Soil sampler robot with localization for agro purposes

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ABSTRACT

This paper presents a Soil sampler robot with localization, a new methodology for analyzing the soil samples at various locations in an open cultivation land Extended Kalman Filter algorithm .The design criteria of this project involve the localization of the robot for sampling using state estimation method which provides a minimum variance of an unknown state vectors and there by controlling the robot position accordingly and thereby locating the position of the sample to be collected ,transfer it through scooper mechanism into an analyzing chamber. In the analyzer chamber sensor data measured is encrypted and transferred through a wireless long range communication channel in order to store in a remote terminal which is capable of logging the data with time stamping. The obtained GPS data is also linked with a better tracking system like Google maps which can be used for further error minimization procedure and also enables the robot's position which can be tracked globally by transferring the data valued of Latitude and longitude through a hypertext transfer protocol with string control.

Key Words: Regolith, auger, scooper, Localization, Raspberry pi, Lab view.

1. INTRODUCTION

Unmanned soil sampling and subsurface explorations have received a lot of attention in recent years. Path planning of such automated robot systems is arguably the most important goal to solve. It deals with automatic generation of feasible paths for robots in the presence of obstacles. So far, the major concern was to merely find a feasible path. But these days, quality of the path carries more interest than merely finding a collision free path.

This problem has been solved mostly by using randomized algorithms, such as Probabilistic Road-Maps (PRM) Soil Sampling and path planning technique handles complex problems in high-dimensional spaces but usually operate in a binary world aiming to find out collision free solutions rather than the optimal path. Classical grid based methods can be used to compute resolution optimal paths over a cost map. To find paths quickly in large search spaces, roadmap based planners are ideal. Optimization of generated paths using randomized algorithms is addressed by that presents an iterative algorithm to optimize raw paths. Some of the methods extract optimized paths from motion planning roadmaps enabling collision detection and kinematic constraints. The road map is created by using reachability roadmap method which is particularly suited for motion planning in real time environments. Before planning for any kind of plantation it is required to estimate of the yield of a crop which can be performed by analyzing the soil sample and conduct in-situ analysis of geological soil samples. The soil sampling can be achieved by deploying devices for sampling process. Many researchers have studied and developed sample acquisition systems and driller or corer systems which already proved well in performance. The soil sample can also be extracted using a scooper like mechanism which is capable of collecting both the sub surface and surface soil which is required for the plant growth which contains most of the growth nutrients of the plant.

Excavation process varies from soil to soil based on the texture, strength and other parameters. Auger mechanism is well known mechanism for drilling the soil samples, auger used for digging post holes is called an 'earth auger', 'handheld power earth drill', 'soil auger', or 'mechanized post hole digger'. The above extraction of soil sample can also be achieved for low depths on terrain surface by using the scooping, the sample and transferring the soil through tilting the scooper so that the extracted material can be transferred to the analyzer chamber for further analysis of the soil. The regolith layer or the subsurface soil contains essential nutrients which helps in proper growth of a plant, analysis of these nutrients along with the relative humidity is essential for the pre plantations for any agricultural crop.

Mobile robot localization is the problem of finding out a robot's coordinates relatives to its environment, assuming that one is provided with a map of the environment. We can distinguish two different cases: the re-localization case and the global localization case. The re-localization problem tries to keep track of the mobile robot's pose, where the robot knows its initial position (at least approximately) and therefore has to maintain the robot localized along the given mission. The global localization problem does not assume any knowledge about the robot's initial position and therefore has to globally localize itself. The global localization problem can be solved to some extent by GPS system which provides the co-ordinates of Latitude and Longitude with standard values of the deviation for a given global location. Similarly the inertial navigation system or an Inertial measurement unit (IMU) using an accelerometer with a Gyro for estimation of the system or a robot for its position and orientation will help the EKF in order to estimate the pose and position with a better accuracy and least errors possible during the movement of the robot. Similar system is used in most of the IMU based position tracking and state estimation systems for higher velocities and speed.

2. SYSTEM DESIGN

This section of the report discusses the complete overview of implementation of the system.

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Implementation of overall system: The block diagram shown in Fig2.1 comprises mainly the control system that provides the necessary actions that are required to perform the soil sampling through the state estimation methodology.

The control system consists of Raspberry pi model b version, the sensor units are interfaced with the control system with necessary signal conditioning circuitry. The data transmission is a bi directional communication system with PAN ID encrypted string. The string values are received on the remote terminal provides the state of the robot. These string values are processed using string value extraction based on the position of the string number and alpha numeric values.

Mechanical structure of scooping mechanism: Scooping mechanism of material extraction and transfer mechanism is a proven technology for its stability and performance. This mechanism can be adapter for the purpose of the extraction and material transfer of the regolith layer of the agricultural land which comprises of small and medium sized stones.

The project comprises of two horizontally aligned and welded scoops of length 140mmThe scooping tip comprises of three sharpened projections of length 50 mm which enables the scooper for easy extraction of the soil samples.

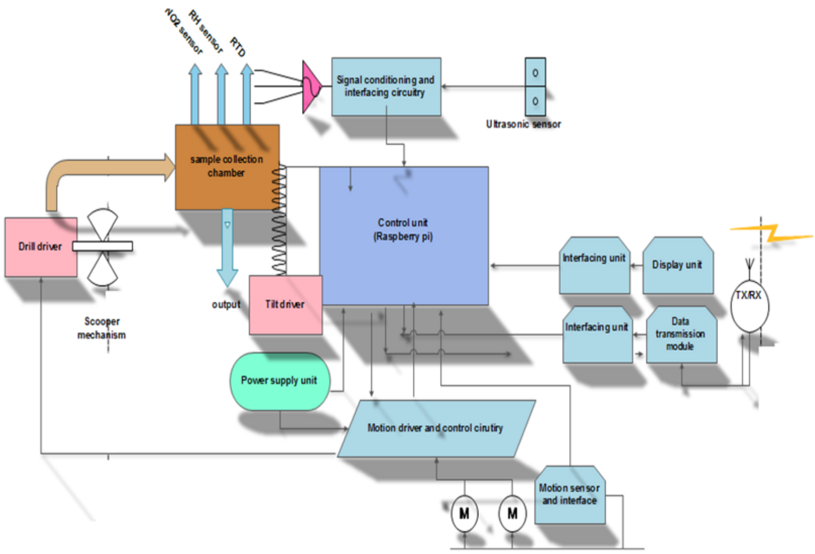

Figure.1.Block diagram of soil Analyzerbot Robot structure

Wheel selection: The total distance covered by the wheel in one revolution is nothing but the perimeter distance. So the wheel diameter can be designed based up on the speed required. Diameter of the wheel is 7', then the radius becomes 3.5' the perimeter of the wheel is πd which is equal to the 22' of distance it can cover in one complete revolution.

The number of revolutions of the DC motor be N, for a minute of time the motor is N/60. In the design the motor is directly connected to the wheel causing to rotate N/60 rotations. For each rotation the distance covered is 21' based on this concept the wheel is selected. Figure 4.3 show the wheel of the robot.

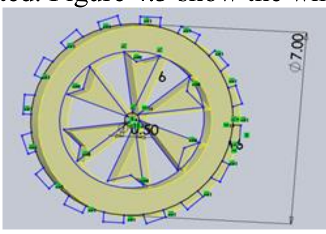

Figure.2.Wheel structure

Chassis design: The chassis comprises of mainly 4 parts they are Scooper and Tilter mechanism with sensor assembly, Wheel and drive mechanism, Suspension, Electronics board.

Scooper mechanism: Scooper mechanism comprises of 3 major components.

i. Two Scooper cups aligned oppositely.
ii. Shaft welded to the scoopers with Supported bearings.
iii. Geared Driven by an electric DC motor.
iv. Two scooper s of length 12' are aligned with the shaft of length 14' with dual bearing support firmly fitted to the Tilter sheet. Pictorial representation of Scooper mechanism is shown in the figure 4.4.
v. The shaft welded with the two scooper is of 14' length is made out of MS of diameter 20 mm in size.

vi. The gear mechanism is of Bevel gear type aligned 90° apart comprising of equal gears of 21 numbers with an outer angle of 42°. The whole gear assembly is freely held by the shaft bearing mechanism on the either sides of the scooper. Where one end of the scooper shaft is connected to the driven gear, the driving gear is powered by the 15kg cm torque Dc motor controlled by the PWM signal.

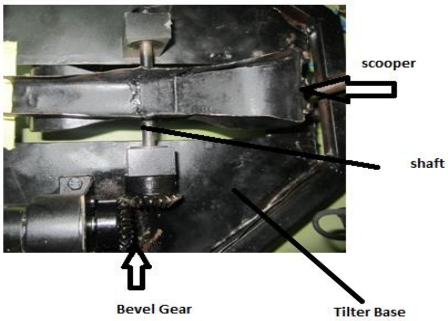

Figure.3.Scooper mechanism

The drive mechanism comprises of 4 wheels of them front 2 wheels are the driver wheels and the rear wheels are the free wheels. The drivers wheels are coupled to the shaft through the tight hallow shaft mechanism. The rear wheels are the free wheels which are freely suspended.

The suspension system comprises of 4 spring s which are connected to the legs of the wheels firmly bolted on the either sides of the spring. Keeping in view of front load the total weight of the tilter mechanism along with gear and driver motor and the scooper is 9 kg vehicle suspension springs are subjected to rapid changes in length and their mass must be kept as low as possible to minimize undesirable dynamic effects. The force that is acting on each of the spring is given by the Eq.2.1

9 kg = 88.25 N

88.25 N/4 = 22.06 N (2.1)

Each spring should be capable of bearing a load of 22.06 Newton

Calculations involved in designing the spring are as given in Eq.4.16, 4.17.

The spring constant *k* is given by

$k = (Gd^4)/8D^3n_a$ (2.2)

Where

G = found from the elastic modulus E and poisons ratio n.

G = E/ (2(1+v))

d = internal diameter of the spring

D = Mean diameter of the spring

The deflection occurs in a spring is given by the Eq. 4.17

$\delta = (8FD^3N)/Gd^4$. (2.3)

Where

δ = Deflection or change in length (dl).

F = Force action in Newton's.

D = Mean diameter of the spring.

G =Shear modulus of elasticity.

d =Inner diameter of the spring.

G = spring index s * d

Stress in a spring is given by the Eq.4.18.

$t = k_w * (8FD)/\prod d^3$ (2.4)

t = Stress acting on the spring

k_w = static load acting upon the spring.

The static load acting upon the robot is 9 kg, then the t value is 109 N /m but the load acting is 88.9 N/n, so the robot spring can with stand a stress of about +/- 22 N/m.

Weight Estimation and modeling: The total weight of the robot should be calculated in order to select the driving torque and power estimation for the amount of working time. The power source (battery) ampere hour calculation is done based on the amount of the load acting on the robot drive mechanism. Calculation of the Scooper prime mover, tilter prime mover, and lead screw mechanisms equally for their operation.

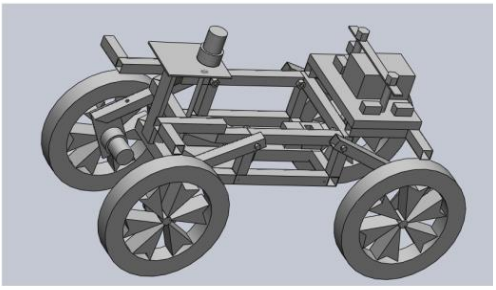

Figure.4.Solid Works Model of Soil Analyzerbot

The structure, Scooper, and the battery weight are also considered for the weight estimation of the robot. Wheel assembly, motor weight was also included in the calculation of the load action on the motor driver which has a good impact on the movement on the terrain surface. In order to arrest the position of the robot geared motors were used and their transverse rotation enable in holding the position during the scooping operation. Other methodologies stated in the literature review chapter uses a plunger holding mechanism which restricts the robot to a wired one but not an autonomous one. The following table provides the details of the weight estimates of the robot.The total weight of the robot after calculating the individual components is 6690 grams, taking the factor of safety into consideration the total weight is rounded off in to 7500 grams. The total torque required from the motors in order to drive the whole robot required is 20 kg cm, the available torque from the front wheel drive motors is 30kg cm so the factor of safety of 10 kg cm is considered for the motor movement on the terrain surface.

Methodology:

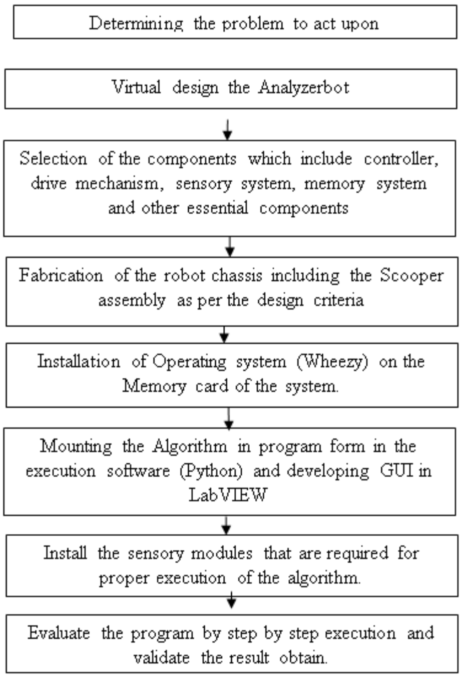

Figure.5.Methodology flow chart

The complete methodology in Fig. 2.6 has been split in different phases which comprise of selection of model of development board, motor and other drive element selection, designing of the auger mechanism and its drive, development of the algorithm for sample point location and obstacle avoidance.

3. RESULTS AND DISCUSSION

Flow of Sample Extraction process: The execution of the steps in collection of the soil sample starts with the initial position estimation based on the location of the robot. Next robot moves to the subsequent state estimated by the EKF algorithm. The lead screw mechanism makes the tilter to reach the soil surface; the scooper rotates collecting the sample. Then again tilter reaches the home position causing the collected sample to transfer into the analyzing chamber. The sensors located in the chamber perform the analysis and the soil moves to the exit during the next operation. The above operation sequence continues until the final state of the robot is reached. The soil analysis data is transferred to the remote location for every loop iteration. The proposed algorithm comprises of the extracting the locations of the robot and thereby controlling the position of the robot using the control algorithm, which also includes developing the prototype for the proposed scooper mechanism works on the speed control of the driver mechanism achieved using the PWM signal control.

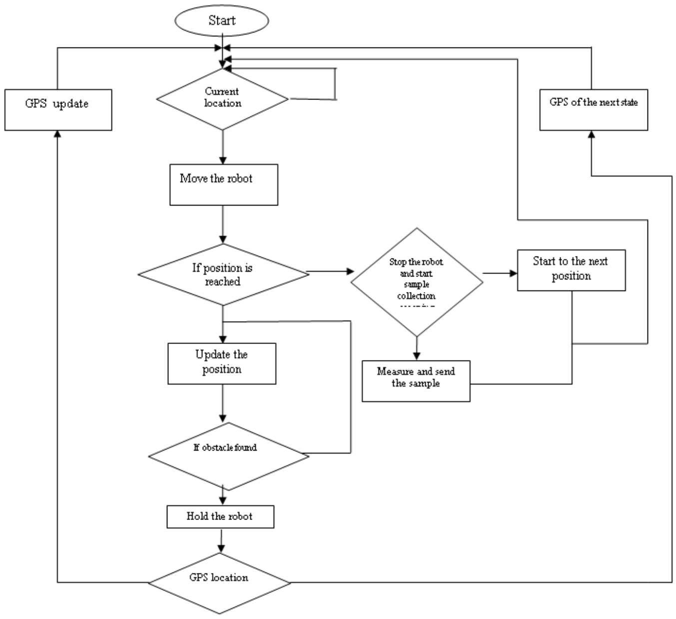

Figure.6.Flow chart for execution of sample collection

The locations are also integrated to Google a map which is a well proved application for geo tagging the locations of any GPS based data with a better accuracy than any other applications existing in current. Figure 7 provides the data related to the positions and the corresponding acceleration values.

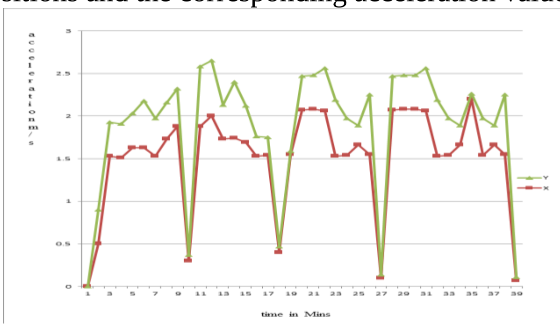

Figure.7.Graphrepresenting the speed of robotat various sample points

Physical structure of the robot: Figure 4.3 shows the physical structure of soil sampler robot at different stages in fabrication to the final assembly and working on a terrain.


a **b**

c

Figure.8.Soil sampler robot states of working; a. Fabrication and Electronics assembly; b. Front view after full assembly of robot; c. Working on terrain

Front panel GUI: The front panel comprises of the graphical representation and numerical values which are extracted from a PAN ID encrypted string send by the robot, the values are updated based on the time. The values are separated from the string.

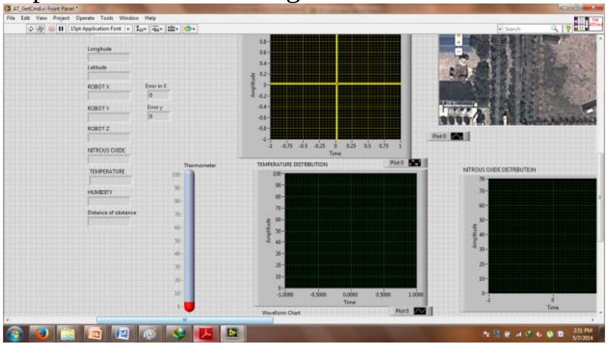

Figure.9.Screen shot of the front panel

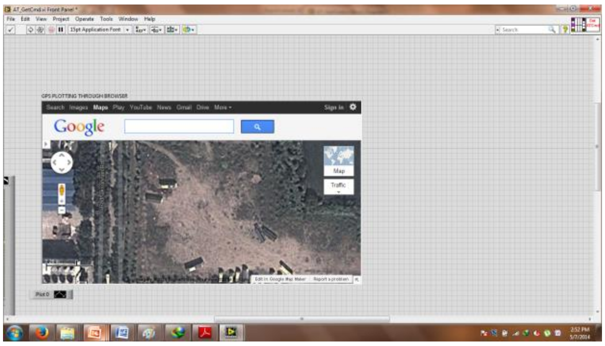

Figure.10.Screen shot showing GPS location of the robot

4. CONCLUSION AND FUTURE SCOPE

The work accomplished comprises of proposing a new approach of integrating the localization concept with the control mechanism in the real time environment for a mobile robot which is capable of extracting the samples of regolith. Hence, it can be concluded this methodology can be adapted for agricultural and other soil collection methods at various terrain lands.

Scope for future applications: Since India is an agricultural based country, and the skilled human resources are decreasing day to day, this project can be applied in terrain surfaces of the agricultural land where skilled personnel are required for soil sampling for testing purpose. The project can be improvised by applying the following concepts Application of simultaneous localization and mapping (SLAM) for better accuracy of the environment mapping. Wi-Max can be used instead of the Xbee pro version used for data transmission over the higher band width and large scale data. Video or picture capture for implementing SLAM approach, and better tracking the end points in agricultural land. Integrating other sensors like PH, Sodium, and Calcium for non-contact measurement of the Soil properties.

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