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EXPERIMENTAL EVALUATION OF TWO TOURING SIMULATORS FOR TRAINING OPERATORS OF MOBOT

EKSPERYMENTALNA OCENA DWÓCH SYMULATORÓW MARSZRUTY DO SZKOLENIA OPERATORÓW MOBOTA

A b s t r a c t

In the paper two versions of a touring simulator are presented and evaluated. Both versions were developed for training mobot operators. Operators improve their skills playing a game based on the simulator. For simulators the problem of the precision of simulation usually appears. The same is here. Therefore, the simulators differ in quality of graphics. In the paper a usefulness of the simulators for training is evaluated. Experiments answered the question how important for efficient training is high quality of graphics generated by the simulator.

Keywords: *mobile robots*, *simulator*, *virtual reality*

S t r e s z c z e n i e

W artykule przedstawiono i porównano dwie wersje symulatora marszruty. Obie wersje zostały przygotowane w celu trenowania operatorów mobilnego robota (mobota). Operatorzy poszerzają swoje umiejętności w trakcie gry opartej na symulatorze. W przypadku symulatorów zawsze pojawia się problem precyzji symulacji. Z tego powodu wersje symulatora różnią się precyzją odwzorowania trasy mobota. W artykule porównano przydatność obu wersji do trenowania operatorów. Przeprowadzone eksperymenty pozwoliły odpowiedzieć na pytanie, jak ważna dla wydajnego szkolenia jest precyzja symulatora.

Słowa kluczowe: *mobilne roboty*, *symulator*, *wirtualna rzeczywistość*

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1. Introduction

Mobile robots (mobots) are often used for exploring areas dangerous or not accessible for human being [1, 2]. When such an area changes dynamically (is devastated by uncontrolled forces, for example) then a mobot must be remotely controlled by a human operator. Let us suppose the operator has a map of the area. If his goal is to gather, as soon as possible, data about all of the changes in the area, then he must plan on the fly an optimal track for the mobot. Such task is neither easy nor simple [3–6]. Therefore, a mobot should not be controlled by an occasional person. An operator of the mobot should detect all changes precisely (should be perceptive) and quickly (should respond fast but without emotions). Moreover, the operator should make wise decisions and be stress resistant strategist. Hence, the operator should be systematically trained. Touring simulator is suitable for this task, as the real mobot might be expensive.

Our previous research shows that with the help of touring simulator skills of the operators can be considerably increased [7]. Usually, simulation should be fast and precise. Speed of simulation is very important here because many operators may train in parallel. However, it is not clear how precise the simulation should be. Actually it is not known whether virtual reality will result in faster improvement of their skills or not. Perhaps simpler, easier to investigate scenes will encourage the operators to higher concentration and then be better for training. Therefore, two versions of the simulator were developed. They differed in qualities of images generated by the simulator.

The simulator with very simple graphics was started first. This required less work and was simpler in implementation. Moreover, images stored in the database were smaller and then less computer resources were needed. Next, to verify whether such simplification of environment of a mobot is correct or not the second version of the simulator was developed. In this version more realistic graphics was used. The question arises which of the simulators is better for training and whether or not the graphics should be farther improved.

In the paper the question how quality of graphics in touring simulator influences on quality of training operators of mobile robot is answered. Section 2 describes the simulator and the training. Our experiment is presented in section 3. Experimental results are given in section 4. The paper ends with conclusions.

2. Touring and training

Touring simulator and a game based on it were developed for training operators of a mobot [8, 9]. The simulator generates a board for the game (a room) where virtual mobot is touring. A floor of the room is like a chess-board where all squares are covered with the same texture. Objects are placed on the mesh only, and the mobot can move along paths of the board mesh (Fig. 1). In one step the mobot can move forward or backward to the next square of the floor or can turn 45 degrees to the left or to the right. An operator of the mobot (a player) is equipped with a map of the board and he can control the mobot. The player sees exactly the same pictures as the mobot would see by its camera. He takes decisions in which direction the mobot should step and when the mobot should take a picture. All pictures are pre-rendered and stored in a database. When the player takes the picture then corresponding image is selected from the database and displayed on a screen of the simulator. Java application is a front-end of the simulator. It maintains pictures, maps, mobot control buttons and so on[1].

A task for the player is to detect all changes in a room in limited time [7–9]. The changes in a room may be categorized as follows:

– an appearance of a new object in the room,
– a disappearance of an object from the room,
– a modification of an object in the room (change of color or rotation).

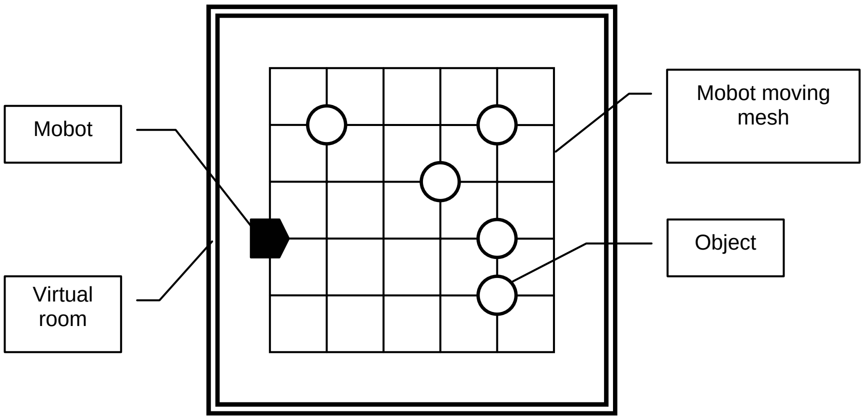

Fig. 1. Chess-board for the game

Rys. 1. Plansza gry

When the game is running then information about all activities of the player are automatically collected and stored. When the game is over these data are used for calculation a quality of monitoring Q for the operator. It is defined as follows

$$Q = f(D, D_L, C_W, C_O, C_B, C_P, I, M, P)$$

where D denotes % of detected changes, D_L denotes % of changes detected too late, C_W denotes total number of collisions with walls, C_O denotes total number of collisions with objects, C_B denotes total number of attempts of crossing walls, C_P denotes total number of attempts of going out of predefined path, I denotes % of incorrectly detected changes, M denotes total number of moves, and P denotes total number of pictures taken.

The experiment consisted of three phases. During each of the phases the player was playing on a few boards. Each of the chess-boards was filled up with objects of different configurations and intensities. Moreover, different ranges of visibility and frequency of changes were applied. Each phase of the experiment was focused on different aspect of learning. These are as follows:

1) *familiarization* where a player was acquainted with the game,
2) *learning* where the same set of boards was played three times and all tours were predefined,
3) *strategy* where a player was allowed for planning his own tour for each of the boards.

[1] http://kin.tu.kielce.pl/game/index2.html.

Our previous research showed [7, 8] *Q* is individual factor for each of the players. The initial qualities of the monitoring (after the first phase of the experiment) almost match to a normal distribution (Fig. 3, 4). Moreover, playing the game almost always considerably improves *Q*.

3. Experiment

The first group of operators used touring simulator with very simple graphics. Objects placed in a room were simple geometric primitives like spheres, cuboids, cones, toruses and octahedrons (Fig. 2A). Objects were colored in one of a few predefined colors with no textures. Only walls and floor of a room were textured. Every object was in one the three sizes.

The second group of operators used touring simulator with a little more realistic graphics. Objects placed in a room were more complex and textured. These were tables, cabinets, flowers in a pot, chairs and table lamps (Fig. 2B). Objects from one kind were also a bit different because three styles of chairs, three flower species etc. were available. A room of the game was supplemented with textured ceiling and special textures representing (fake) doors and windows. Almost the same model for lighting, shading and fogging was used as before. This was supplemented only by a simple object which showed shadows on the floor respecting a source of light. Rules of the game were exactly the same as before.

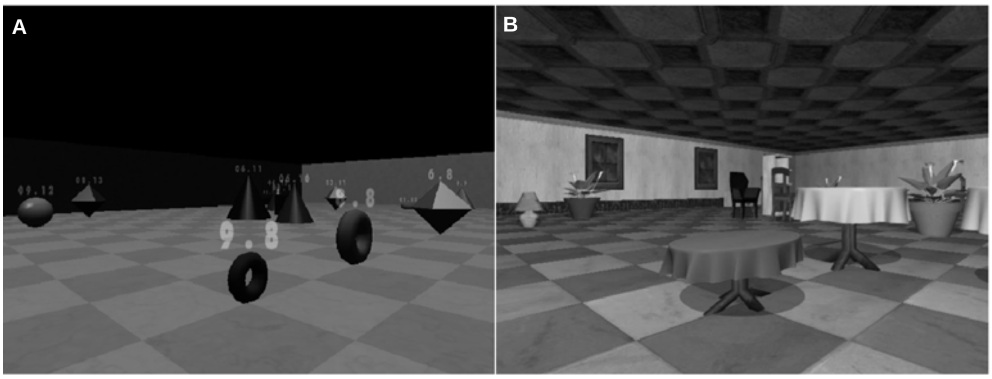

Fig. 2. Examples of simple graphics (A) and more realistic graphics (B)

Rys. 2. Przykłady grafiki uproszczonej (A) i realistycznej (B)

4. Experimental results

For each of the operators his *Q* was calculated after the first phase of the experiment (*familiarization*). The distribution of *Q* in ranges was almost a normal distribution (Fig. 3). Thus the sample of operators seemed to be random and the experiment would lead to reliable conclusions.

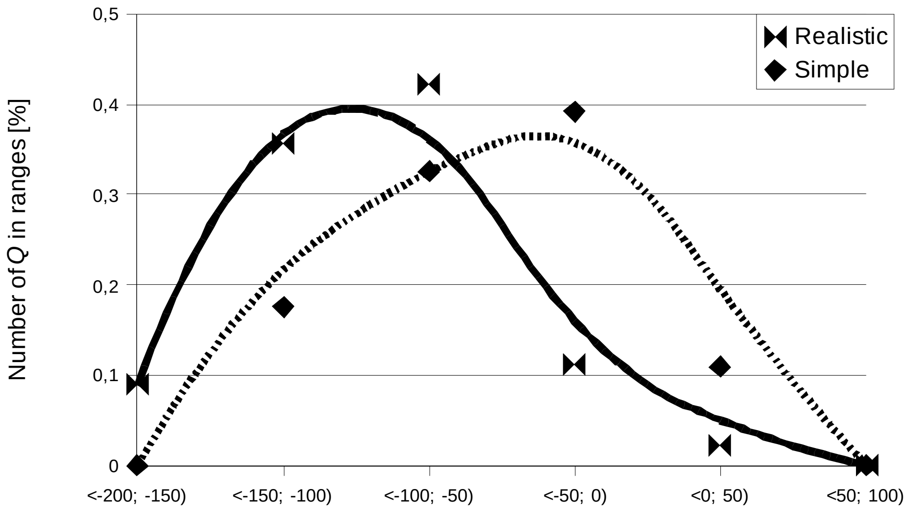

Fig. 3. Monitoring quality distribution before the training

Rys. 3. Rozkład jakości monitorowania przed rozpoczęciem treningu

Average values of Q for each phase of the experiment are shown on Fig. 4. Curves for the first and for the second group of operators are similar. This means the progress of learning in each of the group was also similar. Only values of Q for the second group are lower.

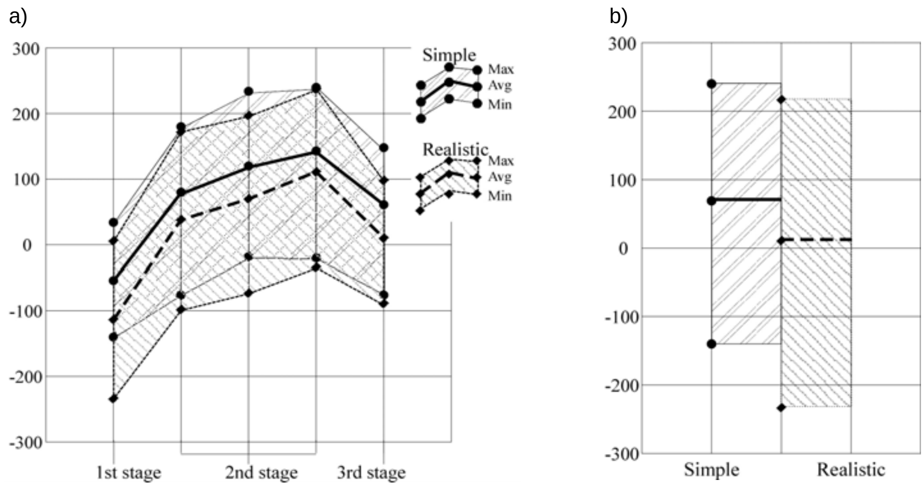

Fig. 4. Average, minimal and maximal Q after each phase of the experiment (a) and after the experiment (b)

Rys. 4. Średnia, minimalna i maksymalna wartość Q po każdej fazie eksperymentu (a) oraz po jego zakończeniu (b)

Q is a function of many variables. To know whether there is a variable having considerably different values for the groups or not would be very useful. This would indicate the factor of Q which strongest depends on quality of graphics. From the experiment it results that the highest difference is in the number of detected changes (sum of D and D_L). Figures 5a) and 5b) show these phenomena. Values of the other variables are similar for both simulator versions.

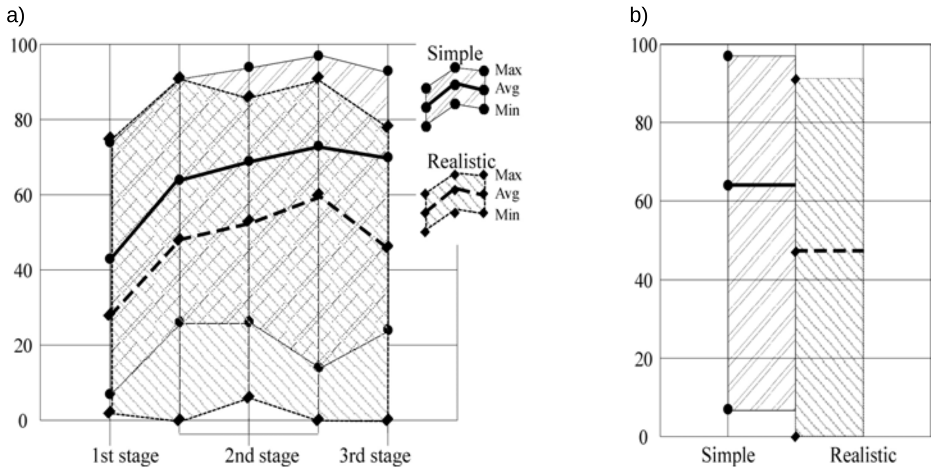

Fig. 5. Average, minimal and maximal number of changes detected ($D + D_L$) during each phase of the experiment (a) and after the experiment (b)

Rys. 5. Średnia, minimalna i maksymalna liczba wykrytych zmian ($D + D_L$) w trakcie każdej fazy eksperymentu (a) oraz po jego zakończeniu (b)

At the first phase of the experiment (*familiarization*) novice players had more problems with more realistic graphics than with less realistic one. For the second phase (*learning*) the progress of learning expressed by values of Q is similar for both groups of the players, and even better for those working with more realistic graphics. At the end of the experiment players using more realistic graphics showed considerably better results.

Table 1

Skill improvement during training for both simulator versions

	Avg Q before learning	Avg Q after learning	Sill improvement	
			in points	percentage
Simple version	80,5	142,87	62,37	77
Realistic version	37,75	110,65	72,9	193

For the group which worked with simple graphics an average value of Q after the training was greater than before the training about 77%. For the group which worked with more realistic graphics Q increased about 193% (Table 1).

5. Conclusions

As far as *learning* is concerned Q increases in very similar way (almost identical curves on Fig. 3) no matter which graphics is used. More realistic graphics results in smaller Q after the training than simple graphics does. However, its relative improvement is higher (Table 1). Not surprisingly, the easier exercise the better results and the harder exercise the better progress of skills after the training.

The last phase of the experiment (*strategy*) showed the group which worked with more realistic graphics had lower Q than the group which worked with simple graphics. This is in agreement with the conclusions coming from Table 1 and concerning *learning*. For an explanation of this phenomenon more experiments are necessary. More realistic graphics produces more complicated pictures which are full of details. If a player wants to find the best tour then an analysis of all details may take a lot of time. This may be one of the reasons that the player gives up precise analysis of the board and select a tour far from optimal. This, in turn, results in smaller average Q.

Summarizing, an answer to the question which graphics, more realistic or less realistic, should be used in a touring simulator is neither straight nor easy. Training with a simulator which uses simple and not-textured objects gives better Q. Moreover, development of such plain graphics is easier and requires much less work. Also requirements for hardware resources are weaker (cheaper video graphics adapter, slower CPU etc.). On the other hand very important question arises. Will an operator, who is used to work with very simple objects and situations, still react properly in real-life situations and environments? To answer the question an experiment with a real mobot is going to be performed.

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