Industry 4.0, Innovation and Design.
A new approach for ergonomic analysis in manufacturing system

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Abstract: The contribution proposes the individuation of innovative methods for the design of systems-products in production through the use of virtual reality, from the interaction between the discipline of design and the technology in the manufacturing systems in constant evolving. Industry 4.0 represents the transformation through digital information systems that generate a productive and socio-economic change and the level necessary to address the major contemporary competitive challenges. The new production paradigm a new level of human-machine interaction. The role of the person changes and takes on greater importance in the digitized factory through the contribution of Ergonomics, highlighting the centrality of design by the virtual ergonomics that allows the preliminary verification of the issues related to the postures of the operator of production during the working activities increasing the well-being. Virtual technologies and discipline of design anticipate new design experiences and multiple scenarios for the configuration of new products and services.

Keywords: industry 4.0, design, innovation, process, ergonomics, virtual reality

1. New Industrial Revolution: Industry 4.0.
In the current manufacturing context the introduction of new technologies represents a challenge for the national and international manufacturing industry making them more exposed to the market competition. The technological change, defined as an industrial revolution, determines a strong impact in terms of growth, profitability and employment in this sector.

Environment, competitiveness and safety are the main current drivers of innovation of products and process, achievable through the implementation of the current production systems of digitization, simulation of processes and use of advanced digital technologies.

In a context ever-changing the manufacturing sector has the main objective of maintaining and improving the ability to innovate in different productive sectors, through experimentation and technological innovations in the management of production processes.
From the Research Report Factory of the future (2014): “The basic scenario in which Industry 4.0 is conceived is the new relationship between the physical world of human beings (that is of the actors of the economic and social system, such as entrepreneurs, workers, consumers, etc.) and the digital world (computers, sensors, the virtual world of simulations, and so on). The union of these two worlds is very complicated, and there are a lot of studies looking for the most suitable interfaces for it, but the synergies and benefits that would be obtained are very high, because it would allow us to exploit the enormous potential of digital technologies of which today we use just a small part”.

In the current production environment a transformation called Industry 4.0 is in progress, a paradigm change whose boundaries and times are still difficult to define and will manage to involve the entire international manufacturing sector.

For the description of this innovative and complex process, different synonyms exist with the term Industry 4.0 such as Smart Manufacturing, IV Industrial Revolution, Intelligent Factory, Factory of the Future and, depending on the country of implementation, were born initiatives for the development and dissemination of technologies underlying the Industry 4.0 paradigm. Industrial Internet in United States, Industrie 4.0 in Germany, Industrie du Futur in France, High Value Manufacturing in UK and Fabbrica del Futuro in Italy, whose peculiarities are the same and are mainly identified in the integration of the physical processes with digital technologies. In detail, the European model of Industry 4.0 is being defined on the basis of the activities of the individual member states and on the intervention of the European Commission through the initiatives of Horizon 2020 in order to increase European industrial competitiveness with targeted investments to the realization of smart factory.

“The world of factories, in Italy as elsewhere, is at the threshold of a deep transformation which, according to many voices of technological and social scientists, business leaders and trade unionists - this will not be any transformation. It is a paradigm change that has at heart a technological break never existed: the fusion of the real world of industrial plants and the virtual world of what is called Internet of Things, an integrated system of interconnected and intelligent devices that knows how to put in contact through the network, objects, people and places. [...] The production process will be simulated in a virtual environment to identify and resolve problems before physically building it” (Magone, Mazali, 2016).

Industry 4.0, an evolution of the previous industrial revolutions that respectively have seen the introduction of water and steam power, to mechanize the production of electricity for mass production and information technology and the digital age to increase output levels of automation using electronic systems and information technology.
Innovation, one of the major sources of competitive advantage in the long term, pursues the strategy that generates products and services with a radical new meaning, a major factor in the development of society and advanced economies across different nations that respectively to its ability to feed over time a continuous development of innovation determines the economic and technological supremacy in the global market. A technological innovation leads inevitably to an innovation from the organizational point of view of the company.

“A technological or organizational innovation can not simply be an idea, a project, a prototype of a new project, a new process or a new organizational practice, but it must be translated into everyday practice, in routine and standardized procedures that enable the efficient production of the new product, the implementation of the new production process and the daily exercise of the new organizational practice. This translation is the result of two processes closely linked to each other: one of organizational learning, through which the organization acquires and disseminates among its new knowledge and new methods of operating; the other of organizational change. One of the crucial aspects of innovation in enterprises is that it must almost always and is almost necessary to be accompanied by an organizational change. New technologies, new markets, new ways of operating will inevitably bring changes in the organizational structure” (Viale, 2008).

It is a new mode of production in which the combination of manufacturing and innovation is strengthened by the use of digital technologies in its production processes through potential hybridizations between the physical world and the virtual world whose centrality is represented by the evolution of the world of production. From the fusion of the two worlds a system called cyber-physical (Cyber-Physical System) is born, composed of a complex network of machines, physical products, virtual items, computing facilities and storage, communication devices that interact with each other and exploit the enormous potential of new technologies, these are currently not yet fully explored.
The use of a cyber-physical system will bring an improvement in the industrial and distribution processes, achieving increased efficiency through the reduction of production costs and the consequent decrease in selling prices, increasing the number of new products and services to market variables through the use of current technological resources.

“In a context where the market paradigms change so radically in a very short time, the efforts of private and public companies should be set in the rapid adoption of the digital value chains as a strategic element of recovery, growth and acceleration. The digital transformation can not represent just an option or accessory channel, but a central element on which to focus, through dissemination of skills, investment in research and measures concerning the connectivity infrastructure, data center and access to the Internet, evolution of operating models, coherent management culture and entrepreneurial humus - from testing to the start-up” (Poggiani, Tedeschi, 2014).

The new manufacturing changes the value chain, creates a new relationship between man and machine, enhancing cooperation whilst leaving the primary role of the user unchanged also defining the importance of the most advanced and professional skills. With the advent of digital manufacturing and robotics in factories we are seeing a paradigm change in the world of work. It will be important to identify and plan transversal skills as the capabilities of the human capital present in the production realities.

“Whatever the rate of change or the final result of these changes, we can be sure of one thing: the workers of tomorrow will need skills that enable them to create economic value in a world where more and more large areas of the work market will likely be replaced by automation, software and robots” (European Schoolnet, DigitalEurope, 2014).

The new business environment will lead to increased experience and know-how of the worker in the design, use and supervision of intelligent machines capable of assisting human resources in the performance of tasks.

2. Technologies in new manufacturing context

Industry 4.0 consists of a transformation of industrial production driven by technological advances and governed by nine main technologies/pillars, representing the vision of the productive system of the future. The main technologies, placed to the service of the company, represent the new interpretation for to the manufacturing environment, interconnected between them and used for the purpose of innovating the “factory” system, improving the tangible products in terms of quality.

“Digital technologies entered in a strong and pervasive way in everyday life of hundreds of millions of people around the world. The development of technical and functional solutions in a business field is advanced and, in different industrial sectors, also their implementation is established and implemented to meet the higher requirements placed by the customers of the process or directly by consumers. The current challenge for the companies of the manufacturing sector is therefore to grasp the potentialities of the models and digital technologies with an overall strategic vision, in order to allow the design of production processes in an integrated way with the available technological solutions” (Poli et al, 2014).

Internet of things, big data, cloud computing, simulation, augmented reality, robotics, additive manufacturing, cybersecurity and integration of horizontal and vertical systems are the key words of Industry 4.0.
In the new factory the new production process, identified by the name of Digital Manufacturing, is the integration of some of the Industry 4.0 technologies such as 3D printing, Internet of Things, big data and simulation tools and three-dimensional visualization. Through this method it is possible to simulate the entire production cycle prior to implementation in the physical way, in order to verify the possible improvements and simulate in detail the behavior of individual actors involved: machinery, workers, raw materials and components.

Currently the enabling technologies are in a mature stage to support new approaches and processes in the light of innovative paradigms, connecting the products to the operator who realizes them and to the production lines, interconnections that determine the optimization of the entire production process and the improvement of the products. From the point of view of innovation of product and service, these smart technologies enable the identification of ever more advanced design solutions of the product and for the process innovation lead to new solutions related to the logistics, to the more adaptive and dynamic production, to the assistance and maintenance of the process and of the phases of which it is composed also remotely with the aid of innovative instrumentation.

One of the main technologies used in the actual industrial environment is virtual reality, an economically efficient tool supporting the productive development and anticipatory resolution of issues related to ergonomic aspects and performance in industrial environments, in different fields of applications, from automotive to defense, from medicine to education, etc.

In line with the principles of Industry 4.0, in addition to allowing ergonomic assessments in a short time compared to the standard methods, virtual reality is a "communicative experience" in which the user, involved through the different sensory channels, becomes the main protagonist within the space generated by the computer.

"Virtual reality can be considered an "experiential" interface, in which the perceptive component (visual, tactile, kinesthetic) rests with the interactivity: I know the objects and use them to learn through direct experience and real-time of their reactions as a function of my actions. However, to achieve this experience, the integration of very different elements is required between them" (Morganti, Riva, 2006).
Virtual process, achieved through dedicated advanced systems, allows the three-dimensional viewing of simulated environment and anticipatory detection of any issues relating to incongruous postures of production operative and provides the ability to validate the assembly activities in the design and industrialization, reducing the time and cost of production of the physical product. The aim of this contribution is to evaluate and verify the value of this technology in production processes in support of the current standard methods of ergonomic evaluation, during assembly phases and in carrying out work activities in manual workstations. The interaction between the discipline of ergonomics and virtual reality technology brought about the concept of virtual ergonomics, defined as the main form of preventative ergonomics.

3. Design and Ergonomics in Industry 4.0

The contribution is based on a multidisciplinary approach and emphasizes the interaction between different skills and knowledge from fields that also seem distant. The discipline of design integrates with engineering and occupational medicine. Through the use of advanced technologies, there are many possibilities offered for design. Through the discipline of design, seen as a tool to innovate, it is possible to define and design equipment, tools and manual workstations through the ergonomic approach, starting from the use of virtual reality.

The design methods allow you to establish a direct link with the user by detecting and understanding the needs and focusing on the potential of technology and the impact on culture and society. As defined by 'ICSID International Council of Societies of Industrial Design:
"Design is a creative activity whose aim is to define the multiple qualities of objects, processes, services and their systems throughout their life cycle. Design is therefore the central factor in the humanization of technologies and the crucial factor for cultural and economic exchanges."

Figure 3. New approach for Design with Virtual Ergonomics
The current industrial revolution employing the discipline of design involves companies through investment in equipment and acts to create new patterns of consumption, to generate knowledge and provide innovative services.

Underlining the specific contribution of the technological project "to the development of an industrial culture intended to balance the emotional and aesthetic data of design with the technical-productive data", where design becomes the "place of convergence of ideas and skills related to fattuality" based on a multidisciplinary intelligence" (Vittoria. 1999).

"The design approach to innovation also qualifies for the ability to combine two different orientations: on the one side, the search of new knowledge and scientific and technological opportunities and market (exploration) and, on the other, the ability to leverage (explotation) the basis of the knowledge of designs-products already on the market, ensuring an incremental innovation" (Casoni, Fanzini. 2011).

In an era of constant transformation and technological experiments, design plays a central role in the new manufacturing environment, where ergonomics is the focal point for the improvement in terms of product and production process with a focus on well-being of the user and for his safety; the main actor in the digitized factory is the production operator who interfaces with the different equipment present in line.

"The ergonomics applied to industrial design is now very active in the field of industrial products of large series and those with advanced technologies, both for the great weight that the industrial design began to have for the development of quality, both for the evolution of the complex relationships involved in the project the technology, the design and the user satisfaction" (Bandini Buti, 2008).

Industrial design and ergonomics represent in parallel new opportunities for the investigation offered by the current technological innovations to be translated into tangible products and creating a direct bridge between technology, society and the world of production.

In current industrial contexts ergonomics is applied in preventive form through the use of digital systems that allow to reduce the time of verification and validation of ergonomic analyzes for the improvement in the phase of design of the equipment used during the production process stages. Modern technologies of Industry 4.0, in detail the virtualization of process and the use of virtual reality in industrial context create Virtual Ergonomics through which it is possible to offer valuable support in decision making as part of the design process of new production lines, or parts of it, reducing the need for physical prototypes and reducing time and costs of development. Through this method it is possible to evaluate the Human Factors (HF) introducing in virtual environments, already created for the prototypes of product and process, virtual dummies, digital biomechanical models to simulate the man from the kinematic and dynamic point of view.

“Simulation models can be quickly obtained, equally as quickly, viewed from every angle, and modified if necessary. Therefore, the positive impact on the improvement of a product is significant, so much so that, thanks to the biomechanics, designers, engineers and other specialists who are able to conduct a very thorough study of every aspect of the project in its abilities and potential. Biomechanics is one of the components of ergonomics and it is intimately related to the human factor of design; while the common denominator of the three disciplines can be found in technology” (Lupacchini, 2008).

The use of digital models allows a mathematical description of the operator’s movement during the operational phases, which parallel to the visualization techniques of virtual environments, provides the designer-ergonomist with otherwise unavailable data. Through data processing requirements are
verified to be complied with the manual workstation or the use of certain equipment present along the production line including visibility, accessibility and affordability, monitoring of ergonomic indexes, anthropometric analysis.

In order to validate the methodology a significant case study has been developed as part of the collaboration project between the University of Studies of Campania “Luigi Vanvitelli” and the company FCA Fiat Chrysler Automobiles, aimed at identifying new ways to optimize the assembly phases in a virtual environment in terms of overall integration of materials management, tasks and organization of the working and the layout, starting from the principles of "WorkPlace organization" and the theories of "Lean Production".

The project involves contributions from multiple disciplines with different skills in order to improve and implement the existing production process. Technological devices and tracking systems were used and allowed to reproduce a section of the production chain in the virtual environment and analyze a work task in the assembly stage.

Digitization and computerization give life to “intelligent factory”, smart, innovative, flexible and collaborative in which adaptation, efficiency and ergonomics were the main guidelines of this case study.

In detail it has been realized a pilot case for the application of virtual reality tools in the automotive production context. Through the use of the software Tecnomatix Process Simulate Siemens® has been reproduced a virtual scenario to be tested with the insertion of 3D models of the different equipments present in productive line and with the virtual manikin that, depending on the business requirements of the tasks, it can possible to manipulate and define very realistic behaviors.

Subsequently, the staged virtual scene has been explored in an “immersive” way through the use of motion tracking systems that have enabled the detection of a series of data in a fast and intuitive manner.

Through the implementation of "virtual ergonomics", the mannequin driven by the real operator "browse" quickly a virtual scene, is placed in a short time in the workstation and takes real posture during the execution of a work’s task.
It is possible also to verify a priori the reachability of a working point or for the use of equipment through the dynamic acquisition of ergonomic data by the different movements of the dummy. The virtual world is integrated into the real one, the external operator is synchronized with the virtual dummy and becomes part of the simulated world, transferring the avatar gestures and actions. Following the analysis of the interaction between man and system ergonomic data were detected on a supplement to standard methods of the operators ergonomic postures for the verification process. It was possible to verify the coherence of ergonomic indexes derived from standard methods with those obtained with the virtual approach.

Currently standard methods have long time and are made through a series of models that are generated and based on the direct observation of the operators during the course of their work. Through this new method for the detection of ergonomic data it will be possible to bring a substantial innovation in existing production environments in which denotes an increased attention to the welfare and safety of the operator. Through technological support, the improvement of workers' activities is a key aspect employing their full potential in performing the various processing steps.

4. Conclusions

New technologies, transversal and pervasive, represent an inexhaustible potential for innovation and problem solving related to the interaction between man-machine in complex industrial work environments and provide a contribution in terms of efficiency and productivity.

The digital transformation is one of the main challenges of the automotive industry whose efficiency increases with the support of ICT.

The fusion of the activities of design, industry and society generates the change in management and analysis of the production process through the implementation of advanced technologies for Industry 4.0.

Through the application of virtual reality in the new industry it has been possible to identify a new method for the ergonomic study of the workplace that would guarantee maximum results for the saving of used resources spent for the progress of the project providing an important competitive leverage tool for the productive industry. This method has provided the opportunity to obtain additional information and to proactively assess different variants to optimize the key factors of the given operation of manual work, visibility, accessibility, usability of equipment, comfort and risk factors, putting designer-ergonomist in the optimal conditions for the development of processing procedures and configurations of the production layout, supporting decision-making processes in the preventive phase of industrialization.

The method has allowed to define the starting point for the ergonomic design of tools and equipments of the production process on the basis of different user needs and to the identification and configuration of flexible solutions that adapt to the operator, the realized products and the automated elements, making the adaptable and innovative production processes.

The search will continue towards the analysis and verification of further implementations within the automotive production system through the use of virtual reality technology and the use of more advanced technological systems, also investigating the possibility of technology transfer from the automotive industry to other industrial contexts.
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