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D8.2 A Survey of Physical World in manufacturing and traceability scenarios

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1. Executive summary

The ebbits project works with the Internet of Things, People and Services (IoTPS). This deliverable is about the things and services that are available in the two ebbits scenarios. It focuses mostly on what types of sensors and actuators that could interact with the ebbits system.

In the manufacturing scenario the main focus is on reducing operating costs. There are two systems that facilitate in operation. They are Enterprise Resource Planning and Manufacturing Execution System. These two systems are provided by the manufacturer of the plants machines but operated by the plant staff. These systems control all parameters of the plant's production.

The current state of sensors in manufacturing focus on placement of the products, both in large scale (where in the factory is this component) and macro scale (position of component inside a welding robot). Various sensor used for this application are then described. The future of manufacturing is to optimize the production, that means reduce resource usage and minimize maintenance. This can only be done with integrating more sensors to analyse the current production state.

Sensors and actuators found within the agricultural domain are also investigated. In the field today there are sensors in many places that provide information to farmers and authorities. The information from these sensors is mostly used in closed control systems or in proprietary Enterprise Resource Planning systems. To insert these measurements into the ebbits network an ebbits middleware needs to be installed.

The survey of physical world in traceability is divided into subcategories that are field, feed production, animal production, slaughterhouse, retail and transportation. The sensors and systems in these sub categories are then explained generally. The future of sensors in traceability focuses much on RFID and how increased usage of RIFD tags will augment the possibilities in traceability to increase optimization and food safety.

2. Introduction

2.1 Purpose, context and scope of this deliverable

This document describes the current state of the interaction possibilities with the physical world in the manufacturing and traceability scenarios. That is, provides an overview of the available sensors and possibilities to influence the physical world as it is found within the two ebbits scenarios. It also describes where the entry point is to the data provided by the sensors.

Furthermore it briefly describes new developments within the two scenarios seen in the immediate future.

The descriptions are to be used as a starting point for implementing the integration layer between the ebbits middleware and the physical world. Thus, the document does not describe in detail how ebbits may interact with the physical world (protocols etc.). There is also no reference to specific sensors or systems as there are too many available to describe in detail. Details and specifics will be provided in D8.4 Integration of Physical World in manufacturing scenario (ebbits-consortium 2011a) and D8.6 Integration of Physical World in traceability scenario (ebbits-consortium 2012a).

2.2 Deliverable Organization

The deliverable is organized as follows:

- Chapter 3 describes the physical world in the manufacturing scenario. It includes a full overview of the production process from the higher planning level to the effective production process. Also the interaction between the production and the maintenance is described because it plays an important role in the process.
- Chapter 4 describes the physical world in the traceability scenario. It is composed of subsections describing the situation for each of the elements in the food chain. That is, field, feed production, farm, slaughter house and retail. Additionally it describes the transport that links different parts together.
- Chapter 5 contains the conclusion.

3. Physical World in Manufacturing

In the manufacturing scenario (ebbits-consortium, 2010a) a large amount of machines and devices are involved in the production of goods. During all the steps of the process a large data flow from a central controlling unit and the machines on the field manages their activity. According to the type of data to be collected and the output expected specific sensors or computational devices must be selected and installed on the field. More detailed information can be found in (ebbits-consortium 2011a) and in (ebbits-consortium 2011b), where the manufacturing scenario has already been widely described and also the prototypes have been taken into account.

3.1 Current State

As already described, the production process is performed by a machine composed by several stations (called also cells), each of them is composed by several devices that interacting among them contribute to the realization of the final product. Basically in a production line it is usual to find PLCs, robots, drives, fieldbuses, valve packs, sensors, HMIs and a SCADA. Figure 1 shows a section of a manufacturing plant used in the welding process for the construction of a car: a welding cell.

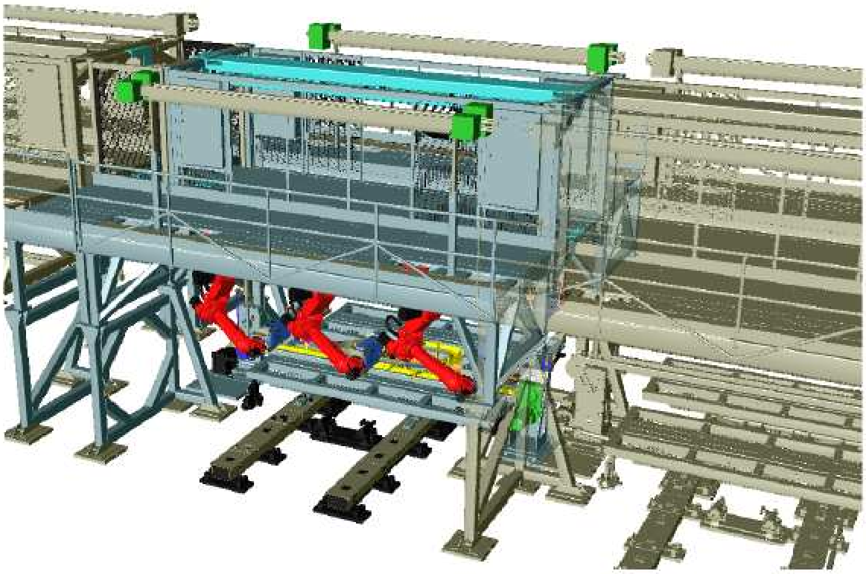

Figure 1: welding cell

In the manufacturing scenario a large amount of data is exchanged between the field and the management level, passing through a long chain of devices.

In general the data flow and the interactions during the production process could be summarized as shown in Figure 2:

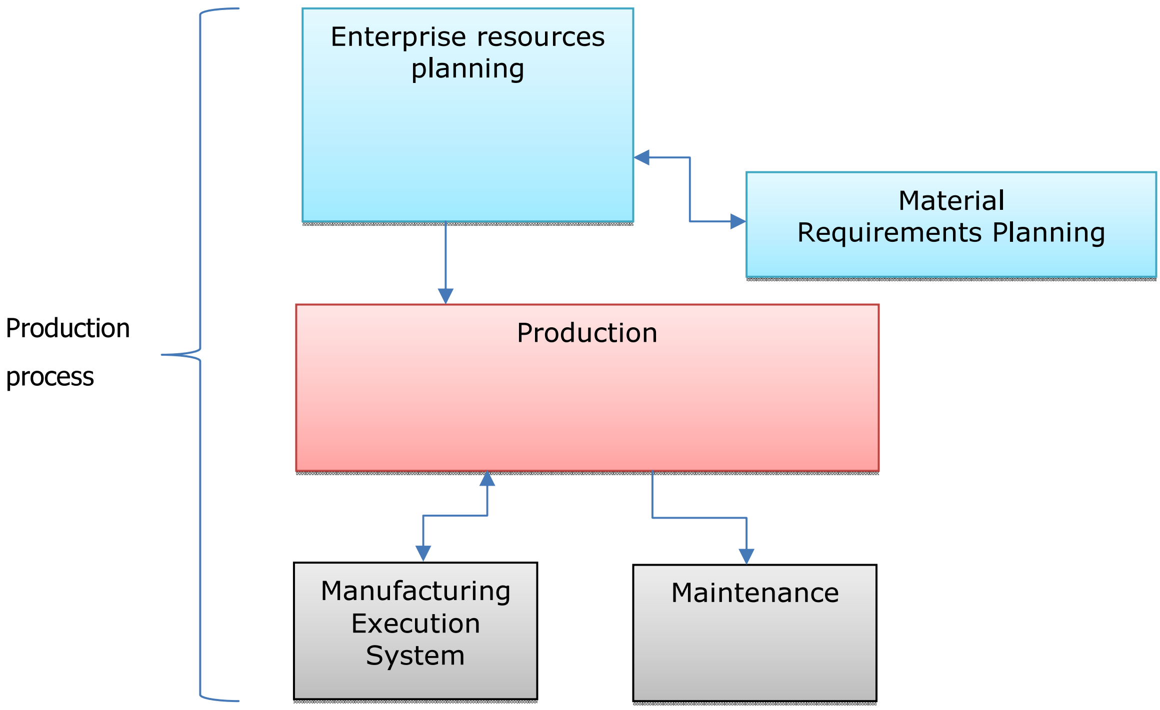

Figure 2: Dataflow in manufacturing scenario

The different entities involved in the production process are basically divided into a Higher Level and a Lower level. The first is composed by the Enterprise Resources Planning (ERP) and the Material Requirements Planning (MRP). The lower level includes Manufacturing Execution System (MES) and maintenance.

3.1.1 ERP and MRP

In the automotive manufacturing plant the first level composed by the ERP and the MRP is usually considered by the manufacturing supplier that provides the machines to the manufacturer in order to optimize the process, but it is managed by the customer (the manufacturer).

In this level the influence on the production process is given through a different management of the production target such as the increase or reduction in the production.

3.1.2 Production

The production is the level with the highest amount of the interaction possibilities with the physical world. Here large quantities of sensors are used in order to collect various types of data with two purposes: execution and monitoring of each step of the process.

- **The PLC:**
  As described before, the manufacturing plants are usually controlled by a PLC (Programmable Logic Controller) able to collect data from field through sensors and react consequently in order to perform the production process. The heart of the machines in manufacturing plant is the PLC. It is a digital computer intended for the automation of electromechanical processes. Unlike general-purpose computers, the PLC is designed for extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. It can arrange multiple inputs and output, using expansion cards,

and through dedicated field buses it can interface with various field devices. A Siemens PLC can be seen in Figure 3.

Figure 3: PLC Siemens S7-400 especially suitable for data-intensive tasks

Programming: a specific development program need to be installed on the computer and the connection is possible through several interfaces generally USB, RS-232, RS-485 and Ethernet.

- **The Robot:**
  As stated by the Robot Institute of America, the robot is "A reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks". The main task of the robots is to help or substitute people in the works that would be dangerous, boring or difficult for humans to do.

  In manufacturing plant they are mainly used for:

  - **Handling** part to be assembled.
  - **Welding** parts with several technologies, the mainly used are the spot welding and the laser welding.
  - **Sealing** with glue the parts during the assembly of the body in white.
  - **Inspecting and measuring** the produced parts during several steps of the production process using vision systems that create a subsystem able to detect deviations from the expected production.
  - **Painting** the body at the end of its assembly.

Figure 4 summarizes the main areas of uses of the robots

Programming: the programs used on the robot controller are written in PDL2 programming language. The methods used for the creation of such programs may vary widely depending on the programmer and on the application.
The main development environment in called “IDE environment” and it has to be used to develop the motion programs on the programming terminal.

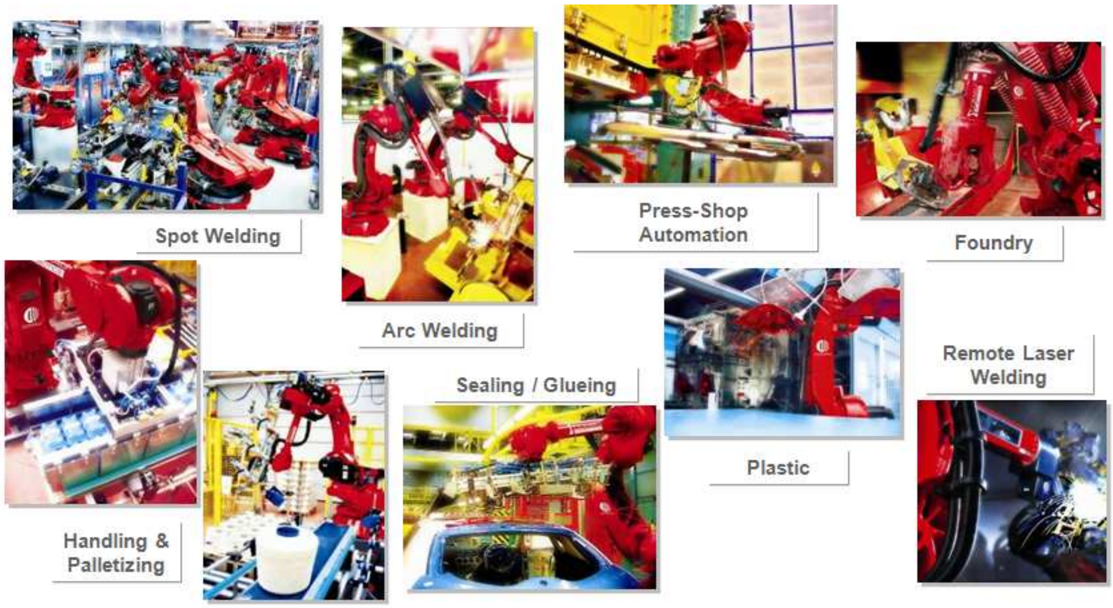

Figure 4: Main robot applications

- **The drive:** inside a manufacturing plant it is usual to find rollers, elevators and turn tables used for the handling of the products during the several steps of the production process. This equipment is moved through servo motors that are not directly connected to the PLCs, but they use electronic amplifiers which continually adjust the output parameters according to the deviation from the expected behaviour. The servos are nodes on the fieldbus network and can integrate safety parts allowing emergency stops according to the European norms. Servo drive can be seen in Figure 5.

Figure 5: Lenze Fu 9400 Servo Drive

- **The fieldbus:** Some years ago each device was connected to the PLC directly with a cable, all this meant big quantities of cables coming to the cabinets and running though the plants. For an easy installation and a better standardization the field-bus was born: a cable connecting all the devices and arriving to the PLC that took the place of all the old cables, using only one protocol and just one kind of connections. The mostly used fieldbuses in automotive manufacturing plants are Interbus, Profibus, PROFINET and Devicenet.

- **The valve packs:** are packets of electromechanical valves used typically for compressed air, water or sealing material. The first is used for moving lock pins and clamps used to center and hold the parts to be machined, the second is used as coolant in the welding systems. Figure 6 shows a valve pack.

Figure 6: Festo valve pack

- **PC-based HMI (Human Machine Interface):** Computers used for monitoring the industrial process. Each HMI runs a customized program and connects to the Programmable Logic Controller (PLC) via Ethernet TCP/IP and OPC protocols. They convert the real-time signals status proceeding from the PLC into easy-to-understand visual pages depicting the process status. On an average automatic line one HMI per station is typically present.

- **The Scada PC (Supervisory Control And Data Acquisition):** Consists of a PC connected to the plant (usually via Ethernet or serial communication interfaces) and executes specific program used in industrial process control applications for centralised monitoring and recording the status of switches, temperatures, information about production. It provides the operator with a user interface to quickly visualize a full real-time overview of the production process. Usually there is one Scada PC per line providing the overview of the manufacturing operations.

- **The sensors:** In particular during the execution of the process it is extremely important for the PLCs to collect data about the position of the parts worked and all the components on the field like robots, rollers and lifters. Several sensors are connected to the PLCs or to devices connected with a common bus in the factory. Figure 7 shows various sensors used in manufacturing.
  The most used sensors are:
    - **Inductive**: they are normally used for object detection of ferrous metals. With this kind of sensor the PLC is able to identify if the part into the station is correctly positioned in order to be worked.
    - **Capacitive**: used for detection of any material, even non-conducting; this type of sensors is rarely used in the body in white production, normally it is used to detect liquids and plastic parts in the assembly.
    - **Photoelectric:** used when it is necessary to check thickness, distance, shape or just presence of a part in a particular position. They are normally used on the grippers of the handling robot.

Figure 7: Various sensors made by Balluff GmbH

Other sensors that are used during the production process can be found inside a manufacturing plant. In particular it is common to use the RFID and barcode devices for the recognition of pieces to be worked or assembled.

- **The RFID Sensors** are generally installed on the pallets that sustain the car during all the welding and painting process. RFIDs are used as they are not affected by dirt, paint and other interferences in the factories. RFIDs and RFID scanners also require minimal amount of maintenance. Figure 8 shows Balluff RFID tags and readers. These sensors generally store data that allow the identification of the part to be worked, like order number, type of engine, number of doors, type of roof (open or closed), colour, etc.

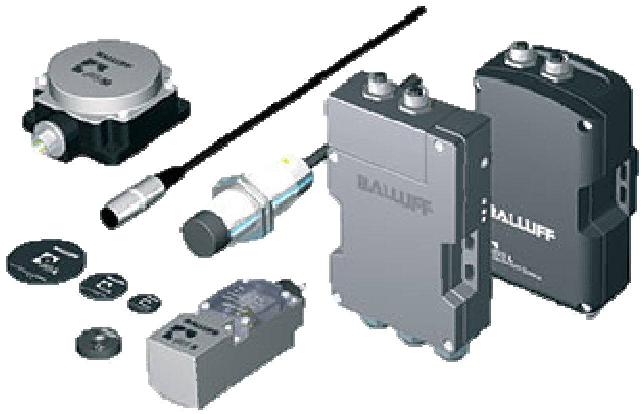

Figure 8: Balluff RFID receivers and transmitters

- **The barcode** readers can usually be found on the assembly lines, after the painting process. This choice is due to the large amount of sub-groups to be prepared and identified. Here the environment is generally much cleaner than the previous (welding and painting). Another application of the barcode readers is on the absolute encoders. A barcode is installed on each pallet that contains an element produced and moves on the roller and provides to the barcode reader the instant position of the element on the roller. In this way the servo drive that controls the motor on the roller is able to adjust current parameter sent to the motor in order to reach the correct position of the pallet on it.

3.1.3 Maintenance and MES

The maintenance system and the MES are strictly related to the machine activity in the production process: while the MES is more focused on the production management and on the performance analysis, the maintenance is closer to the production process and to the fault management.

Three different kinds of approach are used by the maintenance personnel:

-Preventive Maintenance: that consists in the care and servicing by qualified personnel in order to maintain the equipment in satisfactory operating condition correcting and replacing parts preventing faults from occurring.

-Reactive Maintenance: that consists in the intervention, repair and replacement strategies application only after the occurrence of a fault and it is also called "Run To-Failure Maintenance".

-Proactive Maintenance: it is the combination of the preventive and the reactive maintenance. It consists in the continuous improvement of the system in cooperating with the development department. That is redesigning problematic components to reducing the maintenance required.

These maintenance approaches are summarized in Figure 9:

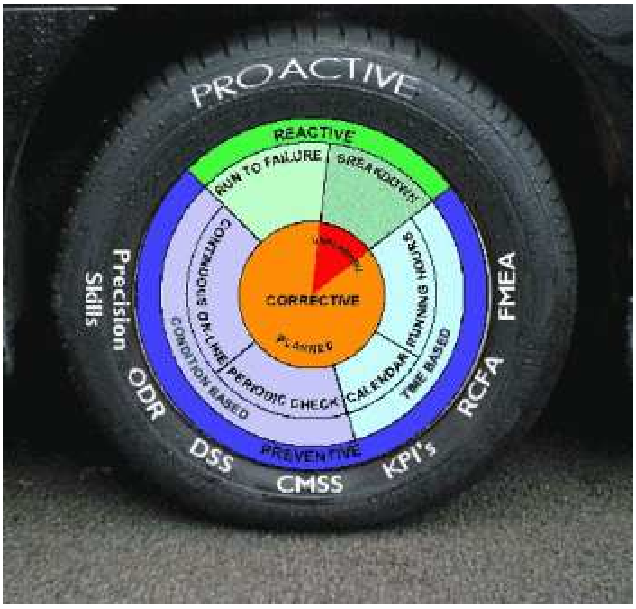

Figure 9: The "Maintenance Wheel"

For both Maintenance and MES it is extremely important to interface with the field in order to collect data and to monitor the functional status of the machines. To perform this operation several sensors are installed on the devices. The most common are the flow meters, used in water and air circuits. They are able to detect if an insufficient quantity of compressed air or water is flowing in the circuit and can evolve in quality risk for the product or a risk of damage for the machine.

These sensors are becoming even more frequent also in relation with the customers' requests are increasingly focused on the construction and use of plants with low environmental impact.

Generally inside a manufacturing plant compressed air is used to move the mechanical equipment and the water as cooling liquid to decrease the temperature of the devices involved in the production process, and in particular during the welding process.

As obvious consequence of this overview the main parameters controlled in the manufacturing plant are related to temperature, water flow, air flow and energy consumption. Machining centres often provide interfaces for these sensors and are capable of analysing the data. The situation is more complicated inside the welding plants where the number of devices that compose a line (the machine) is very high and generally these values are collected only on a "macro-level".

3.2 Future

As already described before and in (ebbits-consortium 2011b), actually a lot of sensors are available on the manufacturing field. The interaction is possible on several levels from the management to the production passing through the maintenance. It will be possible to increase the level of details by installing all the necessary sensors performing this operation on a single robot, as shown in Figure 10.

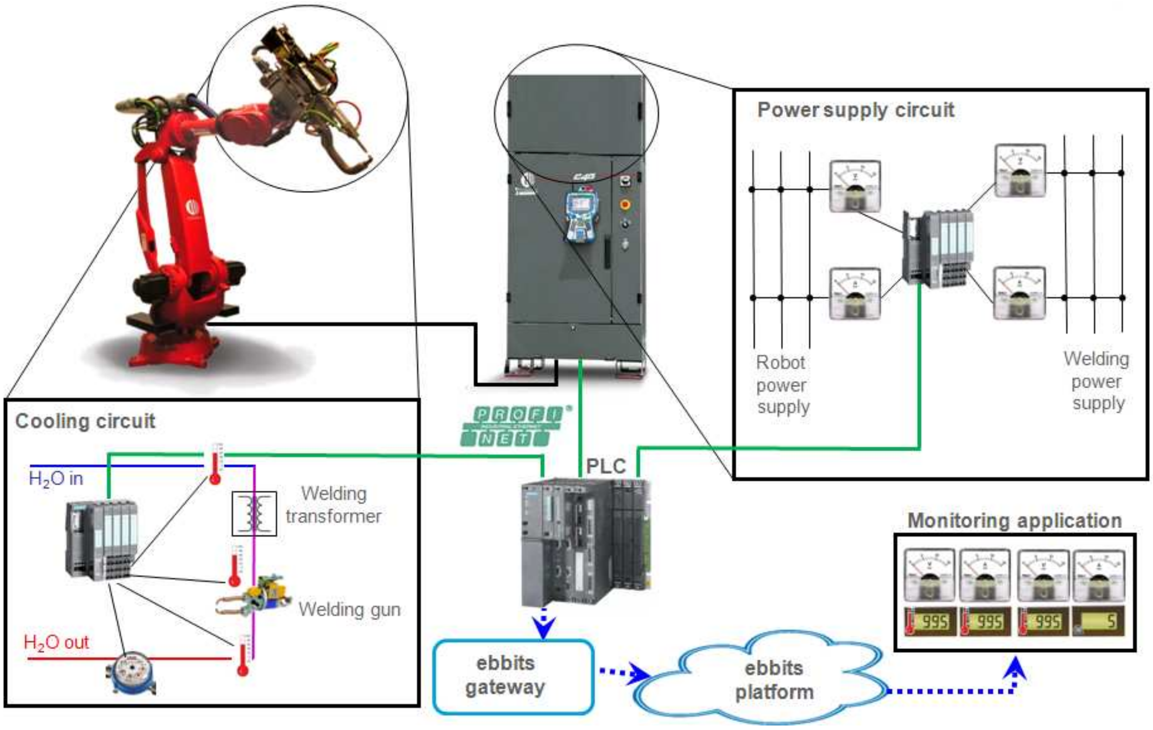

Figure 10:M10 manufacturing prototype setup

Figure 10 shows the idea developed for the manufacturing scenario prototype setup. In a welding cell the main device involved in the process is a robot equipped with a welding gun and its controller. The welding circuit needs a cooling system for the correct operation and it is important to monitor the water flow and its temperature in each stage. In the same way the power consumption needs to be monitored in order to perform a consumption analysis installing a voltmeter and an ammeter in the power supply circuits.

The vision for the future is the implementation of this monitoring system as default in each machine provided. Each device should be able to make a self-check in order to prevent machine faults and production losses.

By adopting the integration of data acquisition, devices should drastically reduce costs for the data acquisition process, conducting to its standardization, not only on the software side, but also on the hardware side. This means the production of low invasive sensors, without specific cables. An example could be the use of WSN and standard networks with Power over Ethernet (PoE) integrated.

A second step could be the implementation of sensors able to detect any magnitude from the device connected, with a swarming of sensors on the field.

All these characteristics could lead to the flexibility of the network infrastructure, namely the ability to detect physical quantities where it is necessary to investigate in detail the faults. For example, the network has detected that there is a greater power consumption of an engine of a transfer device, the operator installs a wireless accelerometer to check the relationship between energy consumed and movement produced. Another option is an ability to point out abnormal vibration due to mechanical harsh, misalignment of the rails, worn gears, etc.

4. Physical World in Traceability

The traceability scenario (ebbits-consortium, 2010a) spans a number of separate locations or steps in the physical world. The survey handles each location in a separate subsection. Also, in order to transport produce and animals from location to location several logistic operations take place. Therefore sensors and registrations in the logistic parts of the chain are also described. Figure 11 shows the food production chain.

This deliverable will focus on the lower level components. The general purpose higher level components have been described in (ebbits-consortium, 2011b).

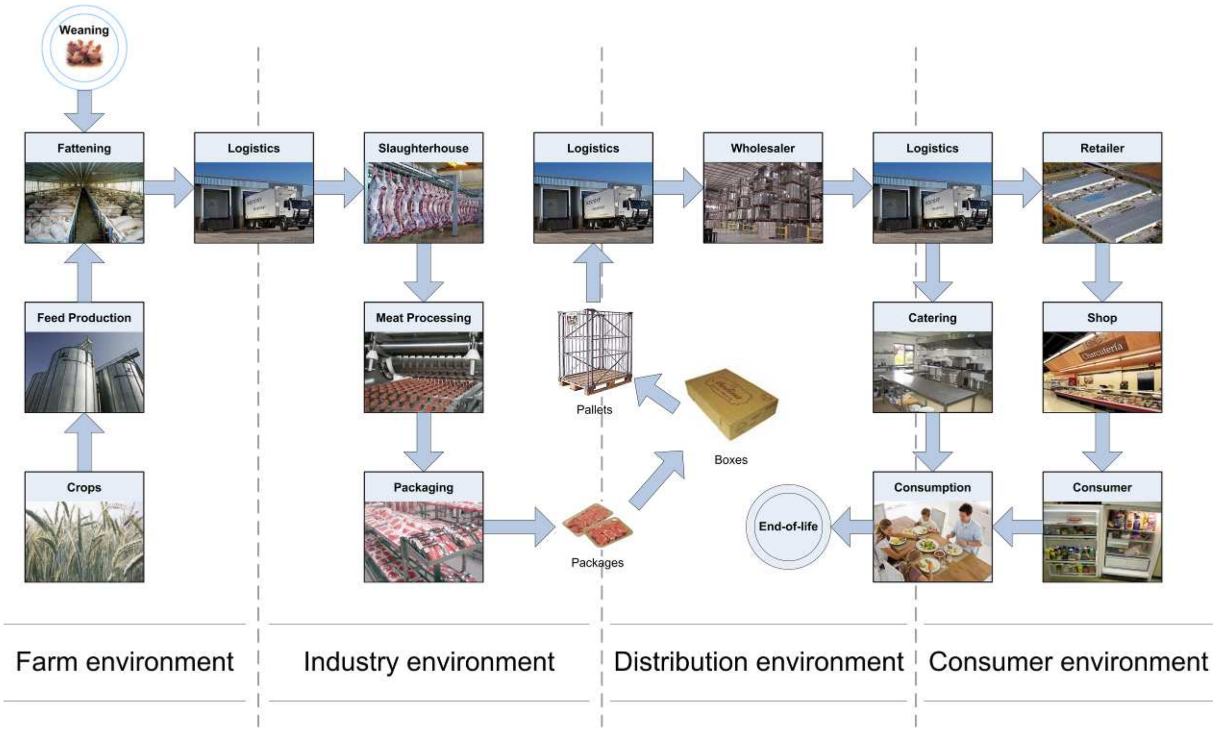

Figure 11: The food production chain

4.1 Current State

A number of sensors are used to control the production throughout the production chain. The sensor readings are in many cases used to control the production and at times the sensors are only used for data collection.

Generally, the sensors are connected directly to the systems that utilise their measurements, that is, they are not directly attached to a standard non-proprietary network. That implies that ebbits must implement a number of proxies in order to access the currently available sensors.

4.1.1 Field

The main sensor for intelligent farming on field equipment is the GPS. Together with a sensor such as a flow meter, the amount of added fertilizer can be measured (and controlled) according to the soil condition on various parts of the field. The GPS may also be used to auto-pilot the tractor around the field providing for more accurate ploughing, sowing etc.

In a traceability scenario it would be of interest to obtain information on the type and amount of fertilizer and herbicides used on the field as consumers may have an interest in discerning between organic and non-organic products.

Similarly, the harvester can record the yield of a particular part of a field.

Tractors communicate with equipment via ISOBUS (ISO 11783). The standard specifies data formats for data exchange, how terminals should be constructed, data definitions and also the physical, data and network layer. The ISOBUS is a specialization of the CAN-bus. However, automatic access and extraction of data from the tractors ISOBUS system is not standardized.

4.1.2 Feed Production

The job of the feed production facility is to produce feed to a precise specification. That is, feed with a specific amount of energy, minerals, amino acids and other nutrients. In order to do so the incoming batches of raw feed stuff are analysed for the various components. The analysis is based on samples taken from the batches and is performed in laboratories.

The feed is then mixed based on the analysis to meet the requirements set for a specific type of feed. In order to do so the feed production facility utilizes flow meters and scales.

Data from the analyses and the actual recipe used to produce a batch of feed is stored in the ERP system of the feed production plant.

Thus, in order to get information about the origins of feed stuff, ebbits must extract the relevant information from the ERP system of feed production facility.

4.1.3 Animal Production

In order to optimize production and reduce the amount of manual work a farm may introduce a number of automated systems. Each of these systems has some sensors in order to perform their task. In order to perform a given task the systems are attached to various motors, valves and the like.

As a general rule all sensors and actuators are hidden behind the system as each system is designed to function independently of the others. Thus, in order to get data or to perform actions it is necessary to go through the interfaces given by the individual manufactures because no universal standards are currently implemented. That also implies that the farmer sometimes needs to input the same data in multiple places as system from various vendors rarely are able to communicate.

Climate

The climate is important for the comfort of the animals. A too hot or too cold environment may yield slower growth and in severe cases even death of the animals.

In order to sense the environment the climate system may utilize temperature sensors inside and outside of the animal houses. Furthermore, the climate system may also be equipped with humidity sensors and CO_2 sensors.

If the climate control system needs to change the condition of the animal house it can take a number of actions. For example,

- Open ventilation ducts for passive ventilation
- Start active ventilation using fans
- Spray or vaporize water in order to cool the environment
- Start heating equipment

Feeding

The feeding system feeds the animals by mixing and dosing feed according to a feeding program. Basically, two systems exist

1. Electronic sow feeding systems where each animal is identified via an RFID ear tag. The feeding system is provided with data about the animals such as their cycle day in order to determine the amount of feed given to each animal.
2. Valve feeding where the number of animals attending a given feeding valve is provided by the farmer. In case of slaughter pigs the system also needs input on the average weight of the animals.

The feeding system uses pumps and valves in order to get the feed from mixing tanks to the feeding troughs.

Dairy Production

In the dairy production it has become more common to introduce milking robots, either semi-automatic or fully automatic. The cows are trained to go to the milking robots when they are due for milking. Each cow is tagged with a RFID ear tag so that the milking robot is able to identify the given cow.

Usually the robot analyses the milk from each cow. It may measure features such as the amount of milk, milk flow speed and the cell number. The data is stored in the milking robots management system, where it is used to monitor production, control amount of feed and detect abnormal conditions. In Denmark, the milking data is also stored in a national database.

Animal Tagging

Most animals must be tagged albeit not necessarily with electronic tags such as RFID tags. RFID tags are currently only used if any of the equipment on the farm has the need to identify and animal. Such equipment includes some feeding stations and milking robots as described in the sections above.

Smaller animals such as goats and sheep are not tagged electronically and the smallest animals such as chickens and other types of poultry are not tagged at all.

Miscellaneous

Most animals are given as much water as they please and water consumption has not been a focus point. However, with water prices rising and the possibility to detect problems in the production some farms have several water meters installed. These are often attached to the climate system.

The typical farm uses considerable amounts of energy to power the various components and systems. Most often there is only one power meter for each production facility. Many power meters have sensor interfaces but energy sensors are rarely installed.

4.1.4 Slaughterhouse

The slaughterhouse is for the most part a highly manual and labour intensive facility. However, more automation is starting to be used in order to reduce costs.

As the farmer is paid by the weight of the delivered animals the slaughterhouse facilitates scales at several places in the production line. In some cases vision based systems are used to measure for instance the lean meat percentage of each animal. The lean meat percentage also has influence on the price to the farmer.

Automated slaughterhouses use RFID technologies to keep track of hooks and boxes containing meat.

Furthermore, the slaughterhouse also employs a number of veterinarians that visually inspect each animal. If they suspect a problem with an animal they take the carcass of the animal for further analysis.

Information about the weights, lean meat percentage, comments by veterinarians etc. of each animal is stored in the ERP system of the slaughterhouse. The ERP system of the slaughterhouse is therefore the entry point for data.

Currently in the pork meat production the slaughterhouse is able to track the origin a piece of meat going out to a set of one to three farms. The difficulty lies in that the animal is cut into several pieces and for some products, ham for instance, meat from different animals and possibly from different farms are but together in the final product.

4.1.5 Retail

The main interface to the physical world in the retail area is the bar code. It is used in the stores as well as in the storage and wholesale in order to identity goods such as food. The bar code readers interact with the ERP systems of the retail chains such that the inventory is kept correct and up to date.

The most standardized system in this scenario is the barcode system used for product identification. The EAN-13 barcode system is administered by GS1[1] which is an international not-for-profit organization which has member organizations in over 100 countries. This means that the system is global and the whole supply chain can use it to identify products with cheap laser scanners.

Newer versions of barcodes are used in many applications but are not in widespread use. GS1 has a newer barcode standard (GS1, 2007) which allows for more information to be stored in the barcode. There are also two dimensional barcodes, like QR codes[2], which can store much information in limited space but the readers for 2D barcodes are more expensive than for the one dimensional type.

Naturally, there are other sensors present in this part of the supply chain. For example, there are temperature sensors in the area where the food needs to be kept cool. However, these sensors are generally not accessible, but are simply integrated with the cooling systems to keep a constant temperature.

4.1.6 Transport

Between the farm, feed factory, slaughter house and retail there is a need for transport of feed, live animals and food.

The transport vehicles may have GPS systems installed such that the 'main office' can track where their vehicles are. Furthermore, trucks are required to have tachographs (speed registration) (EEC 3821/85)installed such that a authorities are able to control whether the driver has complied with speed limits and resting time regulations. The tachographs used to register the speed on pieces of paper. However, it is required for all new trucks to be equipped with digital tachographs (EC 1360/02). Furthermore, it is required to keep the registrations for one year.

The trucks used to transport live animals may be equipped with ventilation systems and drinking facilities in order to reduce stress on the animals. Furthermore, the trucks may be equipped with a scale. It can be used to compute the prices of a batch of animals when they are transferred between farms.

4.2 Future

In general the amount of information gathered and stored in food production will increase as many stakeholders have interest in the information. Authorities are interested in information gathering to increase food safety and the farmers are interested in the information to maximizing yield in the production.

When RFID tags become more affordable they are likely to be commonplace in the whole food production chain, from tagging animals to tagging retail packaging. With a framework like ebbits that is able to fuse sensors and data into meaningful information would allow easier integration of

[1] www.gs1.org
[2] http://www.denso-wave.com/qrcode/index-e.html

more sensors in more places. Combining RFIDs and sensor information would then increase food safety and traceability.

There are also available RFID tags with integrated temperature sensors. This allows the RFID readers to get the temperature history of the product. Other types of sensor could also be integrated, like shock sensors, humidity sensors or GPS sensors.

5. Conclusion

This deliverable is a survey of physical world in manufacturing and traceability. It focuses much on the sensory information available for accessing with the ebbits network in the manufacturing scenario and in the traceability scenario.

The manufacturing scenario offers a large amount of sensors and actuator and system for collecting information. In particular it is possible to find **inductive**, **capacitive** and **photoelectric** sensors used by the PLC during the production process. **RFIDs** and **barcodes** are other kinds of sensors used for the identification of the parts to be produced.

The traceability scenario spans many locations and participants. Each has their own sensors and actuator and system for collecting information.

- In the field the farmer can have **flow sensor** for measuring amount of fertilizer and herbicides on the field. There are also available **scales** or **volume sensors** for measuring crop yield. This information combined with **GPS sensor** gives detail information about the crop.
- In feed production the information comes mostly from laboratory analysis and not directly from sensors in the process. The various components in the feeding mix are measure using **flow meters** or **scales.**
- In animal production the climate is controlled with **temperature sensor** (inside and outside), **CO_2 sensors** and **humidity sensors.** The feeding amount is often controlled with **RFID readers** identifying the animal and giving it proper amount of feed. High tech milking robots have **flow sensor** and other **quality measuring sensors**.
- In slaughterhouse they have **scales** in many places and also use **vision systems** to analyse the lean meat percentage. **RFID readers** track the hooks and boxes for cuts.
- In retail and transport it is important the keep the cold chain unbroken so there are many **temperature sensors** to keep the goods at optimal storage conditions. They also have **barcode readers** to identify product types.

6. List of Figures

7. References

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