Deliverable 6.1: Cross Domain Demonstrator design and specification

CREATE

Creating Evolution Capable Co-operating Applications in Industrial Automation

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Project number:	ITEA 2 ip10020
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Date:	30.10.2013
Document version no.:	*0.4*

Revision History

Date	Version	Description	Author
10.10.2013	0.0	Basic template for partners to add their contributions.	Fernando Perales (TRIMEK)
18.10.2013	0.1	Contribution from Dutch consortium	Anastasios Martidis (TIE)
22.10.2013	0.2	Contribution from Spanish consortium	Fernando Perales (TRIMEK)and Silvia de la Maza (Innovalia)
23.10.2013	0.3	Contribution from Swedish consortium	Peter Funk (MDH)
30.10.2013	0.4	Final Edition	Fernando Perales (TRIMEK)

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1. Introduction

The main objective of the CREATE project is the generation of a methodology that enables the customization of the production line depending on the product and market requirements. So far, it has been developed three different use cases following the CREATE architecture. In this document, we will define the requirements and specifications to implement a new demonstrator that integrates tools and solutions from them: flexible material flow, industrial metrology and monitoring, quality control and diagnosis.

The generation of a new proof-of-concept based on existing solutions represent the core philosophy of the CREATE project. It is not necessary to develop or buy new solutions each time the production line needs some adjustment. The modularization of the tools allows the companies to implement the configuration that maximize the productivity of the lines.

This Cross Domain Demonstrator (CDD) will exploit the main properties of the previous industrial cases:

i. From the Flexible material flow, the TIE SmartBridge: Exploiting the communication between modules due to the capabilities to translate data formats and languages.

ii. From the industrial metrology, the virtual metrology concept and the customization of the 3D scanning equipment depending of the product and production line requirements.

From the Monitoring, quality control and diagnosis, the decisions support system reusing real cases from the production line and able to learn and improve, will be included.

Finally, all these solutions will be controlled and accessible via a common user interface that allow to the workers and managers, depending on their user profile and security rules, access to the information, visualize the evolution of the line and take the adequate decisions.

Overall, the result of this work is another industrial case, fitting the CREATE architecture, that is developed from the tools and solutions created beforehand. The main properties of the CREATE methodology that enables this, are: modularization, flexibility, interoperability, easy to use and set.

2. CREATE architecture/methodology

The architecture implemented in the CDD will be the same like the other industrial cases. It is divided in physical objects, services and resources, knowledge base, service front-end and cloud/service oriented infrastructure. (Figure 1)

Figure 1: CREATE architecture

From this general architecture, the automation pyramid (Figure 2) can be customized in order to meet all the functionalities that will be shown in this demonstrator. In this case:

- **Sensor level**: It will be used 3D optical scanning to get information from the manufactured pieces and other measurements from the fixturing.

- **Device level**: Robots to move and locate the optical sensor in the adequate orientation to scan.

- **Control level**: Communication protocols to enable synchronization between sensors and robots; TIE SmartBridge to communicate different data sources. Besides,

metrology SW to get information from the raw data and the monitoring, quality and diagnosis module (MQD) to provide suggested reactive actions.

- **Enterprise level**: CREATE portal, to control and monitor all the modules and the information processed in each of them.
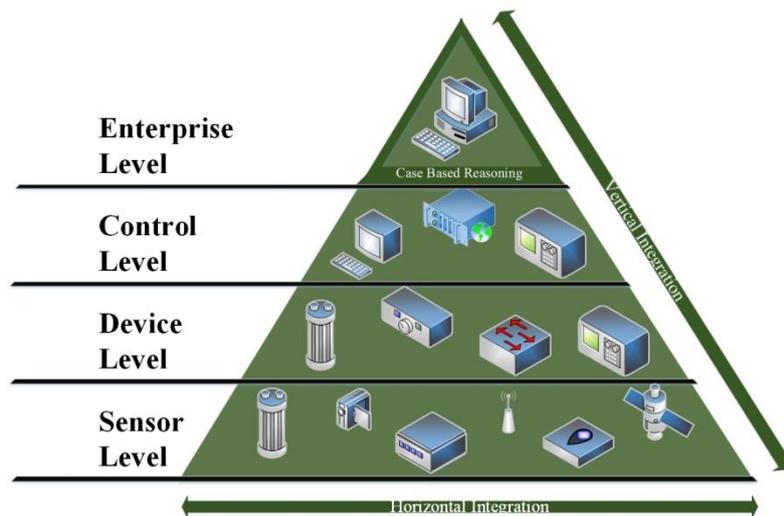

Figure 2: Automation pyramid

3. Vision of CDD, *business scenario* for the implementation

3.1 Business scenario and added value

The business scenario behind the Cross Domain Demonstrator (CDD) starts from the Volvo Car Corporation manufacturing cell. Different components can be added in the production system in a plug and play approach because the system is able of integrating variety of components exchanging messages in diverse formats. Users, that can be operators, production managers and system administrators, interact with the system via an intuitive and interactive GUI that can be accessed from any device equipped with a Web browser.

The CREATE approach as will be demonstrated in the CDD scenario brings value to production lines and industrial systems that adopt its architecture, on specific and crucial areas,

- *Increased control*: Assembly lines in manufacturing cells, are better controlled and monitored

- *Simulations of hardware*: Production components are transferred to virtual world with scans and visualization of the scanned parts providing capabilities for simulations of the hardware.

- *Decision support*: Information from the assembly lines is used to optimize production processes along with artificial intelligence algorithms providing technicians with input for decision making support

- *Visually rich, intuitive interaction*: user centred GUI, visually expressive, for interacting with the system in the manufacturing cell

3.2 CDD implementation with CREATE method

The CREATE method already demonstrates its value and potential when applied in the national demonstrators. The Cross Domain Demonstrator will also implement the CREATE architecture, exposing smart sensors, diagnostic, and metrology devices to the virtual world as web services. These web services are available through an ESB and are used by human operators, production managers and administrators through interaction with a friendly user interface. Users can make use of the information from the manufacturing cell thanks to artificial intelligence applications such as Virtual Metrology and Case Based Reasoning (CBR) that turns dimensional data from 3D optical sensors and other devices in the fixturing into knowledge and valuable input, assisting the decision making process in the assembly lines.

The Cross Domain Demonstrator (CDD) starts from the Volvo C.C. manufacturing cell. The advances in the assembly lines are focused on the positioning of shims in the gore of the car. During assembly, adjustments are necessary to compensate the variation of the ingoing parts in order to reach the specification demands on the final sub assembly, the gore. In order to do that optimal for human operators, they need years of expertise but it is still an error prone process. In the CDD, human operators are assisted by measurement sensors, virtual parts, diagnostic devices such as the SEMA-TEC SAC (Sensor Actuator Component) module and CBR applications of the generated data in the Monitoring, Diagnostics and Quality Control (MQD) module. Then, the final product is completely digitalized by the 3D optical scanning system and measured applying the virtual metrology (i.e. measure the geometries in the virtual part, instead of in the physical one).

The production system in Volvo manufacturing cell, for the CDD, is going to be enhanced by components from the other use cases such as from the Industrial Metrology use case where **metrology hardware and software** are used to scan the components, get the reports with the planned measurements and communicate the information to MQD module and the GUI for 3D and 2D visualization. From the flexible Material Flow the ESB that serves as a backbone for the communication of the components (**TIE SmartBridge**) is used, performing mappings from the DMIS format that the diagnostics and metrology devices produce, to XML that **MQD** module is understanding, as well as the **CREATE portal**; the GUI with which users

interact, entering information, using it to receive adjustment proposals from MQD and see visualization of scanned parts and other measurements from the manufacturing cell. (Figure 3)
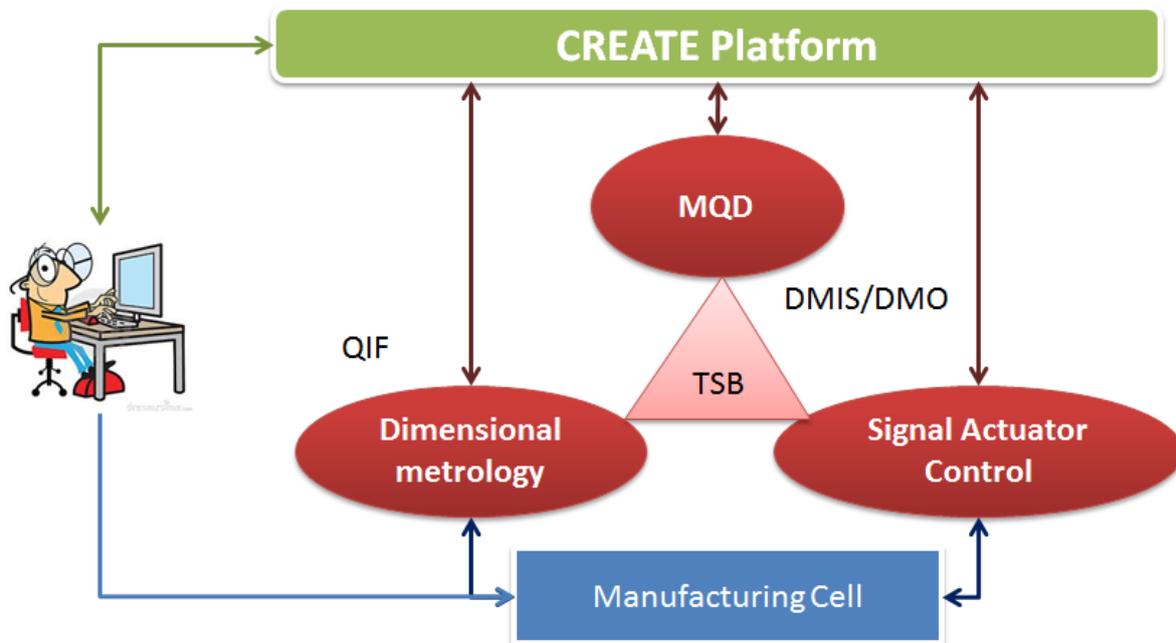

Figure 3 CDD business scenario

4. Components of the CDD

4.1 Modules from Flexible Material Flow demonstrator

a. TIE SmartBridge (TSB)

TIE SmartBridge (TSB) is a message exchanging platform that works efficiently with a variety of formats. TSB transports messages from a source point to its destination, performing the adequate message transformations and routing. TSB is a core Enterprise Service Bus (ESB), designed with constraints that benefit throughput and reliability. TSB efficiently accommodates systems with:

- Built-in message transformation
- High security
- Support of distributed workflows
- High fault tolerance
- High throughput/performance

- Orchestration, choreography
- Extendable connectivity

From a technical standpoint, TSB brings value by providing functionalities such as:

Application Integration: enabling the exchange of messages, to and from back end applications through the Web. Serving as the backbone of systems architecture, it integrates physically distributed components in a logically centralized approach. TSB offers monitoring of the message exchange status via acknowledgments, status and process messages.

Data Transformation: TSB supports a number of message formats including UN/EDIFACT, ANSI/ X12, GENCOD, VDA, CARGOIMP, ODETTE, TRADACOMS, and XML. The numerous supported formats can be exchanged through TSB as well as apply mappings of the data transforming from one format to the other, along with the TIE SMartIntegrator (TSI).

Partner Communication: TSB routes messages from the back-end application to external partners, and vice-versa. It also integrates with various VANs, including FreeConnect, GXS, IBM Information Exchange, X400/P7 mailbox systems, InterCommIT Go-secure and IPmail XS. TSB uses several Communication Modules (e.g. SMTP, FTP/S, File System I/O).

Alerts: TSB notifies administrators or the message's senders with alerts send via emails with errors that occurred during communication and message processing. The messages can be sent to multiple e-mail addresses based on the type of the error (e.g. the frequency of the error). Users are able to configure the alert level that will cause an alert message to be sent.
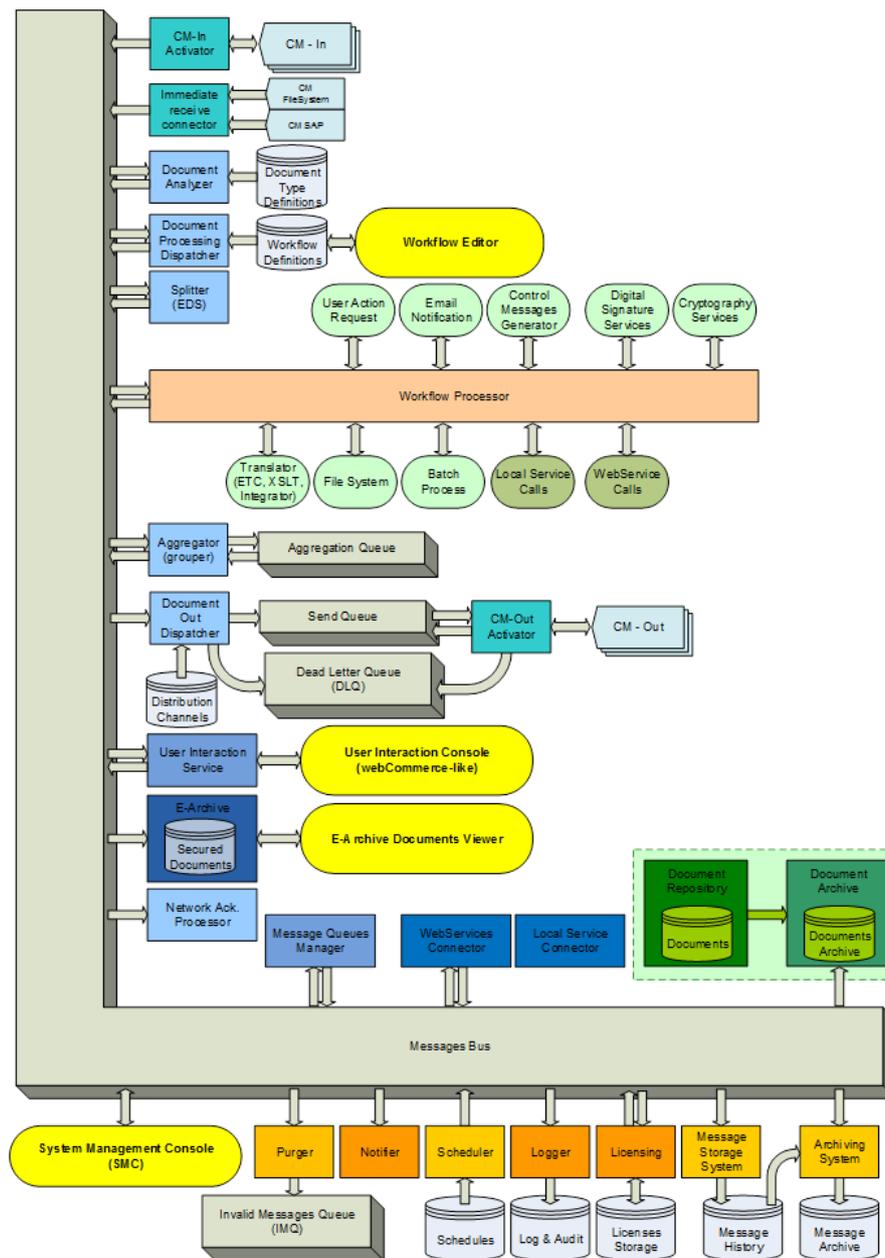
Figure 4: TIE SmartBridge (TSB) architecture

Role in the CDD and interactions with other modules

TSB is the integrator of the components in the Cross Domain Demonstrator. Through TSB messages from the manufacturing cell, originating from various sources such as human operators (via GUI), smart sensors, diagnostic modules, and metrology devices will be communicated to the Monitoring and Quality Control (MQD) module and the CREATE portal. The ability of TSB to transport messages in various formats is crucial, since the components exchange heterogeneous messages and specifically messages including DMIS,

XML and Excel formats. TSB is communicating with practically all components of the Cross Domain Demonstrator, integrating the different modules, from the operators input in Excel sheets, the diagnostic and metrology measurements in DMIS format, the interaction with the MQD module and the CREATE portal with XML. TSB serves as the backbone of the Cross Domain Demonstrator, playing the role of ESB as defined in the CREATE architecture.

Functionalities to be shown

TSB in the Cross Domain Demonstrator is one of the pillars of CREATE architecture and will follow the functional and non-functional requirements as defined in the architecture. Specifically TSB in CDD will realize:

- The exchange of messages in various formats from the different components
- Reliable and real-time transportation as required by the production processes
- Definition of workflows by the user and operation according to them
- Transformation between the various message formats, assisted by the TIE SmartIntegrator (TSI)

b. TIE SmartIntegrator (TSI)

TIE SmartIntegrator (TSI) facilitates and simplifies the mappings of different data/information schemas, employing a semantic mapping application that hides the complexity behind a user friendly, rich client application, useable by business analysts. TSI workbench can be used for mapping messages, e.g. EDI or XML to RDB, ontologies alignment, or the mappings of information schemas of different type of repositories. In the Cross Domain Demonstrator (CDD), TSI will be used to perform mappings on the diverse information schemas/formats of the various components, such as DMIS to XML, Excel to XML, etc.

The mapping of information schemas with TSI has the following workflow:

1. Import schema information ("Your schema")
2. Identify semantic entities ("Your semantics")
3. Share information in a semantic space ("Repository")
4. Map semantic entities to each other ("Semantic link")
5. Generate mapping file, compatible with a data transformation tool of your choice ("Maps")
6. Deployment of the generated mapping file into data transformation engine of choice
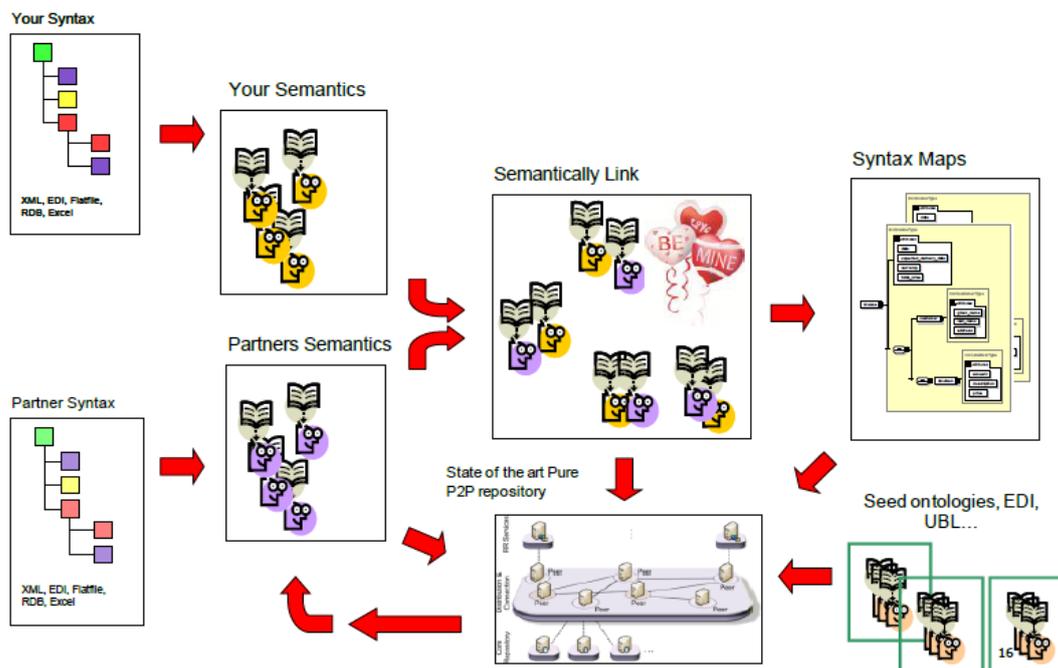
Figure 5: Mapping data schemas with TSI

Import schema information: Users import their schemas, in the format they exist in their systems. TSI then automatically translates them into a content neutral format called, Stasis Neutral Format (SNF). When the information schema is in SNF format, can be read, manipulated, analysed and reasoned using semantic web based applications.

Identify semantic entities: TSI instead on focusing on traditional syntactic mappings, employs identification of semantic entities and maps them. Users can define from TSI the so-called Semantic Entities (SSEs) which represent specific elements with a semantic meaning. Users through a friendly GUI can define syntax elements from their schema files as SSEs and perform the most crucial/complex mappings themselves to ensure the validity of the schema mappings. Moreover, from the GUI they can add Methlets to their mappings which represent functions between the mappings of elements that users can insert, such as logical expressions, concatenations and basically any type of logic the user wants to apply while transforming specific schema elements.

Share information in semantic space: All elements created by TSI are stored and managed in a semantic repository which provides end point with a support of a semantic query language SPARQL. The common semantic space for OWL based elements allows users to share semantic information with each other in a scalable network. The usage of a standards aware semantic end point gives TSI another significant advantage over traditional mapping creation tools as TSI participants may reuse semantic entities, mappings or schema

definitions. It allows TSI to make mapping suggestions by reusing mapping information from earlier semantic links.

Map semantic entities to each other and **Generate Mapping File:** At this point users have transformed their schemas into the SNF format as well as transformation of the end result format into SNF. They performed mappings manually using the GUI or using the TSI suggestions or a combination of both. Now they can generate the mapping file which will be used to map the actual data from one schema to another and can from now on be used to transform data between files with between these mapped schemas.

Deployment of mapping files on a transformation engine of your choice: This is the final step of the process. The current development taken under OPDM project allows users to generate mapping files compatible with TIE Integrator and deploy them on an instance of Integrator that run as a software service (SaaS). Due to the internal representation of mapping files and extendable, pluggable nature of TSI workbench in order to make a new exporter (e.g. for new type of mapping files compatible with other transformation engines) it is necessary to implement specified software interfaces and deploy a new implementation into TSI client.

Role in the CDD and interactions with other modules

In the Cross Domain Demonstrator, different components come together and need to communicate with each other. TIE SmartBridge (TSB) is able to transfer the diverse message formats, but it is with use of TSI that provides flexibility and easy introduction of new components in the system. The diagnostic and mechatronic devices generate information in DMIS format and will send them to MQD module through TSB. With TSI the information will be mapped to RDB and will be ready to be hosted to the databases maintained by the MQD module with no effort from MQD, the diagnostic device or the mechatronic sensor. Moreover, the input from operators that is entered in excel sheets will be transformed to RDB as well. In a nutshell, TSI will allow components to share their information "as is" and will make sure the recipients will understand and will be able to use the information.

Functionalities to be shown

TSI will contribute to the transformation between the various information schemas of the components that exist in the Cross Domain Demonstrator. The functionalities to show are:

- Transformation of DMIS schemas to RDB or XML
- Transformation of Excel sheets to RDB or XML
- Any other transformation between schemas that may occur from new components in the CDD

c.   CREATE portal

CREATE portal is an easy to use GUI, developed in a user centred design, with numerous graphs and charts for visualization of data and intuitive interaction workflows. CREATE portal can be accessed from any device that is equipped with a web browser such as tablets, smartphones and laptops/PCs. The portal acts as an entrance point and as a visually rich interaction panel for consuming services available in the CREATE platform.

The CREATE portal is composed by workspaces implemented as widgets in a well-structured user friendly interface that is highly customizable. CREATE portal can be used from different users (roles) with different privileges in the manufacturing cell and for different users can customize different widgets with different functionalities. These widgets will be hosted in Apache Rave which is an open source mashup engine and widgets will be developed using HTML5, CSS and JavaScript. Moreover, libraries for 3D and 2D visualizations of information from the manufacturing cell such as scans of parts. A depiction of how CREATE portal looks for the Flexible Material Flow demonstrator is shown below:
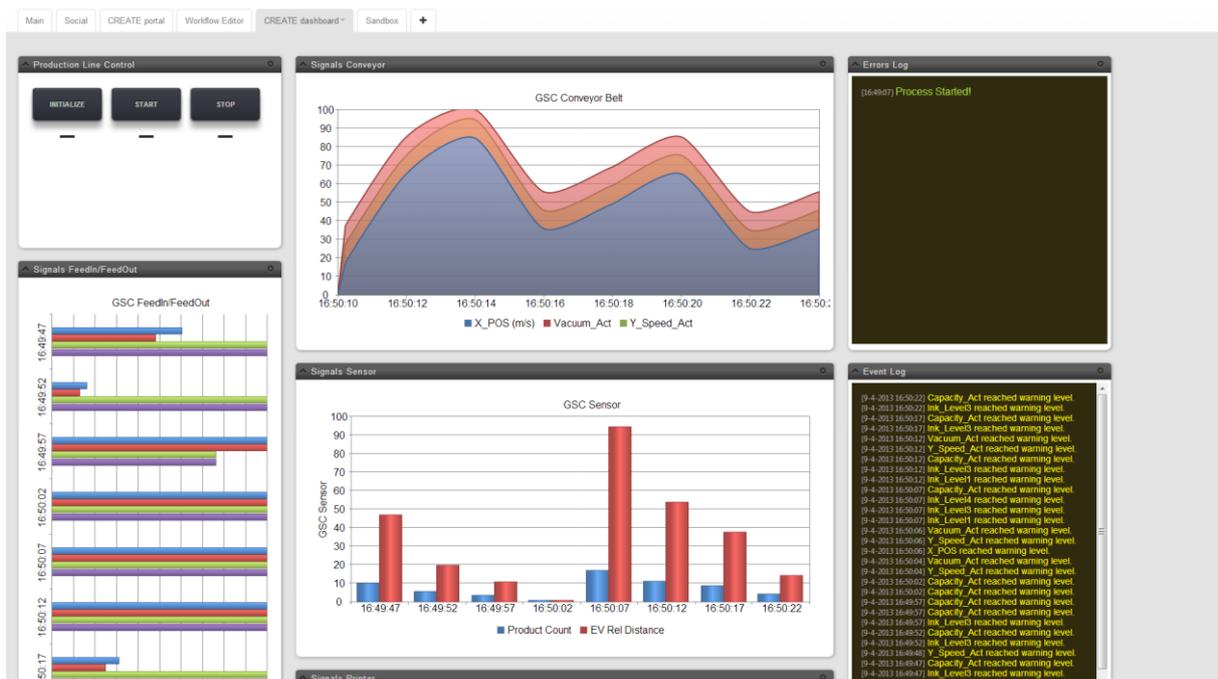

Figure 6: CREATE portal dashboard

Role in the CDD and interactions with other modules

CREATE portal is the interface between users and the CREATE system in the manufacturing cell for the Cross Domain Demonstrator. Users such as operators, managers, administrators will use CREATE portal:

- For visualization of data originating from the manufacturing cell such as virtual scans of parts
- To enter information from production and send to MQD module (e.g. fixture s)
- To get the results of Cased Based Reasoning (CBR) applications for adjustment that improve production
- For management and administration of the MQD database for the CBR applications

Functionalities to be shown

CREATE portal and its use in the Cross Domain Demonstrator must show that it is intuitive in use and that its design is optimal for the workflows of its users in CREATE. It must show portability and be accessible for use from several devices equipped with browser. CREATE portal must be able to communicate with modules based on user interaction, in real time and respecting the processes and workflows that take place during production, so that it employing the CREATE approach provides only enhancements without requiring further training for users of the CREATE platform.

4.2 Modules from Industrial Metrology demonstrator

a. Virtual Metrology

Short description

The virtual metrology module enables a high increase in the knowledge generated from the dimensional quality control. The HW part is based on a 3D optical scanning coupled in a robot; the SW component allows the scanning of the piece, the data acquisition and the processing of the pointcloud, generating the final measurements according a measuring plan.

The main advantage of this approach is that once the part is digitalized, the user does not need it anymore. All the measurements are made in its digital version whenever required, even in the far future, if some critical defect is detected, the user can access to past samples and monitor the evolution of this geometrical feature.

Furthermore, the CREATE methodology has improved these benefits by modularizing the components and increasing the communication and interoperability properties. In this way, the dimensional metrology system can be completely customized depending on both the production (product shape and size, production rate, etc…) and market requirements (new standards).
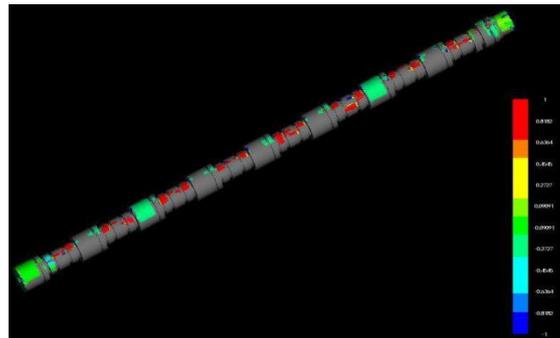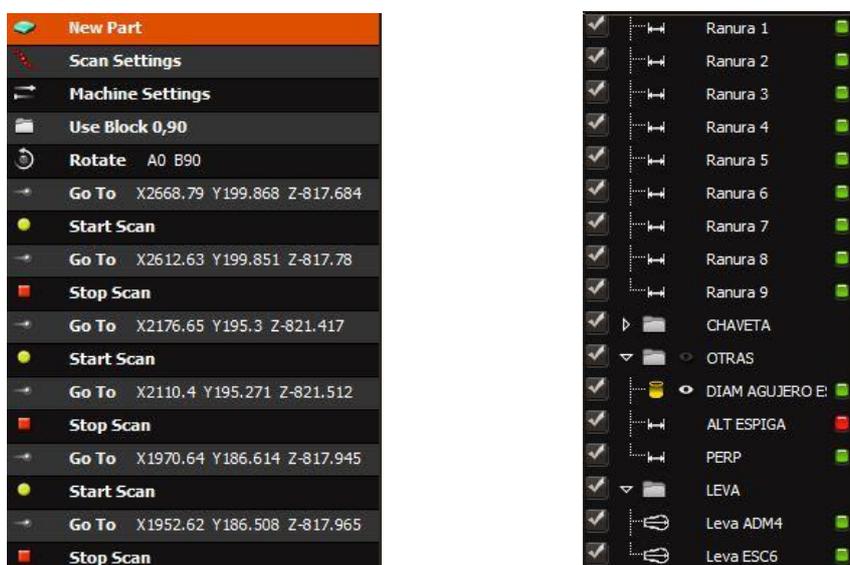
Figure 7: Virtual part compared to the CAD model

Figure 8: Scanning (left) and measuring plan (right)

Role in the CDD and interactions with other modules

Virtual metrology module will represent the main data source for the quality control of the Volvo case. Firstly, this system will scan the final product manufactured (bumpers), generating the virtual parts. Then, based on the measuring plan, the dimensional features and geometries will be calculated and compared to the maximum and minimum tolerances. This information will be shared in QIF standard. Secondly, these results will be send to the other modules, such as MQD to provide inputs based on real information to generate reactive actions to correct the detected deviations.

Functionalities to be shown

Scalability: The virtual metrology module has been developed following a modular philosophy. For example, the DataAssembler is a single module that can be used for each robot-sensor set up used in the line. Moreover, the metrology SW can process pointcloud

independently of the technology used in the acquisition. This property generates the capability of design the dimensional quality control based on the production line requirements, instead of the metrology system particularities.

Customization: This system enables the customization of the HW and SW. In the HW side, a wide variety of sensors (optical and tactile) and robots (articulated, CMM) can be selected in order to meet the production requirements, so the metrology system is highly flexible. In the SW side, both the measuring and scanning plans can be programmed depending on the product properties, optimizing scanning time and data processing resources.

Communication/Interoperability: This module shows the capability of the metrology software to communicate with the sensors and robots. In this way, scanning plans can be programmed easily from a single user interface.

Synchronization: Data acquired from the sensors and the robots must be synchronized to obtain a single pointcloud with no deviations from the real part.

Standardization: The data and information generated by this multi-module will be standardized following the Quality Information Framework (QIF).

4.3 Modules from Monitoring, Quality control and diagnosis demonstrator

a. MQD Case-Based Decision Support Module

Flexible integration of intelligence and decision support in the area of monitoring, quality control and diagnosis into production lines will enable manufacturing industry to become more cost effective and more competitive manly by:

- Flexible transition between human tasks and semi automated tasks
- Fast setup of new MQD-modules in new production lines
- Collecting and reusing experience enabling faster correction and preventive actions.

The MQD module at Volvo Car Corporation implements artificial intelligence methods and techniques in order to enable efficient decision support based on learning and experience reuse.
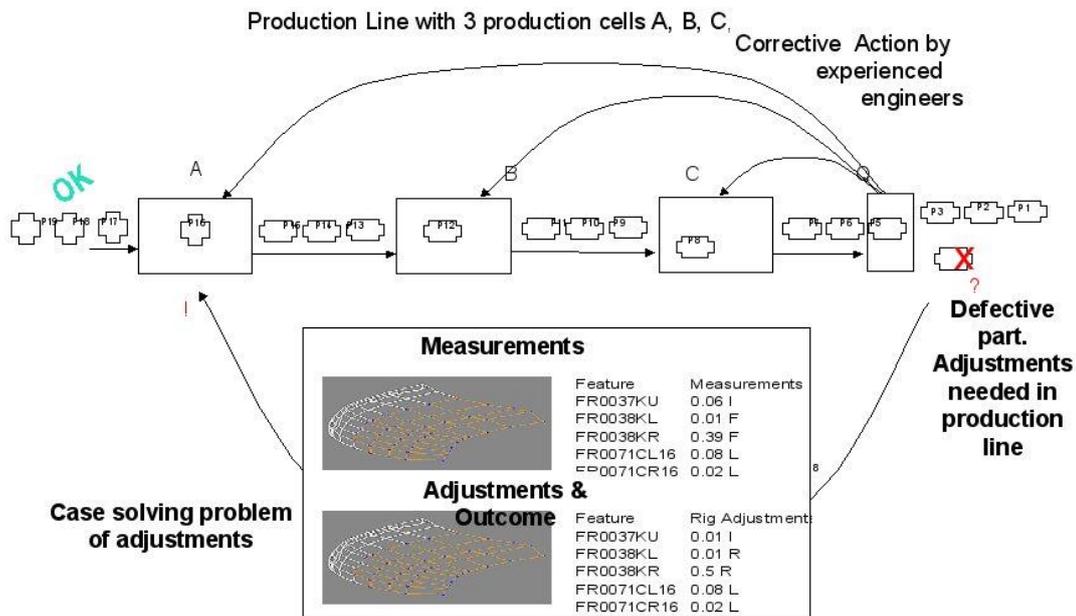
Figure 9: Example of how cases can be used in a production line.

Today experienced technician know what to change in previous production cells if a part does not meet the requirements. Experience often gained through trial and error since manufacturing processes.

The advantages of case-based reasoning include simplicity, easy understanding, good explanation, as well as the ability to survive with a small number of cases.

- The MQD module is able to learn from human experience and every new solved case will improve the performance of the system.

- The MQD module has been validated with 56 real cases and 70 reference cases.

- The MQD module has a generic methodology based on hybrid case-based reasoning that can be adapted to different MQD tasks.

- The MQD module can act as an intelligent agent making corrective action if safe (high confidence in the solution), otherwise involve humans in the decision process.
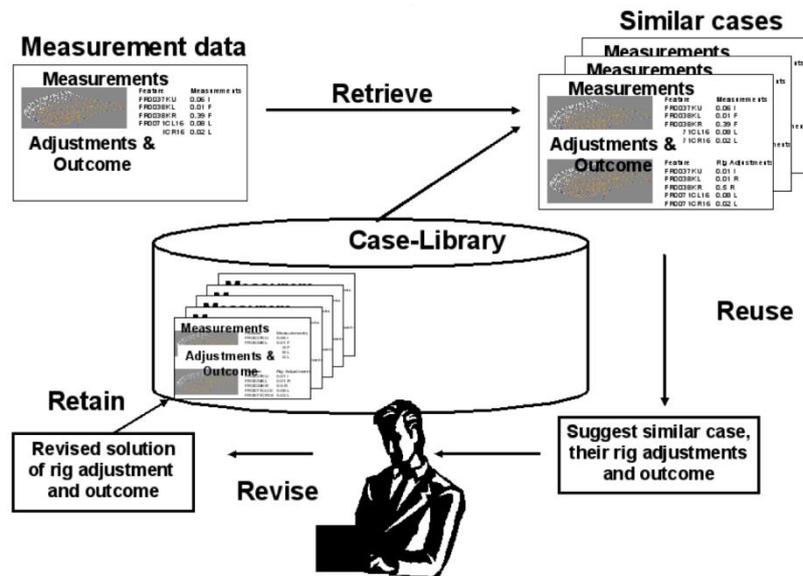
Figure 10: Illustration of the principals behind the MQD module.

Fault diagnosis and prognosis of industrial equipment become increasingly important for improving the quality of manufacturing and reducing the cost for product testing. This paper advocates that computer-based diagnosis systems can be built based on sensor information and by using case-based reasoning methodology. The intelligent signal analysis methods are outlined in this context. We then explain how case-based reasoning can be applied to support diagnosis tasks and four application examples are given as illustration. Further, discussions are made on how CBR systems can be integrated with machine learning techniques to enhance its performance in practical scenarios.

Role in the CDD and interactions with other modules

The roll of the MQD module in the CDD is central since it is an example how the modularity enables flexibility, cost reduction, easy reconfiguration of manufacturing and particularly in Monitoring, quality control and diagnostic. Learning "intelligent" decision support modules can be integrated in the CREATE architecture in a flexible way using the TSB and enabling different providers of decision support systems (DSS). It also gives an example of how the CREATE concept allows flexible transition between manual, semi automated and automated production. Initially the decision made on the monitoring may be performed manually, once enough cases have been collected then these cases can be used in a Case-Based DSS. If not enough past cases can be collected before activating the DSS then reference cases may be collected in advance before activating the system.

The MQD module will be a separate CREATE module that can be located by a service provider. The CREATE portal will be used to interact with the technicians and the MQD

module. The information will be transferred to the MySQL database by the TIE Smart bridge module. The MQD module can also easily be reconfigured to handle MQD tasks in different production lines. It will also be able to handle other input than dimensional data. TIE SmartIntegrator (TSI) will be used to integrate the dataformat used by the MQD module with external date from other sources (sensors) and in other format.

Functionalities to be shown

MQD in the Cross Domain Demonstrator is a key example on how flexibility and intelligence can be added using the CREATE architecture. Specifically MQD in CDD will realize:

- <u>Flexibility</u> between manual and semi-automated work. It shows how a tasks can migrate from manual monitoring, quality control and diagnosis to semi automated (using a decision support system continuously collecting experience and improving performance).

- <u>Learning and reconfigurable</u>, how a new production line can be configured to collect cases and after a short initiation activate semi-automated MQD.

- <u>Cost reduction</u> by experience reuse, showing how experience in the form of case can be collected and used to reduce time and effort when solving similar future problems. Technicians and engineers often say that if they would have access to past similar cases with diagnosis, and action taken (adjustments made, spare parts, etc) they would be able to save effort in the magnitude of 30%. Down time in manufacturing bears huge costs in lost revenue, reducing downtime with 30% would significantly reduce costs and environmental impact.

5. Conclusions

The CDD has been designed in order to show the main benefits of the CREATE project. The integration of already proved solution in the national demos in this one confirms that the modularization of components enables a high customization and flexibility in the manufacturing domain.

Each national demo contributes with the most representative module of its own demo. This selection covers all the main roles and solutions needed in every manufacturing line, from the manufacturer, to the data acquisition, data processing and decision support and the communication enabler to share all the data and information.

Moreover, one of the main strongest aspects is that this demo is also based on a real case, Volvo Car Components that manufactures bumpers. In this way, the results obtained from the evaluation of the CDD will be highly representative of the benefits that the CREATE project will provide to the manufacturing industry.