels and braking after the sound was heard, and that the ultrasonic sensor was able to read the distance to the obstacles or cargo below. Since this was basic testing, there was no real experimental rigour towards this. At this stage, we concluded that each subsystem was working, however it was not very robust as we had not organised the wires very well, resulting in them getting unplugged at times. This was a major point of concern for the design.

After constructing the final prototype, each system was again individually tested to confirm that they were all working. During this testing, we discovered that a major source of unreliability in our design came from the two dowels that guided the pickup mechanism. Despite our attempts to stabilise the container, the whole mechanism still swung as it was being raised and lowered. Occasionally, the dowels might reach an angle at which they would become stuck in the hole, requiring manual adjustment, which defeated the purpose of the autonomous system.

However, on the day of final testing itself, we spent a lot of time reconnecting and soldering wires, because some parts were still not working together as they should have. This was amid running more tests in the actual testing environment, i.e. with the guide rails. Before official testing started, we came to the conclusion that the device was working well and should perform nicely during evaluations. At that time, without an egg to test with, it seemed like the system could reliably detect and respond to the control module. Furthermore, the container was able to be raised and lowered to an appropriate height with the guidance of the ultrasonic sensor. It was also able to be opened and closed. However, due to the lack of time, we failed to evaluate how robust the system was, since we could only have a few test attempts before the first group was called up. This eventually became a major issue for us as we did not realise that the device was more unreliable than we anticipated.

5. Analysis of Final Testing Result

The final results were very good. The first criteria, autonomy, was clearly fulfilled. During testing, after the start button was pressed, provided the control module was in a suitable location close to the device, it was able to detect and respond to the sounds on its own. It managed to complete a delivery without human intervention. This also fulfils the criteria of detecting the control module. Our device was also able to avoid obstacles well, since it could raise the container after it had picked up the egg. Finally, our system was clearly able to fit on the provided guide rails. However, these criteria were not fulfilled in all tests. On our second attempt, the pickup mechanism failed to function, due to the guide rods jamming on the edge of the guide holes. This required manual adjustment. All other systems still functioned. In order to achieve this, we could have either lubricated the hole or the dowel, or drilled a slightly bigger hole, so that the dowel could fit through more easily.

Each aspect of our design contributed its own part to the success of our final testing. Despite our simple design, it managed to perform well during the test, even during the drop test, which proved its robustness. However, due to its simplicity and ease of manufacture, we sacrificed style for function, not devoting much time to making the device look good. Firstly, the main platform on which our components were mounted was large, allowing for greater stability while travelling, as well as ensuring that we could fit well onto the guide rails. Straight travel was allowed by the two guiding pieces of wood mounted on the underside of the platform. The large platform also allowed us to keep our wires relatively spread out, to make maintenance and repairs easier compared to if they were all compacted into a small case.

The pickup mechanism was effective however it could've been refined more. Since the mechanism was very simple, there was very little that could have gone wrong with it, making reliability less of a problem than it could have been. The problems we did have were easily troubleshooted. The mechanism itself worked almost all the time. But the pulley system that carried the pick-up mechanism was slightly unreliable and did not work all the time, though the times that it did were major successes. Our container proved to be easier to build and more effective than a clamp, which was one of our earlier ideas. It had a high degree of room for error, offsetting the potential uncertainties introduced by inaccuracies in the ultrasonic sensor or positioning of the de-vice over the egg. This was our greatest innovation in our device. Our motors too were relatively simple, only requiring two circuits – one to drive the device forward and one to raise and lower the container. This again simplistic solution was highly effective and was all we needed to complete the task.

A small but crucial part of our design was the distance sensor. This ensured that we would be able to pinpoint the height of the pickup and drop-off location quickly and easily. The sensor was also extremely easy to implement, only requiring a bit of code to calculate distance. Sound detection was slightly more complicated, requiring a bit of extra circuitry in the filter, but also proved to be a relatively simple design. The fact that we used a sound detector instead of making a microphone/amplifier circuit from scratch greatly decreased the difficulty in ensuring that the subsystem worked.

Looking back, whilst the design brief mentioned speed of delivery as a criterion, this was never tested for in the final assessment. This meant that we had to reprogram our device to increase accuracy when travelling instead of speed, as this then became the most important criteria. We still managed to get the change done in time, leading to a successful test. Another mistake we made was overcomplicating the pickup mechanism. We had originally designed a system using two boxes that came together to encapsulate the egg, however we realised it was too hard to get them back open once we closed it. Fortunately, our new, simpler design proved to be as effective, or even more so than our old design. This was reinforced by the simple tests we conducted before final testing to ensure everything was working. It was actually compliance testing which gave us the confidence to redo our entire design because we learnt that we had got everything else, especially the coding, to work well, hence we could concentrate on the pickup mechanism.

6. Key Lessons Learned

In this project, our team developed a basic understanding of electronics and applying them with an Arduino board, including the coding required to drive the device. Most of this basic understanding began with the Lab Exploratory Exercises provided. In conjunction with the technical lectures, they provided us with a good start to learning more about electronics needed to design and build our ACD system. One team member Mun Joon for example, took it upon himself to visit many online forums and websites for Arduino tutorials to further familairse himself with the board to work on the coding. Despite being comfortable with the coding syntax, one particular challenge presented to Mun Joon and other team members with Computer Science backgrounds was understanding how to use the various libraries and ensure that the circuit could function properly after the addition of the Arduino board. We eventually overcame this through rigorous trialing by running simulations.

Ultimately, most of our design was similar to the original concept, however we had to completely alter our pick-up mechanism, because our original design as outlined in the design proposal was not feasible with the Arduino Uno. Fortunately, during final testing it worked well, despite the lack of reliability in our system. Whilst we prepared well for the test, messy wiring and an unreliable guidance system for the pickup mechanism resulted in us failing to deliver the second egg. Given another chance, we would have liked to refine the pickup mechanism by not having it being guided merely by two shafts, as the large amount of friction caused inconsistencies in its movement.

From surveying our whole team, we all agree that our approach to group-based projects has developed further. Compared to high school, where everyone had a good understanding of each other's technical strengths, the teamwork involved in this project has been much more difficult to manage. The fact that we were a large group of complete strangers who had few prior knowledge of the problem was what complicated it. So the whole course was very challenging in that we not only had to work with different people with varying backgrounds and talents, but also pull our own weight and try our hardest to contribute to the project in different ways and coordinate properly. However, we all realise this course has taught us how group projects in the real world may mimik ours and be very difficult to get right. The key lies in communication skills which some of us felt has certainly developed after working with different people.

Another important part of the project was the ability to learn quickly. Almost all of the knowledge required to design and build our ACD device for it to work were new to most of us. What stood out was the sheer amount of knowledge needed to simply drive a motor or write the code for responding to an audio signal. Without the ability to learn quickly, one would become a dead weight very soon as he or she would find it really difficult to contribute much beyond concept generation. Some of us were able to master our own subsystems, but relied on others to integrate all the subsystems into one device, which again required a surprising amount of knowledge to realise. Although reflecting on this, some of us believe putting in additional time and effort to acquire these knowledge to contribute more is achievable despite the short timeframe.

Overall, we learnt that teamwork is difficult and may very well be an uphill battle to the final product. It is not enough to simply trust your teammates to fulfil their duties whilst concentrating on one's own duties as some of us were used to. Some people will inevitably not contribute as much as they need to either because of varying expectations or simply slacking off. This will need to be addressed in any group work situation, for example by chasing up on people of their tasks, as it can impede progress and even cause economic loss in the real world. Unfortunately, for our project, much of the work over the lead up to final testing fell on those who knew what they were doing due to the sheer technical difficulty. This problem was compounded by the almost completely self-driven nature of the project, as evident through the groups that have already built various prototypes well ahead of the pack. Some of us who have contributed to only one subsystem genuinely felt helpless before final testing as our prototype basically became the product of only two people. For this reason, it is also very difficult to really improve on what we did with limited expertise apart from the two. Better leadership and coordination could have potentially improved our performance, but this comes with experience.

7. Effectiveness of Organisational Support

As an introduction to electronics, the technical lectures and Lab Exploration Exercises were appropriate. The exercises were challenging enough to be meaningful and the lectures were a good starting point to begin learning with, especially for people who don't study electrical engineering. They did cover a lot of content, which was very good, but there was a lot of pressure to complete all six checkpoints, resulting in many people simply choosing the six easiest ones, thereby not learning much at all from the exercises. It would've been better to require that we do two complete modules, so that we get a thorough understanding of a few components. Some of us tried to do this and felt it was quite helpful to do so as we really got to understand how to use the Arduino together with the circuit with the final lab exercise. This was bolstered by the assistance we received from the demonstrators who came to the labs. They were very helpful in allowing us to understand the way the circuits, Arduino and CRO worked, which resulted in us being able to complete the checkpoints, namely a significant milestone in configuring the sound detection device and the ultrasonic sensor to work with the Arduino. However, we did find that a few particular checkpoints were extremely hard to do, only completing them after one of our team mate who does electrical engineering and showed us techniques not covered on the tutorial notes.

On the other hand, Mun Joon who attended the Arduino lectures found that it wasn't very helpful. His feedback was that they seemed to be aimed at complete novices. He felt like despite with little programming experience before, he did not learn anything new from those lectures besides basic Arduino functionality, which could be self-taught in the lab exercises. Anyone who decided to take on the coding for this project would be someone who understands at least a little bit of code, due to how difficult it is, unless one was unlucky enough to be placed in a team where no one knew how to program. Hence, they would not benefit from such a lecture. Much of the difficult content was left for us to explore ourselves in the lab exercises, and Mun Joon was hoping for the Arduino lectures to cover some of those exercises as well as perhaps extending them further. Though we do realise that the lectures are meant to be for all groups, so perhaps the lectures could cover topics that are essential for all despite varying group composition and skill levels, such as driving a motor or more than one motor using a motor driver.

We all agree that many topics covered in the common lectures, such as the background to engineering design, did not help us work towards our final goal. Other topics like how to give a presentation may be unnecessary – it is difficult to simply tell someone how to give a speech. It is more effective that one learns through experience and constructive feedback. We may however in the future find ourselves referring back to the conceptualisation of the engineering design process and the techniques involved as they can be important in certain projects, for example ones that engineering consultancies work on as lean principles are proven to improve performance in this industry by 40% (Marzouk, Bakry and El-Said, 2012)

Our weekly mentor sessions were helpful as a platform to talk about our progress. Our mentor was also really supportive, although most advices were general rather than technical, partly because our experienced members already had the answers to questions the rest of the team raised. We found that the mentor sessions could have been better organised as there did not seem to be a set structure in place apart from requiring the mentors to check on our presentations or design journals.

In the end, while some of our team made tremendous progress through the help of the lab exercises and demonstrators, it seemed that more of our team did not really rely on the support provided by the course, due to the presence of a few very capable teammates. Before some of us even got to think about the other components of the device, we found out that they had already begun constructing them. Despite the various resources provided to us by the course, we believe that without strong background knowledge in electronics and coding, regardless of how much one turns to the course staff, it is difficult to strongly contribute to the construction of the device. This is due to the large amount of knowledge required. It would take a long time to even learn enough to properly assist in the development of the project, let alone actually build it. Even after completing the lab exercises, most of us still felt lost in terms of how to combine all the subsystems into a compact system, leaving that for our more experienced teammates to complete and put everything together.

8. Summary

Our final design involves a pickup mechanism is a container able to be opened and closed to secure the egg, whilst also being able to be moved vertically up and down. This is mounted onto a main platform, along with the Arduino Uno board and breadboards, which is able to move via an additional set of motors driving the rear wheels.

The design addressed many of the design criteria well, but did not do so consistently. The container itself was an innovative, simple design which could securely hold an egg, and has proven to work during the tests we conducted on each subsystems, prior to final testing. Whilst the device was able to carry the egg from one point to another, while responding to the control module, the raising and lowering of the container sometimes did not work. This was especially evident during final testing, where we failed the second run.

Overall, we were able to design and build a device which could autonomously deliver cargo between two points accurately and somewhat reliably. The course itself was a good learning experience mostly on teamwork and the engineering design process.

9. References

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10. Appendices

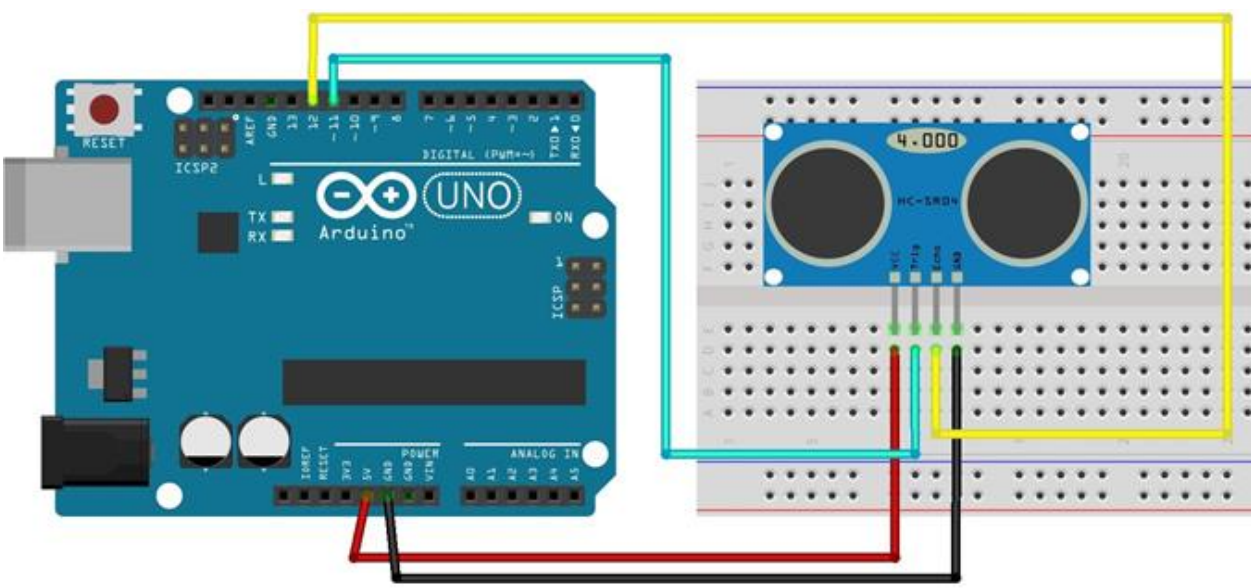

Figure 1. Circuit Diagram of the HC-SR04 Sensor and Arduino Uno board