# Application of Virtual/Augmented Reality in steelmaking plants layout planning and logistics

**A.F. Ciuffini, C. Di Cecca, F. Ferrise, C. Mapelli, S. Barella**

In the past years, Virtual or immersive Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) technologies have largely been developed for the military, although it has been used for commercial purposes as well, especially for the development of virtual museums, exhibitions, games, and other cultural and amusement projects. Moreover, as realistic and productive visual simulation continues to develop, coupled with a drop in prices for image generators, the market for architectural design systems based on AR is expected to rapidly grow.
Nowadays, the human-computer interaction, due to its long-established approach, can show drawbacks and limitations of traditional interfaces. Promising alternatives are offered by Virtual or immersive Reality (VR) and by Augmented Reality (AR), enabling humans to behave in a nearly natural way. Natural interaction means human actions in the real world with other humans and/or with real world objects. In order to achieve these results, prototype tools, build on video-based interaction, support construction and plant layout planning.
The exploitation of Virtual Reality (VR) and Augmented Reality (AR) has already been studied and used in architecture, construction and logistics, application fields with many common duties to the steelmaking industry.
In detail, the best possible configuration and arrangement of all production units and transport systems are necessary prerequisites to maximize productivity. Furthermore, also the rationalization of the logistics is a crucial point in order to achieve both the lowest operating costs and a seamless material flow without bottlenecks. These reasons grant to Facility Layout Planning (FLP) and logistics a very promising scenario for VR/AR employment in steel industry. Consequently, possible on-field applications in a near future have been investigated. Indeed, although the metal industry is still conservative, the need for more efficiency and an overall optimization of whole plants would lead to the integration of these new technologies in the daily practice.

**KEYWORDS:** VIRTUAL REALITY (VR) - AUGMENTED REALITY (AR) - FACILITY LAYOUT PLANNING (FLP) - LOGISTICS

## INTRODUCTION

Steelmaking factories are very complex plants, covering large areas with many buildings of very different features and purposes. Since their functions are strongly interdependent from each other, their arrangement within the steelmaking factories areas results to be crucial in order to maximize factory productivity. Moreover, also the machineries and equipment, present within the plants, are extremely complex, interdependent from each other and requiring special needs to achieve their best performances (Fig. 1). Taking into account these considerations, it results glaring the importance of the plant layout planning during both the design of a new factory or the refurbishing of an old steelshop.
Moreover, typical electric arc furnaces have a load capacity of 80-100 tons per hour and blast furnaces process even higher material volumes. Taking these considerations into account, the material flow within a steelmaking plant can be calculated as thousands tons per day. Due to this extremely high volume of

**A.F. Ciuffini, C. Di Cecca, F. Ferrise, C. Mapelli, S. Barella**
Department of Mechanical Engineering,
Politecnico di Milano, via La Masa 1,
20156 Milano, Italy

handled material in a steelmaking plant, the rationalization of the logistics and internal transports of materials results to be significant both in the operating costs both in the obtainment of a seamless material flow avoiding bottlenecks creation. [01, 02] Virtual Reality (VR) is already playing an important role in these tasks. On the other hand, the exploitation of Augmented Reality (AR) has already been studied in order to be implemented in different application fields, such as architecture and construction, with many similarities and common duties to the steelmaking industry. Although any on-field study has been not performed yet in steel industry, AR is promising to be a very useful tool in a near future.

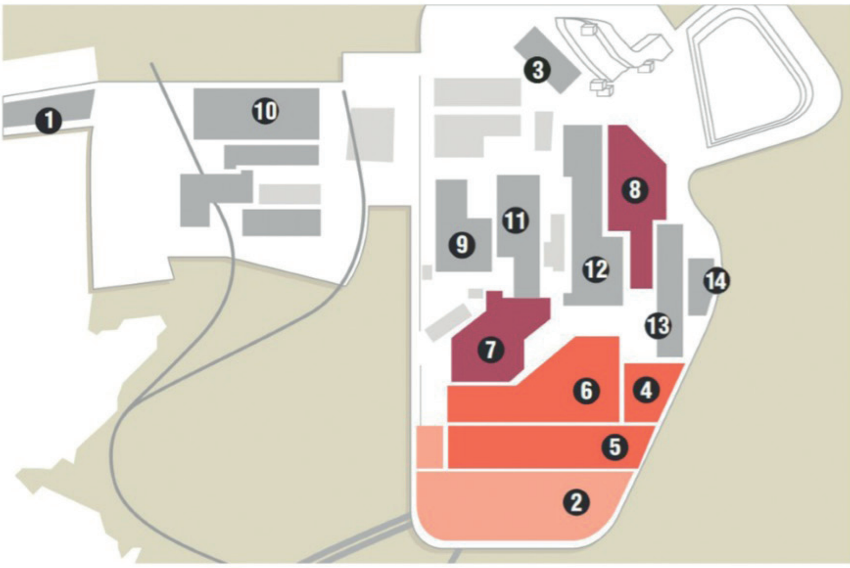



**Fig. 1** - Schematic map of a steelmaking plant.

**PLANT LAYOUT PLANNING**

In order to maximize steelmaking plants productivity, the best possible configuration and arrangement of all production units and transport systems are necessary prerequisites. A totally optimized plant layout and logistics ensure the highest possible plant productivity, minimized investment costs, the lowest achievable plant operating costs, the prediction of equipment utilization and maintenance and, last but not least the preventive detection and the elimination of bottle necks.

Due to the extremely large volumes involved, the material handling is of paramount importance in designing a steel plant layout so much that in one type of a layout railway tracks are laid out first, in order to get the best material flow optimization, than the rest of equipment are positioned accordingly. Apart from the routine movements of main materials, steelmaking plants need to be maintained and refurbished periodically. The maintenance scheduled, which is planned in the layout design, don't have to interfere with the regular working of other equipment and other furnaces. As different units and equipment have their own life-cycle, which develop inefficiency at different rates, an initially well planned layout, may be thrown out of balance in due course of time and its overall efficiency may decrease. All technological processes and their future potential declining capacity, therefore, should be duly taken into account in the initial planning itself.

It must be clearly understood that an ideal layout is almost impossible to be achieved and that some degree of improvement is always possible at a latter date. However, while designing, particularly a new plant, all possible care should be taken toward an ideal layout. [01-03]

Nowadays, Virtual Reality technology development has led to a new approach to Facility Layout Planning (FLP), providing a virtual environment, where the users can manipulate the virtual facilities manually. The VR-based approach provides an interface for manual planning and facilitates FLP by providing visualization of the plans for the users. Thanks to an easy-to-use system interface, the VR-based FLP approach is playing an increasingly important role in factory layout design and many commercial products are already currently available.

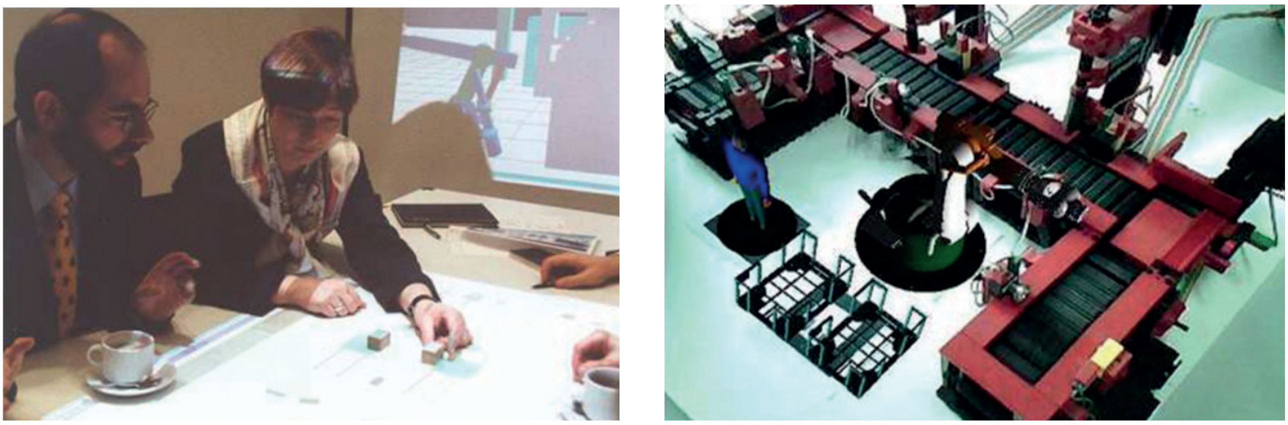


**Fig. 2** - AR-assisted FLP system. [04, 05]

Since the development of AR, different attempts have been made to implement it within FLP. In all these works a common procedure results to be transversal in the development of these AR-based FLP systems (Fig. 2).

The main steps involved in this common procedure are:

1. The rendering of the new facilities or the real shopfloor to be refurbished through the use of a number of markers;
2. Definition of pre-defined criteria which rule the layout planning;
3. The adoption of a manual planning procedure.

The sense of reality experienced by the users can facilitate the exploitation of human intuitiveness. During the planning process, displacements of the real objects are reflected in the virtual map and the users can design the layout plans cooperatively and interactively. Although these AR-based FLP approaches have successfully provided an alternative solution to the FLP problems, the obvious drawbacks, such as, the lack of proper evaluation mechanisms, restricted interaction between real and virtual objects, have greatly reduced the adaptability and the usability of the AR-based approach. [04-06]
In order to overcome these disadvantages and limitations, different techniques have been developed.

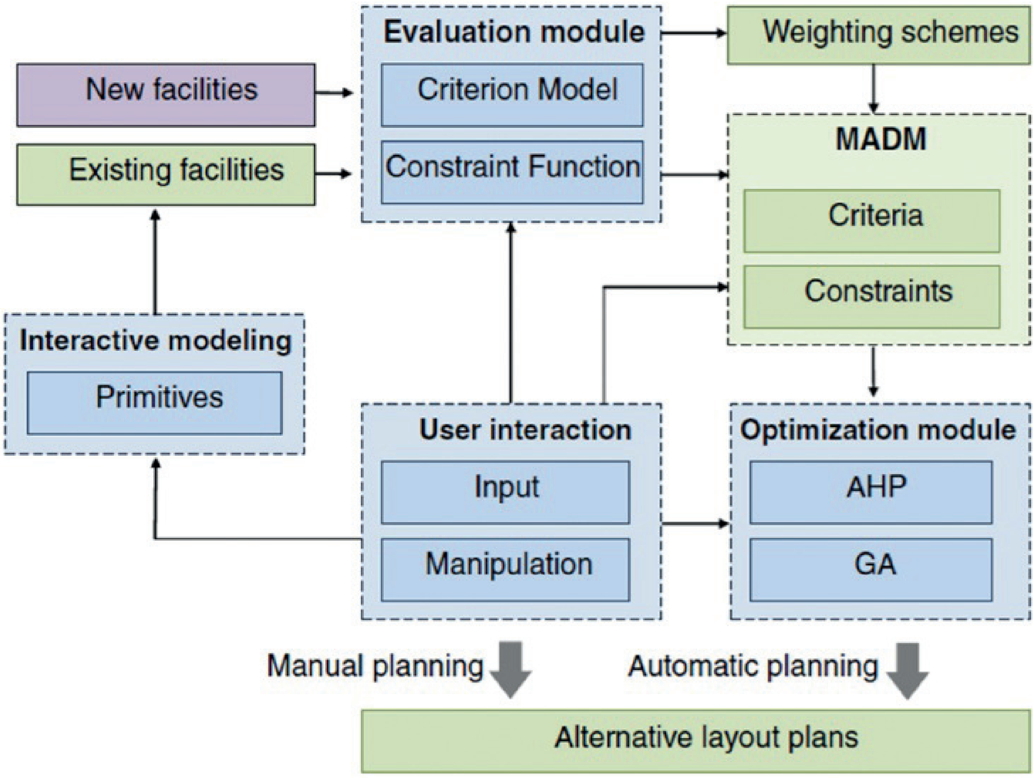


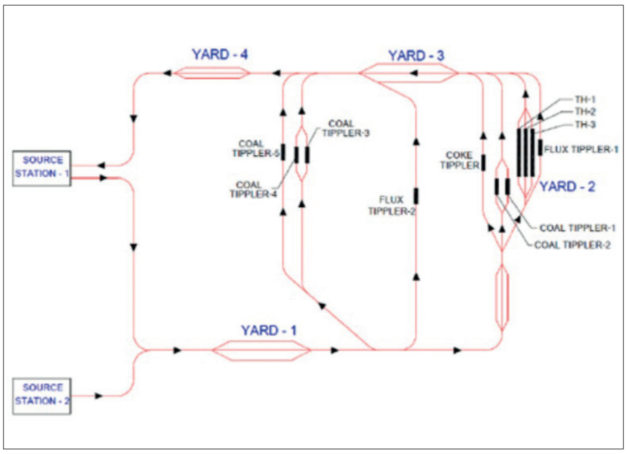

**Fig. 3** - Architecture of the coupled manual and automatic planning. [07]

Systems using an image-based tracking method which finds an arbitrary feature from actual images, such as a safety sign; such images can be used instead of an artificial marker because they are easily acquired on site. These systems provide a mixed reality-based virtual factory layout planning systems with a demonstrated effectiveness in the simulation of process layout planning.
Moreover, algorithmic approaches, adopting mathematical models to formulate the FLP problems and using heuristic algorithms to solve the models, have been developed to produce the layout plans. The utilization of the mathematical models increases the reliability and the definitiveness of the plans produced. By using the virtual models representing the new/existing facilities, the Generic Method for defining the Criteria and Constraints (GMCC) method allows the users to define the criteria and constraints to formulate FLP problems as Multi-Attribute Decision Making (MADM) models and customize the models according to the specific needs in the tasks. Further, VR- and AR-based approaches provide a convenient graphic user interface for planning the layouts manually, in order to fully exploit human intuitiveness within the planning process. Thus, both manual and automatic planning are provided, where human intelligence manual planning and analytic hierarchy process (AHP) - genetic algorithm (GA)-based automatic planning are utilized to facilitate the planning process (Fig. 3). [07, 08]

**LOGISTICS**

Due to the extremely outstanding high volume of handled material in a steelmaking plant, the rationalization of the logistics is a crucial point in order to achieve both the lowest operating costs and a seamless material flow without bottlenecks. Traditional approach to add capacity focuses on increasing capacity without investigating hidden logistics capacity. If these hidden capacities are not properly explored, it may lead to significant operational costs overrun. [09]
However, also AR could play a significant role in order to achieve these results.

In detail, 3D visualized simulation model for simulating transport operations in construction, exploiting a Discrete-Event Simulation (DES) method which models operation processes by arranging a series of events in time sequence, has been already developed. This model consists in an AR technology combining virtual objects and real field settings. As required by 3D visual representation, model component classes were proposed to compose the 3D simulation model, their visual representations and relevant attributes for simulation then were determined through analysis. The prototype system platform integrates AR technology, a 3D component library, a visual interface, and a 3D model. This AR technology utilizes video equipment to capture images of the field, imports them into the system, and then presents them on the visual interface. The 3D component library uses the format of 3D models, and employs 3D drawing technology on the visual interface. Software libraries for building AR-applications have been used and integrated by this prototype system for implementing the function interface and a complete integration of pre-processing and post-processing phases is achieved.
The model, built in 3D space, and, allow to the model information and the simulated results being presented more intuitively and the interactivity of the system interface is enhanced. Furthermore, modelers can directly place 3D model components on the field image through an AR modeling interface. This facilitates not only an accurate positioning of model components by directly selecting the placed locations, but also enables modelers to avoid environmental constraints in route planning. Thus, the integration of virtual model components and actual construction field status is realized. Finally, the user survey results reveal that the proposed system performs better than traditional schematic visualization systems. [10]
Due to the major complexity of the material management, this prototype could be successfully applied within the steel industry and appears to be very promising in the management of the handling machinery routes, optimizing the material flows within steelmaking plants (Fig. 4).



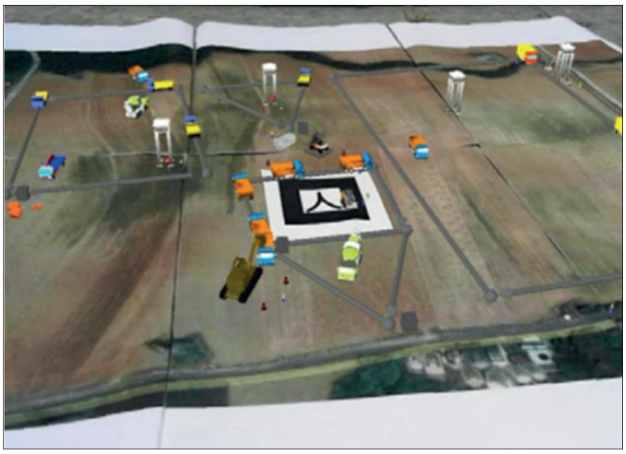



**Fig. 4** - Scheme of the unloading raw materials yard routes and AR system managing logistics interface. [09, 10]

Another possible application field of AR in steelmaking plants logistics is represented by organizing the layout of the in-bound raw materials unloading yard and the semi-finished products storage yards and warehouses. Since the supply of raw materials is linked to the market prices volatility, the possibility to exploit the in-bound raw materials unloading yard also as storage area could allow significant cost savings. On the other hand, the operating practice in steel industry consists in the production of large quantities of the same product before switching to a different product with a change in the production set-up. Moreover, hydrogen embrittlement relief treatment could be performed via a room temperature bakeout for 120 h, increasing the stationing time within these areas. As consequence, also the organization of the semi-finished products storage yards and warehouses plays an important role in steelmaking plants logistics. [11, 12]

The layout processing of an area is one of the most studied applications of AR in construction field, which could be implemented within steelmaking industries. In the AR layout processing, it is necessary to perform either a distance or angle measurement, or both, from a known starting point in order to decide the positions of new reference points on the site. In order to determine correct reference points on the site, time is required to set up a measuring device and read precise measurements. However, virtual marked reference points in the digital design model and then superimposed accurately onto the worker's view of the site may free workers from the task of measuring to establish the reference points on the site (Fig. 1). Workers can identify the positions of reference points easily and mark them on the site by simply observing the rendered virtual reference points, and with an appropriately designed display (viewing device) may not even need to physically mark reference points or lines because they would be able to see virtual references as they need such guidance (Fig. 5). Thus, this AR system would save time and duties for workers; moreover, it could be easily exploited to define and optimize the area layout a-priori. [13]

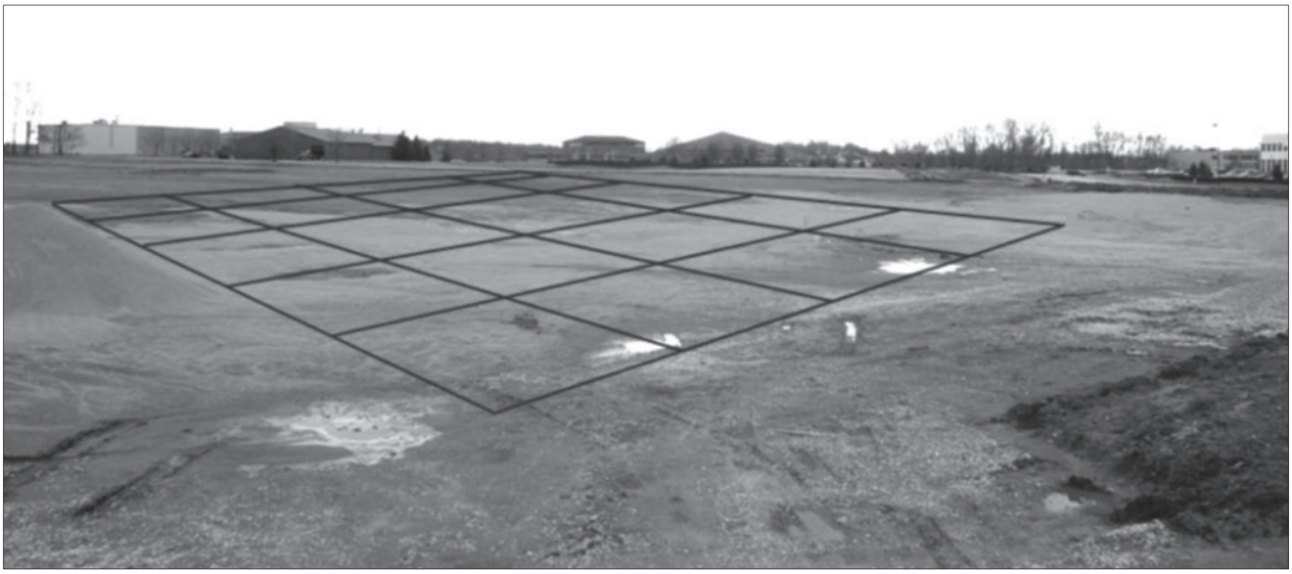


**Fig. 5** - A conceptual view of AR overlay for layout. [13]

## CONCLUSIONS

While AR has proved to be beneficial in a number of applications, the metal industry is still cautious in the utilization of this tool. However, the need for more efficient control and a comprehensive optimization of whole plants, in alternative to the more conventional technique of separate control of single variables, these developments will obviously emphasize the importance of computer-based management-and-control methods. [14]

In this work, a list of the most interesting AR technologies developed for application fields with needs similar to steelmaking plants has been provided, focusing on layout planning and logistics management. Furthermore, possible applications in steel industry have been investigated, highlighting their positive contributions.

## ACKNOWLEDGEMENT

The authors are very much grateful to Prof. M. Bordegoni, holding the Politecnico di Milano Summer School in INTERACTIVE VIRTUAL PROTOTYPING - METHODS AND TOOLS, by the inspiration and the supervision of this work.

## REFERENCES

[01] Y. Yang, K. Raipala and L. Holappa - Treatise on Process Metallurgy, Volume 3: Industrial Processes - Chapter 1.1 Ironmaking - Elsevier (2013)

[02] W. Nicodemi, C. Mapelli - Siderurgia - A.I.M. (2011)

[03] B.P. Bhardwaj - Steel and Iron Handbook - Niir Project Consultancy Services (2014)

[04] H. Kato, M. Billinghurst, I. Poupyrev, K. Imamoto, K.

Tachibana - Proc. Int'l Symp. Augmented Reality 2000 (ISAR '00), IEEE CS Press (2000), pp. 111–119.
[05] M. Rauterberg, M. Bichsel, M. Meier, M. Fjeld - Proc. Int'l Workshop on Robot and Human Communication 1997, IEEE CS Press (1997), pp. 212–217.
[06] K. Pentenrieder, C. Bade, F. Doil, P. Meier – Proc. Int'l Conference Mixed and Augmented Reality 2007 (ISMAR 2007). IEEE CS Press (2007).
[07] J. Lee, S. Han, J. Yang - Computers in Industry Vol. 62 (2011), pp. 86–98.
[08] S. Jiang, S.K. Ong, A.Y.C. Nee - Int J Adv Manuf Technol Vol. 72 (2014), pp. 457–473.
[09] A. Mukherjee, A. Som, A. Adak, P. Raj, S. Kirtania - Proc. of the 2012 Winter Simulation Conference (WSC '12), IEEE CS Press (2012).
[10] H.-M. Chen, P.-H. Huang - Automation in Construction Vol. 33 (2013), pp. 123–136.
[11] S. Wan, J.-F. Lu, H. Zhang - Proc. Int'l Conference Audio Language and Image Processing (ICALIP), IEEE CS Press (2010), pp.873–876.
[12] L. Raymond - Hydrogen Embrittlement: Prevention and Control - ASTM International (1988)
[13] X. Wang, M.A. Schnabel - Mixed Reality in Architecture, Design and Construction - Springer Science (2009)
[14] B.T. Cronhjort, A.J. Niemi, E. Suoninen - Control Eng. Practice Vol. 5, No 2 (1997) pp. 239-245.