IoT sensor based Mobility Performance Test-bed for Disaster Response Robots

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***Abstract*— Recently, thanks to development of advanced IoT technology, the disaster prevention service that helps to search and rescue survivors in the disaster site using robots and special equipment is greatly increased. The introduction of these advanced equipments will help to improve rescue operations within golden time and also ensure the safety of firefighters. However, the disaster environment is still very difficult to approach and pass through it due to collapses, obstacles and dangerous materials. In this paper, we design and implement a mobility performance evaluation test-bed which can overcome various risk situations where a robot and special equipment may encounter while driving and passing them. In addition, the test-bed adopts various Internet of Things (IoT) sensors in order to quantitatively evaluate the performance. The test-bed is consists of gaps, continuous ramp, crossing ramp, inclined planes, stairs, vertical climbing, narrow passage, pipe passage, water passage and etc. The level of difficulty for each track can be adjusted to provide a basis for the performance rating of the target robots.**

Keywords—Test-bed, Mobility Performance, IoT sensors, Disaster Simulation

I. Introduction

Recently, in order to overcome extreme disaster environments, various firefighting robots and special equipments with complicated functions have been developed by combining various sensor and robust driving technologies. However, when developed robots are actually dispatched into the real field, unexpected problems are often found. Thus, we need to verify the performance of the designed robot before dispatching the robot in the field. For this, the National Institute of Standards and Technology (NIST) has developed reference test arenas for urban search and rescue robots [1-4]. In particular, they have been used to annual urban search and recue (USAR) robot competitions and ‘RoboCup Rescue league’ since 2001. However, most of these test methods have been evaluated by the supervisor’s naked eye and did not adopt the advanced sensor based quantitative measurement method.

In this paper, we designed and implemented a novel evaluation test-bed which analyzes the disaster environment patterns that are most frequently seen in actual disaster environment and quantitatively simulates them.

II. Design of Test-bed

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The proposed performance evaluation test-bed consists of gap passage, vertical climbing, stairs passage, crossing ramp, pipe passage, and etc. The conceptual architecture of the test-bed is shown in figure 1-5. Some tracks provide a grading of performance by providing advanced, intermediate, and low difficulty levels. In case of gap passage, interval spacing of 60cm, 30cm, and 10cm were defined as upper, intermediate, and lower, respectively. The criteria of difficulty level is based on the setting of both fire and architectural regulations, so that the maximum obstacle specification does not exceed the legal limit. It is also possible to distinguish the superiority of performance by setting the passage time for each section. Although the gap passage and vertical climbing track are similar to the previous studies in terms of overcoming the ruggedness, the randomness is added by changing the arrangement angle of the gaps and vertical obstacles. That is, it can evaluate whether only one wheel of both wheels (or four wheels) can overcome a specific obstacle.

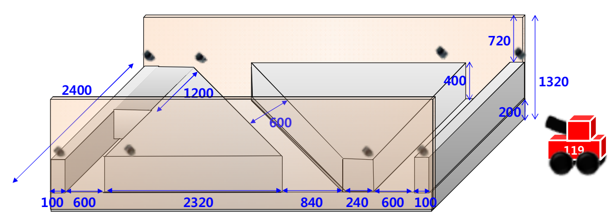

Fig. 1. Test-bed for Gap Passage

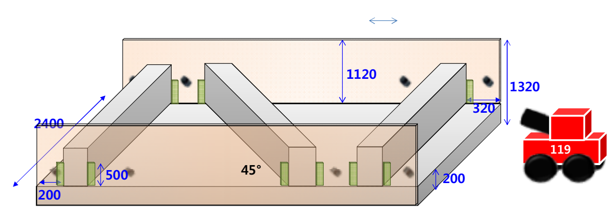

Fig. 2. Test-bed ofVertical Climbing

For automation and quantitative evaluation, the proposed system is composed of a laser and infrared sensor which can confirm the position of the robot in the test-bed, an embedded control board which can collect and process measured information, a LCD screen, and a battery which is capable of driving the above Internet of Things (IoT) equipments. The

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2.4Ghz Wi-Fi module (IEEE 802.11a/b/g/n) [5] is attached to the embedded board so that the measured information can be transmitted to a remote server or a supervisor terminal. In order to construct the automated evaluation system in each mobility track using the above IoT sensors, the measurement sensors are deployed at regular distance according to the passage subsection of the track. For example, the stairs track is consisted of three subsections which are ascending, descending, and landing.

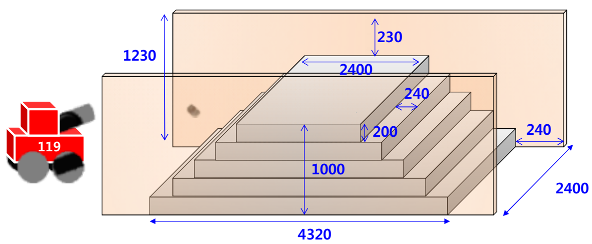

Fig. 3. Test-bed for Stair Passage

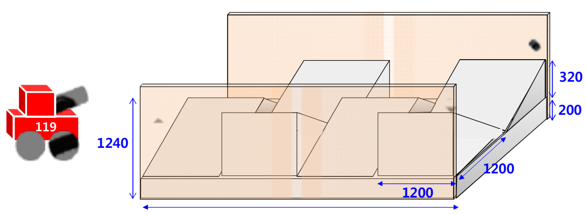

Fig. 4. Test-bed for Crossing Ramp Passage

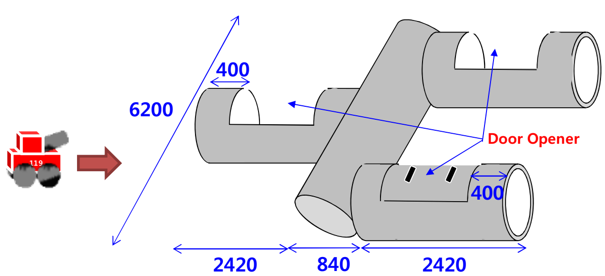

Fig. 5. Test-bed for Pipe Passage

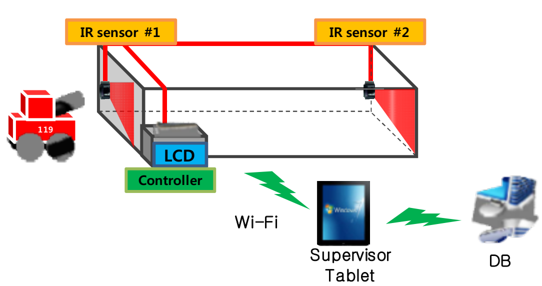

Fig. 6. Layout of IoT Devices

The passage principle of each session is shown in figure 6. A pair of IR sensors are installed at regular intervals, and the position of the robot is measured at an error of less than 1 cm at the corresponding point. The robot passes the first starting point (IR sensor #1) and then the second point (IR sensor #2).

At this time, the control board measures the moving distance, travel time and velocity. The measured data is transferred to the supervisory terminal via Wi-Fi, and then stored in the database of the remotely located server. Figure 7 shows the measured performance data after the robot traveled 4 subsections. Figure 7 describes that the total travel time of the four sections is 6.2 seconds and the average velocity is 1.7km/h.

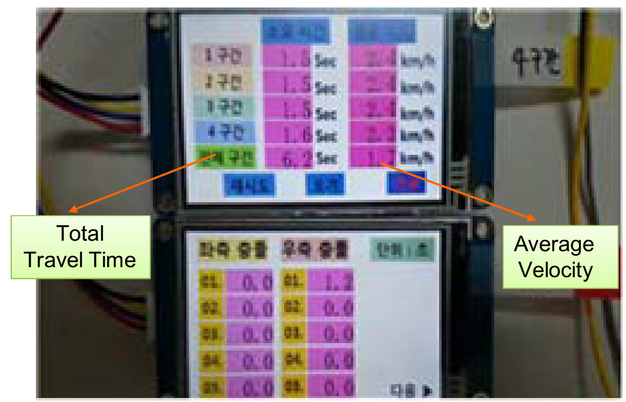

Fig. 7. Display of Measured Data

III. Conclusion and Future Work

In this paper, a disaster scene and its simulated test-bed is developed in order to evaluate the mobility performance of firefighting robots and special equipments which can be used in a disaster scene. In addition, real time measurement system is designed and experimented by using various IoT sensors. The core sensors include laser/infrared sensor, embedded board, WiFi, wireless router, and etc. After configuration of experiments, successful transmission of information is confirmed using 2.4Ghz wireless network. For the future works, we plan to build extended environments such as high temperature and smoke simulating fire, and then integrate with existing test bed.

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