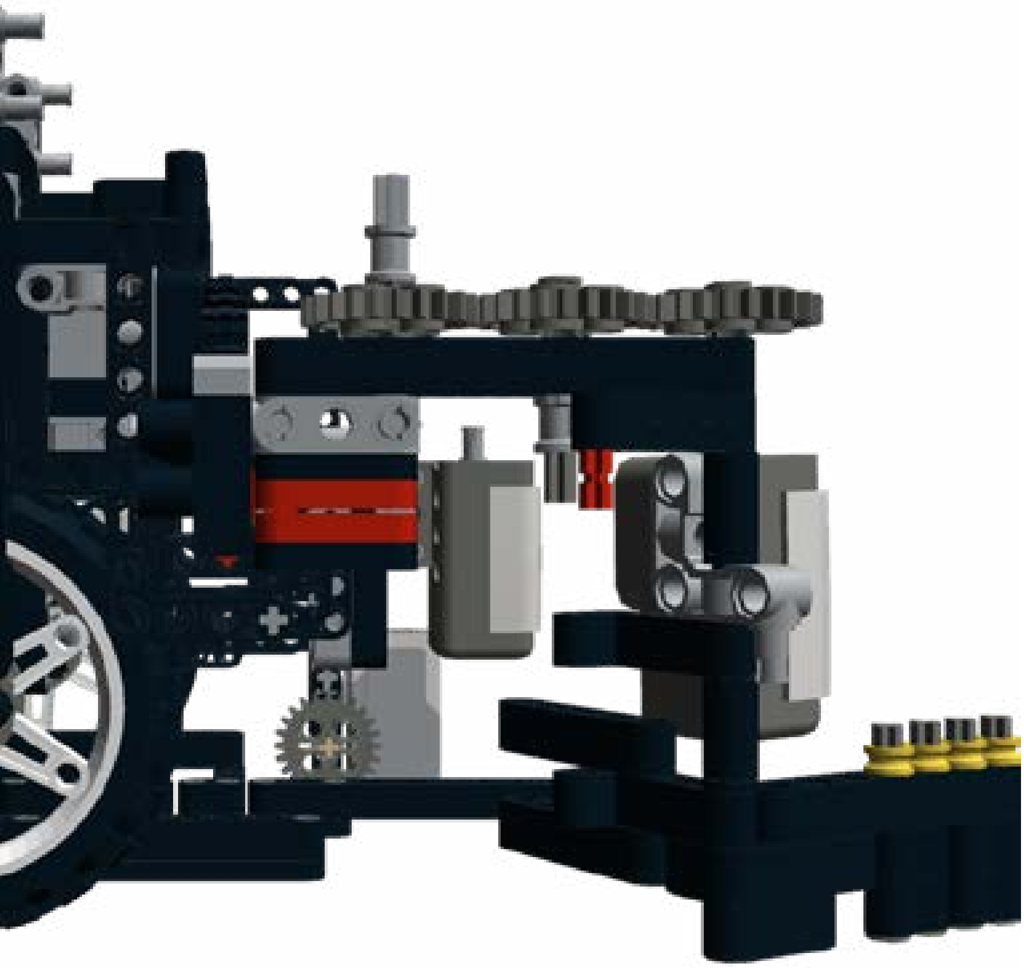
Engineering Design



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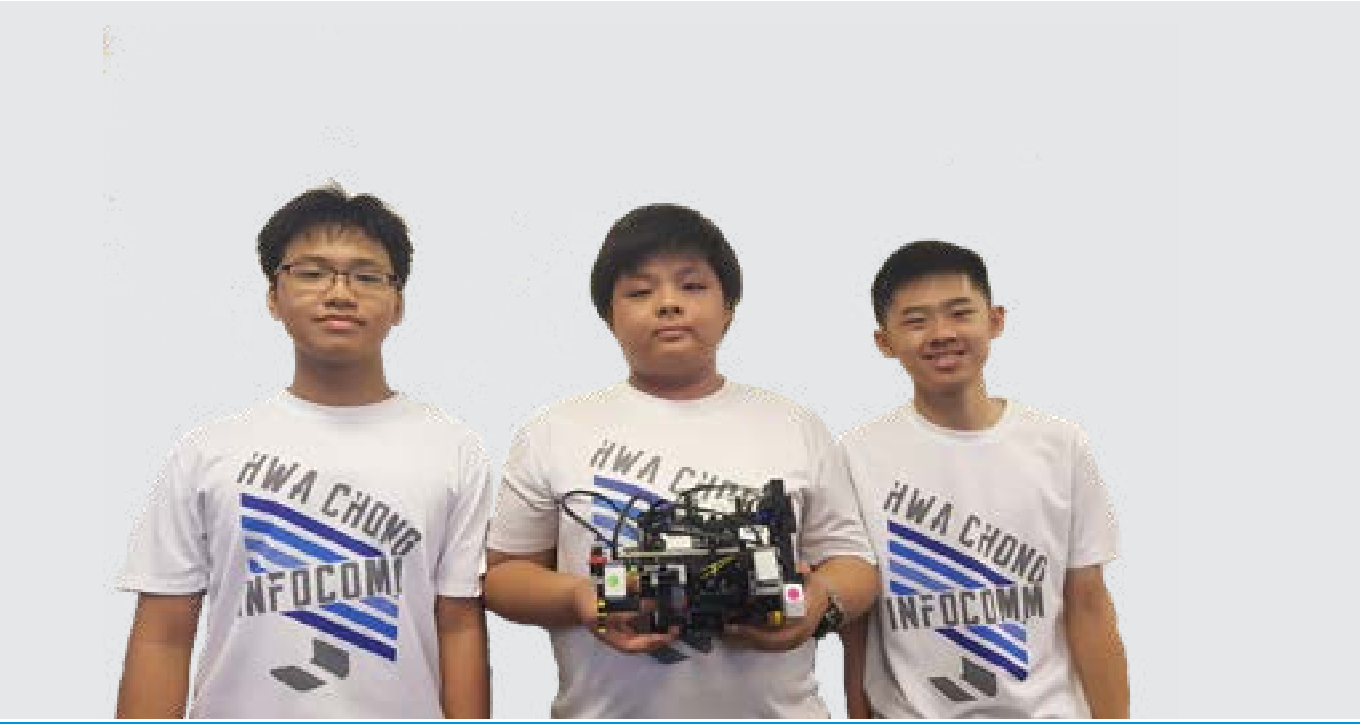
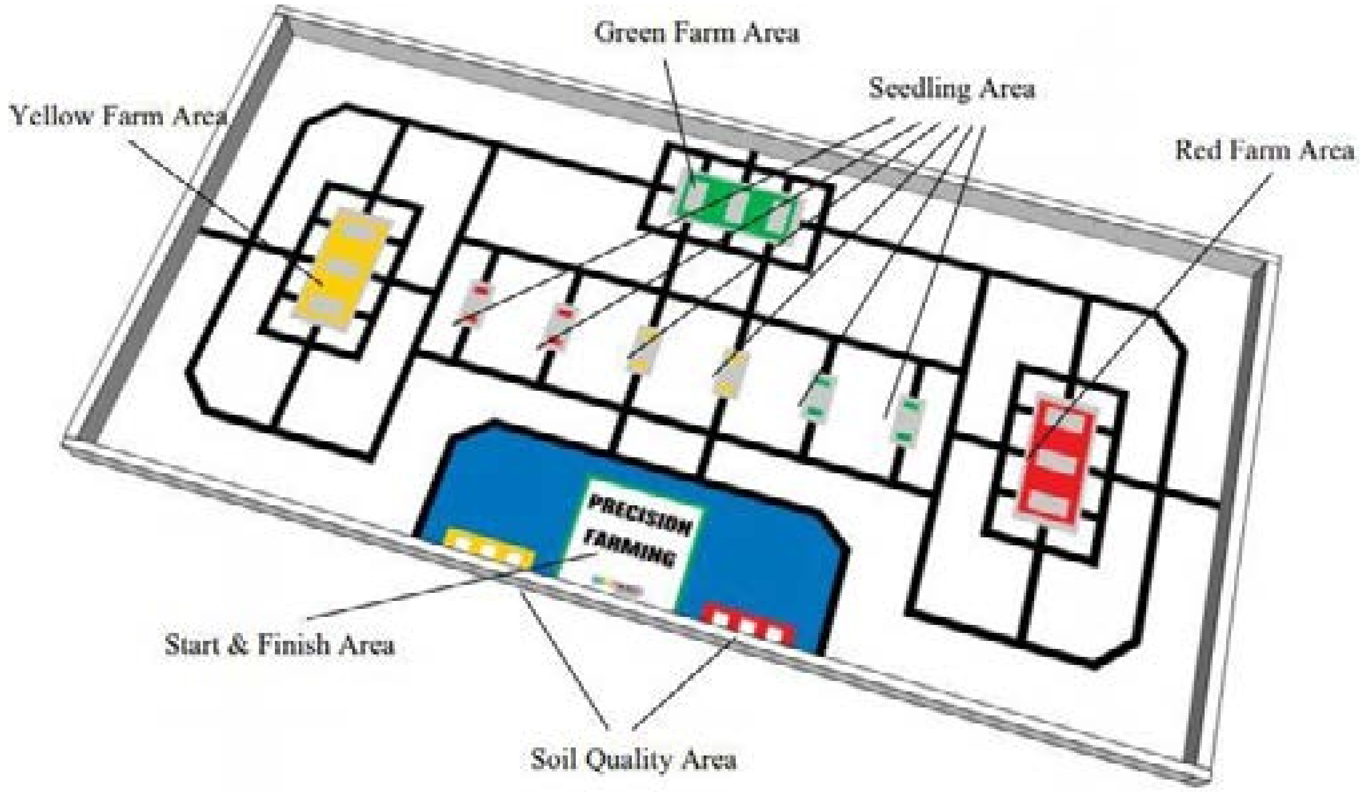
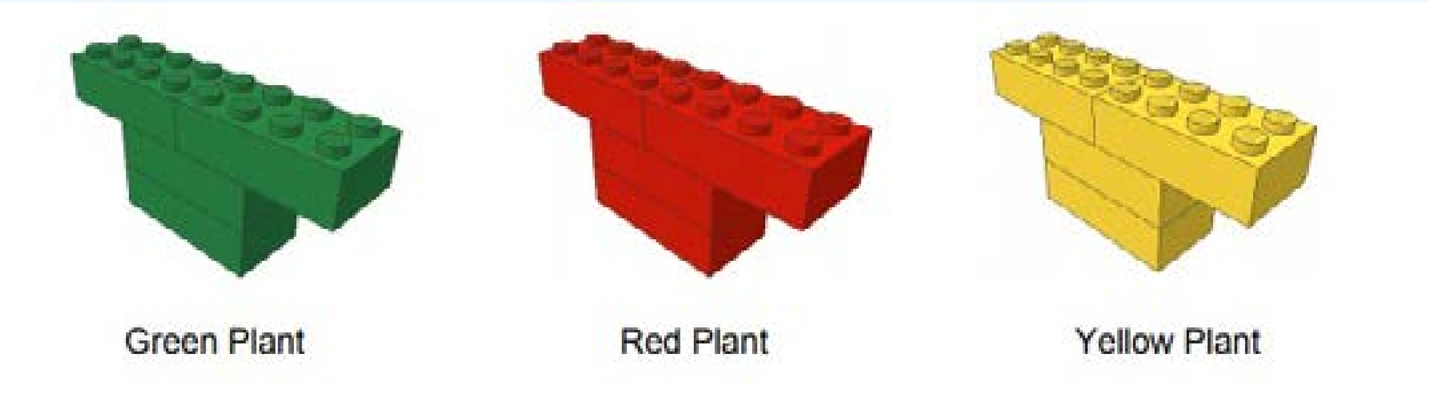
About Us



We are a group of students from Hwa Chong Institution. National Robotics Competition (NRC) is a great platform for us to incorporate our knowledge on robotics to think of effective and realistic methods to solve real world problems, so that we would be ready to take on challenges that profoundly affect the world in the future . For the past few years, with the population in the world increasing in astronomical proportions, food production needs to be proliferated every year. This can be achieved through the use of advanced technologies such as robots, drones, and satellites to improve the usage of arable land. Satellites and drones can provide accurate data on the soil quality of the different areas of the arable land. This data can be used by robots to plant different seedlings on the land depending on the soil quality. In this way, the seedlings are adapted to the growing environment, which will improve the growth of the seedlings, which brings us to this mission.

Mission





In this mission, we are required to place the appropriate plants in the corresponding fields in the 3 farms. The cubes at the starting area are either black or white, which will indicate the fields that we have to place the plants in. 7 trees will have to be collected from the seedling areas and be deposited in the various fields in the farm areas.

Our Robot Designs

For this mission, our main objective was to be able to collect and deposit the plants in the various fields efficiently and to make sure that our collection & depositing process was accurate and consistent. Also, we wanted the simplest design that could complete the whole mission within the shortest time so that we would stand a higher chance of entering the finals for the robot run.

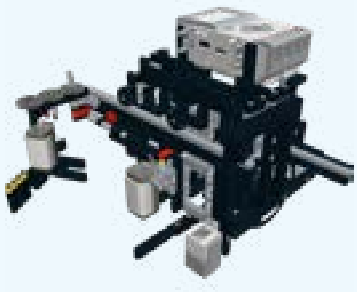
Therefore, we came out with different designs along the way so that we can have the best design possible:

The Robot Designs:

Conveyor Belt

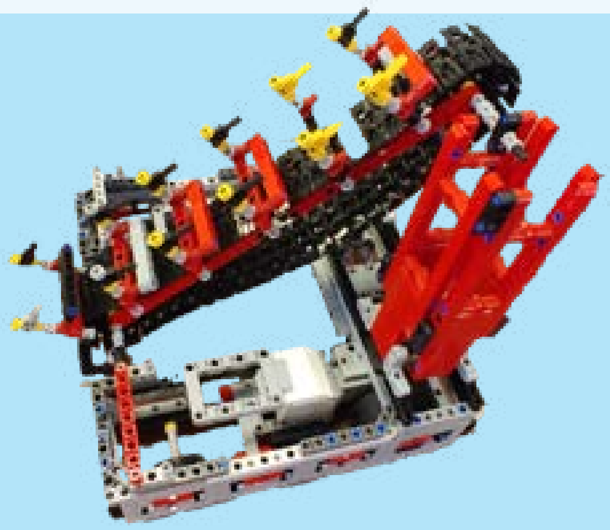
Grab and Lift

Pusher Mech



Conveyor Belt Robot

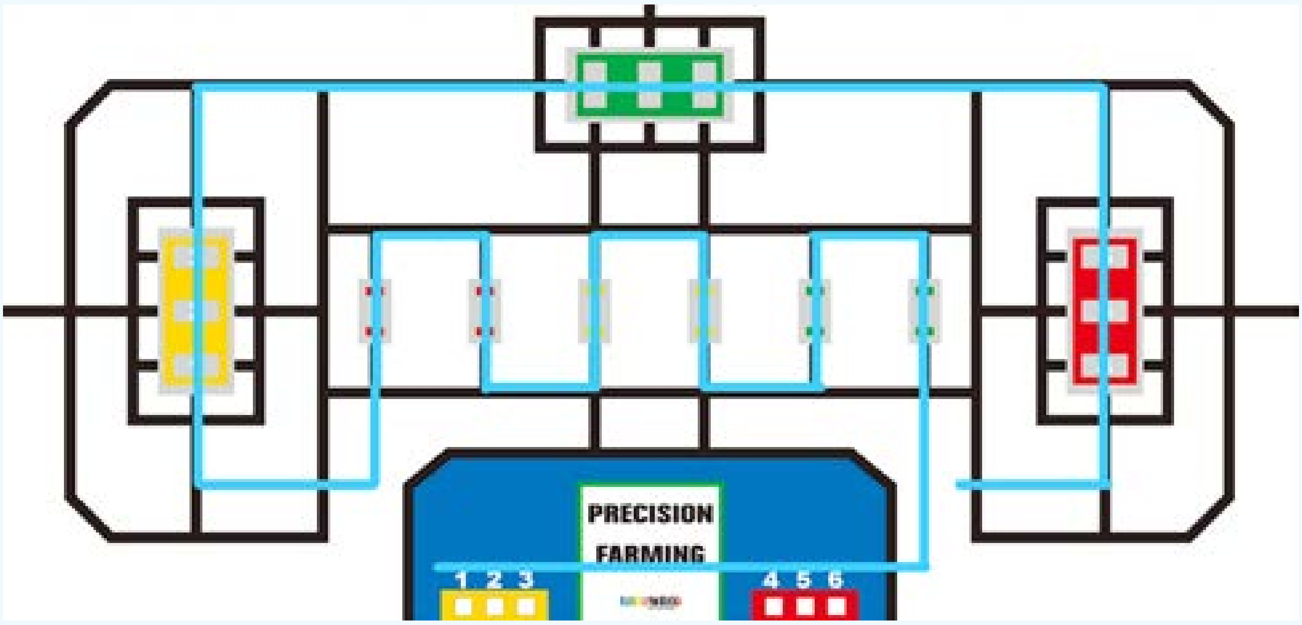
Initial Idea:



This is our idea of building a conveyor belt on a robot, which statifies our requirements as it can collect and deposit 7 plants in one go.

After long deliberation, we thought that if we could create a robot that was able to collect all 7 plants at the same time and score effectively. This drastically reduces our robot run timing as we wouldn't need have the robot to go to and fro when collecting and depositing the plants. With this, our robot should be able to consistently and steadily achieve a decent timing when finishing the mission.

Robot Run Route:



Mission is completed efficiently and effectively in one go, saving lots of time.

Thought Process behind Conveyor Belt......

We started working on this robot before the NRC competition details were released. Since we were unable to test the measurements of our robot with the NRC field and only had the WRO challenge manual to work with, we wanted a mechanism that was capable of collecting all 7 plants. With some prior designs that we have seen from other robotic competitions, we decided that a conveyor belt that collects the plants vertically would be the most accurate for collecting and depositing.

In order to construct our conveyor belt, we needed our base to be hollow at the front. Also, since our conveyor belt is supposed to collect all 7 plants, we needed to mount the conveyor belt high which requires 2 towers at the side of the conveyor belt to hold it stationary.

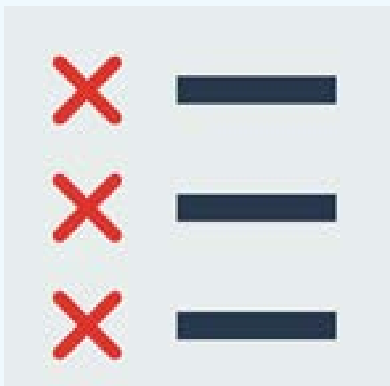
With our mechanism built, we constructed our robot base according to the dimensions of our conveyor belt and the tower.

Pros and Cons in Theory:

Pros:

- Capable of collecting and depositing 7 plants in one go
- Robot design is aestatically pleasing

Cons:

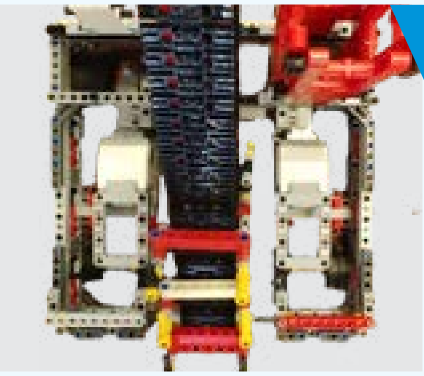


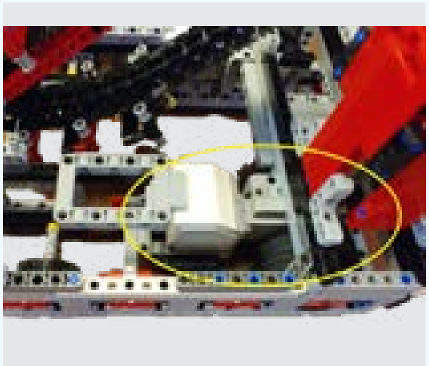
- Conveyor belt is too big, causing robot to be too bulky.
- Collection of plants is very inefficient
- Depostition of plants is inaccurate due to the instability of the hooks
- Concept of a conveyor causes unecessary addition of weight, slowing the robot down

Mechanical Design - Base

Base:

Our robot is heavy and bulky, especially since there is a huge mechanism on top of it. We must ensure that we have a very sturdy base that is able to support the entire robot so that the robot can move steadily throughout the run. Therefore, all the following components of the robot were carefully planned out according to our requirements above.





25cm^3 wide base:

This wide base is perfect for a complex and huge robot, providing it with stability to ensure errors minimised

U-shaped base:

Not only allow the robot to have sufficient base support, it also allows the conveyor mechanism to be able to collect the plants without any difficulty and within size limit.

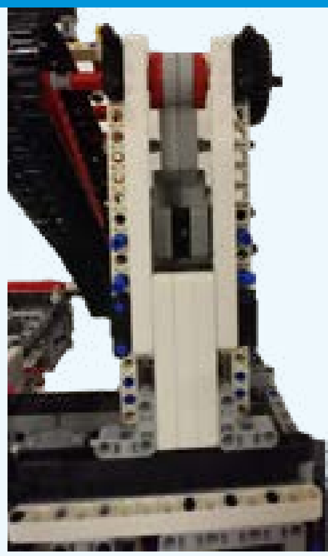
Double Large Motor:

This base is powered by two large motors. Large motors are used instead of medium motors as it has greater strength than medium motors though it is slower. Since this robot is heavy, large motors were chosen to ensure that there is enough strength for the robot to move.

56 x 28 Tires

These tires were used instead of other wheels such as motorcycle wheels as this robot has a wide base. Large and wide wheels are needed to ensure maximum stability, so that the recording of values, collection of plants and the movements of the robot can be more consistent and accurate.

Mechanical Design - Mechanism



Conveyor Belt:

It is built using lego technic caterpillar tracks instead of others such as the link chain 3711 as it is wider, allowing the claws mounted on the conveyor belt o be much more stable, increasing the accuracy and consistency of the collection of trees.

The 7 “Hooks”:

There are 7 “hooks” mounted on the conveyor belt. With this, the robot is able to hook up the plants and lift them up, and when dispensing, the robot will go over the wall and the conveyor mechanism will dispense the plants into the fields one by one

Large Motor:

There is a large motor mounted into one of the two towers, which is also connected to one of the gears through an axle. This enables the robot to be able to control the mechanism at will with sufficient strength

Mounting:

The conveyor belt is wrapped around two pulley gears mounted within the mechanism, one at the top of the base and one at the sides of the two towers. By being connected to two points, with one end being significantly higher than the other, it creates a gradient for the mechanism to not only be capable of storing 7 plants at the same time, but also be capable of storing the plants without the risk of the plants falling out due to gravity or due to sudden jerks during the robot run.

Building Process - Challenges we faced

Challenge Faced: Allocation of Space

Had troubles finding space for the conveyor belt since we needed it to be long enough to collect 7 plants

Had troubles calculating the correct angle for the conveyor belt has to be positioned to minimise the gradient of the conveyor belt so that we can collect the plants better

How did we overcome this challenge:

Space had to be properly calculated before the robot is being built, such as calculating the angle and gradient of the conveyor belt to maximise the length of the conveyor while ensuring that it is not too steep

Challenge Faced: Could only work based on WRO rules

We thought that we could select the program after the soil quality data blocks have been assigned

How did we overcome this challenge:

We edited the robot design according to the NRC rules, hence we allocated space for the colour sensors at the side of the robot to sense the colours of the soil quality data blocks

Overall Conclusion:

Even though the conveyor belt design suits our requirements initially, after some tests, we realised that this robot was simply too bulky and too slow. The collection process for the robot was too sluggish as compared to the designs proposed by other teams. We also realised that our disadvantages overruled our advantages and there was no reason for us to continue with this design anymore. By the time we finished building the robot, we had already brainstormed better designs that were more efficient in many ways. Moreover, our design has failed to execute its purpose. The initial purpose of our conveyor belt design was to collect all 7 plants to reduce our runtime. However, due to the complexity of the pathway of our robot's movement, our runtime was unnecessarily adversely affected. Hence, we decided to abandon the conveyor belt design and move on to the better designs we had, which brings us to the next robot design.

Grab and Lift

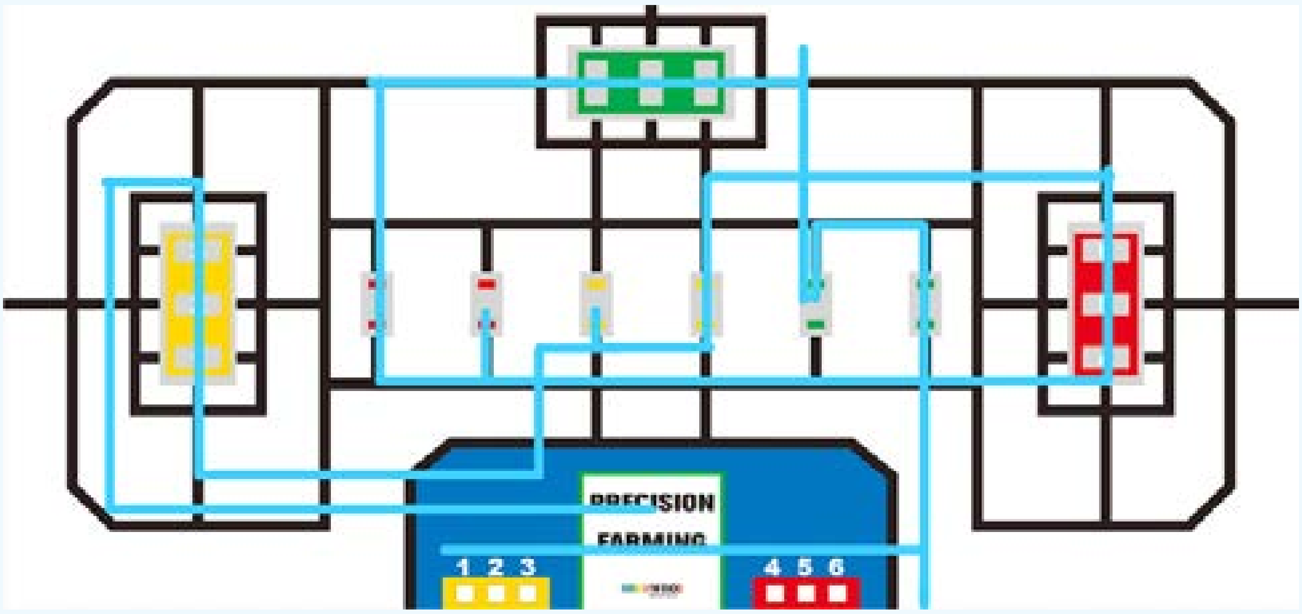
Grab and Lift Robot

Our Idea:

This is our idea of a grab and lift robot, which satisfies our requirements as it can collect and deposit 3 plants in n a short period of time

As we abandoned the conveyor belt robot, we decided to refine our requirements for our robot. After much thought, we decided that if we could create a robot that was able to collect efficiently and score effectively even though we are restricted to 2-3 plants at one time, we should be able to get a good timing since the robot is small, light and compact which allows it to move around quickly.

Robot Run Route:



Even though the robot is seen to be going to and fro, the robot moves around at high speed as it is light, which will in turn reduce the period of time taken to complete the mission..

Thought Process behind Grab and Lift......

From last year's experience, we decided to build a simple robot that was easy to be programmed to ensure that we can get full points before moving on to more complex robots. Moreover, it was around this time when the rules in the challenge manual changed where we had to build on the spot without any pre-built robot components. This grab and lift robot was our simple design. We wanted a simple robot that is light and can grab at least 3 trees, move fast and deposit plants fast.

As stated earlier in our strategies, we built the grab and lift mechanism such that it is only able to be lifted to about 60° inclined from rest position. This prevents the possibility of the plants jerking out of the grab and lift, increasing its consistency in its collection and reducing

With our mechanism built, we constructed our robot base as sturdy and yet as light and simple as possible so that the mission can be completed within the shortest period of time.

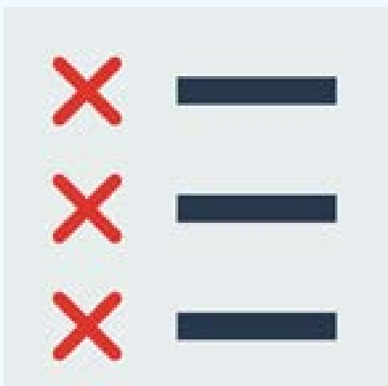
Pros and Cons in Theory:

Pros:

- High Speed due to medium motor
- Lightweight - greater velocity
- Mission completed in short time
- Simple design: build in short time
- More leeway and room for error

Cons:

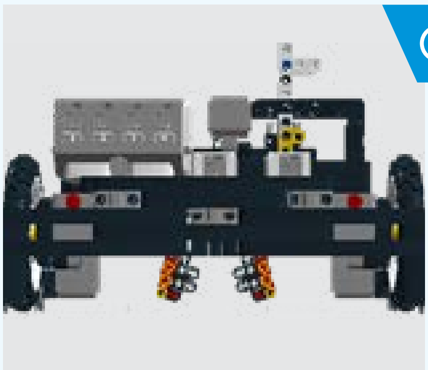
- Store max of 3 plants, wasting time on trip going to and fro
- Programming algorithms complicated - more time on programming
- Occasional inconsistency when dipositing, increasing errors made



Mechanical Design - Base

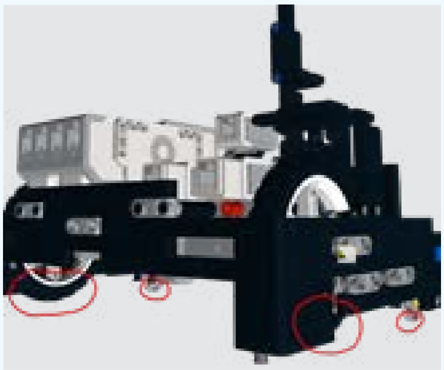
Base:

Even though we aim for the lightest base, we still must ensure that we have a sturdy base that is able to prevent the robot from wobbling so that robot can still move steadily throughout the run. Therefore, all the following components of the robot were carefully planned out according to our requirements above.



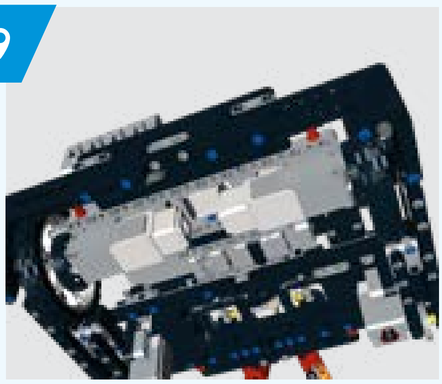
Wide and Hollow

This robot has a wide and hollow base, having a wide gap underneath the robot. This is to allow the robot to travel over the wall at the various farms so that it eases the depositing of plants in the fields.



4 Point ofContact

Due to its wide base and the 4 points of contact with the ground from the 4 corners of the robot (the two motorcycle wheels at the back and the two pulley wheels in the front), this robot is extremely stable and it accommodates for the high-speed movements during the run.



DuoMedium Motor:

Medium motor provides a greater speed than the large motor, even though it has lesser strength. Since our robot is light and we plan to finish the entire mission within the least amount of time, the medium motor is the best choice to move the robot's base.

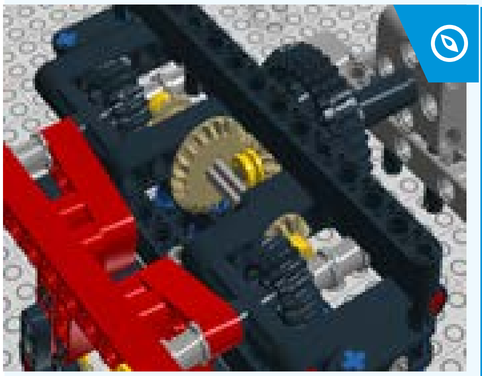
Motorcycle Tires

Motorcycle wheels are also used in the base as it provides the greatest height distance between the base and the ground, providing leeway and greater distance between the top of the plant and the base so that it will minimise errors made during the run.

Mechanical Design - Mechanism

Mechanism:

Our unique and simple grab and lift mechanism. This is used to collect and deposit plants. As the name states, this mechanism is capable of grabbing the plants and lifting them up, then lowering the plants and depositing. them

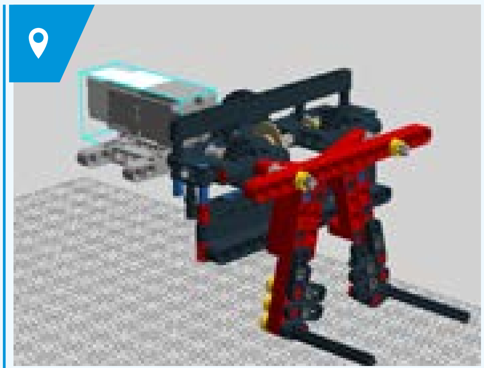


Gearing System:

This mechanism functions through a gearing system. The grab and lift is geared in a high torque gear configuration 9:25 from the medium motor. The purpose for a high torque gear configuration for the grab and lift is to give the grab and lift more grip, ensuring that the plants will not jerk out of the grab and lift

Stability:

Moreover, our robot is very stable despite its small size. Our center of mass is around the center of the robot and our rectangular support polygon is wide given that the chances of our center of mass leaving the support polygon is almost impossible, hence our robot is very stable and will probably never topple.



Medium Motor:

Medium motor is used in this mechanism as not much strength is needed, since only a maximum of 3 plants are lifted at a time. Limiters are placed to prevent the plants from going through the claw when robot is collecting the next plant. Also, medium motors are lighter than large motors, allowing our robot move at greater speed.

Others:

Cube Sensor:

There is also a movable light sensor that can be lowered down to detect the soil quality data blocks and be lifted up so that the robot would be within size limit

Building Process - Challenges we faced

Challenge Faced: Placement of Colour Sensor

Due to the simplicity and the design of our base, there were not any suitable location for the olour sensor to be mounted to sense the soil quality data blocks.

How did we overcome this challenge:

In order to remain within the size limit and to make sure that our colour sensor doesn't hit the other plants during collection, we decided to mount a moveable colour sensor.

Challenge Faced: Size of Motorcycle wheels

The motorcycle wheels mounted at the back of the robot that are supposed to drive the robot are actually half hole above the ground, causing the entire robot to slant to one side.

How did we overcome this challenge:

Stuffing was added to the tires to increase the diameter of the wheel. With the stuffing we added, we increased the radius of the wheel by half hole, allowing our robot to be perfectly balanced on the ground.

Pros: (Actual)

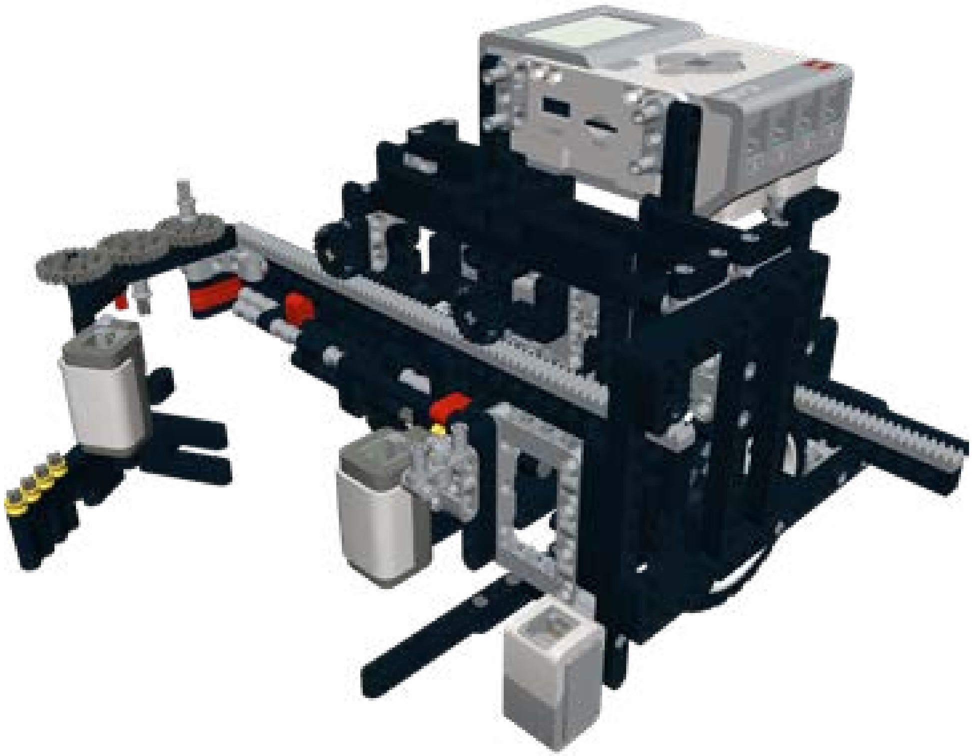
- Adaptable to suprise rule
- Lots of room for error
- Fast and Smooth

(Actual) Cons

- Both collection and deposition of plants are inefficient
- Depositing of plants is inconsistent- more error

Overall Conclusion:

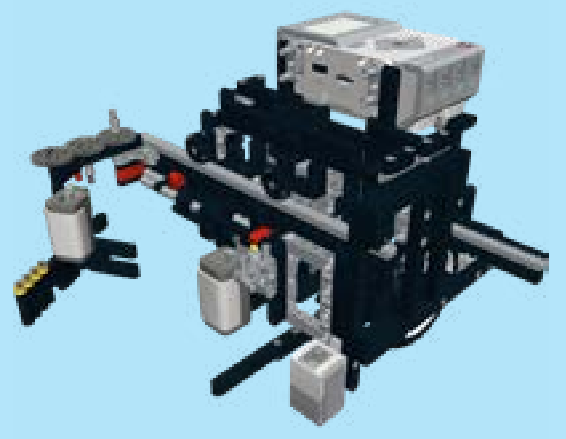
We concluded that our grab and lift design was not the best concept and decided to change to better one. The main flaw of this design is the need to recollect the plants since it was only able to collect 3 at a time. Furthermore, the consistency of the grab and lift simply cannot be risked. The deposition of plants for the grab and lift was very inconsistent and the robot was overall rather ineffective. Even though this robot was quite a huge improvement from the previous design, the conveyor belt design, we still had some time so we tried to come up with a better, more efficient and more effective design that could solve all the problem we were facing. Hence, we decided to move on from this design.



Current Robot: Pusher Mech

Pusher Mech Robot

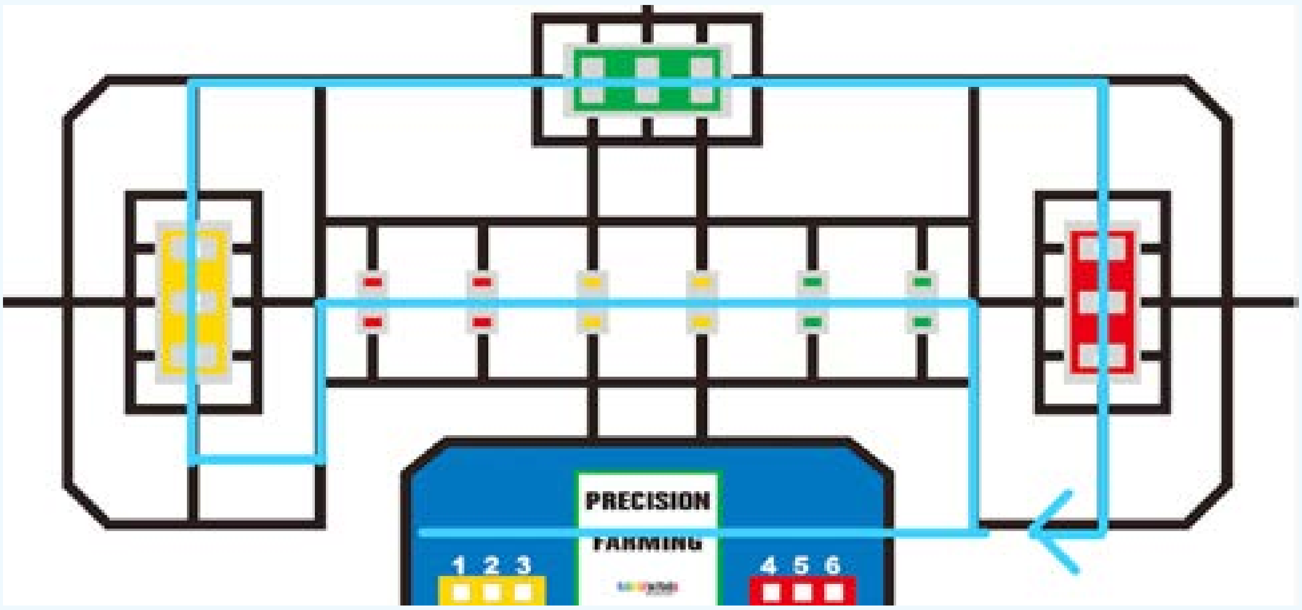
Our Idea:



This is our current and working robot design that is not only able to finish the mission within a short amt of time, but also do it efficiently, accurately and consistently.

After thinking through and witnessing the lack of efficiency in the grab and lift robot, we decided to return to our initial objective, which to be capable of collecting all plants in one go and score effectively. We sought a more effecient and less time-consuming method for collection and deposition of plants. We went to review our past robots and thought of ways to resolve all. With that, the pusher mech robot is invented

Robot Run Route:



As seen in the above robot run route, it is much more efficient and time-saving than the conveyor belt and the grab and lift, as the robot would be able to collect 7 plants in one go and without wasting time on turning in to grab the plants

Thought Process behind Pusher Mech......

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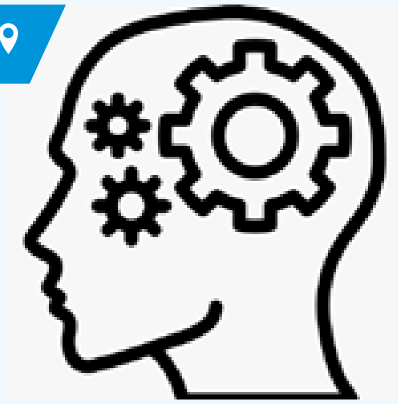
After building two different robots that are inefficient in their own ways, we thought that what if we could build a robot that encompasses the advantages of both robots and yet would not display the disadvantges both robots had. The first robot was able to collect 7 plants at the same time and we plan to keep this aspect to avoid the current robot having the same disadvantages as the grab and lift. Then, the grab and lift has lots of room for error during collection and deposition and we plan to include that in our robot design as well

Therefore, we brainstromed on how we can have a robot to collect all 7 plants in one go and yet ensure that there is lots of room for error and the collection and deposition of plants is consistent, accurate and efficient. We also want the new robot design to not turn in to collect the plants, saving more



After much planning and brianstorming, we found the almost perfect robot design for this mission, which is the pusher mech robot. This design greatly satisfies our requirements.

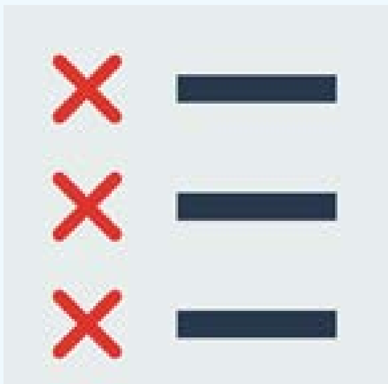
Pros and Cons in Theory:

Pros:

- Collection & deposition is effecient
- Lots of room for error throughout run
- Easy to program
- Mission completed in short time
- Capable of collecting and depositing 7 plants in one go
- Adaptable to surprice rules

Cons:

- Building may be slightly intensive
- Robot run still could not be complet-ed in 30 sec



Mechanical Design - Base

Base:

The base of this robot is simple and compact so as to accommodate the double mechanism at the front and at the back of the robot.

Stacking Medium Motors:

As our base has to be as compact as possible, the two medium motors that are used to move the two mechanisms are stacked on top of one another, the top activating the sweeper at the front while the bottom activating the pusher at the back. This saves so much space and yet still ensuring that the mechanisms still work.

Veritcal Large Motors:

Similarly, as our base has to be as compact as possible, both large motors, used to move the robot, are mounted vertically. Also, by mounting them vertically there is sufficient space for the cage underneath the robot to store the plants for deposition.

Cage under Robot:

Our mechanism requires the plants to be stored somewhere after the latter is being collected.. Also, as the pusher is at the back while the sweeper is at the front, it is perfect for the cage to act as both the pathway and a storage for the plants to be collected and deposited underneath the robot.

Motorcycle Wheels:

Motorcycle wheels are used in this robot as when the plants are collected, they will have to go underneath the robot. The whees provides the greatest height distance between the base and the ground, providing leeway and greater distance between the top of the plant and the base. Also, since we need the most compact base possibe, the motorcycle wheel is the most suitable as it is the thinnest out of all types fo wheels

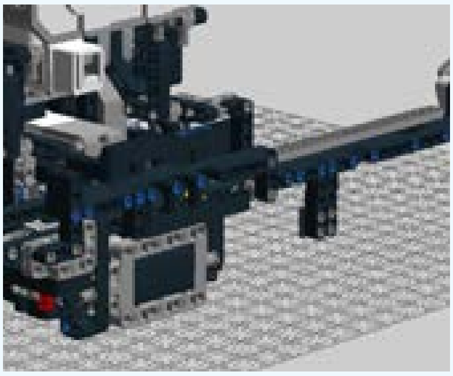
Mechanical Design - Mechanism

Mechanism:

This is the unique component of our robot. The sweeper and the pusher are the main components of the mechanism, which is what makes this entire mechanism unique and our robot to finish the mission efficiently.

Sweeping Mech (Collector):

The sweeping mech is mounted at the front of the robot where it is controlled by the gear connected to the medium motor. As the gear turn, the gear rack on the sweeping mech moves accordingly. The sweeping mech is made such that as it moves out, the claw opens up and as it moves in, the claw closes. This tunrs the plants such that they are of correct orientation for deposition



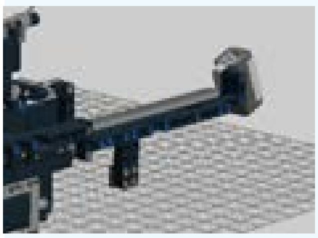
Pushing Mech (Dispenser):

The pushing mech is mounted at the back of the robot where it is controlled by a smaller gear connected to the other medium motor. This pusher mech has an extension down such that it can limit the plants from moving out of the plant unintentionally. This extension is also used to push the plant out into the fields

Mech Activator:

This mech activator is the component used to gradually turn the sweeping mechanism. This mech activator is made from axles and beams extended out from the base. As the sweeping mechanism comes in contact with the mech activator, the mechanism will gradually trn to orientate the plants into the correct position for deposition.

Others:



Cube Sensor:

The NXT ight sensor is mounted in a 35 degree angle at the end of the pusher. When the pusher extends out, the lightsensor would be at the correct position to sense the soil quality data block

Building Process - Challenges we faced

Challenge Faced: Imbalanced Weight Distribution

When the robot was built, we found that the CoM is slightly at the right side of the robot, which causes the robot to drift right whenever it tries to travel straight

How did we overcome this challenge:

We had to counter the extra weight made by the sweeper and usher mechanism. So, we placed two weightsat the left side of the robot. This ,made the robot travel straight and resolved the problem of it drifting right

Challenge Faced: Size of Motorcycle wheels

The same problem occured previously when the motorcycle wheels mounted at the back of the robot that are supposed to drive the robot are actually half hole above the ground, causing the entire robot to slant forward and this affects the collection of the trees

How did we overcome this challenge:

We stuffed the motorcycle wheels and we also added pulley wheel in front. We added half beams at the bottom of the cage for support.

Challenge Faced: Turning of sweeping mech is too rapid

The turning of the swweping mechanism is too rapid, which causes the mechanism to shoot the plants out instead of into the cage.

How did we overcome this challenge:

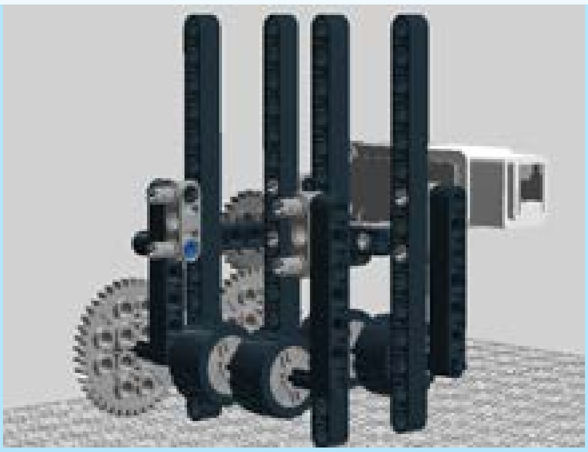
We added layers of axles that are shorter each layer so as to ensure that the swweping mechanism turns gradually to push the plants nicely into the cage below the robot

Overall Conclusion:

With all these chalenges resolved, we are able to achieve what we always wanted, which is the possibility of completing the mission within the shortest time possible, both efficiently and effectively. This unique robot design also completes the mission with high accuracy and consistency. We are satisfied with this robot design and proceeded on with the compeition.

Additional Design - Sucking Mech

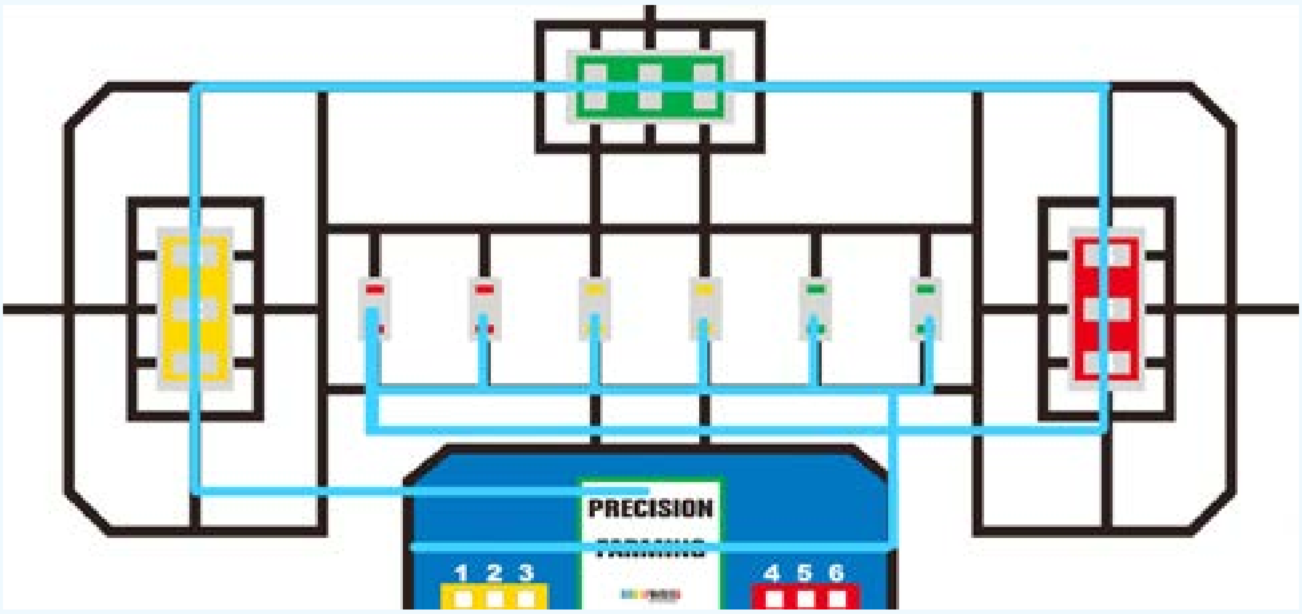
Our Idea:



This is our idea of a sucking mechanism where it can suck the plants into a vertical cage and obot can dispense it by simply releasing it from the cage.

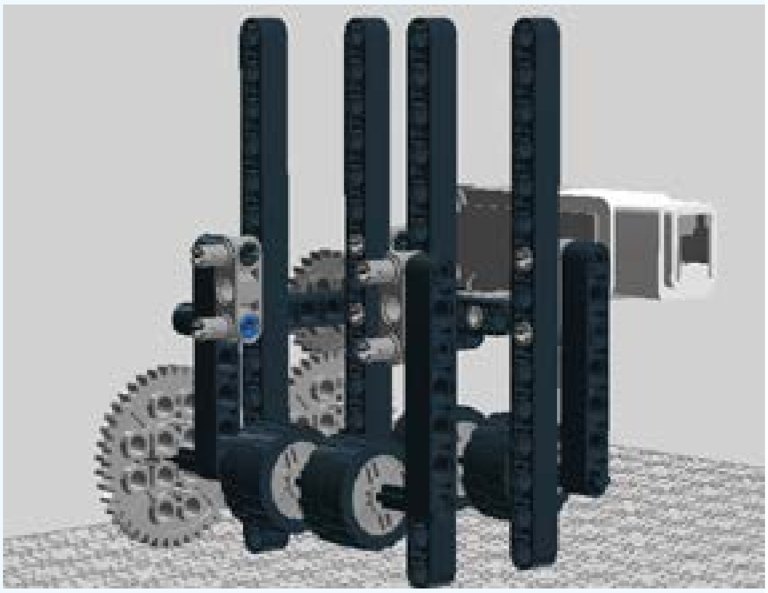
Other than the above 3 robots, we came out with an alternative that has not been tested. We thought of having a similar concept as our conveyor robot, where we can collect all 7 plants at the same time but it is lighter and it can collect the plants with greater consistency and efficiency. Hence, we thought of a robot with a sucking mechanism.

Robot Run Route:



Even though this robot will be significantly faster than the comveyor belt robot, it is still not as fast as the grab and lift or our current robot as thr robot still has to turn in many times when collecting the plants

Additional Design - Sucking Mech



The robot will have a sucking mechanism that is capable of sucking up plants and storing it at the cage above. The sucker has a cage with a capacity of 7 plants and the sucking mechanism is mounted below the cage. The sucking mechanism works by having two pairs of rubber wheels, powered by a medium motor, spin in the opposite direction to either suck up or push out the plants. Then, during collection, there will be a large motor which lowers the sucking mechanism to the level of the plants such that the plants comes in contact with the 2 pairs of rolling rubber wheels. Due to frictional force between the sides of the plant and the rubbery surface of the wheels, the plants is being sucked upwards before lifting the mechanism upwards to collect the next plants. Depositing of plants would work in the same way, but the wheels and the motor will turn in the opposite direction. One important aspect to take note is the size of the wheels used. The size of the wheels chosen must be perfect as the gap between the pairs of wheels as it must be slightly smaller than the width of the plant, so that it is still capable of sucking up the plants but it is able to prevent the plants from falling out unintentionally.

Overall Conclusion:

This sucking mechanism is much lighter as compared to the conveyor mechanism, which will allow our robot to move at a greater speed to complete the mission. However, even though it is effective and consistent, it requires a very high amount of accuracy when collecting and depositing the plants. With this drawback, together with our ready built robot, we decided not to build this robot and implement this idea, and proceed on with our current robot instead.

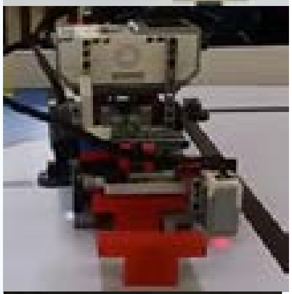
Our Robot Research

Throughout our entire building process, we came across various designs by other teams globally. We did several comparisons between our robot and their robot design and weighed the pros and cons, allowing us to be assured that our robot design is the most suitable to ensure that we will complete the mission with the greatest efficiency, effectiveness and within the shortest time.

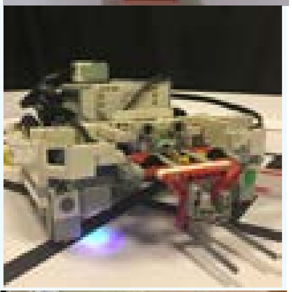
The Research Designs

Movable Cage Within Robot

Static Cage Within Robot

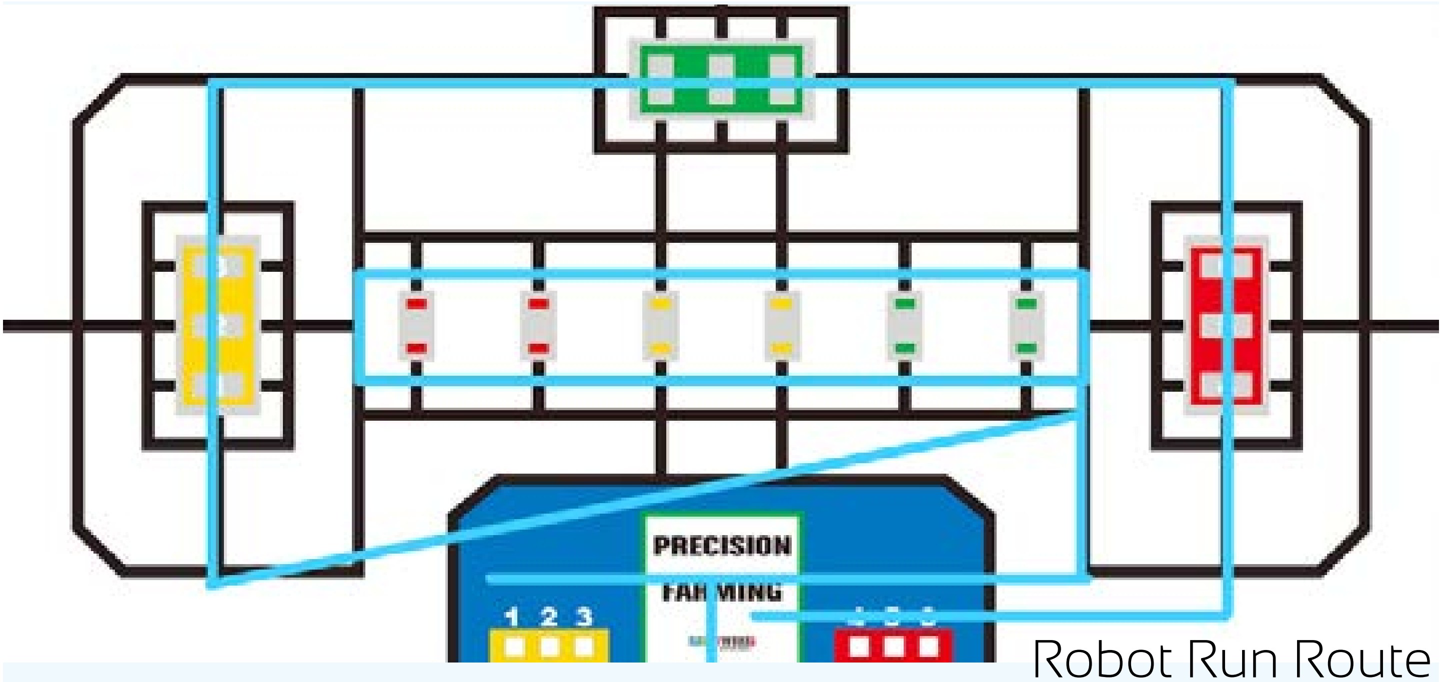


Grab and Lift



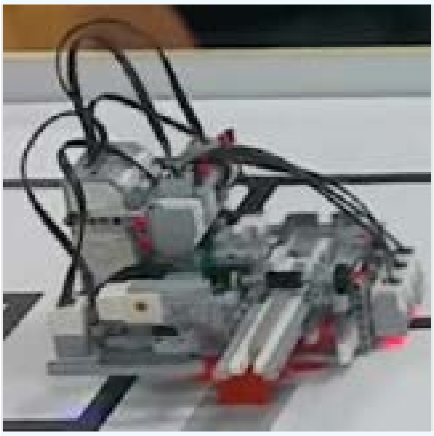
Sucker

Movable Cage Within Robot



Robot Run Route

Robot Design



Collection

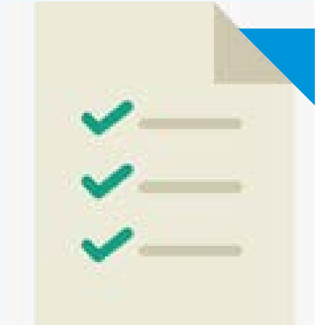
A medium motor at the side that controls a pushing mechanism to spin, pushing the plants into a cage which is within the robot.

Deposition

Another medium motor at the center that controlled the cage to move left and right, allowing it to push the plants into the field area with the locker at the end of the cage.

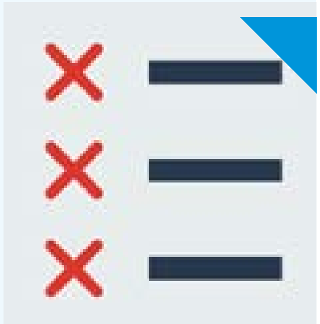
Evaluation Of Robot

Pros



- The robot run was swift. (42 sec)
- Effective deposition (15 sec)

Cons



- Had to move around the seedling area since it takes in only 1 plant at a time
- Collection requires high accuracy

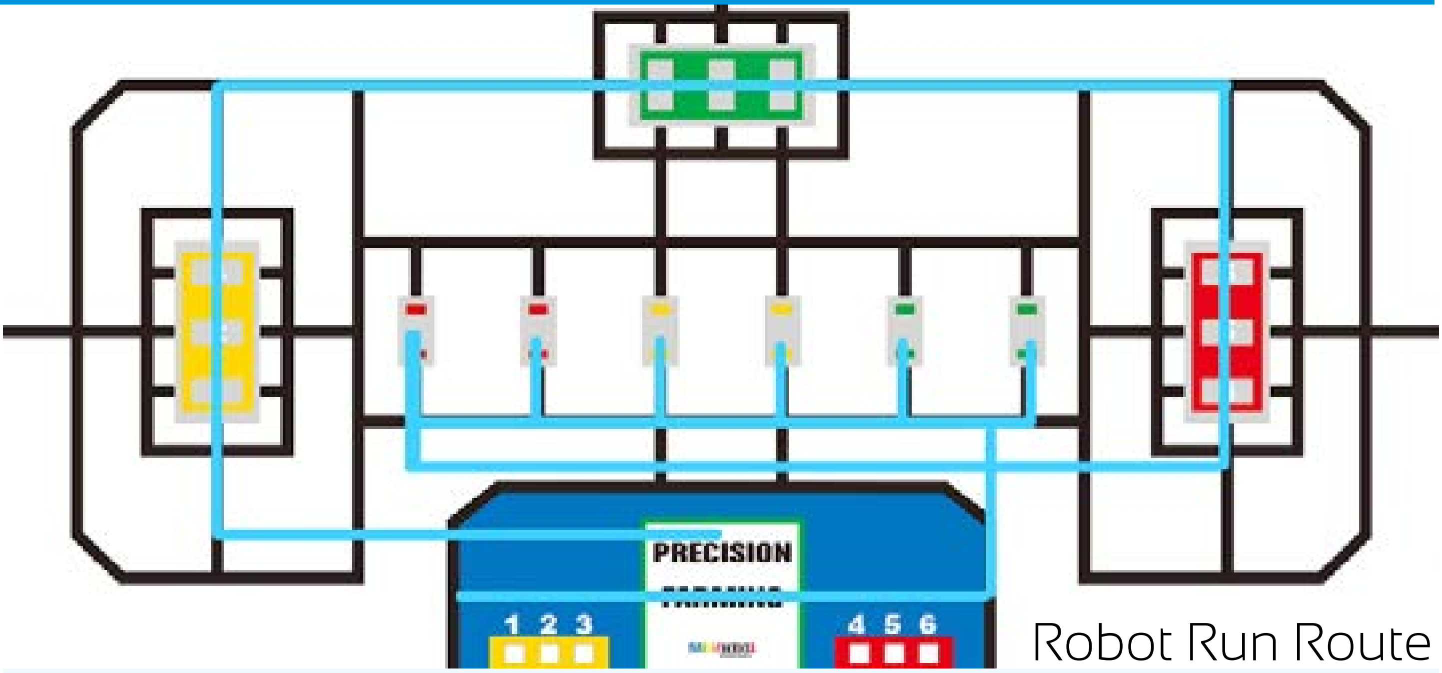
Takeaways

Fast Robot Run	✓	Effective Collection	—
Effective Deposition	✓	Run Accuracy	—
Run Consistency	✓	Adaptability	—

Conclusion

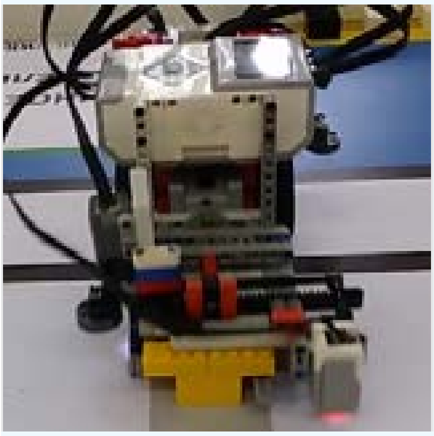
The robot was almost perfect so we decided to innovate from this design and solve their problems to give us a better run time.

Static Cage Within Robot



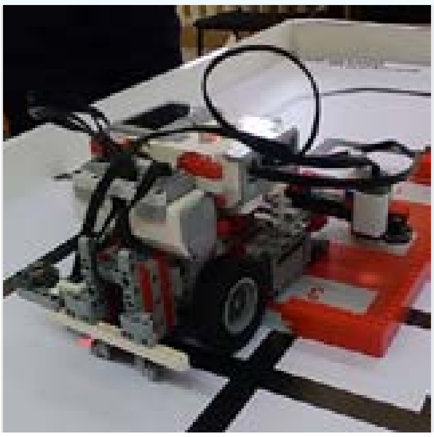
Robot Run Route

Robot Design



Collection

A cage is built within the robot which is programmed to move forward to collect the plants. The cages then closed before collecting the next plant.

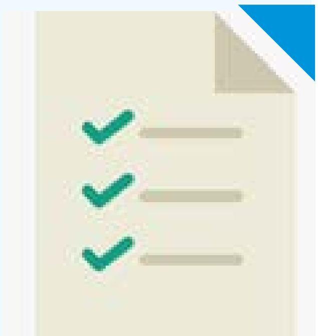


Deposition

A pusher at the front of the robot, which allows the robot to dispense the plants by pushing the plants out of the cage.

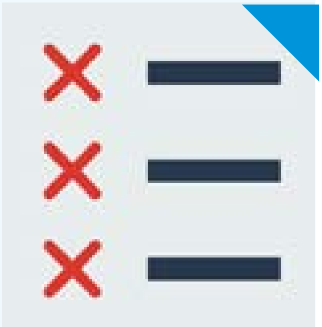
Evaluation Of Robot

Pros



- Greater leeway for collection
- Simple yet reliable

Cons



- Had to move around the seedling area since we needed the right orientation
- Orientation of plants in cage have to be controlled with robot movement

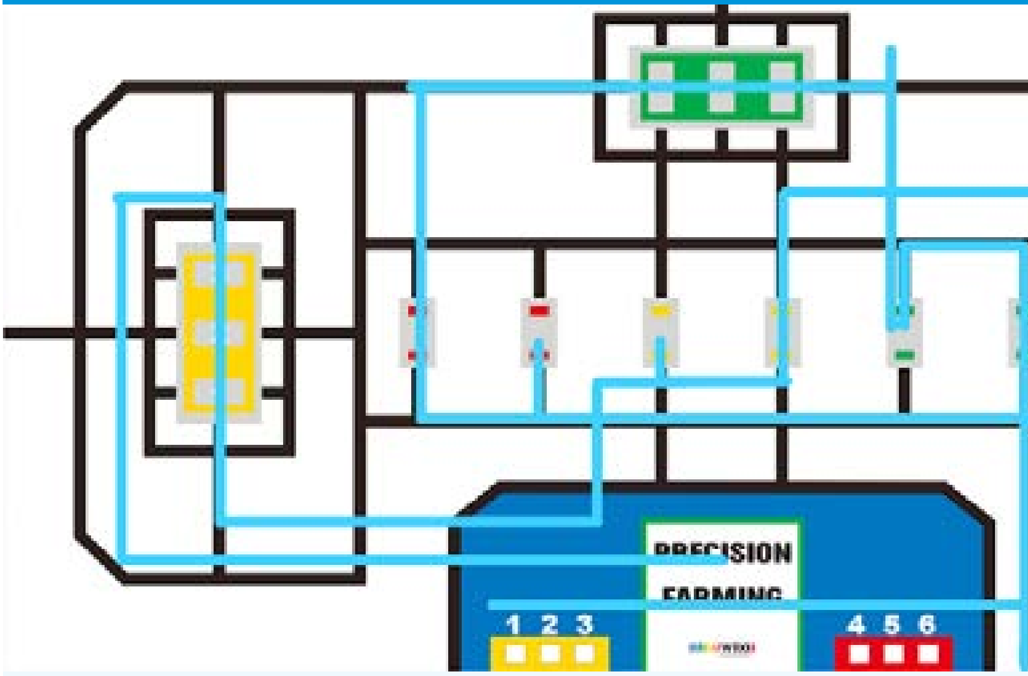
Takeaways

Fast Robot Run	✔	Effective Collection	—
Effective Deposition	✔	Run Accuracy	✔
Run Consistency	✔	Adaptability	—

Conclusion

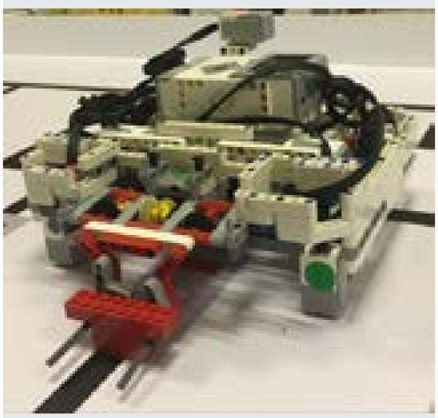
The robot was fast, accurate and consistent, however its only setback is its requirement to move through the cubes to collect them.

Grab And Lift



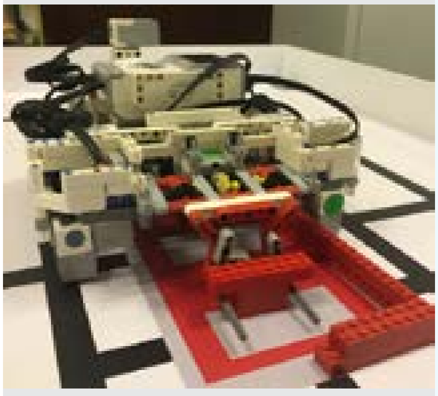
Robot Run Route

Robot Design



Collection

A claw at the front will grab the plants, allowing it to go over the wall to deposit the plants in the respective fields.

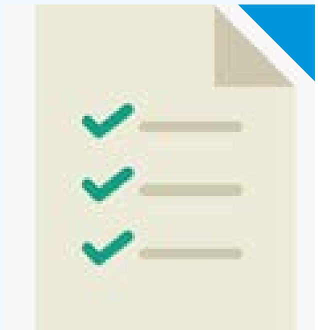


Deposition

The mechanism will lower the plants, move back and lift the remaining plants for further deposition. This process is repeated until all the trees have been deposited.

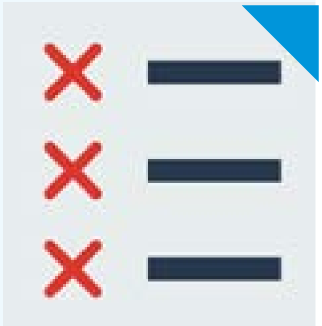
Evaluation Of Robot

Pros



- Robot design is simple
- Adaptable to different scenarios (Beneficial for surprise missions)

Cons



- Had to repeat 3 rounds of collection since it can only hold 3 plants at a time
- Inconsistent deposition of plants

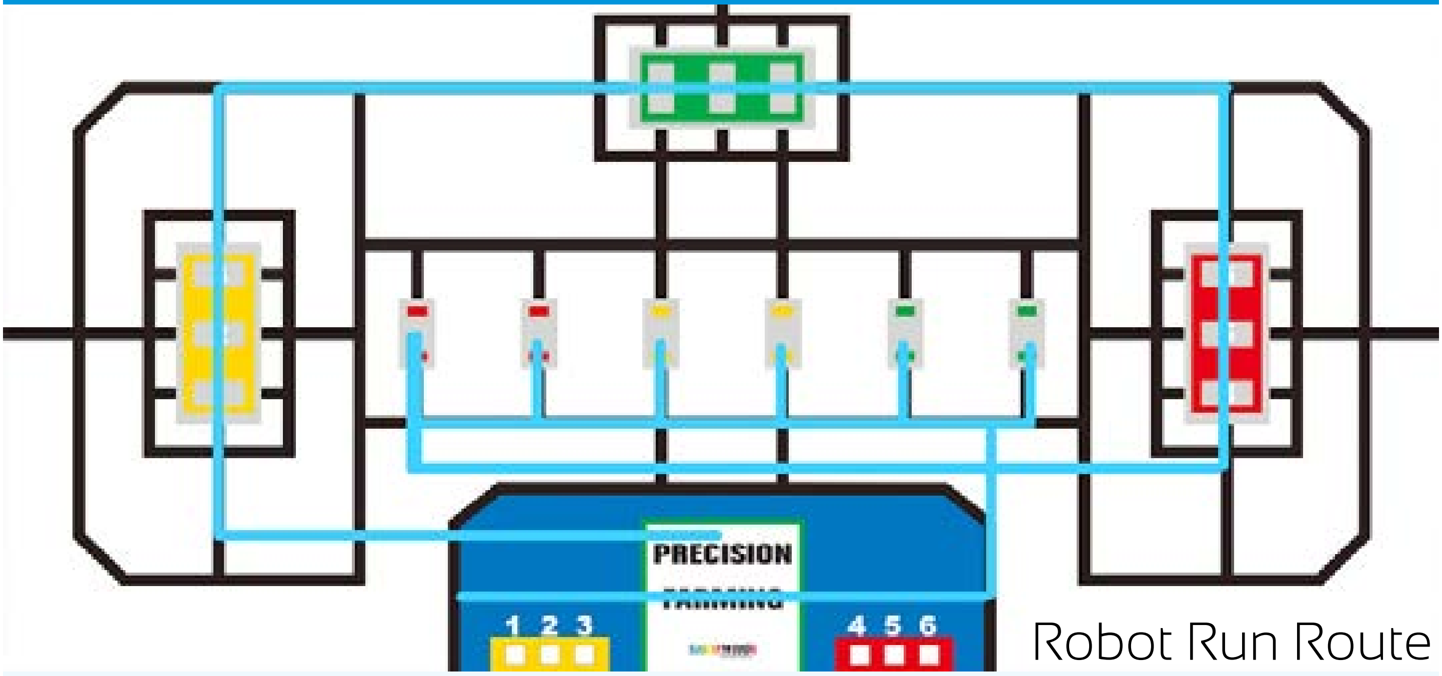
Takeaways

Fast Robot Run	✖	Effective Collection	✖
Effective Deposition	✖	Run Accuracy	—
Run Consistency	—	Adaptability	—

Conclusion

There is nothing outstandingly good about this robot design, hence this design was not considered.

Sucking Mech Robot

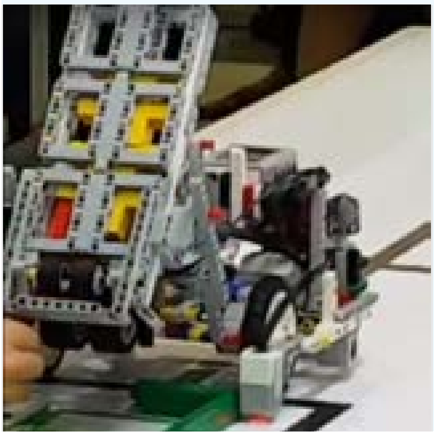


Robot Run Route

Robot Design

Collection

The mechanism is lowered then activated by a medium motor, spinning the wheels and rolling the plants up into the cage before lifting the cage back up.



Deposition

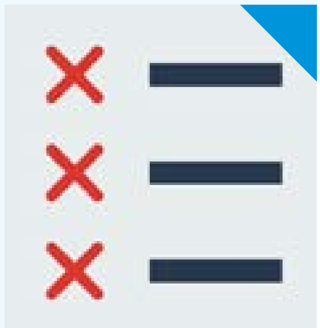
The mechanism is lowered then activated by a medium motor, spinning the wheels the opposite way and rolling the plants out of the cage before lifting the cage back up.

Evaluation Of Robot

Pros

- Collects all 7 plants at once
- Adaptable to different scenarios (Beneficial for surprise missions)

Cons



- Slow collection and deposition
- Unstable (CoM at the front)
- Requires high accuracy

Takeaways

Fast Robot Run	✗	Effective Collection	—
Effective Deposition	✗	Run Accuracy	—
Run Consistency	✗	Adaptablility	—

Conclusion

There is also nothing outstandingly good about this robot design and in fact it is quite risky, hence this design was not considered.

By Team Rafflesia:

Tan Kai Cong

Kenneth Wong

Aegan Chew

华侨中学

HWA CHONG INSTITUTION