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A Low Cost Aurdino Controlled Floor Mopping Robot

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Abstract*—The floor mopping robot is a upcoming application in service industry. Many researchers are working in this area of development and control of the cleaning robot. This paper focuses on new model development of floor mopping robot in particular at a optimum cost and high mechanical efficiency and also a new low cost algorithm for area filling. The motion of robot will be controlled by using two wheels coupled with stepper motors which will be controlled using Arduino board. Ultrasonic proximity sensors will be used for obstacle detection. The task of area filling, localisation and mapping will be carried out using the data from position encoders of motors, ultrasonic sensors, and a graphical user interface.

***Keywords*—Mopping robot; Area filling techniques; Mapping; Obstacle avoidance**

I. Introduction

Currently there are many machines available in market for vacuum cleaning or sweeping of floor. However this cannot replace or eliminate the need of mopping the floor. The present day scenario shows that this kind of equipments are available on a very small scale in Indian market for large scale applications like washing of roads, hospitals, etc. This large scale applications add to the cost as well as bulkiness of the equipment.

The household job of mopping is tedious as well as time consuming. Moreover even if the efforts involved in cleaning are reduced to certain extent by present day equipments they require human attention or intervention. The equipments which do not demand human intervention have very high costs. Hence there is a need to optimize the mopping equipment with respect to cost and make it suitable for domestic purposes. Also the rising cost of labour all over the world demands such kind of service robots for carrying out various human jobs.

This paper deals with design and development of model of a floor mopping robot. The hardware developed for this project can be implemented in various mopping equipment with different control and navigation algorithms to optimize its performance to next level. The logic which is going to be developed for mapping, localisation and navigation can be used in various other applications like autonomous lawn movers, autonomous vacuum cleaners, mapping in unmanned or hazardous areas, automatically driven accident avoiding car, etc. Further there is a scope for building vacuum cleaning and mopping modules on same base with certain easy to make hardware modifications in same unit which will eliminate need for two different equipments for dry and wet cleaning. Also a device for inspection can be incorporated to inspect the level of cleanliness attained.

II. Literature Review

The working of floor mopping robot can be divided into two parts. The hardware for cleaning like brushes, water spraying mechanism, water collecting mechanism, drive system, etc, and area filling technique used. The area filling problem has been identified and worked upon long before. Yasutomi et al.[i] (1988) proposed a algorithm for area filling in unknown environments which suited only to structured regions. Cao et al. [ii] (1988) used raster scanning technique in lawn mover. This was made for working in a known boundary with unknown obstacles. When a obstacle is detected a local search for its boundary is done using omni-directional vision system, and as per its feedback the path planning for robot was done automatically by the system. Hofner et al.[iii] (1995) proposed a algorithm in which 2D map was used for path planning and it was updated according to the obstacles faced. Vehicle control was done using Hierarchical control structure and sonar and dead reckoning were used for localisation. Gonzalez and Suarez et al.[iv] in 1996 developed a similar algorithm for area filling. In this a topographical map for knowing the environment was used and the technique of localisation was similar to Hofner. Chang et al. [v] (1993) used a technique of dividing area into sub-regions. More recently Ilari and Jane et al.[vi] used magnetic field based simultaneous localization and mapping. In this method a magnetic field sensor is used. There are certain distortions in indoor magnetic fields due to presence of certain objects. This technique makes use of this distortions along with odometric data given by the sensors for mapping. The maps generations are found to be accurate enough for guiding or area filling.

Sherman et al. [vii] (1998) developed a logic for controlling behaviour of mobile robots for floor cleaning. It used fuzzy controllers for implementing behaviours, and state machine architecture for co-ordinating tasks like navigation, area filling and obstacle avoidance. Palacin et al.[viii] used ultrasonic sensors for map building. The motor was controlled using a PID controller and a microcontroller was used for controlling robot.

Yunbo Hang et al.[ix] (2014) proposed a model for multifunction floor cleaning which included two different modules for vacuum cleaning and mopping. The technique of used water collection used is this design is the most effective and cheap one. Ynng-.loo Oh' and Yoshio Watanabe'[x] made a small cleaning robot which followed random paths. It had no provision for area filling.

The currently available automatic floor mops in market make use of a vacuum pump to recollect the used water and then a cloth to absorb the traces of water. This is a less effective technique as it sometimes leaves the marks of cleaning path followed. Also the area filling task is achieved using a indoor navigation system from north star, in which the robot receiver follows the signals from the transmitter and gets stuck sometimes in complicated environments.

III. Mechanical Design & 3DModel

The mechanical design of the robot consists of a two wheeled circular platform as shown in figure 1 below. The circular platform is attached with a nozzle for spraying of water, brush and a sponge. When the robot is turned on the nozzle starts spraying water, then the brush rotates performing the cleaning action for tough stains after which sponge rolls over absorbing the water. For collecting the used water from sponge, a baffle is used. The sponge is pressed against the ground due to which it is compressed by 1mm thickness along the diameter and the baffle compresses the sponge by 2 mm, thus all the used water absorbed per revolution is collected from the sponge in a collector attached to the baffle. The water from the collector is then transferred to the used water tank using a 12V DC pump. Stepper motors are used for wheels as position control is required there, sponge and brush are rotated using DC motors. The robotic base, tank, collector are made out of acrylic sheet.

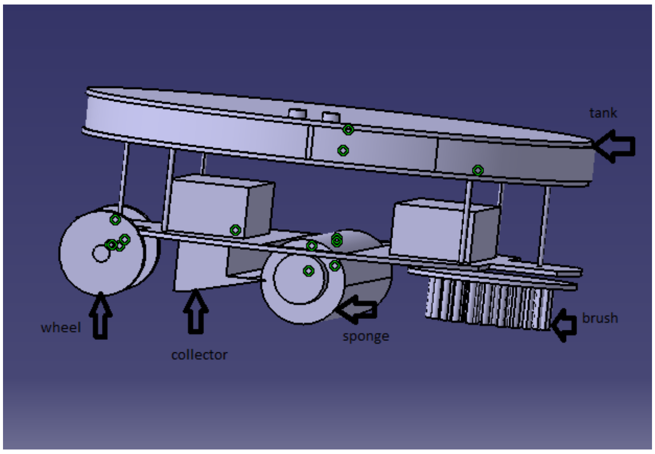

Fig.1: CATIA model of floor mopping robot.

The motor torque required to move the structure by wheels can be calculated as follows:

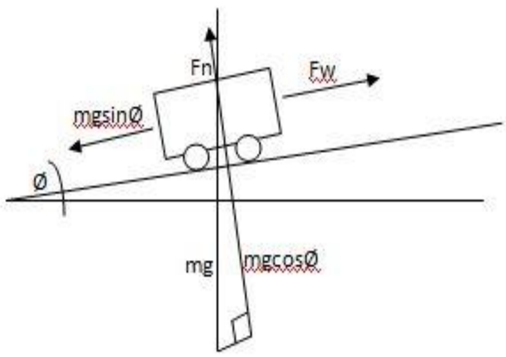

Fig 2: Dynamic equilibrium for robot moving on incline

To calculate motor torque for worst loading condition consider a situation when robot is starting from rest and needs to accelerate up the incline to full speed.

Fw- Net force required by wheels.

Fn- Normal force.

To determine size of motors we define following:

Maximum weight to be carried= 3 kg

Maximum incline to climb= 10˚

Maximum speed, v= 0.25m/s

Assuming time required to accelerate from rest to full speed is

2s, To reach maximum speed in 5 secs, $a = \frac{v-u}{t} = \frac{0.25-0}{2} = 0.125m$

Wheel Diameter= 6cm= 0.06m

$$\sum F = Fw - mgsin\emptyset - \mu Fn = ma$$

Along the axis of wheels there is a sponge rotating and in contact with the floor.

The coefficient of friction of sponge with respect to floor is 0.63.

$$Fw = ma + mgsin\emptyset + \mu mgcos\emptyset$$
$$= m(a + gsin\emptyset + \mu gcos\emptyset)$$
$$= 3(0.125 + 9.8sin10 + 0.63 \times 9.8 \times cos10)$$
$$Fw = 23.72N$$

Torque,

$$T = Fw$$
$$= 23.72 \times 0.030$$
$$T = 0.7116Nm$$

We are using two motors, hence torque per motor is,

$$T = 0.3558Nm$$
$$T = 0.3558 \times 10.1971621298kgcm$$
$$T = 3.628kg.$$

IV Control Algorithm

The position control of wheels is achieved using position sensors attached to the stepper motor of wheels. Dead Reckoning is used for determining the position. On a laptop the movement of robot is traced using a graphical user interface (GUI). Seven ultrasonic sensors are used for obstacle detection. The controller used is a 40 pin arduino board. Fuzzy control is implied. Firstly the robot starts filling area by raster scanning. During this motion whenever a obstacle is faced by the robot a line appears on the GUI at that location. The area filled also appears on the screen.

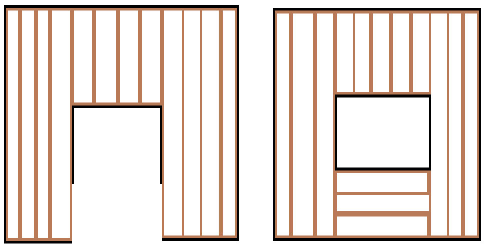

Fig. 3 Area filling algorithm

Fig 3 shows the area filling algorithm used.The black line represents the obstacle whereas the brown rectangles show the area traversed by the robot. In the first figure the area covered by the robot is shown by the simple logic of 180 degree turn after detection of obstacle. After this as the black lines of obstacle does not complete a loop this shows that the area is not completely filled. Hence the robot searches for another boundary in order to complete the loop of black line without re-traversing the covered area. When the line of obstacles forms a complete loop this shows that the area is filled this is shown in second part of the figure. This method ensures that the area is completely filled and does not require any indoor navigation system and hence is a cheaper alternative for area filling.

V Conclusion

In this paper design and development of Floor Mopping Robot is discussed. Proposed hardware eliminates the need of vacuum pump for used water collection. Also the technique of water collection is mechanically efficient and cheaper. The area filling algorithm used does not require any navigation system and ensures complete filling of area. The cost of floor mops is significantly reduced to less than 50% of the currently available mops in the market. The estimated cost of equipment is INR 7000.

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