SAF€RA project no. 22
Smart PRocess INdustry CranEs
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Smart PRocess INdustry CranEs

(project acronym SPRINCE)

Implementation of the solution on cranes of different contexts using a different scalability aspect

Report activity WP1.2

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Notes

With respect to the version of December 2015, this report includes an extension to a third Italian Company, which will take part to experimental activity of the project, although only one company was planned in the project proposal.

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University of Messina **University of Belgrade** **University of Defence**

DELIVERABLE no. D02-SPRINCE

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Title: Implementation of the solution on cranes of different contexts using a different scalability aspect.

Responsible: Faculty of Mechanical Engineering - University of Belgrade (*FME UB*)

Active partners: Faculty of Mechanical Engineering - University of Belgrade (*FME UB*)
University of Messina (*UM*)

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Table of Contents

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1. Objectives

The SPRINCE project is based on the idea that crane accidents caused by obstructed view and visual tension problems are preventable, thus it promotes a real-time computer-aided visual feedback and gives its assessment. The literature has highlighted the main needs for crane design (capability to be safely operated, easy maintenance and reduction of typical human problem factors), but up to now worldwide research has not been focused on the crane navigation system. Typical crane operator interfaces actually appear to be simple in terms of the number of controls; by moving the spreader quickly and accurately, with or without a container, it requires an exceptional sense of its dynamics, including how to effectively stop the moving mass. The need of a new solution for crane visual tension problems is emerging. In this frame the aim of the SPRINCE project is to improve the performance of industrial cranes with innovative real-time computer-aided visual feedback control and estimate new and emerging risks with early warning indicators tools [1].

In order to define the optimum real-time computer-aided visual feedback, which is part of the activity *WP1.2*, beside the development of an adequate software (activity *WP1.1*), there are several important elements that need to be consider, such as monitor size and position, type of monitor, selection of keyboard or touch screen, selection of adequate resolution, etc. These decisions will depend upon different factors including how quick and with what precision operator needs to see the information or picture on the display, if he/she needs to entry data to the device and how much data has to entry, what kind of configuration will provide him/her with most comfortable working postures and the least tension in his/her vision.

2. Description of performed activities

The activity *WP1.2* "Implementation of the solution on cranes of different contexts using a different scalability aspect" is devoted to the implementation of a real-time object detection solution in cranes. Thanks to non-monetary/in-kind contribution of selected industrial partners, Italian and Serbian research groups are going to implement it on cranes of some industrial contexts by using different scalability aspects. The tasks associated with *WP1.2* are:

- *T1.2.1 - Definition of the scalability factors (size/shape/resolution factors and ergonomic factors*
- *T1.2.2 - Selection of a case-study in Italy*
- *T1.2.3 - Selection of a case-study in Serbia*

FME-UB (Faculty of Mechanical Engineering – University of Belgrade) is the responsible for the activity *WP1.2* and *UM* (University of Messina) will cooperate within the activity, mainly in the task *T1.2.2*.

A number of scalability factors will be defined by all the research groups (*T1.2.1*), including view and ergonomic elements. View factors relate to the size/shape of objects to be detected and the resolution of the images given back by the system; the size and shape of several objects must be analysed to make the detector able to recognise them; finally, it is expect that, as the number of objects and views increases, the detection time gracefully scales. Monitor size and image ratio have to be optimised for the improvement of the system's ergonomics. At least two companies will be chosen (one per country) in Italy (*T1.2.2*) and in Serbia (*T.1.2.3*) to implement the real-time object detection solution in cranes.

2.1. Definition of the scalability factors (size/shape/resolution factors and ergonomic factors)

As pointed out by Barron et al. (2005) [2], inadequate field of view can lead to decreased usage of capacity and properties of the machine, increased operators' health problems (due to awkward positions in which he/she operates because of the poor field of view) and, at the end, also increased danger to the both operator and the crew working near the machine. Thus, ergonomic design of operators' working space regarding navigation system has to take into account optimal location of machine displays and appropriate sized window space for the viewing of respective machine operations, as well as operator posture required to enhance task visibility while in a working position [2].

2.1.1. Display size and resolution

As graphical processing power of the PC has increased, flat panel displays became available in large sizes and, over the time, quite affordable [3]. Nevertheless most users still possess displays whose surface area is less than 10% of their physical workspace area [4]. To our knowledge, there has not been an empirical research on impact of display size on the crane operators' performance. Moreover, in the literature, there are very few empirical investigations demonstrating in general real or perceived productivity benefits from using large displays [3-4]. Contexts, where cranes are used, are the case despite the fact that there are many qualitative claims confirming benefits of using a larger display while working. Those studies that have investigated display size effects, in regards to human-display interaction, all had same conclusion which is that larger displays are better than small ones.

For instance, Czerwinski et al. (2003) tested several different models of displays to examine whether a very large display influence human performance compared to traditional single-monitor displays. Their goal was to start a process of identifying productivity benefits, which are provided by interacting with very large displays for typical computing tasks. Significant benefits were observed in the use of a prototype, larger display (including a 42" wide surface display, called DSharp), in addition to significant positive user preference and satisfaction with its use over a small display (size 15"). Users were significantly faster working on the large display, finishing their tasks about 11 seconds faster than when they use a smaller display. This gained time amounts to just over a 9% increase in productivity on the larger display. Moreover, 14 of 15 participants preferred carrying out the tasks on the larger display surface and the user satisfaction measures were significantly better for the larger display. However this study did not include the analysis of different viewing distances or differences in resolution.

Another study examining the correlation between display size and productivity was conducted by Simmons and Manahan [5-6]. They used three experiments and 50 participants to determine the effects of display size on the user performance and preferences. Parameters that were measured during experiments included the time to complete task, the percentage of users attempting task, the percentage of users successfully completing tasks and the preference measures collected via nine-point bipolar scales. This study did not involve evaluation of influence of different resolutions and, as a result based on users' preferences and rankings, authors recommended several resolutions for different display sizes. Results showed that some tasks were performed by users in significantly less time on the larger display then on smaller ones. In addition, users ranked displays from the least to the most preferred one and there was significant difference between larger and smaller displays, the preference scores were much higher for the former than the latter.

Another interesting example is the research made by Johnsen in 2010 [7], which mixed reality display configuration by including very large displays with a life-size virtual human. The study resulted in significantly different behaviour along important social dimensions when compared to virtual human presented on a typical LCD monitor. They emphasised that media psychology have already shown that there is a strong positive correlation between imagery size and emotional response, in a way that humans have much more stronger reaction while watching large displays. In order to comprehend the manner in which social constructs that authors chosen could be affected by the display configuration, they video recorded the verbal and non-verbal response behaviour to a virtual human under these two fundamentally different display configurations. Videos were evaluated by five evaluators, who were not aware of the different displays that participants were subjected to. Results clearly showed that display configuration can have a strong influence on both cognition and behaviour and also that designers should be aware of the limitations of small desktop display configuration.

Ball and North in 2005 studied the effects of a large tiled display with a resolution of 3840x3072 compared with two smaller displays (1560x2048 and 1280x1024) [3]. They argued that there is not enough evidence that high resolution is a better option and it is not known at what extent high it could contribute, especially when users' task is to absorb a lot of information in a short time. There are some evidences that large size, but low resolution and mixed density displays implements focus on the context, moreover by combining a small and a large size display, both at low resolution, visualisation advantages are provided. However displays with better resolution provide a larger view port. Hence, Ball and North conducted an experiment to determine tradeoffs between low- and high-resolution displays for basic low-level visualisation and navigation tasks. Participants were required to find various visual features within the large 2D space (2D virtual navigation is based on simple zoom plus pan interaction); then their time to complete each task was measured. Results showed that the larger configurations produce a better performance than the smaller configurations when dealing with finer detail data. On the other extreme, participant's performance (time complete each task) on the bigger configuration was less than half than the performance on the smaller monitor configuration. It was interesting to note that participants preferred zooming over the panning, but choose not to interact with the mouse at all whenever they could, even when they have to squint to see the indistinct targets. This might be due to fact that people do not like to lose overall context of what they are doing, which is what happens when they zoom or span. As overall conclusion, higher resolution displays that use physical navigation significantly outperform smaller displays that use pan and zoom navigation with finely detailed data. Moreover, larger display is less stressful and creates a better sense of confidence than by using smaller displays.

Taking into account all available information, regarding display size, it can be concluded that larger display could be a better solution for crane operators' cabin. However, since precise data are not available, during this project two different sizes of display shall be implemented in different cranes. Afterword, data from operators will be collected that are solely related to the size of the display, in order to provide new information on optimal size of the display in this particular situation.

2.1.2. Data entry

There are a number of studies dealing with the issue of choosing the best option for data input. Options vary from mouse, keyboards to joystick and light-pens. In 1991 Sears and Shneiderman [8] made an interesting comparison amongst touchscreen and mouse for tasks requiring accurate selection of small targets. They concluded that touchscreen is as fast and accurate as a mouse when selecting these small targets. On the other hand, while touchscreens have been slower than standard keyboards for typing, there are situations where the use of a touchscreen for data entry may be useful, for instance, when infrequent data entry is needed [8]. Therefore in situations when keyboard can consume a lot of work space, without a real need, a touchscreen could be more appropriate. There is, of course, an obvious advantage when using touchscreen keyboards that is the possibility for user to choose the kind of keyboard that suits his personal needs and preferences. Different kinds of keyboards include QWERTY, Dvorak, French, Swedish or any other keyboard the user wants.

In the case of crane operators, they obviously have not a large amount of data to entry, nevertheless it is crucial that those entries that they have to make are as precise, fast and comfort as possible. This is important because operator has to stay focused on the load and everything around him while dealing with his navigation system.

Wallace et al., in their work [9], were concerned with content redirection (where content from one device is mirrored onto another) and input redirection (moving a user's control focus from one display to another) from a variety of seating positions in Multi-Display Environments (MDE). They particularly analysed the situation when content of the shared display is redirected to a personal device in a manner that would allow the user easily viewing and interacting with the content. To evaluate this, they used four different interfaces, where each used either the keyboard or mouse to transition between displays, and then they measured parameters such as task completion time, accuracy, workload and preference. With keyboard transitions, redirection is activated by pressing a keyboard button, whereas with mouse transitions this functionality is triggered by moving the mouse cursor. Experiment consisted of the dock stage and a dialog stage and sixteen right-handed people participated in it. Participants sat with the laptop and mouse on a table positioned approximately 6‟ from a large projected display. They found that, in the case of transitioning back to the local display, participants took significantly longer to transition when using the mouse than when using the keyboard and, in the case of transitioning from the local display, the result was the same, but the difference was not statistically significant. Content redirection, by using the keyboard, was significantly faster than using the mouse.

Sears and Shneiderman investigated the use of touchscreen keyboards for limited data entry [8]. They analysed several design issues, including key size and the location of touchable regions, to develop an improved touchscreen keyboard. The experiment involved three input devices, a touchscreen, a mouse and a standard QWERTY keyboard. When using the touchscreen and a mouse, a QWERTY keyboard was presented on the screen and data was entered by selecting keys on that keyboard. Each of the nine subjects (all familiar with all three input methods) was required to enter one practice string with each input device; the use of each device to enter six strings was repeated several times during several days. Typing times were converted to words per minute (WPM), assuming 5 characters per word. Results were the following: the mean number of total errors was 0.9 by using the mouse, 1.4 with the keyboard and 1.8 with the touchscreen. Mean typing speeds for the last trial are 17.1, 25.4 and 58.2, respectively, for the mouse, touchscreen and keyboard. These results were in accordance with previous studies. What was encouraging here is that typing speed for the touchscreen is considerably faster than what would be predicted from previous studies.

An interesting study was conducted by Brasel and Gips in 2014 [10], which was initiated by the fact that mouse-driven desktop computers are in many cases being replaced with touchpad laptops and touchscreen tablets. They argued that touchscreen interfaces can increase perceived psychological ownership and this in turn magnifies the endowment effect. It is known that consumers respond better to products that have to be touched when used then to ones that do not. Authors hypothesised that relation of level of interface touch and psychological ownership is moderated by the importance of haptic for a product, in a way that products high in haptic importance have a stronger relation between touch and psychological ownership. Touchscreen devices may have this effect, even more pronounced than other products, as consumers have a sense of control because every touch executes their own command and it is known that perceived control is a key precursor and driver of psychological ownership. In addition, touch devices such as smartphones and tablets have a more direct association with a consumer's extended self. In order to test their hypothesis, authors conducted two separate studies. One with a multi-interface computer, in which levels of touch and product haptic issues were analysed, and other with laptops and tablets, in which conclusions from the first study were supported by means of interface ownership. The first study showed that touchscreen interfaces generate stronger levels of endowment when compared to touchpads and mice, as a result of phenomena of psychological ownership. Confirming the findings of the first study, the second one showed that touchscreens generate stronger levels of endowment when compared to indirect touch on a touchpad. These results illuminate that interfaces shape consumer reactions to identical content, and raise new areas for future research.

Taking into account the available literature, it can be concluded that, as expected, the usage of keyboard is the best solution for the crane cabin as entering the data on it is fastest, but the study Sears and Shneiderman [8] showed interesting alternative. If for some reasons, the standard keyboard is not appropriate and there is now need for entry of large amount of data, as is the case of crane operators, touchscreen keyboards are probably a good option.

2.1.3. Display positioning

After the display size is defined, the question of display position should be addressed. Position can directly affect performances and subjective workload [9]. There are several options to be considered, whether it should be positioned vertically, horizontally or titled.

Forlines et al. in 2005 conducted an experiment to answer some of questions regarding display position and number of displays that are used for visual search [11]. They emphasised that it is very important to understand in which manner single or multiple display, as well as vertical or horizontal positioning of them, impacts human performance when performing their tasks. Their experiment involved groups of one, two and four people and three display configurations, i.e. a single vertical display (with participants sitting shoulder to shoulder in front of a single display which rested on a desktop at a comfortable working height), a single horizontal display (positioned horizontally at a height of 70 cm with single participants sitting along the bottom edge of the display, pairs sitting across from one another and groups of four sitting at each side of the display) and four vertical displays (positioned in a row on the same desktop where single participants were seated in the centre of the four display, pairs in front of the centre of two displays and groups have each participant in front of each display) as shown in Figure 1.

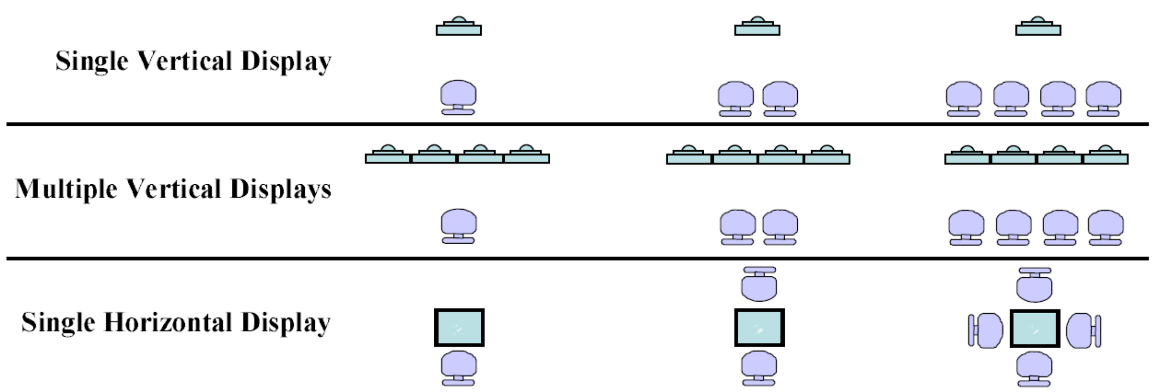

Figure 1 Three different configurations used in the experiment of Forlines et al. [11].

The results from this study, which are useful for the present project, include the finding that individuals show poor performance when dealing with a multiple vertical display configuration. Results show that the solution of multiple configurations needs 30% longer time for searching stimulus then in single configuration. If this was accompanied with reduction in error rate, it could be consider as option, but authors did not find such reduction. Reflecting these findings, it was decided that a single monitor is best solution in crane operators' cabin. Even though Forlines et al. have not found significant differences in the performance of individual on vertical compared to horizontal positioned displays, some other researchers showed bad results with a horizontal display. For instance Lawson et al. (2000) showed that the horizontal workspace may emphasise the foreshortening and distortion of images, which reduces performance in visual searching tasks [12]. Therefore it is concluded that display in crane cabin should be positioned vertically, with remaining question of mounting angle.

In another work, primarily concerned with way of data entry into devices, Sears and Shneiderman also provided valuable information about the angle at which users prefer to work with touchscreens [8]. As a previous research showed [13], different mounting angles of the touchscreen can significantly influence users' performance and fatigue. In this study users repeatedly performed simple menu selection tasks with the touchscreen mounted at 90, 60, 45, 30, 22.5 and 0 degrees from horizontal and results clearly showed that angle of 30 degrees was optimal and caused less fatigue then others. Based on this and other similar studies, Sears and Shneiderman chose angles of 30, 45 and 75 degrees from horizontal (75 is approximately the standard monitor position). Their hypothesis was that 30 degree angle will result in less fatigue and be preferred by users. Ten computer science students and staff members at the University of Maryland participated in the experiment, from which six were familiar with touchscreens. Every subject was required to touch twice seventy small targets presented in a 10 by 7 matrix, but without stressing time or accuracy. Afterwards subjects ranked the three screen angles for fatigue and preference for extended use. Authors found that there is significant effect of screen angle for both fatigue and preference; results clearly showed that angle of 30 degrees was more preferable on both terms. As expected, the 75 degree angle was rated as the most fatiguing and least preferred. The analysis of these few studies clearly indicate that best option for mounting angle of the touchscreen would be 30 degrees.

Barron et al. [2] pointed out that the previous literature suggested that warning displays should be within 301 of the normal line of sight or 451 for a "sit–stand" working position, and for secondary displays within 601 of the normal line of sight, while ergonomic guidelines require that a machine operator should have a free view of the operating zone without having to adjust posture. Therefore they concluded that the operator should not have to turn their head more than 301 to either side and that the head should not be tilted more than 51 up and 251 down for sustained comfort.

In the work of Wallace et al. [9] four seating positions relative to the display were explored, namely North, South, East and West positions as shown in the Figure 2. They found that users' time to perform task was significantly affected with their position. Although participants were the slowest in performing the task in the North position, followed by the West, the East and the South ones. In accordance with this study as well as with practical experience, display in the crane cabin will be positioned in the South or West position.

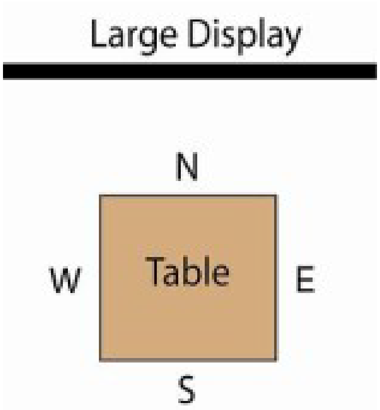

Figure 2. Different seating position relative to the display according to Wallace et al. [9].

2.1.4. Key size

Another aspect to be considered, regarding input device in the crane operators' cabin or anywhere else, is the size of the keys. In most cases, the keys' arrangements and/or their sizes are significant factors influencing the operation efficiency [14]. The appropriate size of the key on the keyboard will provide lower error rate and faster typing. Earlier studies [15-16] showed that targets 26 mm per side result in over 99% accuracy when users are sitting in front of the monitor, while 20 mm would be the lower limit for key size in order not to have too many errors. However, these studies did not take into account touch biases which depend of monitor position. This problem was analysed in [8], together with defining the optimum key size. Sears and Shneiderman used the locations of all actual collected touches from experiment to calculate square keys and the result was 2.61 cm per side. By considering the interaction between touch biases and key size they showed that correcting for biases, it was allowed keys to be reduced from 2.61 cm per side to 2.27 cm per side while maintaining an error rate of less than 1%. This is illustrated in Figure 3.

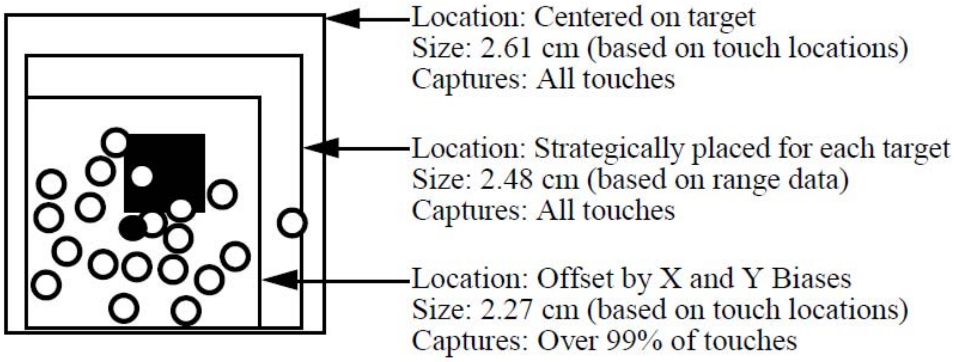

Figure 3. Diagram of possible square key sizes according to Sears and Shneiderman [8].

2.1.5. Software interface

Users of computer have a contact with an information system only with the help of an interface that defines information flow rules between a human and a machine [14]. Whenever new software is developed or when there is a need to choose among several existing software, for whatever purpose, interface is something that must be carefully considered. Michalskia et al. examined the effects of a computer screen interface design and its related geometrical characteristics. They were primarily concerned with point and click method, which require the usage of many available devices, for instance light-pens, digitisers, joysticks, touchscreens and most efficient tool of all computer mouse. They wanted to show specifically how computer interface features impact the visual search task efficiency. Some earlier studies showed, for example, that search time was shorter for the vertical than for horizontal menu configurations, as well as for the smaller number of items in the menu. Also it was proved that effect of icon quantity and quality considerably influenced search mean times. First part of the Michalskia et al. research was to further investigate the problem of designing efficient graphical panels. 490 participants were included in the experiment with special-purpose computer application, designed by authors. They varied three independent variables, namely graphical object size, panel location on the screen and panel configuration and measured two dependent variables, i.e. the acquisition time and the number of errors made. There were several conclusions from this experiment, which overall confirm that geometrical factors significantly affect operational efficiency in the visual interactions of a human-computer interface. The operation was shown to be shorter when graphical objects are larger. It was also shown that graphical structures composition had a significant impact on operation efficiency, as configurations of nine rows and four columns had shortest time of operation and vertical orientation, consisting of two columns and 18 rows had longest. Panel location had no impact. The total number of errors did not exceed 1.7% on any of the trials and authors found this generally consistent with other studies. Authors concluded as a general rule that small graphical items should be avoided in interface design, however they emphasised one should search in the literature, in order to find if there was a research of an optimum of item size. They also advised that if square configurations are not applicable, compact horizontal panels should be used and vertical arrangements should be avoid complete.

2.2. Selection of case-studies

The support of non-monetary/in-kind contribution of industrial partners allowed the implementation of the real-time object detection solution on cranes of some selected industrial contexts by using different scalability aspects. Table 1 lists the companies where the real-time object detection solution is going to be implemented. Some agreements were established with these companies (Annex 1-3).

Table 1. Companies available to implement the real-time object detection solution.

Company	**Country**	**Activity**	**Crane type**
Company 1 - Lorefice & Ponzio	Italy	Mobile crane rental	Mobile crane
Company 2 - Edipower - a2a Group	Italy	Thermoelectric power plant	Overhead crane
Company 3 - Bajina Basta	Serbia	Hydroelectric power plant	Overhead crane

2.2.1. Company 1

The first company is "Lorefice & Ponzio", whose activity is the rental of mobile cranes to be used in various industrial and non-industrial contexts, depending on the characteristics of the crane itself. The collaboration agreement was formalised through a simple e-mail exchange (Annex 1), through which it has been filled in the questionnaire prepared in the activity WP1.1 to collect basic information and were provided the details (technical specifications) of the crane that will be used for the implementation of the real-time object detection solution.

The crane used to test the developed system is a Liebherr LTM 1200-5.1 (Figures 1-5) [17]. It has a very long telescopic boom which can be extended using various lattice extensions and a folding jib. Its entire operating range features outstanding load capacities [18]: max. load capacity = 200 t; telescopic boom = 72 m; max. hoist height= 101 m; max. radius = 80 m; no. of axles = 5.

Figure 1. Selected crane from the Lorefice & Ponzio Company (Liebherr LTM 1200-5.1), source [17].

Figure 2. Telescopic boom movement of a crane Liebherr LTM 1200-5.1, source [17].

Figure 3. Maximum extension of the telescopic boom of a crane Liebherr LTM 1200-5.1.

Figure 4. Operating crane Liebherr LTM 1200-5.1.

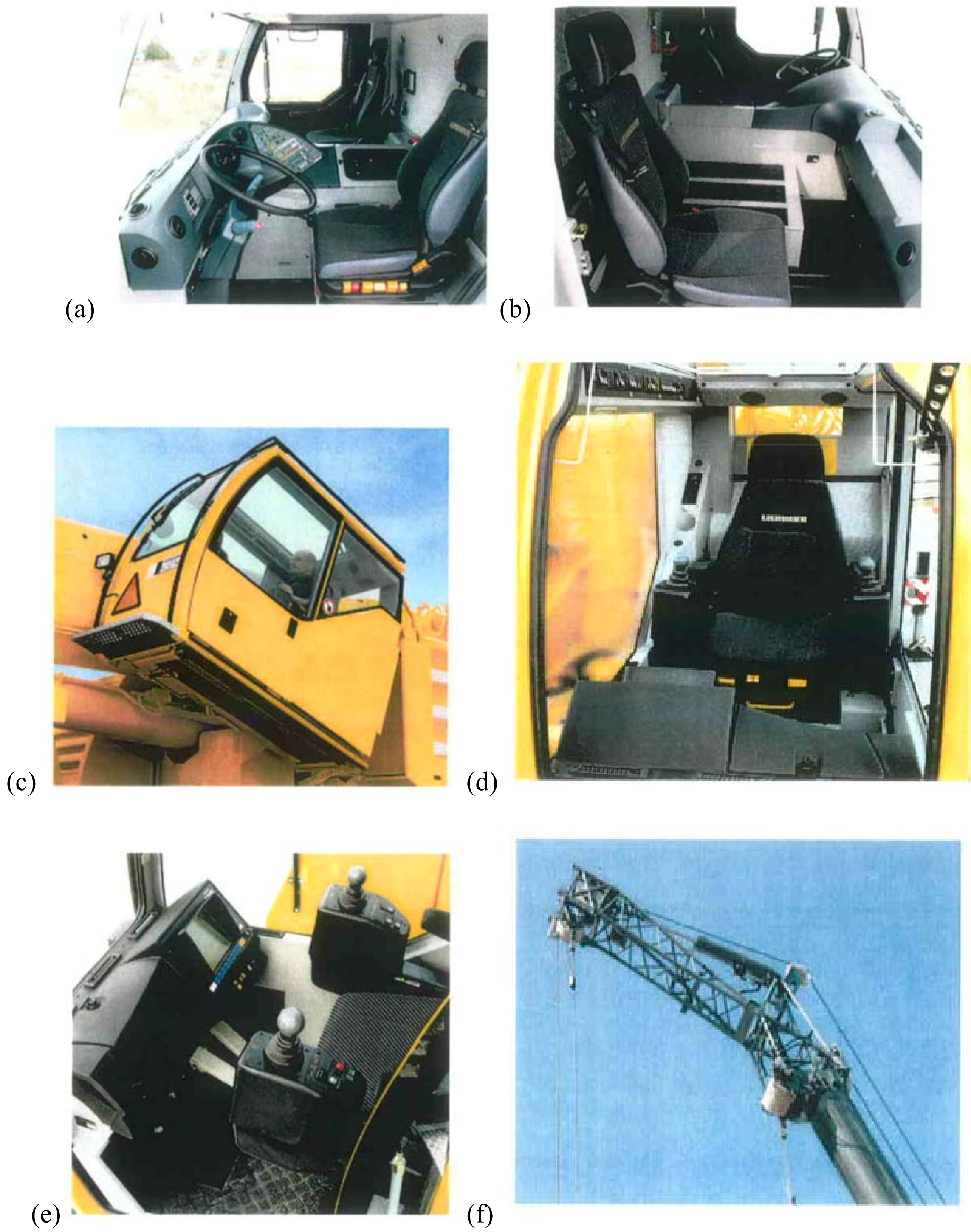

Figure 5. Some elements of a crane Liebherr LTM 1200-5.1 (source [18]): (a) driver's cab left side; (b) driver's cab right side; (c) external view of the tilted crane cab; (d) internal view of the crane cab; (e) control levers; (f) swim away jib.

2.2.2. Company 2

The Italian company is a thermoelectric power plant, namely "Edipower - a2a Group" located in San Filippo del Mela [19]. The crane, which will be used for the implementation of the solution, is a bridge cranes Galileo 150 60 51 (Figures 6-8). Such a crane is devoted to the maintenance operations connected to the turbine.

The company Edipower has formalised its availability to cooperate to SPRINCE project through the letters given in Annex 2.

Figure 6. Selected crane in the Edipower Company (Galileo 150 60 51).

Figure 7. Trolley view from the floor of the crane Galileo 150 60 51.

Figure 8. Machine hall and selected crane of the Edipower Company.

2.2.3. Company 3

In Serbia the implementation of innovative solution will be implemented in the hydroelectric plant *Bajina Basta* Perućac. The activity will be performed in the machine hall and on the bridge crane produced by Ivo Lola Ribar with capacity of 63/20 t, structure group DIN H2B3, span 22m, lifting height 25 m, the speed of the main hook 5/0.5 m/min, auxiliary hook speed 6.3 m/min, trolley speed 16 m/min and the speed of the bridge 25 m/min.

This case study has been selected because crane serves large number of inaccessible places in the machine hall, which are out of the operator's field of view, as it can be seen in Figures 9-14. This crane serves the machine hall, which has two levels. Field visibility for the operator on the first level of performance is not optimal, while in the second level below the engine room operator has no visibility at all, but the work is carried out with the help of signalmen as support staff.

The approval for the execution of this case study was requested by letter IC MF that follows as an attachment. The execution of this case study in HE Bajina Basta was approved by e-mail by Mr. Zlatan Jovanovic (which authorizes the Director of mechanical maintenance services Trivuna Vučetić to inform about the same), which is also found in the appendix, after the letter ICMF.

Figure 9. Machine hall and selected crane in HEPP "Bajina Basta".

Figure 10. The operator in the crane cabin

Figure 11. Visual field of the operator in the crane cabin (view below)

Figure 12. Interior of the crane cabin.

Figure 13. The lowest level of machine hall served by the selected crane (view from the crane cabin level).

Figure 14. The lowest level of machine hall served by the selected crane (view from lower level).

3. Results

Table 1 shows a summary of the conclusions drawn from the literature survey on the scalability factors. In addition to these factors, related assessment parameters and the studies that support them are given.

Table 1. Scalability factors.

Factor	Characteristics	Evaluation parameter	Reference
Display size	Large	• Productivity measured as: 1. Task completion time 2. % of users successfully completing tasks • Collected preference measures	[3-7]
Display Resolution	Non influential if a large display is available with the use of pan and zoom navigation	Collected preference measures	[3]
Data entry	Keyboard	• Productivity measured as task completion time • Collected preference measures • Accuracy • Aorkload • Operation velocity • Amount of data to entry	[8-9]
Display position	30°	• Risk factors • Ergonomic factors	[8,13]
No. display	Single	• Risk factors • Ergonomic factors	[9, 11-12]
Seating position	South position with respect the display position	• Risk factors • Ergonomic factors	[2,9]
Key size	2.27 cm	• Lower error rate • Faster typing	[8, 14-16]
Software interface	Computer interface features: • Vertical menu configuration • Large graphical items • Small no. of items in the menu • Horizontal panels	• Search time • Acquisition time • No. of errors made	[14]

The choices, which have been adopted to realise the optimum real-time computer-aided visual feedback to be implemented in the company, are reported in Table 2.

Table 2. Choices for the optimum real-time computer-aided visual feedback.

Factor	**Choice**	**Notes**
Display size	2 dimensions: • 29.7x21 cm (laptop) • 19x12 cm (tablet 7")	--
Display Resolution	• Any kind for laptop • 1280x752(800) or 1024×600 for tablet	Non influential for laptop if display is available with the use of pan and zoom navigation
Data entry	• Keyboard – QWERTY or touchscreen • Mouse or touchscreen	Depending on display option for laptop QWERTY and mouse and for tablet touchscreen
Display position	30°	--
No. display	Single	--
Seating position	South or West position	--
Key size	2.27 cm	For touchscreen option
Software interface	Computer interface features: • Vertical menu configuration • Large graphical items • Small no. of items in the menu • Horizontal panels	--

Given that precise data on display size are not available, during this project two different sizes of display shall be implemented in different cranes: 29.7x21 cm (laptop) and 19x12 cm (tablet). The need to have a large display collides with the limited available space in the crane-cab, thus participant companies have been questioned, in order to collect their own preferences for the display size to be positioned in the cab. All have manifested preference for a tablet (see Report SPRINCE project D01-SPRINCE [20]).

Display resolution is not influential parameter for larger screens, such as laptop, but for tablet option it should as large as possible, i.e. 1280x752(800) or 1024×600.

Keyboard, mouse and touchscreen have to be chosen depending on display size option. For laptop QWERTY keyboard and mouse are recommended, while for tablet touchscreen is possible choice.

The choice of the display position, no. of display and seating position has been done according to ergonomics and safety rules, the parameter will be set, respectively, as 30°, single and N or W.

Key size is significant influential factor for touchscreen options and its recommended size is 2.27 cm.

As discussed before, software interface should include a menu configuration with smaller number of items in the menu and, since graphical structures have a significant impact on operation efficiency it is recommended to have large graphical items. Figure 15 shows the interface and the included items. The main interface includes also a window with the video streaming.

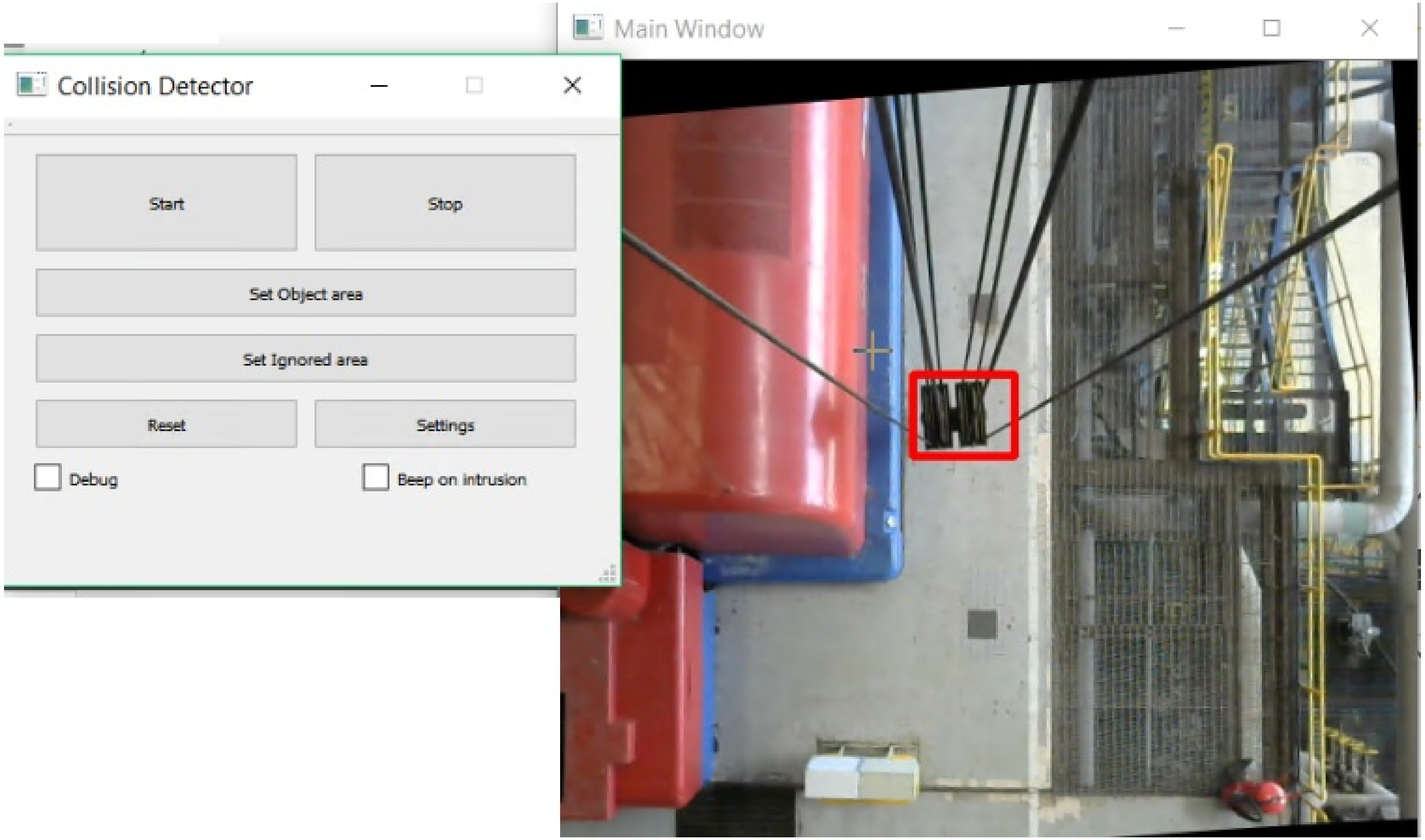

Figure 15. Software interface.

4. Major problems encountered and corrective actions

The major problem, encountered when performing task *T1.2.1* - Definition of the scalability factors (size/shape/resolution factors and ergonomic factors), represents the fact that the literature on this issue is scarce. There is very little information available on the broad topic, as it was expected in this highly innovative project. Results are combined taking into account the literature, but also the contextual influences, thus relying on that information, decisions for the optimum real-time computer-aided visual feedback have been made.

Tasks *T1.2.2* - Selection of a case-study in Italy - and *T1.2.3* - Selection of a case-study in Serbia - are executed without any problems encountered. Task *T1.2.2* has an extended the study on two companies. Finally, three case-studies that cover contexts with high risk values are covered.

5. Deviations from the work plan

According to the workplan, all tasks have been executed on time. It is important to point out that the scope of the project in *WP1.2* has been extended and that there are two Italian companies included in experimental part of the project although only one company was planned. The third case study has been included later than planned, but the extension on the third company does not make any significant deviations from the work plan. It can be stated that D02-SPRINCE is delivered on time and the beginning of *WP3* has not been delayed.

6. Produced publications

Concerning the activity *WP1.2* "Implementation of the solution on cranes of different contexts using a different scalability aspect", the following publications have been produced:

- Milazzo M.F., Ancione G., Spasojevic Brkic V., 2015. Safety in crane operations: an overview on crane-related accidents. Proc. 6th International Symposium on Industrial Engineering SIE, 36-39, Belgrade, Serbia (24-25 September 2015).
- Veljković Z., Spasojević Brkić V., Brkić A., 2015 Crane Cabins' Safety and Ergonomics Characteristics Evaluation based on Sweden Port Data. Proc. 6th International Symposium on Industrial Engineering SIE, 40-45, Belgrade, Serbia (24-25 September 2015).
- Spasojević Brkić V., Milazzo M.F., Brkić, A. Maneski T., 2015. Emerging risks in smart process industry cranes survey: SAF€RA research project SPRINCE. Serbian Journal of Management 10(2): 247-254.
- Milazzo M.F., Spasojevic Brkic V., Valis D., 2016. Improving Cranes' Safety: Development of a Real-Time Visual Guidance System to Move Loads in Process Industry. Communication at the SAF€RA Symposium "Emergence of a New Collaborative Work Programme on Industrial Safety", Athens, Greece, 11-12 April 2016.
- Milazzo M.F., Ancione G., Spasojevic Brkic V., Valis D., 2016. Investigation of crane operation safety by analysing main accident causes. Submitted at ESREL 2016 conference.
- Spasojevic Brkic V., Putnik G., Veljković Z.A., Shah V., Essdai A., 2017. Interfaces for Distributed Remote User Controlled Manufacturing as Collaborative Environment. In *Advances in Human Factors and System Interactions*, pp. 335-347. Springer International Publishing.

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http://www.edipower.it/edp/cms/edipower/

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Annex 1

Agreement Company Lorefice & Ponzio

First email contact with Lorefice & Ponzio through the Eng. Sebastiano Spampinato (ISAB Energy)

Zimbra **mfmilazzo@unime.it**

I: Progetto gru

Da : sebspampinato@isab.com mar, 04 ago 2015, 18:16

Oggetto : I: Progetto gru 1 allegato

A : loreficeeponzio@tiscali.it

Cc : mfmilazzo@unime.it

Gentile sig. Lorefice per far partire il progetto di ricerca che le avevo accennato per telefono, ci servono le informazioni sulla gru di riferimento che intenderemo usare. Per cui Le chiedo di compilare il questionario allegato.
Su questa gru, infatti, dovrà essere implementato un sistema di telecamere frutto di un progetto pilota che scaturirà da una ricerca con l'Università di Messina ed altre.
Non ci sono oneri per la Vostra azienda.
La prof.ssa Milazzo, che ci legge in copia, potrà darle ulteriori informazioni in merito.

Cordiali saluti
S. Spampinato

Data transmission from Lorefice & Ponzio and communication to collaborate to the SPRINCE Project

Zimbra **mfmilazzo@unime.it**

Progetto gru

Da : Lorefice & Ponzio <loreficeeponzio@tiscali.it> gio, 06 ago 2015, 11:16
Oggetto : Progetto gru 2 allegati
A : mfmilazzo@unime.it
Cc : sebspampinato@isab.com

Buongiorno Dott.sa Milazzo,

Le trasmetto in allegato questionario e scheda tecnica dell'autogrù pilota.

Rimango a disposizione per eventuali ulteriori chiarimenti e/o informazioni.

Saluti.

Lorefice Domenico

Zimbra **mfmilazzo@unime.it**

Progetto gru

Da : Lorefice & Ponzio <loreficeeponzio@tiscali.it> gio, 06 ago 2015, 11:25
Oggetto : Progetto gru 1 allegato
A : mfmilazzo@unime.it
Cc : sebspampinato@isab.com

salve,

Le inoltre integrazione tecnica relativa alla strumentazione di bordo,
preciso, inoltre che il ns. mezzo è dotato di sistema di controllo antecedente alla versione Liccon 2 è non è dotato di radiocamando.

Saluti.

Lorefice

Annex 2

Agreement Company Edipower – a2a Group

Request to cooperate to the SPRINCE Project

Zimbra **mfmilazzo@unime.it**

Collaborazione per progetto SPRINCE

Da : Maria Francesca Milazzo <mfmilazzo@unime.it> mar, 06 ott 2015, 17:01
Oggetto : Collaborazione per progetto SPRINCE
A : Mancuso Valeria <valeria.mancuso@edipower.it>
Cc : Bragatto Paolo Angelo <p.bragatto@inail.it>

Ciao Valeria,

il progetto europeo di cui ti parlavo al telefono ha titolo "Smart Process INdustry CranEs" (SPRINCE). L'Università di Messina è capofila e gli altri partner coinvolti sono l'Università di Belgrado e l'Università di Brno, gli sponsor di questa ricerca sono l'INAIL per l'Italia (contact person Dr. Paolo Bragatto) e il MESTD Ministry of Education, Science and Technological Development (contact person Prof. Aleksandar Sedmak) per la Serbia. Il progetto si pone l'obiettivo di realizzare un prototipo telecamera-monitor da installare su gru industriali e un programmino dotato di un'interfaccia user-friendly che aiuti l'operatore (gruista) nella movimentazione dei carichi. Il fine è quello di ridurre gli incidenti legati alla non perfetta visibilità del carico movimentato dalla cabina, a cui spesso si ovvia attraverso un operatore che suggerisce le manovre da terra.
Quello che ci interesserebbe, spero attraverso una vostra collaborazione, fare è poter installare il prototipo quando sarà pronto su una vostra gru e farlo testare e poi trarre attraverso un questionario che verrà realizzato le impressioni dell'operatore, che ci consentiranno di definire degli indici di sicurezza per le gru.

Ti ringrazio per l'attenzione, ci aggiorniamo

Francesca

Request to authorise the experimental activity of the SPRINCE Project

Zimbra **mfmilazzo@unime.it**

Autorizzazione a svolgere attività di sperimentazione di un prototipo per il rilevamento di oggetti e ostacoli movimentati da gru presso Centrale Edipower

Da : Maria Francesca Milazzo <mfmilazzo@unime.it> ven, 01 apr 2016, 11:46

Oggetto : Autorizzazione a svolgere attività di sperimentazione di un prototipo per il rilevamento di oggetti e ostacoli movimentati da gru presso Centrale Edipower 1 allegato

A : salvatore marchese <salvatore.marchese@edipower.it>

Cc : Mancuso Valeria <valeria.mancuso@edipower.it>

Gent.le Ing. Marchese,

A seguito dei contatti intercorsi con la Dott.ssa Valeria Mancuso, Le allego una richiesta di autorizzazione a svolgere una fase di sperimentazione di un prototipo per il rilevamento di oggetti e ostacoli movimentati da gru presso i Vs. impianti. Il prototipo è stato assemblato nell'ambito di un progetto europeo i cui dettagli sono forniti nella lettera allegata.

La ringrazio per l'attenzione e resto a disposizione per qualsiasi richiesta di chiarimento.

Cordialmente
Maria Francesca Milazzo

UNIVERSITA' DEGLI STUDI di MESSINA
Dipartimento di Ingegneria
Contrada Di Dio, 98166- MESSINA (ITALIA)

Messina, 01/04/2016

Al Capo Centrale
Ing. Salvatore Marchese
Centrale Edipower
San Filippo del Mela

Oggetto: Autorizzazione a svolgere attività di sperimentazione di un prototipo per il rilevamento di oggetti e ostacoli movimentati da gru presso Centrale Edipower.

La sottoscritta Dott.ssa Maria Francesca Milazzo, ricercatore d'Impianti Chimici presso il Dipartimento di Ingegneria dell'Università di Messina, a seguito dei contatti telefonici intercorsi con la Dott.ssa Valeria Mancuso, chiede che sia autorizzato l'accesso ai Dott. Giuseppa Ancione e Isak Kavasidis presso i Vs. impianti per svolgere una fase di sperimentazione di un prototipo per il rilevamento di oggetti e ostacoli movimentati da gru.

I Dott. Ancione e Kavasidis sono borsisti che svolgono la loro attività nell'ambito progetto europeo dal titolo "Smart Process INdustry CranEs" (SPRINCE), sotto la supervisione della sottoscritta. Il progetto SPRINCE, del quale l'Università di Messina è capofila, coinvolge come partners l'Università di Belgrado e l'Università di Difesa di Brno ed è sponsorizzato dall'INAIL (contact person Dott. Paolo Bragatto) e dal MESTD Ministry of Education, Science and Technological Development (contact person Prof. Aleksandar Sedmak). Il progetto si pone l'obiettivo di realizzare un prototipo telecamera-monitor da installare su gru industriali e un sistema di rilevamento visivo di ostacoli durante la movimentazione di carichi mediante gru. Tale sistema mira a supportare l'operatore mediante un feedback visivo (e sonoro) in caso di rilevamenti di potenziali ostacoli e sarà dotato di un'interfaccia user-friendly che aiuti l'operatore (gruista) nella movimentazione dei carichi. Lo scopo è ridurre gli incidenti legati alla non perfetta visibilità del carico movimentato dalla cabina cui spesso si ovvia attraverso un operatore che suggerisce le manovre da terra.

La fase di sperimentazione che si vuole realizzare presso i Vs. impianti prevede il test del sistema di rilevamento visivo e la raccolta delle impressioni degli operatori, secondo la seguente articolazione:

Fase 1. Identificazione del punto di posizionamento del sistema di telecamere e realizzazione di un video-demo (visita 1)

- *stabilire posizione e modalità di posizionamento del box 35x28x8 cm contenente le camere (possibilmente in prossimità del gancio, ovviamente senza che esso interferisca con le operazioni di movimentazione dello stesso).*
- *posizionare il box, avviare le normali operazioni del carro-ponte e registrare un video demo attraverso le camere contenute nel box (il video servirà alla calibrazione del sistema stereoscopico).*

Fase 2. Test del sistema di rilevamento (visita 2 e forse 3)

- *Riposizionamento del box sul carro-ponte e alloggiamento di un dispositivo di visualizzazione (computer portatile) davanti all'operatore che movimenta il carro-ponte. Durante la movimentazione dei carichi, si farà testare il sistema allo stesso operatore.*
- *Alla fine di un certo numero di operazioni, l'operatore sarà intervistato attraverso un questionario per trarne le impressioni in merito all'utilizzo del sistema di rilevamento.*
- *Ripetere le operazioni a) e b) se possibile con altri gruisti.*

La sottoscritta precisa inoltre quanto segue:

1. durante l'esecuzione dell'attività di sperimentazione su campo i Dott. Ancione e Kavasidis saranno autorizzati a recarsi presso l'impianto dal Direttore del Dipartimento di Ingegneria e quindi saranno dotati di copertura assicurativa a carico dell'Università di Messina in quanto borsisti a carico del progetto SPRINCE.
2. L'uso delle telecamere per l'esecuzione della sperimentazione non comporta violazione della privacy per l'operatore su campo (D.Lgs. 30 giugno 2003, n. 196), in quanto la risoluzione delle immagini è sufficiente a rilevare l'ostacolo fornendo una zona scura ma non è tale da rendere riconoscibile il volto. Tuttavia eventuali video prodotti, in cui potrebbero essere filmati operatori d'impianto, saranno oscurati sui volti nell'ottica di garantire il rispetto della privacy.

Distinti Saluti

Prof. Maria Francesca Milazzo

Authorisation of the experimental activity

Zimbra **mfmilazzo@unime.it**

R: Autorizzazione a svolgere attività di sperimentazione di un prototipo per il rilevamento di oggetti e ostacoli movimentati da gru presso Centrale Edipower

Da : Mancuso Valeria <Valeria.Mancuso@edipower.it> lun, 18 apr 2016, 12:34

Oggetto : R: Autorizzazione a svolgere attività di sperimentazione di un prototipo per il rilevamento di oggetti e ostacoli movimentati da gru presso Centrale Edipower — 2 allegati

A : Maria Francesca Milazzo <mfmilazzo@unime.it>

Cc : Marchese Salvatore <Salvatore.Marchese@edipower.it>, Foti Giuseppe <Giuseppe.Foti@edipower.it>

Gentile Professoressa Milazzo,
Le anticipo la copia della lettera di autorizzazione alla sperimentazione, l'originale le arriverà per mezzo posta.

Cordiali saluti
Valeria Mancuso

Valeria Mancuso
Edipower S.p.A. – Gruppo A2A
Responsabile Ambiente e Sicurezza
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Destinatario: UNIVERSITA' DEGLI STUDI di MESSINA
Dipartimento di Ingegneria
c.a. Prof. ssa Maria Francesca Milazzo
Contrada Di Dio
98166 Messina

Prot. N° 927
San Filippo del Mela, 15 APR. 2016

Oggetto: Autorizzazione a svolgere attività di sperimentazione di un prototipo per il rilevamento di oggetti e ostacoli movimentati da gru presso Centrale Edipower.

In riferimento alla Sua richiesta del 1.04.2016, siamo lieti di poter dare seguito alla sperimentazione di cui in oggetto, autorizzando l'ingresso ai Dottori Giuseppa Ancione e Isak Kavasidis. La informiamo che, i Dottori da Lei indicati, saranno assistiti in impianto da personale interno allo stabilimento.

Distinti saluti

Edipower
Gruppo a2a
Centrale Termoelettrica di S. Filippo del Mela
Ing. Salvatore Marchese
(Capo Centrale)

Annex 3

Agreement Company Bajina Basta

Agreement

УНИВЕРЗИТЕТ У БЕОГРАДУ | UNIVERZITET U BEOGRADU | UNIVERSITY OF BELGRADE
МАШИНСКИ ФАКУЛТЕТ | MAŠINSKI FAKULTET | FACULTY OF MECHANICAL ENGINEERING

http://www.mas.bg.ac.rs

ЈП ЕПС
Београд, Царице Милице 2
ОГРАНАК „ДРИНСКО-ЛИМСКЕ ХЕ"
Бајина Башта, Трг Душана Јерковића 1
031/ 590 500
ХЕ „БАЈИНА БАШТА"
Перућац
031/590 950

Директору

Поштовани колега Јовановићу,

Иновациони центар Машинског факултета у Београду једина је српска институција која учествује у међународном научном пројекту програма САФЕРА који испред Србије финансира Министарство просвете, науке и технолошког развоја Републике Србије, усмереном ка повећању индустријске безбедности. Пројекат Иновационог Центра "Паметне дизалице у процесној индустрији" има за циљ одабир најбоље платформе за решење проблема визуелизације навигације објекта на жељену позицију код индустријских дизалица, која укључује једноставност интеграције, велику брзину рада и ниске трошкове система за прецизно позиционирање објекта путем web камера. Заснован је за идеји да се инциденти при руковању дизалицама, који за узрок имају смањено видно поље оператера, могу избећи коришћењем иновативног система за визуелизацију навигације. Користи од овог пројекта су вишеструке почев од смањења броја несрећа на раду, преко олакшања посла руковаоцима кроз бољу видљивост терета, повећање продуктивности, смањене трошкове одржавања и др. У реализацији овог европског пројекта учествују и Универзитет Месина, Месина, Италија, Универзитет одбране, Брно, Чешка, и компанија Fagioli S.p.A. –Italy, која је позната по извлачењу олупина крузера Costa Concordia из мора. Такође, и са српске стране је потребна партнерска фирма, која би омогућила имплементацију решења које предлаже пројекат на дизалицама које поседује (систем за визуелизацију навигације је трошак пројекта, односно Иновационог центра Машинског факултета у Београду).

Током израде Пројекта ревитализације вашег крана 2x250/63t у РХЕ видели смо и ваш мосни кран 63/20t у машинској сали РХЕ, који би представљао идеални објекат за реализацију овог пројекта у нашој земљи, јер током рада може да опслужује неприступачна места на више висинских кота у Машинској згради. Такође смо се до сада уверили и у стручност и спремност за сарадњу ваших запослених.

Неколико колега из ваше машинске службе смо консултовали током тражења погодног објекта за имплементацију иновативног решења овог пројекта и стекли смо утисак да су спремни да учествују у њему, па се надамо да ћете и Ви дати сагласност за учешће ХЕ "Бајина Башта" у реализацији овог пројекта.

С поштовањем,
10.09.2015. у Београду

Проф. др Весна Спасојевић Бркић
Руководилац пројекта

Проф. др Александар Седмак
Директор Иновационог центра
Машинског факултета у Београду

П.С. Због кратког рока (инострани партнери из Италије долазе у Београд 24.09.2015. на уводни састанак у поводу почетка пројекта) допис вам упућујемо путем e-maila, а оригинал ћемо проследити и поштом.

Краљице Марије 16, 11120 Београд 35, поштански фах 34
Тел: 011/33-70-350, факс: 011/33-70-364

Kraljice Marije 16, 11120 Belgrade 35, Serbia
Phone: +381-11-33-70-350, Fax: +381-11-33-70-364

Текући рачун за сопствене приходе: 840-1876666-10, код У.Т., филијала Палилула, Београд
Текући рачун за приходе из буџета: 840-1876640-28, код У.Т., филијала Палилула, Београд
МБР: 7032501
ПИБ: 100209517

From: **Trivun Vucetic** <trivun.vucetic@dlhe.rs>
Date: 2015-09-15 10:44 GMT+02:00
Subject: RE: Molba za pomoc pri izradi projekta SAFERA
To: Aleksandar Brkic <abrkic@mas.bg.ac.rs>

Postovani

U dogovoru sa Direktorom Zlatanom Jovanovicem obavestavam vas da smo saglasni sa ucescem HE Bajina Basta u medjunarodnom projektu SAFERA.

S postovanjem

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