Design and Development of Mopping Robot—‘HotBot’

M. R. Khan¹, N. M. L. Huq, M. M. Billah, S. M. Ahmmad
Department of Mechatronics Engineering, Kulliyah of Engineering, International Islamic University Malaysia, Jalan Gombak, Kuala Lumpur – 53100, Malaysia.

E-mail: raisuddin@iium.edu.my

Abstract. To have a healthy, comfortable, and fresh civilized life we need to do some unhealthy households. Cleaning the dirty floor with a mop is one of the most disgusting and scary house hold jobs. Mopping robots are a solution of such problem. However, these robots are still on the way to be smart enough. Many points limit their efficiency, i.e. cleaning sticky dirt, having dry floor after cleaning, monitoring, cost etc. ‘HotBot’ is a mopping robot that can clean dirty floor with nice efficiency leaving no sticky dirt. Hot water can be used for heavy stains or normal water for usual situation and economy. It needs neither to be monitored during mopping nor to wipe the floor after it. ‘HotBot’ has sensors to detect obstacles and a control mechanism to avoid those. Moreover, it cleans sequentially and equipped with several accident-protection-systems. Moreover, it is also cost effective compared to the robots available so far.

1. Introduction
Throughout the years, many engineering applications and devices has made our lives easier and more comfortable. Although devices such as washing machines and dishwashers have served this purpose, it still requires some degree of human input. In developing a cleaning robot, there are several challenges that one has to confront, i.e. the method of cleaning, path planning, covering the whole floor, cleaning the sticky dirt, cleaning it completely, leaving a dry floor behind, maintenance so on and so forth. It becomes even more complicated when safety, economy, energy consumption are considered to be in optimum level. Moreover, making it acceptable socially becomes the highest challenge especially when it is a new product.

The development of cleaning robots started almost three decades before [1]. Since then several industries came out with different ideas of cleaning robots and got popularities in developed countries and a try to make these robots acceptable at home continued. The early age was focused on the development and optimization of these robots. Hofner, C., and Schmidt, G. (1995) [2] used 2D map and kinematic and geometric robot model for a cleaning path planning. At the same time in another research Horn, J., and Schmidt, G. (1995) [3] described a localization system for mobile robots. The position and orientation was determined through a 3D-laser-range-image by comparing it to a 3D-environment model. For the autonomy of a mobile robot, it should know about its working region. Thus, a model of the environment is very much useful for it. So, Magin, G., Ruß, A., Burschka, D., and Färber, G. (1995) [4] developed a dynamic 3D model of the environment using computer graphics.

¹ To whom any correspondence should be addressed.
and data base technology. Besides the modelling and mapping of the environment the control over movement is equally important for a mobile robot. Palacin, J., Salse, J. A., Valganon, I., and Clua, X. (2004) [5] built a mobile robot for floor cleaning considering motor control, robot control, safety etc. They concluded that the robot cleaning process must be isolated from the human beings, which are due to interruption in its environment. In case of having no map of the workspace for the robot, it is very difficult for it to work and decide according to Magin, G. et al. [4]. Moreover, crowded area is even more difficult to work in, as stated by [5]. For such conditions Jansri, A., Klomkarn, K., and Sooraksa, P. (2004) [6] developed and simulated several chaotic patterns for robots path and compared the performance of the robots. Martins-Filho, L. S., and Macau, E. E. (2007) [7] studied the robots and their dynamic features of chaotic system and proposed a planning for robots that those robots should be introduced to the chaotic motion behavior by a planner goal position sequence.

The above developments took place in the technical sides of the cleaning robots. Meanwhile some researchers were engaged in analysing the acceptance level of these robots in society. Jodi Forlizzi, J., & DiSalvo, C. (2006) [8] worked on the effect of the design on human-robot interaction at home and found that the acceptability of these robots to the society varies according to their introduction to the family but it is mostly welcomed. Several other works had been carried out on social effects and acceptability of these robots in home. Sung, J. Y., Grinter, R. E., Christensen, H. I., & Guo, L. (2008) [9] found that most of the robot users for both sex are almost equal in percentage and are educated with technical background and they are mostly young. These robots are also considered to be working in public places of organizations where robot-human interaction is even more critical. Thus, their design and function plays a vital role to help the situation [10]. Moreover, shaping of the relationship with robots at home change over time and goes through several stages like pre-adoption, adoption, adaptation, and use retention [11] and modification to the environment to support the navigation of the robot is largely accepted [12].

This project shows the implementation of the above concepts into a mobile platform that can mop a room following a pattern (not in a random path). It shows the fact that the consumption of both water and energy can be reduced if the robot is properly programmed. Saving resources is coherent with engineering practices as it is good for the environment and economy. The dimensions and user-friendliness of the mobile platform are taken into consideration.

2. Methodology
The goal of this research is to develop a user-friendly moping robot. Thus, the activities needed are to enhance desired functionality in the robot blending of different mechanisms is desirable. It helps to achieve an optimum design. The robot mechanism designing moves forward considering the various aspects of machine design, performance, and viability. Actuators, links are designed at this stage. For the locomotion, cleaning, avoiding obstacles, and safety of the robot, optimized motion control was achieved through designing, analysing, and modifying the algorithm. In order to have proper locomotion and functionality a controller was designed according to the algorithm, considering as many exceptional and accidental cases as possible. Finally, the robot was fabricated to with proper functionality, which is consistent with the design of the controller.

3. Development
The development of the robot started with two main goals. Firstly, the product should be hassle free, and secondly, it should be economical. With these aims in front, the materials are chosen and design was made.

3.1. Hardware
The main body of the robot is cylindrical in shape with a diameter of 375mm and is made of tin sheet of thickness 1mm at the sides and top and bottom are made of acrylic plates of thickness 3mm. The bottom was reinforced by a 375×75×4mm³ aluminium plate to sustain the weights of the equipment inside. The robot is about 250mm high from the ground.

Two individually motor powered wheels accomplish the movement of the robot. There is one supporting wheel at front of the robot. The front wheel also can adjust the front height of the robot using a dc motor-screw attachment. The front height determines the amount of pressure applied on the floor by the mopping roller. The mopping roller is powered by a dc motor with speed reduction gear set and the whole set is clamped beneath the base platform of the robot. The roller is equipped with a cloth to wipe away the dirt and water from the floor. A hot water nozzle is placed at the front of the robot at a height of 193mm from the ground that spray water from the water tank with the help of a centrifugal pump. A complete perspective view of the ‘HotBot’ is shown in Figure 1.

![Image of hardware components](image)

**Figure 1**: Hardware of the Robot: (a) front perspective view of ‘HotBot’, (b) wheel motor, (c) pump, (d) roller motor, (e) controller circuit, (f) battery, (g) roller, (h) rear perspective view of ‘HotBot’.

The energy source of the robot is a maintenance free sealed lead acid battery with a rating of 7.2Ah and voltage of 12V, as all the electrical equipment used inside require 12V to run. A microcontroller is used to run the control program and to control the operation sequence. A summarized configuration is shown in Table 1.

| Specification       | Use                        |
|---------------------|----------------------------|
| Wheel Motor         | 12 volt, 85 rpm, 2.95 N.m torque. Used to move the robot. |
| Water Pump          | 12 volt, 2200 ml/min delivery. Used to spray the water. |
| Roller Motor        | 12 volt, 26 rpm, 2.1 N.m torque. Used to rotate the cleaning roller. |
| Battery             | 12 volt, 7.2 Ah, 2.1 initial current. Used as the main source of energy. |

### 3.2. Software

Behavioral approaches are used to autonomously operate and control the mopping robot. ‘HotBot’ control software is designed using the MPLAB IDE. The algorithm shown figure 2 relates the actors responsible for the autonomous movement with the robot peripheral elements by means of the sequence of events performed by each actor. The algorithm is implemented for studying the robot
structure by attributes and relationships among. Finally, the algorithm is generated to visualize where the different system components are distributed among the hardware devices.

Table 2. The working principles of Behavioral approaches are discussed with the following algorithms.

| Use of the function | Description |
|---------------------|-------------|
| Moving ( ):         | It is the behavior for the moving of the robot from one place to another. By moving around, the robot is used the roller to wipe the place. |
| Avoidance ( ):      | It is the behavior to avoid obstacles such as walls, objects, etc. It uses sensors to detect obstacles and keeping data into the mop model. |
| Timer ( ):          | The behavior bounds the mopping time. |
| ObstacleDir( ):     | It is the behavior to search for obstacle direction for determining to find the moving way. |
| DistanceMeasure( ): | It is the behavior to spray water for cleaning the place by detecting no obstacle. |

Figure 2: Flow-chart of working sequence.

4. Features
‘HotBot’ needs list attention during its operation. Starting from a particular home position it continues throughout the room or space to be cleaned and cleans sequentially. It can detect obstacles as well as falls, stairs, or holes and avoid accordingly. After being started ‘HotBot’ initially checks all its prerequisite conditions and then starts working. If any of the parameters, such as water level, battery charge level, water temperature etc., is in abnormal state it gives signal associated with that parameter. Using the hot water spray system it can remove sticky dirt with less amount of water that helps keeping the floor almost dry after the process is over. A user can choose between the optimum mood and the economy mode to operate. The optimum mode is for usual operation and gives fine cleaning. On the other hand, economy mode can be used for light dirt and can be used to save energy.

5. Results and Discussions
At the beginning, the user needs to plug in the robot to start the heating of water. After reaching to the optimum temperature, the heater will stop automatically and give a signal to unplug the robot. If the
water level is low, it will give corresponding signal to the user to refill the water pot. Then the user
needs to press the start button and the set the time for the robot to work and the user is done.
Afterwards the robot will check its initial conditions and start operating according to the instruction
given in the controller. At the end of the process, i.e. when the timer ends the robot will go back to its
initial position. The robot uses simple program and equipments (optical sensors) to avoid obstacles for
cleaning. According to the information provided for the capacity of the robot to clean, the user has to
set the timer and thus the robot will continue cleaning. It will maintain a continuous communication
with the base sensor during this time and will understand its position. In case of obstacle, it just moves
to the sensor that shows no obstacle or turns around.

From the inspection, the robot can clean sticky dirt from the floor. In this operation robot uses hot
water to clean dirt. Figure 3 shows the implementation of the mopping application algorithm with
‘HotBot’. The place shown in the Figure 3 is very dirty. However, at key points, the robot does show
the behavioural approaches to clean the place and perform obstacle avoidance navigation. The robot
starts its navigation by spraying hot water from its start position as shown in Figure 3(a). Figure 3(b)
shows that the robot performs its navigation and keeps cleaning the place, shown in Figure 3(c). The
robot measures distance once it finds any obstacle as shown in Figure 3(d) and it applies obstacle
avoidance algorithm to perform smooth navigation, Figure 3(e). At this moment of obstacle avoidance
robot does not perform water spraying and roller movement. Once it is free from obstacle, it again
starts cleaning. Finally, robot come to its home position as shown in Figure 3(f) once it run out of time
that is set by the user. In this operation, hot water is not only helps to clean the sticky dirt but also it
consumes more energy than the normal operation. It consumes approximately 42W and with the
energy source supplied can run for 1.25 hours. The robot has an average speed of 8.5 m/min and the
mopping roller has a length of 21 cm. Thus, the robot is capable of wiping approximately 14 m² (as a
standard room) in 10 minutes.

![Figure 3: Robot in operation: (a) Start position (b) Navigation (c) Mopping (d) Obstacle measurement (e) Obstacle avoidance (f) End position.](image)

6. Conclusion
The technology that helps us in our daily life with a minimum human assistance is one of the most
expected and useful one. ‘HotBot’ gives almost the output as expected. From visual observations, it
served with adequate efficiency on several occasions. It cleans heavy stains, leaves almost dry floor,
and can do it quick. On the other hand, ‘HotBot’ has several safety equipments to avoid obstacles,
holes, and stairs, to prevent accident or malfunction at low water level, low battery, or low water temperature. In such cases, it gives necessary signals and stops the function that may cause harm to it. It is capable of working in power and economy moods.

Despite of having several positive features, it requires more modification for more optimistic outcome. The cleanliness was not measured based on any scientific method but visual inspection. The structure can be made more attractive for better acceptance at home or office environments. Heating system is dependent on AC power supply and unfavorable for battery, especially for long operation and cost effectiveness. The mopping roller replacement is not convenient once it is worn out. However, the ‘HotBot’ is capable of proving itself as a good cleaning servant.

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