Simulation Platform for Performance Test for Robots and Human Operations

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Abstract

In this paper, we propose a simulation platform for the performance testing of robots and human operations. Robots have been used in disaster scenarios, where the environment is unstable. Human operators may have no prior experience in dealing with such dynamically changing environments, which may also be unstable for robotic tasks. To develop rescue robots, disaster situation emulation and human-in-loop test platform are required in addition to robot simulators. The proposed platform is used to design, develop robots and to conduct drills for robot operations, and to carry out experiments. And the results of experiments are presented.

Introduction

Rescue work is important to save human lives when disaster strikes. The necessity of rescue robots has been widely accepted after disasters such as great earthquakes of 1995 Hanshin Awaji, and the September 11 attack on the World Trade Center. After the 2011 Higashi Nippon Earthquake, several robots have been used to explore the interiors of the buildings at the Fukushima nuclear reactors, and other robots are available for further exploration. These robots are supposed to used in unstable and dynamically changing environments. The situations encountered at the reactor buildings are not ones that have been experienced before, and therefore, human operators may not be trained to operate the robots. The robots may be not designed to move in such situations when they were designed.

Commanders collect information on emergency situations involving fires, chemicals, hazardous materials, etc., while trained personnel plan rescue operations. They make assumptions about disaster situations and command their teams to contain disasters. It is desirable to check the plans in virtual hazardous situations, as they would have done in real situations. In order to test the robots's performance at disaster areas, a platform must simulate both robots movements when operated by a human and disaster situations that dynamically change. We propose a simulation platform for performance testing of robots and human operations.
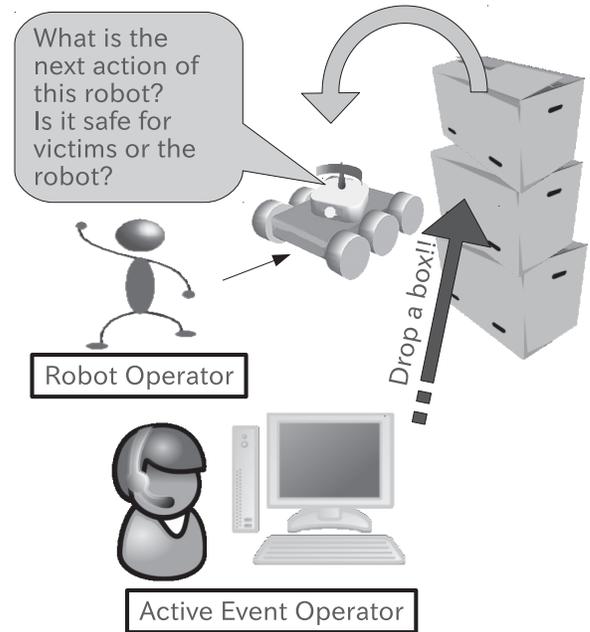
Figure 1: Framework of performance test simulations. With this simulator, robot developers can evaluate behaviors of their robot under active environments.

Background and Related Works

An emergency management system (EMS) is extremely important during disasters as it provides the necessary support to rescue commanders (de Walle and (edited) 2007). The following are features of an ideal EMS;

1. Emergency situations contain extensive factors.

   (a) Natural and man-made disasters are simulated.

   (b) Human behavior consists of rescue operations, evacuation behaviors, and so. These behaviors are simulated.

   (c) The rescue operations are interactions between human and disaster, and among humans. Effects of the interaction are taken into consideration in the simulations.

2. EMS is combined smoothly with everyday operation systems (Takahashi 2009).

(a) Before disasters, EMSs are used to check plans for preparing disasters.

(b) During disasters, EMSs are used to reduce damage from disasters where the situations will be dynamically changing.

(c) After disasters, EMSs are used to make plans to prepare for future disasters.

Since the September 11 attack on the World Trade Center, rescue robots have been widely accepted as one of the rescue tools at disasters sites where human rescuers cannot enter. Such a situation was realized at the Fukushima nuclear reactors in Japan after the Higashi Nippon Earthquake that occurred on March 11 2011. The interior of the buildings were destroyed by the earthquake. This led to an unpredictable environment inside the buildings, and some areas were highly contaminated by radiation. Several types of robots have been used to explore areas inside the reactor buildings where humans could not enter.

The following are typical scenarios where robots will be used in disaster situations.

1. Robots are brought to locations near disaster areas.

2. Maps of the areas before the disasters are assumed to be known, and humans operate rescue robots at disaster areas.

3. The robots are mainly used to explore the disaster area and search the areas for victims to help in planning the rescue operations.

RoboCup Rescue project is a project with one objective; to promote research and to develop topics related to rescue robots (RoboCupRescue). Real and virtual robot competitions have been held to meet the above aim, and to demonstrate advanced robotic capabilities for emergency response. Robots that have participated in the RoboCup Rescue competition were actually utilized in Fukushima (FukushimaQuince date11 Aug 2011).

Proposal of Performance Test System

Figure 1 shows a simple framework of such rescue robots operations and the following are requirements to test the performance of these operations.

1. The operator moves the robots by viewing images that are sent from a camera mounted on the robot.

2. The operator may make mistakes due to noise in the camera images or unexpected and sudden movements such as the robot slipping or jumping.

3. Poor operations of the robot causes collision with boxes, causing the top box to fall on the floor.

4. The fallen box becomes an obstacle that prevents the robot from exploring certain areas.

Human operators are tarined to manipulate a robot enough to pass near boxes without colliding with the boxes. In order to test the operator's performance, unexpected events or noise inputs are introduced at a fixed intervals. An active event operator in Figure 1 plays a role that sets events and makes dynamically changing scenarios. This
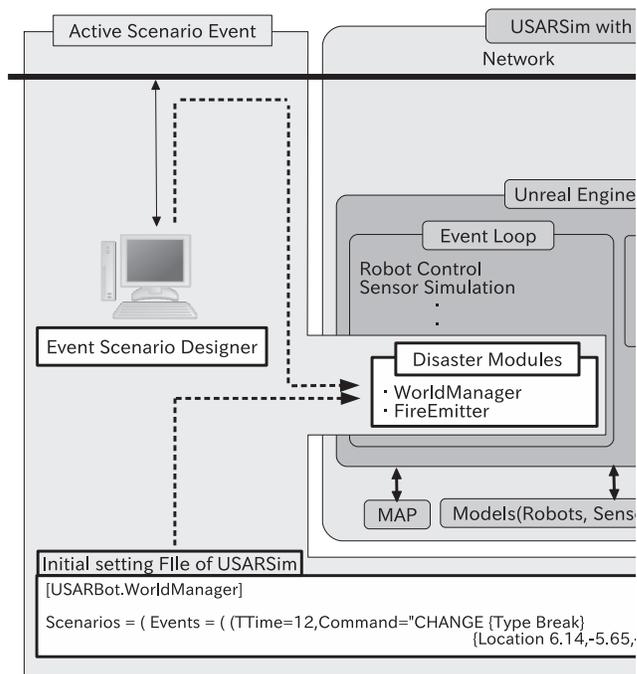

Figure 2: Configuration of performance platform system: The diagram of command and data flow of USARSim enhanced active environment. White rectangles are new modules for the active environment. Dark gray rectangles are modified modules.

platform provides an environment that can be used for designing/developing rescue robots and drills for robot operations.

Training stages

The human operators improve their operation skills by doing drills step-by-step. The following are examples of such training steps:

step1: mastering necessary robot operations In this step, operators get fundamental training by manipulating robots in easy situations. The easy situations are those when the floor is flat, the sensing data are without noise, and the response time is predictable. Factory environments where AGV (Automated Guided Vehicle) systems are introduced are examples of the easy situations.

step2: robot operations in unstructured situations
Disaster situations are not ones where robots can move smoothly. The floor is uneven, or slippery. The transmissions from cameras or mikes are interrupted sometimes. These noisy signals make robot operation difficult.

step3: robot operations in destroyed environments
Disaster situations change dynamically as the robots movem. The changes are not ones that the operator can predict, and make the operation tough.

step4: robot operations with interactions between robots
There is more than one robots in this situation, and the

operators are sometimes asked to operate them to perform a common task.

Performance Test Platform

Figure 2 shows the configuration of the performance platform system. It uses USARSim (Unified System for Automation and Robot Simulation) (Yotsukura and Takahashi 2009).

USARSim USARSim (Unified System for Automation and Robot Simulation) is a high-fidelity simulation of robots and environments based on the Unreal Tournament game engine. The game engine provides 3D maps and physical engines with which users can design several types of robots. The robots are controlled via client programs.

Event Action Mechanism Disaster Scenario

Dynamically changing environments is one of requirements for training the robot operators in disaster situations. Event Action Mechanism is implemented to change situations that USARSim provides. Using the mechanism, a sequence of disaster can be simulated in the training.

The following is an example of an event scenario (the left bottom box of Fig. 2).

```
Scenarios=(Events=(
  (Time=12,Command=
    "CHANGE {Type Break}
      {Location 6.14,-5.65,-1.74}")))
```

This command results in the collapse of walls at 12 seconds after the robot starts. Figure 7 (c) shows the result of this scenario command.

Experiment of Performance drill in robot operations

User Interface of robot operation

(a) P2AT robot

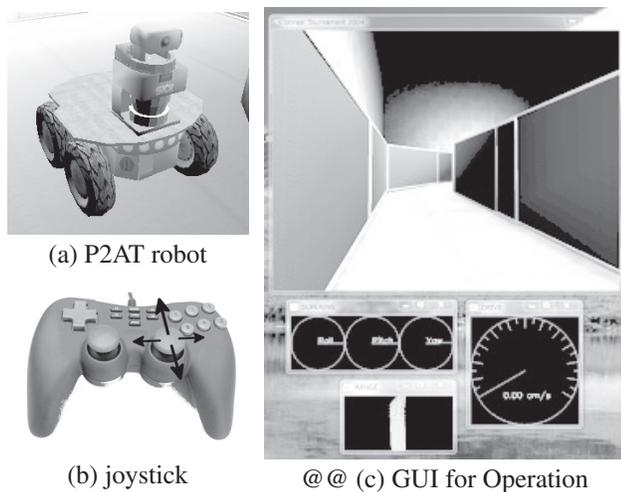
(b) joystick @@ (c) GUI for Operation

Figure 3: Robot design, control system, and GUI for operations.

Robot and operation interface Figure 3 shows the P2AT robot that is used for our performance test system and its GUI. The GUI is run on the client program. The P2AT robot is a wheel-based robot and has a laser sensor and a camera. The operator maneuvers the P2AT using images that are sent from the robot.

Figure 3 (a) and (b) show the design of the P2AT robot and a joystick that is used to manipulate the robot. The P2AT robot has a camera, a 3D acceleration sensor, a range finder, and a dead reckoning system. The joystick is an analog one, and tilting the joystick makes the robot move or turn towards the same direction. Figure 3 (c) is the GUI panels for the robot operations. The upper part displays images that are taken by a camera mounted on the robot. Indicators are laid-out at the lower part. The indicators show the roll, pitch, and yaw for the robot's tilting angle, range image from the range scanner, and speed of the robot.

Overview of performance test and experiment results

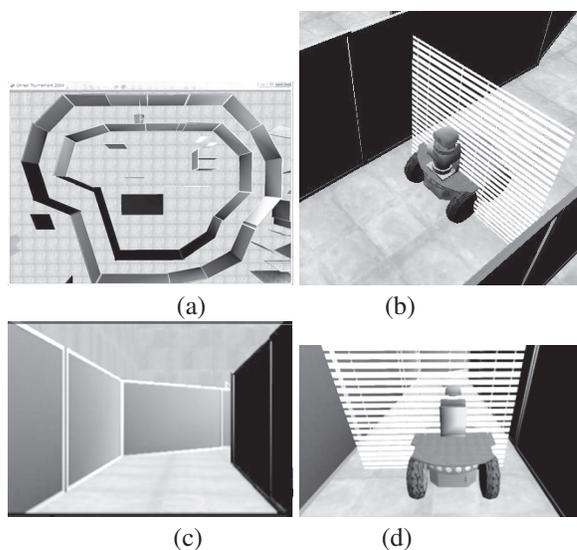

(a)   (b)

(c)   (d)

Figure 4: Test field for training at stage 1.(a) training course; (b) starting point; (c) image from a camera mounted at the front; (4) image from a camera mounted at the rear, the image includes the robot.

Table 1: Results of drill 1

GUI		time (s)		num.of
camera view	panel	avg.	std.	pauses
front	-	50.2	3.2	3
front	indicator	50.3	3.4	5
behind	-	47.3	0.4	0

front: camera mounted at the front of a robot.
backward: camera mounted at the rear of a robot.
avg. and std. stand for average and standard deviation, respectively.
pause: operator paused robot operations and restarted to continue the course.

Two test subjects, one in his 30s and the other is in his 20s, participated five times in the drills from step 1 to step 4. At each step, the first three trials are treated as practice sessions, and only the data from the last two trials are used in the following Tables 1 to 4.

step 1 drill: Figure 4 shows simulation environments for the step 1 drill. The operator works on fundamental operation skills by moving a robot around the course that is shown in Figure 4 (a). The course is walled off by the panels, and the starting and end points are marked with a white curtain (Figure 4 (b)). Figure 4 (c) and (d) are images that users see during the operations, and (c) is an image taken from a camera mounted at the front of the robot and (d) is an image taken from behind of the robot.

Table 1 shows the average time of a lap of the course and the number of pauses that the operator takes to consider how to move the robot. Viewing images that are taken from the back of the robot allows it to be controlled faster, with no pause to complete a lap , compared to when viewing images form a camera mounted at the front of the robot.

Mounting a camera at the rear of the robot is not a realistic way for rescue robots. Hence, the camera is mounted at the front of the robot for the following drills.
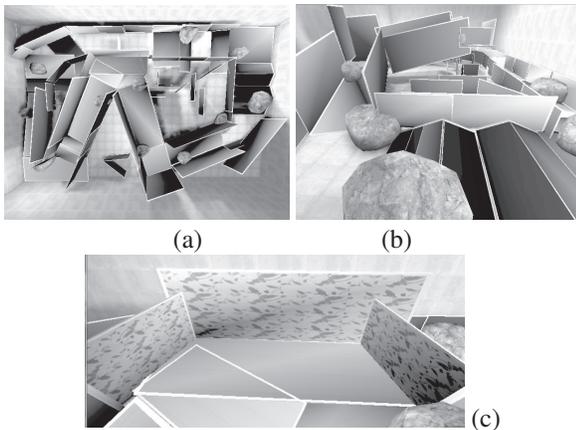

(a)   (b)

(c)

Figure 5: Test field for steps 2 and 3. (a) drill 2 course viewed from above; (b) step 2 course viewed from side, steep slopes are set at several places; (c) texture painted on walls.

Table 2: Results of drill 2

conditions		time (s)		num.of	
GUI panel	Wall	avg.	std.	pauses	failures
-	-	98.3	3.8	2	1
-	texture	106.5	5.7	7	0
indicator	-	93.3	3.0	0	2
indicator	texture	93.5	3.4	0	0

failure: operator fails to navigate a robot around the course.

step 2 drill: Figure 5 shows simulation environments for steps 2 and 3's drills. The operators are required to move
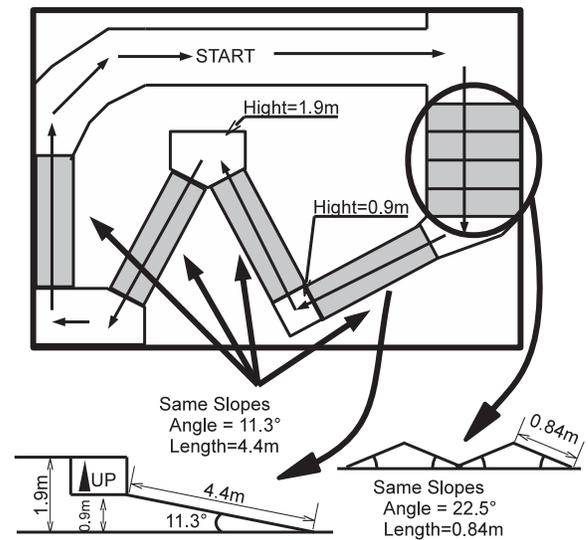

Figure 6: Course description of test field for steps 2 and 3. Robot goes around this course in a clock-wise direction. For step 2(and 4), there are two up-down movements. The angle of each slope is 22.5 degrees, and the slope's length is 0.84 m. For steps 2 and 3 (and 4), there is a long, high route that is composed of 4 long slopes. Each slope angle is 11.3 degrees and with a length of 4.4 m. The highest place has a height of 1.9 m.

the robot in a course with two floors and some obstacles. Figure 5 (a) and (b) shows a map viewed from above and the side, respectively. We can see from the side view that there is a steep slope that makes the robot operation difficult. The steep slopes restrict the view of the operator and make the movement of robots bumpy. The operator is required to move the robot while checking the clinometer in the panel (Figure 3). The operator moves the robots up to a landing and turns it onto another slope. At the highest landing, the operator is required to turn the robot around and navigate the robot down to the floor again. Figure 5 (c) is texture painted on walls, which are thought to make the operation easier than monochromatic wall.

Figure 6 is the course description of the test field for steps 2, 3, and 4. Robots go around this course in a clock wise direction. After starting, a robot arrives at two small hills. These two small hills are for step 2 and step 4. Each hill slope angle is 22.5 degrees, and the slope's length is 0.84 m. After passing the two small hills, the robot arrives at a long high route consisting of 4 long slopes. This highway is for steps 2, 3, and 4. These slopes have an angle of 11.3 degrees and length of 4.4 m. The first and second slopes are for ascending, while the third and fourth slopes are for descending. The highest place of this course is 1.9 m from the ground.

Table 2 shows the results of the step 2 drill. Four types of user interfaces are tested; whether an indicator panel that shows tilts of robot is in the robot operation GUI or not, whether the wall is painted with monotone or with textures

that help operators recognize the tilt of robots. Without the texture, the operators sometimes fail to navigate the robot around the course. The number of failures is how many times they failed to complete four trials. Walls with texture decrease the number of failures, while the indication panel decreases the time needed.

(a)   (b)
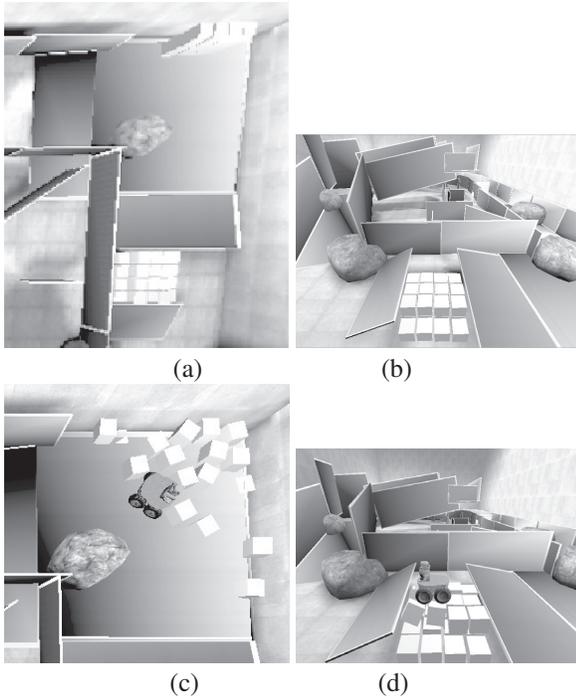
(c)   (d)

Figure 7: Test field for step 3. (a) step 3 course has a breaking wall and breakable floor(top view). (b) a floor (side view). (c) automatically collapsed boxes automatically in the scenario. (d) moving boxes caused by the robot moving on the boxes.

Table 3: Results of drill 3

	time (s)		num.of	
GUI panel	avg.	std.	pauses	failures
-	97.1	11.4	5	0
indicator	92.1	6.9	1	0

step 3 drill: In step 3, the course is the same as the one from step 2, with textured walls, except that the course in step 3 has dynamically changing parts. Figure 7 (a) shows the parts, a wall and a path. They are painted white, and the wall collides at time = 12. The colliding time is set when the robot passes the wall. The operators have to be careful to pass the bridge. Event Action Mechanism changes the situations dynamically and provides constant environments for the drill. Figure 7 (a) shows white boxes theat are automatically broken in the scenario.

After the robot pass the wall, it arrives at the breakable path (Figure 7 (b)). The operators have to be careful to pass

the bridge. Figure 7 (d) shows that the breakable bridge's boxes have moved due to the robot's movement.

Table 3 shows that both the lap time and the number of pauses indicators are useful in robot operation.

(a)

(b)

Figure 8: Step 4 drill. (a) Snapshots of upper row are camera views of first robot (left) and second (right), respectively. The lower row shows robots moving in tandem. (b) Operator's table.

step 4 drill: Figure 8 (a) and (b) show simulation environments for the step 4 drill and operation table. The course in step 4 is the same as the one in step 2 with the textured wall except that there is no wall on either side of the slopes. The main feature of step 4 is that two robots are used. The camera of the second robot gives the images that are taken from behind the first robot (cf. Table.1). [1]

Operators of robots collaborate to move robots safely and smoothly. Operators of the first robot (OP_1) and the second robot (OP_2) sit side by side and communicate each other. For example, "wait for a moment" or "come hurry". The communication between OP_1 and OP_2, and sharing images from two cameras are useful in operating the robots.

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[1]In this drill, there are no walls at the landings. When the operators see no changes in images from their own cameras, they look at the images of the other robot to confirm the status of their own robots. In most cases, the second robot is at lower level compared to the first robot so only its upper part is displayed. This caused some failures in this drill when the robot fell during the practice operations.

Table 4: Results of drill 4.

conditions		time (s)		num.of	
GUI panel	robots	avg.	std.	pauses	failures
-	OP$_1$	117.1	3.2	4	0
	OP$_2$	108.3	2.5	6	0
	both	112.7	5.2	10	0
indicator	OP$_1$	122.8	7.1	5	0
	OP$_2$	92.7	2.3	0	0
	both	107.7	15.9	5	0

"robots" column shows which operator moved the first robot.

Table 4 shows the results of the experiments. A column labeled "robots" shows which operator moves the first robot. It is interesting that the lap time is shorter when OP$_2$ moves the first robot, and the case when OP$_2$ moves the first robot using the indicator panels is the fastest. This indicates that individual traits have to be considered in manipulating robots.

Discussion and Summary

Summary of what we learned from the experiments is provided below.

1. The platform provides a realistic test field. The following natural consequences are reproduced in the platform:

   - Repeated drills of the courses made operation faster.
   - After getting used to operations, there are some cases where mistakes in robot operation caused fatal situations such as a wheel of a robot slipping off a slope. This is also similar to real operations.
   - Dynamically changing situations made the lap time longer.

2. In step 4 where cooperation between operators is required, OP$_1$ and OP$_2$ tried to communicate by voice at first. After several trials, they managed to play their roles autonomously.

- OP$_1$ waits for the arrival of the second robot when he needs his robot's own image. OP$_1$ tries to take pictures of the second robot at places where he thinks it is difficult to operate.
- OP$_2$ follows the pace of the first one so that the the first robot is in the images of the second robot.

In this paper, we have presented a simulation platform for performance test for robots and human operations. Adding the Event Action Mechanism to USARsim provides a platform for drills of human operations, performance test for robots, and to measure human factors.

The results of step 4 show that our system has the possibility to be used in design-ing/developing robots, and for drills in robot operations. Especially, as reported at Fukushima(GUIZZO date23 Aug 2011), situations, the system can select team members who operator robots, for example one combining wired and the other wireless connection, efficiently.

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