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New Generation Interoperable Simulators for Port Operations

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Abstract

This paper explores the concept of serious games for simulation-based training, an important approach that combines gaming elements with educational objectives based on the MS2G (Modeling, Simulation and Serious Games) paradigm. Serious games are designed to serve specific purposes such as skill development and knowledge acquisition. Indeed, the study emphasizes the importance of high-fidelity simulation, closely resembling real-world scenarios. It is demonstrated potential of serious games for training as flexible and cost-effective solutions, which could adapt their difficulty according to the learners' achievements. A case study related to training of port crane personnel using simulation and serious games approach is provided.

Keywords: Modeling and Simulation, Training

1. Introduction

Seaports are critical infrastructures and serve as vital hubs for global and regional trade, handling various cargoes, including containers, raw materials and other numerous types of products. Among other characteristics, it is important to highlight the fact that ports are very dangerous environments, which is caused by presence of heavy and bulky equipment, dangerous goods and other factors. For example, typical weights of containers is of tens of tones, while even smallest and simplest cranes capable to move them weight several times more. These factors impose various requirements on the port procedures, as these needs to be done ensuring safety of personnel and to avoid damages of equipment and of transported goods. Indeed, in case of poor attention from the personnel on site, it is possible to have an accident.

In order to ensure safe and efficient operation of seaports, it is essential that all involved personnel is sufficiently trained, is aware of risks and is capable to operate accordingly. However, it could be difficult to reproduce realistic conditions for training, without exposing persons and machines to real risk. Hence, it could be very challenging to guarantee sufficient level of preparation for someone who never operated on site.

Considering this, the authors propose an innovative simulation-based training solution for operators in seaports, with particular attention to the case study of training of portainer operators. Indeed, this type of cranes is used to load and unload big container ships and is typically biggest and heaviest machine in a port.

2. Training of Port Personnel

Considering presence of bulky equipment, heavy objects and dangerous assets, it is evident that the training of port personnel is essential to guarantee efficient and safe port operations.

In order to ensure quality of preparation, a training course needs to contain different parts, starting from theoretical classroom training, required to address fundamentals of crane operations and components, safety protocols, norms and regulations, communication procedures etc. At the next step, a practical training is required (Thai, 2012). While in traditional approach a real crane is typically used, nowadays it is convenient to employ simulation (Haller, 2015). Indeed, crane simulators that replicate real-world crane operations in a controlled environment could be an efficient alternative, as simulators allow trainees to practice handling of goods in various scenarios, including adverse

weather conditions, while avoiding any risk of accidents (Rouvinen, 2015). This helps build confidence and competence before actual on-site operations.

Considering this, the training of port personnel employed in handling of various goods need to address following main arguments:

2.1. Safety

As anticipated, ports are characterized by high number of different sources of risk, such as heavy equipment, moving vehicles, often-limited visibility, as well as potential risks associated with handling different types of dangerous goods (e.g. toxic and corrosive substances) (Trbojevic, 2000). Considering this, proper training ensures that port personnel are equipped with the necessary knowledge and skills to operate safely, reducing the probability and severity of accidents, injuries, and fatalities.

2.2. Efficiency

Seaports are essential nodes of trade and moving of goods. Indeed, in case of poor efficiency it could cause problems for numerous connected activities of various nature. In particular, efficient operations at ports are essential to minimize waiting times for vessels, reduce congestion, and optimize cargo handling processes, ultimately leading to cost savings and improved productivity. Moreover, ports employ a wide range of specialized equipment like cranes, forklifts, container handlers, and different cargo loading systems. In order to prevent damages and accidents as well as to guarantee high performance, proper preparation and assessment of the personnel are required (Ducruet, 2014).

Considering this, it is important that port personnel is capable to carry out their tasks with greater efficiency and effectiveness.

2.3. Compliance

Ports are typically subject to various national and international regulations and standards related to safety, environmental protection, customs procedures, and security (Ziarati, 2009). Considering this, it is necessary to ensure that personnel are aware of these regulations and can adhere to them, avoiding potential fines, penalties, or delays in port operations.

In overall, the training of port personnel is essential to guarantee safe and efficient operations; it directly impacts safety, efficiency, security, compliance, environmental protection, customer satisfaction, and the overall success of the port.

3. Simulation-based Training and Serious Games

When simulation-based training is used, it is necessary to guarantee sufficient realism and immersivity of the proposed environment. Indeed, training need to be performed in similar conditions and provide realistic experience, similar to that one of a physical system. In this particular case study, crane control mechanisms must be represented by a high fidelity replica, providing proper Human-Machine interface, including joysticks, levers, buttons and other input mechanisms, vice versa visual, acoustic and vibrational outputs need to resemble as much as possible the experience of a real workplace (Bruzzone et al., 2013). Indeed, advanced training of personnel of machines and vehicles is often done using motion platforms, capable to reproduce vibrations, rotations, inclinations and even strikes (Bruzzone et al., 2020).

Very important concept related to simulation-based training is Serious Games, often boosted by Interoperable Modeling techniques, introducing MS2G (Modeling and interoperable Simulation for Serious Games) paradigm (Bruzzone et al., 2018). Serious games combine gaming elements with educational objectives, leading to engaging and efficient training experiences. Indeed, these serious games go beyond simple entertainment and serve a specific purpose, typically a skill development or knowledge acquisition. Hence, serious games benefit from gamification principles, which make the overall learning experience more enjoyable and motivating for trainees. Advanced solutions may employ also adaptive difficulty level, in order to adapt the training procedure according to the progress of specific trainee, hence, to use available for training time as efficient as possible (Berta et al., 2016; Bellotti et al., 2009). Serious games should include progress-tracking mechanisms, allowing learners and instructors to monitor individual performance, identify shortfalls, and propose ways for improvement.

Interoperable simulation allows creation of shared synthetic environments, including multiplayer ones, created by coordinated execution of various models; for instance, when one model is responsible for the crane itself, while others are responsible for operations of other assets, as well as environmental conditions, e.g. movement of the sea (Massei et al., 2013).

Indeed, in order to provide a realistic environment for training, it is necessary to employ various models, in particular:

3.1. Crane Operation Simulator

Most important model is that one of crane itself and of physical interactions between objects, including handling of containers and their collisions with different structures and machines as well as between one another. Indeed, it is essential to create a realistic user experience as well as to evaluate efficiency of the player (Juang, 2013). For example, one of errors that novice could do is improper handling of containers, such as collisions with different objects or harsh movements. Hence, the simulator need to use this information as one of metrics for evaluation of efficiency of players.

3.2. Model of Environmental Conditions

This model is required to introduce trainees to various weather conditions and environmental factors, that can affect crane operations, such as time of the day and lighting conditions, wind, rain, fog, and tidal movements of the sea and consequently of the ship to be loaded/unloaded. Indeed, crane operations are highly affected by wind, which, together with storms, are one of main reasons of interruptions in port activities. For instance, it is evident how dangerously could winds move a container, hanging on cables near open sea or ocean. Furthermore, such effects as fog or rain could drastically reduce situational awareness of an operator. Hence, learning to operate cranes under different weather conditions enhances adaptability and safety awareness.

3.3. Virtual Environment

Proper familiarization with operation on equipment requires realistic representation of the environment. Indeed, in order for training to be effective, it is necessary that the conditions during this period are as similar as possible to the real ones, which the future operator will encounter in real life. For example,

discrepancies between conditions observed during training and operations on a real crane may lead to a lack of proper situational awareness, hence, to an accident.

In order to produce a high fidelity view, it is possible to adopt different approaches. In the past, the authors experimented with such visualization and interaction solutions as CAVE (Cave Automatic Virtual Environment) and VR (Virtual Reality) headsets (Bruzzone et al., 2021). Based on requirements to specific system, it could be adopted one of these solutions, taking into considerations their strong points and weaknesses. In particular, VR headsets are compact, immersive and relatively cheap, however they are prone to motion sickness, vice versa, CAVEs are more expensive but may offer better experience to the user.

Overall, it is essential that the training system is capable to resemble real work conditions, while maintaining high level of engagement for entire training sessions.

4. State of the Art

Complexity of equipment and procedures and relative risks, make training of port crane operators dangerous and expensive. Considering this, the interest in efficient yet safe and relatively less expensive simulation-based training is very high. Indeed, the authors worked since many years in this field, creating simulation-based training solutions for various types of port workers (Bruzzone et al., 2011a; 2008).

One of disadvantages of training on real equipment, especially bulky as port cranes, is limitation of training to only specially prepared dedicated areas. Considering this, some simulated-based solutions offer modular and movable structure, which allows fast and easy relocation of training equipment, without necessity in specific dedicated training area (Massei & Tremori, 2011).

Another important aspect is related to assessment of psychophysical conditions of trainee (Leban et al., 2017). Indeed, only measurement of changes in performance is not sufficient to understand causes of such variations, which may be explained by stress or fatigue of the operator, as well as by other factors. Vice versa, acquisition of this kind of metrics allows to understand reasons of certain variations as well as to adjust training procedures or even the model itself. Indeed, this information may provide valuable feedback, essential for adjustment and improvement of the simulator. For example, in order to obtain this information it may be useful to employ biomedical devices, e.g. to track heartbeat, blood pressure, movement of eyes etc. (Fancello et al., 2010)

5. Proposed Solution and Results

In this research, the authors focused their attention on creation of innovative simulation-based environment for training of port crane operators.

The simulator reproduces the workstation of a portainer operator, set in virtual 3D environment of quay port. The 3D port model has been recreated from a real port, using open data of terrain models of Cagliari port. The crane has been recreated in all its component, allowing the operator to drive it as in real system. The operator can take control of the crane with the joysticks, by which can control each part of the crane: the main body which moves in the quay, and the trolley/spreader which carry containers. Trucks, vessels and surrounding vehicles are not under operator control, instead are Intelligent Agents that interact with player's actions.

Particular attention has been paid to spreader movement. The spreader is responsible to carry containers, and it is attached to the trolley by cables, which makes it somewhat similar to a pendulum. The movement of the trolley is along the crane arm, while the spreader is allowed to move up and down and rotate on its axes. The operator has direct control on crane movements, which can be commanded by using the joysticks. For nature of operations, the spreader is a critical component, which has to be properly maneuvered to load/unload container in limited space (as to precisely unload container on position) and to avoid collisions with surrounding objects. This is particularly dangerous in extreme conditions, when the wind may cause unwanted swings or the spreader may get stuck while carrying under-deck containers. Furthermore, little misalignment may occur when positioning containers in place. The operator could face different difficult situation, which occurs during the simulation. The crane should be maneuvered in optimal way, as to not decrease productivity.

Considering operations, the crane operator has to load/unload containers both in import and export. During import activity, the operator has to unload the container vessel, bringing container on quay trucks. As the opposite, during export the operator unload trucks in order to load the vessel. Container ships differ in in number of TEUs, dimensions and disposition of containers. In proposed case study, a 11.000 TEUs vessel was considered. In this case the procedure covered the movement of containers located upper-deck, removal of deck's hatches and handling of containers under-deck.

Because containers have to be located in determined positions according to container loading plan, a proper logic has been used in order to solve this problem.

The logic considers containers stored in three-dimensional matrices, which elements have dimensions multiple of 1 TEU container. Each matrix is located in desired position, such as upper or lower deck, with elements positioned as bays, rows and tiers. Each bay may be composed by two elements with 20 feets length, as to store one 2 TEU container instead of 2 by 1 TEU. Each container is then associated with its matrix position, as well as can be associated with a target position when the container is handled. Each matrix element has position and orientation, which is updated in time; each associated container is then updated as well, furthermore misalignment in container position can be tracked. The same logic is applied also for hatches, defining similar matrices as for containers.

Figure 1. Simulator view: container handling

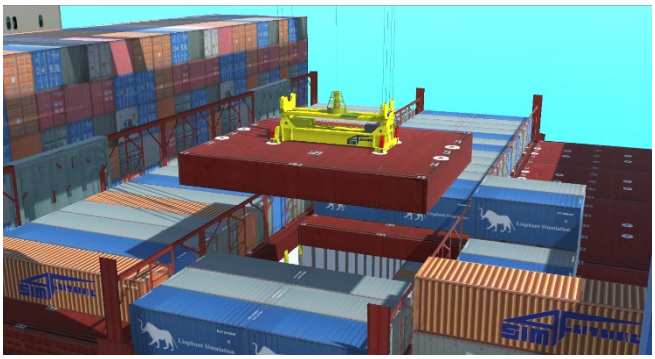

Figure 2. Simulator view: hatch removal

6. Conclusions

Training of specialized operators needs proper assessment and tools, especially if trainers will operate in dangerous environment, such as the proposed case in which operators have to pilot a portainer.

Simulation based training tools can be used to assist training activities as to recreate a system in laboratory in a safety environment. In this paper a crane simulator has been developed with MS2G paradigm, thus integrating classical concepts of M&S with Computer Games technologies and devices, which allowed to recreate the operator workplace. The result is a training system with greater immersion, which can be used to familiarize with crane's commands, risks and dangerous movement sequences, as well as to understand concepts of container-handling operations. Furthermore, variety of scenarios and conditions that can be simulated increases knowledge and understanding of current situation, thus providing knowledge that would take greater time to be acquired on field.

References

Bellotti, F., Berta, R., De Gloria, A. & Primavera, L. (2009). Adaptive experience engine for serious games. IEEE Transactions on Computational Intelligence and AI in Games, 1(4), 264-280.

Berta, R., Bellotti, F., van der Spek, E. & Winkler, T. (2016). A tangible serious game approach to science, technology, engineering, and mathematics (STEM) education. Handbook of Digital Games and Entertainment Technologies, 1-22.

Bruzzone, A. G., Sinelshikov, K., Massei, M., Giovannetti, A., Tarone, F., Longo, F., Fancello, G., Giliberti, C., Mariconte, R., Diano, M., Gotelli, M. & Fabbrini, G. (2021). Reducing Dangers within Industrial Plants by Extended Reality. In Proceedings of 33rd European Modeling & Simulation Symposium.

Bruzzone, A. G., Sinelshchikov, K., Massei, M., Fabbrini, G. & Gotelli, M. (2020). Extended Reality Technologies for Industrial Innovation. In European Modeling and Simulation Symposium, EMSS (Vol. 202, pp. 1-9).

Bruzzone, A. G., Di Matteo, R. & Sinelshchikov, K. (2018). Strategic Engineering & Innovative Modeling Paradigms. In Proceedings of Workshop on Applied Modelling & Simulation (p. 14).

Bruzzone, A. G. & Longo, F. (2013). 3D simulation as training tool in container terminals: The TRAINPORTS simulator. Journal of Manufacturing systems, 32(1), 85-98.

Bruzzone, A., Fadda, P., Fancello, G., Massei, M., Bocca, E., Tremori, A., Tarone, F. & D'Errico, G. (2011a). Logistics node simulator as an enabler for supply chain development: innovative portainer simulator as the assessment tool for human factors in port cranes. Simulation, 87(10), 857-874.

Bruzzone, A. G., Fancello, G., Fadda, P., Bocca, E., D'Errico, G. & Massei, M. (2010). Virtual world and biometrics as strongholds for the development of innovative port interoperable simulators for supporting both training and R&D. International Journal of Simulation and Process Modelling, 6(1), 89-102.

Bruzzone, A. G., Poggi, S. & Bocca, E. (2008). Framework for interoperable operations in port facilities. In Proceedings of 22nd EUROPEAN Conference on Modelling and Simulation ECMS 2008.

Ducruet, C., Itoh, H., & Merk, O. (2014). Time efficiency at world container ports.

Fancello, G., Bruzzone, A., Carta, M. G., Bocca, E., Tremori, A. & Fadda, P. (2010). Truck simulator an instrument for research and training. Trends in Driving Simulation Design and Experiments, 243.

Haller, A., Putz, L. M., & Schauer, O. (2015, August). Transhipment simulators for training of ports' personnel. In Advanced Engineering Forum (Vol. 13, pp. 277-281). Trans Tech Publications Ltd.

Juang, J. R., Hung, W. H., & Kang, S. C. (2013). SimCrane 3D+: A crane simulator with kinesthetic and stereoscopic vision. Advanced Engineering Informatics, 27(4), 506-518.

Leban, B., Fancello, G., Fadda, P. & Pau, M. (2017). Changes in trunk sway of quay crane operators during work shift: A possible marker for fatigue?. Applied Ergonomics, 65, 105-111.

Massei, M., Tremori, A., Poggi, S. & Nicoletti, L. (2013). HLA-based real time distributed simulation of a marine port for training purposes. International Journal of Simulation and Process Modelling, 8(1), 42-51.

Massei, M. & Tremori, A. (2011). Mobile training solutions based on st_vp: a HLA virtual simulation for training and virtual prototyping within ports. Proceedings SCM MEMTS, 29-30.

Rouvinen, A., Lehtinen, T., & Korkealaakso, P. (2005). Container gantry crane simulator for operator training. Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics, 219(4), 325-336.

Thai, V. V. (2012). Competencies required by port personnel in the new era: conceptual framework and case study. International Journal of Shipping and Transport Logistics, 4(1), 49-77.

Trbojevic, V. M., & Carr, B. J. (2000). Risk based methodology for safety improvements in ports. Journal of hazardous materials, 71(1-3), 467-480.

Ziarati, R., Ziarati, M., & Çalbaş, B. (2009, July). Improving safety at sea and ports by developing standards for maritime English. In Bridge conference, Finland.