Use Case of Quay Crane Container Handling Operations Monitoring using ICT to Detect Abnormalities in Operator Actions

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Abstract: This paper presents the initial research findings from the Klaipeda port monitoring action related to Blue economy development initiative in the Baltic Sea. Use case study demonstrates the possibility to address the problem of information system deployment in harsh industrial environment to gather valuable statistical knowledge. Custom made monitoring and data transmission units were developed to utilize the best practice of engineering to solve real problems of Klaipeda Port. Several key operations and parameters were monitored during the research, including containers spreader movements, physical characteristics of the cables, metal constructions. Initial results suggested that crane operators' involvement in the control of the cargo movement produced incorrect control patterns (joystick movements) that delayed port operations. Each control movement of the joystick needs to have a direct real-time feedback from the spreader (actual movement of the cargo). Feedback control functionality will allow adjusting the spreader movement according to the operator and will decrease the cargo transportation time during constant breaks.

1 INTRODUCTION

Klaipeda Sea Port has distinguished itself in the Baltic Region due to its rapid increase in cargo flows and adoption of Blue Economy regulations and strategies, that require decrease of CO2 and other harmful gasses in industry surrounding the Sea Port and related to Port activities (including shipbuilding, bulk cargo transit, fossil fuel transship, fishing and production).

Many practioners' and action methodology developers in the transport chain did research in this area. Ranging from communication and control systems application with deep insights and relevant reviews, economical calculations and practical use cases (Tuan et al., 2018; Golovin and Palis, 2019; Henikl et al., 2012; Sha et al., 2017). Overall, possibility to adopt new technologies in such closed environments is a rare opportunity. In practice, the realization of complex control solutions limited by the cost efficiency in comparison to standardized and commonly used solutions (Jakovlev et al., 2012; Andziulis et al., 2012).

Adoption of new ideas is difficult even to "modern minds" (Eglynas et al., 2013). In practice, it is difficult to come close to working equipment and to acquire agreement for their monitoring on-site. Initial visual analysis suggested developing new ideas how to lower fluctuations of the containers gripper. Its movements are random in nature, due to external impacts, such as wind or physical contact with other objects. It is difficult to predict such random deviations in practice (Golovin and Palis, 2019; Trabke, 2014).

In comparison, European ports such as Rotterdam or Hanover apply new systems for vibration decrease

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in the cables during lowering procedures. Dampening control systems decrease unnecessary strains arising during accelerated movement of containers by synchronizing operators' actions with the total lowering process engines and control units. Artificial Intelligence (AI) systems with stochastic algorithms for efficient learning and fast adoption to unlikely events used in scenarios with high risks (Tuan et al., 2012). Control and coordination of operator movement is a task for unconventional systems, mainly used to solve competence shortage problems in engineering, medicine and explorations environments (Jakovlev et al., 2011; Jakovlev et al., 2013).

Today, most Baltic Sea Region Ports handled automated systems, but only on the surface. Context procedures and IT operations automated in most "brutal" fashion. Equipment is bought, but not relied upon to solve critical tasks. That is why inclusion of the quay crane even in modern ports is still innovation-theoretical. In reality, the crane operator has to wait for the Automated Guided Vehicle (AGV) or the AGV has to wait for the operator to finish his unloading routine, even when the most modern control systems are used.

Depending on the actual position of the AGV or the crane, decisions made systematically to slow down the speed of movement so that the target point reached at the same time by all involved bodies. This saves both energy resources and technical resources, and increases crane and consequently, the entire port efficiency.

2 DESCRIPTION OF THE MONITORING EQUIPMENT

In the experimental research DL1 - MK2 data logger/analyzer was used to acquire and transfer statistical data. It uses three-axis accelerometer. Dynamical characteristics examined, including acceleration, speed and position. GPS antenna used to increase the accuracy. Movement speed detection accuracy set to 0.16 km/h due to technological reasons and data logging accuracy set to 1% due to irregularities in the electronics.

Figure 1 demonstrates the used equipment. In addition, horizontal and vertical acceleration sensors have standard industry set accuracy level of 0.05 m/s^2 with maximum detection acceleration set to 20 m/s^2. Higher speeds and accelerations are statistically unlikely due to technological and structural reasons.

Mounting point was set on the spreader, shown in Figure 2.

Figure 1: Demonstration of the secured case with DL-1 MK2 Data logger, GPS antenna and additional connector for output connections.

Figure 2: Demonstration of the Data Acquisition sensory hardware placement on the crane spreader.

This position chosen as a more reliable and safe due to constant movements and obstructions, unnecessary hits in all areas. Battery life was not an essential part of the equipment. Its full capacity lifetime was enough to function on a regular basis for the entire period of experimentation (8 000 mAh).

DL1 – MK2 data logger chosen because it allows all the data to be referenced to not just time, but also to a position during 3D movement. This allows the data to be interpreted in a strict understandable way, referenced clearly to the actual position and time stamp. Braking points and gripper usage was analysed with the built in 3-axis accelerometer enhanced for high downforce applications. It is capable of detecting minute changes with 100Hz update rate on all attached sensors and accelerometer channels. It also provides an 8 analogue channels (with 0-20 V battery voltage) for sensor inputs ready for additional measurements and 2 CAN channels with up to 1 M baud rate with 14 CAN filters per channel (CAN 2.0 compatible). Logger itself has an IP50 environmental protection, but due to the harsh working environment, it was decided to add additional protection via the secured hard plastic mounting case. Maximum power consumption set to 1.6 W.

3 EXPERIMENTAL MEASUREMENT RESULTS

Number of container loading and unloading measurements set to 278, due to port operations strict rules and cooperation agreements for the measurement period. Crane operators were warned that measurements took place during their working hours to avoid legal problems. During the meeting with the working crane operators and truck drivers (who are also AGV operators), discussions were made to address the importance of these measurements and to see the vector of improvement. Some of the crane operators even expressed appreciation for the research. The following Figures provide casual measurements from the loading and unloading procedures.

Each measurement had its own deviation and irregularity, considering the operator "best choice" scenario set by the operational manual. Figure 3 demonstrates the positional movement of the container unloading procedure. Each container varied in mass, therefore, average mass of 20 metric tons considered for the mean calculations. At this exact measurement, the mass of the container measured at 19.220 kg.

Figure 3 and the following Figures 4-5 demonstrate 7 stages of operational consideration:

- 1. Container raising with hooking;
- 2. Vertical raising of container;
- 3. Bias raising of container;
- 4. Horizontal transportation of container;
- 5. Bias lowering of the container;
- 6. Vertical lowering of the container;
- 7. Container placement on the transport means (truck or AGV).

The following Figure 4 demonstrates the actual speed values during these 7 stages for the process, described in Figure 3.

The following Figure 5 demonstrates spreader and container sway oscillation values. These values are of high importance, because higher values correlate with the actual speed of the operation during the 7th stage, by lowering the speed of container positioning on the transport means or AGV.

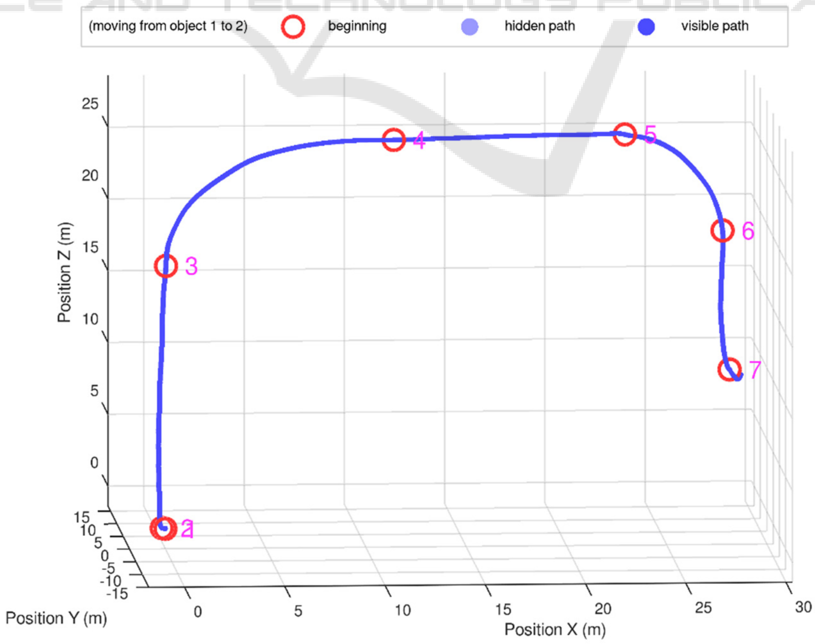

Figure 3: Spreader position detection and movement points during the container unloading operation from the ship.

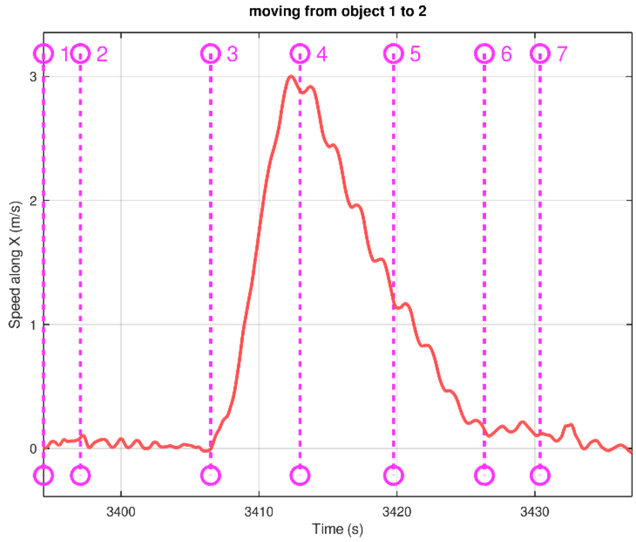

Figure 4: Demonstration of spreader speed actual values during the 7 stages of operation.

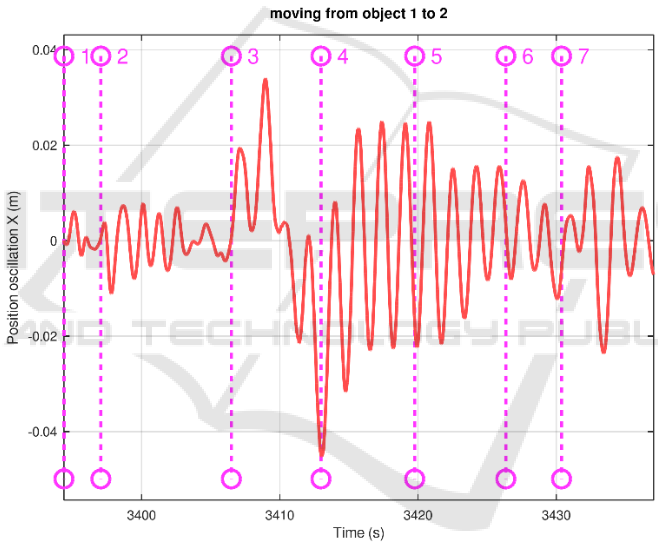

Figure 5: Demonstration of spreader and container sway oscillation during the 7 stages of operation.

The overall transportation process is then prolonged in order to compensate the sway and keep up with the work standard for safety of cargo and security of operation. These operations are mostly synchronized with the on-site AGV operators and working standards to keep up with the ship unloading procedure. Yet, due to technological reasons, delays occur on a daily basis.

4 RESULTS AND DISCUSSION

Initial results suggest that during the operator did not maintain the same speed during the horizontal transfer of the container. Operator made sudden joystick control movements to stop the transportation process for a short period. Figure 4 demonstrates the ladder shape of the speed values, which correlates with the initial suggestion. This is due to operator mistake, lack of experience and unsynchronized actions between AGV or truck and the crane. Each ladder produces additional oscillation, which is kept up to the final 7th stage.

Operational standard regulates the maximum speed of the spreader movement. Due to these factors, each container transported with an average of 8.1 seconds delay for the 278 measurements and the average speed of operation calculated as 40.4

seconds. This indicates that the working efficiency of the operation is only 80%. Each crane is capable of delivering much more container if the operator movement controlled by AI system with pre-defined algorithms for optimal movement of containers with different masses and environmental conditions.

5 CONCLUSIONS

Authors indicate the importance of these researches in terms of the new Blue Economy regulations for Ports CO2 decrease (Kavakeb et al., 2013). Autonomous and electrical AGVs and trucks are now in operation in several ports of the world, and their synchronization with the operational standards is still a real "headache" for engineers and operators on-site. That is why these problems need to be addressed and real operational statistical data collected.

The containers handling operational actions of the Klaipeda port were analysed in detail. Use case study proved possible to deploy and use information system in harsh conditions to gather valuable statistical knowledge.

Custom monitoring and data transmission units were developed to detect the problem areas of the Klaipeda Port. Containers spreader movements, physical characteristics of the cables, metal constructions and crane operators' involvement were monitored.

It was detected that each operator made control mistakes when handling cargo, which in return delayed overall port operations.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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