Management of Production Flow Using RTLS

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ABSTRACT

The article focuses on practical use of Real Time Locating System (RTLS) in management of production flow. As the reference project, a project from the field of automotive was chosen as it is one of the most progressive and, at the same time, the most important industrial sectors of the present. The first part of the article describes the implementation and use of RTLS in the environment of final assembly of cars, and also directly usable outputs of this system. In the next part of the article, other ways of use of the system are outlined, based on data processing.

Keywords: RFID, RTLS, UWB, Industry 4.0, Automotive

1. INTRODUCTION

Recently, the RTLS systems have become one of the most perspective fields in the area of industrial automation. Even though all the necessary technologies are available, their greater expansion in industry is hampered by their relatively high cost, and above all the lack of workers and companies who have real and long-term experience with the implementation and use of such a system. Very important factor for expanding RTLS systems in industry is an emerging Industry 4.0 trend. One of the cornerstones of Industry 4.0 is the ability to create a so-called digital twin. The quality of the created digital twin and the outputs directly depend on the quantity and especially the quality of the input data.

As the article goes on to describe, even without a highly sophisticated model such as a digital twin, very good results can be achieved in the field of operations management and early prediction of some crisis situations. A typical example of this is the bottleneck detection in the production flow and the subsequent early prediction of possible causes of the process delay.

2. SYSTEM SPECIFICATION

The article is based on the information obtained by the authors during the development of the system, which took place between 2011 and 2016. Since 2014, the system is in full operation in several assembly halls in the EU. In the first phase, the task was to develop and implement a system that could detect the position of car bodies on the assembly line, and then, without any break, detect the positions of individual cars coming from this production line, during all the processes that took place after the assembly. These processes include for example functional testing, individual vehicle components adjustment and initial driving tests. The whole process is then completed by the expedition of the finished car. This is where the tracking process ends.

In addition to the electronic and software part, the development included also the solution of mechanical parts of all the components of the system, as well as their adaptation to given production systems and processes.

3. BASIC REQUIREMENTS

The essential requirement was to create a system allowing indoor and outdoor real-time localization. As a primary source of information about the position of individual objects, the technology of active RFID (A-RFID) is used.

The whole production process was divided into two sections:

- assembly line - start of the assembly process where the body moves in a fixed order and is physically connected to the assembly line

- post-production operations - here almost finished cars move outside the assembly line

In the first section, great demands are put on the accuracy of the position detection, but the monitored bodies are firmly connected to the assembly line and the order of individual bodies is known and they do not change in the assembly process. Most of the time, the speed of the bodies is constant, or constant in discrete sections of assembly line, and precisely limited by the technical parameters of the assembly line. The required accuracy of the position detection is lower than ± 0.25 m – with detection success of 99.66% with this accuracy. Such a high reliability requirement is caused by the intention to use the information about the body position for real-time management of production technologies. Due to the nature of this application, the position detection requirement was degraded to 1-D detection, because motion outside the direction of the line movement is not common in this phase.

However, achieving the desired parameters only with the use of A-RFID would not be guaranteed. The system therefore had to be supplemented with other sources of information, such as:

- MEMS accelerometers for TAG
- IR position detection of TAG
- magnetic detection of attachment to the body

The second part of the production process is realized outside the assembly line and cars can use their own wheels and their own drive. This implies a requirement for at least 2-D detecting. As opposed to the assembly line, there is no need for such high accuracy of localization, because the primary requirement is to know the position of the cars in relation to the map base, as well as the relative position of the cars. These requirements being considered, the required precision was set to ± 1.2 m. A significant drawback is that the car can go up to 40 km/h in some areas and it is difficult to predict its direction or speed.

The area of space intended for RTLS coverage is between 50,000 and 100,000 m^2. The number of objects located in this area has been limited to 5,000. In real operation, the number of objects is not higher than 3,000 (situation in 2017).

4. Technologies Used

In the first stage of development, a system based on the RSSI measurement method was tested. In the early stages, there wasn't any intention to use this method as a primary source of information for the position detecting system, but with respect to its use in other applications (e.g. PTS for deep mines), it was decided to use this technology as an additional source of information.

Due to the demanded accuracy and reliability of localization, only technologies based on the principle of measuring the time of flight of the radio signal. In the first phase, a technology by Nanotron, operating in the 2400 MHz ISM band, was chosen. This choice was based on the fact that almost no other technology was commercially available in the EU in 2010/2011. Another important factor was that this technology could work in accordance with current EU legislation. This technology has proven to be a good practice and many systems based on this technology are still in operation.

In many ways, however, it is currently insufficient. Theoretical accuracy of this technology is better than ± 1 m. In real environment, especially in complex indoor areas, the output positions suffer from considerable noise and it is therefore necessary to introduce complicated post processing to achieve the required accuracy in combination with the required reliability. Such post processing has to involve filters with long time window, which results in longer reaction time of the system. Another significant drawback is the gradual occupation of the 2400 MHz band by a number of industrial systems using wireless communications, and we can assume that this trend will continue in the future.

UWB

The current version of the system uses UWB technology by Decawave (specifically DW1000 chipset). With this chip, it is possible to operate in the frequency range of 3 GHz - 6 GHz with a bandwidth of up to 800 MHz. Such a high bandwidth mainly affects the elimination of interference and reception of signals that travel from the transmitter to the receiver indirectly (i.e. a way that contains reflections). This increases the resolution and accuracy of the position detection. Unlike the systems operating in the ISM bands, the use of fixed UWB transmitters in the open air is not allowed by the EU. This limitation requires a solution of mutual synchronization of fixed parts of the system (anchors) by means of wire or optical infrastructure.

5. System Topology, Infrastructure

The position detection system uses the TDOA (Time Difference Of Arrival) method. This requires all fixed parts of the system (anchors) to maintain synchronized real-time clock (RTC) with very high accuracy, in the order of 10-10, relative to the reference clock source. Time synchronization is developed along with communication and power lines. In terms of data collection, the system is divided into individual circuits, up to 16 components (anchors), which are connected in the circuit by their own cabling. This cabling ensures data communication, clock synchronization and power supply. In terms of data communication, individual circuits are connected to the central component (server) via Ethernet. Regarding the synchronization of real-time clocks, individual circuits can form a tree with respect to the central component (central clock signal source) – i.e., individual circuits can also chain together.

This complicated time synchronization system ensures very accurate synchronization of all components of the system. Each component (anchor, data concentrator) contains an exact temperature-stabilized oscillator (TCXO) that is joined to its parent by a PLL. No component is therefore directly dependent on the presence of the sync signal. In case of a system component failure, the system is divided on individual domains that maintain their own internal synchronization of their components. In case of a single component failure, the whole system splits into two separate domains that can be software-synchronized again in post processing (e.g. by using TAG packets that are simultaneously received by the anchors from both domains).

6. Position Calculation

Position calculation is divided into two levels:

- Local
- Global

Local calculations are performed on dedicated industrial computers, always within smaller areas, and the results of the calculations are used, for example, for real-time control of some production processes. Because the position calculations are limited to the area (number of anchors), as well as the number of localized TAGs, these calculations can be performed very quickly with minimal latency.

Global position calculation involves all fixed (anchors) and moving (TAG) components of the system, and therefore requires high computing power. In some situations, the latency of the system may be in the order of 10 s. Outputs from this calculation are used for visualization and other tasks that do not require guaranteed minimum latency, such as visualization, production information system, quality management system, etc.

7. Visualization

Visualization of the assembly hall is designed to provide a clear view of the whole operation (Figure 1). Individual cars are represented by rectangles whose color in the basic view corresponds to the color of the car. This information is obtained when connecting a TAG and a specific body. The orientation of the rectangle in the visualization can be vertical or horizontal according to the assumed position of the car. Orientation is determined based on the latest known motion and a predefined mask in visualization. This greatly improves the intuitiveness of the entire visualization.

The visualization itself provides a powerful tool for efficient operations management, especially during the exchange of shifts.

The view is then divided into several zones, and the system automatically evaluates the number of cars in each zone. The maximum number of cars in the zone is one of the parameters that can activate an alarm to alert you to a non-standard situation. However, the display of the location and movement of individual cars is only useful as a preview for a human, or for tracking a particular car or monitoring a very small area. With simultaneous display of hundreds of cars and a total area of more than 50,000 m^2, one is not able to capture or assess hazardous situations.

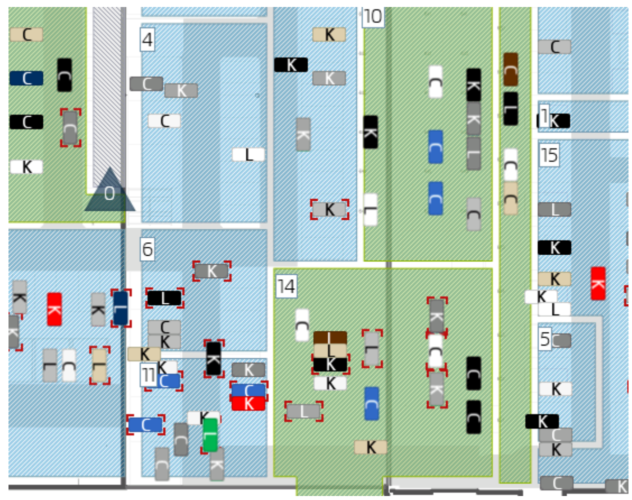

Figure 1: *General view*

Detection and Display of Crisis Situations

Typical example of a crisis situation is reducing the capacity of some of the transit zones or, conversely, exceeding the capacity of the zone. A zone represents a workplace, where specific kind of production or service operation is performed. In the first case, for example, there is a situation where a failure occurs on a part of the technology in a given zone, or a local loss of workforce occurs, which results in reduced throughput capacity of the zone. In the second case, the throughput capacity of a given zone (workplace) is exceeded due to increased number of incoming cars. This situation can be effectively detected using a view that takes into account the time that each car spends in a given zone (Figure 2). If the times are well-defined, it is possible to distinguish the areas where normal operation occurs and zones where the throughput is reduced. The color attribution of the remaining time (green OK, orange warnings, red ERR) then makes it very easy to determine if there is a zone in the monitored area, whose throughput is already saturated.

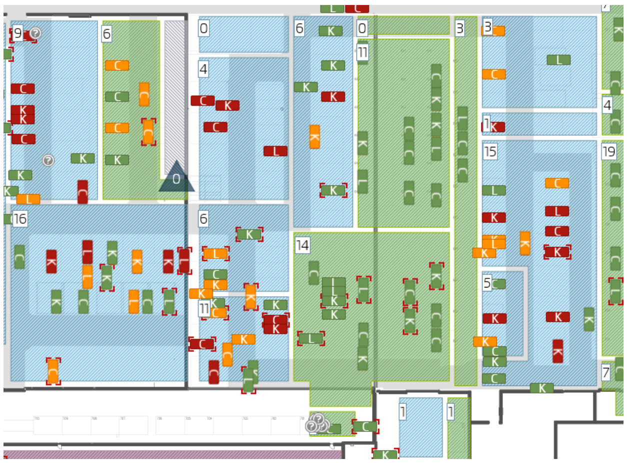

Figure 2: *View by stall time*

In case of a critical situation, the RTLS system provides the possibility to detect such a state with minimal time lag, and the management has considerably more space for dealing with such a situation.

Another of the possible views is the view by the destination zone (Figure 3). If a destination zone is assigned to one of the external systems, the color attribution can be used to track how many cars will target specific zones. Such a view allows a skilled worker to estimate the future occupancy of the individual zones according to the color attribution. In practice, however, such a view is more likely to be used for logistics purposes.

Figure 3: *View by destination*

Crisis Situations Prediction

The described system in its present form enables swift management of the production flow based on current information, which means that it allows decision making only on the basis of knowledge of the current state of the system. The disadvantage is that although the system makes it possible to significantly speed up the response to the problem (and thus reduce its consequences), it does not allow for automatic prediction of these crisis situations and hence no elimination of such situations. However, the system provides enough information about current position and direction, so it is theoretically possible to predict the occurrence of crisis situations based on knowledge of models of the entire production process. Based on real-time data, several simulations have been performed that have led to the prediction of the critical state of an area with an accuracy of up to 85%. These simulations were performed on a sample of historical data before the occurrence of such events in order to verify the results of the simulation by comparing with reality.

8. Conclusion

The described system was gradually installed in three production units in the final assembly of cars in 2014, 2016 and 2017. At present, the production area is approximately 300,000 square meters and during the time of its use, over 2,500,000 cars were monitored. Such extensive deployment has enabled reliable verification of all aspects and evaluation of the properties.

Speaking of the technical aspects, the required parameters were met. With UWB technology, it is possible to achieve a location accuracy within buildings better than $\pm$ 1 m, with a refresh rate of about 1 s. Reliability in normal environments is then better than 95% and may include considerably higher coverage if some additional sensors are used.

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