Internship Report

CONTROLS AND EMBEDDED SYSTEMS

BY

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CONTENTS

CONTROLS AND SIMULATIONS

CONTROLS

We, at the intern, had a test bot which had 2 Hercules motor drivers and an Arduino Due and the mobility of the bot had to be controlled properly so that further testing could be done on it. The bot has 2 flipper motor and 2 motors for its motion. The motors need to be controlled accurately so that its motion would be fine and the flipper motors would be able to lift the bot at a particular position. I used PID control and Arduino software to achieve the above.

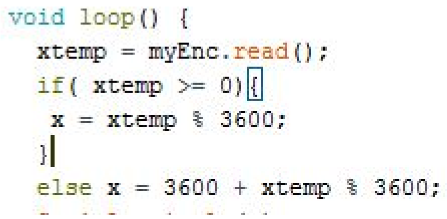
Flipper Control

The flipper has to go to a particular position and resist change to its final position by an application of force. In order to go the particular position i used the encoder feedback of the flipper motors and Proportional and derivative control.

1. First i needed to get encoder feedback data and for that i used "*Encoder.h*" library which is easily available online. The motors had quadrature encoder and gave 3600 counts on full rotation of the shaft of the motor.

2. Initially i used simple speed proportional and derivative control to go to a particular position smoothly and hold that position.

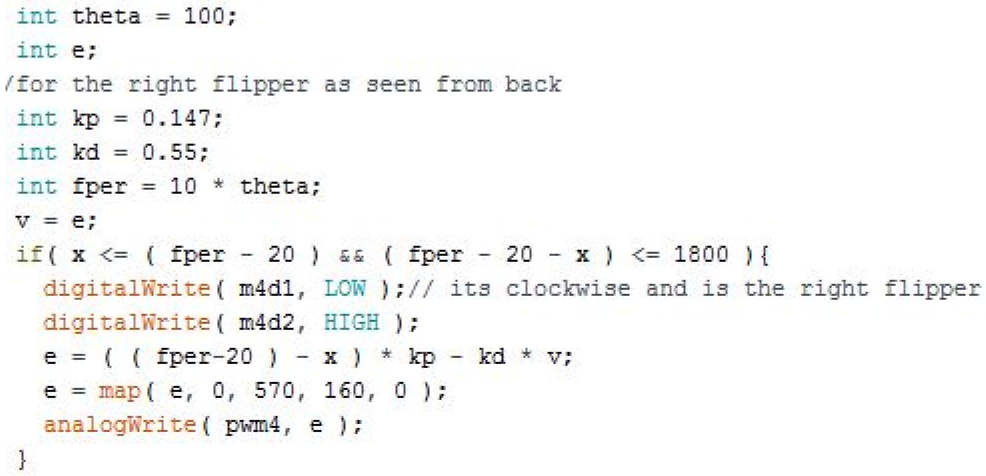
Code for getting encoder data:-



```
void loop() {
  xtemp = myEnc.read();
  if( xtemp >= 0){
   x = xtemp % 3600;
  }
  else x = 3600 + xtemp % 3600;
```

Here x is the encoder value.

Code of control loop with P & D

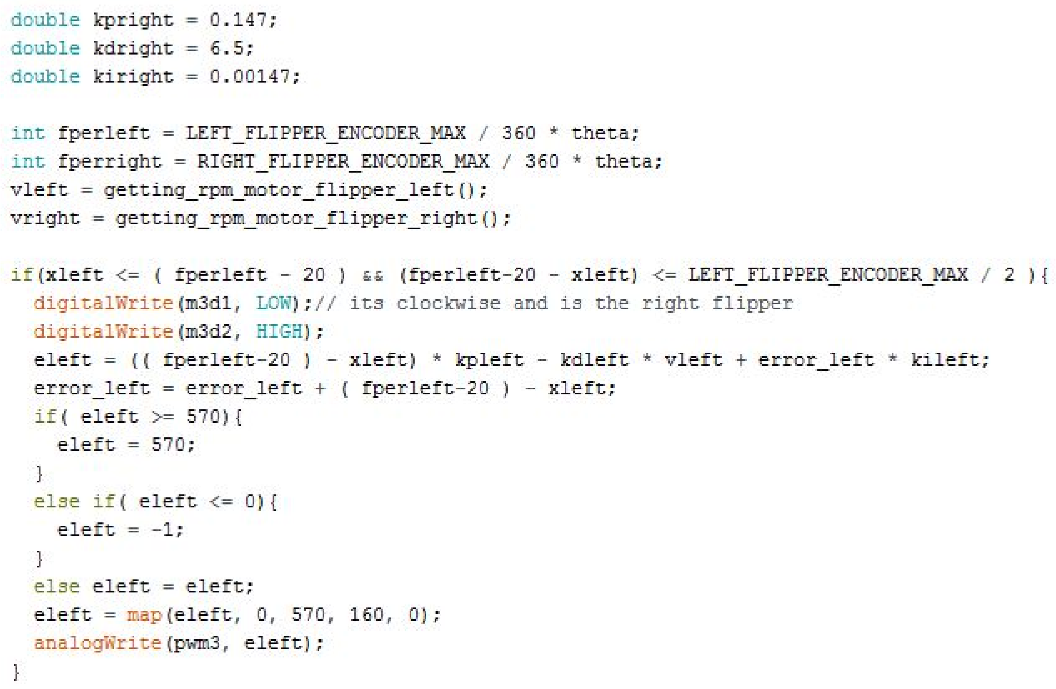


```
 int theta = 100;
 int e;
/for the right flipper as seen from back
 int kp = 0.147;
 int kd = 0.55;
 int fper = 10 * theta;
 v = e;
 if( x <= ( fper - 20 ) && ( fper - 20 - x ) <= 1800 ){
   digitalWrite( m4d1, LOW );// its clockwise and is the right flipper
   digitalWrite( m4d2, HIGH );
   e = ( ( fper-20 ) - x ) * kp - kd * v;
   e = map( e, 0, 570, 160, 0 );
   analogWrite( pwm4, e );
 }
```

theta is the final position the flipper has to go, *fper* is the corresponding encoder value the flipper has to go to, *kp & kd* are constants and *e* is the pwm value given to the microcontroller Arduino Due.

The above code had one problem *i.e* the flippers were not able to lift the bot if instructed to do so. The flippers were trying to go that particular position but were not able to because they needed more force or more velocity at the point of lifting. So in order to achieve that i used Integrator control loop also.

Code with P, I & D



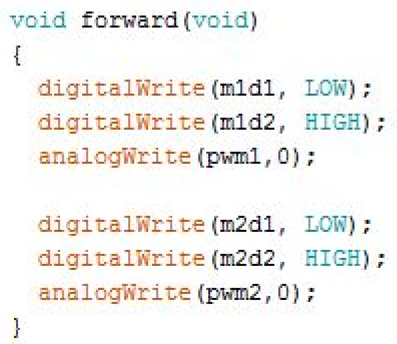
```
double kpright = 0.147;
double kdright = 6.5;
double kiright = 0.00147;

int fperleft = LEFT_FLIPPER_ENCODER_MAX / 360 * theta;
int fperright = RIGHT_FLIPPER_ENCODER_MAX / 360 * theta;
vleft = getting_rpm_motor_flipper_left();
vright = getting_rpm_motor_flipper_right();

if(xleft <= ( fperleft - 20 ) && (fperleft-20 - xleft) <= LEFT_FLIPPER_ENCODER_MAX / 2 ){
  digitalWrite(m3d1, LOW);// its clockwise and is the right flipper
  digitalWrite(m3d2, HIGH);
  eleft = (( fperleft-20 ) - xleft) * kpleft - kdleft * vleft + error_left * kileft;
  error_left = error_left + ( fperleft-20 ) - xleft;
  if( eleft >= 570){
    eleft = 570;
  }
  else if( eleft <= 0){
    eleft = -1;
  }
  else eleft = eleft;
  eleft = map(eleft, 0, 570, 160, 0);
  analogWrite(pwm3, eleft);
}
```

Here *kpright, kdright and kiright* are P, D and I constants. *Vleft* is the current rpm of the left flipper. With the above modification the flippers were able to lift the bot and hold the bot in that position in presence of an external force.

Motion Control

I wrote Forward, backward, right and left functions and used differential control for turning of the bot.

Code for forward

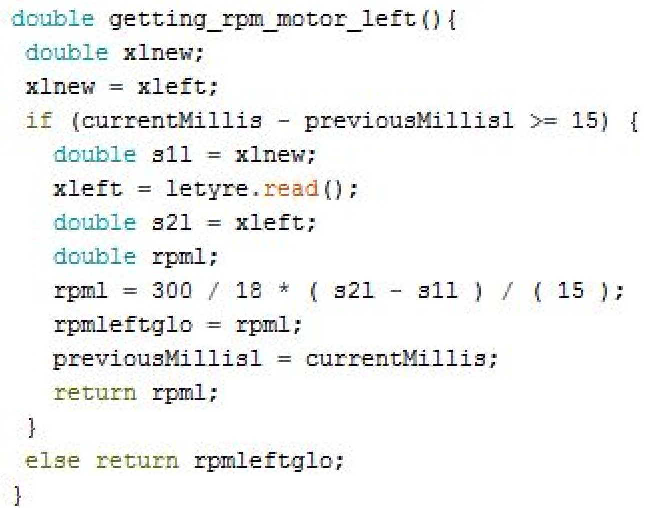


```
void forward(void)
{
  digitalWrite(m1d1, LOW);
  digitalWrite(m1d2, HIGH);
  analogWrite(pwm1,0);

  digitalWrite(m2d1, LOW);
  digitalWrite(m2d2, HIGH);
  analogWrite(pwm2,0);
}
```

The codes for backward, right and left are similar.

In order to acheive nice motion control of the bot the at present rpmm of the motors had to measured. I wrote the following code with the help of Sohrab Mistri

Code for getting the rpm of the motor

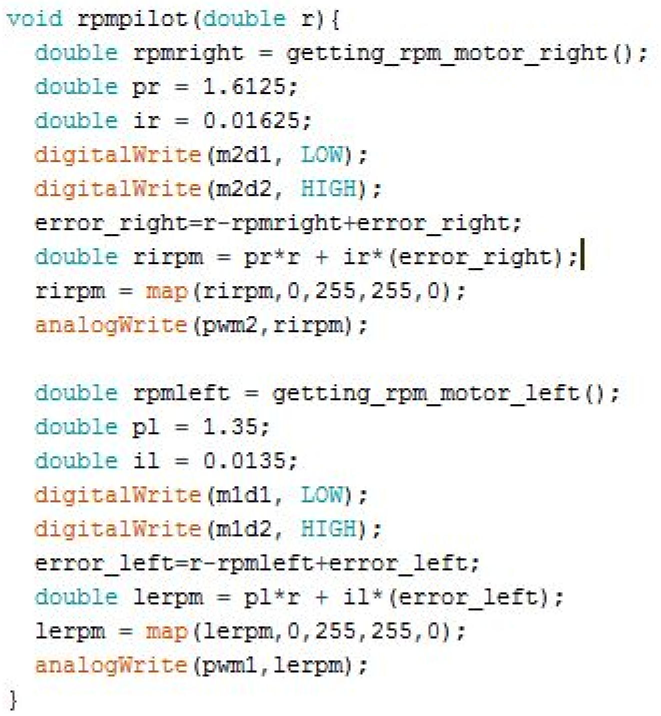


```
double getting_rpm_motor_left(){
 double xlnew;
 xlnew = xleft;
 if (currentMillis - previousMillisl >= 15) {
   double s1l = xlnew;
   xleft = letyre.read();
   double s2l = xleft;
   double rpml;
   rpml = 300 / 18 * ( s2l - s1l ) / ( 15 );
   rpmleftglo = rpml;
   previousMillisl = currentMillis;
   return rpml;
 }
 else return rpmleftglo;
}
```

Here *xleft* is the previous encoder data and after an interval of 15 ms another reading of the encoder is taken, from these two values the rpm of the motor is calculated.

Now suppose the pilot gives a command to the bot to go at a particular speed, the motors have to go to a particular rpm. The motors have to move at the same rpm so that the forward and the backward motion of the bot would be fine. So in order to match the rpm of the two motors i wrote a code with the help of Sohrab Mistri

Code for rpm matching



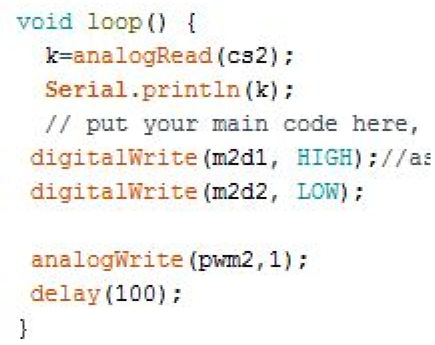
```
void rpmpilot(double r){
  double rpmright = getting_rpm_motor_right();
  double pr = 1.6125;
  double ir = 0.01625;
  digitalWrite(m2d1, LOW);
  digitalWrite(m2d2, HIGH);
  error_right=r-rpmright+error_right;
  double rirpm = pr*r + ir*(error_right);
  rirpm = map(rirpm,0,255,255,0);
  analogWrite(pwm2,rirpm);

  double rpmleft = getting_rpm_motor_left();
  double pl = 1.35;
  double il = 0.0135;
  digitalWrite(m1d1, LOW);
  digitalWrite(m1d2, HIGH);
  error_left=r-rpmleft+error_left;
  double lerpm = pl*r + il*(error_left);
  lerpm = map(lerpm,0,255,255,0);
  analogWrite(pwm1,lerpm);
}
```

Here *r* is the pilot input for rpm of the motors. For the motors to go to the partiicular rpm i used P & I control. This *rpmpilot* function uses the *getting_rpm_motor* function which is used to calculate the error and correspondingly adjust the pwm value of the motor. Using this function i was able to make the motors rotate at a particular rpm even if they were rotating at different rpm’s than the given command.

Getting The Current Data

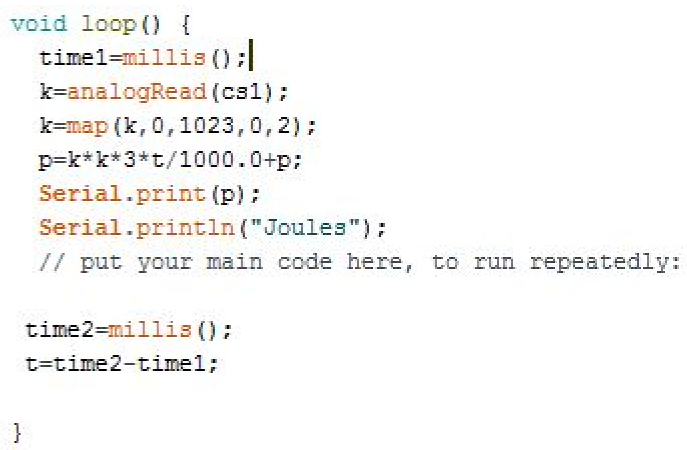
Getting the current data is important for power management and the current value could be used as a feedback instead of encoder data in some cases.The hercules motor drivers had a pin for measuring the currrent in the motors which we can get by the microntroller.

Code for getting the current data



```
void loop() {
  k=analogRead(cs2);
  Serial.println(k);
  // put your main code here,
 digitalWrite(m2d1, HIGH);//as
 digitalWrite(m2d2, LOW);

 analogWrite(pwm2,1);
 delay(100);
}
```

Code for power consumed by the motors

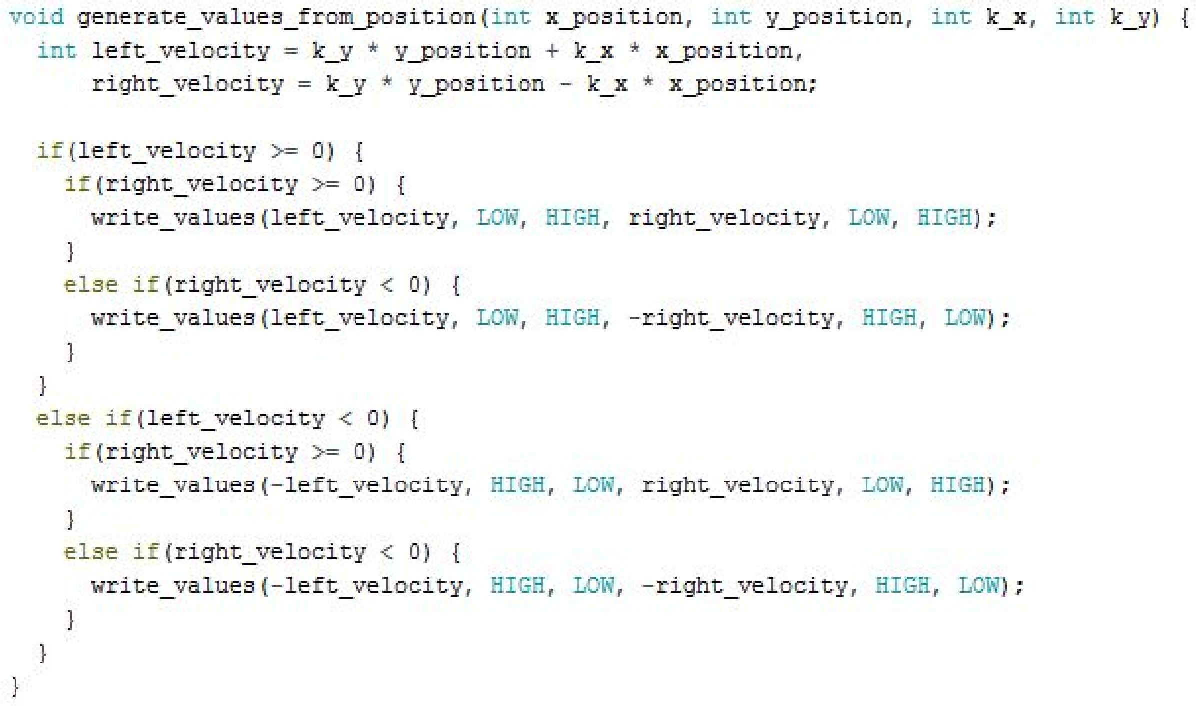


```
void loop() {
  time1=millis();
  k=analogRead(cs1);
  k=map(k,0,1023,0,2);
  p=k*k*3*t/1000.0+p;
  Serial.print(p);
  Serial.println("Joules");
  // put your main code here, to run repeatedly:

 time2=millis();
 t=time2-time1;

}
```

I used (I^2 * R)*(t2-t1) to calculate the energy consumed and summed up the individual energies to calculate the overall energy consumption

Full function for bot control

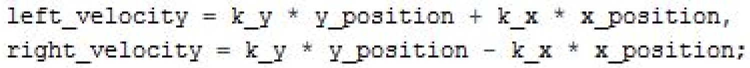
For the user friendly control of the bot, a joystick type control has to be given. For this purpose , I , with help of Sohrab Mistri and Jagadeesh Netaluru wrote a function



```
void generate_values_from_position(int x_position, int y_position, int k_x, int k_y) {
  int left_velocity = k_y * y_position + k_x * x_position,
      right_velocity = k_y * y_position - k_x * x_position;

  if(left_velocity >= 0) {
    if(right_velocity >= 0) {
      write_values(left_velocity, LOW, HIGH, right_velocity, LOW, HIGH);
    }
    else if(right_velocity < 0) {
      write_values(left_velocity, LOW, HIGH, -right_velocity, HIGH, LOW);
    }
  }
  else if(left_velocity < 0) {
    if(right_velocity >= 0) {
      write_values(-left_velocity, HIGH, LOW, right_velocity, LOW, HIGH);
    }
    else if(right_velocity < 0) {
      write_values(-left_velocity, HIGH, LOW, -right_velocity, HIGH, LOW);
    }
  }
}
```

This function accepts values from -255 to 255 for both *x_position* and *y_position* and then sets the motor pwm value. Using this function the control of the bot becomes easy and very intuitive.

For this function a linear map of *x_position* and *y_position was used.*



```
left_velocity = k_y * y_position + k_x * x_position,
right_velocity = k_y * y_position - k_x * x_position;
```

Simulations

I did the following the three simulations

1. Camera positioning|*Done in Matlab*
2. Supercapacitor Circuit Simulation|*Done in Open Modelica*
3. DSMD motion simulation| *Done in Matlab*

Camera Positioning

For a getting particular field of view, the camera has to be placed at a particular position on the bot. In order to decide an optimum position of the camera on the bot me along with Swadhinn Thakkar simulated the effect of the position of the camera on the field of view of the camera in Matlab

The following were the constraints:-

1.The height at which the camera has to be placed should be less due to possible damage to the camera by obstacles

2.The distance of the base of the camera from the front of the bot should be large as possible

3.The field of view should be large as possible

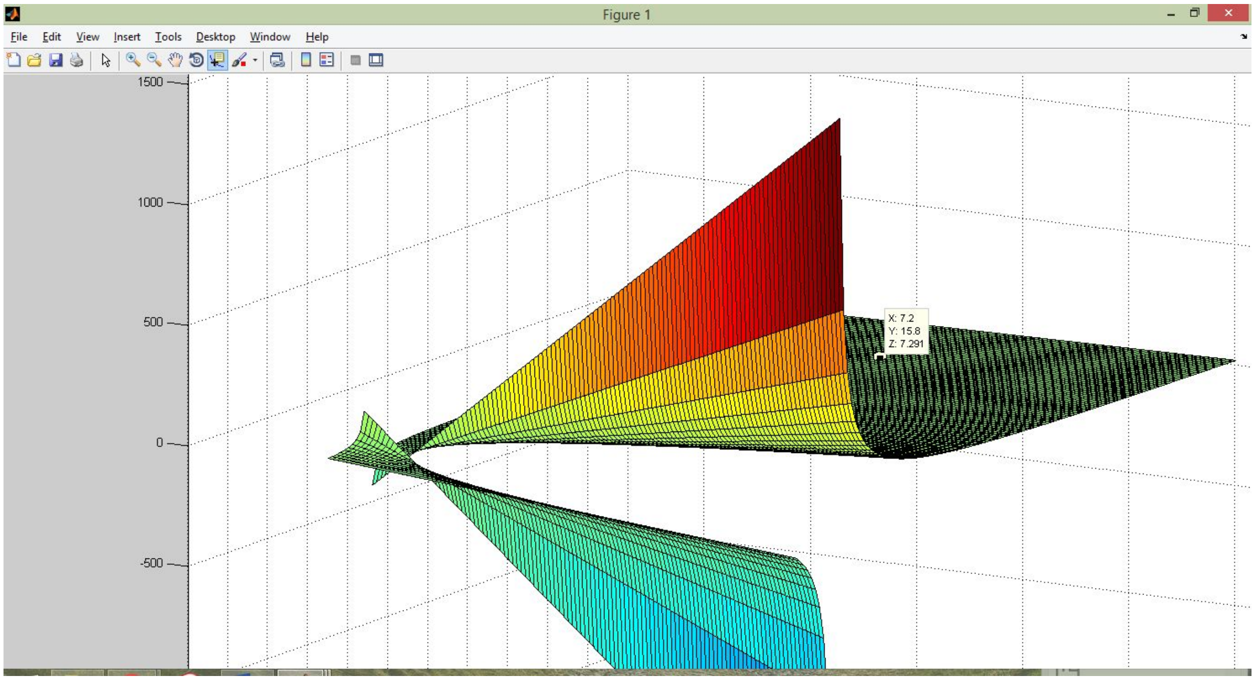
So a function was made consisting of three parameters:-

1.Height at which the camera is placed(**X**)

2.Distance from the front of the bot(**Z**)

3.Minimum distance from the front of the bot of which the camera can get the image(**Y**)

The following result was found appropriate by plotting the function in Matlab and finding out the corresponding values of the above parameters by hit and trial



X=7.2cm

Y=15.8cm

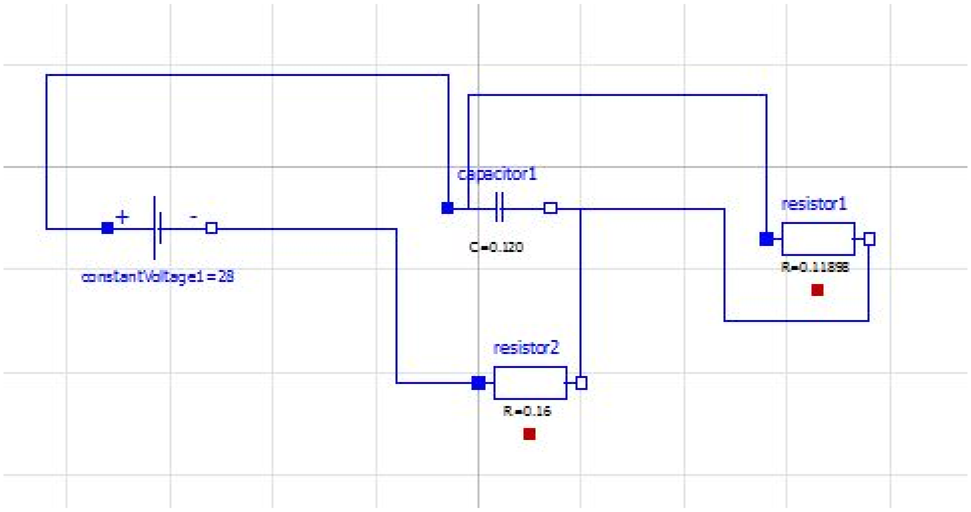
Z=7.291cm

These values were found to be good if we go by the simulation

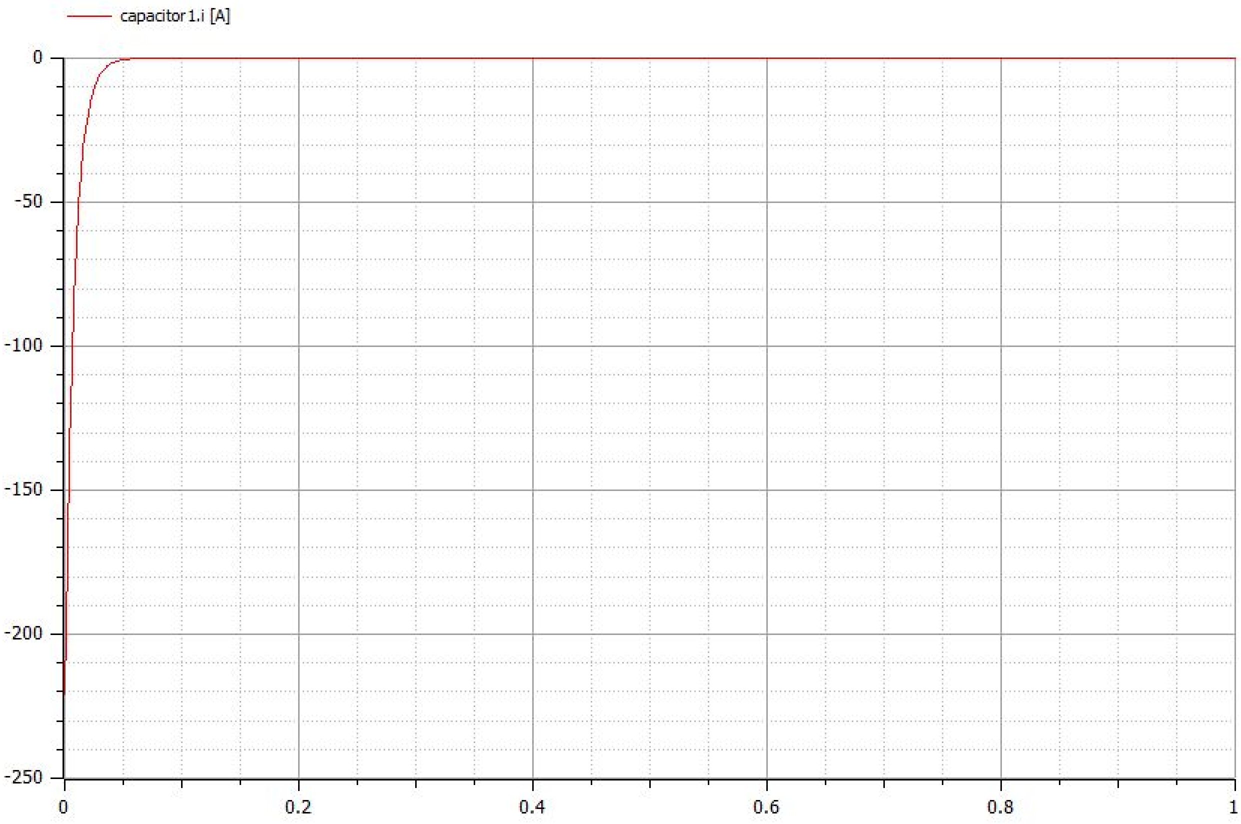
Supercapacitor Circuit Simulation

I did the simulation for the supercapacitor circuit in Open Modelica

The following is the circuit :-



The result that i obtained after simulating the above circuit is:-



This is the current v/s time graph.

This circuit gives pretty high current during starting which is required

DSMD Motion Simulation

The DSMD motion needs to simulated so that the velocity at which the bot, the rate of rotation of the DSMD would be optimized for our requirement. We should be able to cover a patch of area completely and for that the DSMD motion simulation is very important.

I did the simulation in Matlab

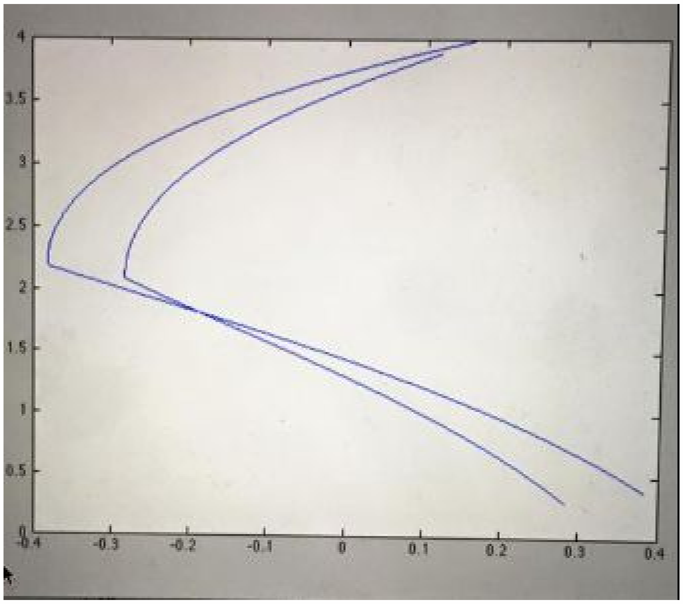
The following is the matlab code:-

```
t=zeros(2000,1);

w=10*pi/180;
vno=0.2;
theno=45/180*pi;
tno=pi/w-2*theno/w;
r=.4;
for i = 2:2000
  t(i) = t(i-1) + tno/1000;
end

v1ry = r*w*cos(w*t+theno)+vno;
v1rx = -r*w*sin(w*t+theno);
v2ry = -r*w*cos(2*pi-3*theno-w*t)+vno;
v2rx = r*w*sin(2*pi-3*theno-w*t+theno);
x = zeros(2000,1);
y = zeros(2000,1);
x(1)=r*cos(theno);
y(1)=r*sin(theno);


for i=2:2000
  if t(i)<= tno
    x(i) = x(i-1) + v1rx(i-1)*tno/1000;
    y(i) = y(i-1) + v1ry(i-1)*tno/1000;
  else
    x(i) = x(i-1) + v2rx(i-1)*tno/1000;
```

```
        y(i) = y(i-1) + v2ry(i-1)*tno/1000;
    end
end

plot(x,y)
hold on

t1=zeros(2000,1);

w1=10*pi/180;

r1=.54;
for i = 2:2000
    t1(i) = t1(i-1) + tno/1000;
end

v1ry1 = r1*w1*cos(w1*t1+theno)+vno;
v1rx1 = -r1*w1*sin(w1*t1+theno);
v2ry1 = -r1*w1*cos(2*pi-3*theno-w1*t1)+vno;
v2rx1 = r1*w1*sin(2*pi-3*theno-w1*t1+theno);
x1 = zeros(2000,1);
y1 = zeros(2000,1);
x1(1)=r1*cos(theno);
y1(1)=r1*sin(theno);


for i=2:2000
    if t1(i)<= tno
        x1(i) = x1(i-1) + v1rx1(i-1)*tno/1000;
        y1(i) = y1(i-1) + v1ry1(i-1)*tno/1000;
    else
        x1(i) = x1(i-1) + v2rx1(i-1)*tno/1000;
        y1(i) = y1(i-1) + v2ry1(i-1)*tno/1000;
    end
end

plot(x1, y1);
```

Vno is the bot’s forward velocity(m/s) and w & w1(radians/sec) are the rates of rotation of the DSMD

The following is the motion of the DSMD



The area between the two lines is the area that the DSMD sweeps

EMBEDDED SYSTEMS AND COMMUNICATION

Communication

For deciding the communication modules one need to know the requirements. The following are the requirements for our system:-

1.Communication should be possible in a circle of radius 200m.

2.The environment is very interfering, forest region.

3.The modules should be IP67(Should sustain a lot of wear and tear)

4.It should work for atleast 4 hours

One can deduce the following from the above requirements:-

1.From point no 1 it is clear that we will need omnidirectional antenna, if any

2.We should have a portable battery which can supply power upto 4 hours at the required rating

3.The obvious one , that the modules should be waterproof and strong

For the product we chose a router of 2.4GHz , antenna , mini PCI Wifi card and we might be using signal booster

There is this point that the environment is very interfering, this needs to be understood more clearly

First, we need an omnidirectional antenna and should be strong enough to transmit signal through forest. This brings more questions, how much should be the power received at the receiving end for proper communication, what should be the gain of the antenna and what is the minimum power receiving sensitivity of the receiver.

We need to know the above and the Friis Transmission Equation can help to some extent.

Friis Transmission Equation

Given two antennas, the ratio of power available at the input of the receiving antenna, P_{r}, to output power to the transmitting antenna, P_{t}, is given by

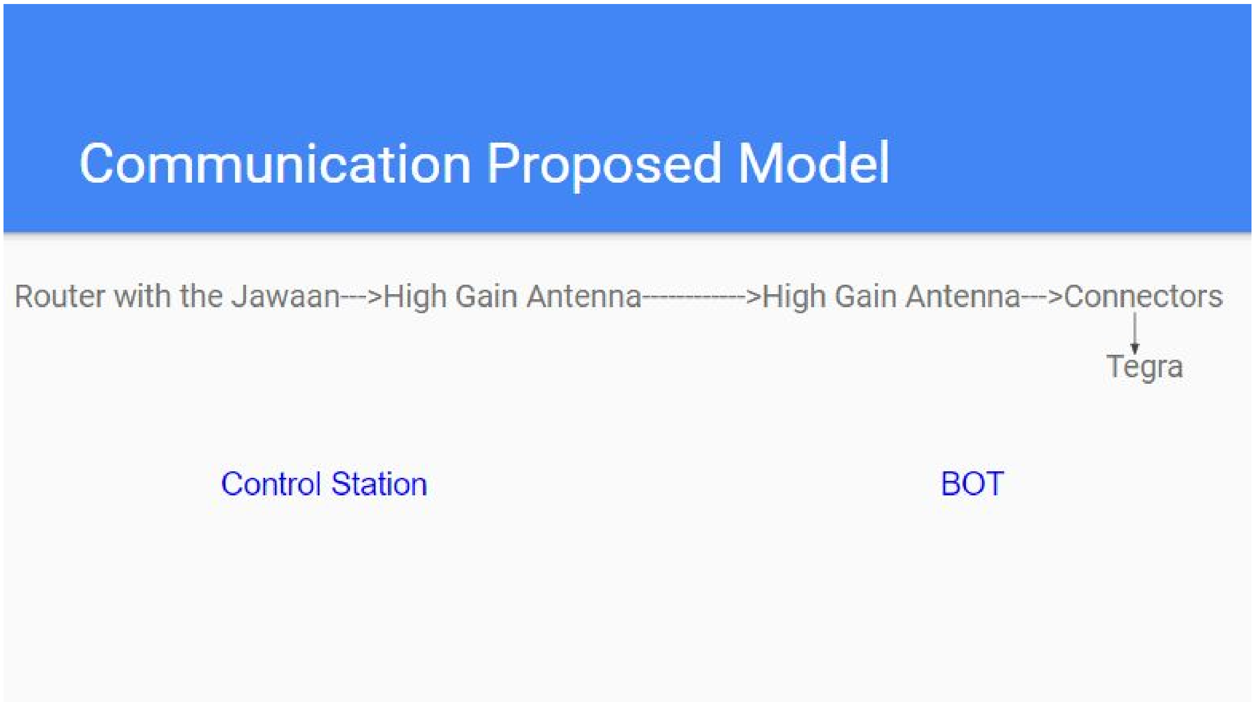
$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2$$

where G_{t} and G_{r} are the antenna gains (with respect to an isotropic radiator) of the transmitting and receiving antennas respectively, lambda is the wavelength, and R is the distance between the antennas. The inverse of the third factor is the so-called free-space path loss.

We are using omnidirectional antennas so their gains are zero and the minimum receiver senstivity of the mini PCI card is around -72dbm.

Using the Friis equation, we found out that we need at least 2W power transmission at the receiver and the transmitting end.

Friis transmission equation can’t tell us anymore. Now we have to find the modules and test them.



Communication Proposed Model

Router with the Jawaan--->High Gain Antenna------------>High Gain Antenna--->Connectors

Tegra

Control Station

BOT

Me and Swadhin searched a lot and found the following suitable routers/hotspot

1.ePMP 1000 Enterprise Hotspot by Cambium Networks(Range 200m)

2.cnPilot E500 by Cambium Networks(Range 280m)

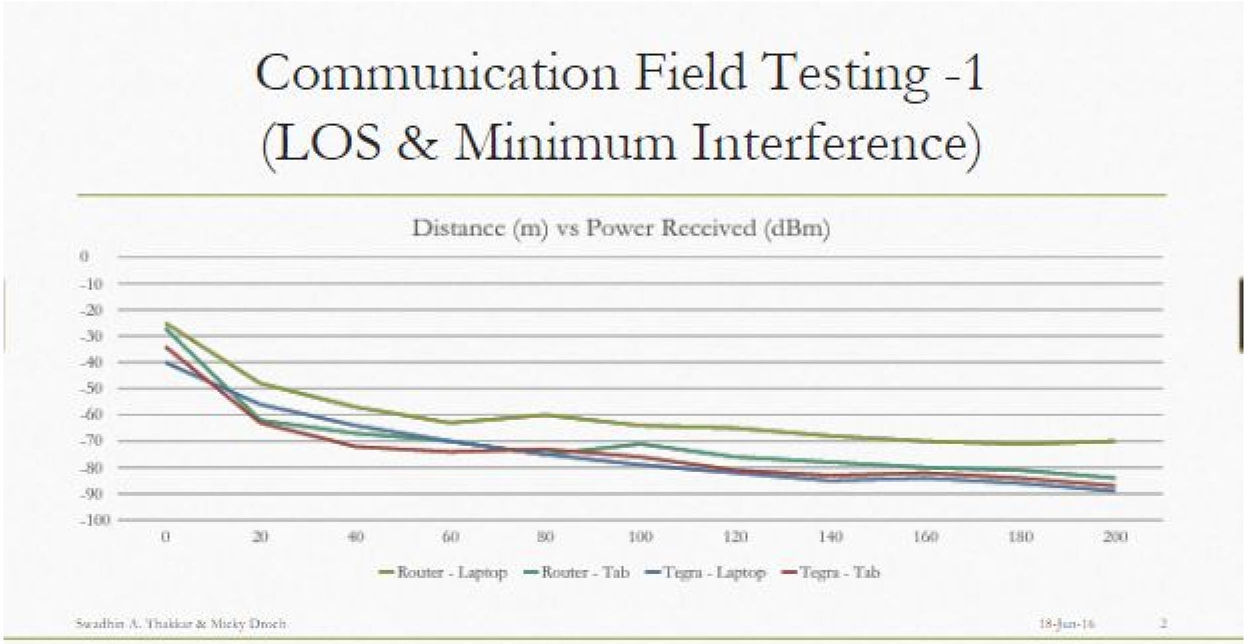
I searched a lot for antennas and found the following antenna suitable:-

8dBi Fiberglass Antenna(black)

*Connector: RP-SMA-K(internal threads and hole) *Support Standards: IEEE802.11b/g/n *Frequency Range: 2.4GHz-2.4835GHz *Craft:anti-scrape, wear-resisting, top grade UV spray paint craft

For gaining more experience, for testing our present communication system and for knowing the effect of forest interference, me and Swadhin tested the modules and found the following results:-

We fixed the mini PCI card at one end and moved the router and the laptop away from it LOS and no interference environment and NON-LOS and moderate(FOREST) interference environment.



Communication Field Testing -1
(LOS & Minimum Interference)

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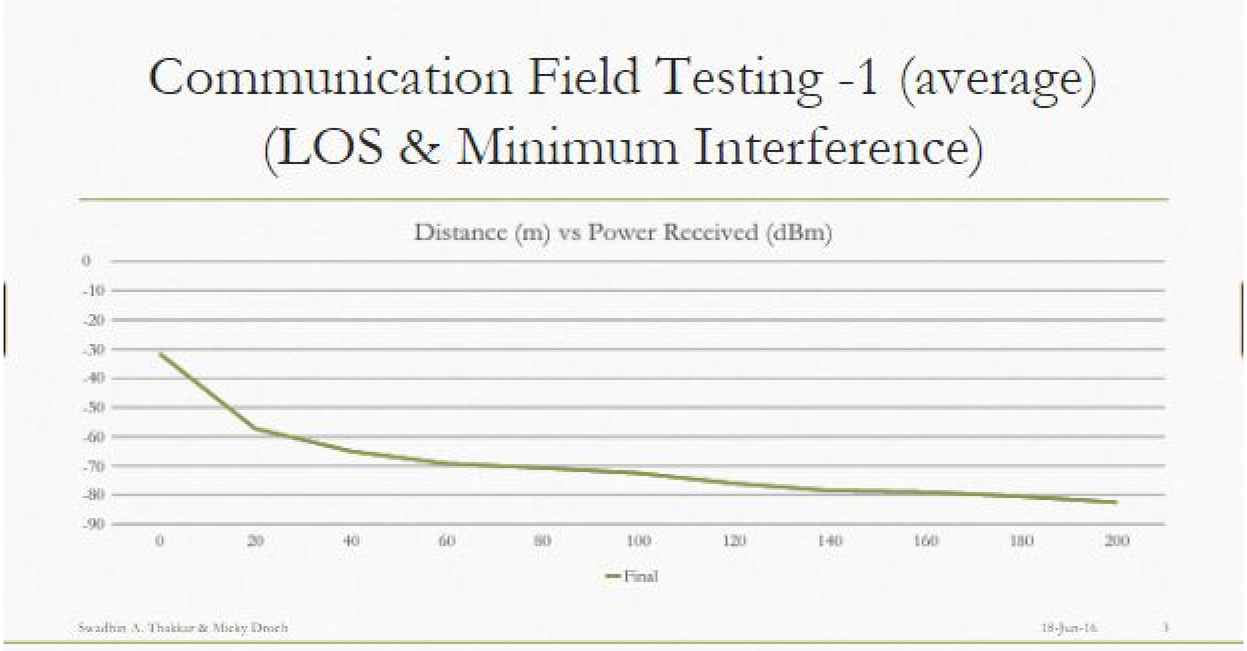
18-Jun-16

2



Communication Field Testing -1 (average) (LOS & Minimum Interference)

Distance (m) vs Power Received (dBm)

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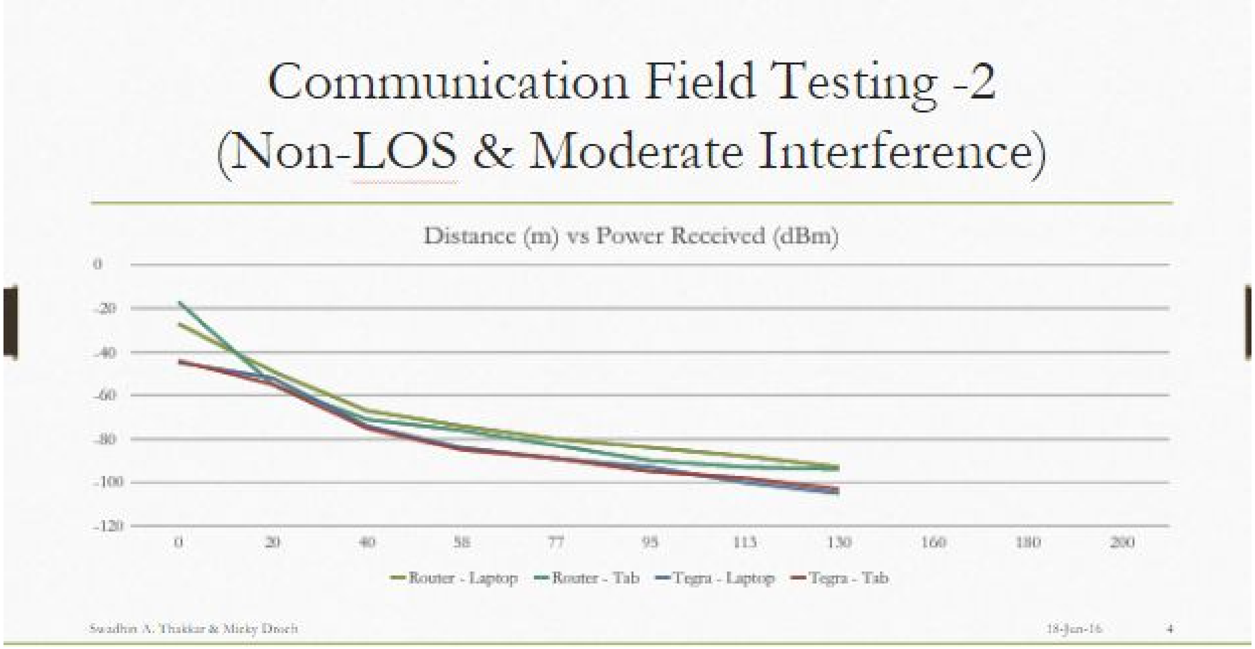

Communication Field Testing -2 (Non-LOS & Moderate Interference)

Distance (m) vs Power Received (dBm)

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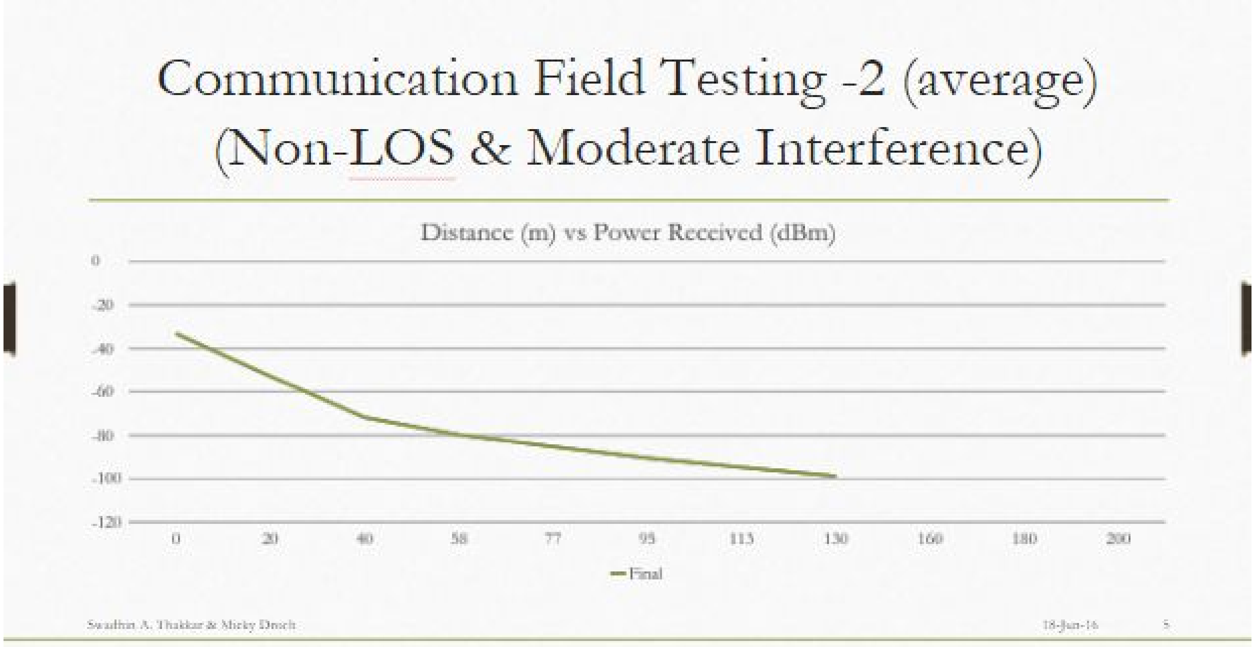

Communication Field Testing -2 (average) (Non-LOS & Moderate Interference)

Distance (m) vs Power Received (dBm)

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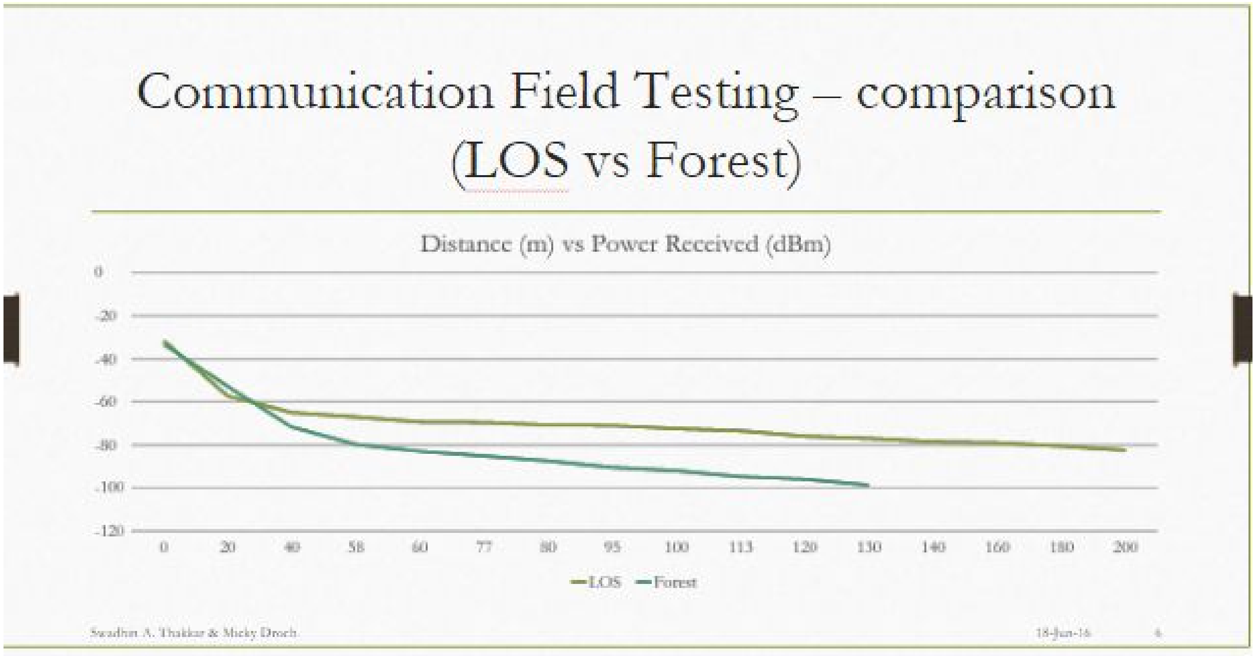

Communication Field Testing – comparison (LOS vs Forest)

Distance (m) vs Power Received (dBm)

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From the last plot we can see the effect of forest, the power received decreases very rapidly.

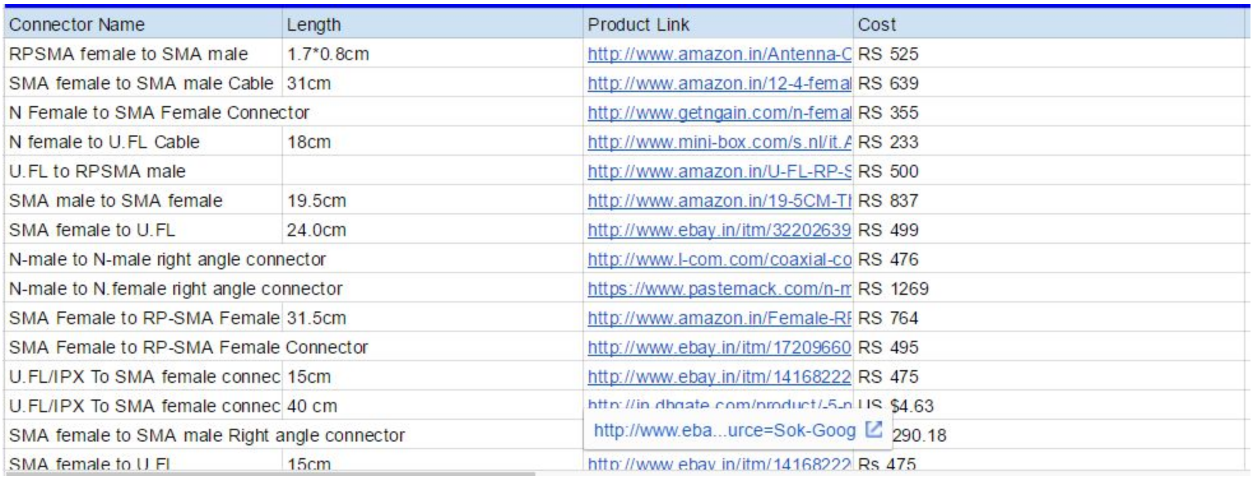
By doing the above test we found out that we need power reception greater than - 65dbm for proper video reception.

On the bot side we need a power transmission greater 2w but mini PCI card can’t supply that so we might use 4w signal booster at the bot side.

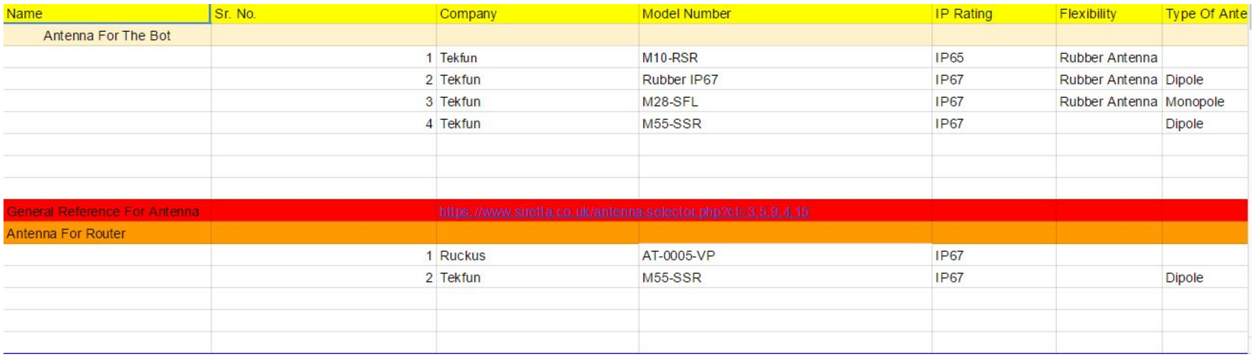
On the router side we need a power source and we found a battery:-

Veracity's Pointsource PoE battery. It can supply the required power for 6 hours.

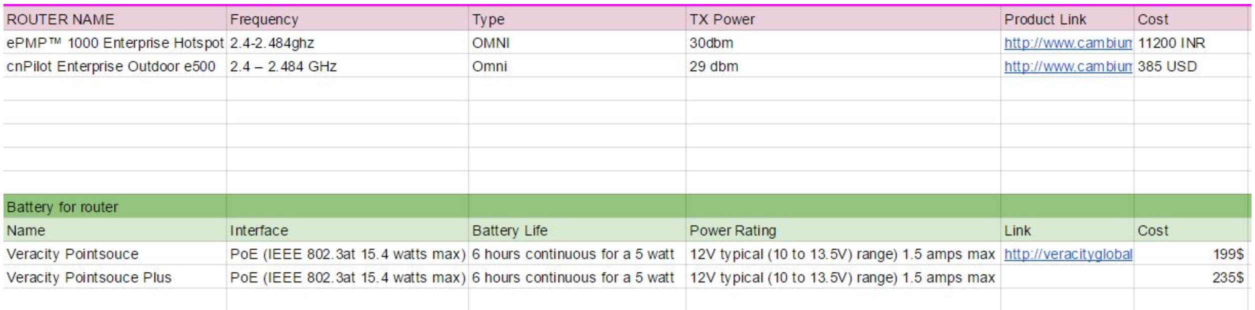
For the connectors, router, antenna , signal booster, battery on the rover and jawaan side i along with Swathin searched a lot and found the following:-



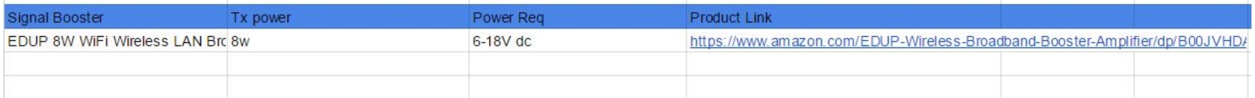
Connector Name	Length	Product Link	Cost
RPSMA female to SMA male	1.7*0.8cm	http://www.amazon.in/Antenna-C	RS 525
SMA female to SMA male Cable	31cm	http://www.amazon.in/12-4-femal	RS 639
N Female to SMA Female Connector		http://www.getngain.com/n-femal	RS 355
N female to U.FL Cable	18cm	http://www.mini-box.com/s.nl/it.A	RS 233
U.FL to RPSMA male		http://www.amazon.in/U-FL-RP-S	RS 500
SMA male to SMA female	19.5cm	http://www.amazon.in/19-5CM-TI	RS 837
SMA female to U.FL	24.0cm	http://www.ebay.in/itm/32202639	RS 499
N-male to N-male right angle connector		http://www.l-com.com/coaxial-co	RS 476
N-male to N.female right angle connector		https://www.pastemack.com/n-m	RS 1269
SMA Female to RP-SMA Female	31.5cm	http://www.amazon.in/Female-RI	RS 764
SMA Female to RP-SMA Female Connector		http://www.ebay.in/itm/17209660	RS 495
U.FL/IPX To SMA female connec	15cm	http://www.ebay.in/itm/14168222	RS 475
U.FL/IPX To SMA female connec	40 cm	http://in.dhgate.com/product/-5-n	US $4.63
SMA female to SMA male Right angle connector		http://www.eba...urce=Sok-Goog	290.18
SMA female to U.FL	15cm	http://www.ebay.in/itm/14168222	Rs 475



Name	Sr. No.	Company	Model Number	IP Rating	Flexibility	Type Of Ante
Antenna For The Bot						
	1	Tekfun	M10-RSR	IP65	Rubber Antenna	
	2	Tekfun	Rubber IP67	IP67	Rubber Antenna	Dipole
	3	Tekfun	M28-SFL	IP67	Rubber Antenna	Monopole
	4	Tekfun	M55-SSR	IP67		Dipole
General Reference For Antenna		https://www.siretta.co.uk/antenna-selector.php?ct=3,5,9,4,15				
Antenna For Router						
	1	Ruckus	AT-0005-VP	IP67		
	2	Tekfun	M55-SSR	IP67		Dipole



ROUTER NAME	Frequency	Type	TX Power	Product Link	Cost
ePMP™ 1000 Enterprise Hotspot	2.4-2.484ghz	OMNI	30dbm	http://www.cambiun	11200 INR
cnPilot Enterprise Outdoor e500	2.4 – 2.484 GHz	Omni	29 dbm	http://www.cambiun	385 USD
Battery for router					
Name	Interface	Battery Life	Power Rating	Link	Cost
Veracity Pointsouce	PoE (IEEE 802.3at 15.4 watts max)	6 hours continuous for a 5 watt	12V typical (10 to 13.5V) range) 1.5 amps max	http://veracityglobal	199$
Veracity Pointsouce Plus	PoE (IEEE 802.3at 15.4 watts max)	6 hours continuous for a 5 watt	12V typical (10 to 13.5V) range) 1.5 amps max		235$



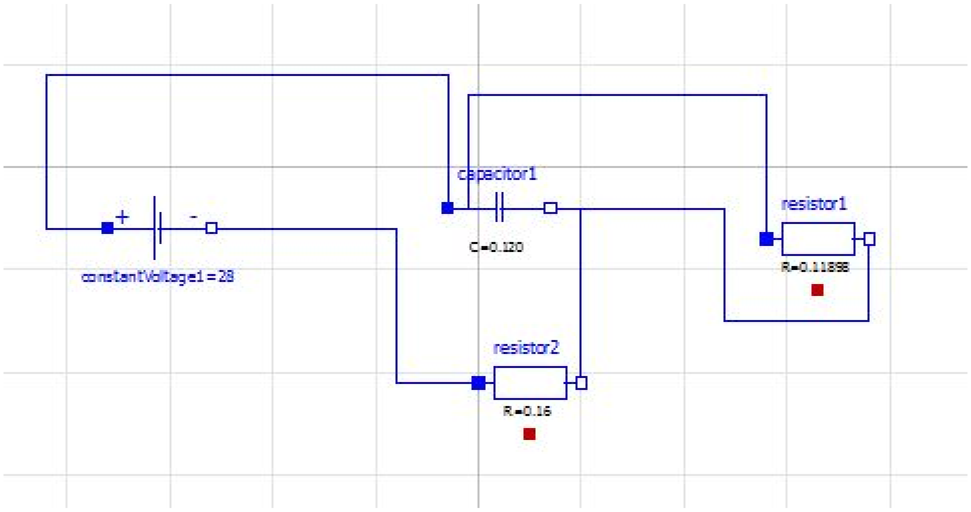
Signal Booster	Tx power	Power Req	Product Link
EDUP 8W WiFi Wireless LAN Brc	8w	6-18V dc	https://www.amazon.com/EDUP-Wireless-Broadband-Booster-Amplifier/dp/B00JVHD/

Supercapacitor

During starting the motors required a lot of current and initially we thought that we might be needing around 100 amps of transitory current .But our battery pack can’t provide 52 amps of current , so a need was felt to have supercapacitor circuit.

Supercapacitors can provide very high current for some amount of time.

So me and Prashant Dharawath thought of the following circuit without the microcontroller and switches.



Later on we found out that we will need a circuit containing microcontroller, buck -boost circuits and this circuit won’t work.   We redid our calculations for current requirement during the starting of the bot and found out that we need around 50 amps and that our battery can provide.So we left the idea of having a supercapacitor in our system

PCB Designing ,ESD Protection ICs And Circuit For Test Bot

I tried to make the USB 3.0 multiplexer circuit in the Eagle software .During this process many IC's eagle libraries were not available, so i made the eagle libraries of those IC's with the help of Prashant Dharawath.

For ESD protection of the circuit i found the following IC's suitable:-

1.USB 3.0-TPD2EUSB30

2.ETHERNET- TPS23753A

3.ESD Protection for High-Speed Video and Data Interface-TPD4S009, TPD4S010, TPD8S009

4.HDMI-TPD12S520

5.VGA- TPD7S019

6.USB 2.0-TPD4S014

Circuit For Test Bot

I ,along with Prashant, made the following circuit for the test bot which consists of Arduino Due , Hercules Motor drivers and battery

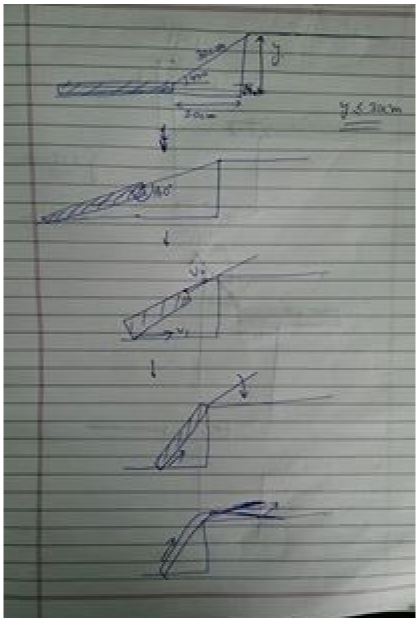
Software

Algorithms and ROS

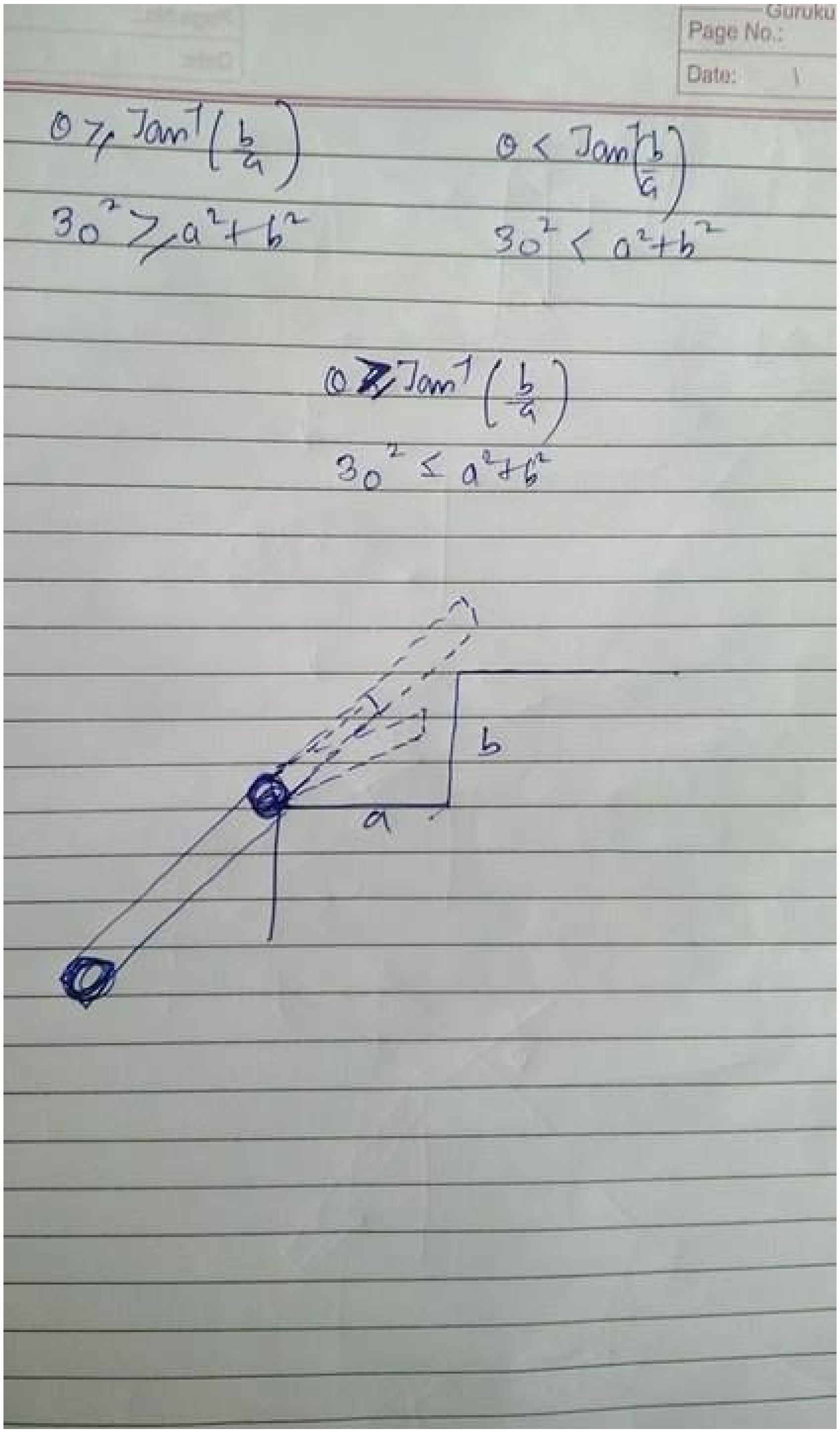
I did the ros tutorials and converted the arduino code into ros with the help of Shubham Yadav

The following algorithms were ideated by me, Shubham Yadav and Swadhin Thakkar:-

1.Discussed the automatic algorithm for the step climb and got an iteration 1 of the algorithm which will work but can be made better.



2.Discussed the automatic algorithm for the stairs climb and got an iteration 1 of the algorithm which will work but can be made better.



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$\theta \geq \tan^{-1}\left(\frac{b}{a}\right)$

$30^2 \geq a^2+b^2$

$\theta < \tan^{-1}\left(\frac{b}{a}\right)$

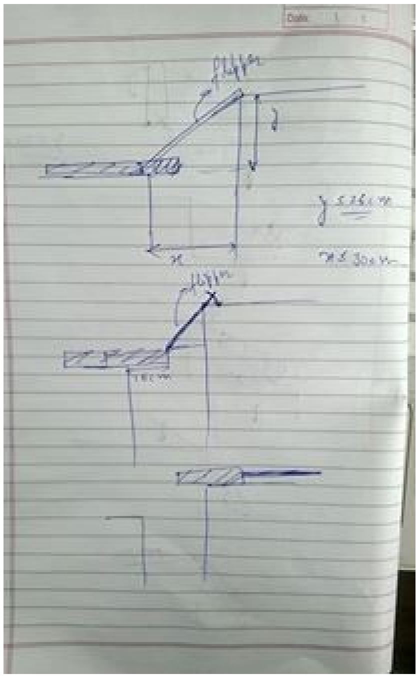
$30^2 < a^2+b^2$

$\theta \geq \tan^{-1}\left(\frac{b}{a}\right)$

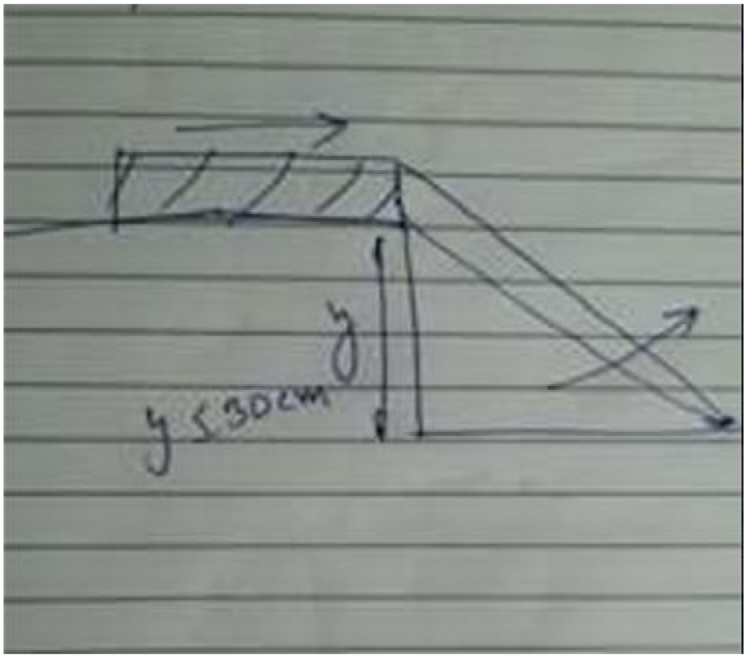
$30^2 \leq a^2+b^2$

b
a

3.Discussed the automatic algorithm for crossing the trench and got an iteration 1 of the algorithm which will work but can be made better.



4.Discussed the automatic algorithm for the step descent and got an iteration 1 of the algorithm which will work but can be made better



5.Discussed the automatic algorithm for the stairs descent and got an iteration 1 of the algorithm which will work but can be made better.
It is the extension of the step descent algorithm