Preliminary Design document

Skittle Sorter

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Report Summary:

The following preliminary design report will discuss and examine the benefits of a mechatronics system that is able to sort a sample of skittles based on their colour. The foundational design and action plan of a robot that accomplishes this goal will be outlined. The scope of the report will encompass both the problem analysis and description, it will also go over the specific tasks which the robot must complete.

Followed, 3 potential design proposals will be determined for the solution in the form of an engineering graphic design. The three designs will then be examined and evaluated with respect to their own advantages and disadvantages. The three designs will also be evaluated based off whether they can feasibly complete the required tasks whilst following all design constraints and holding all design requirements. The design which is found to most ideally complete all requirements and be most feasible for construction given the materials will then be finalized for the project.

In addition, the preliminary design report will include a project plan which will organize all required tasks and objectives in a chronological way, while also delegating each task to specific team members. The plan will also set guidelines for the timeframe for the construction process of the hardware of the robot, in addition to the programming of the software on which it will run. Doing so will ensure the project is managed in an organized fashion, and that all deadlines can be met.

Introduction:

Often, when an individual is consuming a certain food of some sort, there can always be a danger of ingesting something which may be harmful to the body. An example of this, would be when an individual has some sort of food allergy, and is eating an assorted snack which may have traces of that specific allergens. One very common food related allergy, which occurs in about 4% of people, is a red food dye allergy [1]. If someone with a red food dye allergy finds themselves eating a bag of, say, skittles for example, there is a high chance that they may accidentally cause an allergic reaction. As such, this introduces a need for a solution which may help individuals prevent such a thing from occurring.

The goal of our robot is to take an unsorted group of skittles, and sort them based on color. The skittle will then be delivered to a jar or location based on the color and the preferences of the user. Sorting candy by color allows an individual to remove flavors they may not be fond of, for improved enjoyment, and would also be able to aid someone with a color dye allergy, like in the problem introduced earlier. By sorting the candy into different colors, the individual will be able to enjoy their skittles without the worry of an allergic reaction.

Stakeholders for such a product include those interested in a system to help them sort candy by colour, whether it be to simply arrange them for amusement purposes, or for preventing potential health

hazards caused by food dye allergies. Individuals in either of these two groups would be able to positively gain from such a product.

In addition to solving the initial problem introduced, working on this project will also help us reach our goal of getting experience working with and learning how to create mechatronic systems which use different sensors and motors simultaneously to solve the daily problems we face throughout our lives. Thanks to the hands-on component of this assignment, this project will likely also help give us a much deeper breadth of understanding of the design theories we have been learning throughout our MTE lectures, and the programming techniques taught in GENE 121.

Background information:

To best understand the nature of the problem at hand, there is some key information which must first be understood. In the case of our robot project, the given problem at hand involves the creation of a mechatronics system which can successfully differentiate object (in this case skittles) based on color, and then sort them into various containers. As such, generally understanding how colour sorters function would be useful.

As stated above, the first part of a colour sorter mechanism, involves using a colour sensor to determine the colour of a given single object. To do this it is crucial that the given object is placed at a correct orientation such that there is a large enough face in the field of the sensor for it to scan.

Secondly, it must be ensured that the mechanism which lets the object pass through into view of the colour sensor only allows for a single object (or skittle) through. Although at the surface this may sound simple, when working with objects as small as skittles, designing a mechanism to filter through only one skittle from a batch can easily become the hardest task; thus, different filter mechanisms will be considered [2].

Scope:

Start-up:

- At this point no motors are on.
- An ultrasonic sensor will be in place in order to determine if the holding chamber has been filled with skittles.
- When empty, the ultrasonic sensor should read a value less than 255 and greater than 3.
- As the chamber fills with skittles, covering the ultrasonic sensor the sensor should return a reading of 255.
- Once the first reading of 255 appears, the program will wait for 10 seconds while checking that the value continues to stay at 255.
- After 10 seconds has passed and the readings confirm that skittles are in the chamber, the user will be prompted to specify how they would like the skittles to be sorted.

Main functionality:

User Specifications:

- Control buttons of the robot correspond with jars labelled 1 through 5.
- For each colour of skittle (i.e. Red, yellow, orange, green, purple) the screen will display a message on the screen reading “What jar would you like (insert colour) skittles to go to?”
- The user can then push the control button corresponding with the jar they would like the skittles of that colour to go to.
- This is repeated for all 5 colours of skittles.

Sorting Process:

- Skittles will be collected one by one by the sorting disk and dropped into another chamber where they can be read by the colour sensor.
- The colour sensor will take a reading of the colour of the skittle 15 times and the most common reading will be determined.
- If this most common reading occurred 7 times or more it can be assumed to be an accurate reading. If not, it will be assumed to be inaccurate.
- The skittle will then be dropped down into a spinning disk that will rotate to drop the skittle into the appropriate jar as determined by its colour reading.
- If the skittle reading has been determined to be inaccurate it will be dropped into a sixth jar meant for “junk”.
- This process is repeated until all the skittles have been sorted.

Skittle Transport and Motors:

- A motor will be used to rotate 2 plates on the same axis simultaneously.

1. The sorting disk at the bottom of the holding chamber.
2. A disk further below that moves the skittle to the location of the colour sensor.

- A static disk exists between the two in order to ensure that only one skittle at a time passes to the colour sensor.
- The two non-static disks are out of alignment. As these two disks rotate back and forth skittles will be able to be passed from the top holding chamber into the chamber where the colour sensor is located one by one

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- The second motor in the robot opens a chamber that allows the skittle to pass from the colour sensor to the leading arm.
- While the skittle’s colour is being read, this motor will shake it back and forth by moving up and down quickly in order to help achieve better readings.

- The final motor rotates the leading arm into the correct position in order to divert the skittle into the proper jar.
- The colour reading of the skittle corresponds to a motor encoder value which marks the location of each jar.

- After delivering a skittle the leading arm stays in place and its current position will be kept track of.
- The way in which the leading arm needs to move in order to get into the proper position will then be based on the position of the next skittles jar.

Shutdown:

- If 20 seconds passes in which the majority of colour sensor reading are black (or at least not red, yellow, green, orange or purple), it will be assumed that all the skittles have been sorted.
- Then the motors will be turned off
- The program will output how many of each color was sorted, waiting 10s for a person to read it before ending the program.

Unexpected situations:

1. Accuracy of the colour sensor

- The colour sensor cannot be trusted to be 100% accurate.
- To account for this, 15 readings will be taken, and the most common reading will be determined.
- The skittle will be shaken back and forth while it is being read so that the sensor can take readings from different angles. This should help to make readings more accurate.
- If this most common reading occurred 7 times or more it can be assumed to be an accurate reading. If not, it will be assumed to be inaccurate.
- If the colour of the skittle cannot be accurately determined it will be dropped into a separate jar meant for “junk”.

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2. Accuracy of the ultrasonic sensor.

- A similar method of averaging the readings as done with the colour sensor will be done in order to help improve the accuracy of the sensor.

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3. Not all skittles fall into the initial hole to be sorted

- The center of the sorting disk is raised to guide the skittles to the edges of the disk putting the skittles in position to fall through the hole.
- A small extrusion will be built into the wall of the collection chamber as well.
- This extrusion will cause a blockage so that when the collection disk rotates any skittles that are sitting on it will be stopped from being rotated along with it.
- As the collection disk continues to spin, skittles will then be pushed back so that they can fall into the hole.
- If the colour sensor does not read a colour reading of any of the colours of skittles, the sorting disk and the other further below will be instructed to rotate again in order to try to collect another skittle for sorting
- This process will continue until another skittle is transported to the colour sensor, or no skittles are read for 20 seconds

4. Skittles jamming inside of the robot

- The holes for the skittles to fall into will be approximately 10mm deep to fit only one skittle at a time. The dimensions of a skittle were measured to be 13mmx8.7mm.
- When the disks rotate, any skittles not properly aligned can then be tapped into place.
- Fillets will be put in parts where jams are most likely to occur in order to aid with the skittle passing into the hole further preventing a jam.
- If a jam does occur, human intervention will be necessary.

Project success and possible extensions:

Before objectively setting the design requirements and constraints, it can be useful to discuss some form of criteria with which we can judge the overall success of our project based off pre-construction expectations. Some of these expectations can be classified as “must-haves” and “nice to haves”.

“Must haves”

- Sort skittles at a minimum accuracy of at least 90%.
- The robot must be able to sort all the skittles that are fed into it, without stopping until then.
- Sorts skittles at a rate of 1 skittle every 3 seconds.

“Nice to have”

- Robot can sort skittles at a rate greater than 1 skittle every 3 seconds
- Sorts skittle with an accuracy greater than 90%

There are also various components to the sorter mechanism which could be considered “difficult”, and so it is useful to try and come up with a simpler alternative which might be used should time constraints lead to a change in design. Something that adds complexity to the robot is the implementation of button input for a user to select exactly which jar is assigned to a given colour. If necessary, a simpler alternative would be to code the program such that the robot is predisposed to sorting each colour into a pre-determined jar.

Criteria and Constraints

Requirements:

Requirement #1: Candy is Not Damaged

The project’s main goal involves enhancing the enjoyment of the Skittle eating process. This would be negatively affected if our sorter produced damaged candies. To assure the candies come out undamaged, we will chamfer the edges of the collection plates. This will remove any sharp edges that could possibly crack or break our skittles as the plates rotate.

Requirement #2: Robot Must Stop by Itself

To increase the independence of the device as well as the convenience for the user, the robot will be built to stop by itself. To achieve this, we will track the time after the color sensor has received a value other than the default wall color. After 20 seconds passes without any input, it can be assumed that there are no more skittles to be sorted.

Constraints:

Constraints #1: Must be fewer than 10% wrong Skittles in Total

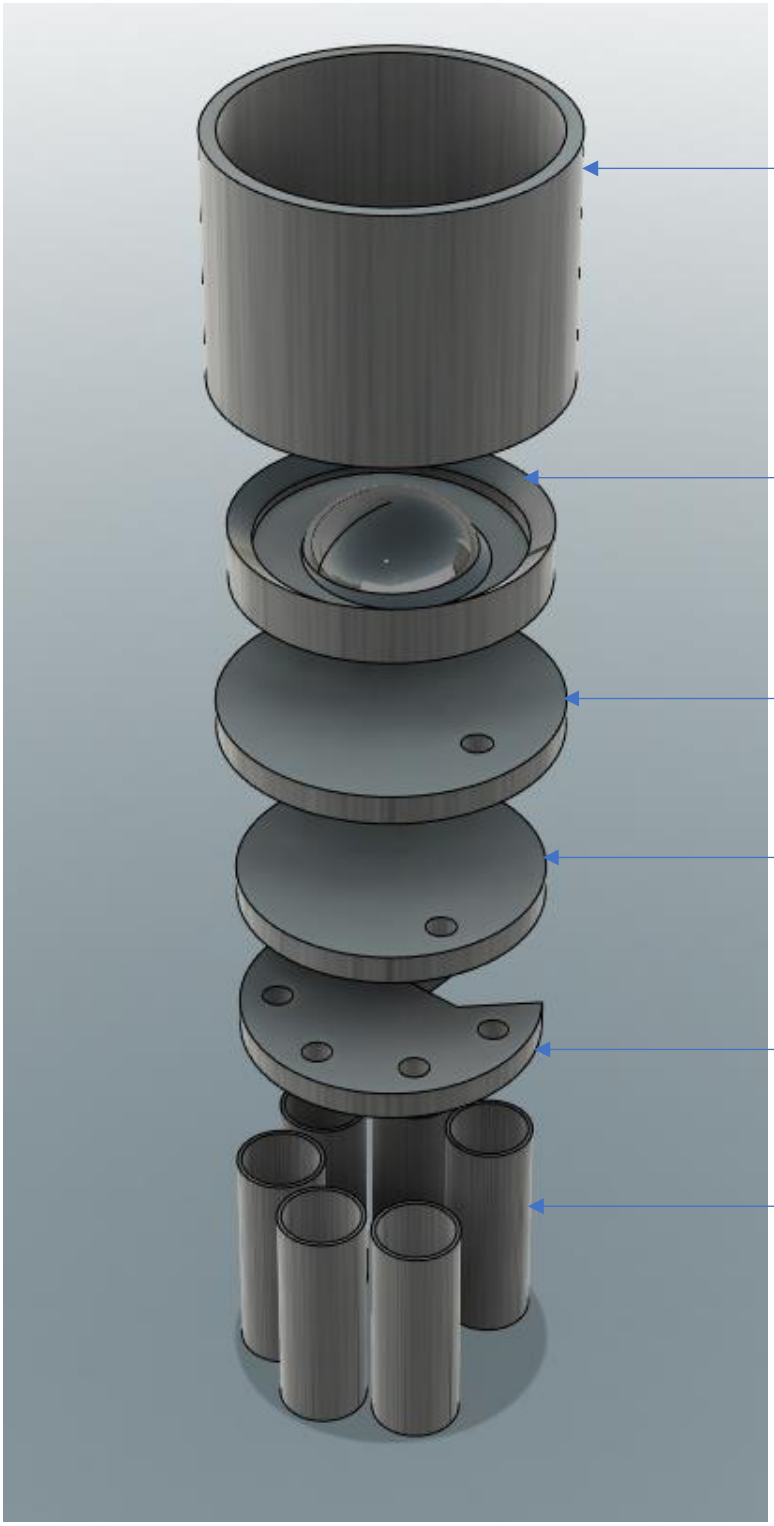
As the robot's main function is to successfully sort skittles by color, it should not be constantly putting Skittles in the wrong containers. A 10% tolerance for error will allow for errors in the color sensor. This is because the position of the skittle coming into the view of the color sensor cannot be controlled from our design [3].

Constraints #2: Must not sort fewer than one Skittle per 3 seconds

To further enhance the enjoyment of skittle consumption, the sorter should operate quickly and efficiently. To achieve this constraint, our robot will move its leading arm the smallest distance possible in order to deliver the skittle to the correct position.

Design:

Design Option #1:



Collection chamber:

All the skittles get poured into here, where they get mixed and taken out one at a time.

Sorting disk:

This disk is grabs one skittle at a time, and puts it into the next disk, by spinning and only allowing one skittle to go through.

Static disk:

This disk does not spin, it holds a skittle for the next disk to collect.

Collection disk:

This disk takes a skittle form the static disk, and puts it over the color sensor to read, then spins to the proper hole for sorting.

Receiving disk:

This disk has 6 holes and a gap. The gap is for the color sensor and the 5 holes are for sorting, and the last being for unknown colors.

Sorting tubes:

Each container corresponds to a sorting option. The tubes hold the final sorted skittles.

Concept:

- The skittles are loaded into the collection chamber of the device, filling the device by any amount triggers the ultrasonic senor and activates the device.
- This device has the sorting disk and the collection disk as the only moving parts, both being attached on the same shaft. The static disk and receiving disk are non-moving disks that move skittles through the system, and are there for aligning purposes, the same shaft for the other two disks goes through these disks but does not move them.
- A single skittle from the sorting disk gets deposited to the static disk.
- Then the collection disk which is thirty degrees behind the position of the sorting disk, picks up the single skittle and brings it to the color sensor. The disk will shake for a better color reading.
- Depending on which hole corresponds to the color, the disk will spin at a high velocity to the destination, stopping over the destination hole and shaking the disk to ensure the skittle has fallen through.
- This design works to save space and time, by rapidly sorting skittles, through the soring process at the final disk. The collection disk, wanting to sort a skittle in the third hole, would travel over holes one and two fast so that the skittle does not fall through the wrong hole, and stop at three to drop off the skittle. Some challenges with the design are the spacing for the parts, as the design itself is very compact, and the speed required for the receiving disk to complete its task, this will likely need a differential setup between all three motors which is difficult to set up and control as there is little experience in this field.

Pros:

- Speed of the device is unmatchable by the other designs.
- Most compact out of every design.
- Easy and fast to manufacture parts (3D printing is not required, as it takes a while to 3D print).

Cons:

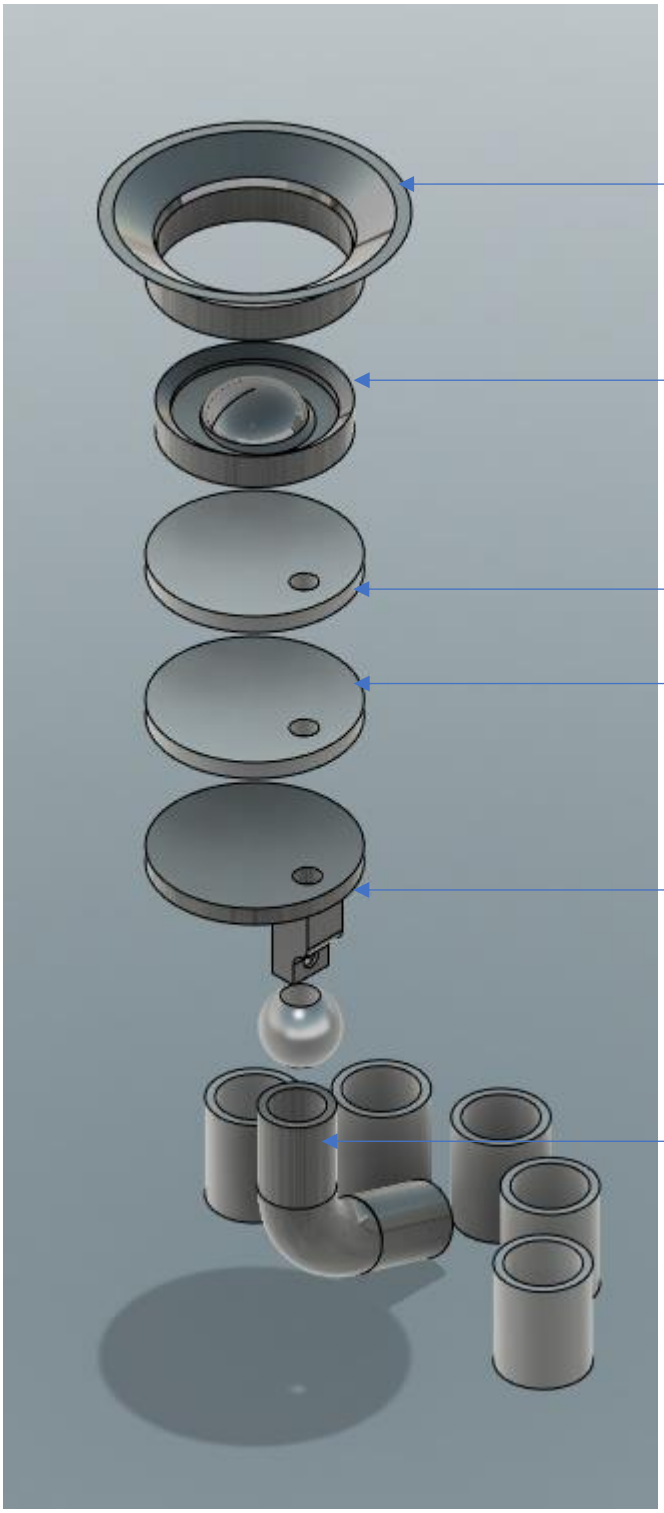
- Difficult to build a differential system.
- Higher than normal risk of jamming.
- Collection containers are difficult to access and must be emptied frequently.
- Friction between the plates is great and will cause a part to break from mechanical fatigue.
- The color sensor will be difficult to mount.
- The color sensor will have worst readings because there is little natural light coming in.

There are three motors that are used to drive the main axial, the two large ones driving a single gear, and the medium sized motor on the main shaft acting as a rotations counter.

The four inputs from this design are the ultrasonic sensor in the sorting chamber, the color sensor, motor encoder of the medium motor, and the buttons on the EV3 for user input.

The design meets our candy safety requirement, and our auto stop requirement. And the restrictions on speed and accuracy of the device.

Design Option #2:



Collection cone:

This is where all the skittles get poured into, the cone design allows for a higher capacity.

Sorting disk:

This disk grabs one skittle at a time, and puts it into the next disk, by spinning and only allowing one skittle to go through.

Static disk/orienting tube:

The disk receives at least one skittle, passing it through the hole to the next disk

Collection disk:

The depth of one hole is that of one skittle's height. When the disk is spinning only one skittle out of the static disk falls through.

Static disk/orienting tube:

The disk receives at least one skittle, passing it through the tube where the skittle is forced to become upright from the passage shape. So that it can be read by the color sensor, through a hole in the side of the tube.

Leading arm:

Once the color is read the tube rotates to the correct color location so that the skittle from the tube falls into the correct container.

Concept:

- The skittles are loaded into the collection cone and the ultrasonic sensor in the wall of the cone triggers the device to initiate the sorting process.
- The sorting wheel spins and drops a single skittle into the static wheel.
- The collection disk moves the single skittle to the second static disk, where the skittle is dropped through into a vertical orientation, to be read by the color sensor.
- When the skittle sits in the measuring tube, an average reading is taken by the color sensor while the skittle rides up on a rough textured sphere, which will move the skittle giving the opportunity of many positions for color measuring, which measures the colour of the skittle through the outer hole on the tube coming out of the second static disk.
- The leading arm travels to the proper position for that colour. Then the sphere goes into an open position where the skittle is let through and so it drops the skittle down the tube into the appropriate container.

Pros:

- Relatively reliable because of its shape
- Most accurate of all reading as there is a dedicated feature to shake to skittle (likely the texture of a golf ball)
- Self-regulating at the start as a touch sensor would reset the position of the leading arm every time the program starts

Cons:

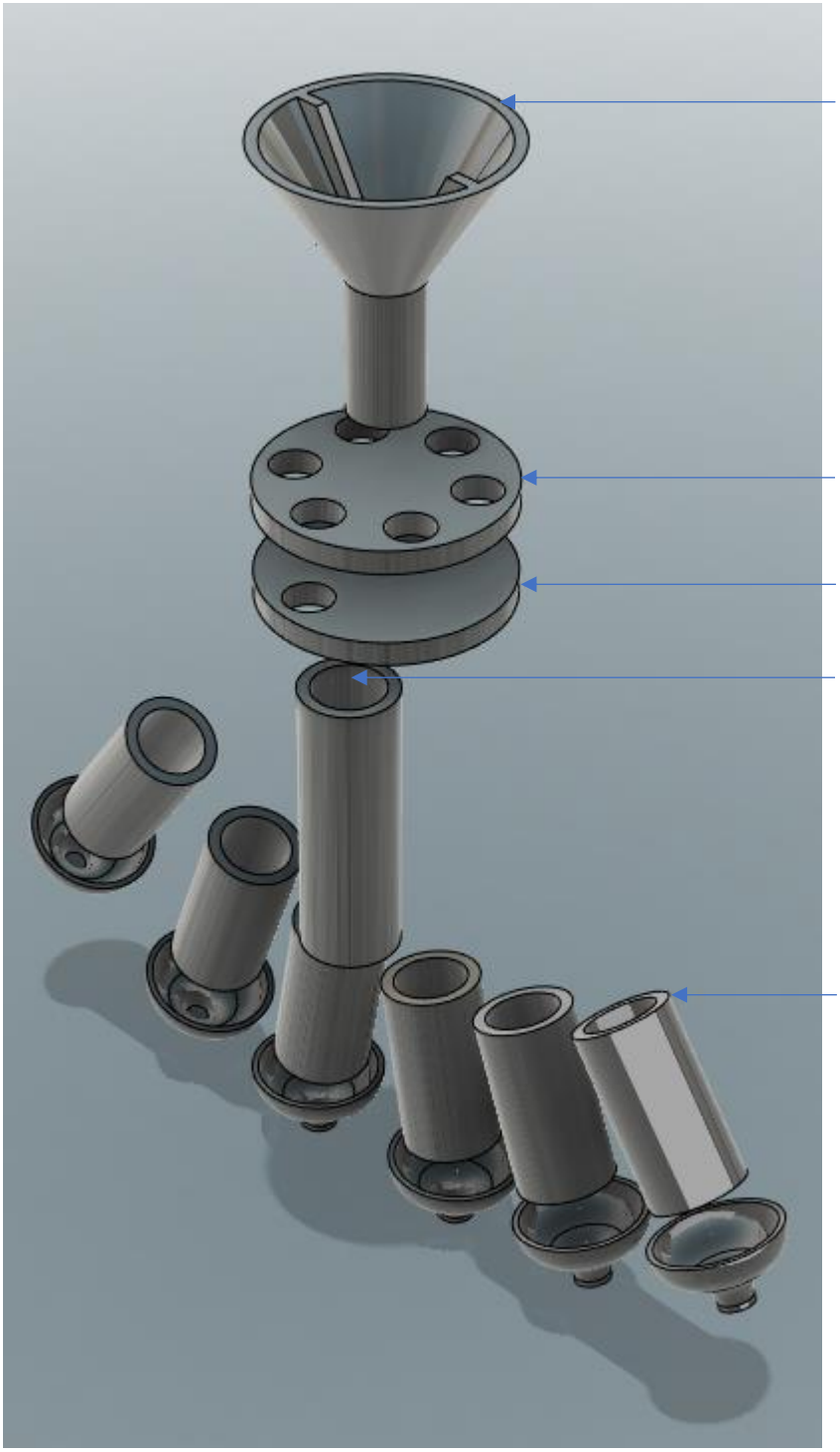
- The design may be complex to bring together as the spacing is a little bit tight.
- The leading arm is difficult to make and attach to a motor.
- Must manually adjust the shaking motor to position zero at the start of every program as a touch sensor would be too big to fit and have the device run continuously without interference.
- More moving parts than all designs.
- Reduced speed due to the travel time in the tube.

There are three motors that are used one to drive the main axial, the other to manipulate the leading arm, and the medium sized motor to spin the sphere under the skittle tube.

The four inputs from this design are the ultrasonic sensor in the sorting chamber, the color sensor, motor encoder of all three motor, the touch sensor to calibrate the leading arm and the buttons on the EV3 for user input.

The design meets our candy safety requirement, and our auto stop requirement. And the restrictions on speed and accuracy of the device.

Design Option #3:



Collection cone:

This is where all the skittles get poured into, the cone design allows for a higher capacity, and is equipped with mixing arms to avoid clogging, as the sorting disk was removed.

Color reading disk:

This disk grabs one skittle at a time, running it under the color sensor. Now in “que” the skittle will be dropped when the arm has moved to the popper position.

Static disk:

This disk just ensures that no skittles fall out when they are not supposed to.

Sorting arm:

The arm moves to the correct position before receiving the next skittle. The arm is controlled by a motor which calibrates at the beginning of every run.

Sorting tubes:

The way the sorting arm is set up does not allow for the arms to be parallel to each other so they must follow a circular path that will accommodate for that, this increases overall speed.

Concept:

- The skittles would be loaded into the top funnel, the user presses a button to start the program.
- The device mixes the funnel constantly through a servo motor, until there are no more skittles detected by the colour sensor in the disk.
- When the skittles are mixed, they are intended to fall in a horizontal orientation through the funnel into the color reading disk, so that they are slid out by the color reading disk one at a time.
- The skittle is in que to get its color read. The skittle will be spun a few times before reaching the color sensor.
- When it reaches the color sensor, it gets shaken around so that multiple reading can be taken and averaged.
- The sorting arm will rotate to the proper position, before the skittle is rotated into the sorting arm.

Pros:

- The design is fast due to the arrangement of the sorting tubes.
- The design would have highly accurate readings as the sensor has natural light
- The design has the least number of disks, making it easier to troubleshoot and take apart
- Unlike other designs, this one does not have a sorting disk. But rather a mixing cone, which has a lower chance of jamming.

Cons:

- The cone will be difficult to spin axially for the mixing motion.
- While the colour reading disk is taking a skittle from the funnel, it may jam, as a vertical skittle may fall instead of a horizontal one.
- A likely jam in the sorting disk to arm can render the system useless.
- The sorting tubes are difficult to place in the proposed orientation, as a fixture of such shape would be difficult to manufacture.

There are three motors that are used, one servo to mix the top cylinder, one driving the color reading disk, and the last manipulating the sorting arm.

The four inputs from this design are the color sensor, motor encoder of the two large motors, a touch sensor to calibrate the sorting arm, and the buttons on the EV3 for user input.

The design meets our candy safety requirement, and our auto stop requirement. And the restrictions on speed and accuracy of the device.

Design Decision:

The second design was chosen as the construction of design three was collectively agreed to be the most difficult out of the three options. For the collection cone to spin constantly a servo motor must attach to the cone through gears, which is both difficult to position and attach to the cone. The other issue is the fixture to hold the sorting tubes. The part will have to hold different length tubes on a path

of a circle (the range of motion of the sorting tube), which is difficult to manufacture without much experience making similar fixtures. As a result, choice three was eliminated.

The first choice was closely considered as it has great speed, very compact, but it was questionable if the bottom collection disk would be able to skip a skittle over a hole, as the speed of the skittle needs to be very high and the device tolerances need to be tight. Furthermore, the differential system would require that the two large motors driving a single axis, with the medium motor on the axis itself counting the main shafts rotations. This setup is difficult to achieve. For these reasons option one was eliminated.

Even though option two has some flaws, the flaws of the other designs out weighs those option two. Its shape is also the most reliable for passing in only one skittle at a time. It was chosen as a result.

Project Plan:

GANTT chart:

TEAM ABU 468

Period Highlight: 1 | Plan Duration | Actual Start | % Complete | Actual (beyond plan) | % Complete (beyond plan

ACTIVITY	PERSONS	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Finish GANTT Chart	Brandon	1	1	1	2	100%
3D Model for Report	Omar	1	1	1	0	100%
Scope for Report	Jessica Ali Jess	1	2	1	0	100%
Introduction for Report	Brandon	1	2	2	0	100%
Conclusion for Report	Ali Omar	2	2	2	0	100%
Finish 3D Model	Omar	2	3	0	0	100%
Mechanical Overview Slides	Omar Brandon	3	2	0	0	100%
Procedure Overview Slides	Ali	3	2	0	0	100%
Software Overview Slides	Jessica	3	2	0	0	100%
Intro Conclusion Slides	Brandon	3	2	0	0	100%
Mechanical Overview Slides	Omar	3	2	0	0	100%
Mechanical Prototype Build	Omar Jess Brandon Ali Omar Brandon	5	2	0	0	100%
Final Design Meeting	Jess Ali	6	1	0	0	100%
CNC Parts	Omar Brandon	6	3	0	0	100%
Skittle Rotation Software Code	Brandon Jess	6	3	0	0	100%
GUI Software Code	Ali Omar	6	3	0	0	100%
Skittle Rotation Software Code	Brandon Jess	6	3	0	0	100%
Assembly of Printed Parts	Omar Brandon	7	3	0	0	100%
Motor Attachment	Ali Jess	9	3	0	0	100%
Final Assembly	Omar Ali Omar Jess	10	4	0	0	100%
Bug Testing Software	Brandon Ali	10	4	0	0	100%
Test Trials For Sorting Skittles	Omar Brandon	10	10	0	0	100%
Test Trials For Dispensing Skittles	Jess Ali Omar Jess	10	10	0	0	100%
Final Troubleshooting for Demo	Brandon Ali	20	1	0	0	100%
Software Component of Report	Jess Ali	21	8	0	0	100%
Physical Component of Report	Brandon Omar	21	8	0	0	100%

PERIODS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36

As shown in the GAANT Chart, the components of the project that have been separated into 3 portions complete with their own side projects and milestones.

The portion after the preliminary design document focuses on the 3D design of the robot followed by the mechanical prototype. These will be done in tandem with the slideshow presentation for increased efficiency. The milestone for this portion of the project is the formal presentation on November 8.

The second side project includes constructing the actual model in tandem with the software. The software portion has been split into separate parts that each group member will contribute to. Ideally, this will be finished well before the software design review on November 12.

The final side project includes the assembly of the created parts, along with testing of the software. This is closely followed by final troubleshooting before the milestone of demo day on November 22.

Conclusion:

In conclusion, the goal and purpose of our robot is to efficiently sort different coloured skittles based on colour into specified jars. Its purpose is to aid someone with particular preferences for skittle flavours, or someone with with a specific food colour dye allergy by offering them the option of setting sorting specifications.

This will be done using the colour sensor, motor encoders, the ultrasonic sensor and button input in the Lego EV3 kit. There will also be 3 motors used in the final design. The final design which has been decided, will be a slight variation of design option 2. The reason that this design was chosen is because for one, it was found to be the most reliable due to its shape, preventing the possibility of more than one skittle passing through and having fewer flaws overall compared to the other design options.

References

[1] M. Mittler, "Red and Yellow Dyes May Be Causing Your Stomach Aches," 4 November 2019. [Online]. Available: https://www.verywellhealth.com/red-and-yellow-may-be-the-cause-3956894. [Accessed 4 November 2019].

[2] snackhistory.com, "Skittles," 2019. [Online]. Available: https://www.snackhistory.com/skittles. [Accessed 4 November 2019].

[3] Lego, "ROBOTC EV3 - Color Sensor," [Online]. Available: http://help.robotc.net/WebHelpMindstorms/Content/Resources/topics/LEGO_EV3/ROBOTC/Sensors/Color_Sensor/Color-Sensor.htm. [Accessed 4 November 2019].