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***KEYNOTE***

# Mobile Robot Deployment Experiment for Mobile Mode of Mobile Monitoring System for Indonesian Volcano

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**Abstract.** Mobile robot navigation algorithm for MONICA Mobile Monitoring System for Indonesian Volcano (a new volcano monitoring system which uses WSN (Wireless Sensor Network) for sensing, processing, distributing and transmitting the data; satellite technology for remote sensing data of the volcano; and mobile robot for replacing a died sensor node in hazard condition), has been simulated and showed a satisfied result indicated by the mobile robot which has successfully navigated through the desired waypoints, while avoiding hazards from its representative terrain. In this research, we did 2 experiments to make our MERLIN (Mobile Experiment Rover for Locomotion and Intelligent Navigation) robot reaching a waypoint and avoid a hazard. The velocity was controlled to decrease at periods of large curvature and controlled to near 2.0 m/s in "safe" regions. This constant speed is a result of a mobile robot running on a high speed for such a long time (more than 8 cm for Merlin).

## 1. Introduction

Our MONICA system (Fig. 1) has been introduced to overcome some problem in seismicity monitoring of Merapi Volcano, Indonesia [1, 2, 3, 4]. This system which activates two modes for normal (fixed-mode) and emergency condition (mobile mode), consists of 10 WSNs for sensing, processing, distributing and transmitting the data; satellite technology for remote sensing data of the volcano and a mobile robot for replacing a died sensor node in hazard condition [1, 2, 3, 4].

In this situation when volcano erupting and breaks the monitoring system, the need of data measurement without human involvement for replacing the broken instrument is highly required. Therefore, we have equipped our system with a mobile robot for this purpose.

Mobile robot has been proposed to acquire data in volcano environment [5, 6, 7]. Our MERLIN (Fig. 2) has also been investigated to be deployed on volcano terrain [3]. The simulation result showed that the robot has successfully arrived at desired location while avoiding hazard in Merapi volcano location [3].

## 2. The System and Method

### 2.1 Merlin

Merlin is a car-like mobile robot (L = 0.36 m), was designed as sensor test vehicle [8] in outdoor application [8] which is uses Ackermann steering [9]. Our sensor node is suitable to be placed on Merlin because of its key design orientation which was the capabilities for a flexible integration of a board range of sensor types [8]. The sensor board is linked to main board through a CAN bus [8].

The sensor board handles both for WSN sensor node system and the signals from sensors of mobile robot itself, such as bumper, four ultrasonic ranging sensors, 3D compass, Gyro, and hall sensors (wheel encoders) [8].

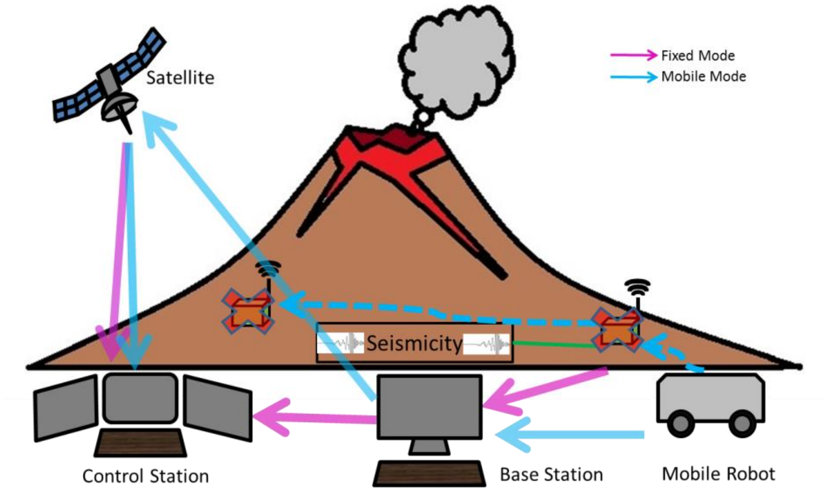


Fig. 1 MONICA system for seismicity monitoring of a volcano

The vehicle chassis is driven by two rear wheels and steered by PWM signals [8] of the 16-bit microcontroller (for low-level control, sensor interface as the core of the main board [8] and sensor processing [10]) to the drive and steering motors, respectively [8]. Not only the C167 microcontroller, but a PC-104 with Linux operating system also be used for more complex and intensive computationally task [10].

### 2.2 Mobile robot deployment

Volcano consists hazard and rough terrain which not easy to be explored by a mobile robot. For this environment, the navigation and control system of mobile robot has to capable to recognize dangerous area and to plan a path toward the specific target. The following is the algorithm for mobile robot deployment:

- Calculate the net potential field from roll over constraint, side slip constraint, desired waypoints location, desired-velocity and hazard locations [3, 11].
- Compute the gradient of the net potential field [3, 9, 11].
- Compute predicted trajectory over time [3, 11].
- Repeat all steps before while virtual time is no more than real time [3, 11].
- Compute maximum safe velocity [3, 11].
- Control velocity profile no more than maximum safe velocity [3, 11].

### 2.3 Laboratory Testing for Mobile Robot

The experimental Merlin is shown in Fig. 6. Merlin is equipped with two fronts the 16-bit microcontroller (for low-level control and sensor interface) to the drive and steering motors, respectively. The mobile robot dimensions are 0.36 x 0.25 x 0.225 m. Experiments were conducted inside a room. In each experiment, the robot initial position was the origin of the inertial frame, with initial heading aligned with the x axis [3, 11].

For the experiment, 1 waypoints was set at (x,y) = {(4.0, 0.0)}. The hazard of 0.2 m radius was set at (x,y) = {(2.5,0.0)}. The desired velocity was 2.0 m/s. This limitation does not influence the convergence behavior of the system. The target waypoint was indexed when the mobile robot moved to within 2.0 m of the start point.

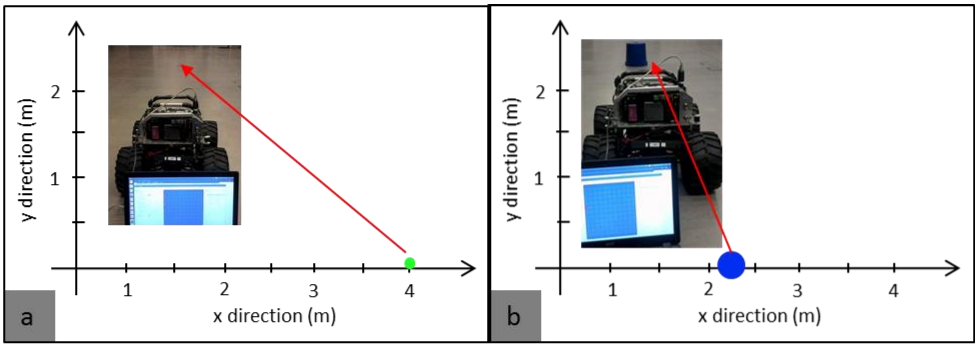


Fig. 2 Mobile robot experiments for 1 waypoint navigation (a) and 1 hazard avoidance (b)

## 3. Result and Discussion

### 3.1 Mobile Robot laboratory testing result

The experimental result is shown in Fig. 7. The mobile robot successfully navigated to the waypoint and avoided hazard.

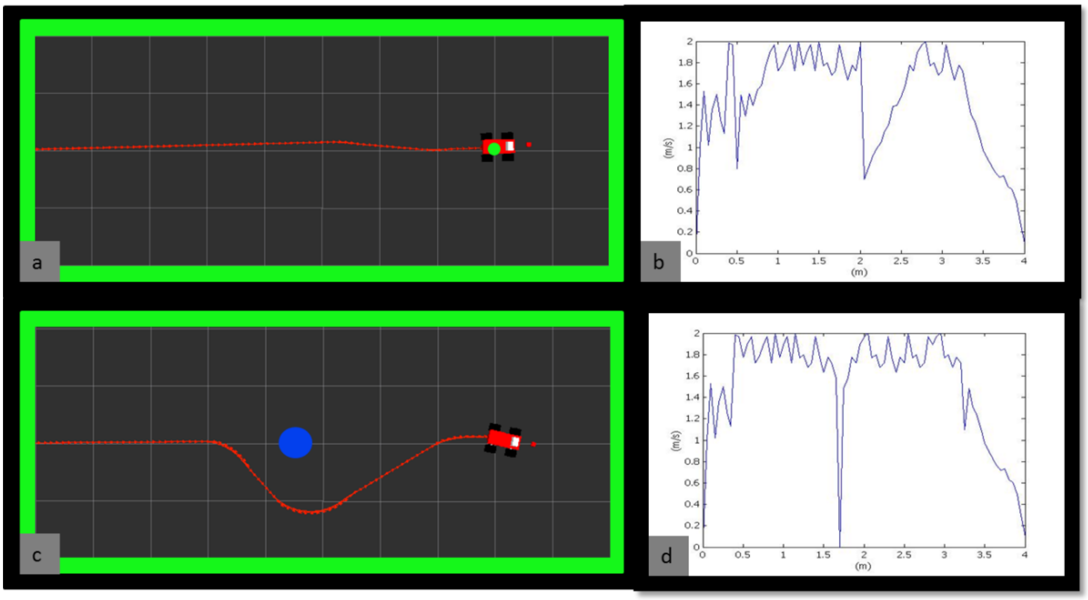


Fig. 3 Experiment result of 1 waypoint navigation (green circle) (a) with its velocity in x-direction travelling distance (b) and 1 hazard avoidance (blue circle) (c) with its velocity in x-direction travelling distance (d)

Mobile robot velocity is shown in Fig. 7b and 7d which are implied speed-position coordination as the product of velocity control. The velocity was controlled to decrease at periods of large curvature (i.e. around x = 1.5 m of hazard avoidance experiment) and controlled to near 2.0 m/s in “safe” regions (i.e. between x = 1 m and 1.5 m for both experiment). This constant speed is a result of a mobile robot running on a high speed for such a long time (more than 8 cm for Merlin) [12].

After passing through the safe region, the mobile robot was navigated to reach the waypoint of first experiment at (2, 0) m as well as during the large curvature for hazard avoidance at (1.5, 0) m (Fig. 7b and 7d). The velocity was controlled to decrease to reach this waypoint which was started from 2 m of traveling distance in x-direction and while hazard avoidance which was started from 1.5 m of the origin.

## 3. Conclusion

From the experiment, the mobile robot has successfully navigated through the desired waypoints and avoiding hazards. The velocity was controlled to decrease at periods of large curvature.

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