Effectiveness test of simulator for e-training in carrying out missions with use of tele-operated vehicles

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Abstract. This paper describes results of effectiveness test of simulator for e-training operators of tele-operated vehicles. The test has been conducted with 20 participants (Warsaw Military Univesity of Technology students) divided into two groups. First group, numbering 11 persons, operated Dromader robot without previous training on the simulator. Members of the second 9-persons group went through simulator training before operating the robot. The trial was composed of two exercises. First of them was devoted to test driving abilities of the operators. The task for operator i was to cover the distance in a short time and not making errors (such as deviations from the route or collisions with obstacles) that was scored negatively. The second exercise was devoted to test manipulation abilities, and manipulation concrete blocks with robot's manipulator was its substance.

1. Introduction

We assumed that training with simulator can make time of training with robot shorter as have been written in [1],[3]. Described in this paper results of test prove that We were right. Dromader is a robot with uneasy user interface. Training of use the interface can be conducted without wasting fuel and even without use of robot.

2. The Dromader robot

Dromader robot (Figure 1) has two-segment chassis connected by an articulated joint. The rear section houses a 15kW combustion drive unit while the front section houses the control system and several components of the platform's drive system. Dromader is equipped with manipulator, mounted on the front section, and with three cameras. A typical gamepad serves as control console for robot operation.

Figure 1 Dromader robot. Robot's cameras marked as 1,2,3

Dromader is operated from an operation stand, with use of camera views. The operation stand engaged during validation trial is presented on the Figure 2.

Figure 2 Dromader's operation stand

For training of Dromader's operators serves simulator developed as TIRAMISU tool. The training stand with the simulator, engaged during validation trial, is presented on the Figure 3, and a view on simulator screen is presented on the Figure 4.

Figure 3 Dromader's training Stand

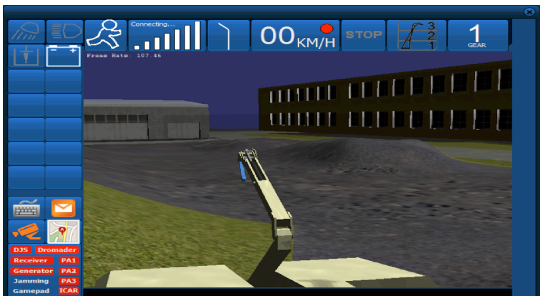

Figure 4 Simulator's screen

3. The course of validation trial

The validation trial has been conducted with 20 participants (WAT's students) divided into two groups. First group, numbering 11 persons, operated Dromader without previous training on the simulator. Members of the second 9-persons group went through simulator training before operating the robot.

The trial was composed of two exercises. First of them was devoted to test driving abilities of the operators. The route to go through this exercise is presented on the Fig.5. The task for operator it was to cover the distance in a short time and not making errors (such as deviations from the route or collisions with obstacles) that was scored negatively, corresponding to Maslowski's work [2] .

Figure 5 The route for testing abilities to drive Dromader

The second exercise was devoted to test manipulation abilities, and manipulation concrete blocks with robot's manipulator was its substance. The exercise, presented on the Fig.6, consisted in driving up certain block, localizing it and grasping (I), and then carrying it to the certain distance (II); errors were scored negatively as well. The block being the manipulation subject was located near a vertical wall making up an obstacle, as well as other concrete objects in the neighborhood did.

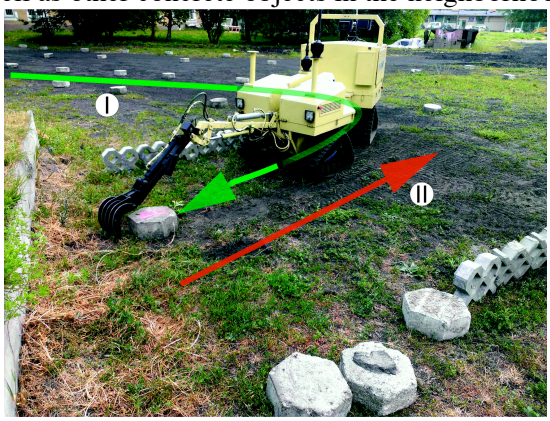

Figure 6 The exercise for testing manipulation abilities

4. Results

Both, in the manipulation and driving exercise, the results have been obtained by comparison of the outcomes of participants of two groups – with and without of previous training on the simulator. In both exercises the time of fulfilling the task, and the number of errors made, were treated as the outcome. Global outcome in relation to the time was calculated in two ways, as an arithmetic mean and as a median, according to the following formulas:

Arithmetic mean:

$$x_{sr} = \sum_{1}^{n} \frac{x}{n}$$

Median $$m_e = \begin{cases} x_{\frac{n+1}{2}} \quad gdy\, n \quad jest \quad nieparzyste \\ \frac{1}{2}\left(x_{\frac{n}{2}} + x_{\frac{n}{2}+1} \right) \quad gdy\, n \quad jest \quad parzyste \end{cases}$$

where: n – number of participants; x – time of fulfilling the task.

The results obtained in the driving exercise are shown in the following tables.

Table 1. Driving outcomes of participants trained on the simulator

Participant	Time of fulfilling the task [s]	Time of training [min]	Number of errors	Arithmetic mean x_{sresz} [s]	Median m_{esz} [s]
1	217	40	0	249	243
2	302	20	1		
3	243	30	3		
4	245	30	3		
5	385	30	4		
6	193	60	4		
7	190	60	5		
8	246	30	5		
9	216	30	0		

After rejecting extreme values, arithmetic mean and median amount adequately 232 and 230.

Table 2. Driving outcomes of participants not trained on the simulator

Participant	Time of fulfilling the task [s]	Number of errors	Arithmetic mean x_{srnsz} [s]	Median m_{ensz} [s]
1	280	3	319	308
2	377	4		
3	324	4		
4	348	8		
5	260	4		
6	308	3		
7	262	2		
8	455	7		
9	254	0		
10	247	0		
11	398	8		

After rejecting extreme values, arithmetic mean and median amount adequately 306 and 294.

Percentage differences between outcomes of two groups were calculated for achieved times according to the following formulas.

$$\Delta x_{sr} = \frac{x_{srnsz} - x_{srsz}}{x_{srnsz}} \cdot 100\%$$

$$\Delta m_e = \frac{m_{ensz} - m_{esz}}{m_{ensz}} \cdot 100\%$$

Obtained values are the following:
$\Delta x_{sr} = 22\%$, and for rejected extreme values 24%

$\Delta m_e = 21\%$, and for rejected extreme values 22%

Percentage differences Δe between outcomes of two groups for errors made during the driving exercise, calculated in the same way, are the following:

$\Delta e = 29\%$ for total number of errors
$\Delta e = 37\%$ for maximal number of errors made by single participant

The results obtained in the manipulation exercise are shown in the following tables.

Table 3. Manipulation outcomes of participants trained on the simulator

Participant	Time of fulfilling the task [s]	Time of training [min]	Number of errors	Arithmetic mean x_{srsz} [s]	Median m_{esz} [s]
1	207	40	1	190	192
2	175	20	3		
3	231	30	0		
4	143	30	0		
5	233	30	3		
6	174	60	1		
7	192	60	3		
8	165	30	0		
9	192	30	1		

Table 4. Manipulation outcomes of participants not trained on the simulator

Participant	Time of fulfilling the task [s]	Number of errors	Arithmetic mean x_{srnsz} [s]	Median m_{ensz} [s]
1	305	4		
2	414	2		
3	283	4		
4	334	1		
5	383	1		
6	294	1	341	334
7	316	2		
8	415	5		
9	249	1		
10	403	2		
11	354	0		

Percentage differences between outcomes of two groups for achieved times of fulfilling the task, calculated in the same way as for the driving exercise, are the following:

$\Delta x_{sr} = 44\%$
$\Delta m_e = 42\%$

Percentage differences Δe between outcomes of two groups for errors made during the manipulation exercise, calculated in the same way, are the following:

$\Delta e = 40\%$ for total number of errors and for maximal number of errors made by single participant

5. Conclusion

The test described in this paper confirm that using simulators in training robot operators is effective way to reduce cost of the training, and let trainee make errors with lower level of stress. Comparing of using real machine during first lessons of robot use it is much faster way to get satisfied results.
Validation was conducted by determining how the simulator under consideration meets requirements of its performance threshold. For the simulator triple-value threshold has been set with 3 performance levels:
Level U - unsuitable tool - less than 10% difference between groups' outcomes;
Level I - tool needs improvement - difference between 10% and 30%;
Level S - suitable tool – the difference bigger than 30%.

Differences of outcomes in driving exercises are in the 21%-24% bracket for times of fulfilling the task, and in 29%-37% bracket for number of errors made.

Differences of outcomes in manipulation exercises are in the 42%-44% bracket for times of fulfilling the task, and come to 40% for number of errors made.

Taking into account that time of fulfilling the task of approach in demining missions is of second importance [4], it's justified to decide level S obtained by the trainer-simulator as a result of the validation trial.

6. References

[1] Łuczyński T., Ostrowski I., Będkowski J., Masłowski A., Przybyłko M., Zoppi M., Wojcieszyńska P., Szczepaniak M., (2013) Mobile Demining Devices Modeling for the Training Purpose using VORTEX Framework, Proc. of the Int. Conf. on Military Engineering – Problems and Prospective, 23-25 April, 2013, Institute of Military Engineering, Wroclaw, Poland, pp. 233-240.

[2] Maslowski, A. (2014) Training in Military Robotics and EOD Unmanned Systems. Conference and Seminars, 30 September - 2 October 2014, NATO EOD Center of Excellence, Trenčín, Slovakia.

[3] Methodology of Training and Support for Urban Search and Rescue With Robots Bedkowski J., Majek K., Ostrowski I., Musialik P., Maslowski A., Adamek, A., Coelho, A., De Cubber, G., ICAS 2013, "The Ninth International Conference on Autonomic and Autonomous Systems", Lisbon 2013, Portugal

[4] Kacprzak, M., Kaczmarczyk, A., Masłowski, A. (2012) Computer training for operators of unmanned vehicles in application to Humanitarian Demining activities. 6th IARP RISE, Warsaw.