Simulation as a Support Tool for Training Logistic Operators

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Abstract—Ports play a very important role in the economy of a nation, as well as other crucial infrastructures like railways, motorways and airports, because, if managed properly, can significantly increase the competitiveness of a particular area. For this reason it is important for Port Authorities, Education Centers and maritime and transportation private companies to invest in training and education for logistic operators in ports, because operators properly trained can improve in a significant way the performance of ports in terms of materials handling. Since the 1990s simulation plays a great role in training logistic operators like crane operators, truck drivers and so on, and nowadays this importance has been increased for different reasons like safety and opportunity ones. CBT (Computer Based Training), especially in the preliminary training phases, can be very useful because the real means can be preserved from having serious accidents involving people’s health, infrastructures integrity and implying very huge costs (it is worth to highlight that a transtainer crane, for instance, costs about € 4 Million), but can also be used for more value added operations like cargo handlings instead of training operators at the very first levels of skills. In this paper will be presented some Virtual Reality (VR) simulation models devoted to train Straddle Carrier (SC), Quay Crane (QC) and Mobile Harbor Crane (MHC) operators in handling Containers, General Cargoes and Bulk Materials, moreover, at the end, a short overview on further developments regarding new frontiers of VR simulation will be discussed.

Keywords— CBT (Computer Based Training) Logistics, Simulation, Virtual Reality, VV&A (Validation, Verification and Accreditation)

I. INTRODUCTION

Since the 1970s the world of ports was involved in significant and radical changes because of economical and environmental phenomena like markets globalization, trade liberalization or production delocalization. This has implied a strong increase of competitiveness among the different countries and, consequently, a significant importance of maritime transportation in freight movement; so, for these reasons, ports acquired a significant role in the logistics and transportation network, and in a country economy.

In order to increase the performance, and so the competitiveness, of ports and intermodal terminals, simulation is a very useful tool for operations like decision management, planning, but firstly for training and improving skills of logistic operators like crane operators, truck drivers and so on. In particular Virtual Reality simulators are devoted to train a class of operators, especially at the first phases, at the same time preserving the real means from risky operations performed by people not so skilled at all on handling and maneuvering cargoes. The authors, in the following sections, will present different simulation models devoted to represent the behavior of a Straddle Carrier (SC), a Quay Crane (QC) and a Mobile Harbor Crane (MHC); the last two models have been developed with three different implements in order to test operators’ skills in handling containers (also for Straddle Carrier), bulk materials, like coal or cereals, and general cargoes (pallets and drums).

II. THE ALTERREAL™ COMPUTER BASED TRAINING

The authors, in cooperation with DIP (Development for Innovative Projects) Consortium and ARI (Applied Research International) Simulation, have developed a set of Crane Operation simulators, called AlterReal™, devoted to train logistic operators in ports and intermodal terminals. AlterReal™ Computer Based Training (CBT) is a Crane Simulator that can run on a single machine providing a fast way to effective training. The simulators developed provide Virtual Reality models information for the Quay Crane (QC), the Straddle Carrier (SC) and the Mobile Harbor Crane (MHC) according to the special implementation made for the different customers.

A QC (also popular as "container handling gantry crane", "ship-to-shore crane" or "Dock Gantry crane") is a large dockside gantry crane, which is used for loading and unloading cargo from ships. The QC traverses along the length of a quay or a yard. The QC is equipped with either a “spreader”, "clam shell" or a “hook” which can be lowered down to the top of the cargo. The MHC traverses along the length and breadth of a quay or a yard. The MHC is equipped with either a “spreader” which can be lowered down to the top of the container and which then
gets locked with the container's four locking points ("corner castings"), using a "twist lock" mechanism, but also with a "clam shell" and a "hook" devoted to handle bulk materials and general cargo respectively.

A Straddle Carrier is used in port terminals and intermodal yards for stacking and moving containers. Straddles pick and carry containers while straddling their load and connecting to the top lifting points via a spreader.

The CBT is made by a single operator station in which the trainer set-up the exercise for the trainee selecting the Crane Type (QC, MHC or Straddle Carrier), the scenario (loading/unloading), the implement (spreader/clam/hook) and the environment condition (rain/fog/wind/daylight). In order to keep the scenario more realistic some random events can be specified on the configuration panel (faults/emergencies). The CBT has a 50” flat monitor, a Dolby Surround™ audio system, two joysticks for crane movement and one keyboard for simulating head movements, but it is possible to configure "ad hoc" solutions with fully detailed mock-ups reproducing the cabin of the simulated mean.

The simulator allows personalizing the training inserting the trainee data, like the name, the age (that should be between 18 and 60), the affiliation, an ID code and other parameters. This data can facilitate identification of the trainees in the feedback report printed at the end of the exercise.

The simulators are also able to test trainees’ skills in maneuvering and operating under different weather conditions (i.e. rain, fog, wind, daylight, nighttime, etc.), as shown in Figure 1; in order to do this, the instructor has just to click on the environment button.

Also the time of day can be set using the provided slider bar. Slider bar can be dragged to any position (Dawn, Noon, Dusk or Night) and the corresponding effect is displayed on the interface as well as the visual screen. Also intensity of rain can be set by dragging the slider bar to None (Zero), Low, Medium and High. The corresponding visual effects are introduced on the interface as well as the visual screen.

The system behaves in the same way also for Fog, Wind and Sea State, just click on the respective icons for changing these parameters.

AlterReal™ Computer Based Training manages also the possibility to introduce faults and emergencies that can randomly occur during the training exercise.

User can select any fault from the displayed list and click on “Apply” button to introduce selected fault.

The faults are explained as follows:

1. PLC Communication errors – All crane operations will be disabled on applying this fault.
2. Snag Load – Hoisting/Lowering operations will be disabled on applying this fault.
3. Hoist upper emergency end stop – Only Hoisting operation will be disabled on applying this fault. Lowering operation will be possible.
4. Gantry start timeout – Long travel of the crane will be disabled on applying this fault.
5. Trolley start timeout – Cross travel of the trolley will be disabled on applying this fault.
6. Boom rope slack – Boom Up/Down motion will be disabled on applying this fault.

The emergencies are explained as follows:

1. Fire – Fire is introduced in the Visual.

Figure 2 represents the simulator under the fire emergency situation.

Once applied to the exercise, faults and emergencies randomly occur, and the trainee has to recognize them and then behave in the same way as he should do in the real mean; after recognizing the fault, the instructor can apply the fault deactivation and let the trainee continue with the training exercise normally.

All these features here presented are common to all the simulation models developed by DIP and ARI Simulation, but...
each one has specific characteristics, that will be presented in the next lines.

A. Clamshell Operations

AlterReal™ Computer Based Training has been developed also to support harbor operations for loading and unloading from ship to truck bulk materials like coal, cereals, iron or other unpacked cargoes. For this reason both QC and MHC are equipped with a clamshell devoted to manage this operation. The trainees can perform on the machine all the real operations that can be done on the real crane, like rotating the clamshell, opening and closing it not completely, causing the loss of material on the wharf or on the sea and so on. The system automatically calculates when the maximum loading/unloading limit of a truck is reached, causing the departure of the first truck and, consequently, the arrival of the next one. It is calculated that clamshell can fulfill a truck with 10 – 11 operations, according with the loading capacity of both of them. Figure 3 shows the ship unloading operation.

The loss of the cargo on the wharf or on the sea automatically generates a major error in the trainee report, while the collision between clamshell and the ship, or the truck, counts as a minor error.

B. Hook Operations

Using Hook requires paying some attention to the loads, in particular here three different types of loads are possible: pallets, drums, boxes.

The CBT hook module is provided for both QC and MHC cranes, in order to manage general cargoes. The system reproduces the real operations that can be performed on a crane equipped with this kind of implement: the hook rotates and, according to inertia and, in case, to the presence of wind, oscillates increasing the complexity and the reality of the exercise. The trainee is “helped” by two different aids provided by the system: a “traffic lights” system, usually implemented also on real cranes, devoted to signal the status of the hook, and a special aid, of course not present on the real means, that indicates that the load can be grabbed/dropped by the hook; the cargo (pallet, box or drum), if the hook is correctly positioned, starts blinking advising the trainee of the possibility to lock/unlock.

As well as happens in the MHC and QC clamshell, collisions between hook, cargoes and ship are reported as errors in the trainee report that can be printed or simply consulted periodically during the exercise.

Figure 4 shows a cargo loading operation, using QC hook.

C. Spreader Operations

Spreader operations require that the trainee will carefully align the implement with the container in order to have an effective movement. In particular three "traffic lights” are present replicating the twist lock lights on top of the spreader. These light represent following conditions:

- Red Light glowing – Spreader locked
- Green Light glowing – Spreader unlocked
- Yellow light glowing – Spreader landed

Enabling shadows in the control panel can facilitate the perfect alignment of the spreader and this guarantees a great help for the operators. In particular this is essential when opening the container bay. Opening the container bay can be regarded as one of the most difficult exercises due to the precision and the small dimension of the connecting pins. However this is necessary to access to the lower deck in order to collecting or positioning the containers, as shown in figure 5.
Figure 5: Positioning a container undercover with MHC

The system reproduces the real movements like rotating, skewing and trimming in order to guarantee the correct alignment with the container hooks, and allows the handling of 20, 40 and also 45 feet containers thanks to the spreader extension, as it happens on the real cranes. Collisions are also reported in this case as errors on the trainee report, in order to have feedbacks on the operator’s performance.

D. Straddle Carrier Operations

Straddle Carrier Operations are devoted to handle containers from a Delivery Zone to the trucks or some dedicated areas, like blocks or yards. These operations require to align the spreader with the container in order to perform an effective movement; to do this, the same three traffic lights (red, green and yellow) of the hook and spreader operations are enabled with the same functions.

Moreover, the trainee can help himself in the operation with the implement shadow on the container. Thanks to its structure, Straddle Carrier allows stacking container one on the top of each other with a maximum of 6 levels (5+1), useful especially for handling empty containers.

The Straddle Carrier trainee report registers all the collisions as errors and, as well as the other cranes, performance parameters like the number of movements, the estimated hourly movement rate, duration of the exercise and so on.

Straddle carrier is equipped with a steering wheel and a pedalboard in order to perform all the real driving movements like forward and backward movements and steering (the steering wheel is provided with a 900° rotation) considering also the inertia.

Physical Dynamics allows the operator to visualize also the effect of “inappropriate” maneuvers or the effect of the mistakes. Particular in case of a material drop at sea or on the quay the material is displayed corrected in such wrong place (except at sea where the material sink).

In case of positioning of a container in an unstable position the Physical Engine will provide with the right behavior causing i.e. falling of loads, wrong positioning, etc. Figure 6 shows a very particular situation in which different failures occur.

Figure 6: Example of the physical dynamics implemented

All these CBT models have been subjected to a strict Verification, Validation and Accreditation (VV&A) process devoted to test the coherence with the real means.

III. THE VERIFICATION, VALIDATION AND ACCREDITATION (VV&A) PROCESS

For all simulation models it is important to test if they work properly and reproduce the reality they want to represent, for this reason it is important to subject them to a Verification, Validation and Accreditation (VV&A) process.

The adoption of simulation models for training can bring with it an inherent risk associated with the risk of using incorrect or inappropriate models and false results of the simulation. Putting the user of the simulation as a decision maker, Harmon and Youngblood, argue that “... the output of the simulation provides information that shape the decision of the trainees in order to hone their skills, thus improving both the fairness of the decision and the response time. If the simulation provides incorrect information so, the skills of the trainee may deviate from the desired state and he cannot be adequately prepared to deal with similar situations in the physical world. For example, a trained pilot with a simulation that does not represent adequately the behavior of an aircraft in a deadlock state cannot respond correctly or quickly enough in the event of a real deadlock, when this should occur”. Hence the need for a process designed to evaluate the credibility or confidence in the training and its correctness.

Credibility is a prerequisite for the use of Modeling and Simulation (M&S), especially when the application is the domain of training and decision-making and problem solving skills. Important features of credibility are the precision of the simulation compared to its destination within the training, the correctness associated with the level of confidence in the data, algorithms, that should be robust and properly implemented, and the fact that the ability of the simulation matches with
which is necessary for the specified application. In the VV&A phase of the simulation models for training, activities are conducted in order to establish this credibility. 

Associated with the credibility of simulation models for training is the motto of "garbage in, garbage out", as revised by Roman in "Garbage in, Hollywood-out", in which decision-makers may be "...unduly influenced by animation at the state of the art and 3D graphics that make the simulation more realistic than what the base data and algorithms can suggest".

As explained by Sargent, "... the simulation models are increasingly used in problem solving and decision making. The developers, the users of these models and the decision makers use the information derived from the results of these models, and people affected by decisions based on these models are all rightly concerned that the model and its results are correct. This concern is addressed through the verification, validation and accreditation of simulation model".

Tullos and Bank define the VV & A of models for training as "...three interrelated processes, but distinct, with the aim of gathering and evaluating evidence to determine the simulation capabilities, limitations and performance compared to the real world object that simulates, based on the intended use of the simulation. The objective of VV & A is helping the user in giving an informed and independent opinion regarding the credibility of simulation models used for training in a program or a specific project of interest to the user ".

DIP Consortium and the development lab have conducted the Verification sub-process, in order to check if the software code works properly, by using Alpha Testing, Beta Testing and other techniques. Moreover the system configuration has been verified with workstations equipped with Windows 7™ both 32 and 64 bit versions. Finally, also the hardware key configuration has been tested, in order to guarantee the security of the software licenses; the models, in fact, are equipped with dongles that provide access to the simulation tool only if physically connected to the workstation.

The authors, during the Validation sub-process, have provided a plan of internal tests finalized to verify the behavior of all the cranes developed, performing loading and unloading exercises in order to check if the model reaches the final user specification. Validation has been performed with a "Top-Down" approach because, in this case, an overview of the system is formulated, specifying but not detailing any first-level subsystems. Each subsystem is then refined in yet greater detail, sometimes in many additional subsystem levels, until the entire specification is reduced to base elements. For instance, the authors started to verify the functionalities of the whole crane, and then investigating on the single particular, like the hoist, the wheels and so on.

The Accreditation sub-process has been conducted by the SME (Subject Matter Experts) of the final user, the Port Training Institute (P.T.I.) of the Arab Academy for Science and Technology (A.A.S.T.). P.T.I. is a department of the Arab Academy for Science and Technology, and it is the official training center for the Arab League, and provides the training for the logistic operators in more than 80 ports located in the Maghreb and Middle East areas for more than 25 years. The simulation models, in fact, have been subjected to P.T.I. staff that, followed remotely by DIP and ARI Simulation staff, has conducted the accreditation, in order to verify their adherence to reality. This phase it is very important because here it is stated whether the model reaches the expectations of the final user; for this reason SME (Subject Matter Experts) with a very long experience in training with both real means and simulators, has carefully tested all the commands and the movements, having a deeper knowledge also on the sensitivity and the speed that the simulated cranes should have.

On these points, in fact, rather than the actual functioning of the models, the authors and the SMEs have found the most of the criticalities during the implementation phase, which required some additional developments. In the following section an overview of the criticalities emerged during the accreditation is presented.

IV. CRITICALITIES EMERGED

After the Validation and the Accreditation processes, the CBT models presented some criticalities that need to be adjusted in order to make the simulation models more adherent to reality.

First of all Subject Matter Experts have identified a little different behavior for what concern crane speed, in particular for hoist and boom in QC and MHC cranes, but also for hoist lowering speed in Straddle Carrier.

Secondly, one of the most critical issues encountered was in the error counting in the trainee report; this was related to the sensitivity level of the collisions between objects.

Finally, some issues were encountered in some particular skewing movements for cranes implemented with a spreader; this was detected because Subject Matter Experts are more confident with the real movements performed by the real cranes. That’s why it is important the Verification, Validation and Accreditation process of the simulators, because only experts with proven experience in the matter can detect some errors or improper behaviors.

The Port Training Institute staff, allowing issues fixing by the DIP labs, has successfully accredited AlterReal™ Computer Based Training system.

V. CONCLUSION AND FURTHER DEVELOPMENTS

Computer Based Training (CBT) is a powerful tool for testing the skills of the trainees that aim to become crane or logistic operators; this increases both operators and means safety, allowing preserving real cranes from having serious accidents caused by the scarce experience of the operators. Simulators moreover increase effectiveness and efficiency of the whole system because the real means can be used for more value added operations, and the operator is more confident with the operations when he starts using the real crane.

Based on the last three years data of the trainees, it is...
possible to state that, on average, the Arab League saves about 150000 Euros/Year in training costs, if the same trend is maintained.

In this work the authors presented a series of Virtual Reality Simulators (AlterReal™, developed in cooperation with DIP Consortium and ARI Simulation) devoted to train logistic operators on Quay Crane (QC), Mobile Harbor Crane (MHC) and Straddle Carrier (SC). The former two are equipped with three different implements: clamshell, hook and spreader, in order to test loading and unloading operation on bulk materials, general cargoes and containers (20, 40 and 45 feet).

The models have been implemented and then subjected to a massive Verification, Validation and Accreditation (VV&A) process, in order to enhance the adherence with reality. For this phase the authors, DIP and ARI Simulation have availed themselves of the cooperation of an important educational center that provides training for logistic operators in more than 80 ports in the Maghreb and in the Middle East.

In the next months the authors will start the development of a new series of models, representing RTG (Rubber Tire Gantry) Crane and Offshore Crane for handling general cargoes offshore. In particular the Offshore Crane will be developed in order to support 3D technology, and it will be equipped with a 3D flat screen with 3D glasses, becoming one of the first virtual reality models adopting this technology, in order to increase the realism of the training.

ACKNOWLEDGMENT

The authors would like to thank DIP Consortium President Dr. Matteo Brandolini and Prof. Roberto Reveetria, Head of the DIP Simulation Department; Dr. Pawan Bagga, Head of the Software Development Area of Applied Research International (ARI) Simulation. Moreover, a special thank for the support in the Accreditation process goes to Port Training Institute (P.T.I.) of the Arab Academy for Science and Technology (A.A.S.T.), in particular Dr. Abdelmonem Ayad, Head of the Simulation Department and his staff, and Port Training Institute Dean, Dr. Akram Soliman.

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He had a working experience in 2004-2005 with Piaggio Aero Industries, Genoa Plant, for reengineering the productive process of an executive aircraft. Since 2005 he worked as ERP consultant in the GDO and in production field and developed HLA (High Level Architecture) Virtual Reality Simulators for port operators’ training.

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