Chapter5

5 Results and Analysis

The main objective of this research is to detect the COF of the pushing object and align it to the centre of the pusher. So the object is kept in several places of the pusher, the MR operated until it detects equal measurements for both motors while it pushes the object in zigzag motion. The time taken to detect the COF of the object depends on several parameters listed below.

- Shape and mass distribution of the object.
- Friction between the terrain and the object.
- Friction between the terrain and the MR
- The amount of rotation of the pusher with the zigzag motion of the robot.
- The starting point of touch of the object with the pusher.

If the shape of the object is symmetrical and easy to push then the COF of the object comes to the centre of the pusher much quicker.

5.1 Test 1: Effect on positive PWM width and the steady state object position

Test 1 is performed using a cylindrical object made out of cement and a rectangular cuboid shaped battery. The weight of the cylindrical object is 950g and the diameter of the circular face is 15cm and the height is 9.5cm.Both cylindrical and rectangular cuboid shaped objects were kept at different positions of the pusher at the starting of the MR movement. The Figures 5-1 to Figure 5-6 shows the variation of final PWM positive width value of the robot motors in zigzag motion when the first touching point of the cylindrical object varies along the pusher. In all the charts we can see that the robot is trying to make both motor driving duty cycles to an equal value. As we know that only when the pushing force is applied from equal distances away from the center of the pusher, it creates equal force in both side movements of the robot. So it is clear that the force created by the two motors become equal. So the firmware for the robot is developed to stop its movement once it detects same positive widths for both motors. Then the touching positions of the object and the pusher is measured using a ruler attached to the pusher.

It can be clearly seen that when the weight of the object changes, then the PWM positive width also changes accordingly. When the object is close to the edge of pusher, the motor attached to that side needs a considerably higher torque to drive the motor. So the positive pulse width becomes higher than the positive pulse width of the other side motor. This is a very good indication to prove the concept that is going to be examined in this research.

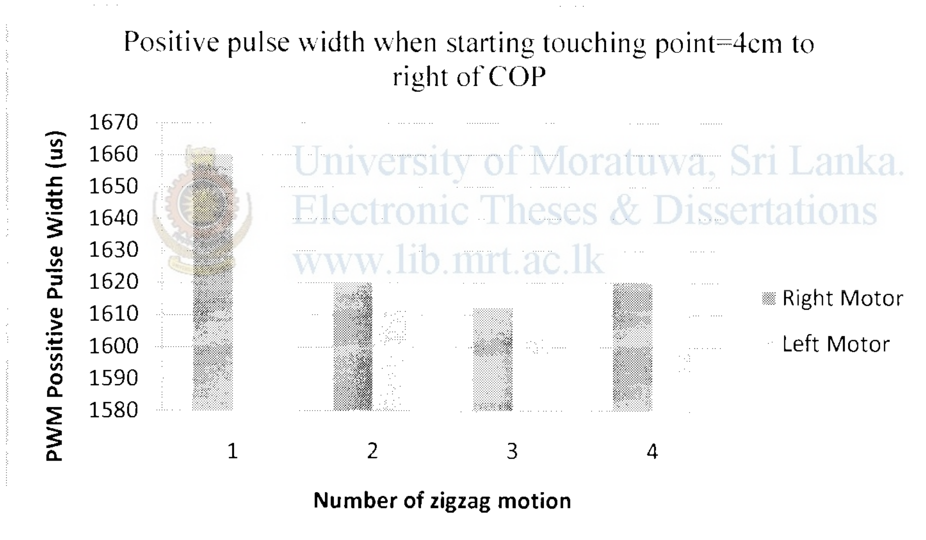

Figure 5-1: Motor driving positive width when the object is kept 4 cm to the right of the COP

Figure 5-1 shows the positive width variation of the zigzag motion when the cylindrical object touches the pusher on the left hand side. The initial touching point is 4cm from the left edge of the pusher. At the first pushing the object might not touch the pusher well and hence sudden impact occurs between the pusher and the object. This might lead to higher positive width to drive the motor.

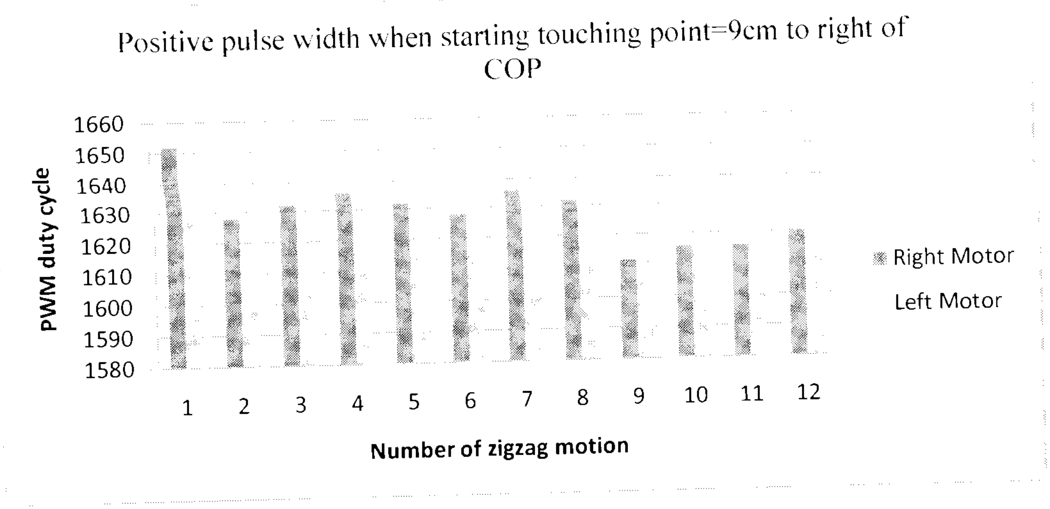

Figure 5-2: Motor driving positive width when the object is kept 9 cm to the right of the COP

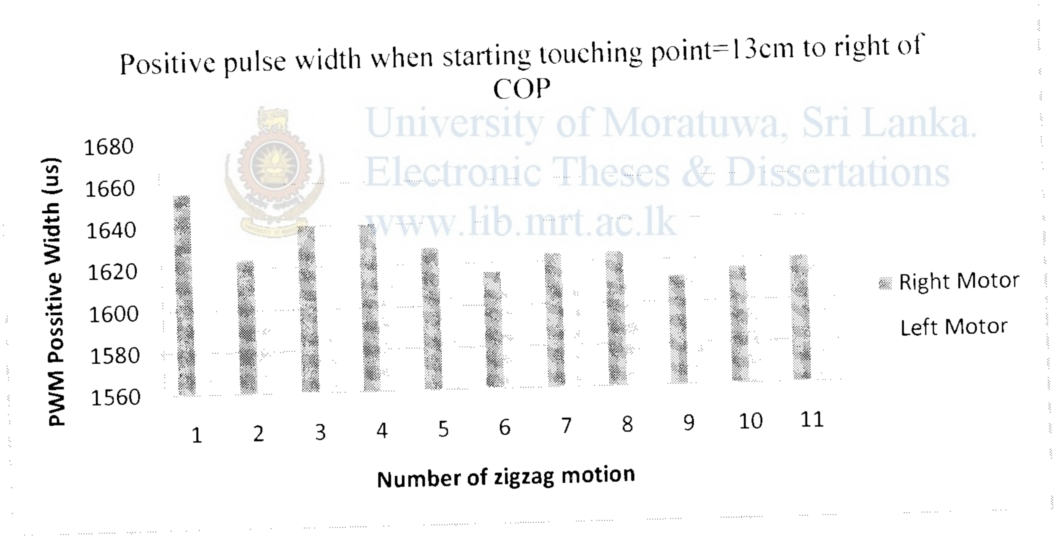

Figure 5-3: Motor driving positive width when the object is kept 13 cm to the right of the COP

Figure 5.3 shows the positive width variation when the first contact point of the pusher and the object is 13cm to the right of the centre of the pusher. It can be clearly observed that the positive pulse width of the right side motor movement is very much higher than that of the left motor at the beginning of the movement. This is because the object touches the pusher at the right corner of the pusher and the right motor has to push the object a long distance. So it will take more time to push the object and hence the motor creates much higher torque. Because of the zigzag movement the object comes towards the pusher and hence difference of the positive widths of both motors becomes less.

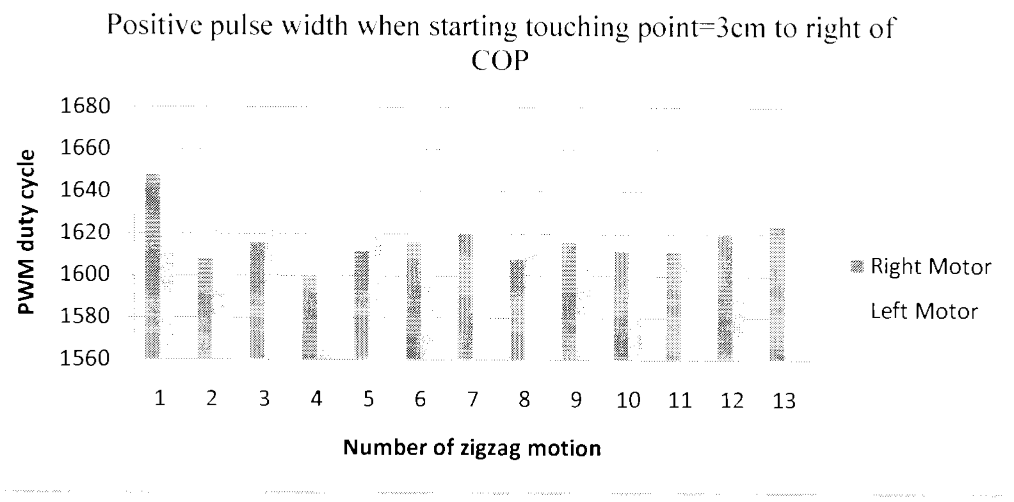

Figure 5-4: Motor driving positive width when the object is kept 3cm to the right of the COP

If the object is kept close to the centre of the pusher as shown in figure 5-4 the motor driving positive width difference of both left and right motors is not very high at the starting of the movement.

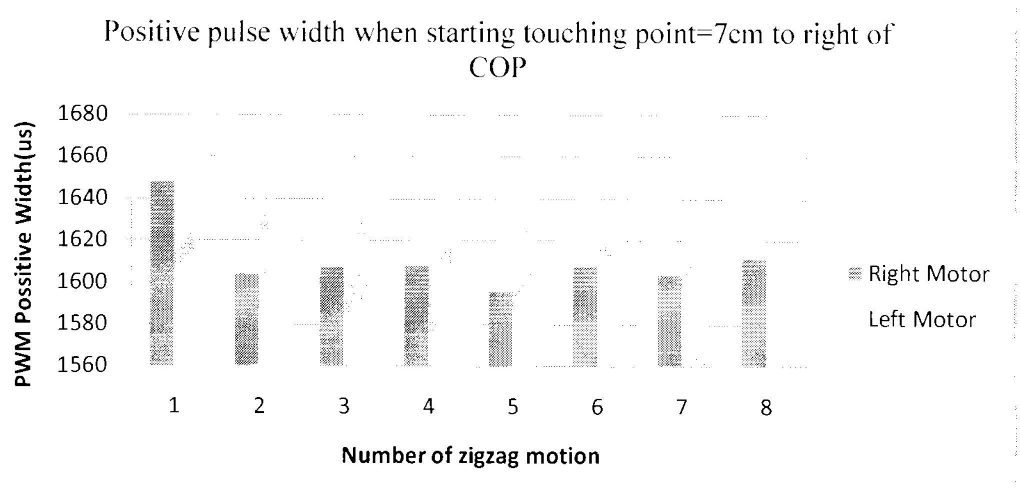

Figure 5-5: Motor driving positive width when the object is kept 7cm to the right of the COP

Though the object kept at different distances from the centre of the pusher the motor driving positive width might not show significant difference at the starting. This is due to the initial touching point of the object and the pusher. At some orientations of the pusher and the object the pusher might turn the object and will not push the object very much. Turning around the COF needs less force than pushing through the COF. So motor torque needed to turn an object is less than the torque needsed to push an object through the COF. In some of these results this phenomenon can be observed.

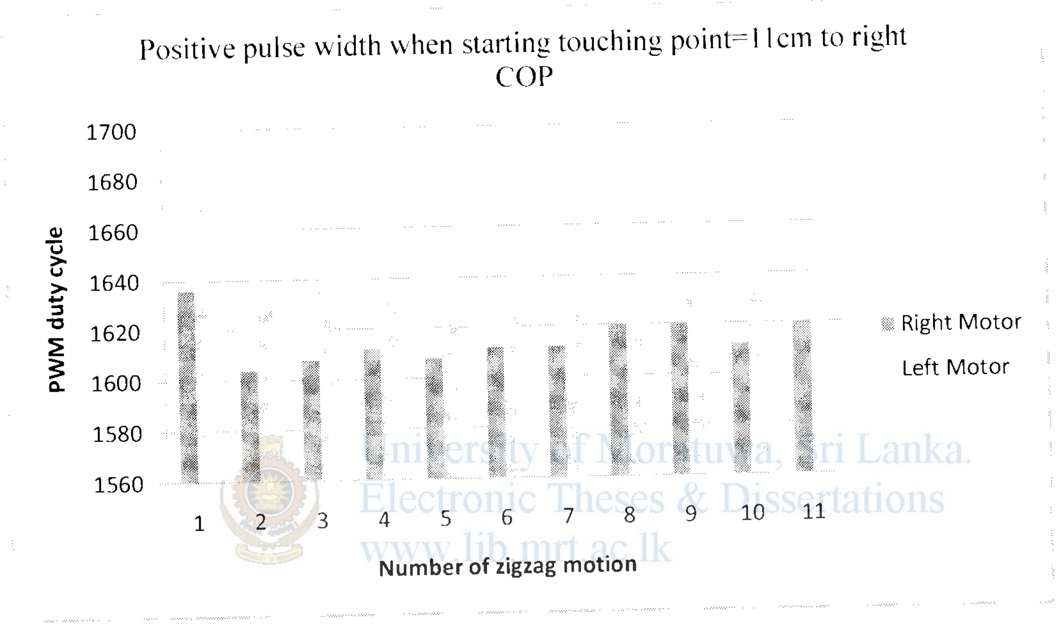

Figure 5-6:Motor driving positive width when the object is kept 11cm to the right of the COP

It can be clearly seen that when the object is kept at the left side of the pusher the left motor needs more torque than the right and vice versa. Hence

Figure 5.7 and 5.8 shows the measurements of the final touching point deviation from the centre of the pusher when both motor driving duty cycles become equal for cylindrical and rectangular cuboid shaped objects respectively. The starting touching point of the object varies along the pusher to get several final touching points

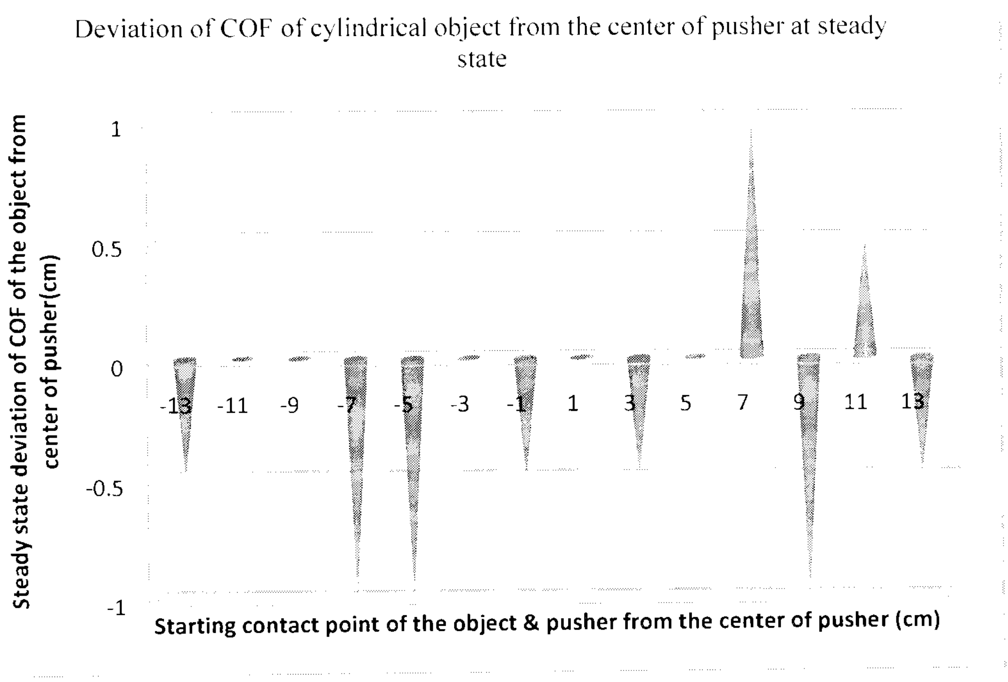

Figure 5-7: Deviation of the COF of a cylindrical shaped object from the center of pusher at steady state.

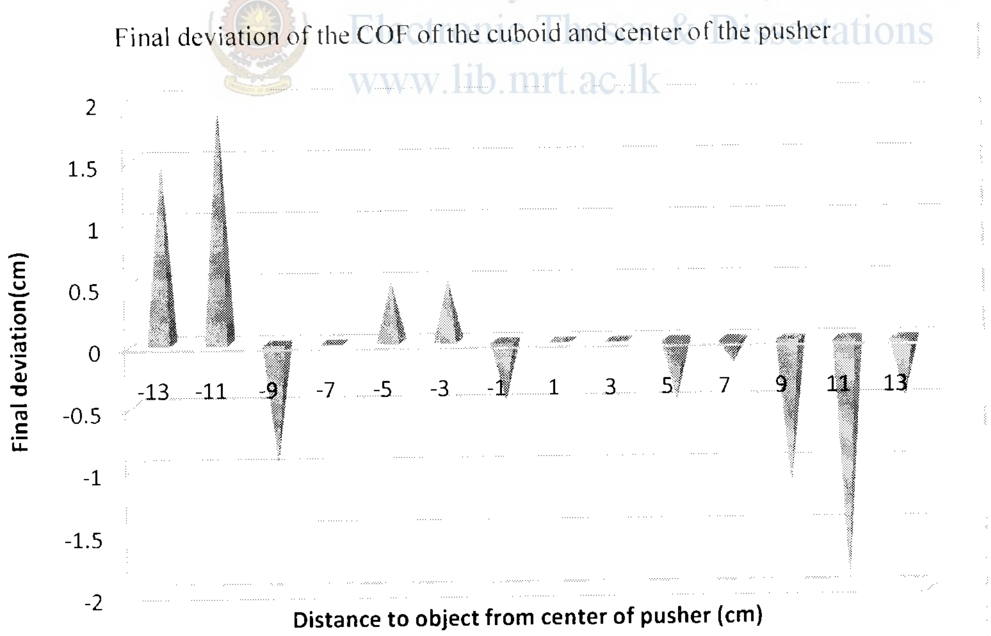

Figure 5-8: Deviation of the COF of a rectangular cuboid shaped object from the center of the pusher at steady state.

For the cylindrical object the maximum deviation of the real centre of friction of the object and the centre of the pusher is in ±1 cm. The above mentioned deviation for the rectangular cuboid is in ±2cm .So it is clear that this method can be effectively used to find the centre of friction of an object.Instead of the above feature this zigzag motion is a very effective method to move any shaped object to the centre of the pusher. This will help to keep the pushing object close to the centre of the pusher all the time that the robot pushes the object.

5.2 Test 2: Effect on the terrain and weight of the object

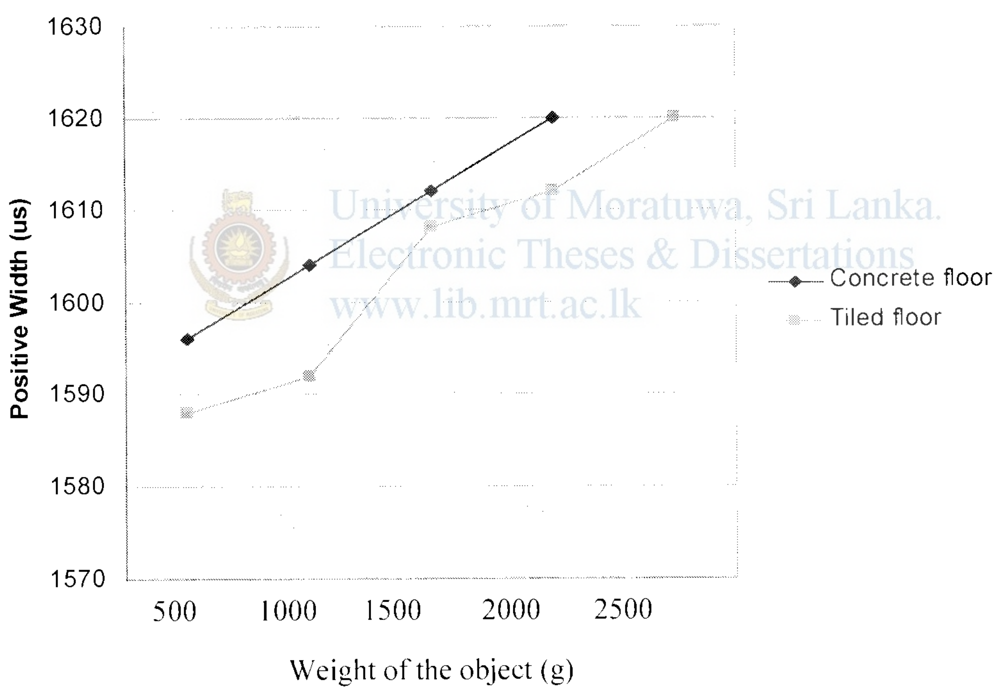

Figure 5-9: The effect on positive pulse width when the weight of the object changed

The second test was performed to find the effect on the positive width of the PWM value when the weight of the object is changed. This test was done for both tiled floor and a concrete floor. A five liter water bottle was used as the object in this test. This bottle was filled with 500ml of water and the first test performed in a tiled floor and got the PWM width at the force balance state. The same test was done by adding 500ml extra water each and every time and got the readings. Figure 5-9 shows the result of the above test. It is difficult to go for higher weights with the existing MR. When the weight increases the wheels start to slip and hence it is hard to go for higher weights. On a concrete floor the result is very much linear than on a tiled floor. This is because the MR may slip on a tiled floor. This slipping may cause an error on the result.

Figure 5-10 shows how the mobile robot pushes the piece of granite with an odd shape. The positive width values of each and every movement of the robot are shown under the images. Here the robot has turned due to the slip. Though it is turned it has no effect on the final result. Finally the object and the pusher got aligned and the positive width values become equal.

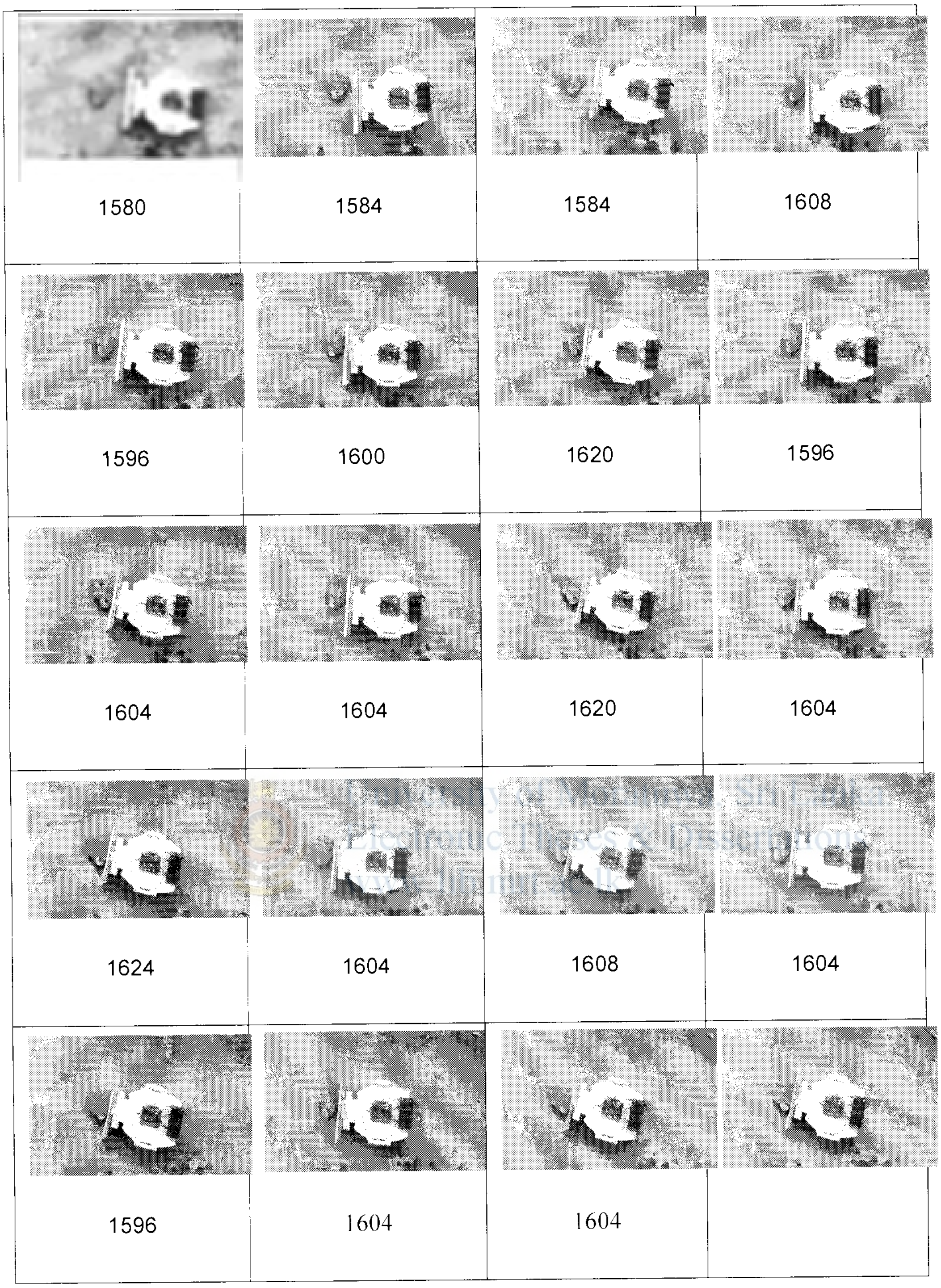

Figure 5-10 Robot pushing a piece of granite