Design and implementation of an IoT-based haptic interface implemented by memetic algorithms to improve competitiveness in an Industry 4.0 model for the manufacturing sector

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Abstract. In the manufacturing industry, priority is given to quality models in the product, to make companies competitive, that is why it has been proposed to implement haptic interfaces capable of detecting anomalies in the operation of the electronic equipment of the companies. cars in the manufacturing sector, that is why through the implementation of Artificial Intelligence and Smart Manufacturing Models, we can get to build intelligent systems for the correct decision making in the auto parts sector in Mexico. Intelligent manufacturing is a subset that employs various techniques of artificial intelligence and emerging technologies coupled with computer control and high levels of adaptability to adapt to changes in product improvement. Intelligent manufacturing is focused on taking advantage of advanced information technologies and even intelligent analysis of data and manufacturing via the Internet of things to allow flexibility in physical processes to address a dynamic market in each society and from a global perspective. There is more training related to the implementation of artificial intelligence of the workforce for such flexibility of adaptability of products and use of emerging technology instead of specific tasks as is usual in traditional manufacturing, and which requires a larger group of individuals for it.

Keywords: Haptic Interface, Internet of Things, Smart Manufacturing. Memetic Algorithms and Smart City.

1 Introduction

1.1 Industry 4.0

The industrial revolution was not an isolated event of the nineteenth century, but it has evolved. Each of these revolutions is named it by number: Industry X.0, where X is the ordinal number of the revolution (Govindarajan, Trappey, & Trappey, 2018). During the fair in Hannover, Germany in 2011, the term *Industrie* 4.0 was coined, which is the fourth industrial revolution (Urquhart & Mcauley, 2017; Xu, Xu, & Li, 2018) and was later announced in official form in 2013 as a strategic initiative of Germany. Smart Manufacturing is a term coined in the United States of America by the Smart Manufacturing Leadership Coalition initiative in 2014, which coincides with the German term Industrie 4.0, which is the one used in Europe. The Boston Consulting Group (Rüßmann et al., 2015) has identified nine pillars of I4.0, which are (i) Big Data and Analytics, (ii) Autonomous Robots, (iii) Simulation, (iv) Vertical and Horizontal Integration of Systems, (v) Industrial Internet of Things (IoT), (vi) Cybersecurity, (vii) Cloud or Cloud, (viii) Additive Manufacturing including 3D printing, and (ix) Augmented Reality. These pillars can all be implemented in factories or take some depending on the case you want to improve.

1.2 Internet of Things

The Internet of Things (IoT) is a network of physical devices, vehicles, appliances, and other devices with embedded electronics, software, sensors, actuators, and connectivity that enable these objects to connect and exchange data. The applications of IoT were mainly observed in logistics and transport, health care, intelligent environments, and personal and social applications, proposing ubiquity as a concept that could materialize in advance (Angelini, Mugellini, Abou Khaled, & Couture, 2018 Atzori, Iera, & Morabito, 2010). In Industry 4.0, the IoT is a fundamental component and its penetration in the market is growing, with potential connected devices from 18 to 50 billion (Khan & Salah, 2018; Scott, 2018; Gartner, 2017). IoT is also a complex environment due to the number of components and layers that make it up. These layers contain many sensors, actors and processing devices with heterogeneous software and different manufacturers (Cheng, Chen, Tao, & Lin, 2018, Harbers et al., 2018). IoT connectivity has introduced more detailed layers between cloud and devices: Fog and Mist (Iorga et al., 2018; Roman, Lopez, & Mambo, 2018; Yannuzzi & Milito, 2014)

1.3 Memetic Algorithms to complete the hybrid operation of our proposed solution

Memetic algorithms (MAs) are population-based metaheuristics. This means that they maintain a set of candidate solutions for the problem considered. According to the jargon used, in estimation algorithms (EAs), each of these tentative solutions is called an individual. As anticipated previously, the nature of the MAs suggests that the agent term is nevertheless more appropriate. The basic reason is the fact that "individual" denotes a passive entity that is subject to evolutionary processes and rules, while the term "agent" implies the existence of an active behavior, directed to the resolution of a certain problem. Saying active behavior is reflected in different typical constituents of the algorithm, such as for example, local search techniques.

Figure 1 shows the general outline of an MA. As in the EAs, the population of agents it is subject to the processes of competition and mutual cooperation. The first is achieved through of the well-known selection procedures (line 6) and replacement (line 12): from the information that provides an ad hoc guide function determines the goodness of the agents in pop; then, a part of them is selected to move to the reproductive phase attending to such kindness. Subsequently, this information is used again to determine which agents will be eliminated from the population to make room for the new agents. In both cases - selection and replacement - any of the typical strategies of the EAs, e.g., tournament, ranking, elitism, among other heuristic operators. In terms of cooperation, this is achieved through reproduction. In this phase, create new agents from existing ones using a series of operators of reproduction. As shown in Figure 1, lines 7-11, can be considered an arbitrary number #op of such operators, which are applied sequentially to the population of segmented way, giving rise to several intermediate populations `auxpop [i]`.

```
Memetic Algorithm
Input: an instance I of a problem P.
Output: a sol solution.
// generate initial population
1: for j ← 1: popsize to do
2: be ind ← GenerateHeuristicSolution (I)
3: be pop [j] ← ImproveLocal (ind, I)
4: end
5: repeat // generational loop
// Selection
6: be breeders ← SelectDePoblaci'on (pop)
// Segmented playback
7: be auxpop [0] ← pop
8: for j ← 1: #op do
9: be auxpop [j] ← ApplyOperator (op [j], auxpop [j - 1],
I)
10: end
11: be newpop ← auxpop [#op]
// Replacement
12: be pop ← UpdateProb (pop, newpop)
// Check convergence
13: yes Convergence (pop) then
14: be pop ← RefrescarPoblaci'on (pop, I)
15: finsi
16: up CriteriaTermination (pop, I)
17: Return Better (pop, I)
```

Where `auxpop [0]` is initialized to `pop`, and `auxpop [#op]` is the final descent. In practice, the most typical situation is to simply use three operators: recombination, mutation, and local improvement. Approve on line 9 of the pseudo code that these operators receive not only the solutions on which they act, but also the instance I that you want to solve. With this it illustrates the fact that the operators of an MA are aware of the problem and base their functioning in the knowledge they incorporate about it (unlike the models more classic EA). One of the reproductive processes that best encapsulates the cooperation between agents (two, or more [16]) is recombination.

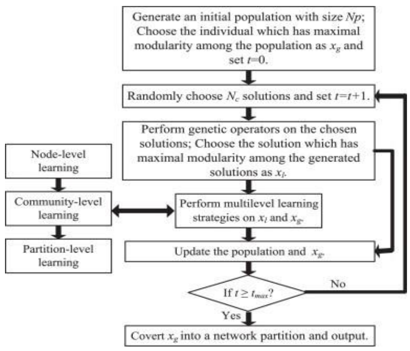

Fig. 1. General template of a memetic algorithm

This is achieved through the construction of new solutions to from the relevant information contained in the cooperating agents. By "relevant" is meant that the information elements considered are important when determining (in one sense or another) the quality of the solutions. This is undoubtedly an interesting notion' that moves away from the most classic synthetic manipulations, typical of simple EAs. We will be back to this later, in the next section. The other classic operator - the mutation - fulfills the role of "keeping the fire alive" by injecting new information in the population continuously (but at a low rate, since otherwise the algorithm would degrade to a pure random search). Of course, this interpretation is which comes from the 'area of genetic algorithms and does not necessarily coincide with the other researchers (those in the area of evolutionary programming without going any further). From in fact, it has sometimes been argued that recombination is not more than a macro-mutation, and certainly that may be the case in numerous applications of EAs in which this operator of recombination simply performs a random mix of information. However, no a similar assessment should be made in the field of MAs, since in these 'recombination' is typically done by using astute strategies, and therefore contribute essential way to the search. Finally, one of the most distinctive characteristics of MAs is the use of strategies of local search (LS). These (note that different LS strategies can be used) in different points of the algorithm) constitute one of the essential reasons why it is appropriate to use the term "agent" in this context: its operation is local, and sometimes even self-employed In this way, an MA can be viewed as a collection of agents who perform Autonomous exploration of the search space, sometimes cooperating through recombination, and competing for computational resources through the mechanisms of selection / replacement. The pseudo-code in Figure 1 shows a component that also deserves attention: The Refresh Population procedure (lines 13-15). This procedure is very important with a view to the use of computational resources: if in a certain moment of the execution all the agents have a similar state (that is, convergence has taken place), the progress of the search becomes very complex. This type of circumstance can be detected using measures such as the entropy of Shannon, setting a minimum threshold below which it is considered that the population has degenerated. Obviously, said threshold depends on the representation of the problem that is being used, and it must be decided therefore particular way in each case.

2 Proposed Solution

2.1 Haptic Interface

The haptic term is related or based on the sense of touch. The research firm Gartner defines haptic as the use of tactile interfaces to provide touch feedback or force as part of its user interface. Vafadar (2013) also defines haptics as the "feedback generation of touch and strength information." Haptics can be studied in three major areas: (i) Human Haptics, which is relative to the touch perceived by humans, (ii) Computational Haptics, which is the software for touching and feeling virtual objects, and (iii) Haptic Machines, which refers to the design and use of machinery that can increase or replace human touch. Haptic devices can be classified according to their interaction: (i) Take or grasp, (ii) carry, and (iii) touch (Angelini et al., 2018, Culbertson, Schorr, & Okamura, 2018, Halunen et al., 2017). On the other hand, the combination of VR and AR in three-dimensional scenarios with haptic feedback has also been carried out in other industries, such as the health industry, where virtual surgeries, rehabilitation systems, video games for training, etc. have been explored. including studying the brain-computer interfaces that receive haptic information among other stimuli (Albert et al., 2017. Wu et al., 2017), or the development called CLAW (Choi, Ofek, Benko, Sinclair, & Holz, 2018, Aijaz, Dohler, Hamid Aghvami, Friderikos, & Frodigh, 2017; Van Den Berg et al., 2017). Other challenge in haptics is transmit sensations through the network, called the "1 ms challenge of the Touch Internet", security and, make the device feel exactly like the original artifact (Tiwari, 2016).

2.2 The Human Role in Industry 4.0 and decision making

Within the manufacturing is also the role of the human and how it works and interacts with I4.0. It is important to underline the four cognitive functions of the human being within I4.0: (i) Perception and Consciousness, where infrastructure sensors and portable sensors (wearables) now take part that capture activities, behavior, context and attention (eg cameras, microphones), tactile gloves); (ii) Modeling and Understanding, which allows the interpretation and progress of the work flow, the identification of the level of experience of the operator and the interpretation of the context of the environment; (iii) Reasoning and Decision Making, to select the best auxiliary and assistance measures depending on progress in the work flow and experience level; (iv) execution of the activities, which now become autonomous acts in I4.0 with actuators of visual, auditory and haptic infrastructures, as well as portable visual, auditory and haptic actuators. The I4.0 seeks to automate the manufacturing process as much as possible and move decision-making and monitoring of the human to the machines, but the human factor in the manufacturing processes is still necessary in manufacturing and therefore considers the process of decision making that the individual will make based on the modeling and recognition of the workflow and its tasks. Decision making is necessary for complex systems and processes that exist in the manufacturing industry and that have not been automated or cannot be automated. (Chong, Ramakrishna, & Singh, 2018; Haslgrübler, Fritz, Gollan, & Ferscha, 2017; Whitmore, Agarwal, & Da Xu, 2015).

3 Resolution problem

The technological development reported in the literature shows the progress in IoT, I4.0 and haptic interfaces. However, these are independent studies, which do not integrate their capabilities to increase their efficiency and benefit. Also, there are still important challenges such as evaluation, latency and processing of the transmission of information. There are proposals for industrial IoT architectures, but they do not interact with the human directly or do so with a computer interface, minimizing or not using haptics. Finally, there are already works developed to take advantage of AR for the process of maintenance of products and machinery, which provide detailed information to identify parts and review the work done, as in a welding process of a car (Halim, 2018; Ni, Yew, Ong, & Nee, 2017; Yelamarthi, Aman, & Abdelgawad, 2017).

3.1 General purpose

Develop an integrative model of IoT and a haptic interface to increase the capacity of decision making in manufacturing processes in Industry 4.0. Figure 2 describes the different actors in the cognitive process within I4.0 that will be used to jointly improve the competitiveness of the manufacturing industry through efficient decision making and supported by IoT and haptic interfaces.

3.2 Specific objectives

- Structure and detail the mental maps of Industry 4.0 or Smart Manufacturing to have a complete model.
- Relate the key indicators of Industry 4.0 and generate the industrial trends that are based on IoT to be visualized in haptic interface.
- Create a data repository to perform the analysis required for decision making.
- Build the intelligent tool based on IoT and haptic interfaces that improve decision making and improve competitiveness.
- Define the appropriate plans and tests to corroborate the proposed solution
- Determine the feasibility and feasibility of the project

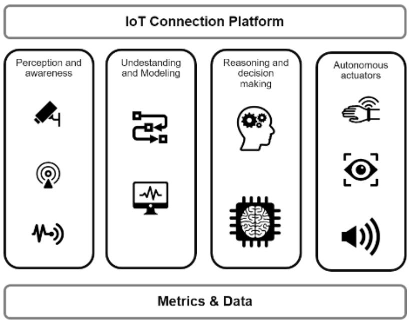

Fig. 2. Cognitive process within I4.0

3.3 Justification

Industry 4.0 is supported by technology that is now viable thanks to the power of computer processing and a scientific area that is developing a lot that is data science - the basis of machine learning. IoT produces a very large amount of data resulting from physically deployed sensors. However, when introducing haptic interfaces to Industry 4.0 and this is combined to help make decisions effectively and efficiently, then this research generates a very important contribution to technology that is not only theoretical knowledge but can be applied and help to obtain benefit to the manufacturing industry or any other. Also, the impact of Industry 4.0 on the economic level for countries is important, as economies are estimating growth between € 90 to € 150 billion in five years. (Rüßmann et al., 2015, IDC 2018). Therefore, IoT research with haptic interface to improve the competitiveness of the manufacturing industry serves the national development project and addresses issues that are necessary to generate opportunities for young graduates to have a field of action to work on what they studied.

3.4 Scope and limitations

The model will allow analyzing and forecasting the effectiveness of decision making for a task within a manufacturing process by adding IoT and haptics. It is expected that this defined model is feasible and feasible by calculating the effectiveness index offered by the automatic learning analysis and forecasting techniques. The practice indicates that a model with an effectiveness index higher than 80% is feasible and feasible. Also, this model limited to a task can serve as a base for the manufacturing industry to replicate it and implement it in other tasks of different manufacturing processes, not limiting its application to this industry exclusively, but it is expected that it can be used for other areas, such as maintenance for example, and in other industries such as transportation, health care, energy, to name a few.

4 Implementation solution

Taking as reference Figure 3, the development of the project is proposed as follows:

A. Structure Industry 4.0 modeling: 1. Detail each of the mental maps of the Industry 4.0 model. 2. Create an index file that allows to relate each of the Industry 4.0 indicators that have been registered. (Technical support with Excel and SQL Server Express).

B. Produce the first indicators from the modeling and using the haptic interface: 3. Generate industrial trends based on IoT to be visualized through the use of a characterized Háptic Interface for the Manufacturing Industry4. Store the information in a database repository in order to have enough information to properly apply the IoT in the Haptic Interface to improve decision making and industrial competitiveness (SQL Server Express Technical Support).

C. Build the intelligent tool based on IoT to improve competitiveness: 5. Create specific trends to the problem to be solved, this will allow building an adequate tool for decision making, considering the changes in the Manufacturing Industry and determining both a tactical plan and a strategic plan applicable to the conditions of the problem. 6. Build an Industry 4.0 model according to the existing problems and improve the performance of the Haptic Interface for the correct Decision Making.

D. Verify the model with manufacturing data.

E. Structure the consultation and visualization windows of the tool for decision making: 7. Apply the results to the previously constructed trend maps in order that the resolution of the problem can interact with the Industry 4.0 model, and determine if it is feasible and feasible to make paradigmatic changes with respect to the Decision Making in the Industry of the Manufacturing using haptic and IoT interfaces. 8. Carry out a corroboration of the solution implemented from the model developed and applying multicriteria analysis techniques in order to support the project to be carried out through a correct Industrial Decision Making. (Weka technical support, Tableau, SQL Server Express, data mining).

F. Plans and Tests of the Intelligent System for decision making: 9. Determine the effectiveness index of the project and assess its validation with other projects based on Smart Manufacturing models. (In the Artificial Intelligence area, a project with an effectiveness index higher than 80% is feasible and feasible).

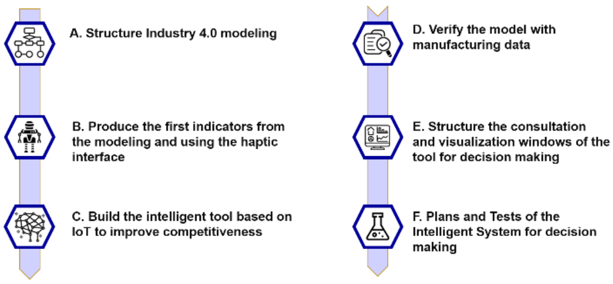

Fig. 3. Proposed methodology for the implementation of the project Design and Implementation of an IoT-based Haptic Interface to improve the competitiveness of an Industry 4.0 Model in the Manufacturing Sector

5 Conclusions and future research

Using two different perspectives for solving a problem related with Industry 4.0 we were able to verify its model with different techniques, such a Metaheuristic method as Memetic Algorithms, additionally we could discover that the use of data mining to determine previous successful models of aid distribution would be very useful for posterior evaluation of the results of the portfolio financed. With this at the future we could verify if the target population would agree on how to access this type of social support.

Also, as future research, social networks could be considered in the evaluation of social experiences. Data mining and a specific Topsis Model based on agents can improve the understanding of change for the better substantial paradigm that ranks communities' agents appropriately in terms of their relationship attribute approach. Goal programming and Ant Colony Optimization provide a powerful alternative to optimization problems. For this reason, is that it provides a comprehensive overview of the cultural phenomenon. This technology leads to the possibility of the generation of experimental knowledge, created by the community of agents for a given application domain. For the most part, the extent of this knowledge is cognitively community of agents that is a topic for future work, as is proposed in Figure 4.

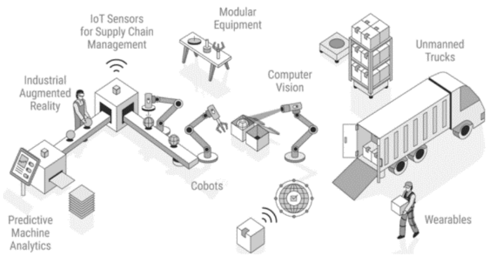

Fig. 4. Our proposal model of Industry 4.0 to a model of Smart Manufacturing.

The specification of each artificial intelligent environment would be a contradiction to traditional systems that don't consider all the factors related with the domain, that's why at the end, the last one generates unfair and inefficient distribution of resources.

A new artificial intelligence could oversee these systems, but it is still far in the horizon, in the same way that we still lack methods to understand the original and peculiar aspects of each society. In future work will attempt to analyze the discussion of priority values for each different necessity of people and what could be the reason for being prioritized over other necessities.

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