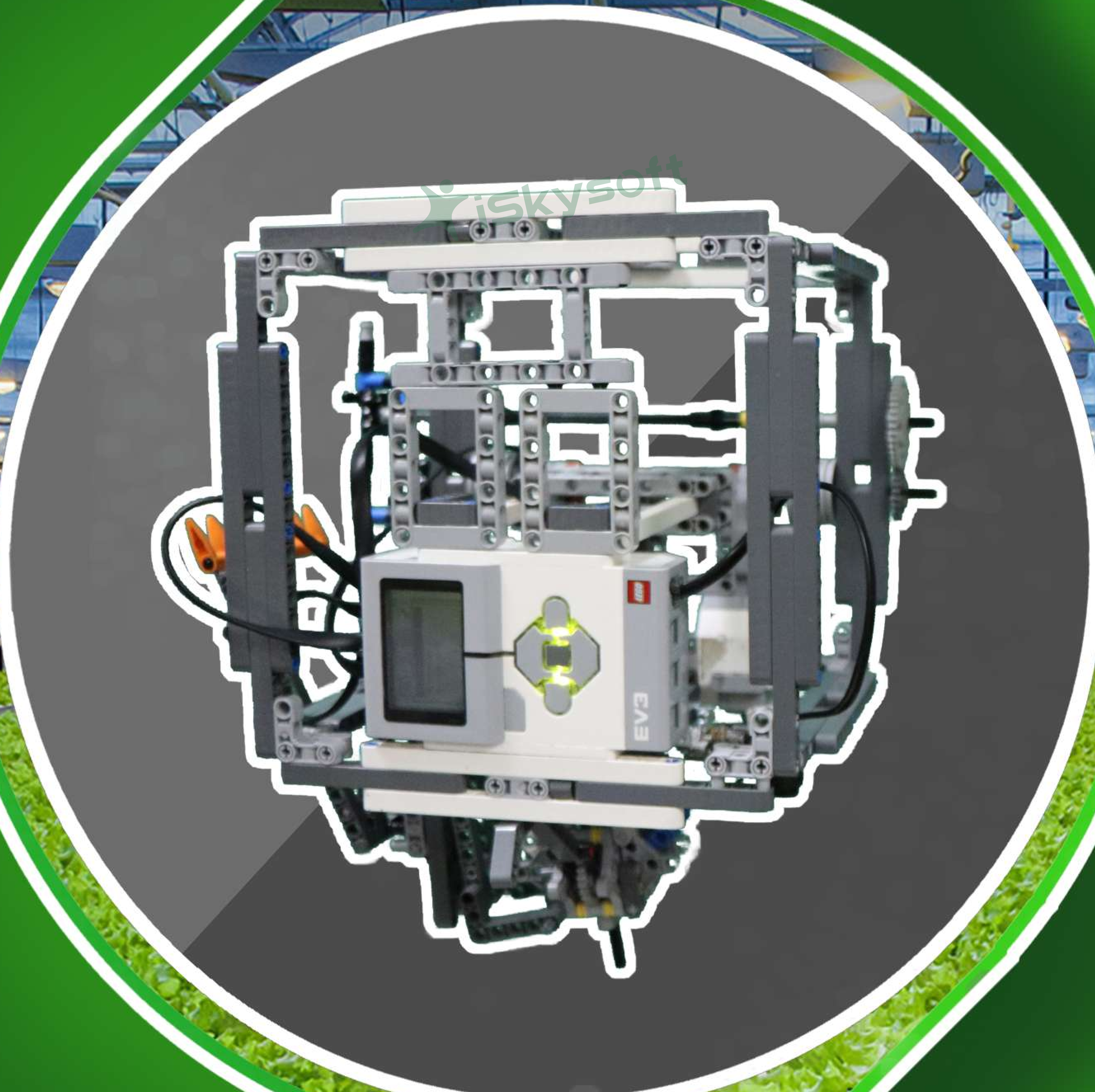
EMERGENCE

BE INSATIABLE — INNOVATE

PROJECT REPORT

CLARA



CABLE LIFTED AUTOMATED ROBOT FOR AGRICULTURE

EMERGENCE

BE INSATIABLE — INNOVATE

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ACKNOWLEDGMENT

The invention of CLARA (Cable Lifted Automated Robot for Agriculture) was possible due to our own hard work and the help and support of friends, family and faculty members. We take this opportunity to acknowledge their help and thank them for their assistance.

We would like to thank our coach, Mr. Udaya Prakash B, for his never-ending support and trust in our capabilities. He has been a great coach throughout the history of the Team.

Special thanks to Chris Jacob, Atin Sakkeer and Marcus Andries for all their help with technical issues in the past couple of months.

Honorable mentions to our friends, Yasin Haider, Kiran Kishor and Abdul Waahid for your love and support towards the Team.

We wish to express our love and thankfulness to our parents and teachers, without whom we would not be where we are today.

And last, but not the least, special thanks to our school, Our Own High School Al Warqa'a and our various sponsors for their support and financial assistance.

Team Emergence thanks each and every one of you for your valuable contributions.

MEET THE TEAM

Coach - Mr. Udaya Prakash: He pays close attention to every segment of the team's development and ensures that the team is able to work together in perfect harmony.

Team Lead - Rahul Arepaka: Rahul's undying determination towards making CLARA a reality and his constant aspiration to soar higher is the team's backbone and main strength.

Graphics Designer - Ashwin JJ: Ashwin's ability to stay focused and constantly provide the team with an urge to work harder was always appreciated by the team.

Arduino Engineer - Jeff Jomon: Jeff has always been great at bringing the team together when we faced some hurdles. His passion for Arduinos helped us make CLARA a better robot.

BE INSATIABLE — INNOVATE

PROLOGUE:

Team Emergence wishes to introduce to the world their invention, CLARA - The Cable Lifted Automated Robot for Agriculture. Our team aims at eradicating the devastating problem of soil compaction through the introduction of new agricultural machinery.

Being one of the leading causes of loss of soil fertility, soil compaction is indeed a problem that needs to be tackled in order to ensure that we are able to generate food resources to meet the global demand.

CLARA is a 100% automated CDPR (Cable-Driven Parallel Robot). Her motion is dependent on 8 NXT motors from which she is suspended using strings. The NXT motors are controlled and commanded by an EV3. She is suitable for use in all types of greenhouses ranging from soil based greenhouses to greenhouses running on hydroponics. This is plausible because she is an all-in-one robot.

CLARA's primary objective is to ensure that every country has food security.

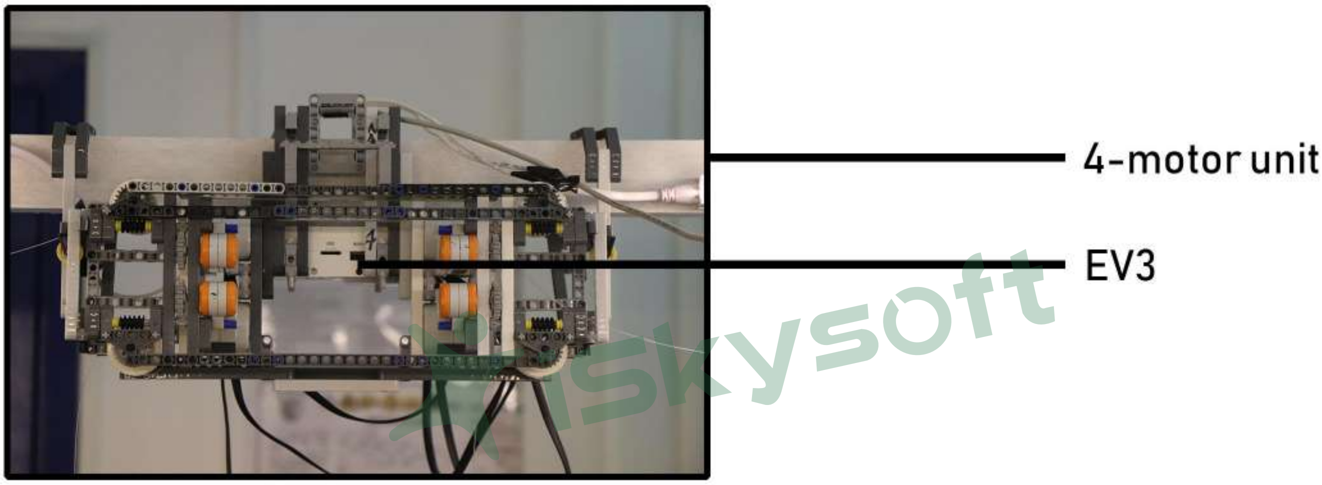
THEORY:

A leading cause of soil compaction is the use of heavy land-based agricultural machinery which leads to loss of air content within the soil. As the human species is about to attain the status of 'Type I Civilization' according to the Kardashev scale, it is mandatory that humans start to move towards objects that are more eco-friendly.

At first glance, the solution is to make an aerial droid to carry out the agricultural processes. But aerial devices like drones may result in the damage of crops due to the pressure exerted by the propellers. And thus we came up with CLARA, a Cable-Driven Parallel Robot (CDPR), who is designed to carry out necessary functions, especially those in tech-based greenhouses.

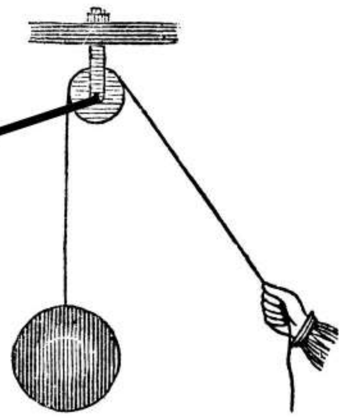
HOW DOES CLARA MOVE?

CLARA is suspended from her vertices using 8 strings (4 strings from the left, 4 from the right) which are attached to the motor units. Each motor unit consists of 4 NXT motors that are each connected to a string.



Most of the motion is controlled by the top 4 strings. The bottom 4 strings do assist in movement within the x-y plane, but their primary function is to give CLARA stability in the air.

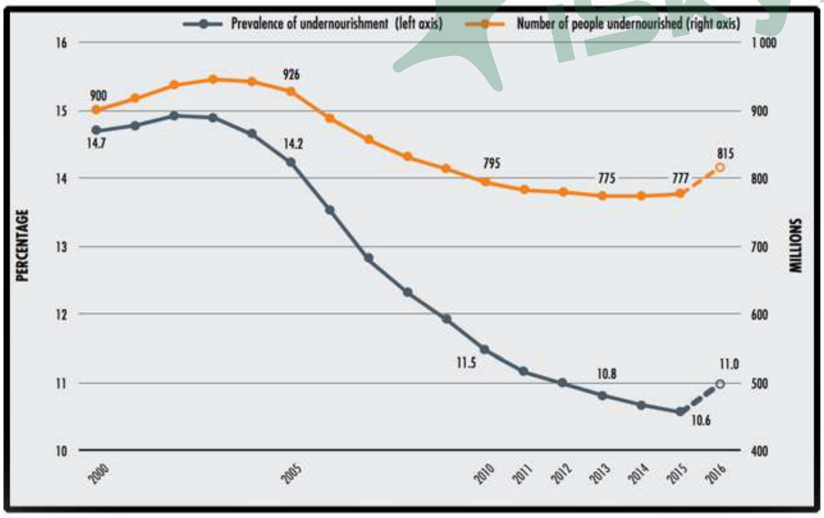
Just like how you'd tug something to pull it closer to you, CLARA can be pulled to any direction just by reeling the strings in that direction. To move forward, the backside strings are loosened and the frontside strings are reeled in. This principle is applicable to CLARA's motion anywhere in the x-y-z coordinate space.



Basic pulley
Principle of motion for CLARA

AN UNTACKLED HURDLE SOIL COMPACTION

For millennia, the human species as a whole has been dependent on agriculture for their sustenance. Agriculture has been proven to be greatly significant for our development. But the problem arises when we see a stagnation in the industry or when the demand for food is much higher than what is being produced. In almost half of the 119 countries studied by concernusa.org, hunger levels were serious or alarming either due to lack of production or due to extremely high demand for food.



Undernourishment has been rising since 2014

The United Arab Emirates is no different. The country we represent, themselves have food independence issues. Nearly 80% of the food is imported from other countries. This is because UAE is a middle-eastern country which barely has any land available for proper agriculture. This makes food production within the UAE a greenhouse based process. The UAE will need to increase its local food production rates in order to avoid future food crises.

And therefore, we aim at making all the countries more food independent than it is right now.

DETRIMENTAL EFFECTS OF SOIL COMPACTION

Wheel Traffic-induced Compaction :

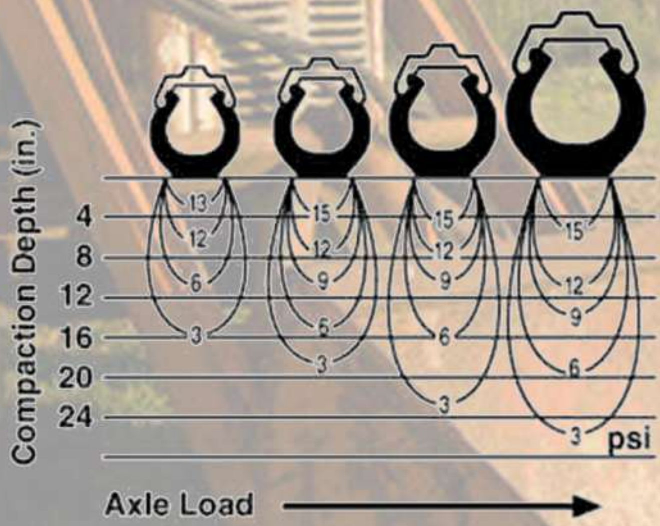
Heavy farm equipment, including tractors, grain carts, combines, trucks, manure spreaders and wheels of pivot irrigation systems, can exert considerable weight onto the soil surface and, consequently, into the subsoil. The effect of equipment weight can penetrate down to 60 cm (24 inches) when soils are moist.

Team Emergence approached greenhouse specialists in the UAE. One of them, Sky Kurtz, gave us great insight on the issues of soil compaction and how CLARA woulddefinitely help reduce drastic effects of soil compaction.

Soil compaction can have a number of negative effects on soil quality and crop production including the following:

Causes soil pore spaces to become smaller.

Reduces water infiltration rate into soil



Decreases the rate that water will penetrate into the soil root zone and subsoil.

Increases the potential for surface water ponding, water runoff, surface soil waterlogging and soil erosion.

(source: agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex13331)

A SOLUTION TO THE DILEMMA

Increasing global crop production rates again, requires as big a leap as the Green Revolution.

A well thought out and a planned solution was brought up by our team that will prove incredibly useful to the economy, citizens and the development of the different countries of the world.

Notable information about CLARA:

CLARA would enable more effective farming within greenhouses, especially tech-based greenhouses.

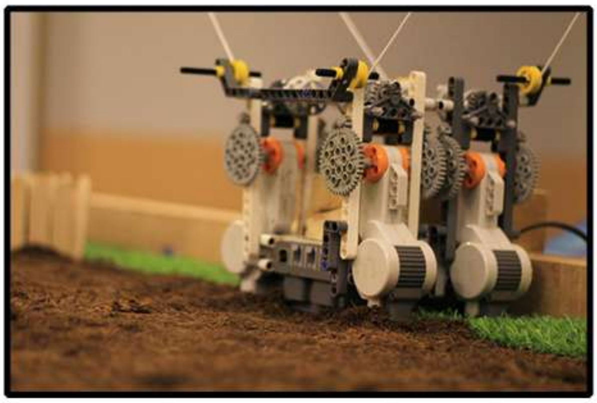
An increase of 31% is estimated in the global produce (From 628.5 MMT to 827 MMT). This is an increase of 200 MMT -- More than 3 times the food demand in the UAE.

Apart from this, CLARA is also economically feasible. Taking into consideration all costs (from plastic molding to miscellaneous costs), CLARA would cost only around 200 USD in terms of hardware.

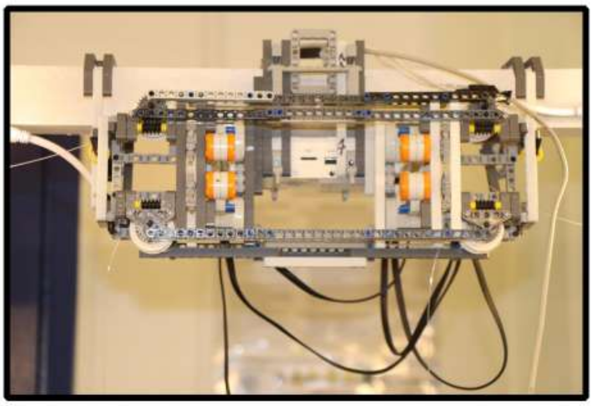
BUILDING CLARA

CLARA was built keeping in mind the limitations of the Lego EV3s and NXT motors. However, we did not want to limit the functions of CLARA and we wanted to make her a 100% automated agribot. For this, we took the help of Arduino microprocessors that work hand-in-hand with the EV3 to ensure that the system remains completely autonomous.

CLARA initially had a wooden skeleton. This was to test out the structural stability of the robot. At this stage, a primitive motor unit design was in use. Later through experimentation, we concluded that the old design was far less efficient than the current one.



Initial design



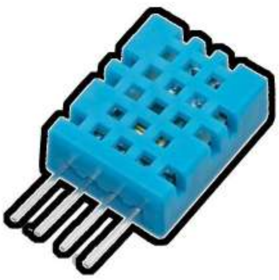
Final design

BUILDING CLARA

We figured out that the most ideal positions for the NXT motors would be in the middle of the upper-side beams. This would allow us to pass the strings through pulleys placed at the corners of the booth and it would make the lego system more compact. It would also make it aesthetically pleasing. On the other hand, placing each motor at different corners just complicates things unnecessarily. It also isn't as visually appealing as the described design.

Setting up CLARA along with the booth

The Arduino components assist CLARA in making her 100% autonomous. Certain things that the EV3 is directly unable to do, such as sending messages through GSM modems, is carried out with the help of the Arduino. Together, the EV3 and Arduino are capable of maximizing agricultural output while being economically feasible, easy to use and secure.

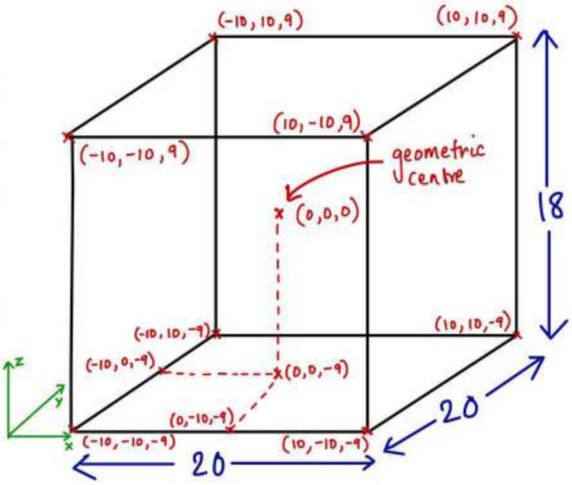


Temperature and Humidity Sensor

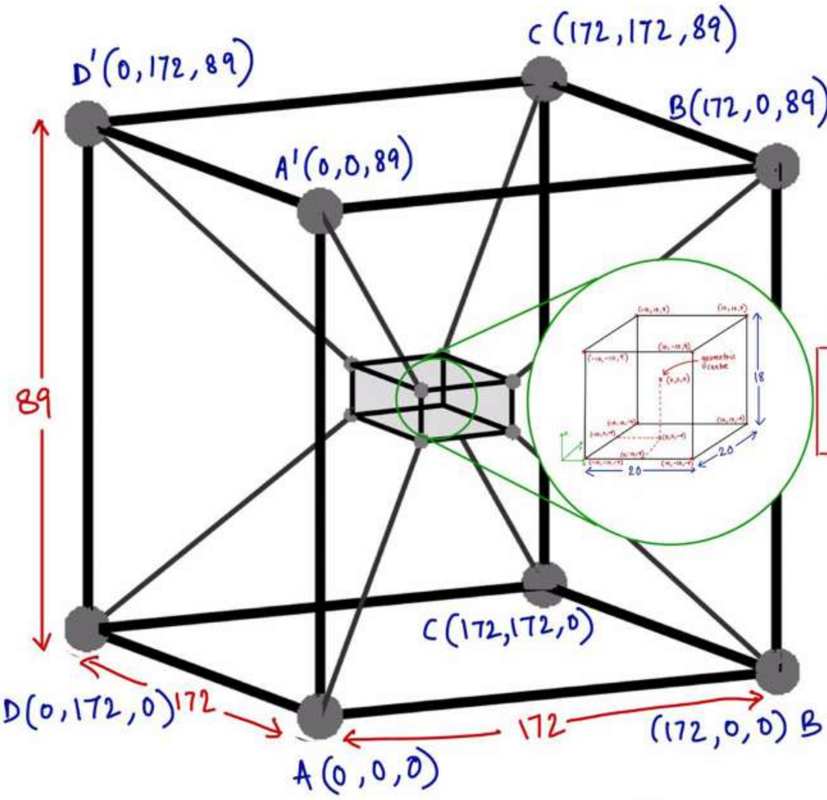
GSM Modem

LEGO PROGRAMMING

The programming of CLARA's coordinate system was influenced greatly by what we are being taught at school. Initially a relation was calculated between the rotation of motors and the length of string reeled. This data was applied to the distance formula for 2 points in 3D space.



The EV3 is programmed to calculate the number of rotations that the respective motors require to make with the help of the gear ratios. It then sends this information to the motors which will then start rotating accordingly.



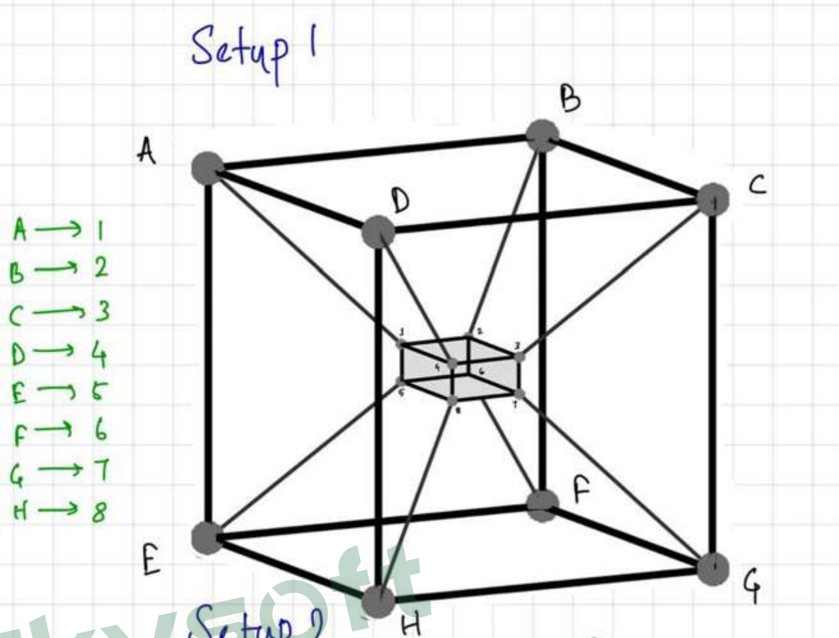
Equation of distance between two points

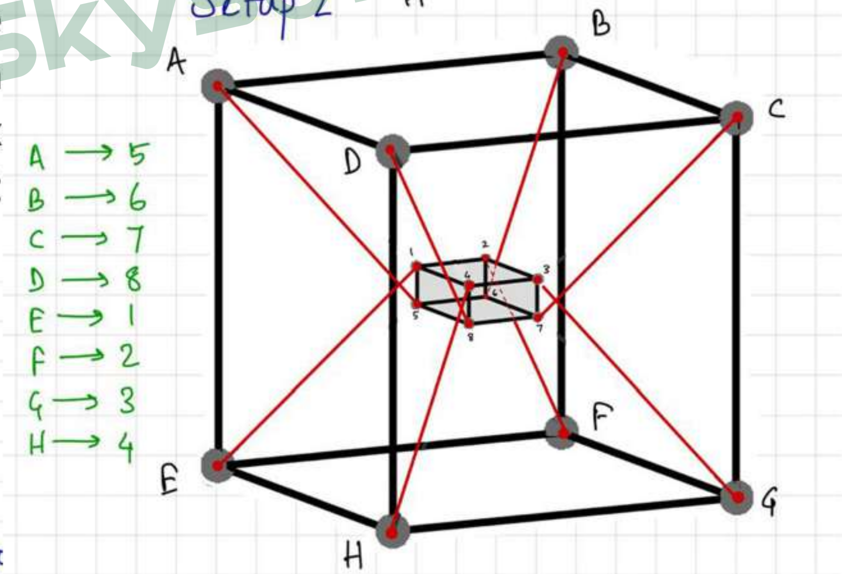
$$\text{Distance} = \left[(x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2\right]^{1/2}$$

LEGO PROGRAMMING

Multiple setups were tried to find the most ideal setup. Setup 1 proved to be the most efficient.

CLARA can move to the coordinate entered in the program. This program is set in a sequence to show the harvesting and refixing of the pots. The color sensors on CLARA determine whether the crop is ready to be harvested or not. CLARA then drops the harvested pot into a box on a conveyor belt that will take it to the drone.





$A'P' = 153.8$, $MA' = 86.5$ $\Rightarrow$ $MA'P' = 240.3$ cm

$\boxed{\text{How to create a reset mechanism/program}}$

- find out how many cms of string each motor has
- set the values into constant variables, eg: A-length, A'-length, etc
- starting position of clara is (83.5, 86.5, 32)
- position of P is (73.5, 76.5, 23)
- length of AP is 147.9 cm
- length of MA (distance between motor to pulley) is ~70 cm
- total length of MAP is (147.9 + 70) = 217.9 cm
- assuming that length of string passing through the pulley A is 300 cm. (← this is assumption of length without checking)
- to reset the motor we subtract 217.9 cm from 300 cm = 82.1
- rotate the motor such that the string is completely extended
- rotate the motor by 82.1 rotations to reset it to length 217.9
- use same method for all motors ⇒ clara can be resetted at inital position

We took the initiative to note down the reset mechanisms of CLARA. Calculations were also done to ensure that we got the details correct.

LEGO PROGRAMMING

$A \rightarrow (0,0,0)$
$B \rightarrow (167,0,0)$
$C \rightarrow (167,173,0)$
$D \rightarrow (0,173,0)$

$A' \rightarrow (0,0,89)$
$B' \rightarrow (167,0,89)$
$C' \rightarrow (167,173,89)$
$D' \rightarrow (0,173,89)$

If Clara starts at origin

Distance from $A \rightarrow P$
Distance from $B \rightarrow Q$
Distance from $C \rightarrow R$
Distance from $D \rightarrow S$
Distance from $A' \rightarrow P'$
Distance from $B' \rightarrow Q'$
Distance from $C' \rightarrow R'$
Distance from $D' \rightarrow S'$

If Clara starts at starting point

Distance from $A \rightarrow P = 108.5$
Distance from $B \rightarrow Q = 108.5$
Distance from $C \rightarrow R = 108.5$
Distance from $D \rightarrow S = 108.5$
Distance from $A' \rightarrow P' = 116.4$
Distance from $B' \rightarrow Q' = 116.4$
Distance from $C' \rightarrow R' = 116.4$
Distance from $D' \rightarrow S' = 116.4$

Clara at centre

$O \rightarrow (83.5, 86.5, 32)$
$P \rightarrow (73.5, 76.5, 23)$
$Q \rightarrow (93.5, 76.5, 23)$
$R \rightarrow (93.5, 96.5, 23)$
$S \rightarrow (73.5, 96.5, 2$
$P' \rightarrow (73.5, 76.5$
$Q' \rightarrow (93.5, 76.5$
$R' \rightarrow (93.5, 96.5$
$S' \rightarrow (73.5, 96.5, ..)$

Subtract these values from new distance variables to find the distance needed to travel and minus this from the old distance variable for next position

$AP_{new} - AP_{old} = 147.9 - 108.5 = \boxed{39.4}$
$BQ_{new} - BQ_{old} = 82.9 - 108.5 = \boxed{-25.6}$
$CR_{new} - CR_{old} = 82.9 - 108.5 = \boxed{-25.6}$
$DS_{new} - DS_{old} = 147.9 - 108.5 = \boxed{39.4}$
$A'P'_{new} - A'P'_{old} = 153.8 - 116.4 = \boxed{37.4}$
$B'Q'_{new} - B'Q'_{old} = 93.1 - 116.4 = \boxed{-23.3}$
$C'R'_{new} - C'R'_{old} = 93.1 - 116.4 = \boxed{-23.3}$
$D'S'_{new} - D'S'_{old} = 153.8 - 116.4 = \boxed{37.4}$

If Clara starts at crop A

these values will be used for old distance variable

Distance from $A \rightarrow P = \boxed{147.9}$
Distance from $B \rightarrow Q = \boxed{82.9}$
Distance from $C \rightarrow R = \boxed{82.9}$
Distance from $D \rightarrow S = \boxed{147.9}$
Distance from $A' \rightarrow P' = \boxed{153.8}$
Distance from $B' \rightarrow Q' = \boxed{93.1}$
Distance from $C' \rightarrow R' = \boxed{93.1}$
Distance from $D' \rightarrow S' = \boxed{153.8}$

Clara at crop A

$O \rightarrow (134.5, 86.5, 32)$
$P \rightarrow (124.5, 76.5, 23)$
$Q \rightarrow (144.5, 76.5, 23)$
$R \rightarrow (144.5, 96.5, 23)$
$S \rightarrow (124.5, 96.5, 23)$
$P' \rightarrow (124.5, 76.5, 41)$
$Q' \rightarrow (144.5, 76.5, 41)$
$R' \rightarrow (144.5, 96.5, 41)$
$S' \rightarrow (124.5, 96.5, 41)$

Using Cross-multiplication

Distance	Time
39.4	1
25.6	x

$x = 25.6 / 39.4 = 0.64$

D	t
39.4	100
25.6	x

$$x = \frac{100 \times 25.6}{39.4} = 64.97$$

If the motor which needs to travel more is moving at speed 100, then the motor which needs to travel lesser will need to be at a speed of 64.97 ~ 65

Speed Ratio = Long : Short = 1.53 : 1

motor which needs to rotate more to cover more distance

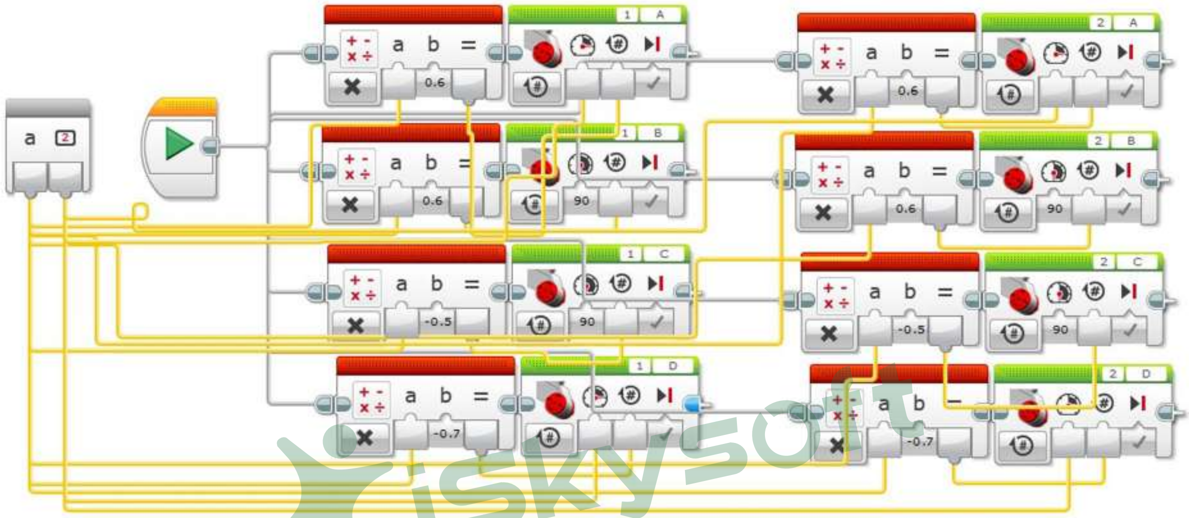
motor which needs to rotate less to cover lesser distance.

CASE STUDY

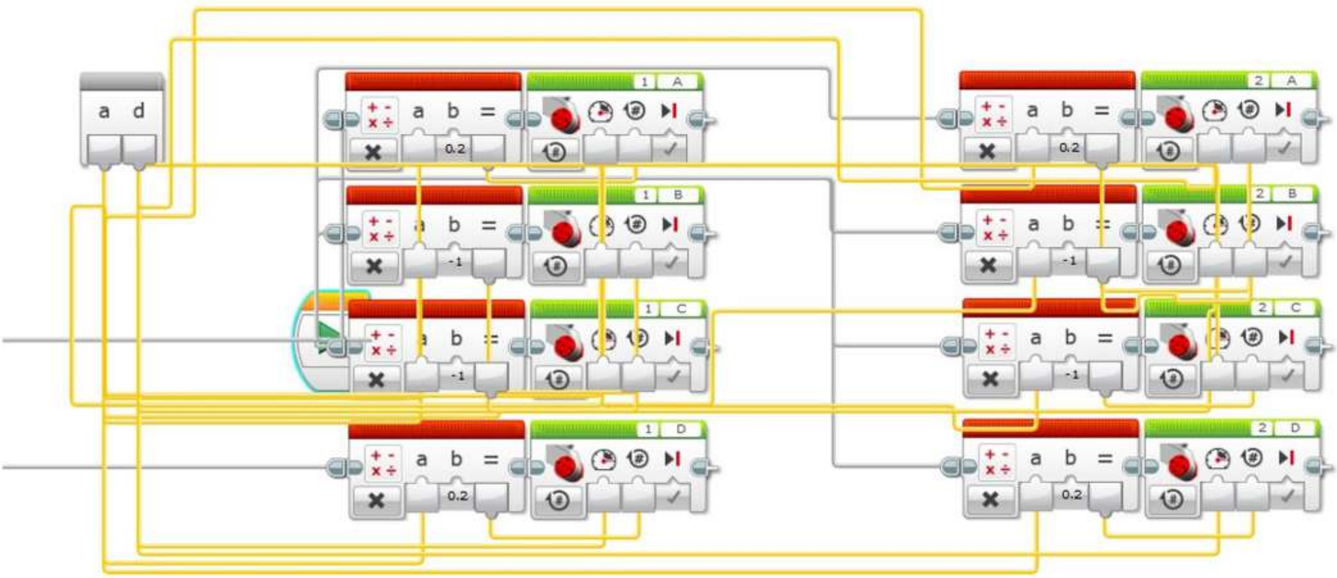
- UAE and GCC imports 80% of fresh produce and 100% in summers
- producing locally is inneficient due to harsh climate
- we use 80% water resources, and producing less than 1% GDP and less than 15% food supply
- technology enabled agro-project
- IOT-enabled agro-culture
- control climate management systems and other tech.
- create perfect climate year around
- average farm uses 240 litres → produce 1kg food
  to 30 litres ⟶ " " "
- step change in resource efficiency
  tackling challenges: - food security
  - water conservation
  - need to diversify economy away from oil
  - sustainability
- carbon negative footprint
- water is used to cool and irrigate crops in UAE atm.
- quality of food is poor even after so much water is used
- production doesnt reach demand of the growing population
- semi-closed greenhouse - captures humidity that the plants transpirates and preserve for later use
  controlled environment agriculture
- most of the water consumption is not for crops, but for cooling
- hydroponic growing methods
  mechanical cooling systems captures condensation and re-use
  recirculating irrigation water
  UV-decontamination
  recycle every ounce of water
- 95% is automated ← irrigation, climate control, windows, screens
  5% ← carrying the crops, pruning of the crops, harvesting, packaging, cleaning of the greenhouse

LEGO PROGRAMMING

Forward motion:

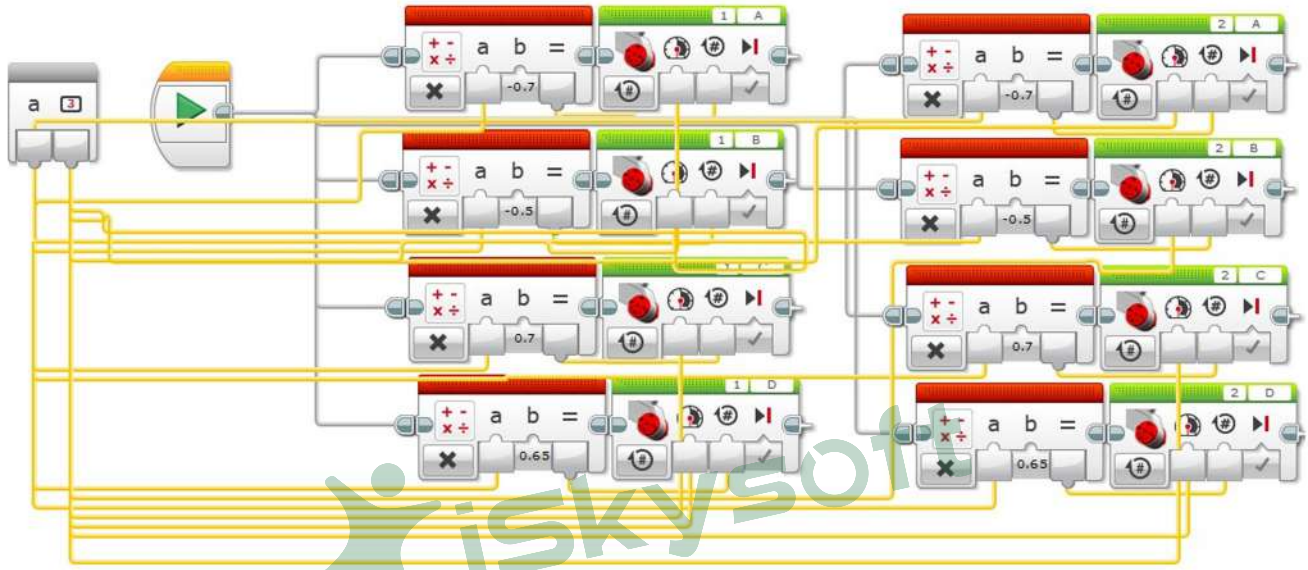


Upward motion:

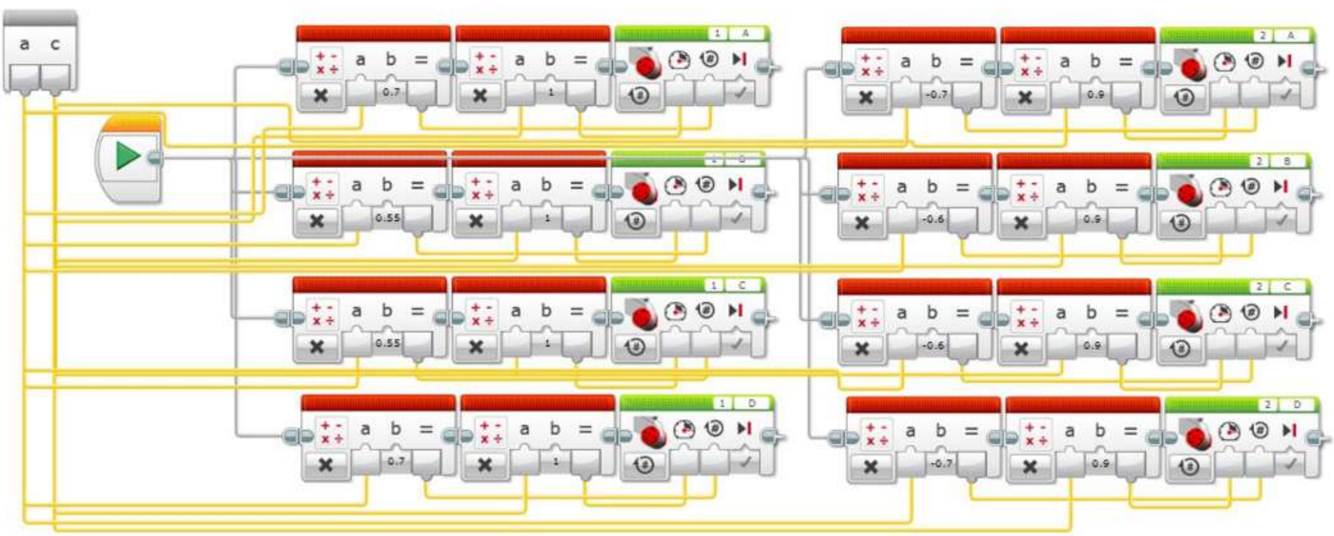


LEGO PROGRAMMING

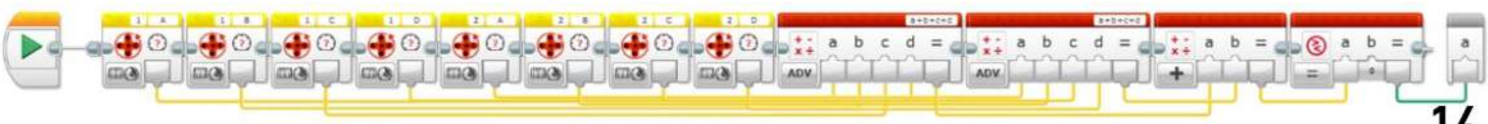
Backward motion:



Right:



Motor stall:



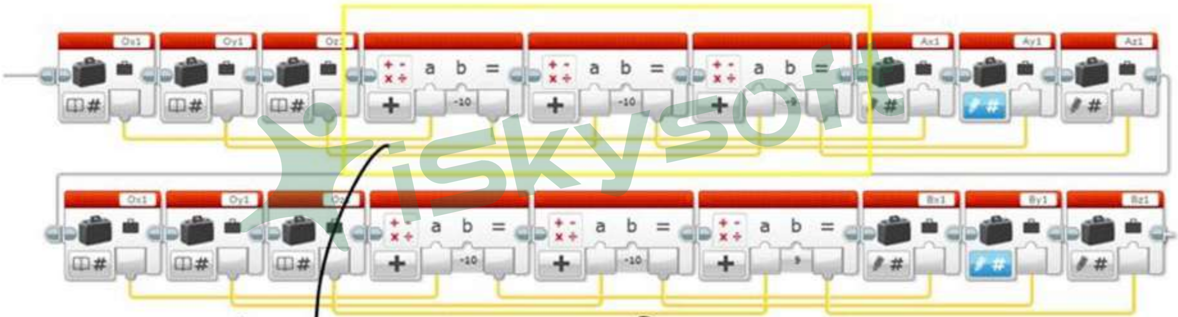
LEGO PROGRAMMING

Declaring the variables

→ coordinates for geometric centre of Clara

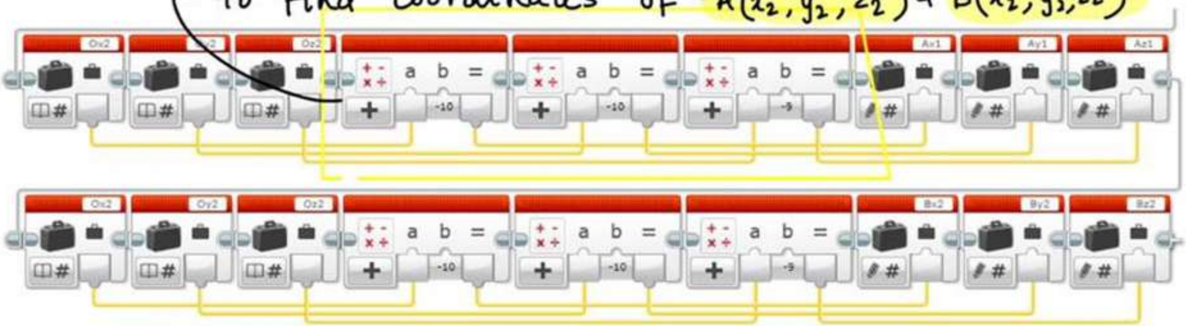
→ coordinates for lower corner

→ coordinates for upper corner

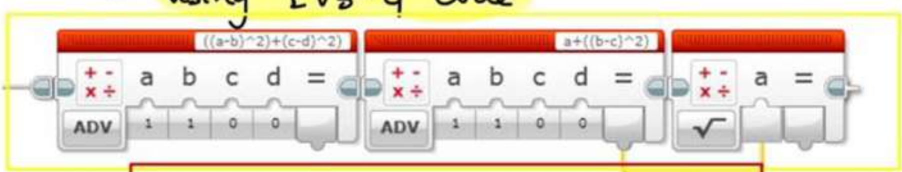


→ using coordinates of geometric centre to find coordinates of $A(x_1, y_1, z_1)$ & $B(x_1, y_1, z_1)$

→ using coordinates of geometric centre to find coordinates of $A(x_2, y_2, z_2)$ & $B(x_2, y_2, z_2)$



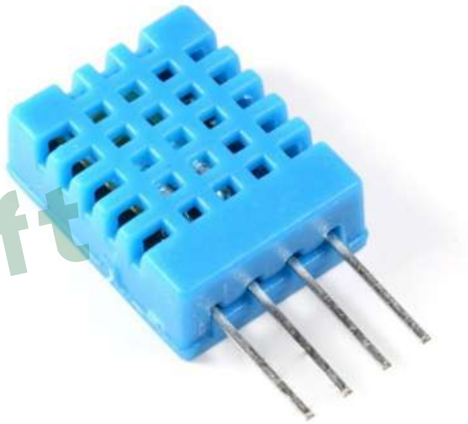
calculating distance between two points in 3D space using EV3-G code



$$\boxed{\sqrt{(x_1-x_2)^2+(y_1-y_2)^2+(z_1-z_2)^2}}$$

ARDUINO PROGRAMMING

The Arduino microprocessor was used to show that the entire greenhouse can be automated. We connected an arduino to the water pumps to simulate replenishment of nutrient water, one to an LED strip to simulate an audio visualizer for aesthetic purposes, one for the GSM Modem to send SMS and one for addressable LEDs to show the movement of water.



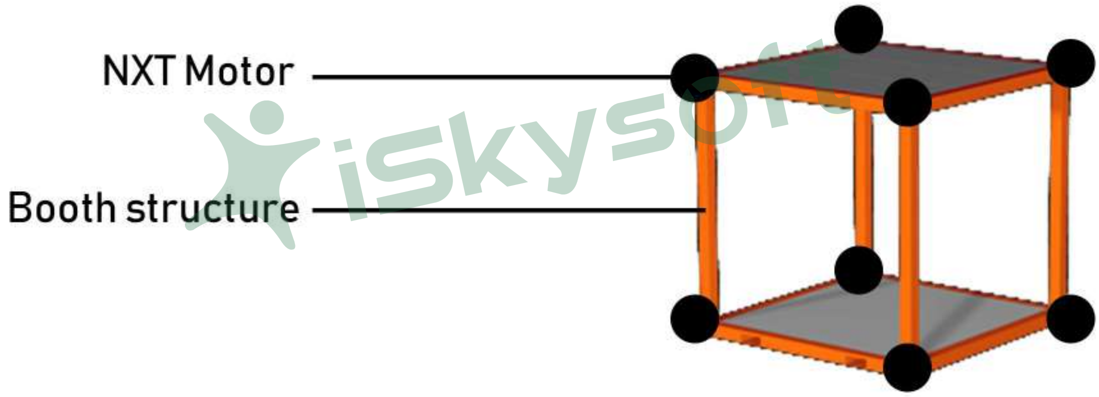
Arduino programming proved to be challenging but also quite interesting due to its complexity.

Example of program used for DHT11 sensor:

```
#include "dht.h"
#define dht_apin A0 // Analog Pin sensor is connected to

dht DHT;

void setup(){

  Serial.begin(9600);
  delay(500);//Delay to let system boot
  Serial.println("DHT11 Humidity & temperature Sensor\n\n");
  delay(1000);//Wait before accessing Sensor

}//end "setup()"

void loop(){
  //Start of Program

    DHT.read11(dht_apin);

    Serial.print("Current humidity = ");
    Serial.print(DHT.humidity);
    Serial.print("%  ");
    Serial.print("temperature = ");
    Serial.print(DHT.temperature);
    Serial.println("C  ");

    delay(5000);//Wait 5 seconds before accessing sensor again.

  //Fastest should be once every two seconds.

}// end loop()
```

TECHNICAL CHALLENGES FACED

1. The installation of CLARA proved to be a challenging task. The ideal position for the placement of the 8 motors had to be determined. The motors were initially placed at each corner of the supports, followed by placing them all next to the bottom support. None of these positions seemed to be ideal due to the increased frictional force.

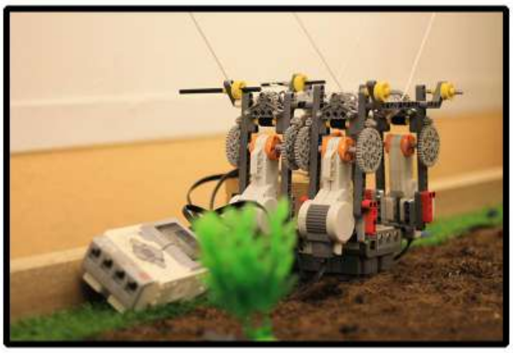


2. We needed to find out the maximum load capacity of CLARA. We were aware that NXT motors cannot support a lot of weight but we wanted to test whether the necessary parts could be lifted using the NXT motors.

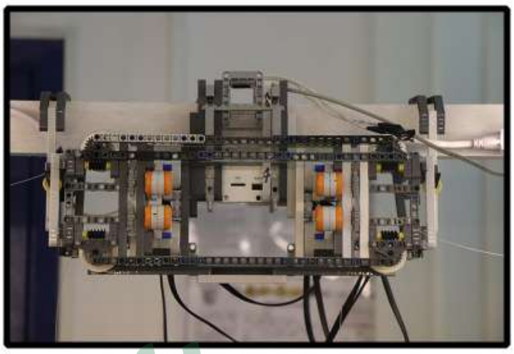
3. The accuracy of harvesting and replacing the plant-pots was a challenge since our initial design contained a mechanical claw. There were chances that a slippage could drop the pots.

OVERCOMING THE CHALLENGES

1. Rather than placing the 8 motors in 8 different locations, we decided to implement motor units in which, each unit consists of 4 motors. We had two design ideas for the motor units.



Design one

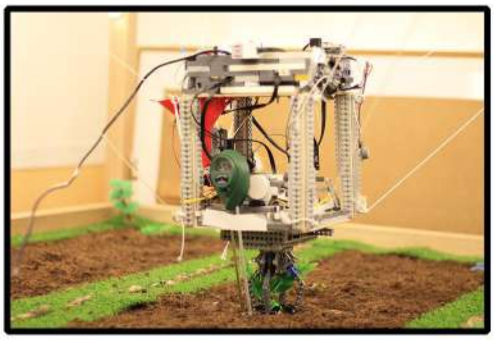


Design two

After extensive testing, we concluded that design two was better than design one for the following reasons:

a. The suspension cables could run through with less friction.
b. The unit could easily be mounted on the top beams.

Wood frame CLARA



Dimensions:
30 x 30 x 30 cm

2. The team originally built a wood frame model of CLARA and mounted all the required parts on it. At this stage, motor unit design 1 was used to lift the robot. We concluded that the robot could, in fact, support the required weight.

3. To fix the accuracy issue with the claw, we didn't try to modify the claw. Rather, we implemented a new mechanism involving magnets which ensured that the pots could be lifted and placed back with ease. This drastically reduced the error margin.

PROJECT TRANSFORMATION BLOSSOMING OF A NEW ERA

A variety of changes were made during the course of our Journey.

During the national's round, our team had presented a land-based agribot who we named Companion for his user-friendly features. Soon after the nationals, we felt the necessity to change our model to tackle even more problems while also solving those mentioned in the nationals round.

To tackle the issue of soil compaction alongside food security, we decided to shift to an aerial model. This transition proved to be extremely challenging due to the new model's complexity. To shift to an aerial robot meant completely dismantling our previous model.

Companion
Terrestrial Agribot

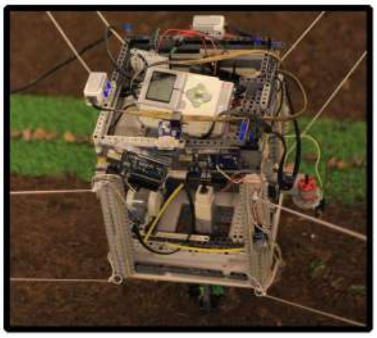
And thus, a beautiful 6-month journey began. Our team worked hard during the 6 months to ensure that CLARA is able to analyze and tackle the problems we wish to overcome.

HEADING 500 MILES AN HOUR TOWARDS THE FUTURE

PROJECT TRANSFORMATION BLOSSOMING OF A NEW ERA

Recent changes:

1. Wood frame removed and replaced with lego parts.



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2. Claw mechanism replaced with a magnetic mechanism for increased accuracy during harvesting.

3. Sowing and Harvesting processes involve the removal and addition of plant pots from and to the hydroponic system.

4. Removal of pH and soil moisture sensor due to the movement of the project towards a hydroponic system

Never stop wanting to create more. Never stop wanting to make better.

THE BOOTH DESIGN

Since CLARA is a suspended robot, we needed to test her on a premade booth. With the help of our school and coach, we were able to arrange a 1.9m^3 booth for building the robot. The booth can be disassembled and reassembled easily as the different sections are simply nailed in. Prior to receiving the booth, the team planned out multiple designs for CLARA from which we tried to choose the best. We set up the designs and held the motors manually at different locations (or even on salvaged wood stumps) to test out whether the concept works.

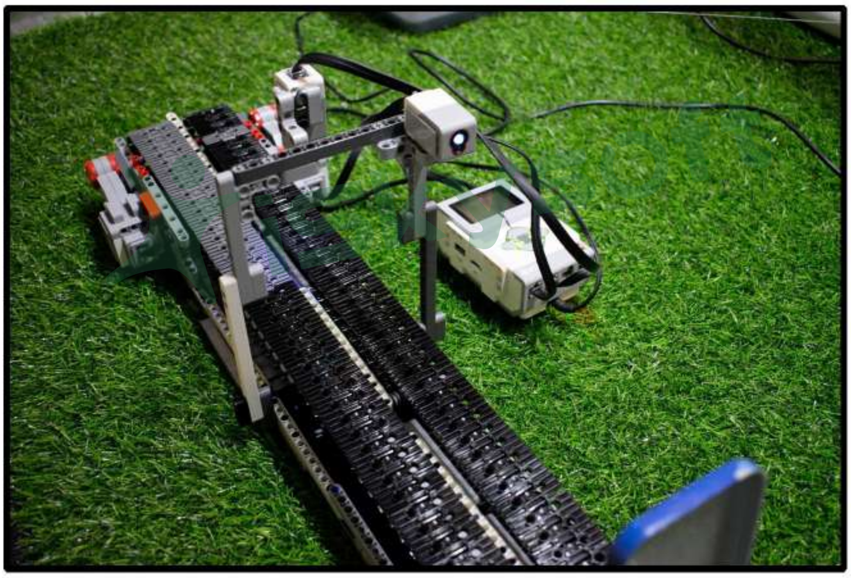
The booth was transported from the UAE to the venue. Being smaller in dimensions than the WRO booth, the prebuilt booth could simply be pushed into the WRO booth.

It was troublesome to plan out the transportation of the booth since we were doubtful about fitting the longer pieces on the flight. But ultimately, we were able to cut the bigger pieces down to transportable sizes.

Latches were installed on the wooden plank since we wouldnt be able to access the inner parts of the booth once pushed into the WRO booth. The aesthetic designs of the booth were arranged keeping in mind the limitation of accessing the booth once completely set up.

THE CONVEYOR BELT

The conveyor belt found in the farm carries the harvested crops that CLARA delivers to it. The plant pots harvested by CLARA are dropped into a box on the conveyor belt that carries it to the sorting area. Based on the pot color, the boxes are sorted and are sent to the drone for delivery purposes. Conveyor belts are useful since they can handle a wide range of bulk materials and require less horsepower to operate than other types of conveyors.



THE DRONE

The Drone is connected to the conveyor system. It is used for delivering the produce to different locations such as the market. The storage box of the drone is secured using RFID. This ensures that beyond processing, nothing is being tampered with. Delivery drones are much better than other alternatives for delivery because they are much faster and accurate in delivery than the average delivery man and require less energy.

CHALLENGES FACED BY THE TEAM

Project expenses: Since we were building CLARA from scratch, the project expenses were relatively high. Our team was unwilling to negotiate with second-hand parts or lower quality parts; we wanted to use the best of the best.

To cover the cost of planning, carpentry, travel etc. we would require sponsors who are interested in the team. Our team put together a sponsorship letter and a sponsorship proposal to approach different companies. Most companies requested us to present to them our idea and objectives.

Transformation of Companion to CLARA: Since we wanted to move away from the idea of a terrestrial agribot, we spent a lot of time formulating other ideas and testing out several models. Ultimately, this led to a very tight schedule. Since we did not wish to violate the deadlines for submitting the video and report, we tried our hardest to finish off the work as soon as possible.

Accuracy of coordinate system: Given the limitations of the lego motors, it is quite hard to guarantee 100% accuracy in the coordinate system after mutiple uses. To overcome this issue, we replaced a few mechanisms with new ones to decrease the margin of error. For example, the claw (which can be considered a precision-based mechanism) was replaced with a magnetic mechanism.

*"The problem is not the problem.
The problem is how we face the problem"*

EMERGENCE

BE INSATIABLE — INNOVATE

EVOLUTION OF THE TEAM

EMERGENCE

BE INSATIABLE — INNOVATE

Team Emergence always remained determined to complete their work and showcase to the world their creation. Through a course of a few months, the bond in our team has grown stronger every day. The NRO taught us that zenith can only be attained through pure hard work.

This journey converted us from kids to adults. We learned how to be responsible. We learned how to be financially efficient. We applied what we learned in school to our project.

Emergence - a phenomenon where the value of the products is greater than the value of the sum of the individual parts. In layman's terms, 2+2 = 5.

We are Emergence
We are insatiable