ANYCRANE: TOWARDS A BETTER PORT CRANE SIMULATOR FOR TRAINING OPERATORS

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ABSTRACT

In this paper, we present the results of our ongoing project, AnyCrane. The project is dedicated to the development of training simulators for port crane operators. In contrast to existing well-known systems, our research is two-fold: 1) we focus on the simulation of different processes and situations involving portal crane operator and port personnel; 2) we introduce an adaptive self-training approach integrated into the simulator to help a trainee to acquire required skills.

INTRODUCTION

The effectiveness and productivity of complex technological processes in modern ports and terminals is mainly defined by the competence and professionalism of the personnel. In particular, port crane operators are required to have specific skills to perform complex technological operations timely and accurately, excellent knowledge of the process, as well as fast and proper reaction in different regular and extreme situations. Training of crane operators on real technological objects is quite expensive and, due to the danger of the process, it puts a high responsibility on an instructor. Thus, training of beginners typically starts with simulators.

There are several world leading simulators developed by companies such as "CM Labs[1]", "Liebherr[2]", "Global Sim[3]", "SPM[4]", and "Forward[5]". Their products are mainly focused on recreating a realistic environment, including rendering the virtual environment, modeling various objects in ports and terminals, as well as using control panels and chairs similar to those of real cranes. In particular, CM Labs' port equipment training simulators for different cranes render 3D models of the scene with their textures,

Figure 1: Interaction of a trainee with the virtual environment, AnyCrane

different weather conditions, as well as features and physics of various objects with high resolution and impressive precision.

Simulators of the mentioned companies also implement a training component, that is typically comprises set of exercises. Results of these exercises are represented in terms of data sheets and graphs to be analysed by the instructor and used both to improve the effectiveness of the training (e.g., adapting exercises) and assess the performance of the student.

To the best of our knowledge, regardless of the indicated advantages of modern port crane simulators, they do not pay enough attention to other participants of the cargo handling process. For example: locomotion of the transport and personnel that can explicitly or by implication influence the process, or solely used to model the environment. In addition, in smaller ports and terminals with less rigorous requirements to cargos, a slinger is an indispensable part of the handling process. He hooks, unhooks the load, and coordinates the work of the crane operator. Thus, his role and participation should be correctly defined and incorporated into the training. Our research is aimed at modeling these aspects, which we implement in our simulator, presented in this paper.

Furthermore, according to our research and the feedback received from instructors using contemporary training simulators, the training component should be enhanced and be more "intelligent" (Bouhnik and Carmi 2012; Ashtiani el al. 2013;). In particular, it should be able to analyse the progress the student makes, its performance and, based on the goals

[1] https://www.cm-labs.com
[2] https://www.liebherr.com/
[3] http://www.globalsim.com
[4] http://specprofmat.ru
[5] http://www.autotrenajer.ru

specified, provide relevant supportive hints and accordingly modify the training process. The system should additionally provide the student and instructor with information regarding the development of specific skills and abilities, instead of “raw” exercise-specific data. On the one hand, this allows the student to get better control on his achievements and be more independent, and, on the other hand, allows the instructor to concentrate on more fundamental aspects of the learning process related to knowledge, abilities, and skills. We implement this in our training component of the simulator.

THE CRANE TRAINING SIMULATOR

Our simulator consists of seven main components to simulate a dynamic visual environment: physics and mathematics module, logical module, graphical module, audio module, engine, display, and control panel (see Fig. 2).

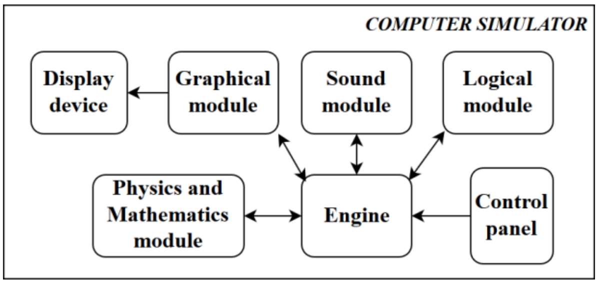

Figure 2: Structure of the training simulator

The physics and mathematics component models physical features of various objects that can be found at the port (be it a cargo, wire rope, or liquids) and the reaction of the virtual environment and its objects to signals coming from the control panel. Our training simulator has a control panel and levers similar to those of a typical port crane (see Fig. 1). In accordance with the specification of the crane, signals from controls are transmitted to the crane electric actuators, described by the second order differential equations. Electric actuators, in turn, drive the structural elements of the crane, setting in motion of the crane (e.g., turning the tower or moving the boom). Any movement of structural elements changes the position of the suspension point and causes oscillations of the cable-cargo system. Thus, this system plays a crucial role in the cargo handling processes.
We model the cable-cargo system with two main goals in mind: 1) to reflect an adequate physical behavior and 2) render realistic visual model. A cable is interpolated by a set of interconnected points with a specific set of applied restrictions (e.g., on the length between points) (Khabibulin and Shklyaev 2015). This model is suitable for realistic simulation of the physical features of the wire rope (e.g., oscillations or cable break). The virtual environment simulating the dynamics of the overload process is shown in Fig. 3.
A scenario is realized and composed by the logical module. It determines traffic routes and the frequency of the transport appearance. We also model a port staff,

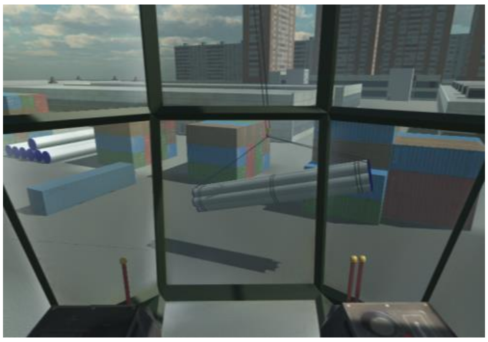

Figure 3: Simulating the dynamics of the overload process

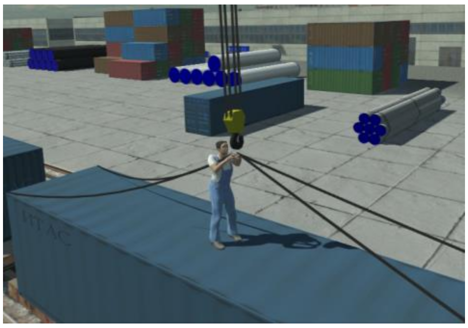

Figure 4: Simulation of the process of slinging a cargo container

an essential part of the handling process, performing slinging and showing specific signals to the operator.
The A* path search algorithm is used to simulate locomotion of the staff across the scene. Fig. 4 illustrates the process of slinging a cargo.
The graphic module creates a realistic image. It uses the created 3D models to visualize all objects in the scene. The sound module allows the simulation of the audio environment. It can be vehicle whistles, engine noise, sound from cargo collisions, etc. The engine unites all the components of the simulator and provides a unified API for integrating third-party modules.

THE TRAINING COMPONENT

The development of professional sensorimotor skills in AnyCrane is performed with the help of exercises, modeling real technological operations in the context of a cargo loading and unloading processes.
The training component of our simulator collects and processes all relevant data reflecting the progress a trainee makes, analyzing its professional knowledge and skills. These data is obtained in real-time from the engine and specify various relevant characteristics of the system, such as the lifting speed of load, the tension of the cable, etc. A schematic structure of the training system and its relation with the computer simulator are shown in Fig. 5.
(1) manages initial settings of the system which correspond to the initial expertise of the student and its goal. Settings are set via a user interface before the training process. The training plan with specific sequence of exercises is formed in (2) according to the initial settings. The functional block (3) analyses

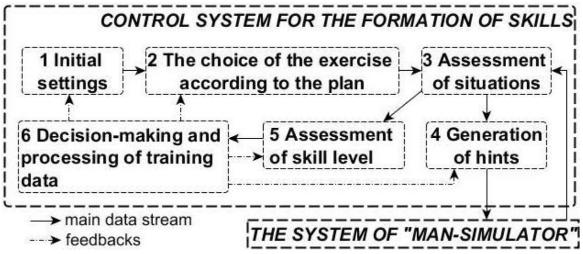

Figure 5: Structure of the control system

various situations identified during exercises and identifies problematic cases. (4) leverages this information and creates set of visual and audio hints and advises to be integrated into the exercise to support the student and enhance the learning process. (5) analyses the performance of the trainee in terms of its skills, abilities and knowledge. The assessment is made based on the evaluation of different situations identified in exercises, individual and integral quality criteria. The decision-making module (6) is activated after the student performed an exercise; it adapts system parameters and defines further training scenario, e.g.: a) repeat the exercise, b) adapt skill assessment criteria, c) correct the set of selected hints, and d) refine initial settings.

The introduced approach ensures good information support and feedback for the student and convey both exercise-specific (3) and training-specific (5) information to the instructor. We believe that this system can considerably enhance the training processes helping the student be more independent from the trainer and have better control of the progress he makes. In **(**Fayzrakhmanov et al. 2017) we present promising results we achieved with the use of our training simulator and its training component (mentioned as Ganz TSC). In particular, our case study shows that students trained with the use of our approach move cargos 15% faster, on average, preserving the required quality of work.

CONCLUSIONS AND FUTURE WORK

In this paper, we introduced a training simulator, results of our ongoing project, AnyCrane. In contrast to existing systems, we focus on modeling the overall variety of relevant and important components of the handling process (including transportation and a slinger). Furthermore, we developed and integrated a training component which is oriented on the improvement of skills, abilities, and knowledge of a student.

Our future work is to enrich a slinger with additional functionality, signals, coordinating the work of the crane operator, and, thus, make interaction between a crane operator and a slinger more realistic. We also plan to develop a port scene constructor for instructor to create a port utilizing existing components (e.g., cranes, slingers, and trucks). Furthermore, we plan to pay more attention on different weather conditions (e.g., wind, rain, and snow) which can affect the cargo handling process.

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