SENSE&REACT

White Paper

A context-aware and user-centric approach for information distribution system in manufacturing

Executive Summary

Sense&React (The context-aware and user-centric information distribution system for manufacturing) is an EU research project (FP7-2012-NMP-ICT-FoF) that develops next generation information distribution services that provide the right information, at the right time and location to the right people working in a manufacturing environment. Sense&React considers that context-awareness should to be a fundamental property of ICT systems installed in modern production facilities. Such information distribution services involve:

- Implementation and validation of an **ICT reference architecture** that enables **intelligent management of manufacturing information in real-time** and that can be used to **develop context-aware applications for the industrial shop-floor.**
- Definition of a factory wide **sensing and ICT end-to-end infrastructure** for sensing data from the manufacturing environment, such as tool and asset localization.
- Developing concepts for **context-based automated adaptation of graphical user interfaces** in shop-floor environments provided onto display devices, such as mobile devices, large screen and industrial touch screens, in order to support the shop-floor personnel with the adequate amount of information also **considering the cognitive load** when performing certain operations.
- Develop **real time optimization** methods that utilize real-time data, in order to optimize production performance and **energy efficiency**.

The Sense&React develops information services and applications for the shop floor that can truly speed up production processes and enable immediate reaction to issues and shortcomings. The generic approach based on services and apps allows cost-efficient adaptation to a wide variety of industries. The project results are tested and validated in real manufacturing environment in four industrial pilot cases stemming from automotive, shipbuilding and white goods sector.

Sense&React Solution contribute to the following industrial driven objectives:

- ✓ **20% reduction of errors** for wrong component selection, for missing components, for low quality assembly
- ✓ **Eliminating** the majority of Team Leader **"non-productive" activities** and correspondent labor cost reduction
- ✓ **10% improvement of Delivery Schedule** Achievement KPI for assembly operations problems
- ✓ **Faster identification of problems**
- ✓ **Reduced solving time** for line stoppages or machine breakdowns
- ✓ **Reduce searching time** for equipment and personnel by **30%**
- ✓ **Reduce work stoppage by 30%**
- ✓ **Reduce response time** to exceptions by **20%**
- ✓ **10% reduction in energy costs**

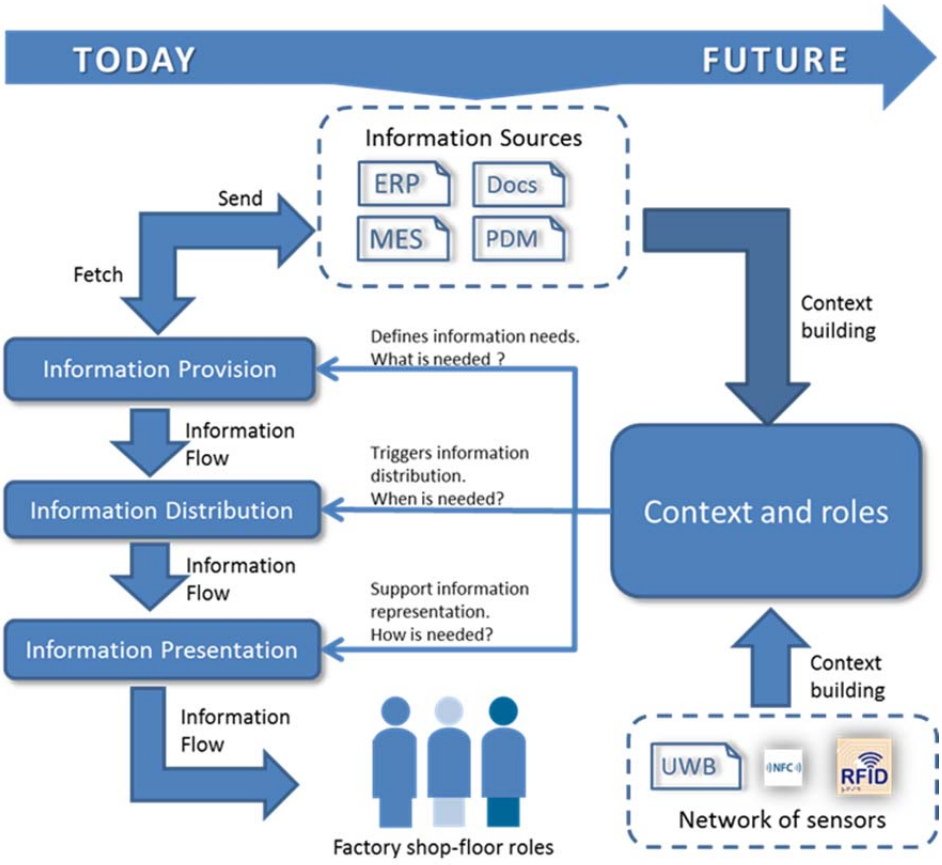
Industrial Challenges

The continuously increasing complexity and amount of information in manufacturing is a major challenge for big enterprises as well as for SMEs. Nowadays manufacturing ICT platforms provide a number of useful tools, including sensors', wireless networks, mobile devices, MES, ERP and information management systems, support shop-floor and back-office personnel in a series of activities. ICT solutions originally intended to support production processes, currently lack the ability to provide the right information at the right situation at the right time and location to the right person. The huge amount of information gathered and generated by IT systems need to be presented in a manner that can truly speed up production processes, enable immediate reaction to issues and shortcomings. This requirement results in several technical shortcomings for the ICT domain to overcome and support manufacturing companies.

- **Information Provision:** in many cases, information infrastructure fails to successfully aggregate and manage data from factory-wide sensor networks as well as from various data sources, namely MES or ERP, analyze the data and deliver it to different users in a context-based manner.

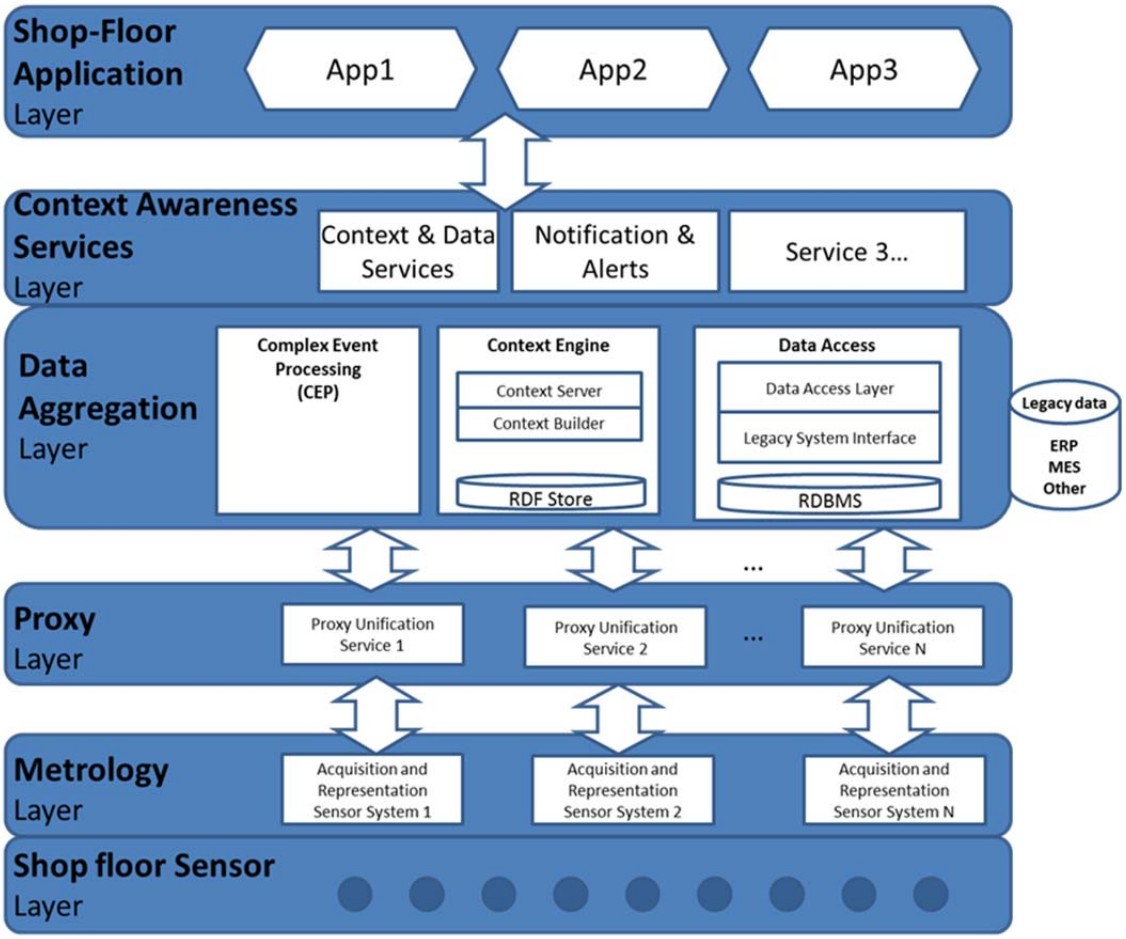
- **Information distribution** usually neglects different user roles that may change according to the context the user operates in the production environment. Consequently, the information source is not aware of the information receiver's role and thus, fails in delivering the required subset of information.

- **Information Personalization:** for the delivery of personalized data and services to people in a production facility, the cognitive domains such as information retrieval, decision making, and situation awareness are required. For example, the cognitive load, especially of shop-floor operators, working under harsh conditions, is not properly addressed during the distribution of information.



The Sense&React Solution

Sense&React provides next generation information distribution services for manufacturing floor that can truly speed up production processes and enable immediate reaction to issues and shortcomings. This is achieved by providing the right information, at the right time and location to the right people working in a manufacturing environment.



The framework is based upon a five layered architecture and each layer contributes to increasing visibility and context-awareness in a manufacturing environment by gradually enabling the easy sharing of various context information and sensor data, so that they can be used to complement each other and cover a factory-wide application environment.

- **Metrology and shop-floor sensor layer (Sensing and ICT infrastructure):** The shop-floor sensor data layer contains the physical hardware (sensors) and the adequate software (e.g. firmware). The sensor data are initially available as "raw" data. Then the sensor "raw" data go through the first processing stage in order to improve their representation. The Metrology layer interprets the "raw" data into initial context information, and then stores it if needed. For example sensor tracked signals are translated into valid shop-floor coordinates.

- **Proxy Layer:** Sensors of various types should be supported in the shop-floor environment providing information for the context. These

sensors produce a heavy data load on a centralized architecture. The architectural approach followed that would tangle the data coming from the network of sensors follows the "divide and conquer" principle by dividing the data to different proxies with pre-processing capabilities. Each Proxy would manage the data coming from a limited number of sensors, the data will be pre-processed and after pre-processing them data will be forwarded to the main/server system for advanced processing and storage.

- **Data aggregation and context awareness (Manufacturing information management):** In data aggregation layer context information produced by different shop-floor sources is aggregated and a database holding the relevant information (real-time information, roles repository, historical data and solution patterns) is maintained. An administration component manages the stored information and provides authentication services to accessing stored data. In the context awareness layer high-level manufacturing activities context inference takes place based on the aggregated information. The knowledge discovery and problem identification modules combine in an integrated manner the real-time data, the historical data and the existing or mined knowledge to provide reliable info about the events that occur so as to warn the users. Moreover, the role-based data assembly module aggregates and provides the required functionality for automatic consolidation of the data that needs to be delivered to specific user roles, at specific time.

- **Context Awareness Services layer:** The services layer fulfills the following main functions. The first function is to handle data service requests from the applications. The second function is to inform the applications to changes in the manufacturing context. The third function is to provide critical alerts and notifications to the applications.

- **Shop-floor applications layer:** In this layer, different context-enabled applications are deployed and provided to the final users (operators, production engineers, maintenance engineers and others) through different display devices. In factory environments, various visualization device types can be utilized to display and collect production-related data and information. The proposed architecture is generic enough to allow for different applications to utilize this infrastructure and provide specific end-user services. Typical aspects of these applications that can be deployed in the proposed framework, can be used for example, to provide assembly instructions to an operator, on the basis of the product and workstation he is working on or to provide production schedule information based on the production line and the user's role

Industrial Pilot Cases

The Sense&React solution is applied to four different real industrial cases aiming to demonstrate its potential benefits. The first industrial pilot case stems from a typical mass manufacturing system and deals with a washing machine assembling line. The second case comes from the automotive industry and particularly the foundry, while the third has to do with the steel workshop segment of a shipyard. The first and the third case are presented with the help of two scenarios showing the functionalities and the benefits of the Sense&React solution

White Goods - Assembly Line

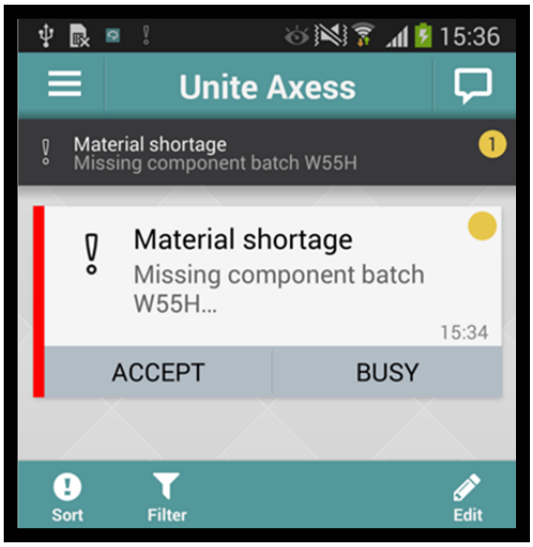
The first seven steps of the scenario concern assembly support, while the last two are related to an emergency situation, specifically a machine breakdown.

Step 1: Situation-aware Login to Workstation. The operator is logged in automatically without the need of entering a username and a password by placing the NFC card close to the NFC reader located in the workstation.

Step 2: Receiving Personalized Production Plans. Based on his role and his location to the workstation the user is provided with customized information about the daily production plan as well as information on the current production batch. The proper application for delivering such information is automatically put in front to the user by the context identification service.

Step 3: Receiving Assembly Instructions. Based on his role and based on the current status of the assembly process, the user is provided with assembly instructions.

Step 4: Monitoring Material Supply. The system constantly senses the material supply at the workstation and reacts in case of an emerging material shortage. The proper application that informs the user in case of critical material event is put into focus in the display.



Step 5: Communicating Material Shortage. In case of an emerging material shortage, the system supports the workstation operator in creating messages to the responsible team leader warehouse.

Step 6: Confirming Arrival of Material. The arrival of new material is sensed. The updated situation leads to automatic adjustment of the information presented on the user's display.

Step 7: Receiving Information on Upcoming Model Change. Based on the current production situation, the system displays adequate information for the upcoming new models.

Step 8: Communicating a Problem (machine breakdown). The operator is enabled to communicate effectively problems to the Team Leader.

Step 9: Team Leader and WST-O Work together on solving a problem. Based on their joined experience, the team leader and the operator work on solving a problem at the workstation. The system combines the roles of both users and changes shown applications and content of applications accordingly.

Benefits

- ✓ **Increased communication speed** between operators and the Team Leader in case of a problematic situation, i.e. components are not sufficient or are missing, equipment breakdown.
- ✓ **Sub-line bottlenecks elimination by 30%**
- ✓ **20% reduction in communication times** between WST operators and Team Leader.
- ✓ **10% improvement** of **Delivery Schedule Achievement** KPI can be achieved.
- ✓ **Assembly errors reduction by 30%** in the workstation and by **10% in the entire sub-line**; improvement of finished products quality, due to the provision of operators with enhanced information related the work steps, materials, and tool setup that must be used for a specific batch.
- ✓ **Improvement of Team Leader's overall efficiency** due to the elimination of a big portion of Team Leader's non-productive activities

Shipbuilding – Steel Workshop

Step 1: Definition of Working Areas. Production manager checks the working areas and the workers assigned to them. Today a new block for the vessel "Peniche35" is established. For doing so he draws on a map of the ship yard a polygon, representing the working area for block 5, and assigns two welders to them.

Step 2: Situation-aware Login to Working Area. The first welder approaches block 5 of vessel Peniche 35 and since his manager has assigned him to block 5, the system recognizes him via the indoor tracking service and logs him in. The welder sees his profile on the large screen that was placed next to block 5. His colleague arrives 10 seconds later and is recognized by the system too. The system shows both welders in the user list app.

Step 3: Receiving & Confirming Production Plan. The system recognizes that both of workers need to confirm the tasks for today and hence opens two instances of Daily Construction Plan App clearly labeled with the names of the workers. The welders stand next to each other in front of the large display. Via touch interaction they can scroll individually within their instance of the Daily Construction Plan App. They see their individual tasks and the general plan for the block. Finally they confirm that they read the instructions.

Step 4: Receiving Instructions at Working Area. Each worker is provided with instructions to his next task. For the first worker, the apps show a part of the construction plan indicating where to weld steel plates. For the second worker, the app provides an enlarged piece of the construction plan too, but additionally several notes are displayed, informing the second worker of potential problems with this tasks.

Step 5: Monitoring Production Progress. The first worker completes his task of welding the section of the second hull of block 5. He returns to the display. The display switches to first worker's instance of the Construction Supporter App. The first worker presses the button "Task Completed". The system shrinks the App and additionally opens the Daily Production Plan App. It shows the first welding task as completed and highlights the next task. The details of the next task are shown in the Construction Supporter App.

Step 5b: Productivity reduction alert. After the first worker confirmed his task in the Construction Supporter App, State Model Analyzer analyses the deviation of the holding time at his workstation. Because of some unknown problems at welding area the last operation has time more than double

average holding time for this type of product. The message about this fact is sent to the manager. The manager in real time has information about the deviation of production process and draws attention to this problem.

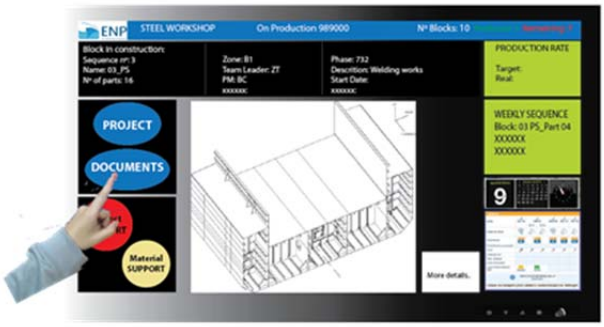
Step 5c: Missing step alert. State Model Analyzer analyses the deviation of the production sequence for this type of the product. Because of some unknown problems at welding area the previous planned operation was not confirmed. May be second worker forgot to confirm it, or may be some unplanned changes of production routing took place. The message about this fact is sent to the manager. The manager in real time has information about the deviation of production process and draws attention to this problem.

Step 6: Notify Colleagues about Plan Updates. The customer made changes to the plan. The size of a crane for the vessel Peniche 35 is changed. This has consequences for block 5 that is currently under construction. The manager quickly checks the Management Tool and puts all tasks on block 5 on hold. This avoids that time and material is wasted on block 5. The manager sends the workers to block 6 to support the colleagues there. He then talks with the construction office. They realize that the changes do not require many changes to the plan. The plan is updated and the changes are transferred to the system and the workers receive notifications that they can proceed with their tasks.

Step 7: Material Availability. After clarifying the changes made to the construction plan of vessel Peniche 35, the laser cutting department starts to cut the metal parts needed to build a larger crane as initially planned. As soon as the parts are ready, Bruno receives a message via the CANA App that he can pick up the parts from the laser cutting workshop. Since "picking up material" is an additional task, his personal Daily Production Plan App is updated. The details listed in the new task tell Bruno the job number with which he can find the material in the cutting workshop along with the information that he should bring a pallet truck (small forklift) for picking up the material. Since he does not know where to find the pallet truck he checks the Tool Finder App. The App shows the current locations of all pallet trucks on the shop floor and their availability. He learns that just behind his block a free pallet truck is parked.

PRESENT

FUTURE



Step 8a: Exception Handling: Automatically Sensing and Communicating a Potential Exception. The first worker's welding machine starts to consume more and more energy. This indicates that the welding machine should go into service. This will avoid damage to the machine as well as reduce the energy consumption of the company. The CANA App sends a message to the technician telling him that welding machine W45 currently used at block 5 needs service. Since the technician has another welding machine in stock, he takes this machine and walks to block 5. The firs worker is somewhat surprised that the technician

already knows that his welding machine is behaving somewhat slow and welcomes the replacement. The technician checks in welding machine W46 as replacement of machine W45.

Step 8b: Exception Handling: Worker Searches for Help to Fix a Problem (Machine Breakdown). The first worker's welding machine has a breakdown. Since the first worker started working as a welder only three month ago, he never experienced this kind of breakdown. The system is aware that Bruno has no experience with broken fuses. Hence the system opens the Expert Finder App. On the app, the first worker sees the foreman and the technician. The foreman is currently engaged in fixing a minor emergency at block 10 so the foreman seems to be the best choice to ask for help. The first worker clicks on the technician icon on the map and a preconfigured message appears. The first worker clicks the "send" button and waits for the technician to appear. Three minutes later the technician shows up, holding the needed fuse in his hand. The system informed the technician about the kind of break down. Since the technician knows this kind of welding machine well he knew which fuse to fetch from the warehouse.

Step 9a: Technician and Welder Work Together on Solving a Problem. While the technician is fixing the first worker's welding machine, the technician realizes that there is another problem with the welding machine. The system has updated the status at block 5 already to "machine breakdown" (due to the fact that the first worker requested the technician to help him via the CANA App). At the time the technician entered the area of block 5, the context-sensitive S&R Shell realized that now enough expertise is present at block 5 for solving this kind of problem. Hence the S&R Shell minimizes the Expert Finder App and opens the Tool Finder App automatically. Technician asks the first worker to identify the position of a special kit of wrenches needed to open the welding machine. The first worker selects this set of tools in the Tool Finder App and immediately sees the current location. It is in block 8 and not in the workshop as it should be. Someone must have forgotten it in block 8. This information saves the first worker from searching the entire ship yard for the wrenches. Two minutes later he is back with the wrenches and the technician fixes the welding machine in another 5 min.

Step 9b: **Finding a tool without network connection.** The technician and the first worker are in a block which completely blocks wireless signals. Technician's tablet opened the Tool Finder application and it presents the last location of the kit of wrenches. The first worker immediately knows in which direction he has to leave the block and brings back the tools.

Benefits

- ✓ **Reduce searching time for equipment and personnel by 30% & Improve operator and team leader efficiency,** due to asset and personnel localization, real time production and machine status.
- ✓ **Work stoppage reduction by 30% and response time to exceptions decrease by 20%** achieved with supporting operators only with relevant information, automatic notification to team leaders/manager about exceptional situations, immediate notification of operators for ship drawing updates, automatic notification for weather conditions that may affect a task.
- ✓ **10% reduction in energy costs,** by automatic recommendation on optimal machine status for breaks and end of shifts, and proactive maintenance based on energy consumption

Conclusion

Sense&React solution is a context aware information distribution system for supporting users in the industrial environment. It provides task-relevant information or services to users in manufacturing shop floor, making tasks more efficient and improving decision making through context-driven recommendations. The Sense&React solution utilizes data collected from sensors located at shop-floor and employs those data for increasing visibility of shop floor processes and provides the right information at the right time to the right people. The Sense&React Solution leads to:

- Increase factory-wide **visibility** and **situation awareness**.
- Decrease **human errors**.
- Increase factory wide **energy efficiency.**
- Increase **quality** of manufactured products
- Increase factory-wide **availability** of manufacturing resources.
- Increase factory-wide **performance** of manufacturing activities.
- Reduction of manufacturing activities cost.
- Increase personnel **safety** via reducing accident rates.
- Increase shop-floor **agility.**

www.sense-react.eu

Dr. Sotiris Makris
Project Manager
LABORATORY FOR MANUFACTURING SYSTEMS and AUTOMATION (LMS)
Director: Professor George Chryssolouris
Department of Mechanical Engineering and Aeronautics
University of Patras
Patras 26500, GREECE
http://www.lms.mech.upatras.gr
Tel.: +30-2610-997262
Fax: +30-2610-997744
e-mail: makris@lms.mech.upatras.gr