TRAINPORTS - TRAINing in marine Port by using Simulation

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ABSTRACT
Modeling & Simulation (M&S) provides nowadays one of the best solutions for personnel and managers training in complex environments. In the paper the authors propose an overview on some advanced simulators, TRAINPORTS, (HLA compliant) that recreate in three-dimensional virtual environments the Gioia Tauro Container Terminal. The simulators include different federates (i.e. Straddle Carriers, Quay Cranes, Reach stackers and Trucks) and can be used to support marine workers training providing the sensation to be in a real container terminal environment. Simulators architecture and Federates/Federation description are provided.

Keywords: Modeling & Simulation, 3D Simulation, containers terminal, virtual environment, HLA

1. INTRODUCTION

In the last decades, Modeling & Simulation (M&S) has become a powerful tool for training purposes. The use of M&S for training occurs when there are situations most expensive or too dangerous to allow trainees to use the real equipment and to do real operations in the real world. The benefits obtained from the use of simulators in training tasks are:

- practicing the theoretical concepts that have been taught and shows the consequences of actions in a very immediate and visual manner;
- providing the instructor with a controlled environment where a large amount of data can be recorded and analyzed to evaluate the trainee's evolution/performances;
- avoiding danger situations that usually occurs when unexperienced users manipulate real machines;
- reducing costs associated to training operations;
- providing trainees with the possibility of working in any desired conditions (i.e. arbitrary weather conditions).

The above listed benefits has motivated an increase of the use of advanced systems based on M&S for operators training in different domains/areas (Wilson et al. 1997). A tremendous amount of researches has been published. Among the existing interactive visual simulators, the flight simulation is the most mature and representative application. Melnyk (1999) built a flight simulator with a complex and effective six Degree-Of-Freedom (DOF) motion system to generate the realistic feeling of takeoff, landing and in-flight turbulence. Menendez and Bernard (2000) used a room of four projected surfaces to create a fix-based airplane and helicopter simulator. Chin-Teng et al. (2001) created a multipurpose virtual-reality-based motion simulator for studying the stability of the 6 DOF Stewart Platform used as a flight simulator. Asiding from the flight simulator, the other well-known application is the driving simulation. Greenberg and Park (1994) developed a driving simulator for the Ford company. Lee et al. (1998) presented a driving simulator based on the use of four PCs only. Freund et al. (2001) proposed a simulator for excavators and construction machines. Park et al. (2001) presented a low-cost driving simulator where four hosts were employed and configured in server/client architecture to construct its computing environment. Other researches studies include various military training programs (Zeltzer et al., 1995) and power-plant operators training (Tam et al., 1998). Zeltzer et al. (1995) designed a simulator to train the officer of the deck on a submarine. Tam et al. (1998) proposed an operator training simulator prototype for power-utility personnel. Moreover, several researchers and scientists used M&S for developing training tools in industrial applications (Jiing-Yih et al. 1997, Cramer et al. 2000, Anon 2000). Other examples of training simulators are reported in Carraro et al. (1998), Ferrazzin et al. (1999) and Kwon et al. (2001). Carraro et al. (1998) developed a bicycle simulator that uses the Virtual Reality Modelling Language browser as its user interface. Ferrazzin et al. (1999) proposed a motorcycle rider simulator being used for testing new prototypes before actually producing them. Kwon et al. (2001) propose an interactive bicycle simulator including a Stewart platform to generate 6 DOF motions, the handle and pedal resistance systems to provide force feedback and the visual simulating system to create the virtual scene. Training in virtual environment has been also successfully used in marine ports and container terminals. Several simulators have been developed for training purposes, specially in activities which involve

high risks and costs, as it is the manipulation of heavy harbor equipment such as different types of cranes, trucks, etc. (Seron et al., 1999; Kim, 2005). Wilson et al. (1998) developed a virtual environment to simulate overhead crane operation by combining 3-D factory drawings with 3-D simulation models of crane and load motion. Huang (2003) presented a method to design an interactive visual simulation on a cluster of desktop computers for the mobile crane training. Daqaq (2003) developed a virtual simulation of ships and ship-mounted cranes to be used as a training platform for ship-mounted crane operators. Rouvinen et al. (2005) developed a gantry crane operator-training simulator to be used for training operators involved for the movement of the containers between the pier and the ships. Furthermore specific research works have been developed also for supporting training of operators for security procedures within terminal containers (Longo et al 2006; Longo, 2010,). Actually the authors have a remarkable experience in developing simulators for operators training in container terminals. For further information refer to Bruzzone et al. (2007), Longo (2007), Bruzzone et al. (2008-a), Bruzzone et al. (2008-b) and Bruzzone et al. (2009), Bruzzone et al. 2010, Cimino et al. (2010).
In the paper the authors propose an overview on the architecture of some advanced simulators (HLA compliant) with specific attention to one of the simulators recently developed: the Gioia Tauro Container Terminal. Simulators developed by authors usually include multiple federates (i.e. Straddle Carriers, Quay Cranes, Reach stackers, Trucks, etc.) and can be used to support marine workers training providing the sensation to be in a real container terminal environment. The development of each federate includes three components: the virtual environment, the geometric model and the dynamic process module. The virtual environment is provided by the software tool Vega Prime (by Presagis) and hosts the marine port environment developed by using the 3D real time modeling tool Creator (by Presagis). The marine port environment includes berth and yard, berth cranes, container handling equipment and facilities. The main port operations are implemented within the dynamic process module (the simulation engine and allows all the interactions in the 3D environment). Before getting into details of the paper, in the sequel a brief description of the paper organization is reported. Section 2 presents the Gioia Tauro Container Terminal (technical charateristics and equipments); section 3 presents the typical simulator architecture; section 4 describes the simulator operational models and, finally, the last section summarizes the scientific contribution of the paper and research activities still on going.

2. THE GIOIA TAURO CONTAINER TERMINAL

The container terminal considered in this research project is the Gioia Tauro container terminal, located in South Italy (see figure 1 for Gioia Tauro container terminal localization). Gioia Tauro port is today one of the bigger container terminals in Italy and the biggest transshipment container terminal in the Mediterranean area.

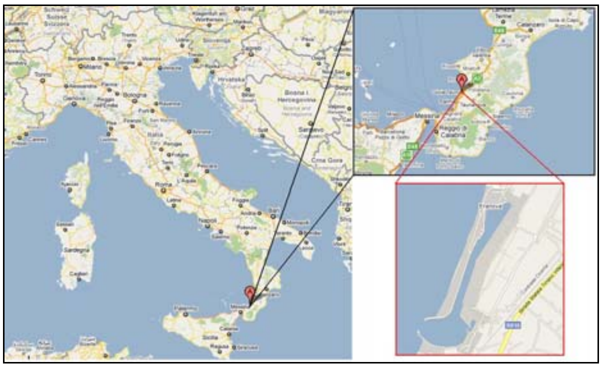

Figure 1: Gioia Tauro Container Terminal localization

It is the seventh biggest container terminal in Europe, handling about 3.7 million TEUs per year (the port handles over one-third of Italy’s national traffic). The structure covers approximately 440 hectares of land area (water excluded) and contains 1.7 milion square meters of stocking yards. The port is connected by road and rail services. The container traffic, which is carried out by the Medcenter Container Terminal SpA, is the main business activity, but the port has also a significant amount of automobile transshipment managed by the BLG Automobile Logistics S.r.l..
The upper part of figure 2 shows a panoramic view of the Gioia Tauro Container Terminal, the lower part depicts the container terminal lay-out.

Figure 2: Panoramic view and lay-out of the Gioia Tauro Container Terminal

The Yard area is characterized by:

- 67,000 yards slots;
- 2350 reefer plugs;
- Handling capacity: 4,200,000 TEU per year;
- Deep water berths: from 12.5 meters up to 18 meters;
- Meters of quays (used by Medcenter Container Terminal SpA): 3,395 meters;
- Meters of wharf (used by Medcenter Container Terminal SpA): 3,395 meters (used by BLG Automobile Logistics Srl): 384 meters;
- Quay Cranes: 22 gauntry cranes, 3 mobile cranes;
- Yard Equipment: 125 Straddle Carriers, 13 Reach Stackers;
- Adjacent rail services;

Figure 3 shows the positive trend of the Gioia Tauro container terminal in terms of number of handled TEU per year starting from 1995.

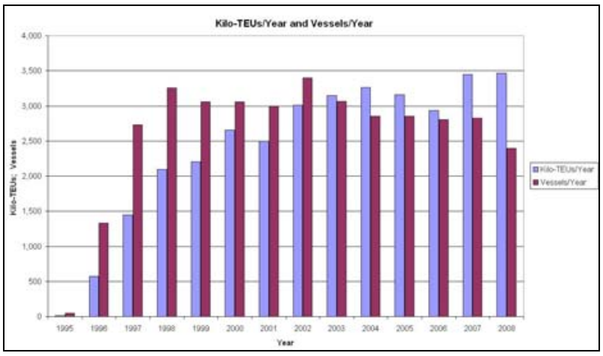

Figure 3: Trends for TEUs/year and Vessels/year

3. SIMULATORS ARCHITECTURE

Usually simulators development for marine operators training takes into account the following aspects:

- provide the user with an advanced simulator to support operators training in container terminals (specifically training of operators involved in containers handling operations);
- provide the user with an enabling technologies for container terminal layout design;
- provide the user with a tool for evaluating operators performances and for investigating interactions between all the actors operating in the yard.

As previously reported, simulators are based on High Level Architecture (standard for interoperable simulation models). The HLA is as integrated approach that has been developed to provide a common architecture for simulation. Before going into the details of simulator architecture let us introduce the following definitions in order to make the reader more familiar with the HLA:

- Federate: an individual HLA-compliant simulator application;
- Federation: a simulation system composed of two or more (often many more) federates that "play" together;
- Run Time Infrastructure (RTI): software that manages the simulation and integrates the simulators;

The HLA architecture is based on a set of rules, defined within the RTI, which govern and define relationships among federation components (federates). The simulator development phase involves the following steps:

1. Federates development: this step focuses on creation of federates to be integrated in the TRAINPORTS federation;
2. Federation development: this step regards the implementation of the federation itself integrating each federate and proceeding in the testing;
3. Federation VV&A: the specific goal is to verificate, validate and accreditate the federation.

As already mentioned the authors developed multiple HLA complaints simulators (see for instance Bruzzone et al. 2010); in this paper the TRAINPORTS simulator consisting of one federation and the following four federates is presented: Straddle Carrier, Quay Crane, Reach Stacker and Truck. Figure 4 shows the TRAINPORTS architecture.

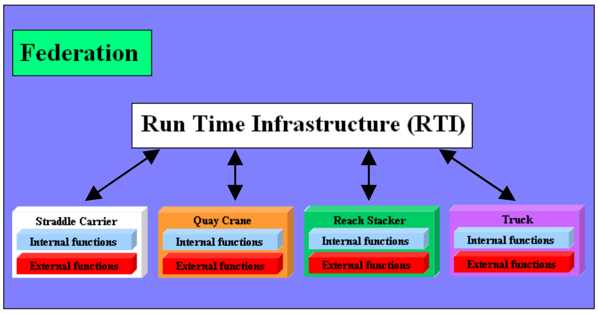

Figure 4: TRAINPORTS architecture

Section 3.1-3.2 goes into the details of the TRAINPORTS development process.

3.1. Federates development

Each federate is characterized by three integrated and cooperating components: a hosting environment (the environment in which the federate is located, the container terminal under consideration), the federate lay-out (federate geometric model), the dynamic interactions that evolve in the hosting environment and modify the federate configuration as time goes by (interactions generated by workers, containers movements, vessels arrival, etc.). Each federate integrates the three above-mentioned components. The translation into computerized models of the three cooperating components is as follows: the hosting environment is a Virtual Environment (VE), the federate layout is a 3D Geometric Model (GM), and the interactions that evolve in the hosting environment and modify the federate configuration are dynamic processes implemented within the Dynamic Processes Module (DPM). Note that the DPM interacts with the GM and, in turn, the GM is contained in the VE. The integration of the DPM, GM, and VE creates the Simulator Architecture as shown in Figure 5.

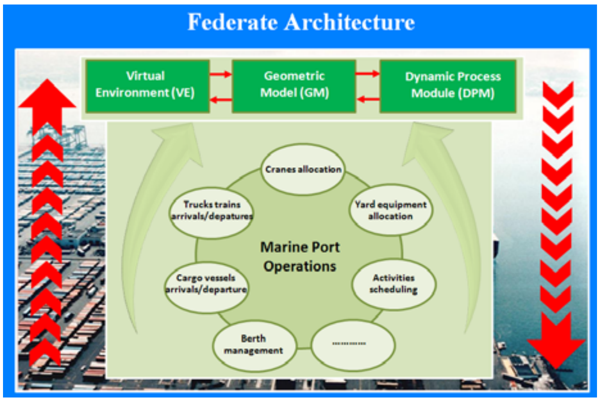

Figure 5: Simulator Architecture

The Federate architecture has been implemented by using different software tools. The VE has to host and interact with port GM. The interactions that take place into the VE recreate the marine port operations; as before mentioned such processes are implemented within the DPM and the DPM can be implemented in the general purpose language C++. As a consequence the VE has to provide an interface with the C++ environment. To this end the Vega Prime platform (developed by Presagis) has been used for implementing the VE. Vega Prime is one of the most widely used tools for the creation of real time 3D application based on visual simulation. The software gives quite good performances on low cost hardware platform and its architecture is completely based on C++. The complete integration of the GM within the VE could be obtained by using the modelling toolset Creator (by Presagis). The Creator allows modelling objects, entities and sites and can be easily interfaced with Vega Prime.

The first step of the federate implementation was the creation of the containers terminal VE by using the software Creator. The geometric models of berths, yard area, cranes, handling equipment, containers have been recreated. After the containers terminal VE implementation, the next step was the development of the federate GM and each of then was then imported into the container terminal virtual environment.

At this stage there are no interactions between the federates GM and the VE. The next step was the implementation of the DPM and its functionalities. The authors implement all the dynamic interactions that evolve in a containers terminal environment into the DPM. The architecture of the DPM has been completely developed using Microsoft Visual C++.

As previously reported TRAINPORTS includes the following four federates:

- *Straddle Carrier Federate (SCF)*: the SCF recreates the operations devoted to move containers in the yard and from/to quay cranes. The SCF will be equipped with a virtual bridge; the virtual bridge will be inserted within the virtual cockpit giving the trainee the possibility to see the container terminal virtual three-dimensional environment. The trainee has the possibility to change different views: from inside the cockpit (to have the sensation to be within the straddle carrier); outside (to see the whole straddle carrier from different points), flight of a bird panoramic (to have a panoramic view of the scene). By using an external steering wheel, pedals and joystick the trainee can move and use the straddle carrier according to inputs he/she provides.
- *Quay Crane Federate (QCF)*: QCF recreates the operation devoted to move the containers from the ships to the berth yard and viceversa. This module is developed to select training candidates, train new operators (to speed more quickly), evaluate and improve operator skills. QCF puts the trainee at the controls of a typical quay crane equipped with telescoping boom and jib, and a variety of loads and hook blocks. Instruments reading is displayed (boom angle, length, height, radius and quadrant) along with a simulated load moment indicator. The driver’s interface is accurate in terms of lights, steering, indicators and pedal controls. The simulated vehicles dynamics are based on mathematical models using actual vehicle information to provide accurate behavioral realism. Moreover, as the SCF, the trainee has the possibility to change different views: from inside the cockpit (to have the sensation to be within the quay crane); outside (to see the whole quay crane from different points), flight of a bird panoramic (to have a panoramic view of the scene).
- *Reach Stacker Federate (RSF):* the RSF recreates the operations required for loading the containers from the yard area to the trucks. Such module puts the trainees at the control of typical mobile virtual stacker and allows them to evaluate and improve their skills. The driver’s interface is accurate in terms of lights, steering, indicators and pedal controls and the trainee has the possibility to change different views;
- *Truck Federate (TF):* the TF recreates the operations devoted to move the containers from the yard area to their final destination. The simulator is designed to provide an excellent training system for heavy vehicle operators and allows the trainee to experience and get familiar with engine dynamics, transmission dynamics,

brake dynamics and steering dynamics. The driver’s interface is accurate in terms of lights, steering, indicators and pedal controls. Finally, the simulator provides training in unpredictable and hazardous situations as well as normal and seasonal weather conditions.

Figure 6 shows the Straddle Carrier while figures 7, 8 and 9 provide the reader with different views of the Gioia Tauro containers terminal VE.

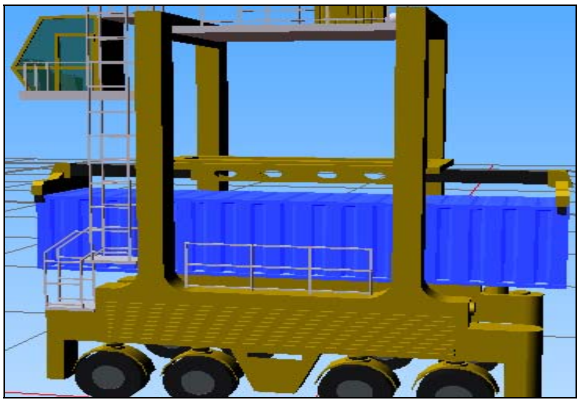

Figure 6: Straddle Carrier GM

Figure 7: Quay Crane GM

Figure 8: Containers terminal VE

Figure 9: Containers terminal VE

3.2. Federation development and validation

Integrating each federate in order to develop the federation and validating the federation in term of proper implementation and correct tuning of the factors and parameters represent another critical step. Considering these aspects the authors proceed in this process by applying standard IEEE 1516.3 High Level Architecture Federation Development and Execution Process as well as fundamentals of 5000.61 directive related to VV&A (Verification, Validation and Accreditation); obviously it will be necessary to tailor properly the VV&A on this specific case; this approach will guarantee to complete effectively the verification and validation of the overall system; the researchers use extensively a network of experts in simulation applied to port logistics in order to guarantee the success of this phase; the availability of real logistics operators will provide full validation of the redesign capabilities of the system in relation to virtual function test of scenarios involving both HIL (Hardware in the Loop, for instance automation systems and sensors on the crane spreader) and MIL (Man in the Loop, for instance policies for exchanging container between different cranes).

4. TRAINPORTS OPERATIONAL MODES

At the beginning of each new training session, TRAINPORTS simulator automatically generates the mission: the user can defines for every single operator which container has to be moved and the new position/destination to be reached.

The mission can be “multiple destinations”, in other words the trainee could be asked for moving the container from a yard allocation or a truck trailer and back again. Also, different levels of complexity can be selected, extra-move included, based on the necessities; to this end the simulator provides the user with “interference” in term of means and persons.

By using C++ language intelligent algorithms have been implemented in TRAINPORTS simulator models and devoted to track other federates during communication drawback. Due to this fact dynamics of physics are introduced in each federate model. In fact, containers and trailers properties are shared among different users, on the contrary trucks, cranes and people properties are functions of each platform user.

The high level of complexity of such procedures can be understood if we consider that during the simulation several kind of vehicles are involved; due to this the containers handling must include a continuous reassignment of the different attributes.
The adopted solution for the federation architecture will allow that different vehicles will be able to interact; this approach will support not only training, but also policy definition, procedure design and infrastructure reengineering. These operations are very important in a intermodal systems where the overall efficiency depend upon synergy and harmony among equipment, people and planning. The policy redesign was already experienced by the researchers in port ship handling by using virtual simulation; in logistics intermodal operation it is also possible to get great benefits from this analysis; in effect the proposed synthetic environment allows to proceed in the redesign of the handling devices themselves; for instance it will be possible to change the virtual cockpit of a crane and to identify the benefits in term of overall logistics performances and safety levels through an experimental campaign on the simulators.

CONCLUSIONS

M&S could provide a promising alternative to real world training. A M&S approach for training allows the trainees to evaluate and improve their skills in using working equipment as well as to do an operation in a safe virtual environment. The paper proposes a virtual 3D Simulator for training for marine workers. The Simulator presented recreates the Gioia Tauro container terminal, one of the bigger container terminals in Italy and the biggest transshipment container terminal in the Mediterranean area. The simulator will be based on the High Level Architecture and the development process consists of three steps. The first step focuses on the creation of federates to be integrated in the TRAINPORTS federation: each federate consists of the main components: the VE, the GM and the DPM. The federate implementation starts with the development of the containers terminal VE by creating the geometric models of berths, yard area, cranes, handling equipment, containers. The containers terminal VE implementation is followed by the development of each federate GM and then each of them is imported into the container terminal virtual environment. The implementation of the DPM and its functionalities completes the federates development step.
After the federate development, the authors integrated each federate in order to develop the federation and validated the federation in term of proper implementation and correct tuning of the factors and parameters by applying standard IEEE 1516.3 High Level Architecture Federation Development and Execution Process as well as fundamentals of 5000.61 directive related to VV&A (Verification, Validation and Accreditation).

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