FFI Line information system architecture – LISA

Project within FFI Sustainable production technology

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Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

Future sustainable competitive production systems need to be productive and flexible, as well as environmentally friendly and safe for the personnel. There are today few system solutions that assist production management with a coherent information model and a modular system architecture that facilitates data gathering regarding products and processes throughout the entire plant.

A hidden resource in the manufacturing industry is data. Recent investigations estimate that 85% of the data and information is still unstructured, 42% of all transactions (i.e. sending and receiving information) are still based on paper. And CEOs in the manufacturing industry claim “we need to do a better job capturing and understanding information rapidly in order to make sound business decisions”

The FFI Line information system architecture – LISA project was organized in seven work packages:

- WP1 Project coordination and result dissemination
- WP2 Formulate requirements on LISA
- WP3 Relevant standards and components for LISA
- WP4 Development of international standards supporting LISA
- WP5 Adapt relevant functions and activities for LISA
- WP6 Final definition of LISA
- WP7 Demonstrators.

The project partners were:

- KTH Royal Institute of Technology
- Chalmers University of Technology
- Lund University, Faculty of Engineering LTH
- Scania
- Volvo Car Corporation.

LISA has delivered and validated a modern flexible and scalable event driven architecture able to implement collection and fusion of data from different automatic production sources with a granularity level that stretch down to the single sensor. This provides, in principle, the possibility to mine and parse data across the different layers of manufacturers’ ICT infrastructure, independently from predefined control logic constraints. Although LISA has also preliminary investigated the transformation of data in meaningful information and the related visualization, a full industrial implementation was well out of the scope of this project.

The developed LISA demonstrator is called the "tweeting factory".

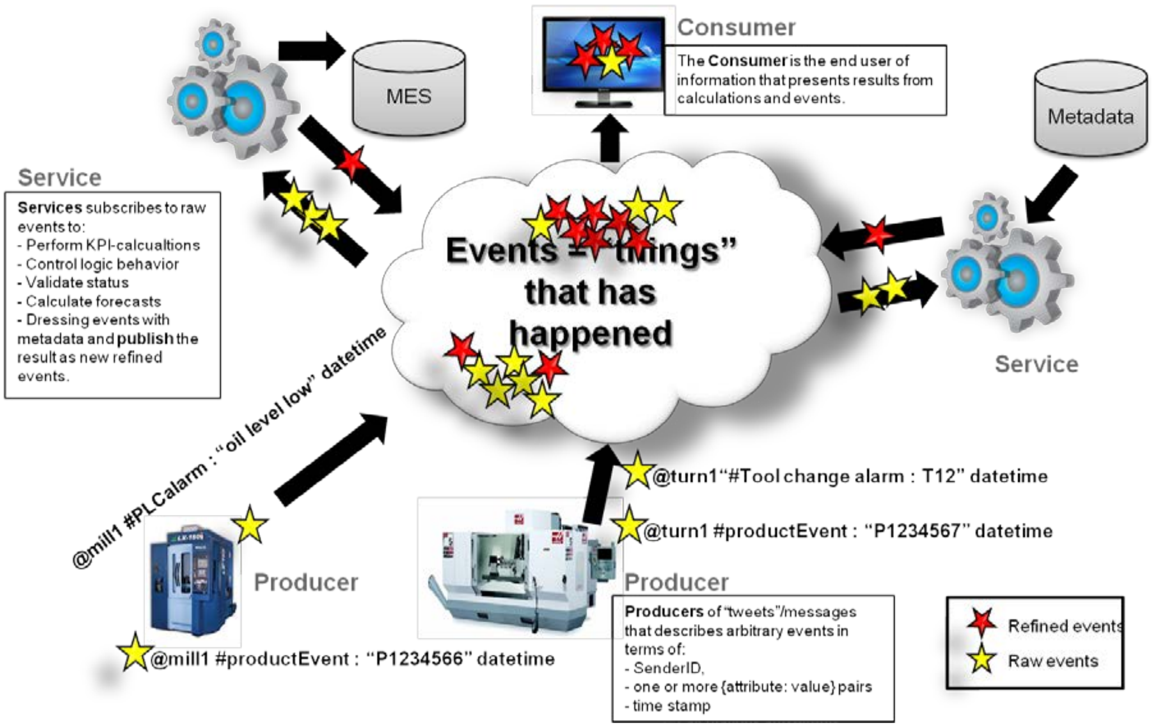

Figure 1 LISA tweeting factory.

2. Background

A hidden resource in the manufacturing industry is data. Recent investigations estimate that 85% of the data and information is still unstructured, 42% of all transactions (i.e. sending and receiving information) are still based on paper. And CEOs in the manufacturing industry claim “we need to do a better job capturing and understanding information rapidly in order to make sound business decisions”.

Future competitive industrial production systems need to use the data available in a much more elaborated way than they do today. Data should be transformed into information that can be used for making decisions. In addition, future sustainable competitive production systems need to be productive and flexible as well as environmentally friendly and safe for the personnel. In order to obtain this, improved control, optimization and human interaction of manufacturing processes are needed. In addition, efficient IT system support for reduced waste of material, capital, energy and media is necessary. The common denominator is the increased need for strategic data management. A prerequisite for strategic data management is a standardized generic information system architecture – in principle missing in the automotive industry today.

3. Objective

The general goal of the project was to develop a line information system architecture – LISA that can be used in automotive production. A system architecture can be thought of as:

- a formal description of a system and its software and hardware components
- relationships and generic interfaces between the different components
- functions and activities performed by the involved components
- principles and guidelines for the design and evolution of these components
- data transformed to information for making decisions on relevant system components during the whole life cycle.

4. Project realization

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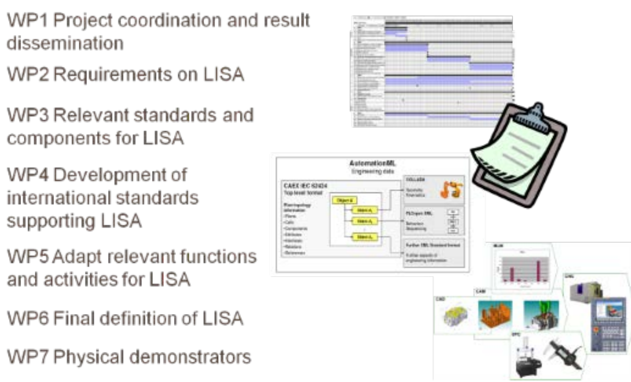

Figure 2 LISA WPs.

The project time was 2011-10-01 – 2014-09-30.

5. Results and deliverables

5.1 Delivery to FFI-goals

Efficient production planning, commissioning and verification of automated equipment **Goal:** **Tools and systems giving shorter lead times and faster production ramp-ups while optimizing of automation solutions by better possibilities for comparisons and evaluations.** **Desired effect:** **Automation solutions attaining a higher degree of thoroughness and expediency at shorter time and with less resources.**

LISA is an event-driven architecture that provides loose coupling of applications and devices, as well as a flexible message structure for integration. The core components of LISA are the message bus, the LISA message format and communication and service endpoints. They enable creation and transformation of events into usable information in a loosely coupled way. When something happens, for example, when a machine changes state, a LISA event with information about the change is sent. It is important with a standardized, structured, and generic concept to describe and implement loosely coupled software applications that are heterogeneous, disparate, and deployed and run independently. LISA uses an enterprise service bus (ESB), a component that takes care of message routing between distributed applications.

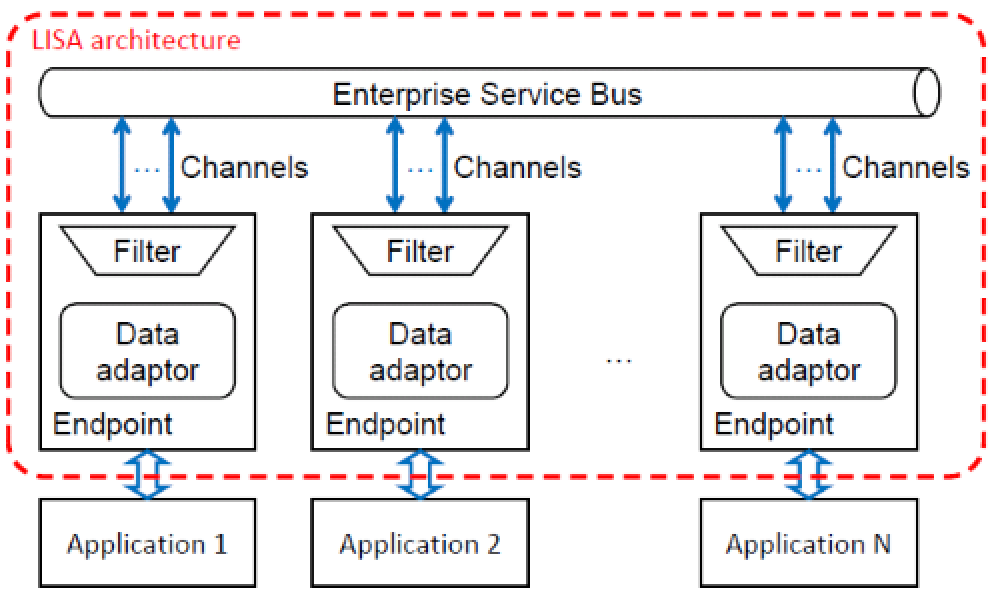

Figure 3 Overview of the LISA communication architecture.

Many devices have limited capabilities and information and they communicate with different device specific protocols and interfaces, for example, OPC or RS-232. To replace all production equipment with new devices which all support the same specific protocol and interface is unfeasible. Instead, the diversity of devices has been embraced. In LISA, devices are integrated with communication endpoints. A communication endpoint is an adapter between a device and the ESB. Device event data are converted to the LISA message format and are published on ESB channels. Similarly, the communication endpoint filters events and converts and communicates event data to the device. If a device is modified or replaced, only the corresponding communication endpoint needs to be updated.

An example of an endpoint that was developed in the LISA project is the MTConnect endpoint for communication with a CNC machining center.

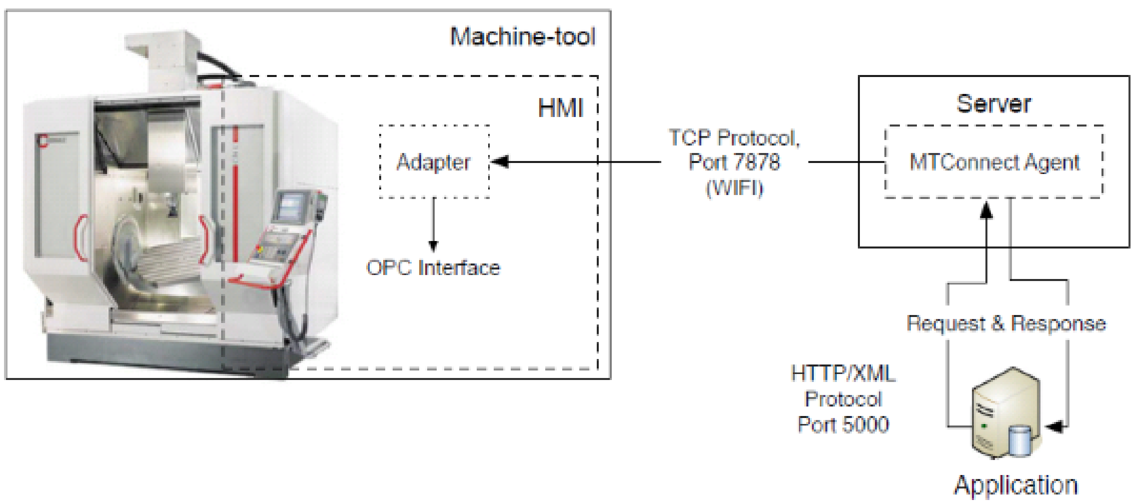

Figure 4 MTConnect demo-setup in the KTH XPRES lab.

Sustainable systems for automated manufacturing **Goal:** **Energy efficient and flexible manufacturing systems reusable by modularized and programmable equipment.** **Desired effects:** **Ability to manage an increased variation in volume and product variants without increased cost.** **Automation equipment with reduced total energy consumption.** **Product changes with short lead time by programming rather than hardware changes.**
Aims of the LISA project were to investigate and adapt relevant standards and components for LISA as well as to be involved in the development of new international standards that supported the formulation of LISA. Standards offer harmonized terminology with the objective to improve communication. Hence, different terms for the same thing or the same term for different things are avoided. Standards also offer concepts to facilitate design and operation of industrial manufacturing systems. Members of the LISA team actively participated in development of new international standards to guarantee that the automotive manufacturer's perspective was taken into account. The standards developed were: • IEC 62264, Enterprise-control system integration (international version of ISA95) • ISO 22400, Key performance indicators (KPIs) for manufacturing operations management (in ISO TC 184/SC 5/WG 9) • ISO 20140, Evaluation of energy efficiency and other factors of environmental influence for manufacturing system (in in ISO TC 184/SC 5/WG 10).
User-friendly man-machine communication and adaptive control systems for automated manufacturing **Goal:** **Automation systems that can be configured and managed without expert competence.** **Desired effects:** **Manage a higher degree of production changes with own staff only** **Equipment requiring a lower degree of previous knowledge** **Standardized user interfaces usable in various automation solutions** **Standardized and modularized information systems allowing development over time and easily reconfigurable to meet changed requirements on the production system.**
New functionality for production planning and maintenance based on formal methods and optimization as well as for sequential control in previously developed open source software tools (Chalmers' Sequence Planner and LTH's JGrafchart) were demonstrated by interfacing with LISA. Control with LISA was evaluated on a system consisting of a real PLC connected to a physical system, a CNC machine, and an order system, each connected through a communication endpoint. The CNC machine was connected via MTConnect, the PLC

system via OPC, JGrafchart was connected via SocketIO, and the order system was a mockup. In the OPC endpoint, all writable variables generated an event when they changed, which ensured acknowledgments for write requests.

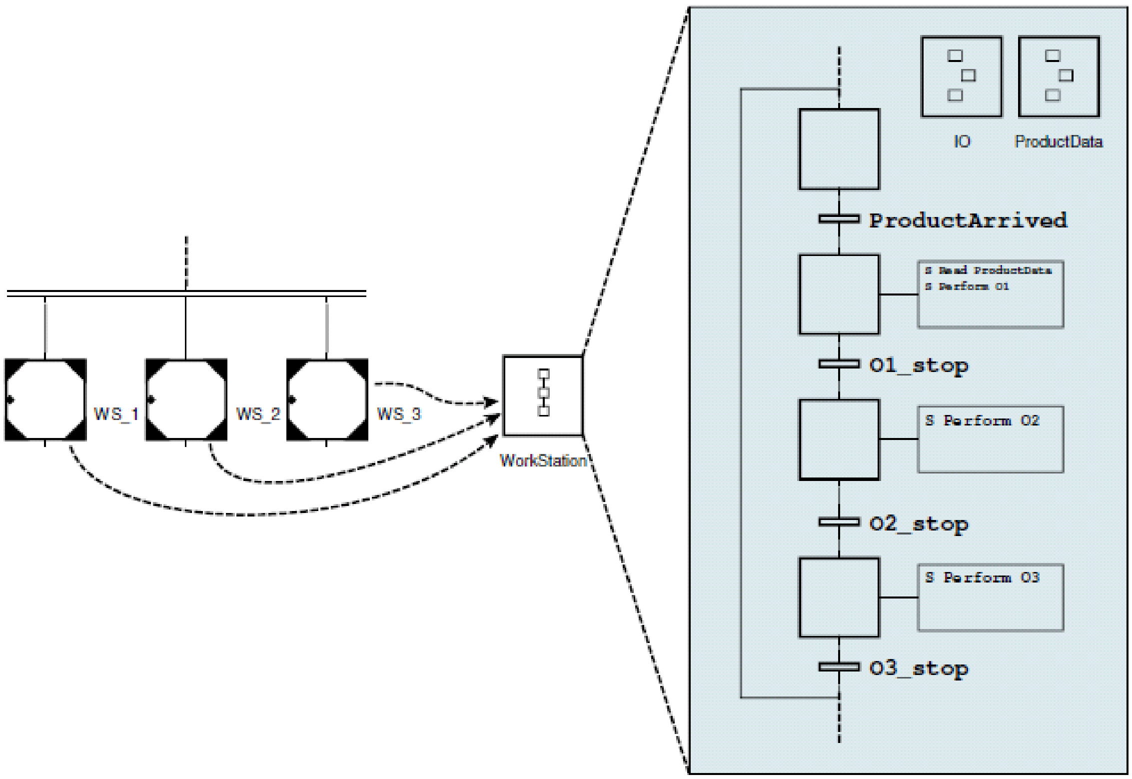

Figure 5 Control with LISA using JGraphchart developed at LTH.

Results generalizable to other manufacturing industries

Great emphasize was put in developing the common tweeting factory demonstrator at Chalmers and KTH.

At Chalmers the focus is on sequence control of automatic assembly operations and at KTH on monitoring of and decision support for machining operations.

Figure 6 Members of the LISA team working with the demonstrator in Chalmers PS lab.

Volvo Car Corporation is using LISA in their new body-in-white plant in Torslanda.

At Scania in Södertälje an engine block line has been modeled based on ISA 95 resource models and attributes using UML for KPI evaluation in a LISA environment. Real production events from Scania was also used to feed the LISA tweeting factory demonstrator with data.

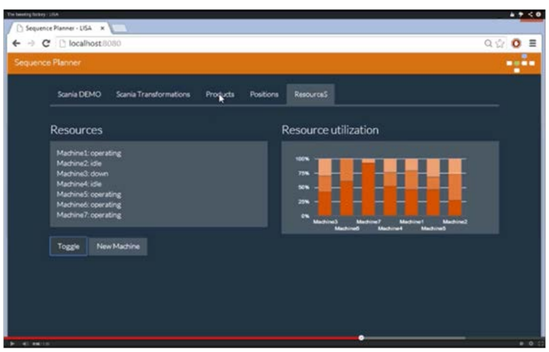

Figure 7 Online KPIs for machine availability.

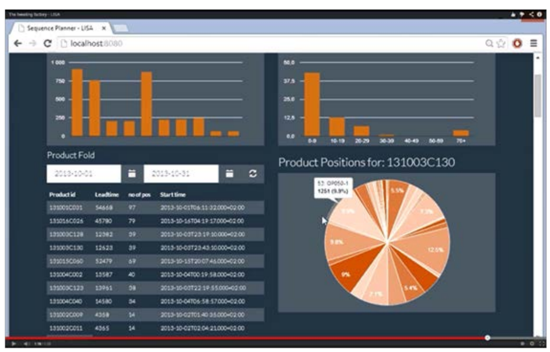

Figure 8 Online KPIs for product lead time (top) and time spent at each position for a single product (bottom).

LISA has been developed with the objective to be industrially applicable. It is to a large extent based on international standards and established off-the-shelf solutions, for example, ActiveMQ. It has been shown to be applicable for discrete manufacturing, for example in the automotive industry, where processes are running asynchronously and the product flow is non-linear. One core aim of LISA is that it should be usable for any device and application. To confirm interoperability, various industrial devices and software have been used in the demonstrator. Involvement of several industrial partners provided valuable feedback on the applicability of the research and permitted evaluation of the architecture. As a result, LISA is an event-based service-oriented architecture which offers flexibility and scalability both for control of low-level applications and aggregation of higher level information, such as KPIs.

The results of the LISA project are doubtless generalizable to other manufacturing industries.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The results in terms of the LISA demonstrator have been presented to the industrial partners. In the proposed FFI LISA[2] project mentioned below, an alignment with the German Industrie 4.0 initiative is planned. It is also possible to directly establish collaborative activities with the Industrie 4.0 organization and this is envisaged to give good opportunities for broader result dissemination, especially in professional media.

6.2 Publications

Provost, J., Fasth, Å., Stahre, J., Lennartson, B., Fabian, M., 2012,Planning in assembly systems – a common modeling for products and resources, IEEE 17th Conference on Emerging Technologies & Factory Automation (ETFA 2012), Krakow, Poland.

Lundholm, T., Lieder, M, Rumpel, G., 2012, Resource efficiency assessment system, 19th CIRP Conference on Life Cycle Engineering (LCE 2012), 23-25 May 2012, Berkeley, USA.

Ollinger L., Zuhlke, D., Theorin A., Johnsson C., 2013, A Reference Architecture for Service-oriented Control Procedures and its Implementation with SysML and Grafchart, Emerging Technology and Factory Automation (ETFA) conference, Cagliari, Italy, September 10-13 2013.

Lieder, M., 2014, Integrated evaluation of resource efficiency and cost effectiveness in production systems, Licentiate thesis, KTH Royal Institute of Technology, Stockholm, Sweden, ISBN 978-91-7595-100-3.

Theorin, A., 2014, A Sequential Control Language for Industrial Automation, PhD thesis, Lund University, Lund, Sweden, ISBN 978-91-7623-110-4.

Submitted:

Theorin, A., Bengtsson, K., Provost, J., Lieder, M., Johnsson, C. Lundholm, T., Lennartson, B. “An Event-Driven Manufacturing Information System Architecture”, 2015 IFAC Symposium on Information Control in Manufacturing (INCOM 2015), invited session on "Towards Industry 4.0 – taking the next step in realizing cyber-physical productions systems", Ottawa, Canada, May 11-13, 2015.

7. Conclusions and future research

Although LISA has also preliminary investigated the transformation of data in meaningful information and related visualization, a full industrial implementation was well out of the scope of such a project and became the main inspiration for a $LISA^2$ proposal. In order to leverage on the LISA nearly unprecedented possibility for flexible collection and communication of data, the consortium will develop and implement a series of engineering and production services, customized for specific industrial needs. Those services will include, but not be limited to:

- production performance analysis, monitoring, optimization and visualization
- devices and MES control
- fast integration and configuration of automation component.

In a first phase, the LISA platform will be implemented in different labs and real production facilities including machine tools, industrial robots, transfer lines and several ICT infrastructures used by the industrial partners. This will set the scene for the case-specific definition of the services that will then be developed. The developed services should be:

- Compliant with the international and industrial standards in use in the automotive sector (where defined and available).
- Self-contained. Interfacing only with the defined sources and visualization access points and including all the necessary algorithms and historical databases. This assures that the services are general purpose and allows transferability and reusability.
- Combinable. The service level of granularity, as well as the scope can be enhanced by aggregating simpler services into complex ones (e.g. $\sum$ machine utilization = line utilization).

Finally, given the highly applied orientation of the initiative, $LISA^2$ will produce a set of demonstrators, both in industry and academia, to validate the practical embodiment of the services produced and the knowledge enhancement in the road towards production cyber-physical system enabling fast integration, reconfigurability and scalability of automatic production resources. The results are expected to be of very large significance for OEM as well as suppliers in Sweden in respect of efficient as well as appropriate information handling.

8. Participating parties and contact person

Figure 9 LISA partners

The project partners are listed below.

- Academic: KTH Royal Institute of Technology, Chalmers University of Technology and Lund University, Faculty of Engineering LTH
- Automotive: Scania and Volvo Car Corporation

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