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UVS DEVELOPMENT REPORT 2

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Summary:

Enclosed is the report of experiment on parameter identification, and waypoint navigation system through dead reckoning .This report gives overview of up to date work that has been till this time .We have carried out series of experiment to figure out eticks, reference length and amount of DC required to both the left and right wheel to keep the vehicle moving in desired positon. The report also include the different approach we took to obtain the result, its failure and lesson learned during the testing and execution of plan. The experiment conducted to determine eticks, PID Tuning and its detail result is presented in the report.

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NOMENCLATURE

ROS=Robot Operating System
NUC=Next Unit of Computing
NiMH=Nickel Metal Hydride
LiPo=Lithium Polymer
DC=Direct Current
PPM=Pulse Position Modulation
PWM=Pulse Width Modulation
GPS=Global Positioning System
V=Voltage

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PROJECT OVERVIEW

It is the multidisciplinary project with five group member from different department. In this project we are developing autonomous rover with help of Phidgets and Intel NUC using dead reckoning in Simulink file to perform waypoint navigation. This report includes brief introduction of each component and layout the related concept, experiment on parameter identification and waypoint navigation. Various experiment to determine the reference length (b), DC- Array and W-Array for lookup table, eticks were carried which results are tabulated in these report.

1 ASSEMBLY OF NUC AND PHIDGETS

Intel NUC and two Phidgets are assembled to thumper pin to carry out the waypoint navigation. The two Phidgets motors gets power from 7.2 NiMH battery and the other end is connected to the left and right encoder motors with 5 pin where yellow and white wired pin provide the signal. The Phidgets motor gets the information from the ROS node which subscribes the message from the GNC block created in the Simulink Matlab file via USB cable. Both Phidgets boards is powered from the same battery with a Y-cable and is other connection cable is screwed into the power ports. Encoder pins for left and right motor are connected in opposite manner (yellow and green), since if connected in same manner would result in one turning in positive while other turns in negative direction with respect to their turn direction.
Intel NUC has both the Linux and Matlab installed in it which can be operated in another PC by team viewer for Windows OS and by hotspot connection for Ubuntu 14.04 Thrusty Linux distribution. In these way we are able to run Simulink /Matlab on the platform during our waypoint navigation. It helps us to run the program and debug it when performing the evaluation of the platform easily and

faster.Matlab supports communication with the motors and s different sensor connected to the NUC either through direct connection or through ROS .This way the GNC algorithms can be run with actual sensor data while the vehicle performs actual mission by the actuator commands produced by the program/code written.

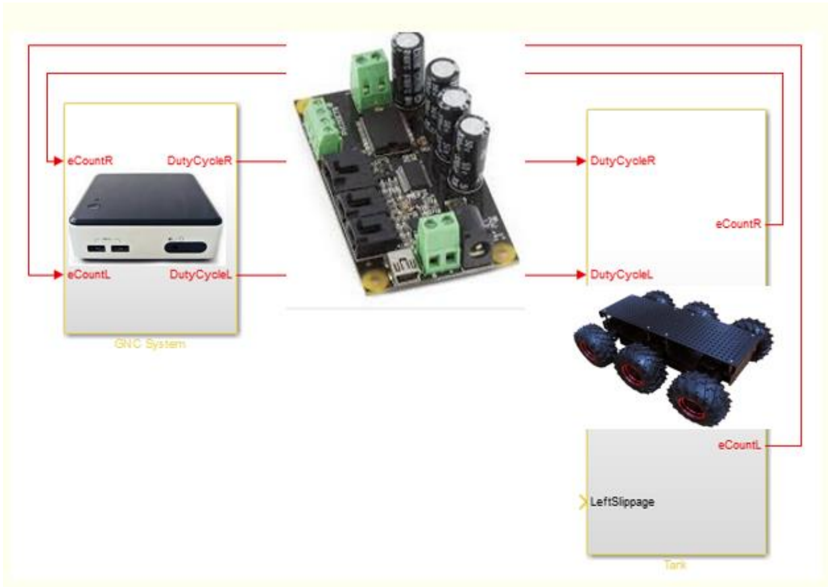

Figure 1: Integration of NUC, Phidgets and Platform

2 CAD MODEL

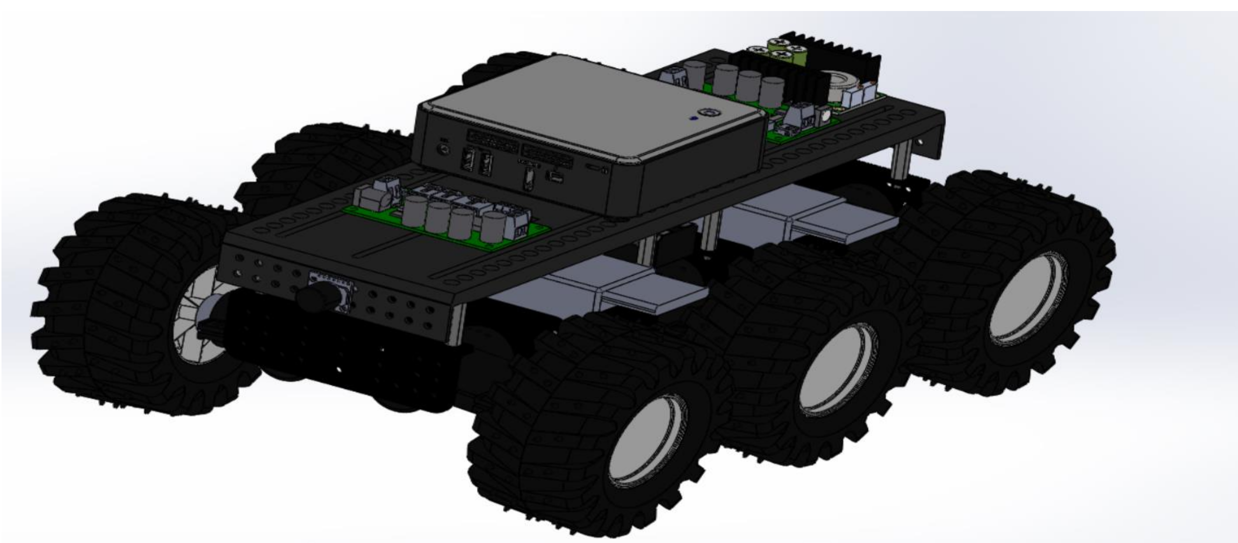

Figure 2: 3D View of Rover Assembly

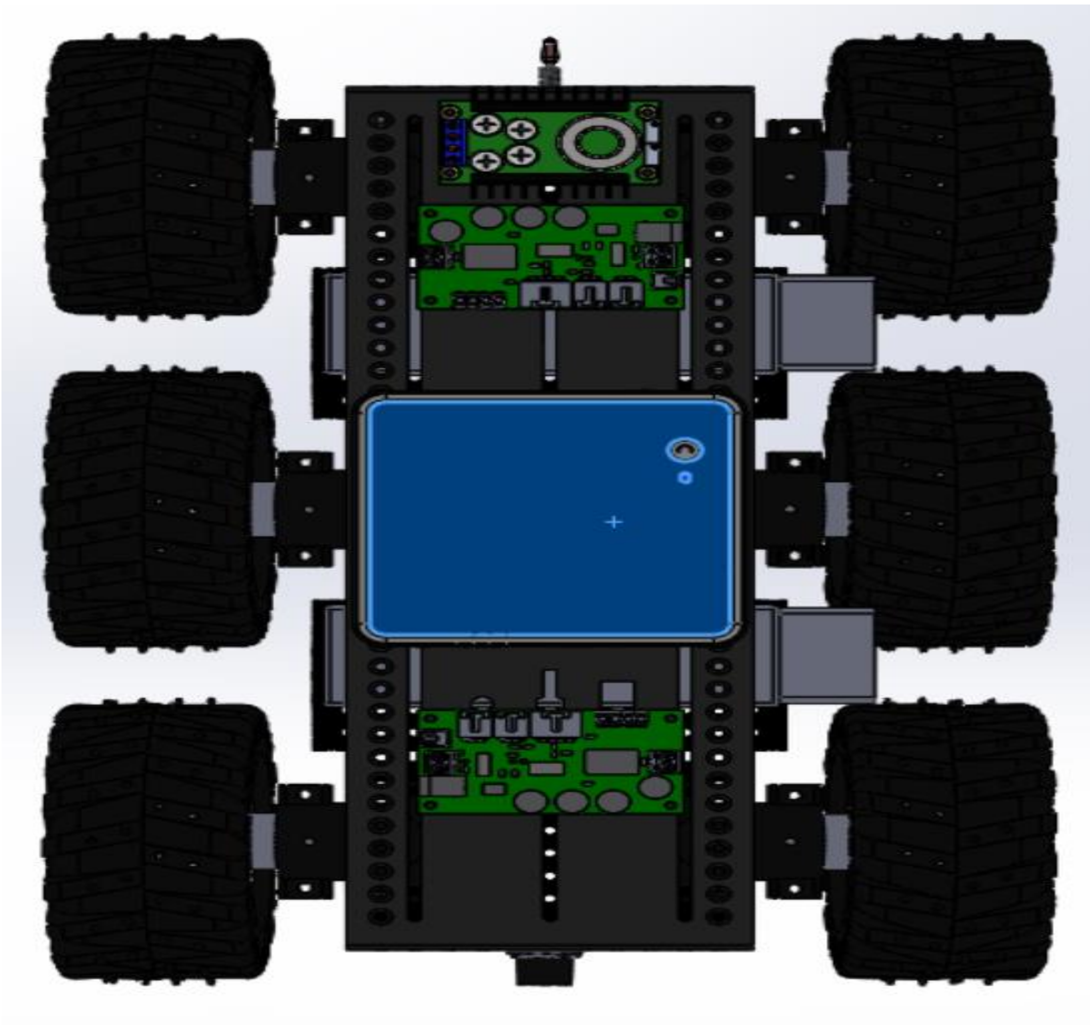

Figure 3: Top view of 3D Rover Assembly (Dead Reckoning)

3 BATTERY

NiMH of 7.2 V is used to power six motors and two Phidgets motor boards. Lithium polymer (LiPo) ion of 14.1 v is used to power NUC via DC to DC converter which get 19V to operate. Lithium batteries are the preferred power sources for most electric modelers today. They are similar to Lithium Ion batteries in that they each have a nominal voltage of 3.6 volts. They offer high discharge rates and a high energy storage/weight ratio. LiPo battery should be handled very carefully while charging.

Figure 4: NiMH/LiPo battery

4 NUC

NUC designed by Intel with Intel® Core™ i5-4250U processor basically,is small computer with central processing unit .It has got 10 GB Samsung SSD with 16 GB DDR3 with the feature of intel WIFI/ Bluetooth card in it .The resistor is used once for connecting into one our personal computer. The NUC is connected to both the motor controller via USB. The Matlab Simulink is inside the NUC is connected to the Phidgets motor via ROS node connection by publishing and subscribing. The NUC gets power supply from 14.8v LiPo battery which converts it to 19 v from DC to DC converter.

Figure 5: NUC

5 DC To DC Converter

It use to convert the voltage from the LiPo battery which is 14.8v to 19V.The requirement for the NUC power supply is 19v. The power and ground supply is connected to input side of the Converter where as the output is connceted to the power cord.Safey precaution must always followed to insure that NUC is not receiving more than 19v. Every naked wired connection must be insulated, heat sink is the best possible way to insulate them in lab.

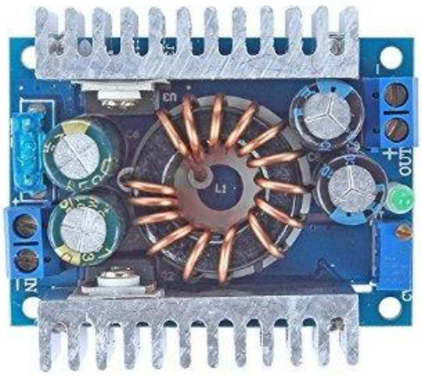

Figure 6: DC to Dc Converter

6 PHIDGETS MOTOR CONTROLLER

Two Phidgets motor is used to control the PWM provided to the middle motor both on left and right wheel respectively. The Phidgets motor has the ability to control the direction, velocity and acceleration of motor. The motor is powered by 7.2 v NiMH and is connected to board by Y cable, current flows through the motor, and it will begin rotating. Depending on the direction of the current, the motor will rotate clockwise or counterclockwise. Switching the voltage very quick the controller is made smaller, more efficient, and cheaper. It is connected to the NUC through USB and it enables MATLAB to drive motor, and enables it to read an encoder counts up to two analog and two digital sensors.

Figure 7: Phidgets motor Controller

7 EXPERIMENT FOR PARAMETER ESTIMATION AND WAY POINT NAVIGATION

The actual path always deviates from the estimated path from the given way point because of slippage and the error in the system. So in order to deal with these problem estimation is done by dead reckoning. The speed and angle were drifting away from the estimated speed and angle. We also observed that these drifting got increased with time. In order to come with the desired performance of the vehicle i.e. way point navigation we have to define and identify the model parameter. These parameter effects the estimation performed by dead reckoning and if defined correctly will helps us our vehicle to drift less from the desired speed and angle.

We have carried out the experiment into three phases to perform our vehicle into desired way.

7.1 PHASE 1

In this phase we tried to run our vehicle in a straight line to the waypoint defined. Initially we tried to run the vehicle by providing the equal amount of DC to both the left and right wheel. We found that our vehicle tend to move toward left. We carried out series of experiment my changing duty cycle to both right and left wheel encoder. We found that increasing the duty cycle in right by the amount of nine more than the left side will move our vehicle in a straight line for the DC of 30/39 and 40/49. This was verified by running the vehicle to the series of waypoint marked on the floor in a straight line for multiple time.

These waypoint was marked by measuring the distance from the reference point at the distance of 2m, 3.5m, 5m and 7m using the masking tape and the sidewinder tape. We carried out these experiment nine time to measure the distance travelled and time taken to travel. In order to have consistency in performing the experiment we made sure that our vehicle is oriented in same direction and in same place every time by placing the vehicle to the marked positon just outside the middle of six wheel.

We took the average distance and average time it took to travelled to calculate the average velocity. The average velocity was found to be 0.661 m/ s for the duty cycle of 31 and 49 to the right and left duty cycle respectively. Using these calculated velocity we are able to move our vehicle to any desired way point for straight line by running the simulation file which will utilize the velocity we found to calculate the time to travel the defined waypoint. In these way we are able to carry out the first phase of our experiment and were successful to move in a straight line.

Table 1: Experiment for Velocity

No of Experiment	Distance(inch)	time(sec)
1	135.25	5
2	131.75	5.02
3	133.25	5.1
4	130.75	5.12
5	129.75	5.07
6	133.25	5
7	131.75	5.22
8	129.75	5.07
9	130.75	5.12
10	133.65	4.95
Average	131.99	5.067

Velocity	26.04894415	inch/sec
	0.661643181	m/sec

7.2 PHASE 2

In this phase we tried to measure the encoder count. We have carried encoder experiment by running the vehicle in a straight line and measuring it ETick both the left and right respectively and distance it travelled. Below is the result for both the experiment.

Table 2: Experiment on Etick and Distance Travelled

	Etick L	Etick R	Duty Cycle L	Duty Cycle R	Distance-d (m)	Etick R/d	Etick L/d
1	459	472	30.1	37.1	1.75006	262.2767219	-20.6278642
2	859	874	30.1	37.1	2.09804	409.4297535	-16.7299003
3	468	475	30.1	37.1	1.7653	265.110746	-19.31683
4	482	498	30.1	37.1	1.7526	275.0199703	-18.8862262
5	521	527	30.1	37.1	1.8288	284.8862642	-17.5524934
6	453	458	30.1	37.1	1.767078	256.3554071	-17.5996758
7	529	565	30.1	37.1	1.85674	284.907957	-16.2112089
9	454	459	30.1	37.1	1.76276	257.5506592	-15.9409108
10	884	895	30.1	37.1	2.0701	427.0325105	-13.091155

Table 3: Experiment on Encoder Counts

	Etick L	Etick R	DC L	DC R	Previous EtickR	Previous EtickL	Distance (m)	EtickR/d	EtickL/d
1	-17755	-13519	70	57	-10818	-15039	2.4892	1085.08	1091.11
2	-20238	-15983	70	57	-13519	-17755	2.28092	1080.26	1088.59
3	-22986	-18710	70	57	-15983	-20238	2.5146	1084.46	1092.81
4	-25674	-21391	70	57	-18710	-22986	2.4638	1088.15	1090.99
5	-28246	-23945	70	57	-21391	-25674	2.35712	1083.52	1091.16
6	-30882	-26567	70	57	-23945	-28246	2.41808	1084.33	1090.12
7	683	398			6	279	0.3736	1049.25	1081.37
8	1088	796			398	683	0.3736	1065.31	1084.04
9	1502	1212			796	1088	0.3736	1113.49	1108.13
10	1100	812			1212	1502	0.3736	1070.66	1076.01
11	686	411			812	1100	0.3736	1073.34	1108.13
							AVG	1084.30	1089.45
							AVG	1086.8	1086

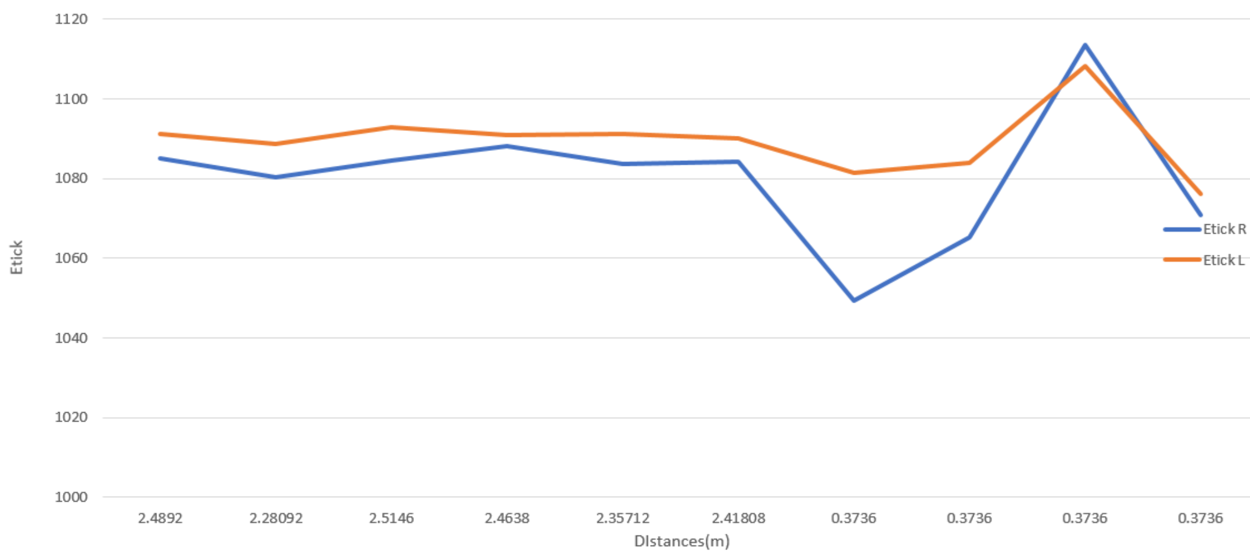

Figure 8: Etick Vs Distance

Table 4: Experiment on Encoder Counts (Recalibrated)

Etick L	Etick R	Distance in	Distance m	Etick/m	DC
1000	1000	47	1.1938	837.66	60
1000	1000	20.5	0.5207	1920.5	40
1000	1000	38.25	0.97155	1029.3	40
1000	1000	37	0.9398	1064.1	40
1000	1000	40	1.016	984.25	50
1000	1000	37.5	0.9525	1049.9	50
1000	1000	36	0.9144	1093.6	50
1000	1000	42	1.0668	937.38	60
1000	1000	36.5	0.9271	1078.6	60
1000	1000	35.5	0.9017	1109	60
1000	1000	42.25	1.07315	931.84	70
1000	1000	36.5	0.9271	1078.6	70
1000	1000	37.5	0.9525	1049.9	70
			Average	1036.9	

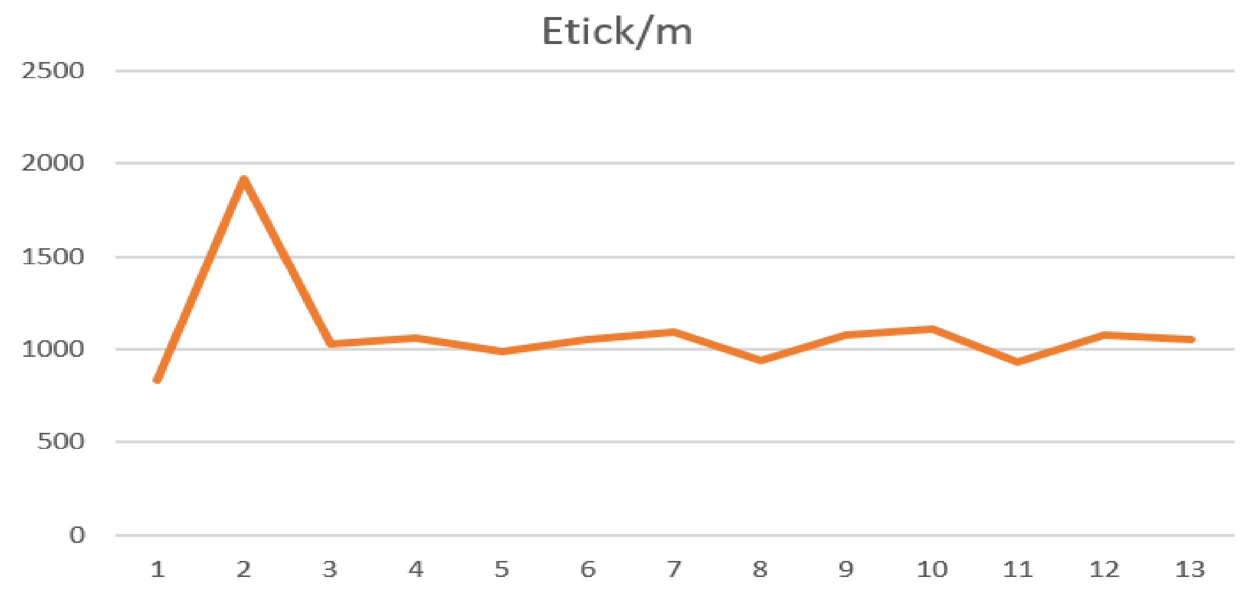

Figure 9: Plot of Etick (Recalibrated)

7.3 Phase 3

In these stage we estimated parameter b. Here we calculated the b by using the left and right etick and encoder count. Similarly, we have conducted experiment for the lookup table.

Table 5: Estimation of b

theta	EtickL	EtickR	b
58.55	1576.456	1091.113611	0.436130116
69.54	1580.356	1088.59583	0.372060373
66.6	1584.466714	1092.817943	0.388396655
68.12	1588.156506	1090.997646	0.383985917
65	1583.525658	1091.162096	0.398535764
63.12	1584.33137	1090.121088	0.411945288
69.4	1589.250535	1081.37045	0.385031681
61.45	1565.310493	1084.047109	0.412055472
71.89	1567.490364	1108.137045	0.336180971
59	1570.663812	1076.017131	0.441100795
		Average	0.396542303

Etick L Pr	Etick R pre	Etick L N	Etick R N	DEtick L	DEtick R	X	Y	Theta	B
7876	10219	9409	11893	1533	1674	77	18.5	0.2358	0.5767

Table 6: Look Up Table

DC	Distance(inches)	Distance(m)	Time	Translational	Angular
-100	-426	-10.8204	2	-5.4102	-93.359793
-90	-402	-10.2108	2	-5.1054	-88.100086
-80	-331.5	-8.4201	2	-4.21005	-72.649698
-70	-300	-7.62	2	-3.81	-65.746333
-60	-257	-6.5278	2	-3.2639	-56.322692
-50	-209	-5.3086	2	-2.6543	-45.803279
-40	-155.5	-3.9497	2	-1.97485	-34.078516
-35	-148	-3.7592	3	-1.253066667	-21.623238
-34	-147.5	-3.7465	3	-1.248833333	-21.550187
-33	-137.5	-3.4925	3	-1.164166667	-20.089157
0	0	0	0		0
33	137.5	3.4925	3	1.1064166667	20.0891573
34	147.5	3.7465	3	1.248833333	21.5501869
35	148	3.7592	3	1.253066667	21.6232384
40	155.5	3.9497	2	1.97485	34.078516
50	209	5.3086	2	2.6543	45.8032787
60	257	6.5278	2	3.2639	56.322692
70	300	7.62	2	3.81	65.746333
80	331.5	8.4201	2	4.21005	72.649698
90	402	10.2108	2	5.1054	88.1000863
100	426	10.8204	2	5.4102	93.3597929

8 PID TUNING

The experiment was setup to determine the correct value for PID where our rover will have smooth motion instead of back and forth motion. We conducted nine experiment to determine the correct value for our PID. The result is demonstrated below on table with brief behaviour of vehicle and with figure obtain from MATLAB Simulink model. There were a lot of iterations and understanding of the correlation between the error and DC which was to be figured out , we had various tests before it.

Table 7: PID Tuning Experiment and Results

KP 1	KP 2	KI 1	KI 2	KD 1	KD 2	Result	Comment
15	10	0.03	0.001	3	0	NS,WPO,FW,LR	
15	10	0.03	0.001	0	0	NS,SB,T	Derivative had solved the back and forth motion problem
15	10	0.03	0.001	3	3	NS,T,R,LR,SB	Derivative on angular caused too much back and forth too much
15	10	0.03	3	3	0	WPO,NS,SB,FW,LR	Lost its control at the final point
15	10	1	3	3	0	NS,T,SB,FW	Way too twitchy with higher integral on speed
14	10	1	3	3	0	NS,WPO,FW,LR,SB	
14	10	0.03	0.001	3	0.1	NS,WPO,FW,LR	
14	10	0.03	0.001	3	0.05	NS,WPO,FW,LR	
14	10	0.01	0.01	0	0		

NS	Not satisfactory
WPO	Way point overshoot
T	Twitchy
SB	Shakes back(rear part) too much
FW	Follows waypoint
R	Reverses a lot
LR	Long radius of turn

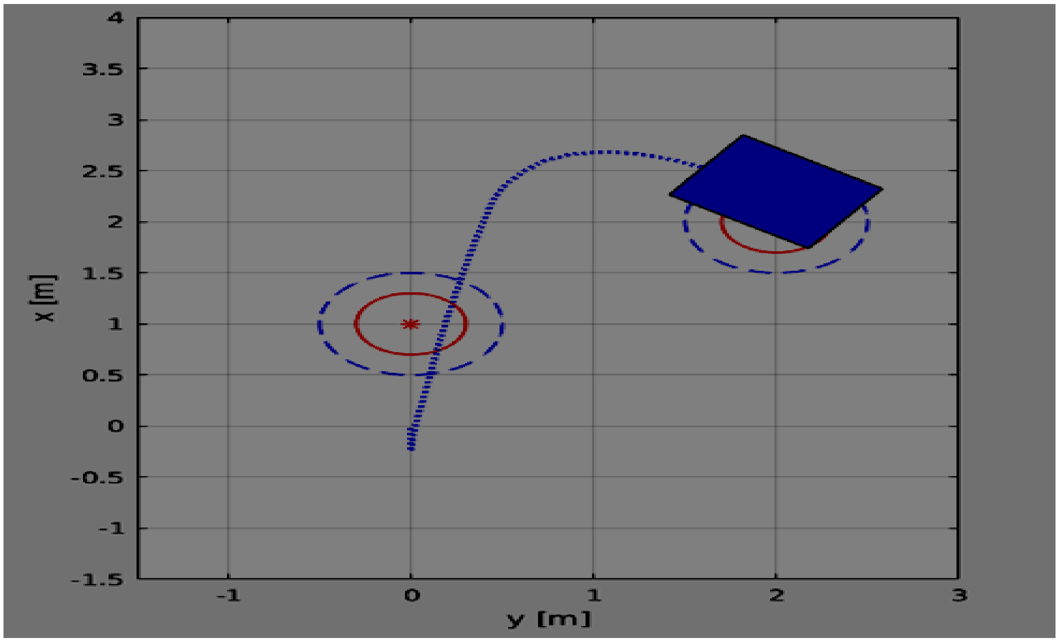

Figure 10: Experiment-1

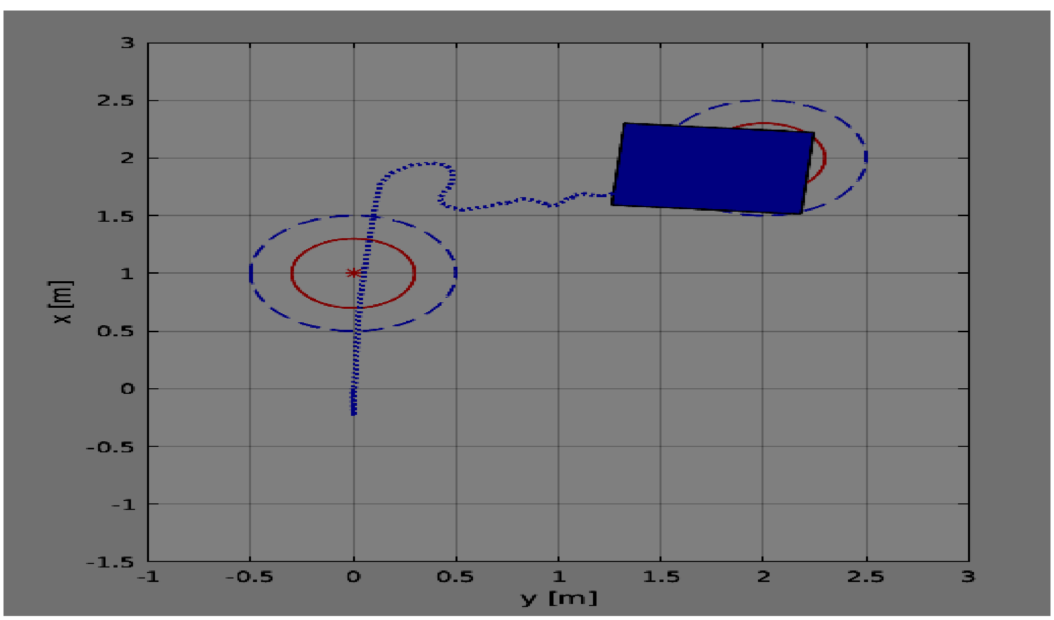

Figure 11: Experiment-2

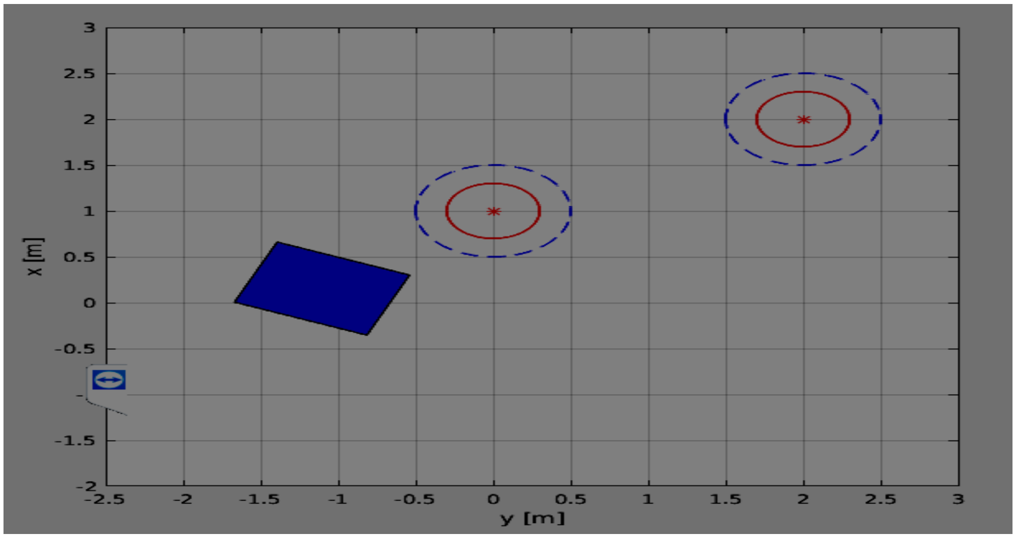

Figure 12: Experiment-3

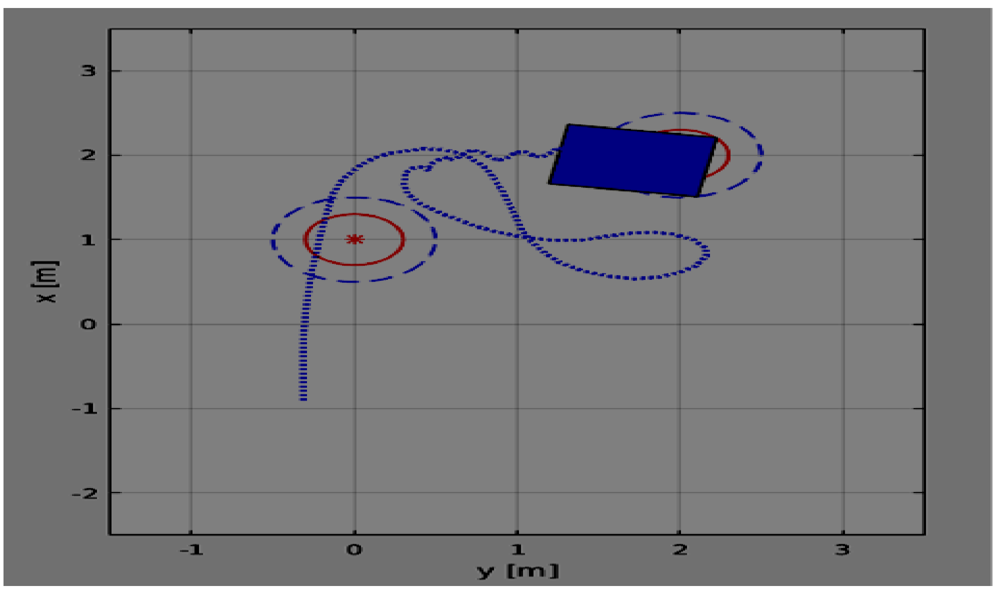

Figure 13: Experiment-4

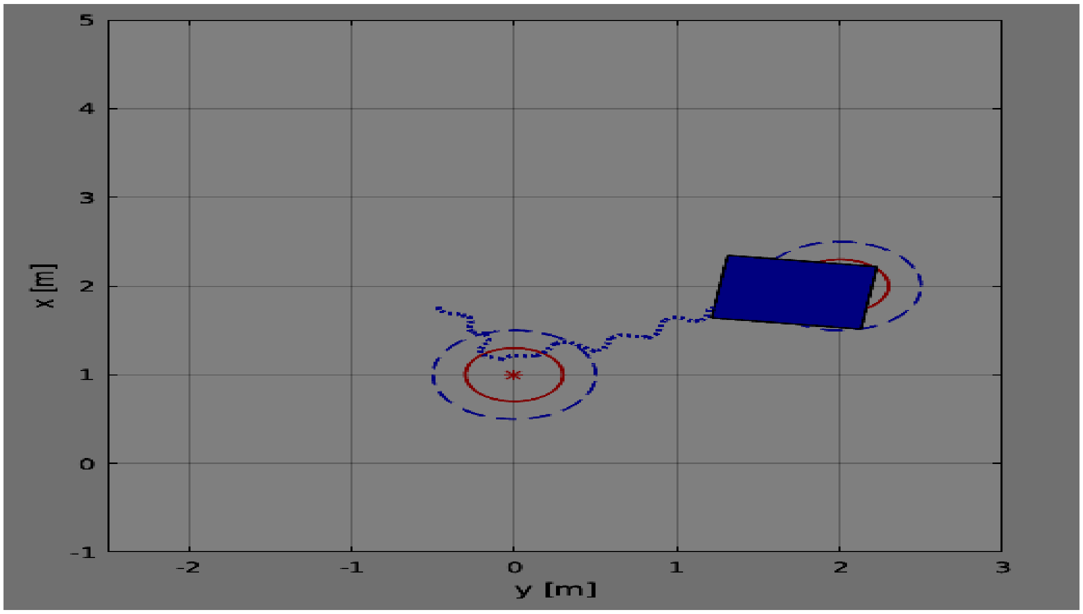

Figure 14: Experiment-5

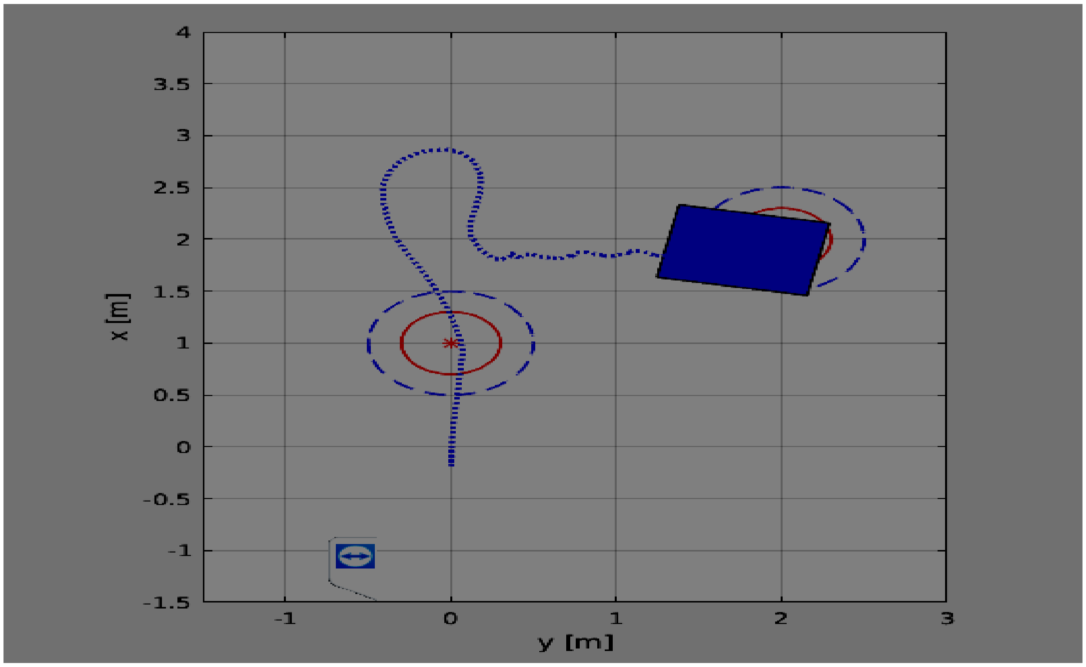

Figure 15: Experiment-6

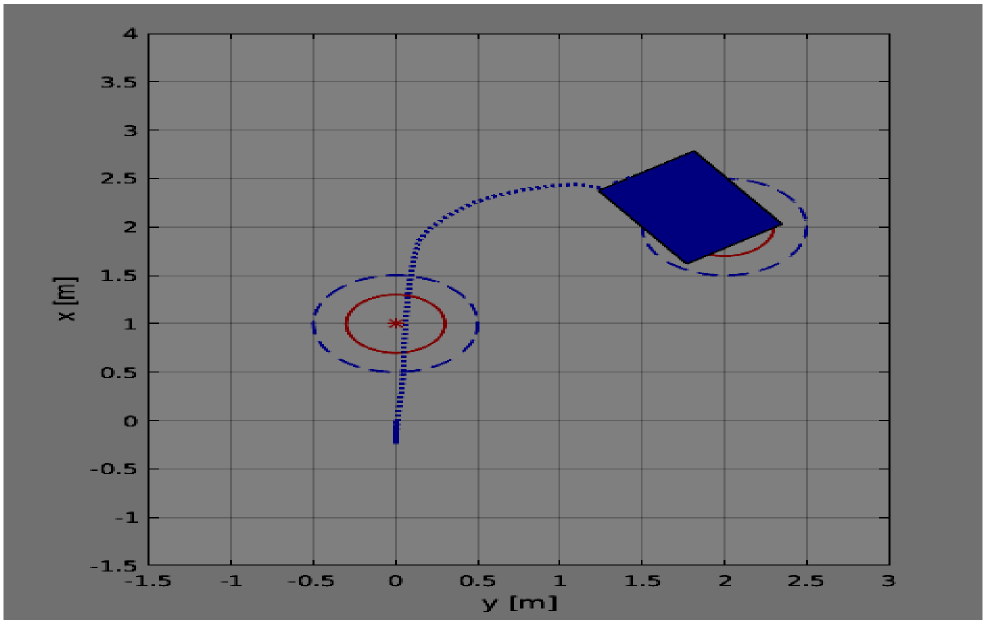

Figure 16: Experiment-7

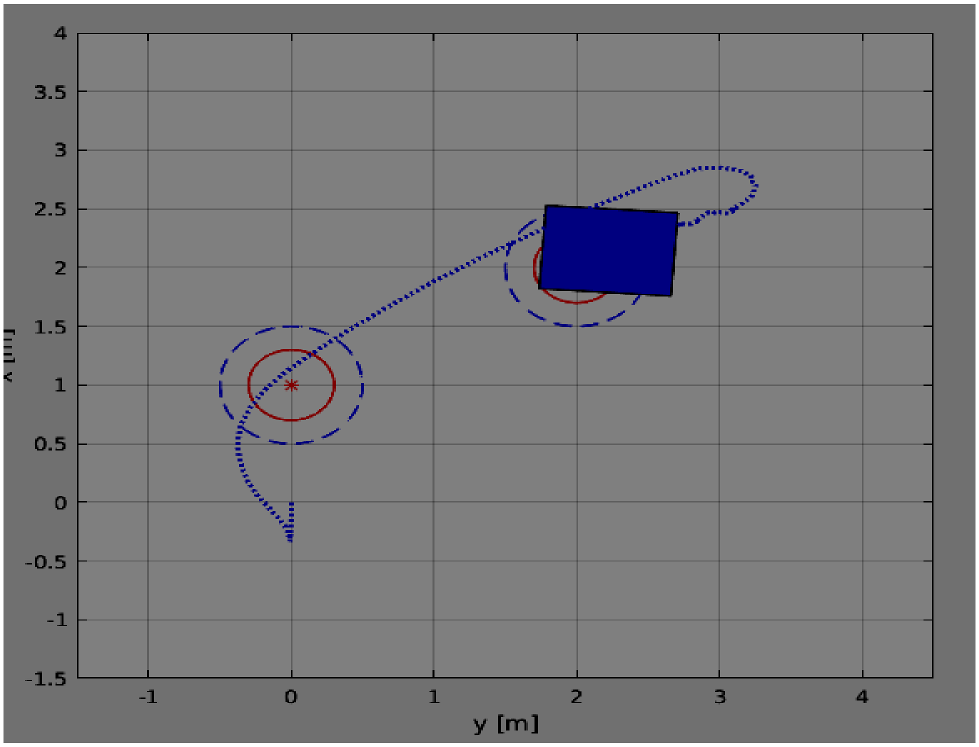

Figure 17: Experiment-8

9 ALTERNATIVE APPROACH

Open loop system wrt to time which was corrected by PID based on encoders making it a semi closed loop programme. The main idea was to use the advantage of speed known to travel and then add ecoder counts missing to ensure the platform reaches its destinatio
Initially different approach was taken to perform the waypoint navigation. We carried series of experiment to measure the Etick count and distance it travelled. First the experiment was carried out to move the vehicle in straight line .The DC was 40/49 for left and right wheel, time taken to travel 2m, 3m, 5m and 7m was measured. Velocity was calculated from these experiment and is utilized to move vehicle to any distance in a straight line. Some simple programming was done to utilize all the velocity, time relationship for waypoint navigation in straight line.
The vehicle was only able to rotate when high duty cycle (85-100) on one side and low duty cycle (0-30) was provided. The problems arised when we started using formulas for heading angles and we couldn't formulate it.
Due to the time constraint to demonstrate the waypoint navigation and some time needed work on our approach, we opted the method that was provided us by professor. It was brave decision initially by our team to approach in a different method which made to understand that it's always wise to use professor method first and work on your method latter on .It was great learning experience for all the team mate through the experiment and putting some though on solutions. So, we carried the experiment method provided by professor which is presented in the above report and was able to perform waypoint navigation successfully.

10 CONCLUSION

We carried out series of experiment to determine etick, duty cycle for left and right wheel of the vehicle to perform the desired action. In order to have consistency the vehicle was placed in same place and in same orientation every time the experiment was conducted. After finding out these parameter the vehicle was able to move in a given waypoint in a straight line.
A part of this mission is to assemble the rover and pix hawk and must be able to operate the rover in autopilot and must go through series of waypoint provided by professor. Although, we were not able show the demonstration on the presentation day due to motor failure, we were successful in accomplishing our goal one the new motor were installed. We were able to control rover manually and in autopilot mode using the pixhawk and GPS connection as desired. The setting in Turnigy 9X remote controller and mission planner setup and configuration was challenging but we were able accomplish the desired result in timely manner.

Although this project seemed simple in theory, the actual implementation of it was more difficult than expected. We encountered many missing components, damaged motor and motor controller which halted our progress as scheduled, during testing of rover. One of our biggest problems was time. Because of the limited component and damaged motor we were not able to work on fixing the rover in time. Initially we found that our middle motor with encoder were damaged, we carried out the objective of performing the manual and auto control of the rover with four motors only. We later on found that load carried by the remaining four motors caused stress on these motor which leads to breakage of the gear on two of the motors.

11 ACKNOWLEDGMENT

First of all, we are very thankful to Professor Dr. Wan for providing us lab and instrument during our project. Similarly, we are very thankful to TA Mr. Songwei for guiding and providing the missing components and new motors for making our project successful.

12 REFERENCES

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