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Research Article

Design of Automated Robot for Line Marking on a Sports Field

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Abstract

Unlike advanced countries which have different sports fields for different sports activities in schools, colleges, etc., countries like India do not have the resources to have different sports fields for different types of sports. The tedious activity of marking a field with the help of limestone material is done manually. Thus an automated robot would reduce human efforts and increase the accuracy and efficiency of the whole process. In this work, the machine described is an Automated Robot for Line Marking (ARFLM), a machine that is capable of marking a sports field with the help of limestone material completely automatically. This would eliminate the tedious and time consuming conventional method of line marking manually thus reducing human efforts and increasing the quality of the marking of the sports field. The machine is designed to travel along the path of the field (as provided by a computer program). Further, a mechanism for the smooth and continuous release of the limestone marking material is described.

Keywords: *Automated Robot, Line Marking, Sports field, Limestone Material, Arduino.*

1. Introduction

The Automated Robot for Line Marking is an effective machine that would make the process of line marking more efficient, faster and much easier for humans. Because of the nature of the material (limestone), it is usually marked manually with bare hands with the help of rudimentary methods for precision such as the use of ropes for straight lines. Though these methods may suffice for immediate need, they may be highly inaccurate and require lots of man power and time. Though there exists mechanism which help in marking the line in case of paints however, presently there is no mechanism which helps in effectively marking sports fields for such cases (limestone marking).This process is completely automated and the robot would make a field upon inputting the dimensions only. This system consists of a main frame, made of aluminium, a mechanism for drive and a mechanism for release of the material.The drive is a differential drive and consists of a PID controller program, an Arduino and feedback is provided by optical encoders for desired motion. The release mechanism consists of a belt type conveyer and a funnel. Material flows on the conveyer and is directed in the funnel at a desired rate. The conveyer is controlled by servo motors. The complete robot is controlled by Arduino and all drive and release mechanism is synchronized in a program.

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Previous attempts include the robots that have been made for painting fields. These include the 'Intelligent One' which comes at approximate cost of Rs 80000. The challenges faced by a robot marking a mud field are different considering those that are faced by one painting a grass field or an astroturf. A mud field has substantially greater number of obstacles and the terrain is highly unlikely to provide any kind of stability to the robot so as to give gain the desired motion so as to mark an accurate sports field. Thus the project includes a lot of trials in the drive and the tracking of the robot in the plane of the field.

2. Release and Drive Mechanism Design

2.1 Release Mechanism

The funnel was designed after trials and an angle of 45 degrees was finalized for the funnel. The release of the material presented various challenges as the material has a low flow coefficient and the Limestone material would get stuck if put in the funnel directly. Thus a release mechanism using a conveyer belt to convey the limestone material to the funnel was designed, a schematic is shown in the figure.The marking material for the ARFLM is selected as limestone powder considering the sports fields in the Indian subcontinent. It, therefore, was necessary to design a release mechanism that would ensure smooth and continuous flow of the limestone powder at a steady flow rate while avoiding building up of lumps that might completely block the marking process. The flow rate consistency would check on the thickness of the marked line on the sports field

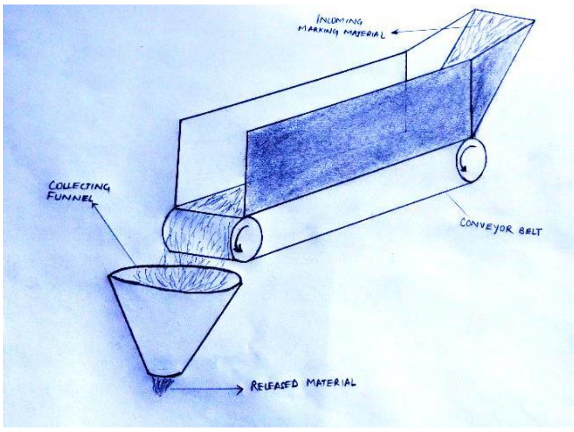

Fig.1 Schematic Representation of Release Mechanism Prototype

At the initial stage, various methods and mechanism for the release of the marking material were tested like; release through a cylinder and ram arrangement, release through a receiving funnel etc.

The cylinder and ram arrangement comprised of marking material filled inside a cylinder being pushed out by a ram further driven by a motor and pulley. The forward motion of the ram, responsible for the release of the marking material, was directly controlled by a pulley and a motor (actuated by Arduino based motor driver). The mechanism suffered with the problems of inadequate and discontinuous flow of the marking material due to the rough motion of the ram in the cylinder caused by the marking material itself.

It is found that the mechanism finalized provides the material at the right flow rate to the funnel resulting in a uniform marked line.

2.2 Drive Mechanism

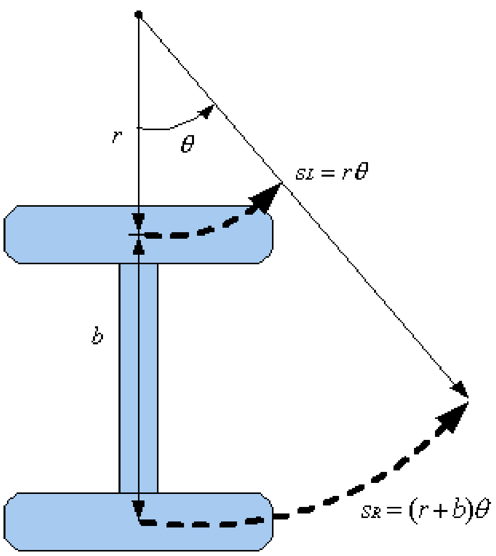

Fig. 2 Rotation of Differential Drive

The differential steered drive system is the same as used in a wheel chair. If both wheels turn simultaneously, the robot moves in a straight line. If one wheel rotates faster, the robot follows a round path towards the slower wheel. If the wheels turn in equal and opposite directions, the robot pivots. Thus, the path travelled by the robot is dependent on the speeds and the directions of rotation of the wheels. The following mathematical expression can be used for implementing a robot control software.

$$s_L = r\theta$$
$$s_R = (r+b)\theta$$
$$s_M = (r+b/2)\theta$$

Consider the x and y coordinates (and orientation) which change with respect to time. For a given instant, the x and y coordinates of the robot's center point change based on its speed and orientation. Orientation is treated as an angle θ measured in radians, counter-clockwise from the x-axis. The vector giving the direction of forward motion for the robot will be $(\cos\theta, \sin\theta)$. The x and y coordinates for the robot's center point will change depending on the speed of its motion along that vector.

Taking $m(t)$ and $\theta(t)$ as time-dependent functions for the robot's speed and orientation, the solution will be in the form:

$$dx/dt = m(t)\cos(\theta(t)),$$
$$dy/dt = m(t)\sin(\theta(t)) \quad [1]$$

The point, taken as reference, is the center point of the left wheel. All motion in this frame of reference are treated relative to the left-wheel point. As the right wheel is mounted perpendicular to the axle, it will follow a circular arc having a radius equal to the length of the axle. The central point itself could be in motion. Hence the actual path of the right wheel will not exactly correspond to that specific circular arc. As we are treating the robot as a rigid body, all points in the system must undergo the same change of orientation. If we pivot the robot 10 degrees, all points undergo through a 10 degree change in orientation. Based on this, a differential equation describing the change in orientation as w.r.t time. The relative velocity of the right wheel gives us that length of arc per unit time. The distance between the wheel and the centre point is equal to the radius. Therefore we get:

$$d\theta/dt = (v_R - v_L)/b \quad [2]$$

Integrating [2] and taking the initial orientation of the robot $\theta(0) = \theta_0$, a function for calculating the robot's orientation as a function of wheel velocity and time is written :

$$\theta(t) = (v_R - v_L)t / b + \theta_0 \quad [3]$$

This change in orientation is applicable to the absolute frame of reference. The robot's overall motion rests on the the velocity of its center point which is average of that for the two wheels, or $(v_R + v_L) / 2$. The following equations are obtained after substituting this velocity,

$$dx/dt = [(v_R + v_L) / 2] \cos(\theta(t))$$
$$dy/dt = [(v_R + v_L) / 2] \sin(\theta(t)) \quad [4]$$

The equations [4] are in the same form as the equation [1]. Integrating and applying the initial position of the robot $x(0) = x_0, y(0) = y_0$, we have

$$x(t) = x_0 + \frac{b(v_R + v_L)}{2(v_R - v_L)}\left[\sin((v_R - v_L)t / b + \theta_0) - \right.$$
$$y(t) = y_0 - \frac{b(v_R + v_L)}{2(v_R - v_L)}\left[\cos((v_R - v_L)t / b + \theta_0) - \right. \quad [5]$$

The equations in [5] affirm that when the wheels of the robot rotate at fixed velocities, the robot travels along a circular trajectory. The term $(b / 2)(v_R + v_L) / (v_R - v_L)$ is the radius of turn for circular path of the robot's center.

Table 1 Specifications

Item no	Item	Specifications
1	DC Motor	Torque 32 Ncm
2	Wheel	Diameter 15 cm
3	Motor Driver	15A
4	Controller	Arduino Uno
5	Battery	LiPo 5000 mAh

Conclusion

The release mechanism has been tested and works at a desired quality necessary or the marking of a uniform line. The drive mechanism is adequate and needs refining in order to make it fully proof against the obstacles that it would face on a highly uneven terrain.

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