EMERGING RISKS IN SMART PROCESS INDUSTRY CRANES SURVEY: SAFЄRA RESEARCH PROJECT SPRINCE

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Abstract

Current accident theories show that the solution to avoid human error cannot be based on focusing only on the correction of operators' behavior, but needs certain innovation that will help to keep an error away. Since, as evidenced by several incident surveys, cranes are the most dangerous equipment in industrial and construction sites and human error is the most frequent cause of accidents, in this frame the crane navigation system is an important and challenging component, with a great potential for safety improvement. However, as the emerging and rapid development of new technologies aims improving the working conditions and environment through solutions regarding existing well-known problems in occupational safety, their implementation also could lead to emerging hazards and risks that must be taken into account and managed. Based on these facts, SPRINCE (Smart PRocess INdustry CranEs) project aims implementing a real-time object detection solution, which deals with cranes' tracking systems and incorporates visual feedback, developing and implementing an innovative tool for evaluation of organizational and human (operator-specific) factors. These factors will be included in the risk indicators of the implemented real-time object detection solution using case studies approach.

Keywords: crane, process industry, risk indicator, safety

1. INTRODUCTION

The emergence and rapid development of new technologies often are aimed improving the working conditions and environment (Fishwick et al., 2010). On the one hand, they offer opportunities for new more adequate solutions regarding existing well-known problems in occupational safety (PEROSH, 2012), but their implementation

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could also lead to the coming up of new hazards and risks that must be taken into account, assessed and solved (Riva et al., 2005). In this frame, industrial safety and innovation can face such issue and, only jointly, contribute to the competitiveness, sustainability and social welfare of European industry.

Cranes are the most dangerous equipment in industrial and construction sites and human error is the most frequent cause of crane-related accidents (Beavers et al., 2006). The danger of cranes` operation has special relevance in the chemical process industry and intermodal transport (Bubbico et al., 2006; Fabiano & Currò, 2012), where accidental events could cause the release of hazardous substances and the subsequent scenarios (such as fires, explosions or toxic dispersions), in some cases these could give also a potential escalation, leading to domino effects (Lisi et al., 2015). Given the size and power of available cranes, the potential for loss of property and life associated with their use is tremendous. A tipped, dropped or mishandled load can directly injure workers or upset the machines and devices. This risk of loss is not limited only to those directly involved in operations, since also pedestrians are often injured or killed (Neitzel et al., 2001; Spasojevic Brkic et al., 2015). Cost implications of crane-related accidents are not negligible (Laufer, 1987). Namely, the increased technical quality of cranes is the main reason why scenarios such as 'crane instability', 'jib instability' and 'hoisting equipment instability' contribute less to accidents today (Swuste, 2007), but human factor problems remain still unsolved (Spasojevic Brkic & Putnik, 2013), that has special importance in process industry, where more than half of the accidental events are connected with substance release and

where the human error is the most frequent cause of fire and explosion (Uth & Weiste, 2004).

Previous investigations have highlighted the need for manufacturers to design cranes that: (1) could be safely operated, (2) are easily maintained and (3) whose typical human factor problems are considerably reduced. The motivation for the surveyed topic lies also in the following facts: a) EU OSH Strategy 2014-2020, as one of three major health and safety at work challenges, has pointed at efficient risk prevention strategies, b) only 12.87% of research in risk field focuses on transport problems, c) the biggest potential for reducing accidents is within the decrease of the number of human errors and, actually, there are no available efforts to the formal inclusion of human and organizational factors into risk assessment, d) although ISO 31000 promotes contextual frame, the assessment of those factors' influence is not available in a large number of field including that related to cranes, e) risk assessment methods usually do not apply scientific methods (only 6.56%), and f) hybrid risk methods remain still at a very low level (6.70%) (Marhavilas et al., 2011; Pinto et al., 2011; Skogdalen & Vinnem, 2011; EU OSH Strategy 2014-2020, 2013).

Current accident theories show that the goal to avoid human error cannot be achieved by focusing on the correction of operators' behavior (Shin, 2015), but needs certain innovation, that will help them to not make an error. Accordingly, the crane navigation system is an important and challenging phenomenon, with a great potential for safety improvement. The typical crane operator interface seems simple in terms of the number of controls to be manipulated, moving the spreader quickly and accurately, with or without a container,

but it requires an exceptional sense of its dynamics, including how to effectively stop the moving mass often facing the "stabbing in the blind" scenario and in that field operators need aid. According to those facts the innovation containing smart crane navigation system is an important and challenging solution with a great prospective for improving safety.

2. SPRINCE PROJECT IDEA

The SPRINCE project is based on the idea that crane accidents caused by obstructed view and visual tension problems are preventable, thus it promotes real-time computer-aided visual feedback and gives its assessment. Real-time object detection techniques dealing with different tracking systems are planned to be used in several industrial and commercial applications, although these have not yet been applied to the operator interfaces at industrial cranes.

The project aims to find the best platform which can improve the positioning phase performance of industrial cranes by offering high execution speed, ease of integration, low cost, low power consumption, less computer memory and good support with precise position visual guidance (video tracker with web cameras) used to navigate the object in the right position.

The applied interdisciplinary research within the SPRINCE project will comprise the following methodological steps, including stakeholders' case studies from different European countries and includes experts in disciplines such as industrial, transport, chemical, construction, production and electronics engineering, informatics and economics to execute the following tasks: (1) the implementation of a real-time object detection solution to the operator interfaces of industrial cranes; (2) the development of a risk indicator tool for the implemented real-time object detection solution, including the evaluation of organizational and human (operator-specific) factors; (3) the application of the innovative indicator tool ; (4) the economic appraisal expected to show internal rate of return and the payback period of investment.

Expected results of the project are: (1) The management of the emerging risk derived by the increased use of integrated operations/remote operations in process industry by means of an improved virtualization technology (crane navigation system); (2) The improved technology reduces the productivity drop due to human-machine interface problems, the large financial losses due to direct and indirect costs for the accidents, the cost of frequent repairs and consequent production losses, the disturbance in material handling schedules and an increased work-load on the other equipment and their consequent quicker downtime and break down; (3) The improved virtualization technology, based on real-time decision-support systems, offers the possibility of improving the safety, sustainability and efficiency of hazardous materials multimodal transport and (4) It is expected to show internal rate of return and the payback period of investment less than three years as a similar preliminary study due to Dondur et al. (2012) shows.

3. ISSUES ADDRESSED AND RELEVANCE

To achieve the aim project partners will implement a real-time object detection solution for cranes in different process

industries, using different screen sizes (scalability aspect), and test it with innovative risk-based early warning indicators tool which includes organizational and human (operator-specific) factors. An economic appraisal, to find payback period of investment in real-time object detection solution, completes the activities of the project. The research method used herein is almost the reverse of traditional studies and may appear to contradict the scientific method. Rather than beginning by researching and developing a hypothesis, the first step after initial development of the model for organizational and human factors will be data collection in industry.

Several questions are to be handled by the SPRINCE project and the main answers expected are the following:

a) Decision-making concerning emerging risks, associated with the real-time computer-aided visual feedback for cranes, are improved by means of the incorporation of uncertainties in the model evaluating organizational and human (operator-specific) factors. The operators support, in the identification of strong points and weaknesses, allows implementing and verifying the model in different contexts (e.g. countries and process industries). This supports an adaptive risk management to the context and the desired safety performance.

b) The use of advanced technology for the object detection improves workers' safety and positively affects maintenance strategies. Strong advantages come also from the economical point of view. The real-time computer-aided visual feedback for crane allows reducing the productivity drop due to human-machine interface problems, direct and indirect costs for accidents, costs for frequent repairs and consequent production losses, the disturbance in material handling

schedules and the increased work-load on the other equipment and their consequent quicker downtime and break down.

c) The project aims at the integration of a new technology enabling dynamic and real-time risk management in the intermodal transport of hazardous materials and goods.

4. METHODOLOGY AND EXPECTED OUTCOMES

A new platform will be implemented aiming at the improvement of the performance of the hook positioning phase of industrial cranes, the obstacle location and the computation of the distance between them. Real-time position measurements obtained from a camera will be displayed as real-time video on a LCD display monitor that is connected to the HDMI port and used to create the force feedback to the operator through the joystick. The visual guidance system will be based on color-based object detection, including motion tracking, through advanced high-level techniques. Each project's partner will implement the real-time object detection solution on a crane in different contexts, such asa selected process industry or an intermodal structure, using a different scalability aspect. The use of risk-based early warning indicators is proposed within the project, these consist of a technical and an organizational factor (Øien et al., 2011). The challenge within the project is to develop operator-specific indicators beside organizational factor, which have a huge impact on maintenance strategies, and to be able to predict future safety performance of smart cranes. Human (operator-specific) indicators will be divided into different types of knowledge needed for the new solution, including cognitive

resources such as work domain knowledge, task knowledge, strategic knowledge, collaboration knowledge, cognitive resources, and interface knowledge and will be described by dimensions depending on complexity of task (Ham et al., 2011).

A questionnaire will be developed and answered by experts (with more than 15 years of experience or with a position above supervisor dedicated to cranes in process industry), to examine the importance of each dimension as it is usually done in aircraft industry (Chang & Wang, 2010). The weighting of each dimension will be obtained and a number of points assigned after that questionnaires will be compiled by two groups, both operators and management staff. Then both the models' reliability and validity will be checked to measure random and systematic errors by using factor and reliability analysis. Thus, the questionnaire having the smallest number of only valid and reliable dimensions, integrating ideas for evaluation of management system, as proposed in API 581 (2000), and complexity factors, as given in Hilburn (2004) and Ham et al. (2011), will be obtained for the application to smart seeing cranes in process industry. The model proposed here will prove that the current situation about human and organizational factors needs improvement and, within the SPRINCE project, will provide guidance for specific improvements.

psychological and social impacts of innovations on workers and bring a European added value to the research described above. All proposed risk indicators for the new technology are context specific, so, usage and risk indicator analysis will improve understanding of what sort of smart solutions and simple, practical and cost effective interventions are effective in improving wellbeing in crane operations, e.g. reducing stress caused by visual tension problems and increasing productivity (as promoted in PEROSH model). Stakeholders from industry, acting as subjects of investigation, have an interest to participate in the project and their participation is intended as "the industry gives data to scientists to prove relations in the model that will give them opportunities to improve performance"; otherwise they could be affected by possible new regulations that do not cover their needs. We expect that large number of industrial companies (with or without an active role in project) will apply the new real-time management concept to solve vision problems to achieve better business (including safety) performance, such as productivity improvement (savings in time of operations /cycle reduction), savings on labour costs, reduced incidence of professional diseases, injuries and life losses, reduction of the crane maintenance and repair costs, environmental benefits and savings due to the extended exploitation lifespan are expected.

5. CONCLUSION

Safety technologies products and services guaranteeing the leadership of the EU safety industry, thus, in that aim tests in industrial companies in the European framework (that are different contexts) aim at defining the

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ИСТРАЖИВАЊЕ НОВОНАСТАЛИХ РИЗИКА КОД ПАМЕТНИХ ДИЗАЛИЦА: ПРОЈЕКАТ "SPRINCE" У ПРОГРАМУ "SAF€RA"

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Извод

Савремене теорије фокусиране на истраживање инцидената показују да смањење удела људских грешака не може да се постигне искључиво корекцијом понашања запослених већ захтева извесне иновације које им могу помоћи у том циљу. Како већи број истраживања показује, дизалице представљају извор опасности како у индустрији тако и у грађевинарству, док је људска грешка најчешћи узрок инцидената. Сходно томе, имплементација иновативног система за навигацију може имати велики потенцијал за унапређење безбедности рада дизалица. Међутим, брзи развој нових технологија усмерених ка унапређењу радних услова и окружења, такође представља извор ризика, које треба узети у обзир и којима треба овладати. Пројекат "SPRINCE" (Паметне дизалице у процесној индустрији) има за циљ примену решења за праћење објекта у реалном времену са визуелним повратним информацијама и развој и примену иновативног алата који подразумева дефинисање и проверу индикатора за процену утицаја организационих и људских (везаних за руковаоца) фактора применом методе студије случаја.

Кључне речи: дизалица, процесна индустрија, индикатор ризика, безбедност

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