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Automated Tracking of Workers in Work Environments through the Implementation of RFID and Zigbee Technologies

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Abstract

This article proposes a technological tool oriented to perform the automated tracking of the employees in work environments; it is sought by implementing RFID and Zigbee technology to obtain information in real time associated with the processes developed in the production lines. This so the observant users or system administrators have a robust information support that facilitates the pertinent traceability, to make decisions attempting to improve and optimize the internal processes of any productive sector. The technologies used in the proposed monitoring stations allow great scalability and are oriented to be linked and adapted to the specific needs of different processes and work environments.

Keywords: Production, RFID, Zigbee, traceability, work environments, Business Analytics.

INTRODUCTION

The objective of studying a production process for (Chase, Aquilano, & Jacobs, 2005) is to look for delays, movements, processes and other elements that involve the use of time, to then be able to simplify operations. With these ideas in mind, in order to have good processes, it is necessary to constantly monitor and measure the work done in the processes [1-5]. However, this scenario of constant measurement is not very common in the industry since it requires having available personnel to perform these tasks, and in addition it generates in the measured operator a state of abnormality, since it tries to work with a higher performance than usual.

As expressed (García Criollo, 2005), within the factors that conform the industrial costs, workforce (direct and indirect) is quite important; besides, it is also needed to know if the effort of the workers is being used efficiently, if the operations are carried out in the correct time and if the administration relies on good bases to program the production and generate the incentive systems. The study of this paper aims to improve the conditions of the worker, while reducing the costs incurred by the employer, meaning the generation of a mutual benefit between the parties [4].

According to NTC ISO-9000:2015, traceability is the "ability to follow the historical, the application or the location of an object", this concept is applicable not only to finished products but also to any element that may be considered within the supply chain such as materials, workforce, machinery, etc [6]. This capacity becomes a competitive advantage for organizations and allows a better response to market challenges [7]. It is only possible to develop this competitive advantage if there is an information system that is sufficiently agile, robust and reliable, which allows real-time analysis to generate changes in favor of the expected results [7-10].

The automation in the industry has solved a lot of problems and has managed to optimize the processes since it has allowed having permanent information, which facilitates the identification and handling of faults or particular adverse events that can occur in the framework of the operation randomness [6]. The automated instruments of measurement in the processes allow to obtain data closer to the reality, since they eliminates the human error in the obtaining of data, besides that it contemplates all the events that take place in a space of time with the real performance of the operators, facilitating the analysis of situations; therefore, these electronic elements become an opportunity to enhance the benefits that the work measurement brings to the industry [10].

More and more entrepreneurs find in the "Business Analytics" an opportunity to improve the performance of organizations, taking advantage of the information collected through technological tools, with the purpose of using these data in the development of strategies focused on improving the supply chain management [6-10].

METHODOLOGY

The proposed methodology is composed of three moments: the definition of traditional methods of measuring work, the determination of advantages in the work measurement with the use of the technological tool and the approach of the technology selected for the proposed tool.

Traditional methods work measuring

In the productive processes in general, work is measured mainly to standardize times and have information that allows analyzing other factors such as performance, productive capacities, among others. Usually, this measurement is made by people in charge of observing in detail the work of interest, making the measurements with a stopwatch and recording times in tables for further analysis and interpretation [2,3][14]. After this stage of data collection, it was proceeded to analyze the results and determine the standard times [1].

Since the measure of an observer do not add value to the final product, these measurements are made in certain periods of time and with only some of the workers, so later with the results obtained inferences about the process in general can me made [2].

It is the analyst's decision to select the worker or workers on which the study is going to be applied, for which some characteristics of the work to be studied are taken into account. On the other hand, to determine the size of the sample or number of measurements to be made, there are two main methods: the first is the use of tables proposed by some authors that indicate a sample size taking into account some aspects such as the cycle time of the tasks to be measured; the second is the statistical method, which takes into account other elements such as an acceptable error in the study, for this case, the following equation is used:

$$n = \frac{Z^2 pq}{d^2}$$

Where:

- n = Sample size
- Z = Level of confidence
- p = Expected proportion
- q = Failure rate (1-p)
- d = precision (acceptable error)

Since the statistical method can indicate samples that are too large, the tools of the first method are usually used, however, this can generate a higher percentage of error in the results than is desired.

After the data collection, the next step is the standardization of times, for which the following equation is applied:

$$TE = (TD * ID) * (1 + T)$$

Where:

- TE = Standard time
- TD = Average performance time per observed unit.
- ID = Performance index. Estimated by the observer, to take into account the overexertion performed by the worker to obtain better results when measured.
- T = Tolerances. Time allocated by the observer, necessary for unavoidable delays inherent to the process.

Additionally, it is possible to do another type of analysis with this information, such as the calculation of the learning curves, for which the equation related below is used:

$$Y_x = kx^n$$

Where:

- Yx = Expected time for repetition x
- k = Time of the first repetition
- n = log b / log 2
- b "learning rate" = second repetition time / first repetition time

Advantages in the work measurement using the technological tool

The use of the technological tool proposed in this article, ostensibly facilitates the work measurement in any productive process, since it allows obtaining a greater amount of data in real time, from different workers simultaneously, in addition to decreasing the calculation error in the standards, inasmuch as a wider panorama of the process is considered, in terms of time and workers [12]; Likewise, the human error in the capture of information is eliminated and the abnormality in the performance of the workers is minimized in some way, as they do not feel measured by an observer directly [2][15].

By having a considerable amount of digitized information, the tool allows in addition to the times standardization, another type of analysis such as the ratio of distances traveled for the employees measured, times in the work stations, workers performance, frequency of displacements and relationships between stations, bottlenecks, among others. These analyzes support the processes management and become a reliable source to sustain the decision making of all kinds, such as the creation and monitoring of production plans, determination of critical routes and physical distributions of the plant, generation of performance indices, etc [10-11].

Selected technology for the proposed tool

The development of the proposal is based on an architecture composed of two fully functional technologies that provide a practical solution to the need to effectively monitor multiple points in a production line; these are: RFID Technology and Zigbee Technology in Mesh topology as support of communications infrastructure. In the first instance, reference is made to the implementation of RFID technology, see Fig. 1, which seeks to take advantage of its non-contact identification capacity at high speed in non-line of sight (NLOS); for this functional block, two fundamental components must be taken into account: the tags and the readers, keeping in mind that the most important factor when selecting these elements is the operating frequency, since this factor is directly related to the distance of communication between the mentioned elements.

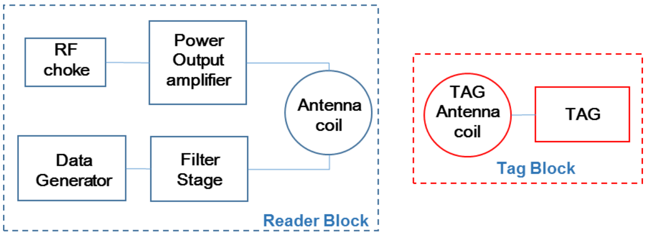


Figure 1: RFID System basic architecture.

Regarding the Zigbee technology as a communications infrastructure, a MESH topology is used, see Fig. 2; this configuration allows the implementation of this monitoring tool in practically any production environment, due to the fact that thanks to its operational characteristics it can count on up to 65536 network nodes to expand the coverage of a monitoring sensors network.

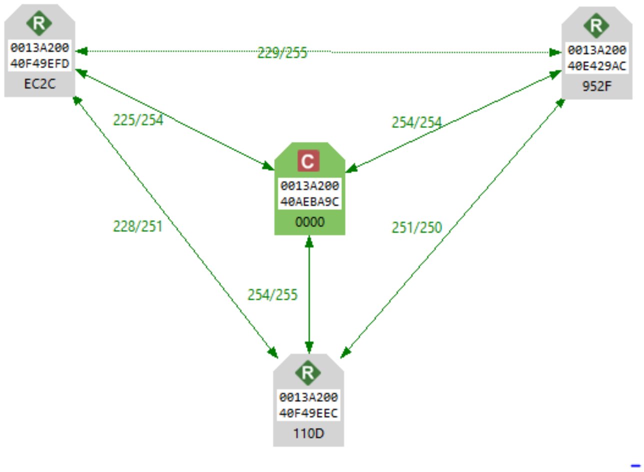


Figure 2: Zigbee wireless network in Mesh topology.

IMPLEMENTATION

Basically the proposed architecture is based on the implementation of a 32-bit microcontroller embedded system, which is responsible for processing and transmitting the reading information of the tags, together with a time record generated by adapting an RTC (Real Time Clock) arranged in each monitoring station, see Fig. 3. Each electronic control unit is provided with a Zigbee communication module configured in Router mode, which points to a hub type card directly connected to a PC. The communication characteristics established for all system components are defined by asynchronous serial communication of 115200, 8, N, 1.

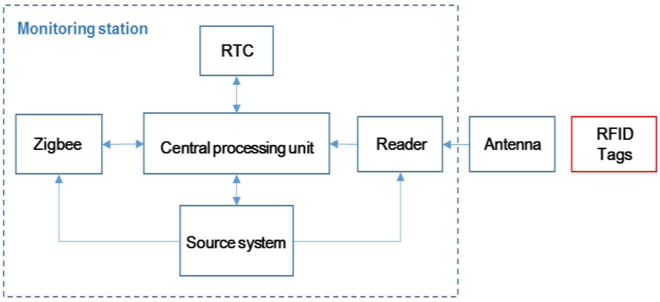


Figure 3: Block diagram of the proposed system.

The verification of the tool was started in a simulated work environment, conformed by five work stations through which the two employees (object of the measurement) had to rotate, as shown in Fig. 4. For this specific case, the tags were located on the workers' ID cards, so each worker involved in the production line can be punctually monitored.

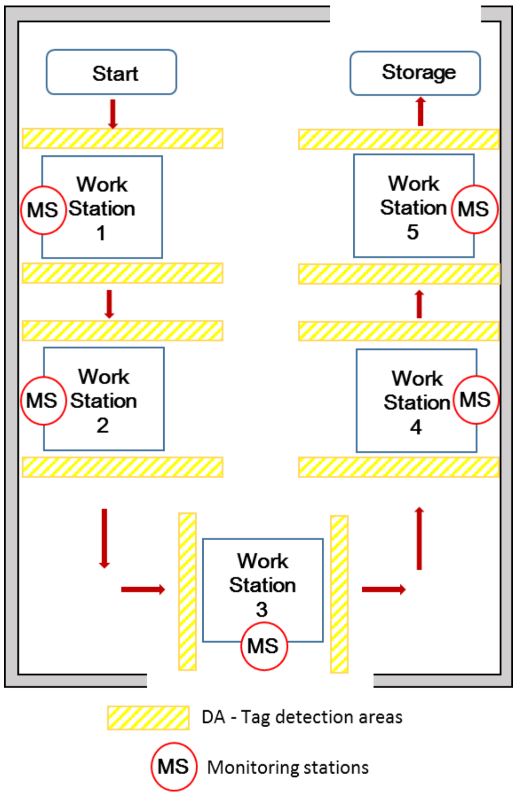
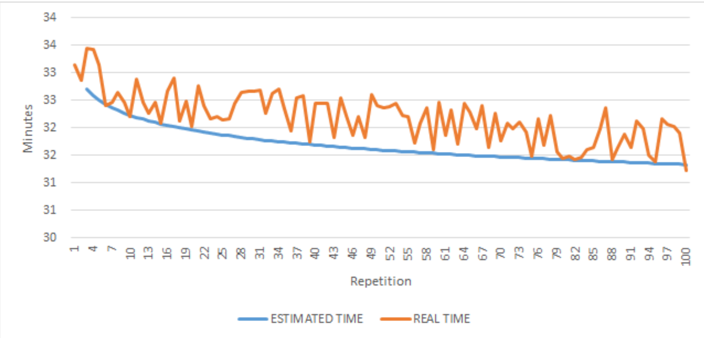


Figure 4: Test environment and location of monitoring stations.

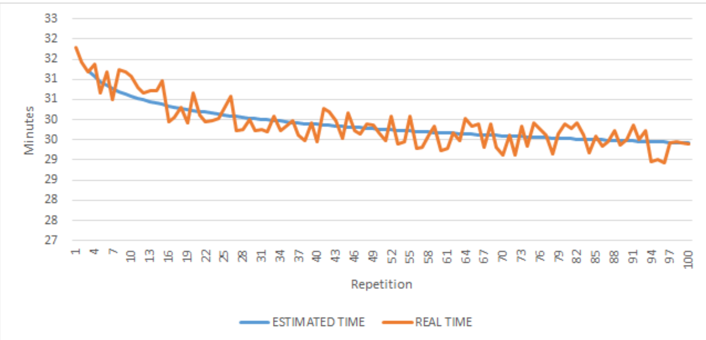
The raw materials and the materials necessary for the pieces assembly are arranged in each of the stations, for which the workers must execute the tasks of sub assembly in each station and move along with the piece to the next station, until having the finished piece at the end of the process.

The sensors are arranged in such a way that they provide information of the workers movement between stations, as well as the time it takes for each of them to perform the corresponding tasks; this is clearly evidenced in the distribution of the monitoring stations (MS) and the tag detection areas marked as (DA), see Fig. 4.

All the information generated is transmitted wirelessly through the network conformed by the Zigbee modules; this data is stored and processed by the software developed in the central server. With the data obtained by the tool, the learning curve for each of the workers in the elaboration of complete pieces was estimated, likewise, given the ease of obtaining the information, it was possible to compare this estimate with the real times in the first hundred repetitions, see Fig. 5, which is quite useful in real work environments for the measurement of workers' performance [13].



a)



b)

Figure 5: Real assembly time ratio vs. Expected, according to the learning curve calculated a) worker 1 b) worker 2.

The standard times were also found for each of the work stations of the exercise, taking into account the measurements made by the system to the two workers during forty hours.

The tool developed is applicable and functional for various work environments even when they differ from one another in terms of working conditions, since the technology and interface used are adaptable to the needs of the process analysts. The coverage for each monitoring station regarding the connection with wireless transmission of information is 30 meters per module, since the Mesh topology configuration provides a very high scalability concept, allowing it to be applied in any production environment. Additionally, the reliability of the information obtained is quite high and makes it easier to have a broader and clearer picture of the operation processes in real time, in order to determine the pertinent action plans that lead to the achievement of established performance indicators.

The traditional process of work measuring presents several obstacles to its application and has an implementation cost directly proportional to the number of measurements made. The results obtained are sensitive to the skill, experience and the method used by the observer when obtaining the results, which means, the higher the desired level of reliability, the higher the cost of the study required. With the proposed tool, on the contrary, the study of the work is simplified and it is possible to have a better level of reliability for the results without implying a higher cost, since it is not necessary to limit neither the time for data collection nor the number of measured employees.

In addition to the standardization of time, the proposed tool allows some complementary analysis in real time of the information obtained, tending to facilitate strategic decision-making by those in charge of the processes, such as the monitoring of performance indicators and productive programs, modification of the physical distribution of workspaces, etcetera. The central server was installed on a development interface in JAVA, this platform runs on a 32-bit Windows 7 operating system, with an Intel Core I5-4200U CPU 2.3 GHz processor and 6 Gbytes RAM.

CONCLUSIONS

The application of automation technologies in work measurement processes, allows a saving in workforce costs for this concept, since the sensors and applied technology are responsible for collecting reliable data and present them in a suitable way for further analysis. The use of tools such as the proposed one allows obtaining more precise data by eliminating the human error present in the traditional measurement; In addition, its application minimizes the possibility that the evaluated personnel work with a level of performance far from the real one, due to the psychological pressure generated by the measurement made by an observer.

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