The Application of 3D Visual Simulation Technology to Highway and Tunnel Emergency Training and Management

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Abstract. The 1999 fire inside the Mont Blanc Tunnel led the French authorities to speed up the process - already planned - of improving the safety of tunnels and roads. The new regulations defined specific measures to ensure user safety and emergency services and led to new requirements regarding the training of operators. Indeed, in this highly regulated environment, operations staff are under increasing pressure. That is why they should receive appropriate training not only during their initial learning, but also later, to ensure the continuous improvement of skills and behaviour particularly in a crisis situation. To be effective, these programs need to immerse operators in situations similar to those they might encounter in real life: management of an important event, communication with stakeholders, and application of complex procedures. For this industry, BMIA has developed an innovative system known as G'Val, a unique solution of 3D real-time traffic simulation on the roads and in tunnels, directly controlled by an original Traffic Control Device, based on the UC-win/Road software from Forum8. This simulator is used to train control centre operators, to validate new operating rules and features, or to evaluate new traffic software. The simulator allows personnel to be trained in a simulated environment that exactly reproduces the real environment: CCTV monitoring, HMI and ADI alarms, total control over road equipment, driving of emergency vehicles, communication with stakeholders... It can play predefined scenarios, replay real situations (accident, beaconing), or rarer events (fire and smoke in a tunnel). With this simulation it is possible to check operator knowledge of existing procedures and test implementation of new ones. The ability to network multiple simulators permits training of operators in complex situations and assessment of their reactions and stress resistance.

1 INTRODUCTION

Over the past decade, improvements in tunnel security and safety have become paramount for operators and concessionaires. The standard way to train operators and emergency service stakeholders in facing emergency situations is to setup field drills that allow them to apply and assess emergency evacuation procedures and intervention plans.

In tandem with these drills, the operator has to develop appropriate response strategies for the various incidents and incorporate them into the final versions of the emergency plans, procedures and manuals.

The debriefings that follow the drills, and the resulting conclusions, should show that the predefined procedures were applied and rescue operations were efficiently managed and conducted.

The main principle of G'Val is to allow these drills to be performed on a simulator instead of in the actual road or tunnel, but still with the real tools such as SCADA system, radio, and phone.

2 PRINCIPLES

2.1 Context

Major tunnel disasters over the last decade and prior have shown how swiftly and badly a simple crash or fire may evolve should the wrong actions be taken by control room operators or traffic managers. Global safety issues and the reactions of operations staff have now become principal concerns for Operations and Maintenance (O&M) service providers.

In 2004, the European Parliament issued a Directive on minimum safety requirements for tunnels that are part of the Trans-European Road Network. This Directive has been implemented in local law in each country concerned, so tunnel operators are now required to comply with the directive as soon as possible – but not later than 10 years after the Directive came into force (i.e. 2014).

Under the EC Directive, all requirements are spelled out in documentation known as the Contractor's Plan in the UK and Ireland, or as the Safety File in continental Europe. This Safety File also contains potential incident and emergencies identified before the opening. The identified,

defined and ranked emergency scenarios provide the basis for appropriate response strategies and are included in the tunnel operator's manual and operational procedures of the police and emergency services.

These procedures are tested, assessed and updated (if necessary) during regular emergency exercises/drills that are carried out to ensure continuous effectiveness of the response strategies. In these exercises, various emergency service stakeholders (fire services, first aid, rescue teams, and police) experience different scenarios and situations, such as fire-fighting, treatment and evacuation of injured users inside the tunnels, dangerous goods identification, management of an accident involving a coach with multiple victims, etc.

2.2 Impact on Operations

As a result of these drills, various operational and emergency services had the opportunity to confront exceptional situations in which severe incidents might arise, and address mitigation measures as part of a program for continuous monitoring and development. The drills also enabled the requisite emergency response units to assess and subsequently improve their behaviour in the event of severe and critical incidents in the tunnels. Notwithstanding coordination and communication between the emergency response units, control room operators and onsite staff always have room for improvement. But the drills enabled new operators and different emergency response units to familiarize themselves with the tunnels and their main management and operational features. It also allowed the different operations personnel and emergency response units' staff to become acquainted with each other.

2.3 State-Of-the-Art

Operating a motorway and/or a tunnel is a complicated undertaking. Multiple and varied pieces of equipment and procedures are required for operators to effectively manage the assets. Each and every piece of that equipment must be mastered by suitably skilled control room operators and other relevant staff.

Operation of roads and tunnels requires a high degree of competency in areas such as equipment requirements and maintenance, establishment of drills to mitigate potential incidents, special training and organization, provision of the appropriate documentation. and implementation of local safety and monitoring requirements, etc..

Detailled procedures must also be developed to coordinate the actions of internal and external staff; these must be very well understood, practiced and tested, particularly by control room operators.

Nevertheless, Tunnel operators as well as Road Control Centre operators are operating in an increasingly complex environment, with factors such as:

- constantly evolving systems and technology
- changes in rules for operation and security
- drastic need to react to unpublished situations

Control room operators must constantly train to a high level to ensure effectiveness within a tailored organization. Any training program must therefore include a wide range of skills and competencies, including both a general understanding of operating systems as well as knowledge about the specific asset. Mastery of the Supervisory Control And Data Acquisition (SCADA) system and equipment is the primary focus but knowledge of internal procedures is also an important part of the training.

Theoretical training and learning are not sufficient, however. Operating a tunnel or a motorway requires the combination of several different skills such as communication and reporting, situational analysis, confidence, self-control and stress resistance.

A survey taken at ITS World shows an overriding lack of specific tools for training.

2.4 Help via a simulator

As Aristotle said: "Anything that we have to learn to do we learn by the actual doing of it". There is definitely no better way to train than to practice with our day to day tools in our usual environment.

The use of simulators is an innovation which is aimed at improving operators' skills and providing new solutions to complex situations.

Simulation is the only way to create and reproduce an unpredictable situation and to allow it to be solved, without stress or cost, in a totally safe context, with detailed features permitting it to be reproduced, paused, stopped, restarted, different solutions to be evaluated,…etc. . All of that can be performed without stopping regular operations and without of the need for complex preparation.

Using a simulator is an efficient support tool for the theoretical training, procedure learning, desktop exercises and assessment that are the basic elements of staff training but which must be completed with live exercises:

- In the pre-operational phase, a simulator may be used to familiarize operators with their future tasks and procedures. Training sessions can therefore take place without the need to access assets.

- In the operational phase, a simulator allows training in situations close to reality but without asset mobilization. This is a particularly important point for tunnels which are often traffic hotspots and where the opportunities to close for training are limited. Moreover, maximum lane availability is often required by new operating contracts, which rarely permits O&M service providers to close assets in order to organize live exercises.

The simulation tool can also be used to 'replay' a real event that occurred in the past, in order familiarize operators with the event so they can better manage a similar event in future. This replay feature contributes to the overall knowledge of the entire staff and enhances the level of overall safety.

Using a simulator allows the trainees to learn procedures, to test them and eventually to make mistakes in their application. The briefings and review of experience given by the trainer after a session has been performed also adds significant value.

When using a simulator, trainees are immersed in a 3D reality and face different events, incidents and accidents. These 'virtual' situations put trainees in a close to real life situation where issues and difficulties identical to the real incident must be dealt with (including communication, equipment failures or blind spots caused by smoke, for example). This degree of realism enables control room operators, as well as patrollers and their on-call managers, to experience highly pressured situations. A simulator is the only way to increase the reliability of the operator in handling realistic crisis situations under stress. This facilitates the assessment of the operator's behaviour during his or her training.

In conclusion, a traffic and safety simulator enhances the overall level of service by increasing asset availability as well as the operator's ability to manage and operate a motorway or a tunnel with full confidence in its management procedures. In addition to control room operators, the simulator also allows on-road operators to be trained in a benign environment.

The end result is that safety at the operating company is significantly improved through the use of these new tools which have been designed to develop operator preparedness for facing his/her day-to-day job.

3 THE G'VAL SIMULATOR

The G'Val simulator has been designed in response to the following requirements:

- Static requirements: to provide clients with an effective solution that is both quickly operational and customizable. The software must be designed to simulate the behaviour of different components of a road operation as well as the various types of equipment and assets available on typical motorways and tunnels (traffic, road signs, emergency calls, rescue teams, climate ...). The simulation tool must be linked to the real SCADA, to train operators in the use of the Control Centre facilities and to commission the SCADA software as well as traffic management principles or new operating rules. A specific Instructor PC will be used to generate different events within the simulator and also to permit driving of all the components of the simulator. The main objective is to provide trainees with general principles and best practice for control rooms: communication; resistance to stress; return of experience; application of appropriate behaviour and so on.
- Dynamic requirements : Traffic scenario library (accident, slow vehicle, …), basic human animations (users, rescue teams, …), special effects (fog, smoke generator, …), realistic simulation of traffic behaviour and flow, capability to drive in VR with possible interactions, full handling of road equipment with adjustable effect on traffic, variable input flow of vehicles, obstructions, speed regulation, traffic diversions, traffic loops data, controllable field cameras (CCTV), video recording and replay capability, …

The G'Val simulator is composed of three main stations.

3.1 First Station: SCADA Station

The first station represents the complete SCADA system with all of the functionality found in the real control room. The man machine interface allows command and control of a full range of equipment in a realistic environment: screens, keyboards; Automatic Incident Detection (AID) alarms; and so on. Screen video walls allow the operator to monitor the entire network.

The tool simulates all types of equipment that a traffic control room operator may have to use: Variable Message Signs (VMS); video cameras; traffic counting stations; barriers; gas detectors; thermometric cable and so on. Each piece of equipment, available in 3D virtual reality, is able to feed the SCADA system with various data. Through this system, the control room operator can directly intervene in the 3D virtual reality, change messages on VMS, manage smoke in the tunnel bores, and close arbitrary lanes. A full range of interventions can be simulated.

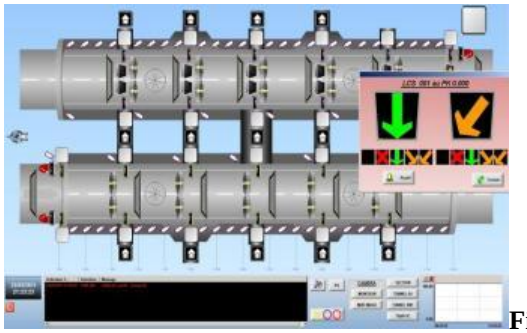

Figure 1: SCADA screen example

The operator also benefits from communication systems such as phones, radio and calls from emergency shelters. Interaction with public services can also be simulated by voice generators.

3.2 Second Station: Driving Simulator

The second station is a driving simulator with a steering wheel and pedals. This is used to assess intervention by patrol personnel at any location on the 3D network. As with his or her colleague(s) in the control room, the patrolling officer is immersed in a arriving on site with a safety vehicle equipped with flashing lights and beacons, the patroller can simulate the appropriate actions, such as management of traffic, first actions with fire extinguishers or catching stray animals.

All driving facilities are directly implemented via the Forum8 UC-win/Road functions.

Figure 2: Driving screen example

3.3 Third Station: Instructor Station

The third station is the trainer's station which manages the whole simulator. The simulated environment is flexible, allowing the trainer to vary (for instance) the number, type and availability of equipment, or the weather conditions on the network. From the third station, the trainer prepares training exercises and scenarios that will be launched during the training sessions. Scenarios available include a slow vehicle, breakdown, injured users, fire and smoke, objects on the carriageway, or roaming animals.

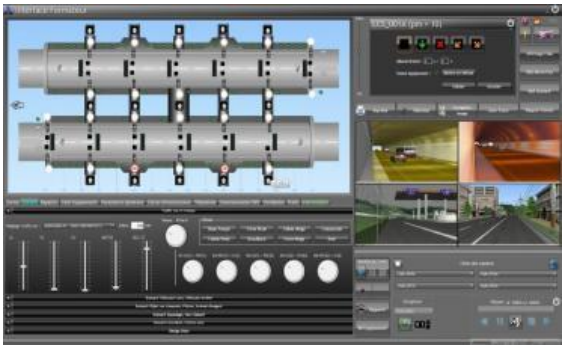

Figure 3: G'Val Instructor interface

The trainer always remains the 'master' of the training session. Indeed, depending on the trainees' behaviour and the procedures being followed, the trainer can adapt the scenario to evolve towards an improving or worsening situation.

All elements of a training session (images, radio communication and SCADA operation) can be recorded and made available in report form.

3.4 Platform Architecture

The G'Val training platform features several embedded software solutions composed of:

- The SCADA system, normally used by the operator.
- A virtual reality (VR) model, build with the Forum8 software UC-win/Road (UCWR) with a 3D network modelled as close as possible to the actual environment.
- An equipment data base with all the interactive equipment of the tunnel (VMS, LCS, Traffic light, road signs, barrier, ventilation, …)
- The different software modules of the G'Val system

A standard platform for training looks like:

Figure 4: G'Val portable platform

G'VAL itself consists of 4 modules:

a) A plugin for UC-winRoad, allowing

- Road-side equipment to be automatically inserted inside the VR from the data of an SQL file. This requires the SQL file to be pre-filled with position data and the textures used as well

as codified names. The equipment is animated via OPC instructions from any OPC Client.

- CCTV camera generation at a position determined by an ACCESS file. These cameras to be displayed on any of the 3 screens output of UCWR on OPC command :
    - Operator screen (4 cameras)
    - Video wall (up to 13 cameras)
    - Instructor screen (up to 4 cameras)
- Generation of appropriate traffic type and volume upon OPC instruction.
- Driving a Patrol car to the incident site and interaction with the incident via game pad command.
- Launching incidents on receipt of an OPC command.

The following incidents can be simulated: slow and stopped vehicle; accident between two vehicles, object or puddle on pavement; wandering animal; beaconing; wounded person; fire and smoke on a vehicle; sending a Patrol car, a Fire truck, an Ambulance, a Police car, or a Tow truck on site …

b) Instructor interface. This interface allows the instructor :

- To stop and launch any kind of traffic topology, density and speed.
- To monitor and command the equipment behaviour and status through an interactive map.
- To monitor traffic behaviour in an embedded screen of 4 cameras that can be recorded as an AVI file and replayed.
- To build and launch any incident and modify it by adding or retrieving features in real time
- To generate the corresponding ADI (Automatic Detection of Incident) alarm for the incident, including mobile alarms.
- To produce a training session report that shows all settings and interactions.

c) Equipment simulator: this optional module works as an embedded PLC to simulate the behaviour of any equipment (ie : for a barrier, the PLC will send a "Opened" signal few seconds after receiving a "Open" command)

d) Communication simulator: this optional device is equivalent to an IPBX with virtual phones (softphones) or physical IP phones connected. A synthetic voice generator allows the G'Val system to generate an automatic message from a virtual user to the trained operator as well as on instructor demand.

The hardware architecture is shown below:

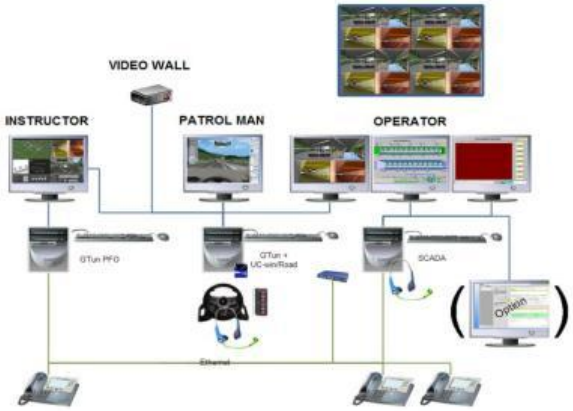

Figure 5: G'Val Standard Hardware Architecture

3.5 G'Val Software Architecture

In terms of software, the entire system is based on an OPC server-centralized architecture. All existing equipment are recorded in this OPC server using a general SQL data base.

This database stores the following information:

- Original tag name and internal tag name
- Equipment type and function
- Equipment localization in the VR
- Inputs and Outputs
- Textures, models, signs and characters used for the scenario
- Typical scenario library
- Tracking of all simulation incidents launched in the simulator

For the simulation to be efficient, the behaviour of each equipment should be modeled, to create the embedded PLC program. This program will ensure that the simulator delivers the right information to the SCADA, as well as processing all orders coming from the SCADA.

For example, if the SCADA sends an "Open barrier" command, the PLC will deliver it to UC-win/Road in order to visualize the barrier opening and after a few seconds will return the information "Barrier opened" to the SCADA so that the correct HMI visualization will be displayed.

The software architecture is as follows:

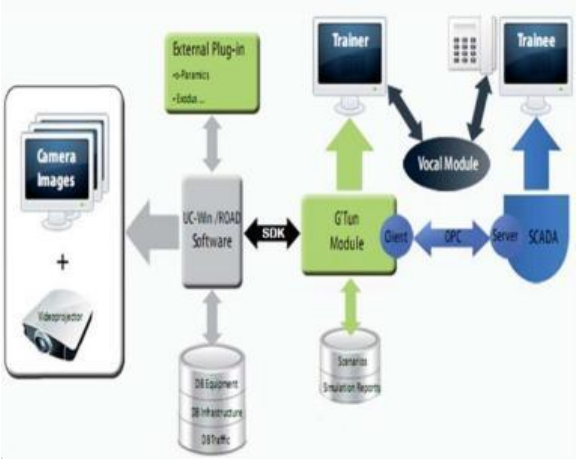

Figure 6: G'Val Standard Software Architecture

4 CONCLUSION-AWARD

The G'VAL real time traffic visual simulator has been designed to help operators, on-road operatives and other stakeholders to prepare for emergency situations. It puts them in realistic situations inside fully equipped tunnels and roads so that they can test, without constraint, their reactions to emergency situations and their assessment and validation of methods of dealing with such events. The simulator offers realistic real-time 3D simulation, drawn from actual plans and satellite maps and using specific project data. The result is the ability to create "near real" situations to assess operator reactions and to train them to react in the most effective way. The system has been developed using expert knowledge of the requirements of road and tunnel operating procedures.

At the 2011 International Tunneling Awards in Hong Kong, the judges commented: "*This is a great new initiative and an innovative use of new 3D modeling visualization technology for the tunneling industry; it has got great opportunities for the future as the system can be widened from current IBM driver training and operations to include many other safety critical areas of the tunneling process*".

Figure 7: International Award for G'Val

This award shows that after the Gotthard tunnel (October 2001, Switzerland), Mont Blanc tunnel (March 1999, France), Frejus tunnel (June 2005, France) and many other accidents, all Tunnel professionals are even more focused on safety than ever before and are very focussed on any solution that could help them to improve their operations.

Figure 7: G'Val in action

Intensive operator training is the only way to achieve their objective of having a safe answer to their customer awareness.

Simulators are the most efficient, economical and pleasurable way of training.

So-called "serious games", such as the G'Val simulator, are effective partly because the learning takes place within a meaningful context. What the operator must learn is directly related to the environment in which they learn and must demonstrate that they have learnt; thus, the learning is not only relevant but applied and practiced within that context. Researchers refer to this principle as 'situated cognition'; its effectiveness has been demonstrated in many studies over the last fifteen years. Researchers have also pointed out that play is a primary socialization and learning mechanism common to all human cultures and many animal species. Lions do not learn to hunt through direct instruction but through modeling and play.

Simulators clearly make use of the principle of play as an instructional strategy.

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