# eTraining in RISE (Robotics for Risky Interventions and Environmental Surveillance)

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ABSTRACT
The need of training of RISE systems' operators is discussed in the article, and the way to satisfy this need by e-training is suggested. Experiences resulted from the project developed by the authors, with the aim to build computer platform enabling generation of trainers-simulators for e-training of operators of inspection-intervention mobile robots are presented.

KEY WORDS
E-training, computer trainers-simulators, platform for generation trainers-simulators.

## 1. Introduction

Contemporary robots used in RISE field are of rather narrow autonomy and need to be driven by skilled operators. Furthermore, although RISE robots' ability to autonomous operation will increase as control technology advances, and yet human operators have to interact with robots for covering tasks responding to altering needs of a mission. Thus, training of RISE robots operators is a necessity. Taking into account that the demand for skilled operators will increase because of increasing both number of robots and their applications, requirement for efficient and suitable for mass-use training methods appears. E-training methods will turn out to be very helpful in this situation. E-training is understood here as an extension of e-learning: e-learning consists in computer-network-based obtaining of knowledge, e-training has in view obtaining of operation skills. Similarly as in the case of e-learning, e-training systems will be able to serve large number of geographically dispersed learners, and self-paced courses accessed 24 hours a day, whenever they are needed, will be possible. As experiences of flight and driving schools show, the use of flight and driving simulators software, even installed on PCs, enables to cut costs of training even by half.

Propaedeutics to e-training in RISE is given by the project under development, named "A platform for design of computer trainer-simulators for operators of inspection-intervention mobile robots", realized by the authors of the paper in the Institute of Mathematical Machines, Warsaw, Poland. Development of such computer platform, intended to enable designing trainers-simulators for training in operation of different types of mobile robots - finding their application in inspection-intervention missions conducted in municipal or industrial environment, as well as in missions of military or police character - and creation of software for them, is the aim of this project. One can anticipate that diverse types of robots, differing by kind of traction, load capacity, range, manipulation ability, equipment with sensors will be applied in these missions. A need to train significant number of persons in operation of these robots, and obtaining high proficiency in operation, will come into being particularly in police and military forces for the sake of possible contact with explosives and toxic substances creating dangers for operator, population, and environment. Training tasks require many hours of exercises

with different types of robots. Conducting of such training with use of real robots would be unprofitable, and probably unfeasible for the technical and organizational reasons – for difficulties of creation of all possible situations and coincidences with which an operator of robots has to cope. The use of trainers, simulating robots' behavior in different situations and circumstances, will be a necessity. Such trainers, for different types and variants of robots, will have to be designed, manufactured, delivered to users and serviced, so establishing of an innovative enterprise of adequate profile will be justified. Computer platform being a subject of the project under consideration will be the basic "manufacturing appliance" of such enterprise.

## 2. Intelligent multi-level training

The first research task of the project under consideration it was drawing up a methodology of multi-level training with use of trainers of different grade of perfection, taking advantages of technologies of virtual reality (VR) and augmented reality (AR). Application of multi-level training, introductory one with use of simplest and not so costly trainers, and at next levels more and more complex, closing to real robot operation, will enable reduction of training costs and facilitate training organization. For multi-level training the following types of trainers are to be used [1]:

- Trainers of the Level 1 – built with use of typical PCs. VR technology is applied. Robot, its environment and control console are simulated.
- Trainers of the Level 2 – built with use of PCs with real robot control consoles connected. VR technology is applied. Robot and its environment are simulated.
- Trainers of the Level 3 – trainers of the Level 1 or 2 with application of AR technology - real robot in the real environment with simulated elements added. A trainee uses special helmet.

In the case of use of trainers of the Level 1 and 2, realization of e-training is possible. Trainers of the Level 2, having application for e-training, should be equipped with simplified control consoles, e.g. typical consoles for computer games. Description of present solutions of e-training of operators of vehicles and appliances is presented in [2].

Computer trainers enable to conduct *intelligent training*, it means such training in which obtaining and perfection of operation abilities is adjusted to individual capabilities of trainees. Training with use of computer trainers consists in realization by a trainee his/her individual *program of training.* Every program of training is a sequence of *training tasks*. An exemplary training task for mobile robots operators is lifting, with use of the robot's gripper, of a certain object, and putting it in a certain container. At the beginning of the training session the trainee is informed on the task to perform, as well as on time limits, grading scale, and penalty points for causing wrong events (e.g. collisions of robot with objects in its environment). The trainee, using virtual or real control console, performs training tasks of the character of a computer game, and after finishing them is informed about the score obtained. During execution of training tasks, the knowledge about trainee's progress is gathered, and on this basis a choice of the next task, or decision on the end of training is made.

## 3. Models of trainers-simulators

Generation of simulator's software should be driven by robot's models [3], but new software: *Environment Generator* and *Training Task Generator* are necessary for precise definition of training tasks. This software creates files which describes a given environment and a required task. Robot's model itself may be created in two ways. If robot's designer applies CAE (computer-aided engineering software), it is possible to create a robot's model and to export the model in the form consistent with accepted standards; the model may be afterwards modified with use of *Robot Model Modification Program*. The second solution it is to build a model from a set of standard building blocks, which are subsequently put together by appropriate constraints with use of *Robot Model Generator.*

Robot's model is composed of some sub-models: physical model, geometric model, sound model, models of sensors and models of actuators. If a real control console is not applied in a simulator, then robot's model should comprise a model of a virtual control console which is created with use of *Virtual Console Generator*. If a real control console is applied in a simulator, then robot's model should comprise a communication module which ensures two-way transfer of data between a robot's model and a real control console.

As a result of the integration of files which describe a robot's model with models of an environment and a training task, an executable program is created, which after installation on simulator's hardware, operating under the supervision of *Training Program Executor* allows performing a training task by an operator. As it was explained earlier, training program is composed of training tasks. Connections among tasks are of dynamic nature: the choice of a next task (or a decision to complete the training) depends on the evaluation of the level of skills achieved by the trainee. Training programs are created by *Training Programs Generator*.

## 4. Functional requirements for trainers-simulators and the platform

Because of practical reasons simulators should be implemented on PC-class computers. Training tasks are to be performed in an interactive mode, in a real-time, with the 3-dimensional visualization of user's activities in a period of time no longer than 100 ms. This is a severe requirement, because a typical operator's fault like a hit of a robot in an obstacle causes the following operation to be performed: a collision detection, a computation of the consequence of the collision for a robot and an obstacle, rendering of the results on the screen. From authors' experience it follows that a computational power of contemporary PC-class computers, equipped with fast multi-core processors, and additionally the ability of use of a computational power of multi-core processors in graphics cards, is sufficient to fulfill this time requirement. So, simulators may be implemented on PCs with sufficiently efficient graphics cards.

Platform should be implemented on PCs not worst than PCs applied in simulators, as a system with distributed hardware architecture (computers connected by a fast local area

network). A fundamental requirement concerning a platform it is to allow a design and a creation of software for simulators of the Level 1 and the Level 2 for land mobile robots. Simulators' software shall guarantee the ability to perform an intelligent multilevel training and model driven creation of the software. Robot's models shall be created by the modification of robot's models generated by robot-oriented CAE programs or by Robot Model Generator which composes models from building blocks. Virtual Console Generator shall allow the use of buttons, switches, displays and joysticks. Environment Generator shall allow: modifications of environments (terrain shape and objects), definitions of any objects (shape, dimensions, mass) and placement of them in environments as static objects, introductions of bad light conditions (fog, smoke, fire etc). Training Tasks Generator shall allow unlimited definitions of events (both expected and treated as operator's faults) and any score designation linked with the events. Training Programs Generator shall allow: definitions of task sequence graphs with dependencies of some logical conditions which reflect levels of skills of trained operators, registrations of obtained results resulting form performed tasks and definitions of final ocean criteria. Other requirements follow:
– already existing system and application software shall be applied as intensively as possible,
– simulator's software shall be modular with well-defined standard export and import capabilities,
– the platform shall be open for modifications and enlargements.

## 5. Prototypes of the platform and of an exemplary trainer-simulator

The prototype of the platform was implemented on PCs under MS Windows XP. Computers are connected by fast LAN with CORBA (TAO version) technology. The platform's software is based on MS Visual Studio 2005/2008 integrated programming environment, graphical libraries Open GL i GLUT, NVIDIA CUDA libraries, tools for the XML standard, tools for the UML language. A general view of the platform is presented in Fig. 1.

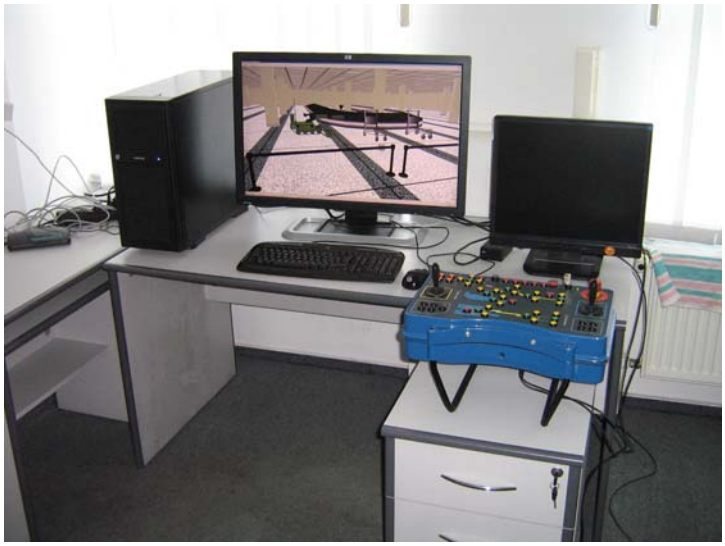

Fig. 1. The prototype of the platform

Sample screens generated by original software tools are presented in Figures 2 – 5.

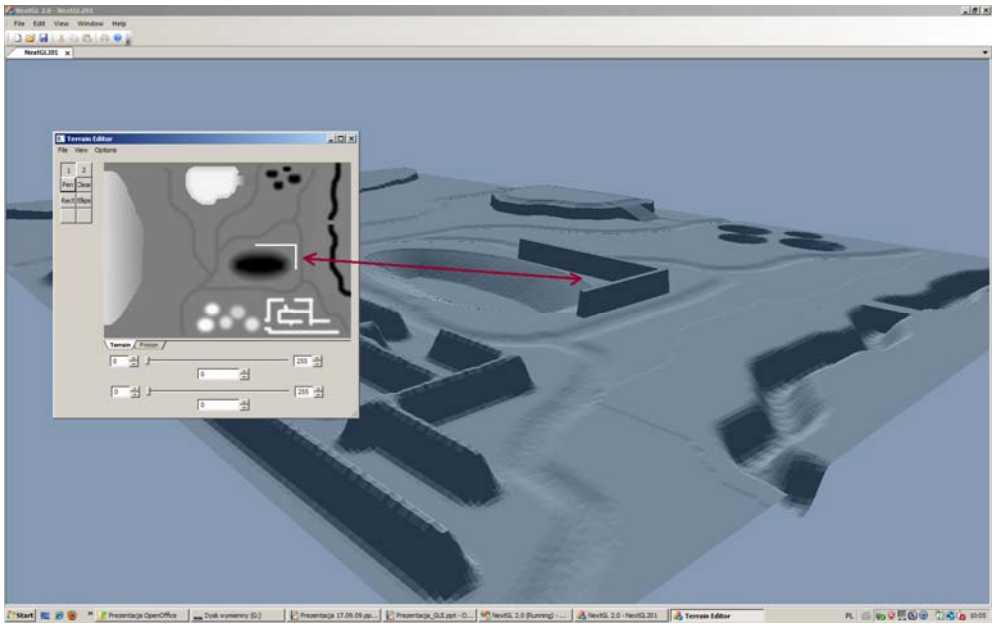

Fig. 2. A sample screen of *Environment Generator*

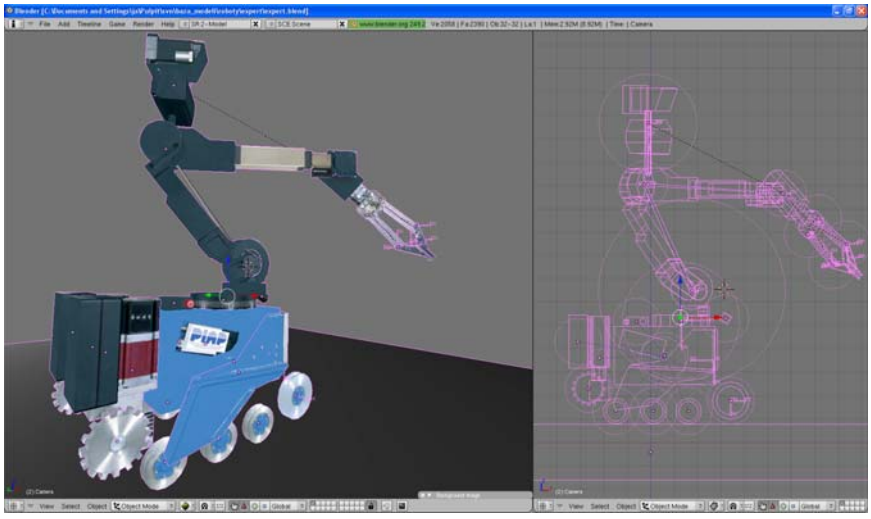

Fig. 3. A sample screen of *Robot Model Generator*

Fig. 4. A sample screen of *Virtual Console Generator*

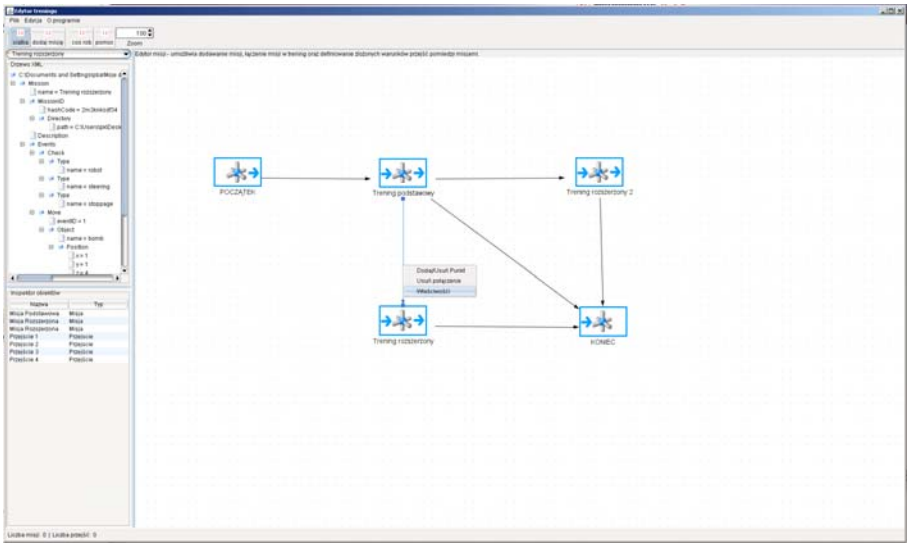

Fig. 5. A sample screen of *Training Programs Generator*

With the use of the platform the software for simulators of the Level 1 and the Level 2 for the "Inspector" robot (made by Industrial Research Institute for Automation and Measurements *PIAP*, Warsaw) was designed and generated. Work in progress concerns simulators' software testing and elaborations of new training tasks and training programs.

## 6. E-training for RISE operators

There are factors that make future e-training of RISE systems' human operators specific, in some aspect different than discussed above e-training of mobile robots operators. One can expect RISE robots development will lead toward their growing intelligence and cognitive skills, so operation has to be conducted by humans at highest level of control. Human operators will interact with robots not only in acting phase but in planning phase as well. Moreover, RISE operators will work in the complex system, so have to interact also with superior levels of the system hierarchy. Multi-robots teams, as well as groups made up of robots and humans can be a subject of supervision and command by system operators. Thus, there is a need to develop adequate methods and means of e-training. Trainer-simulators, taking advantages of computer games technology and e-learning, are the obvious solution. Experiences obtained so far, both in the project discussed above and by other subjects - e.g. [4] - shows that it's purposeful and possible to develop a platform dedicated to generation of such trainers for RISE. Taking up the work upon this platform in coming years one should consider application of promising technological innovations such as use of an evolutionary mechanism [5], chaotic behavior decision algorithms [6], or fuzzification processes [7]. Especially interesting for e-training – however not yet practically available [8] – seems to be use of cloud computing, it means installation of trainers-games on a supercomputer, and streamed them in real time online to distant cloud computers being "thin-client devices", even iPhones. This solution would enable e-training not only RISE operators, but also – in the adequate extent – common public which can be sometime a subject of risky interventions provided by the RISE; besides of such training the public first of all can be informed in attractive form about the RISE existence and function.

Putting e-training for RISE operators into effect needs recognition of the RISE users requirements in the respect of training: profiles and numbers of trainees, taking into account operational needs of different functions and interfaces of the system, as well as needs of certification of the system authorized operators. On this basis a concept of the training and certification should be prepared, and then an offer related to this matter, in connection with RISE dissemination and exploitation, should be formulated.

## 7. Conclusion

Future EU projects in the RISE area should include undertakings that ensure preparation of well-trained operators of the RISE systems, and e-training methods are very useful to this aim. As experiences of the project conducted by the authors, as well as experiences of other subjects show, a computer platform enabling design of trainers-simulators and generation of software for them is the convenient solution to realize successfully such undertakings.

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