Monitoring of manufacturing processes in the automotive industry using indoor location system

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Abstract. This paper presents a method for locating the operators, equipment and parts using radio communications systems. Specifically there will be radio transceiver arranged in a network of active and passive radio receivers placed on personnel, equipment or parts. Based on a radio triangulation method, it is determined the location of the all resources and parts involved in manufacturing process. The transceivers communicate with each other via "routers" - also components of the network. Such a structure may extend over large distances even in indoor spaces where there are obstacles (walls between rooms). The location is done by determining the power of transmission signal for at least three end points. The receiver position is then transmitted over the network through routers, to a central server where all positions of the resources are centralized. Our solution is a non-invasive and low cost method for determining resource position in the factory. The system can be used for both resource planning production for current process more efficient and for further analysis of the movement of resources during previous processes with possible adjustments to the workspace and re-planning of resources for future processes.

1. Introduction

Indoor positioning systems have become very used lately. These systems have been successfully used in many applications such as asset tracking and inventory management [1]. Research efforts have been performed in the idea of increasing the precision of the localization [2]. Thus these systems have become increasingly used to manage different institutions, in particular for monitoring and supervision of staff but access to certain locations as alternatives to traditional security systems based on biometric identification methods [3]. Others systems use different techniques for remote monitoring in automotive [4].

On the other hand, they have done research in the management of industrial production processes in order to increase production efficiency by monitoring techniques to staff and other resources involved. Precise monitoring of the production process enables dynamic re-planning stages, an analysis of how it is possible to intervene in the process, applying different approaches to improve results [5]. Thus, optimal configurations can be determined for human and material resources in production processes to improve working conditions and wellbeing of staff and to increase production performance [6].

There are many methods that can improve the quality of manufacturing processes. These include human resources and equipment planning methods for optimal use. However, there are many cases

where problems arise in the implementation of these methods because of the impossibility of exact location of the resources in the enterprise. This is the case particularly in the auto industry, where production halls are large and personnel should operate on relatively large sectors.

They have done research in monitoring resources in automotive industry such as: stress monitoring of workers during a production process by analysing their thermal map [7] or use virtual reality and augmented reality for preview of possible details of the finished product [8]. Studies include complex methods of analysis of video and data resulting from the production process, conducting surveys or interviews, modelling and simulations of human activities [9].

Our solution involves using radio network for data transmission (operator and parts IDs, activities in production lines) in order to centralize them and stored to a server to be in real time or subsequently analysed by various compartments connected in local network factory. The radio network is an ad hoc network in sense that each component of the network (transceiver) can initiate a session to send data to central radio receiver. Each transceiver can have the function of "end-point" in the network if it collects and transmits data from different equipment or can have the function of "router" if it only takes the data packets from end-points and send to central radio receiver (or others routers).

At the same time, the radio network is used for indoor location of the end-points. Each endpoint collects its own data or sends a signal that reaches the passive receiver placed to the operators, equipment or parts (as a RFID tag). The signal provide power supply for passive signal receiver, after that the transceiver taking the receiver's code (unique for each resource or part) and by measuring the power of the signals transmitted from the other end point determines the position of the receiver in the network. The system was implemented experimentally in a production process (welding) of chassis and analysed its positive impact.

2. System structure

The figure 1 illustrates a block diagram of the system.

The system is based on radio identification (RFID) using active and passive radio transceivers.
All of these are disposed in a radio network.

As can be seen in the figure, transceivers are installed on the following key components of an industrial manufacturing process:

- Parts and raw materials;
- Operators;
- Forklifts or others logistics equipment from factory;
- Manufacturing lines;
- Control workstations.

Transceivers can be placed on boxes of materials after the entry into warehouse. Thus it can monitor the circuit that raw materials have in the factory since taking over the warehouse until it reaches the production line. A piece resulting from the production process may have also placed a transceiver and can be monitored the circuit from the production line to the warehouse and even to load the means of transport for delivery.

Along with components monitoring can be performed and staff monitoring. Both for personnel monitoring and parts/raw materials monitoring are used passive transceivers – RFID tags.

Active transceivers are placed on forklifts. Thus, an active transceiver placed on a forklift can read both the ID of parts or raw materials placed on a container that manipulates and the ID from tag placed on operator. It can transmit to radio network information regarding operations which performed the forklift (transceiver active possess a set of inputs connected to actuators lift truck), information on the operator who handled and information about part or container that has been handled.

Also an active transceiver is placed on the manufacturing line. Here it detects operators who act at a time. Finally, another active transceiver is placed to control workstation. Here it read controller ID and checked part ID.

Reading passive transceivers (tags) on the operators, parts or boxes with raw materials at different points of the enterprise other than forklifts, production lines or control workstations, can be accessed through active transceivers called routers.
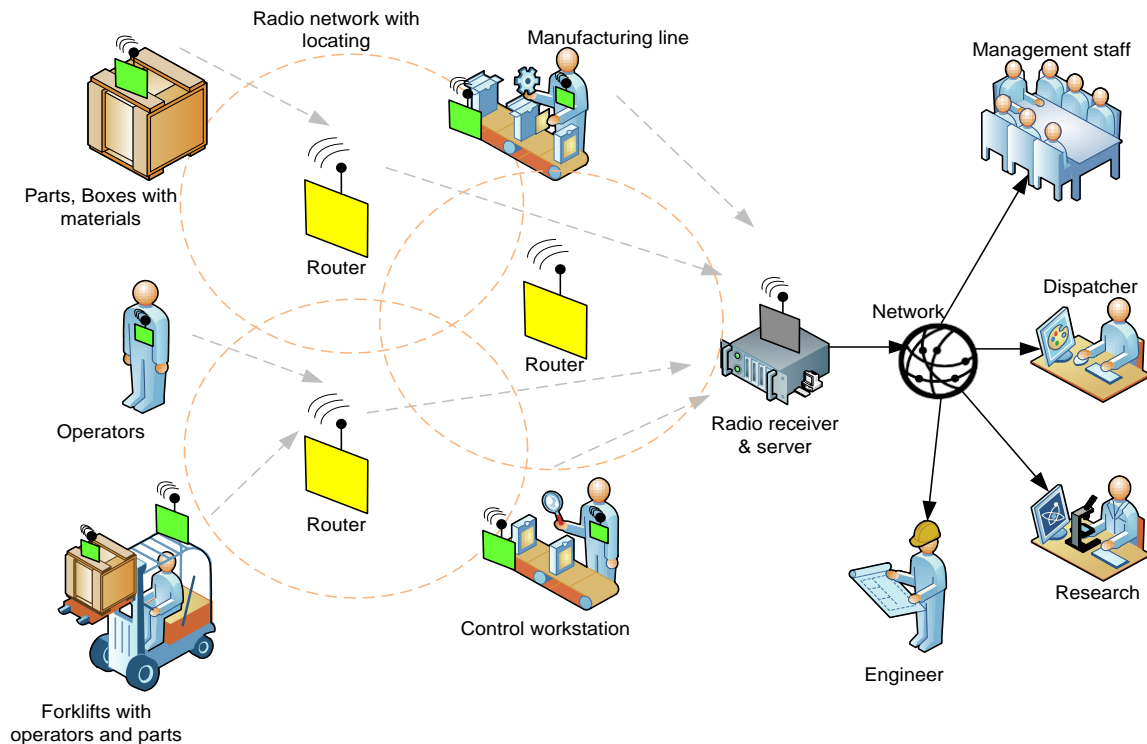

Figure 1. Block diagram of the system

They serve two purposes. First, a router collects data from end-points and sends it to central radio receiver. If the end point is in covered area of central radio receiver, it can transmit directly data to central receiver. Else, it transmits data to a router which acts as a cell from a cellular network. Thus, radio network can be extended to a very large distance, even for indoor conditions, ensuring the coverage for the entire factory.

The second function of a router is transceivers location (active or passive). The analysis is done by detecting the power of radio signal emitted by the active transceivers or by detection of proximity of passive transceivers. Three routers or more can locate an end point using triangulation method.

All information regarding end points activity, operators, parts, manufacturing lines and controls workstations with their location and time when are collected reach to the central collection point: the central radio receiver. The central radio receiver will communicate data to a server where they will be stored. The server provides services to query data stored. Thus, different network applications can use these services and can deliver information to users in different departments of the company.

We have for example a dispatcher that can signal in real-time the critical situations in the production process and can provide information related to the disposition of staff or materials. Dispatcher may inform engineers on these issues in production or manufacturing engineers can automatically be informed of some situations through a mobile application running on a PDA device. The application consists of a console warning and buttons feedback from manufacturing engineer.

All information related to the production process provided by radio network to dispatcher and responses submitted by manufacturing engineers are the database of the process of production.

This can be viewed later by management division devising strategies for future work. It can also be a useful tool for research division which will propose measures for optimizing the production flow.

3. 1. Passive radio transceiver and active radio transceiver

The radio network consists of two basic structures: a passive transceiver used for monitoring personnel, parts or materials and an active transceiver used to monitor the forklifts, production lines and control workstations.

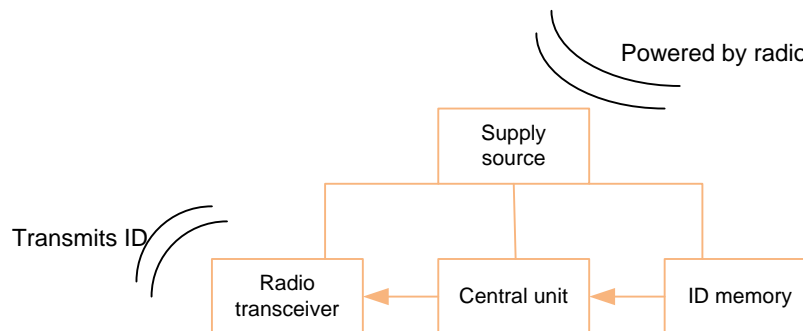The difference between them lies in the type of power supply and sensor placement.

Figure 2. Block diagram of passive radio transceiver

The passive transceivers, with the block diagram in figure 2, have passive power supply. This is fed to the time in which the receptions of a radio signal. Passive transceivers function is simple, just read an ID code located in a small memory and send it to radio. This structure can be integrated in a small circuit located in an access card or as a small point glued to a box or a part.

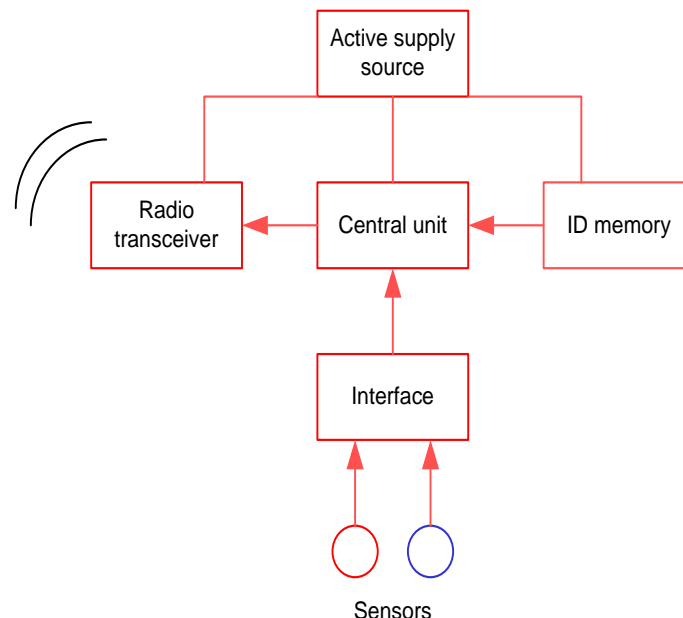In contrast, active transceivers, figure 3, have a higher dimension.

Figure 3. Block diagram of active radio transceiver used in our system

They have active power supply - can be supplied where they are placed having low power consumption. These have connected contact sensors. The sensors transmit information about the drive

elements. Data from the sensors reach the central unit with ID from memory. Also, the transceiver can receive information (ID) of the passive units in range. Then, it encapsulates information from passive units with "local" information from sensors and ID and send the data packet to radio network to central radio receiver.

4. Case study
Such a system was implemented experimentally in an enterprise manufacturing auto parts (track chassis). It monitored the following endpoints:
   - 10 welding operators, 3 forklifts handlers;
   - 6 chassis final products;
   - 24 parts of raw materials;
   - 3 forklifts;
   - 10 welding workstations;
   - 1control workstation.

In total there are 4 welding processes that apply to finalize a chassis. The system collected data into a data storage server (DB server) and provide services from application server. The applications consisted of a dispatcher application and a reporting mobile application.

Along with the ability to closely monitor the entire production process by storing data for later analysis, the system has brought the following benefits:
   - Reduce the distance travelled by each welder operator between workstations;
   - The decrease of transport time for raw materials parts to workstations;
   - Decreasing production time by allocating resources;
   - Increase quality by improving the verification process.

5. Conclusions and future trends
Our system uses a radio network for collect data about resources involved in a manufacturing process: operators, parts, raw materials, logistics, production lines and control workstations. Data are about resource type, location and time when the resource is used. With this system, we can provide information about a current production process stage and for previous processes.

We test our system in an enterprise which manufacturing tracks chassis. The system improves production by reducing time required for parts and raw materials transport and for operators shifting.

As future trends, we will build an expert system which takes data from different servers connected to radio networks placed in different factory and to implement a big data infrastructure.

References
[1]   Liu, Hui, Darabi, Houshang, Banerjee, Pat, 2007, *Survey of wireless indoor positioning techniques and systems*, IEEE Transactions On Systems Man And Cybernetics Part C-Applications And Reviews Volume: 37   Issue: 6 p 1067-1080
[2]   Ni, LM, Liu, YH, Lau, YC, 2004, *LANDMARC: Indoor location sensing using active RFID*, Conference: International Workshop pm Data Engineering for Mobile and Wireless Access Location: Santa Barbara, CA Date: MAY 20, 2001,Wireless Networks Volume: 10   Issue: 6 p 701-710
[3]   Van Haute, Tom, De Poorter, Eli, Crombez, Pieter, 2016, *Performance analysis of multiple Indoor Positioning Systems in a healthcare environment*, International Journal Of Health Geographics Volume: 15   Article Number: 7
[4]   Ceuca E., Tulbure A., Taut A, Pop O., Farkas I., *Embedded System for Remote Monitoring of OBD Bus*, ISSE 2013, 36th International Spring Seminar on Electronics Technology „Automotive Electronics" May 8 – 12, 2013, Alba Iulia, Romania
[5]   Pool, Arnout, Wijngaard, Jacob, van der Zee, Durk-Jouke, 2011 *Lean planning in the semi-process industry, a case study*, International Journal Of Production Economics Volume: 131 Issue: 1   Special Issue: SI p 194-203

[6]   Neumann W. Patrick, Dul, Jan 2010, *Human factors: spanning the gap between OM and HRM*, International Journal Of Operations & Production Management Volume: 30   Issue: 9-10   p 923-950

[7]   Ayyappan, Ramalingam, Sankar, Sambandam, Rajkumar, Paramasivan, et al., 2009, *Work-related heat stress concerns in automotive industries: a case study from Chennai, India*, Global health action Volume: 2

[8]   Lawson, Glyn, Salanitri, Davide, Waterfield, Brian 2016, *Future directions for the development of virtual reality within an automotive manufacturer*, Applied Ergonomics Volume: 53   P: 323-330   Part: B

[9]   Neumann W. P., Winkel, J., Medbo, L. et al. 2006, *Production system design elements influencing productivity and ergonomics - A case study of parallel and serial flow strategies*, International Journal of Operations & Production Management Volume: 26   Issue: 8   p. 904-923