Study about the augmented reality adoption in the maintenance in steelmaking area

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In this work a study about the application of the augmented reality in steelmaking area is presented. Augmented reality systems add virtual computer-generated material to the surrounding physical world. The augmented reality systems use see-through head-worn displays to overlay graphics and sounds on a person's natural vision and hearing. As the person moves about, the position and orientation of the head is tracked, allowing the overlaid material to remain tied to the physical world. An application and description of prototypes to the training and maintenance of continuous casting machine is described.

KEYWORDS: AUGMENTED REALITY - IRONMAKING - STEELMAKING - PROTOTYPES - MAINTENANCE

INTRODUCTION

The steelmaking industry represents one of the most important industry branches because of its great contribution to the manufacturing gross index. Indeed, this is strongly influenced by the metallurgical sector where, as in the emerging countries, this index can reach the value of +27%.

In steelmaking industry, the production volume and costs are very important to have a profitable activity. In this view, the analyses of the whole process to make the right decision and following the right strategies are very important.

Maintenance operation contributes for the total process efficiency. The production section should recognize the benefits of working together with maintenance in order to increase equipment effectiveness and to reduce the overall maintenance costs. The company recognizes the contribution of maintenance to total operations' success and profitability. Effective maintenance and physical asset management are closely linked to success and profitability. [1]

Different maintenance methods have been developed but all of these are related to: plant diagnosis and automation technology, technologies for increasing yield and operating rate and for the development of technologies for extending life [2]. None of these are directly related to maintenance operations.

Different kinds of steelmaking route are actually present. Target of this work is to find a new application field for Augmented Reality (AR) for the maintenance applied in the Electric Arc Furnace (EAF) fig. 1. [3]

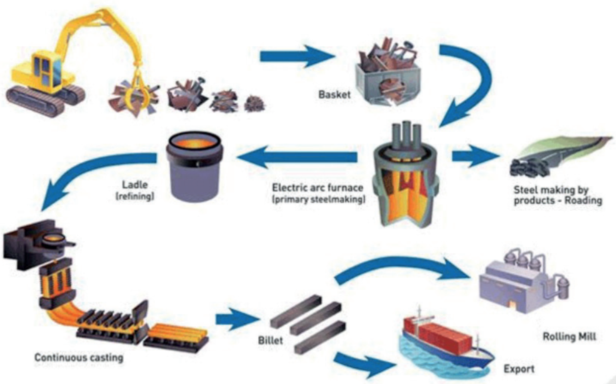

Fig. 1 - Electric Arc Furnace process route

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Maintenance and repair operations represent an interesting domain for the application AR. In this domain, the main activities are conducted with specific procedures organized into sequences of task targeting a particular machinery in a specific location. These procedures are documented on paper or mill server network in a static way.

Maintenance sequences typically span dozens of tasks involving potentially unfamiliar objects randomly distributed across a given area. Moreover, movement in and around these systems can be complicated by their shear size or by structural characteristics that restrict a mechanic's view and freedom of movement.

Augmented reality can trigger the appearance of virtual objects by the user's view of real equipment and structures. This dynamic is very different from technicians' typical interaction with information about equipment. Normally, the information is detached from the equipment, except in the case of control panels and where lighting (because of the frequency of use) and the size of the parts allows physical labels or tags to be jointed to them.

For complex mechanical equipment, as in the case of continuous casting machine or EAF [4], maintainance processes usually demand access to documentation such as technical manuals, either in traditional paper form or digitally e.g. CD-ROM, SD cards or on-line training etc. [5] This is especially important where and when the procedures are performed infrequently.

The information search causes a big time waste and sometimes all the procedures are not updated. For example in the case of "aircraft maintenance" it evokes images of repair actions on actual hardware, but an airline spokesman reported that 45 percent of every technicians' shift is actually spent on finding and reading procedural and related information [6]. From a cognitive point of view, the skills and abilities invoked for these two requirements are often invoked sequentially.

Usually in a steel making plant different maintenance tasks are performed according to following three groups:

- Corrective maintenance. Maintenance tasks are intentionally withheld until an asset stops working or starts failing. Maintenance is then performed as necessitated. In this case are performed some tasks as motor lubrication and similar when these are related to noise and/or vibration.
- Preventive Maintenance. Maintenance tasks are performed at regular intervals, based on industry expected equipment life spans and failure patterns. In this case the lubrication will be performed every a determined number of hours.
- Predictive maintenance. Maintenance is conduced only when it is confirmed necessary through the use of non-destructive tests that detect potential failure conditions before their occurrence. [7]

All these tasks are performed for every machine of the steel shop, in this paper the attention and the examples will be correlated to that of continuous casting machine (Fig. 2). This is characterized by different parts and by a complex assembly, which suggest the adoption of augmented reality in order to avoid the adoption of the information media described before.

Fig. 2 - Example of continuous casting machine

MAINTENANCE COGNITIVE ASPECTS

Towne D.M. measured "the time for two types of behavior in equipment fault isolation tasks: time for actual manipulation of devices and instruments (manual time) and time not engaged with devices or instruments (cognitive time). He found that cognitive time accounted for about 50 percent of total task time. More importantly for our current point, cognitive time was independent of manual time, meaning that individual technicians differed in how much time they devoted to cognitive/ informational chores, but differed little in how much time they devoted to manual chores".

D.Rogers and S. Monsell have shown "that it is easier to keep doing alternate versions of the same task than it is to switch between different tasks, indicating the presence of some overhead chore, such as retrieving "rules" associated with each task. AR can lower the frequency of switching between information and workpiece tasks and therefore to reduce the time and energy demanded in this repetitive switching. When a person wear a Head Mounted Display (HMD) looks like a trance-like state, perhaps holding a tool or touching a workpiece, gazing at the display but appearing to be completely detached from the workpiece task. This is exactly the state we would expect if the user must direct attention to a display that is independent of the workpiece. On the other hand, we would not expect the user of an HMD hosting AR to appear detached from the workpiece task because retrieval and display of information is integrated with views of the workpiece [9-17]".

In some cases the operational procedures considers tasks repeated continously, so manifacturing and maintenance technicians incur in "overlearning" phenomenon. The probability of errors is often a function of the interaction of individual factors such as a worker's expertise and situational factors such as the task environment [10-18][11-19]. For example, high stressful situations generates in novice workers a higher trend to err if compared to expert workers [12-20]. Augmented reality can help novices with an efficient retrieval of information from memory, regardless of the situation. AR provides this expert status in two ways: the first is the basic effect of augmeted reality display, triggering of information with little user effort. Maintenance and manufacturing experience in decision making is characteirzed with evidence that people favor information that is easy to access. [13-21]. The other way augmented reality reduces error is by changing the transition from "information novice" to "information expert." This transition is facilitated by the AR dynamics that complement human associative information processing and memory.

During the training, through AR, the worker can interact with real and virtual objects in the same scene. In particular items can be arranged in a circle and the subject see these through a chair swiveling (Virtual Reality) or directly projeced in a room (Augmented Virtual Reality).

Augmented reality composite scenes are analogous to PC desktop where icons occupies "regions" of virtual spatial layout. The PC graphic user interface allows users to associate functions with spatial locations, it aids visual recognition, and it elicits behavior, such as dragging and interacting with buttons[14]. Some of the potential uses of this control are listed below.

- Influence the user's focus of attention on specific object (e.g., cautions or warnings).
- Enhance user's ability to organize elements into functional sets (e.g., overlay color coding on pipe runs).
- Design objects to be adjustable (e.g., to appear more or less distant from the viewer).
- Make objects dependent on operating conditions (e.g., the continous casting machine is working or not).
- Improve operator's ability of discriminate different operational situations

AUGMENTED REALITY FOR TRAINING APPLICATION

A field, where the documentation and the guidance play a key-role, is the training of workers on new maintenance or complex assembly task. Nowadays the computer based training is joined with on the job training where expert workers train the novice ones. Augmented reality can provide scenes with useful informations especially when the maintenance task increases in complexity. These system is dedicated to situations and aims at:

- Providing assistance to a user who has to perform work on complex mechanical assemblies Fig. 3. [15]
- Increasing the skills of users to perform such processes by providing different training scenarios.

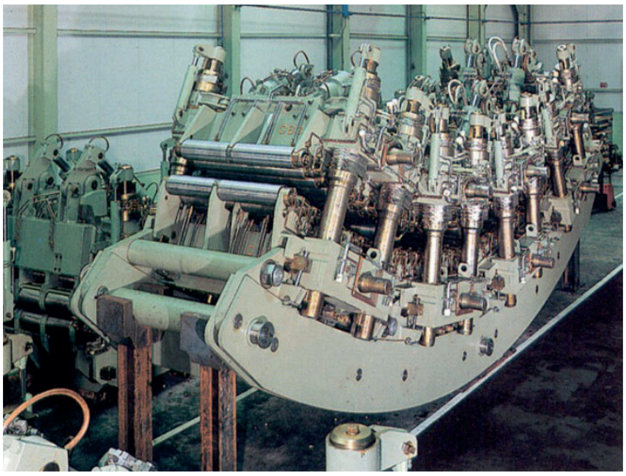

Fig. 3 - Particular of one of the mechanical assembly present in a continuous casting machine

The user can be trained with instructions made by text displayed in the Head Mounted Display and audio through the headphones,tracking of the user or the mechanical assembly (object), 3D overlays, etc. The tracking is useful for making a projection of the overlays at their correct visual place directly on the object. [9-10-16-17]

Different systems have been developed for training and for maintenance that can be used in steelmaking area. In the system presented the user is connected in a fixed stand. The use of stand can be very useful in the case of maintance work made in mechanic or electric workshop where "in-field" application is not needed.

Many AR applications use optical tracking with cameras on the head of the user and markers placed in the work environment, e.g. [11-18]. Due to the integration of the stand into the system, electromagnetic trackers and infrared stereo tracking systems with two fixed cameras and small retro-reflective markers is used in the system.

The total hardware adopted for this kind of stand is composed by:

- The user equipment including a headset and the belt allowing communication between users and processing unit.
- A processing unit for calculations and storing the database (i.e. all augmentations relative to the object)
- A stand including the 3D-tracking systems (optical and magnetic) as well as spots-lights.

For a typical use of this system developed by B. Schwald and B. de Laval [19], the user is equipped as illustrated in Fig. 4, which integrates an optical see-through HMD, a microphone, headphones, and a 3D-positioning sensor with the following functions:

- The HMD allows the user to see the real world augmented by computer generated images.
- The headphones provide the user the possibility to get audio information on the procedures to be achieved as well as visual data.
- 3D augmentations can be directly superimposed on their real counterparts thanks to the data provided by the 3D-positioning sensor of the tracking system (which gives the position of

the objects of interest in the space in relation to user's position).

- The microphone allows the user to easily interact with the system by using speech recognition technology.

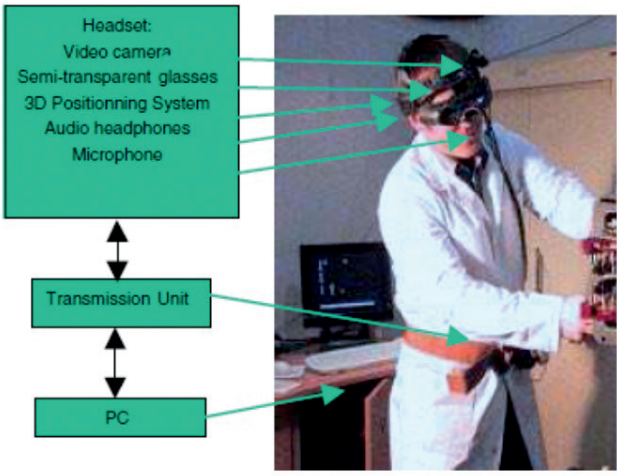

Fig. 4 - Example of user Equipment

The system, due its peculiarites,is fixed and can not be moved in other places. Therefore it is important that the complete equipment is easily installed and configured by the user. A new stand has been designed and developed so as to attach all the elements needed by the system as e.g. lights and tracking systems. (Fig. 5) shows a side view of this stand.

Fig. 5 - Particular of stand

The stand is foldable, easily movable and takes into account the tracking system constraints. Metallic parts of the stand are avoided as much as possible in order to keep distortions of the electromagnetic tracker to a minimum. Augmented Reality is chosen rather than Virtual Reality in order to have the perception of the real environment. 3D model enables to see all the parts in maintenance, how they are integrated into the machinery and how it works. The idea is to train the worker keeping in mind not only the timing and the complexity of tasks but also the importance of safety procedures. [12-19] The latter two aspects are crucial in the modern maintenance practice. This because of the presence of simple errors in the assembly creation can affect the final quality of the product. The error related to incorrect training can lead to different types of quality defects: the most burdensome may even affect the quality of the product such as not to exceed the minimum quality requirements such as straightness tolerance or the formations of porosity to internal billets or blooms. If these errors are present in the final part of the casting process, signs can be present on the surface forcing workers to a repackaging of the product with loss of time and material.

The "AR training" used for purposes such as work safety can be equally important in order to minimize the presence of injury. This will be achieved through the interactive lessons in the presence of 3D virtual elements that would help in defining the best practice in operational cooperation between the security officers and the employees themselves.

The AR can assist also in training for new machinery or prototipes as shown in Fig. 5 where an application of cramper interio of an armored vehicle turret is shown. In this example the informations is combined with the worker view through tracke head-wom display (HWD). Actually this study is a laboratory proof-of-concept system and software and hardware are not created for a production environemnt. The same idea applied in military corps can be transferred to the steelmaking process, where the extreme working conditions for some particular tasks can be considered similar (e.g. presence of dust, high temperature, high number of impacts). Software can be implemented as an application representing a particular task as toggling a switch helped by a graphic that follow a general sequence. (Fig. 6)

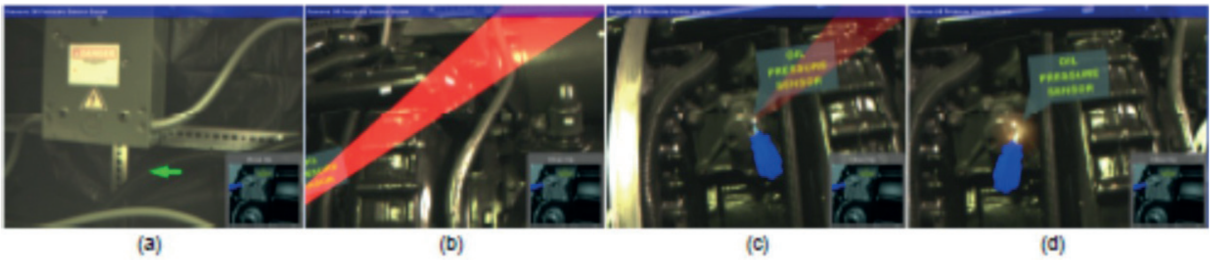

Fig. 6 - A typical localization sequence in our prototype. (a) A screen-fixed arrow indicates the shortest rotation distance to target. (b) As the user orients on the target, a semi-transparent 3D arrow points to the target. (c) When the user orients on the target, the 3D arrow begins a gradual fade to full transparency. (d) When the arrow has completely faded, a brief highlighting effect marks the precise target location.

For complex task 3D models can help the user in making the correct movement in a determined time. In fig. 7 the worker is installing fastner and the animated tools demonstrate the correct tool motion to accomplish the task. All the sequence are synchronized and plays for a finite period of time.

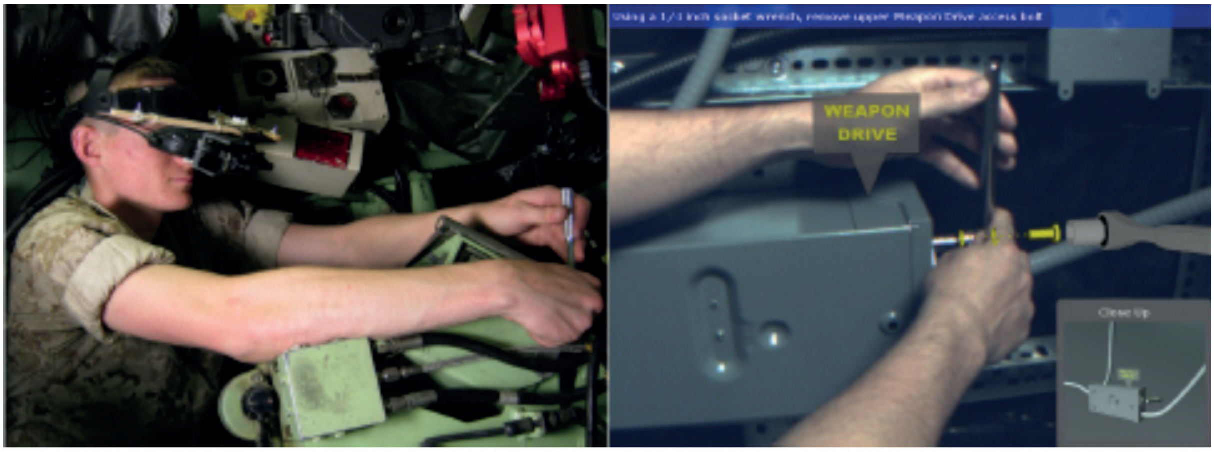

Fig.7 - Particular of military AR animated sequence

If a mechanic wishes to replay an animated sequence or control its speed, they can use a wireless wrist-worn controller, shown in Fig. 8. The controller uses a custom 2D interface application written using the Android SDK, and provides forward and back buttons that allow the mechanic to navigate between maintenance tasks with additional information in the inset button.

Fig. 8 - Mechanic uses the wrist-worn controller to cue the next task in a repair sequence. The inset view shows additional features that appear during applicable tasks for controlling animations.

In S.Henderson and S.Feiner work several participants mentioned the potential utility of the tool in maintaining hydraulic and electrical systems in particular.The participants experiencing the Augmented Reality allowed a population of mechanics to locate individual tasks in a maintenance sequence more quickly than when using an improved version of currently employed methods. The prototype AR application also resulted in mechanics making fewer overall head movements during localization and was favorably received by users in terms of intuitiveness and satisfaction [11-17][12-18].

CONCLUSIONS

Maintenance practice in steelmaking plant, with the current production ratio and the high quality requirements, become anytime more important. Steel shops are composed by different parts and all of these have to be checked and maintained; in this work the focus is poses to the continuous casting machine.

The augmented reality (AR) can be a powerful medium for safety and maintenance training. For the first task a dedicated stand is described. This is constructed in order to minimize time and resources employed for training both for the maintenance training and for safety one.

The operation of maintenance can be improved thanks the adoption of dedicated prototype where 3D arrows, labels, and animated sequences are adopted. In these trials several participants mentioned the potential utility of the tool in maintaining hydraulic and electrical systems in particular.

Thanks the AR utilization the head and neck movements can be reduced and all task performed are more intuitive and faster with an increment both in costs related to the maintenance operations and to the quality of the assemblies where the personnel are working on. This will affect the overall quality of product.

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