Chapter 1

1 Introduction

Manipulation of an object when it is moving from one place to another is one basic task of a robot. With some flexible manipulators the object can be gripped. picked up and placed at any required position. When the object is too large. too heavy or complex to be gripped this method can no longer be utilized to move an object. Hence any sort of a nonprehensile manipulation has to be used. Pushing is a very much suitable alternative in this type of situation. It does not require a special grasping tool. manipulator to lift and support the work pieces.

There are several issues needed to be considered when an object is been pushed by a mobile robot (MR). Some of those factors are listed below.

- Shape of the object
- The properties of the terrain which the object is being pushed.
- Friction between the terrain and the object
- Friction between the terrain and the mobile robot.

The object consist of a surface which does not get stuck on the floor while it is pushing. If the object gets stuck on the floor there is a necessity of applying a considerable large force on the object either to take it out of the place where it stucks or turn the object around that point.

The amount of the object that is sunk into the terrain is also very important. This is depending on the properties of the terrain and the weight of the object. If the terrain is having low dense soil or material it is hard to push the object. The movement of the mobile robot also becomes difficult in this type of terrains. The inclination of the terrain to the horizontal plane of the earth is also a very important factor. If the object is moving on a surface which climbs up, it is hard to push the object. On the other hand it is easy to push an object downwards. But the object is having a tendency to roll down along the terrain at this instance. If rolling occurs it is hard to monitor the object. So it becomes complex and have to use sensors to monitor the object.

This property of the terrain also leads to the friction force between the terrain and the object and that of the terrain and the mobile robot. Moving an object along a smooth surface needs less force than on a rough surface. Since the friction force between the terrain and the robot also changes with the roughness of the terrain slipping may occur on the wheels of the mobile robot.

1.1 Objective

When an object needs to be moved by pushing, there are lots of factors needed to be considered. One factor is the shape of the object. Another factor is the center of friction (COF) of the object that has to be moved. If we can identify the COF of the object we need to apply the force through a line which passes through the COF. If the terrain is homogeneous, the shape of the object is symmetrical and having equal density throughout the object, it is easy to find the COF of the object using image processing techniques. But it is very difficult to find the COF if the object and terrain does not satisfy the above properties.

The objective of this research is to push any shaped object which can be pushed on a terrain, with approximately equal torque on both left and right side motors of the mobile robot. This condition occurs when the COF of the pushing object lies on the symmetrical plane of the MR. The pulse width modulated waveforms used to drive the servo motors and the output of the optical encoder attached to the wheels are the only parameters used to achieve the above task. Only the torque exerted on each motor is used to find the force applied on the object and the output of the optical encoder attached to each wheels is used to get the distance travelled by each wheel. The combination of maximum motor driving torque of each wheel and the moving distance of each wheel is used to get the force applied on the object.

1.2 System Design

The MR base is constructed with a 1cm thick fiber platter. Two caster wheels are attached as the front wheels and two other wheels attached with Futaba servo motors are fixed as the back of the above mentioned platter. Two encoder wheels are attached to both driving wheels. Photo reflector ICs attached to the base, close to the wheel encoder are used to read the encoder pulses generated by white color grooves on the black color encoder wheel. A 30cmX12cm plate made out of MDF board is attached in front. This plate acts as a pushing bar. Controlling the two DC servo motors and reading the encoder pulses are the main tasks of the main controller circuit specially designed for this MR.

1.3 Background of Previous Research

In 1986 Mason[1] first presented research results on pushing a solid object by a manipulator. In his research he analyzed the mechanics of quasi-static pushing operations. This analysis showed the algorithm to determine the rotation direction (clockwise, counter clockwise) of a pushed object, when the pressure distribution is unknown. He showed that the moving object by actively pushing with a manipulator is also flexible and mechanically less complex than pick- and-place, for planer positioning. This process does not require a special grasping tool and the manipulation lift is also not a must. In 1998 Brost[2] utilized the results of Mason[1] to develop an analysis of grasping action with parallel jaw grippers. He analyzed the possible motion of an object being pushed by a fence to obtain the Push Stability Diagram too. Mani and Wilson[3] used the Mason's rules to derive an Edge Stability Map which was used to orient polygonal objects. Peshkin and Sanderson [4][5] extended this analysis of pushing by attempting to solve the motion of the pushed object completely. The pushing operation has been utilized in many applications after these results obtained through the previous researches. Akella and Mason [6][7] studied the use of pushing action to move any polygonal object from any initial configuration to any final configuration. Lynch et. al.[8] studied the problem of transferring a part from one state to another using nonprehensile manipulation. This research includes the quasistatic nonprehensile manipulation and the dynamic nonprehensile manipulation. Agarwal,et. al. [9] considered the path-planning problem for a robot pushing a unit disk with point contact in an obstacle free environment. Besides these open-loop designs of pushing operation series, many researchers have studied the feedback control of the object pushed by robots. Takagi et. al. [10] took the rule-based control scheme to control a mobile robot pushing a box, based on their analysis of the moving equations of the robot and box. Okawa et. al. [11] resolved the same problem with the goal seeking strategy for robot's motor control. Lynch and Kevin [12] developed a control system to translate and orient objects using tactile feedback with the derived motion equations of the pushed objects.

1.4 Outline of Thesis

The remaining part of the thesis is made up as follows.

Chapter 2 deals with the basic requirements and theories needed to be considered when an object is under push. This chapter describes the different types of frictional forces and force diagram of the object. Chapter 3 contains the details of the new technique used to find the center of friction of an object (COF) using the motor driving parameters and encoder output of the MR. It also describes the mechanism of getting the object to the middle of the pushing plate attached to the MR. Chapter 4 deals with the development of MR. This chapter contains all the technical details of each and every part used to develop the MR. The new method of driving 50Hz PWM controlled dc servo motors using the 250Hz PWM output of a PIC microcontroller are also described in this chapter. Chapter 5 shows the result obtained in the new implementation. Chapter 6 deals with the conclusions, some suggested modifications and recommendations.