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Publisher's version / Version de l'éditeur:

Proceedings of Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2012, 12187, 2012-12-06

NRC Publications Record / Notice d'Archives des publications de CNRC:
https://nrc-publications.canada.ca/eng/view/object/?id=1f13bb8b-7661-4e52-acd2-719c85da1a1f
https://publications-cnrc.canada.ca/fra/voir/objet/?id=1f13bb8b-7661-4e52-acd2-719c85da1a1f

Crossing the Barrier: A Scalable Simulator for Course of Fire Training

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ABTRACT

The growing training and operational needs of law enforcement and public safety personnel can no longer be met efficiently and effectively through existing infrastructure and resources. While the demands of day-to-day operations are constantly changing, the training of law enforcement personnel and certification process has largely stayed the same. While several technological solutions exist for enhancing training, widespread adoption of current approaches and solutions, such as virtual training, is hindered by significant cost barriers and by lack of scalability and reach. This creates challenges for smaller geographically disconnected units, which characterizes most rural police departments in North America.

This paper presents MINT-PD, a technological solution for multimodal virtual Course of Fire (COF) training, along with field observations and validation of the technology. One specific application of MINT-PD is to help to increase the rate of success among the trainees who failed a first COF certification round. Success in this context represents significant cost savings by reducing active-duty officers' down-time due to the remedial training and reducing the need for the use of the live firing range. MINT-PD is based on the Multimodal Interactive Trainer (MINT) simulation platform developed by NRC, specifically adapted to address user needs in training and certification for a typical municipal police department.

MINT-PD technology allows users to modify training scenarios, incorporate different types of laser guns and a flashlight, add avatars, and expand the training to include Use of Force scenarios. The conditions and parameters implemented in the virtual COF simulator have been derived from field observations and validated by COF trainers within a medium-size police department. This process of technology development and validation will be described in the paper.

ABOUT THE AUTHORS

Helene Fournier: Dr. Helene Fournier is a Research Officer at the National Research Council. Dr. Fournier joined the NRC in 2002 and holds a Ph.D. in Educational Psychology from McGill University. Her research area is education and technology and she has participated in several research projects focused on the use and evaluation of learner-centered approaches, design and technologies in Personal Learning Environments and in Massive Open Online Courses (MOOCs), and the use of virtual technologies in military and law enforcement training sectors.

Jean-Francois Lapointe: Dr. Lapointe joined NRC as a Research Officer in 1998. He holds a B.Eng. and M.Eng. in mechanical engineering specialized in robotics and a Ph.D. in electrical engineering specialized in human factors, all from the University of Montreal. He is pursuing research on the design, realization and evaluation of interactive technologies for training, supervisory control and entertainment purposes. He participated in several research projects involving the use of virtual reality technologies in the forestry, mining, space robotics, media arts, heritage, military and law enforcement sectors.

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INTRODUCTION

Use of Simulations in Training

There is a growing interest within the Canadian Forces and Law Enforcement sector in using off-the-shelf computer games in training because of the interactivity and engagement they create for the player. However, training simulations and games are designed with different objectives in mind: a game being focused on the entertainment value for the player and a training simulation being focused on the achievement of learning objectives. Roman and Brown present a comparison table of gamers and trainers' preferences (see Table 1), originally presented by Helsdingen [1]. The table shows important and possibly irreconcilable differences between preferences for these two types of technology users. Serious games are aiming at bridging this gap, offering engaging situations for the learner, while, at the same time, being designed with learning objectives in mind.

Table 1. Comparison of gamers' and trainers' preferences

Gamer Preferences	Trainer Preferences
Entertainment	Learning Process
Emotion	Structure
Player Control	Learning Goals
Free Play	Instructor Control
Unpredictable	Standardization
Turn of Events	
Fantasy	Realistic Problems
No Boundaries	Effective and Efficient
Social Interaction	Transfer of Training
Surprise	Validity
Risk	Fidelity
Suspense	
Art and Beauty	

Current approaches and solutions to training also highlight problems such as cost, scalability and reach, with cost being one of the main challenges for the adoption of virtual training solutions [2]. This is particularly relevant for the law enforcement sector, where personnel are located in smaller units, making the procurement of costly virtual training simulators more challenging.

Simulators provide many advantages for training, including high fidelity to real-world operating environments. The main argument is that the closer the training environment to the real world, the better will be the transfer of skills and knowledge acquired during training. However, it is now recognized that a simulator's fidelity must be measured not only by the physical appearance but also by its psychological and cognitive realism from the trainee's perspective [3]. Simulation-based training environments also provide instructors with the capacity to select specific training conditions and monitor performance, with detailed recordings of a trainee's performance for the purpose of performance comparison, diagnostic, and evaluation [4]. Gaming technologies adopt an experience-based approach, allowing for repetition of scenarios without the high costs associated with live simulations, with a significant reduction in training time required to demonstrate proficiency [5] and demonstrated transfer of skills (i.e., pistols skills) from synthetic environments (laser-based dry-fire environment) to real work settings [6]. The availability and access to simulators are factors that have been identified as crucial to maintain readiness and avoid performance degradation [7, 8].

The requirements for simulation-based training for law enforcement personnel are somewhat different than those of military or safety personnel. As such, caution in adopting any technical solution that removes the human decision maker from the process needs to be exercised [9]. Research on expert decision making amongst law enforcement personnel show a reliance on collecting sufficient cues and understanding patterns emerging from these cues in order to recognize the "situation" and appropriate actions to take [9]. In this respect, simulation-based training environments which

provide both behavioral breadth and flexibility contribute to the realism of simulated entities (i.e., targets, threats, and bystanders) and help them to reach potential as a source of experience in attaining expertise in a law enforcement role.

In addition to meeting the training needs of law enforcement officers, the current MINT-PD training simulator project addresses cost and maintenance challenges by developing a system that could be readily acquired, deployed and maintained by a small unit or police department. Moreover, a systematic requirements specification process ensures that the training system is designed to meet the desired level of performance and readiness from police officers or personnel.

COURSE OF FIRE AND USE OF FORCE TRAINING

R&D Background

This research project addresses some of challenges and shortcomings of existing training systems, both physical and virtual, and the specific training needs we identified through field studies in collaboration with local law enforcement (a mid-size municipal police department) and personnel from Canada's National Policing services (Royal Canadian Mounted Police, RCMP).

Some of the major challenges faced by today's training efforts for COF training and certification include cost, efficiency, effectiveness, and safety. Challenges were first identified in the context of infantry training and were further refined as part of field studies of COF training with law enforcement personnel. The challenges include:

- High cost: current training resources are not always reusable (e.g. CO_2 cartridges, bullets, paper targets);
- Inefficiency: layouts are not easily reconfigurable (limitations of physical spaces, static paper targets);
- Lack of realism and predictability;
- Safety needs: certain operations require extreme caution (e.g. use of real bullets, firearms jams and other malfunctions).

One of the issues with live training facilities is their limited ability to simulate different training scenarios for law enforcement or public safety. Virtual technologies for enhanced training are becoming increasingly available; however, such technologies are frequently costly and logistically prohibitive. The current research and development builds on the IRET-MINT prototype which was developed within collaborative R&D effort between the National Research Council Institute for Information Technology (NRC IIT) and DND Combat Training Centre Tactical School at Canadian Forces Base (CFB) in Gagetown.

MINT (Multimodal INteractive Training) technology was first used and tested in the context of Urban Operations for baseline training in practicing shooting precision (e.g., shot placement and accuracy), threat assessment, and for the purpose of practicing room takeover drills [10].

MINT system demonstrations and trials with law enforcement personnel and COF instructors provided researchers with opportunities to collect data, including notes from observations during live COF and MINT testing exercises and demonstration sessions, commentaries from SMEs and COF instructors while interacting with the system and its components, and information from debriefing sessions held with participants. The information gleaned from these exchanges revealed the need for learning scenarios within MINT to be expanded through better customization of simulator parameters (e.g., hits, penalties, times), for improved capacity for tracking teams' performance with multiple laser detection, and for better scenarios for discriminating target depth and perceived distance in the context of developing shooting precision and threat assessment skills.

Field studies and requirements gathering

In addition to initial requirements gathering at the headquarters of Canada's National Policing services (Royal Canadian Mounted Police, RCMP), we carried out observations on the COF at a mid-size municipal police department. The walk through the regular COF certification procedure was conducted by the experienced COF police force instructor and was video recorded. In addition, verbal explanations of conditions and requirements for COF training were recorded and transcribed. Field observations combined with COF training documents and certification standards (i.e., scoring sheet) highlighted the following important parameters and conditions for performance:

- Number of rounds per stage (e.g., 8 rounds, 4 rounds);

- Movement specification (e.g., moving right and left, shooting on your back, room entry, moving and shooting behind cover, shooting from a sitting position in chair, standing, kneeling and prone);
- Training conditions and behaviours to execute for each stage (e.g., red and blue light, body armour drill, shooting with flashlight, mandatory reload).

NRC project team included the following areas of specialization: human computer interaction, cognitive modeling, natural language processing, and educational psychology. After three software development sprints of two weeks each, the first COF prototype for a mid-size municipal police department was completed. A local police department's COF instructor (SME) provided valuable feedback on the first prototype version of the COF system. The COF includes eight stages required for certification, along with a new MINT-PD interactive device - a flashlight built with a Wiimote. The MINT-PD simulator, platform, and the portable system are presented next.

Technology development

The MINT-PD training platform is comprised of a highly customizable set of interconnected technologies that allows law enforcement or public safety personnel to train using a virtual environment in a manner similar to training in a real physical environment. The overall structure of the MINT-PD system is illustrated in Figure 1 below.

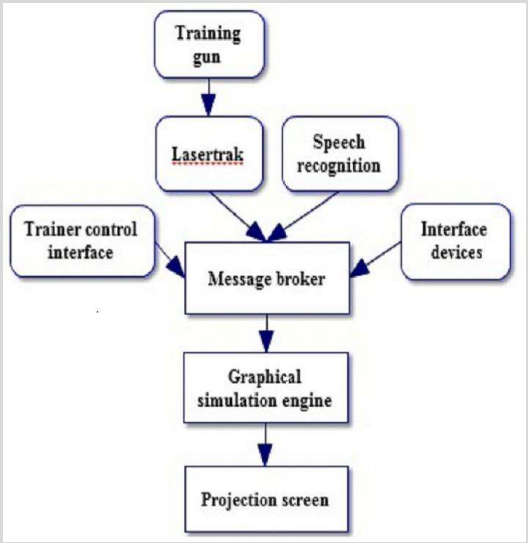

Figure 1. Overall MINT-PD structure

The system is scalable in that the hardware and software, as well as training scenarios can be adapted to the needs and demands of an evolving training program. One possible application of the MINT-PD simulator is to increase the rate of success among the officers who have failed certification. The primary use of the system is to provide remedial training in COF starting from the application of basic skills and judgments with varying conditions and levels of difficulty.

The research team developed a MINT-PD portable system with improved laser detection technology, user-centered speech processing capabilities and COF. The main components of this portable system are illustrated in Figure 2 below.

Figure 2. MINT-PD portable system

COF simulation environment

The COF simulation environment includes elements that were derived from field observations, training and certification standards and information gathering from COF trainers and subject matter experts. It includes eight stages representing different exercises with different level of difficulties. The target's distance varies from 5 meters up to 15 meters depending on the training stage. The last stage involves not only the use of the pistol, but also the use of a flashlight to localize the target. The first stage is illustrated in Figure 3 below.

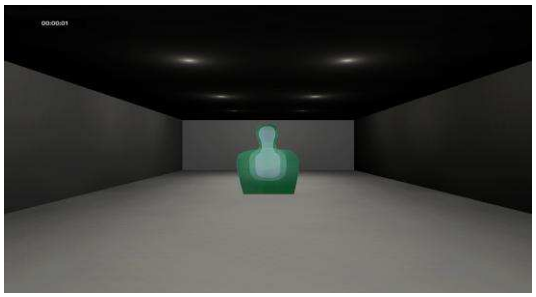

Figure 3. Course of Fire simulation environment

The target is divided into several areas going from

dark green to medium green to light green. It is a replica of the target used for the real COF training (see Figure 4). Any round completely off target is considered a fail in that stage, while any shot within a green area is considered a pass. Shots in the lighter green areas may lead to some recognition (e.g. certification with Cross Pistols level of proficiency or Crown if all shots are in the light green area).

Figure 4. Target used for the real COF training

For the actual certification, the lighting conditions differ for certain stages, from normal to low-light conditions or even in the dark for the last stage (i.e., stage which requires the use of a flashlight).

Some stages use only one repetition while others use two repetitions. An alarm sound is emitted at the beginning of every stage to warn the trainee of a threat. In total, 56 rounds are fired during the COF.

Speech user interface

Speech user interface developed within the MINT project was enhanced with easy to use grammar builder interface that provides instructors with option to make changes within the system vocabulary to reflect police usage scenarios.

Touch-based interaction

Besides trainees, instructors are also users of a training system. As such, appropriate interactive components need to be provided to instructors to enhance the overall realism of the training scenarios. In contrast to traditional training methods, an immersive gaming environment allows for richer and more engaging interactions. To address this, a tablet-based control interface was developed for instructors for facilitating the real-time manipulation of training scenarios (see Figure 5).

The trainer control unit is implemented as a touch-based interface serving as a teaching tool that allows instructors to animate game characters in response to trainees' actions.

Figure 5. Trainer control interface

All the animations and actions that the game can perform could be initiated through this trainer control interface. Moreover, game actions that are initiated by trainees through spoken commands can be overridden by instructors (e.g. when the speech recognition system did not accurately process the command) or reversed by instructors to create "on-the-fly" training situations that test the responsiveness and judgment of the trainees, as, for example, introducing non-compliant behavior for the virtual game characters.

Training guns

In order to simulate the training with real weapons, laser pistols were developed that have the same shape as the real service weapons used by police officers, namely the P-228. The laser pistol depicted in Figure 6 is made up of several subcomponents (pistol, laser, and electronics). All electronics, the assembly, testing and system integration were done in-house.

Figure 6. The laser pistol

The electronics is designed to allow firing short pulses of laser beams each time the trigger is pulled. Laser shots are tracked by a vision-based system that allows recording the shots, their number, and location and provides a timestamp option.

Learning objectives

The MINT-PD training system and COF are aimed at substantially improving trainee's skills of physical tactical techniques through intuitive displays and rich feedback, without significant extra time being required for instructors or trainees to devote to system-specific training or setting up the system for each scenario, e.g. the users can simply walk up to a training unit and start using it.

The use of COF simulation environment will allow trainees to practice shooting and judgment skills and to meet performance levels required to pass COF certification.

Evaluation of multimodal components

The requirements gathering process was focused on identifying aspects of current training procedures that can be performed under more realistic, more cost effective, and safer conditions in a lab-based environment. Among such conditions for COF remedial training we have identified silhouettes (targets), conditions (number of shots, distance), position and movement as important parameters for our MINT-PD system.

The first iterations of the COF components were validated in the following context:

- Shooting range observations;
- Lab-based setting;
- Testing remedial training scenarios with data in the form of direct observations, video recordings, and transcriptions of feedback from the COF instructor/subject matter while using the simulation environment and post interview responses.

The analysis of data collected from first iteration field studies was focused on identifying improvements required for the MINT-PD components, both at implementation level and at design / interface level. The evaluation confirmed the value and role of instructors to the training environment. To address this, interaction within MINT-PD was augmented to allow instructors to manipulate the simulation scenarios dynamically through a tablet-based touch interface.

Feedback from law enforcement officers, including COF instructors who were our subject matter experts, touched upon the following points:

- Regular feedback from COF instructor and iterative process in technology development is a must;
- Input from COF instructors on mobile tablet menu items was obtained and all modification vetted;
- Emphasis on 'manageable' aspect of control interface for instructors—e.g., settings and options for target distance and stages, recording shot;
- Moving targets are highly desirable—especially in practice mode;
- The need for commands for engaging targets—e.g., gun threat (verbalized) as prompt instead of siren or alarm sound;
- Feedback from COF instructor on accuracy of laser shot and additional options—e.g., simulated barrier to hide targets;
- Defining the quality of shots by zone on the body, timed recordings, instructors configurations;
- Control of recorded information—automatic deletion;
- Visual, behavioural cues—e.g., body armour, suspect not falling to the ground when shot;
- The importance of "don't shoot" scenarios—e.g., woman holding a baby;
- Device training barrel, safety and security, simulated firearm jams;
- Having too many options is confusing, less desirable; turn features on/off options as viable.

A revised version of the MINT-PD components was validated in lab-based trials and on-site testing of COF simulated conditions, with the following highlights:

- The virtual training system is well received by its intended users;
- Speech-based interaction for use of force scenarios is critical in ensuring the realism of the interaction with the virtual environment;
- The accuracy of automatic speech recognition can vary significantly across training conditions, but can be easily compensated for by using complementary modalities, such as the tablet-based trainer interface;
- The ability to quickly configure the physical layout of the training environment is an important feature that significantly reduces the down-time between training sessions;

- The simulated conditions (e.g., lighting) and lethal and non-lethal devices that interact with the gaming environment (e.g. flashlight) were seen by participants as important components of the mixed reality training system;
- The touch-based tablet interface for instructors to enable rapid customization and control of scenarios, as well as to react to trainees' mistakes in a timely fashion was very well received by instructors;
- The ability to review scores and timed responses is important, as is automated deletion of records.

The next development phase will focus on: moving targets for practice, instructor mobile control device, and laser fitting with firearms to be conducted at the local police department shooting range. We will also investigate the improvement of Use of Force scenarios based on the training provided to local police officers. Regular feedback from law enforcement and COF instructors will be sought on a regular basis using screen designs and prototypes.

An empirical study related to the use of the MINT-PD simulator for remedial training and preparation for certification is planned for the fall of 2012. Outcomes of this research should reveal whether our simulator is an effective tool for filling in the gap between live fire sessions and better preparing trainees to meet COF certification standards.

OUTCOMES AND LESSONS LEARNED

MINT-PD trial observations and validation exercises with law enforcement and COF instructors yielded valuable information on the significance of simulations in COF remedial training and Use of Force scenarios. The instructors would like to control in the training system:

1) conditions;
2) target distance and movement;
3) features of the system (e.g., generation of scenarios, sequencing, ability to turn on/off feedback option, etc).

Observations and trials of MINT-PD technology also revealed that COF instructors preferred a blended approach for basic to advanced skills training, including target selection and shooting simulations for warm up exercises and skills maintenance, and mixed approaches for remedial training, including mobile displays and VR displays with avatars and wall projections, mobile capability for changing the simulation scenario in real time, moving targets, and timed responses. A recent validation exercise reinforced the potential for expansions of the current applications to include: better customization of simulator parameters such as points earned and penalties, integration of multiple lasers detection within the simulation for team playing, addition of target depth and perceived distance.

Additional simulated events have been identified and could eventually be integrated as part of the simulation-based remedial training for COF and Use of Force. Potential research and development also include eye tracking measurements to capture in detail shooting and threats assessment skills, as well as real-time measurement of stress physiological indicators.

Technology outcomes

The validation of the MINT-PD technologies and COF focused on customizations based on users needs, as determined through field studies and lab evaluations, resulted in several research and technological outcomes:

- Identification of key human factors for interacting by voice with COF simulator;
- Research on Automatic speech recognition (ASR) performance issues in real-life training scenarios;
- Methodologies for the successful adaptation and use of ASR within training environments, taking into account the specific human factors and performance limitations;
- Remote-input technologies to complement speech interactions and allow realistic use of simulated weapons and non-lethal weapons;
- The ability to adjust precisely the aiming of the laser beam on the laser rifles with the addition of a mechanical adjustment system using screws.

CONCLUSIONS

The results of field studies and technology development cycle that were a part of the MINT-PD project lead to important findings regarding the feasibility of a lightweight, scalable, and configurable simulator in addressing the essential needs of COF remedial training for police officers.

COF simulated gaming environment enables users to interact with input devices emitting laser lights, with simulated area weapons and non-lethal devices such as flashlights, and with virtual environments through speech and touch. Field trials and demonstrations with law enforcement have resulted in validation of mixed methods and alternatives to the initial MINT (IRET) chamber prototype (10), including mobile screens equipped with a laser shooting interface to allow for quick reconfiguration for the purpose of COF remedial training and for developing shooting skills, as well as mobile, tablet-based, touch interfaces allowing trainers to dynamically control the simulation interaction. Controlled studies on the design and interactions with MINT-PD platform and COF portable technologies are on a path for a follow-up research project with a broader range of potential end users, including public safety personnel. Continued validation of the current version of MINT-PD, COF remedial training platform needs to address the following issues highlighted by our current research and evaluation: better customization of COF simulator parameters, manageable instructor/control interface for instructors, and multimodal interaction and control features (e.g., commands for controlling and engaging targets, avatar behaviors, changing scenarios on the fly). Furthermore, subsequent developments of the virtual training system should continue to emphasize aspects related to human factors of interacting with immersive environments, such as the accuracy of automatic speech recognition under adverse and high-stress conditions, the interaction with physical embodiments of virtual elements, the usability and usefulness of mobile trainer controls, and the ability to remotely supervise training.

ACKNOWLEDGEMENTS

We would like to acknowledge the contributions of Constable Brent Legere of the City of Fredericton Police Department. His insights and feedback as a Course of Fire and Use of Force subject matter expert and instructor were invaluable to the MINT-PD prototype and validation process. We would also like to thank Gregory Krätzig in Training, Innovation and Research, Royal Canadian Mounted Police, Depot Revision for his comments and feedback on early prototype demos and requirements gathering exercises. We also wish to acknowledge our colleagues from the National Research Council of Canada who have been involved in the research, design, development and testing of MINT-PD, the capture of images for production and promotional purposes, and especially in supporting research staff in creating innovations and in reaching project milestones in a timely fashion: Muhammad Al-Digeil, Ilia Goldfarb, Cedric Martin, Rene Richard, and Danny Damours.

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