TRAINING IN CAR TERMINALS: A MODULAR ARCHITECTURE BASED ON DISTRIBUTED AND INTEROPERABLE SIMULATION

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ABSTRACT

The paper presents a research work focused on simulating car terminal operations. Particular attention is paid on procedures and protocols currently applied when car terminal operations are carried out and a special emphasis is given on learning processes implemented to let car terminal operators learn these procedures. In such a framework, the proposed research relies on a modeling and simulation based approach devoted to improve operator's efficiency and enhance the effectiveness of training activities. As a matter of facts, operators can experience various working conditions and learn the protocols and procedures that have to be applied while interacting with a 3D virtual environment that recreates the car terminal, its processes and its actors.

1. INTRODUCTION

Car terminals are quite complex systems where many operations involving complex coordination problems usually take place. Indeed, operations in car terminals are regulated by security, reliability, optimization and synchronization protocols that each worker has to know and apply when performing his tasks.

In such a context, one of the main problems is to reduce the time taken for training new workers while keeping the risk of accidents, errors and of low performances at work as low as possible.

In the current practice, training activities avail from "traditional" tools and procedures, for instance slides and oral lessons in classroom where protocols, best practices, the terminal environment, the cars that are involved at work and the driving rules are introduced and explained to the training audience. Although this teaching approach is traditionally accepted and well known by workers, today advanced solutions and technologies can be used to make training sessions more engaging and reduce the amount of abstract information and theoretical concepts to be memorized. Furthermore, such solutions allow trainees to experience a number of different situations (e.g. different traffic conditions and weather conditions while driving, different yard and ship layout, etc.) giving evidence of the security issues they may incur. In addition, it is worth noticing that while traditional training approaches may improve the performance of workers, they involve longer times and require direct training on the real system.

Under these premises, ICO-BLG, the car terminal operator working in the port of Gioia Tauro, and the MSC-LES lab at the University of Calabria, are collaborating (under the umbrella of the Calabrian Pole for Logistics, Transport and Transformation) on a joint research project (CTSIM, Car Terminal SIMulator) which aims at innovating teaching and training approaches by using advanced tools based on Modeling and Simulation.

As far as the state of the art in the field of port operations training by using simulation approaches is concerned, it is worth saying that while many research works can be found for container terminals, there are really few works for car terminals. Indeed, in the area of container terminals, simulation is used not only for training by using 3D Virtual Simulation (Ballis and Abacoumkin, 1996; Bruzzone et al. 2010, Bruzzone et al. 2011; Bruzzone and Longo, 2013; Bruzzone et al. 2013; Massei et al. 2013; Longo et al. 2013) but also for decision making (Merkuryev et al., 1998; Henesey et al. 2006; Hadjiconstantinou et al. 2009; Macías and De La Parte, 2004; Latorre-Biel et al., 2014). As for serious games and 3D virtual simulation, many works can be cited, i.e. a meaningful example can be found in Bijl and Boer, 2011. However, a survey of the state of the art clearly shows that there is a lack of research in the field of training in car terminals by using 3D virtual, distributed and interoperable simulation (Longo et al. 2013). To this end, the proposed research work seeks to fill the gap thanks to a simulation architecture, CTSIM indented to support training activities in car terminals.

CTSIM is a 3D Virtual and Interoperable System composed by different simulators among others the parker and the driver simulator this paper focuses on. Within a car terminal, the parker is the worker in charge of giving all the indications the drivers need to park correctly the handled vehicles (e.g. cars). In turn, the driver is the worker in charge of moving vehicles from the yard to the ship and vice-versa (performing also parking operations). This paper introduces both the parker and the driver simulator that can work in a standalone mode (to allow single operator training), but they can even work in a multiplayer mode and interoperate each other sharing the same virtual 3D environment (for cooperative training). For instance, the CTSIM system can host 4 drivers (e.g. for cars) and 1 parker and they can "play" all together in the same scenario sharing the same 3D virtual environment. They can see each other and they can collaborate as it happens in a real car terminal.

Each simulator will be presented in the next paragraphs; however it is worth mentioning that, as far as the technologies involved are concerned, the CTSIM project makes use of the most innovative technologies such as Microsoft Kinect®, tracking gloves, wheel and pedals, etc., that are integrated by using dedicated software and hardware (developed at the MSC-LES lab at the University of Calabria) with the aim of simulating as faithfully as possible car terminal operations.

2. MAIN PROCESSES AND ACTIVITIES IN A CAR TERMINAL

As described in Longo at al. (2013), the main activities in a car terminal involve vehicles unloading from ships and parking in the yard area, and vehicles loading and parking on board of ships. Loading and unloading operations involve different actors with different roles. The main actors are:

- Driver: the driver is in charge of vehicles handling. He is responsible for conducting vehicles from the ship to the yard during unloading operations and from the yard into the ship during loading operations; he is also in charge of vehicles handling inside the yard area during shifting operations. During special manoeuvres he collaborates with the quality checker and with the parker to reduce the possibility of errors.
- Taxi Driver: the taxi driver brings the drivers from the yard onto the ship during unloading operations and from the ship to the yard during loading operations. In addition, the taxi driver also carries out coordination activities, communicating with the Quality Checker and Parker, to ensure the correct loading / unloading sequence.
- Quality Checker: the quality checker has inspection and coordination functions. Inspection functions consist of verifying that: the operations are carried out according to work instructions, the dangerous points are suitably warned and the cars inspected. Coordination functions refer to those activities that are undertaken together with taxi drivers and parkers and are aimed at choosing and communicating the position (in the yard or in the ship) where vehicles should be placed ensuring that the fixed loading/unloading sequence is respected.
- Service Person: the service person is the figure responsible for the viability definition on board of ships and on the ramps; he is also in charge of first intervention and barcode insertion activities.
- Tally Man: the tally man is the figure in charge of scanning the bar code for VIN acquisition (Vehicle Identification Number) and assigning vehicles with a suitable destination (rows/parks) avoiding scanning vehicles (wrongly placed) with a different destination compared to the one assigned to the same row.
- Marshall (Parker): the marshall (parker) will ensure that vehicles are parked according to the work instructions (distances, parking on the line, check handbrake / first gear, etc.).

The activities of drivers and taxi drivers are cyclic; for this reason it becomes important for a driver to be always focused on his job to avoid any loss of efficiency that would negatively affect the overall system performances. It is worth noticing that, as depicted in figure 1, there are some "waste of time" activities like *Waiting to park, Take Taxi, Leave Taxi, Waiting to leave.*

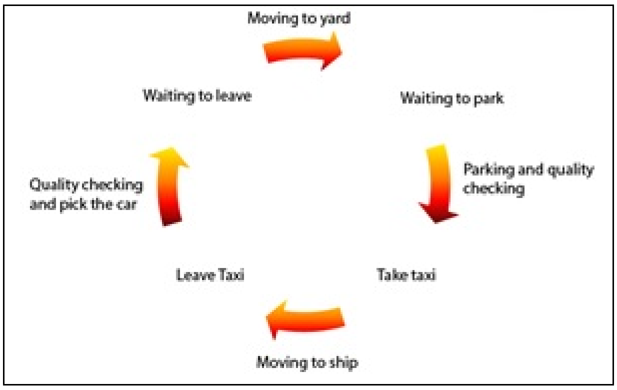

Figure 1: cyclic activities of a driver

Needless to say that all these activities must be carried out as quickly as possible to keep safeguard the terminal productivity.

Furthermore during these activities, drivers and taxi drivers behaviour has to be compliant with security protocols such as:

- they cannot accelerate to much the car;
- they cannot overheat the engine of the car;
- the cannot depart drifting;
- they cannot overpass another car;
- they cannot drive slower than what is expected;
- they cannot drive with flat tires;
- they have to respect the stops signals;
- the taxi has to stay far from the cars, at least 5 meters and maximum 10 meters;
- they have to respect speed limits;
- during the driving, cars have to be 15 meters far each other.

The departing procedure has to follow a specific order to avoid accidents and to reduce traffic problems.

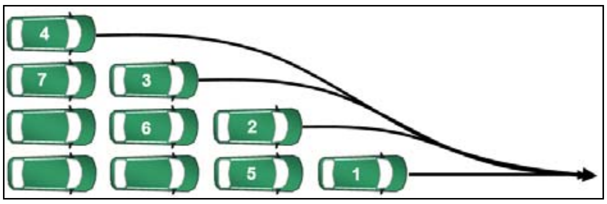

Figure 2: Departing order of cars

Drivers have to pay attention also on the near cars, especially in the break out activity. The steering angle during the departure does not exceed 30° until the car is completely exited from the park position.

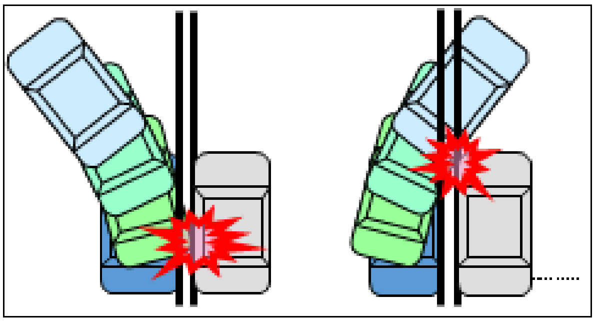

Figure 3: Departing steering angle error

During the movement towards the parking area, cars have to be 15 meters far from each other to avoid any kind of collision.

When the driver arrives to the parking area, he must follow all the instructions given by the parker, who coordinates all the parking operations. When the parking operation is complete, before leaving the car, the driver has to:

- insert 1st gear;
- pull the handbreak;
- backward the seat;
- turn off the lights;
- close the windows.

After completing these operations, the driver takes again the taxi and returns on board the ship to pick another car.

Parkers give the instructions to park the cars and coordinate the traffic. Parker and drivers communicate by gestures as shown in the following pictures.

Figure 4: straight wheels gesture

Figure 5: steer 1/3 to the right gesture

Figure 6: steer completely to the left gesture

Figure 7: stop gesture

Figure 8: put into reverse gesture

3. THE CTSIM ARCHITECTURE

The main idea behind CTSIM is to develop a system based on virtual simulation to train all the actors involved in car terminal operations. Currently there is an ongoing research project (also named CTSIM) carried out by the car terminal operator of the port of Gioia Tauro, Italy (ICO-BLG) and the MSC-LES lab (Modeling & Simulation Center – Laboratory of Enterprise Solutions) at University of Calabria. At this stage the main goal of the research project is to develop the parker simulator (for parkers training) and the car simulator (for drivers training) that will be used to teach parkers and drivers all the protocols, best-practices and procedures.

The car simulator simulates the vehicles physics (a medium size car is considered) including the physics of the engine, the gear, and the wheels friction with asphalt. The car simulator also implements a collision engine that reproduces all the collisions and the related damages (see figure 9). The car simulator includes not only a medium car, but also a truck simulator (with tractor and trailer). In this case, of course all the differences like weight, steering angle, engine behaviour, brakes, velocity, acceleration, etc. are considered.

Figure 9: car simulator – outside view after a collision

Figure 10: car simulator – inside view after a collision

The Parker Simulator is an avatar driven simulator that can be controlled by the parker to perform training operations. The simulator implements gesture recognition and tracks the parker movements by using the Kinect for the body, and a tracking glove for fingers gestures. The tracking glove is needed because the tracking precision of the Kinect is not enough for fingers movements recognition. It is worth saying that the tracking glove has been completely developed at MSC-LES lab in order to reduce costs and come up with a low-cost solution to be integrated as part of the CTSIM architecture (the description of the tracking glove is out of the scope of this paper).

The movement of the avatar is controlled by using a joystick therefore the parker can move in the parking area (on the yard or on board the ship), to provide the drivers with the right indications for supporting cars parking operations.

Figure 11: Parker Simulator, example of hand gestures

The configuration of the environment is another important aspect of CTSIM. Usually, a car terminal can host different types of ships, with different layouts and ramps. Operations may take place with different weather conditions and also with different positions of the cars in the parking area and on board of the ship. As far as the ship configuration is concerned, these features (configuration of the ship) have been included in another CTSIM module called ship simulator. An additional module is currently under development to allow the user to set up different yard configurations and training scenarios.

3.1. Network communications in the CTSIM distributed and interoperable simulation

Interoperable and distributed simulation is a mandatory approach when dealing with cooperative training (Bruzzone et al. 2008). As already mentioned the CTSIM system includes multiple simulators (the car simulator, the parker simulator, the ship simulator, etc.) able to run on different computers (distributed simulation) and to interact each other (interoperable simulation) by sharing the same virtual environment as well as different objects, attributes, interactions and parameters. Therefore each simulator is able to run standalone or combined with other simulators. In addition, multiple instances of the same simulator can run and interact each other, e.g. four car simulators and one parker simulator; this configuration can be used to train (at the same time) four drivers and one parker (figure 12 depicts a double view of the car simulator and the parker simulator).

The CTSIM network architecture is modular, as was explained before. It uses a TCP/UDP connection between all the simulators, with Unity 3D communication protocols and messages and share only the 3D models that each player is using, by sending all the information (e.g., positions, rotations and other useful information) to recreate the same 3D visualization in all the simulators sharing the same 3D scene. The network must be characterized by a low communication latency even considering the high number of entities within each simulator and the complexity of the 3D models. For this reason, the 3D models of the environment (ship, parking area, static objects) are pre-loaded in each client; what the network shares during the simulation are only the 3d models of the cars and parkers, and all the dynamic objects.

Figure 12: Double view: the car simulator and the parker simulator

4. THE CAR SIMULATOR

The Car Simulator recreates the standard operations of various types of vehicles to be loaded/unloaded onto/from ships. All the movements of the vehicle are recorded, and it is possible, at runtime during the simulation, to evaluate the accuracy of each operation.

As described in Longo at al. (2013), the Car Simulator can be controlled by specific hardware interfaces (eg. Steering wheel, pedals, dashboard, etc.). Currently a real car cockpit including steering wheel, pedals, gear and all the other commands that can be usually seen in a real car, is under preparation. The integration of the real car cockpit with the Car Simulator will be done by using Arduino platform, stepper motors as well as other low-cost dedicated hardware. The main goal is to have (at the end of the CTSIM project) a real car cockpit fully integrated with the Car Simulator and multiple secondary workstations equipped with game controls (steering wheel, pedals, joysticks, etc.) and integrated with the Car Simulator. Therefore it will be possible to carry out cooperative training of drivers (one driver using the real car cockpit simulators and the others using the secondary workstations. Each workstation (as well as the real car cockpit) will be equipped with a sound system in order to provide the user with the feeling of driving a real car within a real car terminal environment. The Car Simulator is also equipped with multiple views that allow the visualization of the vehicle from multiple perspectives when moving within the port area.

As far as the collisions engine is concerned, each vehicle has a mesh that is sensible to any kind of collision. Depending on the strength of the collision, the collisions engine calculates the damage and modifies the 3d aspect of the vehicle. This engine is also used to evaluate the level of cars damages, so it is possible to understand the real consequences of a behaviour (currently the collision engine is under modification to include a cost function able to evaluate direct and indirect cost related to vehicles collisions and accidents).

In order to optimize the work of the CPU and GPU, because of the high number of vehicles in a car terminal, the Car Simulator loads only one geometric model for each vehicle and it replicates this model to render all the vehicles displayed in the virtual scene. This approach allows the trainer to set the parking conditions easily and, at the same time, allows the optimization of the GPU workload since only one vehicle is loaded on GPU RAM while the others are rendered as a replication of this one.

Another important part of the Car Simulator, is the performance evaluation module. All the procedures and activities carried out by a driver are evaluated and recorded (real time) during the game. Therefore, it becomes possible to correct mistakes, understand wrong and dangerous behaviours, calculate parking accuracy, keep under control the vehicles velocity and also check if all the security protocols are correctly applied. Data recorded during the training sessions jointly with replay functionalities become an indispensable support for de-briefing sessions in which the trainees have the opportunity to see, in a 3D Virtual Environment, their errors and understand the training gaps that should be filled in.

5. THE PARKER SIMULATOR

The Parker Simulator development is a really complex work that merges different types of technologies to reach a good level of accuracy for tracking correctly all the movements of a real parker and reproducing all these movements in a 3D Virtual Environment by using an avatar. The use of the Microsoft Kinect® in research works is diffused, (especially during the last years and for gestures recognition and training). Examples of works in this area can be found in Guyon et al. (2012), Fothergill et al. (2012).

The tracking of the main bones of the body was performed by using the Microsoft Kinect v2 connected to Unity 3D for visualization. Therefore, the Kinect, by using cameras and IR sensors, understands the position of the bones and sends all these data to Unity 3D, updating the position of each bone in the avatar 3D model. The main problem encountered by using the Kinect is related to the accuracy of fingers and of little parties of the body; such accuracy is pretty low and therefore it is not enough for the purposes of the Parker Simulator (as already shown in figures 4 to 8, the Parker uses the arm, the hand and the fingers to give specific indications to the driver that usually has to perform quite complex parking operations in narrow spaces). For this reasons, in order to track correctly both hands and all the fingers, we decided to use a Tracking Glove created and developed "in-house" at MSC-LES lab. The tracking glove allows recognizing the different gestures of a parker and evaluating the accuracy of these gestures. A literature survey shows that different studies were already made with different types of gloves (e.g. Wang and Popović, 2009) and other technologies to track the movement without gloves (Utsumi et al., 1999). However, the main goal of the Tracking Glove developed as part of the CTSIM project is to create a low-cost solution (less then 500.00 €) to be specifically used for detecting Parkers gestures.

The last thing developed and implemented for the Parker Simulator is the possibility to walk and move in the car terminal. Indeed, for a real parker it becomes critical to move around, look at the distances between vehicles and understand gestures that have to be done for supporting drivers operations. For this reason, by using a joystick the user can walk in the terminal (both in the yard area and on board ship). Therefore 3 different technologies (the Kinect, the tracking glove and the joystick) are jointly used to let the avatar recreating the movements and the gestures of a real parker. These 3 technologies are characterized by low-cost hardware but, at the same time, really suitable for operators training within car terminals.

6. CONCLUSIONS

The paper presents the CTSIM system that is currently under development for operators cooperative training in car terminals. The CTSIM includes multiple simulators but this paper is mostly focused on the car simulator and on the parker simulator. A preliminary study of the state of art was made before proceeding in the design and in the implementation of the simulators; in particular training simulators for port operators were analyzed. The study clearly reveals how Modeling & Simulation can be profitably used for operators training in port environment. Indeed, many simulators have been developed and used to train ships pilots, forklift operators, Reach Stacker operators, Straddle Carrier operators, Gantry Crane operators, Offshore Crane operators, Tower Crane operators, etc. However, there is clearly a lack of research in the field of 3D Virtual Simulators for operators working in car terminals. The analysis of the current procedures used in car terminals has also confirmed the effectiveness and the potential benefits of Modeling & Simulation in such a dynamic and complex environment.

Indeed, the paper illustrates the main activities and processes of a car terminal including security protocols, best-practices for the driver and parker. In such a context, the high number of procedures that each person has to learn and how workers interact each other are relevant. For this reason, the MSC-LES lab at University of Calabria and ICO-BLG decided to carry out a research project to develop a simulation based solution for operators training in a car terminal. In particular, this paper describes the Car Simulator that is able to simulate a medium car, a truck (tractor and trailer) and all the procedures performed by a driver in a car terminal and a Parker Simulator that, by using the Kinect, a tracking glove and a joystick, tracks all the human body and also the fingers gestures, to simulate with a high accuracy all the movements and gestures of the parker.

This two simulators are distributed and interact each other by sharing the same virtual environment; the connection is guaranteed by a TCP/UDP protocol also able to work on separated computers. It is possible also to have more than one Car Simulator and more than one Parker Simulator for cooperative training.

The CTSIM project is still ongoing and the authors are working to complete the whole system by the end of 2014.

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