Exploration of Designed Robot in Non Linear Movement Using EKF SLAM and Its Stability on Loose Concrete Surface

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Abstract: The paper analyze the pressure exerted during movement of robot on path (marble flooring and Pebbled surface) using Gmapping based EKF (Extended Kalman Filter) for SLAM (Simultaneous Localization and Mapping). The experiments were carried out using meta software (vMicro) and Arduino BSP on.Net framework, which was not discussed in collaborative SLAM. In this paper, pressure and physical information captured by various sensors are analyzed and concludes robot's behavior at different surface type with various angles.

Keywords: SLAM, Sectorial Error Probability, pressure

I. I.INTRODUCTION

Simultaneous localization and mapping is a requirement for navigation of a robot. Mapping is important parameter for any robotic application as it defines boundary of terrain in which robot can navigated; it can be random, zig-zag path or on a sector or arc. In this paper, author discusses about sectorial movement of robot. While navigating the robot on a sector/ arc, the probability is that the robot gets diverted from its original path. Authors in this paper classified experimental path among two categories viz marble flooring (surface 1) and pebbled surface with loose stones (surface 2). In this respect, some research had been done in which navigation of robot on random path was analyzed but previously authors were not discussed movement of robot on specific arc or sector in different kind of surfaces.

herefore, the authors in this paper try to analyze for movement of robot on a sectorial path using SLAM (Simultaneous Localization & Mapping) based techniques like Gmapping (Extended Kalaman Filter; tracked robot for localization which estimate position error in estimation which is computed from measurements), MonoSLAM algorithm (works with probabilistic feature based mapping and estimate the current state of operation, it refers to real time structure from motion) and Full SLAM algorithm (For the movement of robot on trajectory of any route that were traversed by robot and is based on previous navigation) estimates Sectorial Error Probability (SEP) Experiments were conducted in such a way that when robot navigate on experimental sector the data received from robot on different forces applied on it which is observed as accelerometer, Gyro in real time duplex communication. In order to simulate various results obtain from navigation of robot Arduino Board Specific Package programming, with Vmicro Meta software is used. Authors in this paper analyze Sectorial Error Probability of robot during its navigation, it is localization probability in map when robot move in s curve with respect from actual position. When robot gets navigated, it has to localize itself in pathway to avoid collision, robot navigating in various angles. During navigation probability of error in co linear sectors is being analyzed for various algorithms.

Section II describes about the previous work done on SLAM techniques, different types of sensors used by authors and features, landmarks detection techniques. In section III authors discusses about arena used for navigation of robot like; marble flooring, rough tile including the experimental setup with various hardware used to design robot with analysis of aforementioned SLAM algorithms with respect to SEP. Section IV discussed about results sets of robot navigation on different surface types followed by conclusion.

II. PREVIOUS WORK

In early work authors had reported work on unknown map, unknown localization. Various experiments had carried out using remote area network (RAN) i.e. Bluetooth, the work was focused on geophysical parameters like force, impulse. The work investigates the analysis of accelerometer mode of eZ430 Chronos and implements force applied on wheel and body of robot over the time interval in navigation on different surface types [1].

Most of the previous work on implementing the SLAM for navigation of robot i.e. cloud based robotics; cloud infrastructure was proposed for implementing multi robot system using micro internet protocol, Software-as-a-service, Platform-as-a-service. Previously, some researchers had reported work on Infrastructure-as-a-service and parallelism in GPU based architecture uses track features (KLT & SIFT). [2][3]

Most of previous work was based on Full SLAM algorithms has feature of estimation on full trajectory of route that traversed by robot and is based on previous navigation with limited data on current position is not estimated. [7]

In [2] researchers talked about Hierarchical SLAM based on intuition which builds a graph matrix in large environment and uses the relative positions whether it is local or global data association for comparing landmarks but is limited to wide open environment e.g. desert area [2].

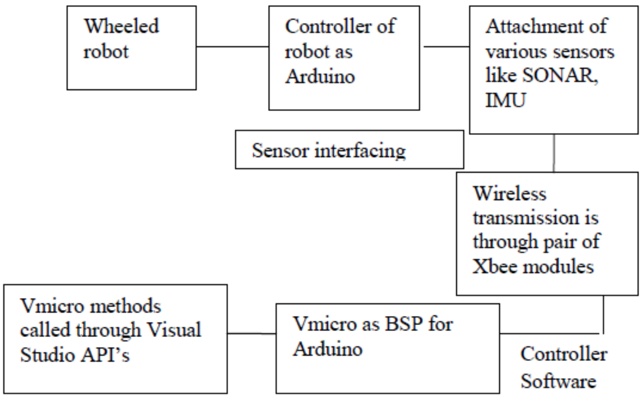
In past most of researchers have implemented Monocular SLAM uses the web camera as the only sensor and is limited to map scaling as depth cannot be infer from single image.
In early work researchers had reported work on Robot Object mapping algorithm builds grid map of environment so that robot can navigate in that environment and has various limitations like; measurement noise, high dimensionality (number of doors, intersection points, rooms) of entities that are being mapped, data association problem [4][5]
Extended Kalman Filtering algorithms was implemented by most of researchers for navigation of robot. Some of the authors uses particle filtering algorithms and estimating camera poses which uses 6- DOF through Kinect designed by Kinect uses OpenNI framework which offers gesture recognition and motion tracking [1][6]
Researchers have talked about visual sensors only. But they hadn't tried to evaluate any other sensory system; they simply combined the data set of different sensors with the help of large computational system.

III. EXPERIMENTAL SETUP

In addition of previously built robot [1] with complete integration, robot is redesigned to enhance its functionality. For this, author enhanced the robot with the following sensors so that it can provide structured map of unknown environment.

1. Arduino UNO Board
2. SONAR sensor
3. Improved IMU (3 axis Accelerometer 3 axis Gyrosope)
4. Pair of Zigbee module for wireless communication
5. Serial/COM port cable
6. Connecting wires

Design of Robot



The navigation of robot is in such a way that it has to localize in its experimental pathway, here authors analyze robot's movement on a sector; as we discussed in previous section that our robot is equipped with SONAR and improved IMU sensor with Zigbee module for communication, so we get our results wirelessly on our systems.
In the experiment, robot navigates in experimental built arena with different surface type like marble flooring, Pebbled surface with the help of Zigbee wireless module which is shown in figure 1. For experiment conduction, authors in this paper uses improved Inertial Measurement Unit sensor as it transmit real time acceleration and gyro data.
With Xbee to SONAR sensor interfacing in Visual Studio 2.0, special API's (Application Program Interface) provides the functionality of COM interfaces which can be used to call methods (vMicro). Visual Micro (vMicro) is an extension which let users enable to do programming on various BSP's. The wireless transmission is done through the pair of Xbee modules; one module work as router and connected to Arduino UNO board, other module work as coordinator and connected with system; through duplex communication data transmitted wirelessly to controller software.

Fig 1 Navigation of robot on a) marble flooring b) Pebbled surface

Next section describes about the results achieved during navigation of robot on a sectorial turn with improved IMU and SONAR sensor associated along with Gmapping (EKF) based SLAM algorithm using experimental robot for localization which estimates change in percentage from its original position

IV. RESULTS

The Sectorial Error Probability is define as relationship between estimate, actual and predicted movement of robot on arc or sector. Map generation and pose estimation done using Extended Kalman Filter based Gmapping SLAM algorithm.

Table 1Navigation of robot on Pebbled surface using Gmapping

Sectorial Turn Angle	Gmapping (EKF)	Improved IMU Sensor					
		A_x	A_y	A_z	G_x	G_y	G_z
		Accelerometer			Gyroscope		
0^0-15^0	3 to 5	-6060	-6924	11856	668	-190	633
15^0-30^0	2.6 to 4.5	-7704	-4824	15184	831	-1204	-507
30^0-45^0	2.5 to 4.2	-6940	-8000	12420	2374	-1663	-738
45^0-60^0	2.1 to 4.1	-6584	-5360	12760	2890	-3404	570
60^0-75^0	1.9 to 4	-6400	-7492	13408	1928	-507	-1027
75^0-90^0	1.7 to 3.8	-1176	-6864	10988	-3657	3297	-6540
90^0-105^0	1.6 to 3.6	-5180	-4636	13840	-2047	7696	248
105^0-120^0	1.5 to 3.4	-3764	-1652	14968	-8953	-3892	-130
120^0-135^0	1.3 to 3.2	1392	-1240	15552	12966	10504	-7796
135^0-150^0	1.1 to 3	6580	6784	-1280	-6586	-102	4003
150^0-165^0	1 to 2.8	1804	-6256	26084	-2931	-5025	-122
165^0-180^0	0.9 to 2.6	-6060	-6924	11856	668	-190	633

Table 2 Navigation of robot on marble flooring using Gmapping

Sectorial Turn Angle	Gmapping (EKF)	Improved IMU Sensor					
		A_x	A_y	A_z	G_x	G_y	G_z
		Accelerometer			Gyroscope		
0^0-15^0	3 to 5	-856	-4668	-16912	501	428	-206
15^0-30^0	2.6 to 4.5	-808	-4580	-16812	548	451	-200
30^0-45^0	2.5 to 4.2	-764	-4820	-16784	511	451	-197
45^0-60^0	2.1 to 4.1	-876	-4620	-16888	550	408	-179
60^0-75^0	1.9 to 4	-828	-4612	-16928	519	431	-203
75^0-90^0	1.7 to 3.8	-804	-4504	-16900	528	430	-186
90^0-105^0	1.6 to 3.6	-944	-4676	-16528	532	419	-180
105^0-120^0	1.5 to 3.4	-864	-4656	-16892	531	454	-167
120^0-135^0	1.3 to 3.2	-800	-4612	-16680	523	426	-191
135^0-150^0	1.1 to 3	-784	-4660	-16860	551	396	-195
150^0-165^0	1 to 2.8	-880	-4756	-16844	525	433	-212
165^0-180^0	0.9 to 2.6	-856	-4668	-16912	501	428	-206

Table 1 and Table 2 depict that when robot is started moving on marble flooring and on loose concrete (pebbled) surface then it is observed certain remarkable change in sectorial angles which are highlighted in Table1 and Table 2. The pressure exerted is random as in case of pebbled surface the friction present in wheeled robot gets decreases which is shown in figure 2 but the pressure is constant during navigation of robot on marble flooring till 135^0 as force is applied in Z direction. When robot navigates on aforementioned surfaces then there is percentage change in acceleration which is shown in table 2. The average acceleration is approximately -80 unit. In figure 3 it is seen that acceleration is constantly applied on robot so it not gets deviated from original path and the percentage change is -70 unit to -93 unit from the average for 0^0 to 135^0.

Now, it has been seen that angle 135^0-150^0 there is steep hike in the acceleration and the change in acceleration varies from -93 unit to 8 unit i.e. 88 above average, this change is due to presence of dust particles on marble flooring. Now, its normal position gets achieved when robot crossed from dust particle.

Similarly there is percentage change in acceleration from 8 unit to -155 unit at 150^0-165^0 i.e. 75 below average. After some movement of time robot navigates on it normal path without much change in acceleration.

When robot navigates on pebbled surface which is shown in table 1, pressure exerted is random the friction present in wheeled robot gets decreases, which is shown in figure 2 the average pressure applied is 500 unit and the percentage change is -307 unit to -318 unit from 0^0 to 60^0 i.e. there is not much change in surface texture.

From 75^0- 90^0 there is change in surface (loose concrete area) the pressure applied on robot is approximately 3000 unit, then the decrease of 650 unit at 90^0- 105^0 and 105^0-120^0.

Similarly, there is steep hike in pressure applied on robot of 3500 unit at 120^0- 135^0 and decrease of 2500 unit 135^0- 150^0 which is shown is figure 2.

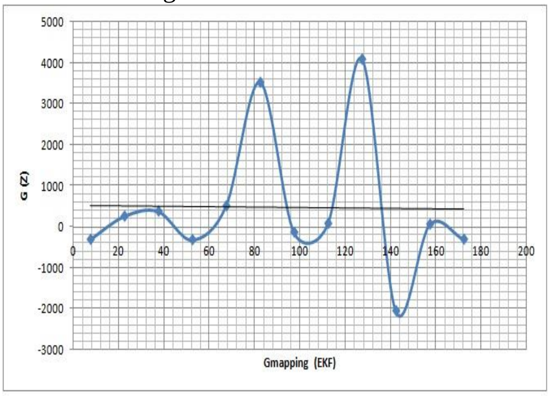


Fig 2 Navigation of robot on Pebbled surface

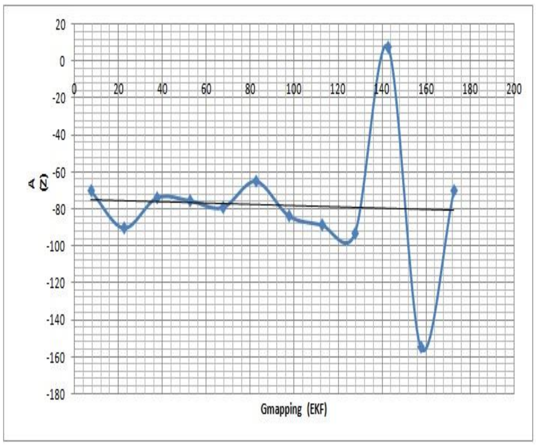


Fig 3 Navigation of robot on Marble flooring

V. CONCLUSION

As per aforementioned results it has been concluded that during navigation of robot using Gmapping EKF algorithm constant pressure is exerted on robot in Z direction but in case of pebbled surface it was random, so in future special blending function is needed which corrects the pressure so that robot navigate in more smoother manner in pebbled surface as it has seen from results that there steep hike and gradual decrease during navigation of robot.

Accelerometer and Gyroscope values in X, Y direction during navigation of robot in pebbled surface can be more improvise if Bezier function implements as, if it is implemented the pressure exerted on robot will released.

The Z direction data for both accelerometer and gyroscope will be used for power management of robot's wheel, it's electronic stability and designing of robot's body for getting better suspension.

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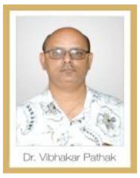

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