Model-driven Service Engineering Towards the Manufacturing Liquid-sensing Enterprise

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Abstract: Information and communication technology (ICT) has facilitated the introduction of mass customisation capabilities into the traditional Enterprise, especially in the domain of manufacturing. Currently individual end-customers are allowed to design and order a product that is uniquely tailored to their preferences. Servitization and product-based services have been gaining momentum to support the integration of products and services with customers. This has enabled companies to maintain a competitive advantage in contemporary markets. However, such capabilities demand more efficient processes, information systems to enable resources optimization, maximized collaborations along the value chains, and interoperable information flows. The FInES Research Roadmap 2025 identifies both Sensing Enterprise and Liquid Enterprise as two Qualities of Being that are strategic for any future enterprise. In fact, the enterprise needs to become self-aware not only in terms of their networked ecosystem but also in face of their inner sub-systems and devices. This paper develops the concept of the liquid-sensing enterprise, exploring how modelling and model-driven development can support the transition and services implementation.

1 INTRODUCTION

There are clear signs that Western countries, and Europe in particular, cannot proceed practicing ‘business as usual’. It is required a change of paradigm to maintain (and improve) the current standard of life (FInES Research Roadmap Task Force, 2012). In fact, the traditional view on manufacturing industry has always been associated with the physical transformation of materials and assembly of components to produce products. As a consequence, production processes, production machinery and the software to control such systems had been the focus so far. This represents an immense opportunity for Future Internet (FI) technologies (including IoT) to make an impact.

Nevertheless, in some cases, products are already morphing into services and products themselves are becoming platforms for services, leading to the creation of highly personalized markets to be exploited, which in turn demand restructuring value chains and changing the relationship with the customer. The companies mastering this scenario will excel, while enterprises anchored in traditional manufacturing values will suffer with more virulence the competition of BRIC countries (Baines et al., 2009).

Relying closely on the IoT, the new Web-based service economy will merge the digital and physical worlds opening up a multitude of niches and value propositions. Hence, we are in the verge of a digital transformation that needs to take place. Westerman et al. (2011) claim that industries are using digital advances such as analytics, social media and smart mbedded devices to improve their use of traditional technologies such as ERP, as well as to perfect customer relationships, internal processes, and value propositions. Indeed, enterprises are individually starting digital transformation addressing key areas of their enterprises, namely customer experience, operational processes and business models.

The Sensing Enterprise and Liquid Enterprise concepts envisioned in the FInES 2025 roadmap can complete that digital transformation, delivering to manufacturing industries across the various sectors the required enablers to connect and use FI technologies, customizing them to address customer

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experience, operational processes and business models. New envisaged services are based upon the convergence of networks, embedded computing, control, content, and sensor feedback. Although smart business systems can be described as an evolution of the IoT, the evolution of traditional enterprises into digital liquid or sensing enterprises represents a fundamental change in the business models that such enterprises will support and will be able to implement.

In this context, a model driven approach can be particularly valuable to support the formalization of the liquid-sensing enterprise based on the fact it uses enterprise models acknowledged by professionals and standard institutions. An approach such as the Model-driven Service Engineering Architecture (MDSEA) is a perfect candidate to help in the system re-engineering (Ducq et al., 2012). It can support the enterprise processes modelling towards the new sensing and liquid services design and implementation. In section 2, this paper introduces the liquid-sensing enterprise (LSE) concept in the scope of OSMOSE research project (www.osmose-project.eu). Then the authors analyse how the MDSEA architecture can be applied to the LSE (section 3), and section 4 presents the advancements on LSE modelling. Finally an example is included in section 5 and 6 concludes.

2 LIQUID-SENSING ENTERPRISE (LSE)

An enterprise is a complex artefact. ISO 15704 defines it as a set of one or more organisations sharing a specific mission, goals and objectives to offer a product or a service (ISO TC184/SC5, 2000). Its unique anatomy is composed of very different passive tangible and intangible elements, and active systems such as the Human or the artificial ICT components. However, with the evolution of business models and the growing of complexity, one must face the idea that humans should (will) no longer have a complete control over all the operations acting on the produced artefacts, gaining themselves a certain level of autonomy and awareness. This is naturally true also for enterprises, which need appropriate mechanisms to keep their systems stable and optimized.

Following this vision, also shared by the 2025 roadmap for Future Internet Enterprise Systems (FInES Research Roadmap Task Force, 2012), today's traditional engineering disciplines do not appear adequate. Systematic methods, based on advanced modelling techniques and model-driven development, are required to correctly address the activities carried out at the different phases of the operational dimension. For instance, Business Process Modelling and Management (Ko et al., 2009) need to be complemented by the autonomic capacity to react to unexpected events (e.g. through Complex Event Processing (Michelson, 2006)).

In this context, both Sensing Enterprise and Liquid Enterprise as two Qualities of Being that are strategic for any future enterprise. The **Liquid Enterprise** *refers to the blurring of the enterprise boundaries, where it is not easy to distinguish the 'inside' and the 'outside', the employees and the partners, the competitors and the collaborators. It is an enterprise having fuzzy boundaries, in terms of human resources, markets, products and processes.* The **Sensing Enterprise** is a complementary concept that emerges with the evolution of the Internet of Things (IoT). It *follows the need to decentralise intelligence, moving to a scenario where the enterprise is seen as a smart complex entity capable of sensing and reacting to (business) stimuli*. The idea is to bring to organizations the tremendous possibilities offered by the cyber worlds, when objects, equipment's, and technological infrastructures will exhibit advanced networking and processing capabilities, actively cooperating to form a sort of 'nervous system' (Arthur, 2011).

Santucci et al. (2012) expect that the confluence of both concepts enable the shift from the "walled manufacture" to "liquid manufacture", and contribute to the vision of the Future Enterprise.

2.1 OSMOSE: IoT-enabled Metaphor from Physics

The European Research Cluster on the Internet of Things (IERC) recognizes that ICT development is generating more and more things/objects embedded with sensors, which are gaining the ability to communicate with each other. This is renovating the real physical world into an augmented information and knowledge system. Hence, IoT is enabling objects in our environment to become active systems, sharing information with many stakeholders, and gaining the skills for recognizing events in their surroundings, to which they are acting and reacting autonomously (IERC, 2011). Each IoT object system has therefore a physical presence in the Real World (RW), a model in the Digital World (DW) specifying predefined pattern or behaviour, and an image in the Virtual World (VW) to project hypothetical what-if scenarios ruled by some laws and policies (e.g. simulating the performance of a production plant given some dynamic inputs).

In this context, the following metaphor can be used to explain the OSMOSE concept, i.e. the implementation of the liquid-sensing enterprise by interconnecting Real, Digital and Virtual Worlds in the same way as a semi-permeable membrane permits the flow of liquid particles through itself: Let us imagine the LSE as a pot internally subdivided into three sectors by means of three membranes delimiting the Real-Digital-Virtual sectors. A blue liquid is poured into the bottom sector (RW), a red liquid into the middle sector (DW) and a green liquid into the top sector (VW). If the membranes are semi-permeable, then following the rules of osmosis the liquid particles could pass and influence the neighbouring world, so that in reality the blue RW also would have a red-green shadow ambassador of the DW/VW, and similarly for the other Worlds (Figure 1). An entity (person, sensor network, an intelligent object) in the blue RW should have control of their shadow images in the red DW and in the green VW, keeping them consistent and passing them just the needed information under pre-defined but flexible privacy and security policies (Spirito et al., 2014).

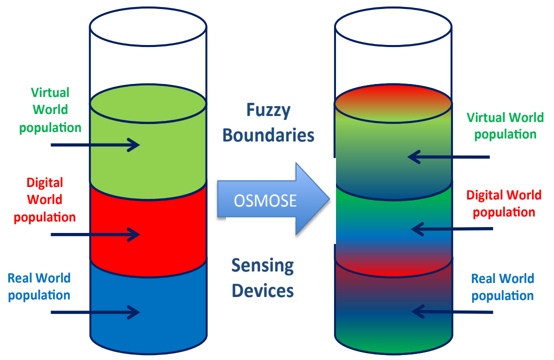

Figure 1: OSMOSE Metaphor.

2.2 Osmosis Processes

In the OSMOSE system, we assume that events could be generated in any of the three worlds of a LSE and that they should be propagated to the other two worlds by interaction and negotiation of the respective stakeholders. A chain reaction of events could also be generated from a set of six processes (osmosis processes):

- *Virtualization* - the Actor-Avatar process which allows to provide data for simulation of hypothetical RW situations;
- *Augmentation* – annotates RW objects with VW data, allowing projections to be superimposed to the RW and providing the user with unprecedented experience of mixing smart physical and virtual objects;
- *Digitalization* – supports modelling and representation of RW data in a computer-tractable form, providing the basis for integration of Event Driven Architectures (EDA) with service orientation;
- *Actuation* - the Agent-Actor osmosis process that is able to plan and implement highly distributed decision-making;
- *Simulation* – the Agent-Avatar process that is able to run hypothetical scenarios fed by DW models, knowledge and rules.
- *Enrichment* - extends the computational and experiential capabilities of the DW with annotations and projections coming from simulations and hypothetical scenarios.

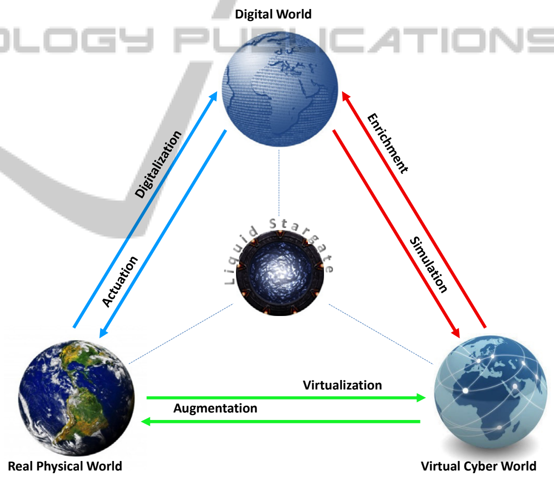

Figure 2: OSMOSE LSE Framework.

A triangular diagram (Figure 2) is used to pictorially represent these processes. As explored along this paper, the use of different IoT/ICT technologies such as the EDA and MDSEA is required for managing the osmosis processes. Traditionally, representing and implementing the interactions between the three worlds is achieved by means of interoperable models and tools. Nevertheless, there should be some automatic, real-time but context-based mechanism for consistency keeping and reconciliation of the shadow images. Thus, regular interoperability techniques for exchanging information should be substituted by a integrated intelligent entities visible through the gates of each World (as in the 1994 Stargate movie teleportation device - imdb.com/title/tt0111282/).

2.3 Event-Driven Architectures (EDA)

An event indicates a significant change in the state of the universe (Chandy et al., 2007). Sensor data, network signals, or application processing information, are examples of simple events, while a complex event is an aggregation of related events (simple or complex). Papadopoulos et al. (2010) describes the importance of complex event representation and semantic enrichment for managing and reviewing emergency incident logs. In that example and others alike, extensive manual effort is necessary to identify critical information, such as person names and locations, in order to align and merge the incoming log entries to make them suitable for managerial decisions.

Generally, IoT applications are characterized by producing a high volume of fine-grained data, which is emitted by sensors. Therefore they must deal with continuously arriving event streams. (Luckham, 2001) Due to the high volume of events and their complex dependencies, no predefined workflow can be specified, and as opposed to traditional DEBS (Distributed Event- Based Systems) IoT creates a highly dynamic application environment. Also, current software architectures such as service-oriented architectures (SOA) do not target event-based systems, because they are based on a process-oriented control flow, which is not appropriate for event-driven systems. In recent years, EDA has been proposed as a new architectural paradigm for event-based applications (Michelson, 2006). The main idea lies in the processing of events as the central architectural concept, i.e. to use complex event processing (CEP) as the process model for event-driven decision support. Event streams generated by sensors contain a large volume of different events, which must be transformed, classified, aggregated and evaluated to initiate appropriate actions.

The Esper (http://esper.codehaus.org) CEP engine supports events in XML, Java -objects and simple attribute value pairs. There are also many CEP vendors such as Tibco, Coral8/Aleri, StreamBase or Progress Apama providing tool suites including a development environment and a CEP engine. Most of the described systems use different SQL-like or XML based complex event pattern definitions, which makes it more difficult to understand and read them. Neither of them provide the knowledge support for event/process/service model-driven integration, capable of satisfying the integration of the entities in each of the three OSMOSE worlds.

3 MODEL-DRIVEN SERVICE ENGINEERING

Embracing the servitization integrated view on product-service systems and extended products, services concern physical products and objects as well as the associated technology, people and knowledge (Chesbrough & Spohrer, 2006). In fact, to deploy an enterprise service, especially in manufacturing, it will be necessary to involve several partners and manage knowledge crossing different boundaries of the enterprise (Zdravkovic et al., 2013), much alike the LSE.

OMG's model-driven architecture (MDA) and model-driven interoperability (MDI) are amongst the pioneer and most prominent technologies for model-based enterprise development and integration (Chen et al., 2008). MDI is more detailed and targeting interoperability. Other approaches exist in the domain of service (e.g. SOMF (Arsanjani, 2004)) but they are all still dedicated to ICT and not manufacturing services. Therefore, to better define, implement, and support the service life cycle, it is necessary to separate the user point of view from technical and from the physical means to realize it.

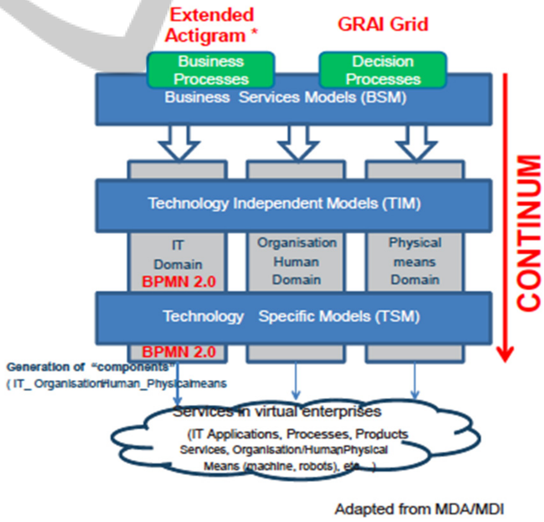

Figure 3: MDSEA (Ducq et al., 2014).

Therefore, the MDSEA architecture was first presented by Ducq, Chen, et al. (2012) to model and guide the transformation continuum from the business requirements of the service system (BSM level) into detailed specifications of components that must be implemented to support the servitization process (TSM level) was proposed. It follow the MDA/MDI principles (Agostinho et al., 2014), and as illustrated in Figure 3, combines that with the manufacturing servitization needs, supporting modelling of three types of components (IT, Organization/Human and Physical Means).

In order to operationalize service engineering using MDSEA, it is necessary to follow a precise method, which begins at the strategic level of companies that want to evolve towards service-oriented business methods. The approach implies that the different models, obtained via model transformation from the upper-level ones, should use dedicated service modelling languages that represent the system with the appropriate level of description. GRAI Integrated Modelling and BPMN 2.0 (OMG, 2011) have been considered as a reference. The MDSEA architecture provided the building blocks for service system development in the scope of an ecosystem of collaborating enterprises, providing:

- The capability to transform a business specific model into a functional one that can then be perfected by a system architect detailing the ICT, Human and Physical components;
- The capability to transform a functional model into a technology specific one envisaging the generation of concrete services.

3.1 Discussion on Service System Design at the LSE

Being a new paradigm for the enterprise, the LSE also requires, as in servitization, modelling to support the formalization of knowledge and facilitate the interoperability with partners. Also, one can consider that the design of services is inherent to the manufacturing LSE. This will be addressed in more detail in the next section, but both MDSEA and LSE need to specify enterprise business processes, identify resources, while relating those with services. Hence, the LSE design could benefit from the methodology behind MDSEA in order to accelerate the transition of the traditional enterprise to the "internet-friendly" and context-aware organization envisaged in OSMOSE. The major question resides on the fact whether the LSE concept and MDSEA strategy are compatible.

The similarity with the strategy for the separation of concerns behind the LSE real and digital worlds is evident. For instance, there is the clear notion that objects on the MDSEA's "Physical Means" domain need to have a shadow image on the "IT" to enable the full design of the service system. The "Organization and Human" domain is somehow spread along both RW and DW with the person and enterprise system belonging to the RW, but with their associated knowledge and structure available at the DW. The VW is not directly apparent in this structure, but for example, methods for simulation of business processes can be derived directly from TIM's IT models (Bazoun et al., 2014).

Hence, even though the initial objectives where different, one can hypothesise that the MDSEA can be applied to support the modelling of the manufacturing liquid-sensing enterprise. The role and complexity behind the enterprise ecosystem that collaborates to co-create the manufacturing services is taken by the 3 worlds in the OSMOSE framework, which need to be integrated. MDSEA might need to be extended to cover aspect such as events and event processing, but it can support the generation of liquid-sensing services implementing the 6 osmosis processes for each enterprise instance. Thus, even if not all LSE concepts are covered by the current version of the MDSEA, it serves to accelerate and guide the LSE modelling and implementation.

4 OSMOSIS PROCESSES FOR A MODEL-DRIVEN LSE

As introduced in section 2.2, the osmosis processes are a special type of process used to moderate the information exchange among the real, digital, and virtual worlds. We distinguish six osmosis processes that, when instantiated will enable to seamlessly integrate the LSE, connecting events across the 3 worlds, triggering services to provide the enterprise full knowledge about its inner systems, and create awareness concerning the interactions with the business partners.

The OSMOSE LSE objectives and the implementation of the semi-permeable membrane require modelling at the various levels of the enterprise (business, platform, implementation). Indeed, constructs such as the ones of *Resource*, *Service*, *Event*, or *Enterprise Process* need to be specified at a certain point of the model-driven continuum. Together, these constructs enable the creation of a distributed knowledge architecture able to manage the integration of the 3 worlds. Figure 4 depicts the relation among the modelling constructs relevant to an *Osmosis Process*, in the scope of business process modelling. The figure makes clear that these special processes extend the enterprise processes running in the different worlds, to moderate the flow between them, crossing the membrane. They can be associated to certain *Services* (through *Activity*), which in turn can trigger *Events* as well as act upon enterprise's *Resources*.

Resources are tangible elements of the *Organization*. They can assume the form of machine or Human systems when they exhibit certain behaviour or functionality, but can also be products or parts. However, all of them can have shadow images in each of the OSMOSE worlds. A *Human*, for example, is an *Actor* in the RW, and can have a shadow *Avatar* in the VW, or *Agent* in the DW. *Services*, *Events*, and *Processes* are different in the sense that they can exist in any of the worlds but are only associated to a single world instance.

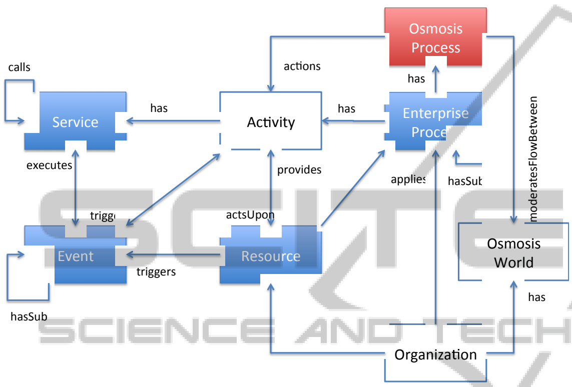

Figure 4: Modelling Constructs: relation with business process modelling.

The *Service* construct does not consider only software services. As addressed along the paper, the manufacturing enterprise can also specify certain services such as product measurement service provided by a certain machine, or a pilot training service for the flight simulator etc. This way, *Resources* may provide *Services*, which in turn, act upon *Resources*. Finally, *Events* are closely related with *Services*. Together they define a chain of Event-Service action-reaction along the 3 Worlds (*Events* executing *Services* and *Services* triggering *Events*). An *Event* can be defined as a significant change in state (modification event), a notification of abnormal situation (alarm event), or any other informative occurrence about a certain *Resource*.

4.1 Representation of Real, Digital and Virtual Worlds

The Real, Digital and Virtual worlds are represented as a set of enterprise processes and sub-processes, with their internal tasks and events generated. Every actor (system or person) is seen as a process and every action is generating a set of events, which can either refer to usual process oriented operations (e.g. start, end or terminate) or be originated during activities execution by actors of the world; for example from IoT system, one can get the value of the room temperature or the average of humidity during the day; from a software it is possible to extract usage of the memory or a software exception. Figure 5 shows a simple abstract process that is originating a set of events during the execution.

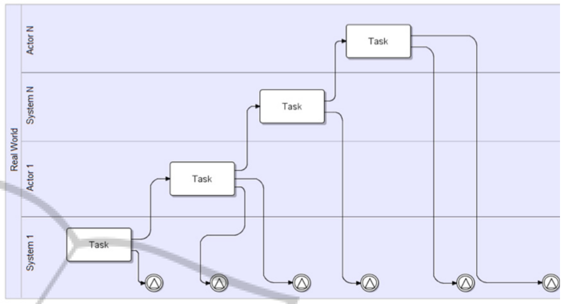

Figure 5: Real, Digital and Virtual Worlds representation.

4.2 Events Typology

We do not commit to a complete event description (i.e. a specific event definition language) but rather assume that the events that are passed between processes provide meta-information, which allows the process to retrieve all data that is relevant for handling it. The meta-information defines an envelope used to send post and receive events to and from the CEP. The information in the envelope allows the receiver to find all details needed for dealing with the event. The following schema provides technical representation details of a possible envelope:

<domain> Automotive Manufacturing </domain>
<worldID> Real World </worldID>
<eventType> Critical Error </eventType>
<timeStamp> Time </timeStamp>
<eventResourceURI> URI </eventResourceURI>
<dataURI> URI </dataURI>

In order to uniform events coming from different worlds, a taxonomy of events is adopted. The first level of the taxonomy is derived from the events available in the business process domain and defined in BPMN2.0 (OMG, 2011). The taxonomy needs, of course, to be extended in order to cover RW, DW and VW requirements to recognize and manipulate events. For example a signal is a non-interrupting event in the process chain that can be extended in order to monitor the temperature level in a certain instant of time as temperatureSignal. Taxonomy is also extended in order to cover membrane needs; for example Danger Event extends Error Event.

4.3 Osmosis Meta-templates

Similarly to what has been provided for MDSEA, also the main LSE constructs are firstly modelled at meta-level following a template to gather data. Due to space constraints, only the templates for *Osmosis Process* and *Service* are presented (Table 1 and Table 2). They extend the original MDSEA templates available at Doumeingts et al. (2012).

Table 1: Osmosis Process Template.

Header	
Identifier	[Identifier of the process instance]
Name	[Name of the process instance]
Type	[Virtualization; Augmentation; Actuation; Digitalization; Enrichment; Simulation]
Body	
Objective	[Description of the process instance]
Causing Events	[List of events that caused the triggering of the osmosis process (e.g. temperature higher than 100ºC)]
Related Resources	[List of system and other resources that are addressed by the process pre/post-actions (e.g. simulator)]
Mode of Operation	[Description of how far the process is automated]
Functionality	[Short textual description of the activities composing the process]
Representation	[Graphical representation of sub-functions (e.g. BPMN)]

Table 2: Service Template.

Header	
Identifier	[Identifier of the service instance]
Name	[Designation of the service instance]
Type	[Software service; manufacturing service; support service; etc.]
Body	
Description	[Short description of this instance]
Functionality	[Short textual description]
Constraint	[Short textual description]
Mode of Operation	[How far the service is automated]
Access	[Specify how, where and when is a service made available]
Consumption	[Specify what is expected where and when by different parties participating in service]
Business Value	[Short textual description (if any)]
Performance Indicators	[List of PI's (if any)]

4.4 Modelling Osmosis Processes and the LSE Membrane

After gathering meta-information for LSE constructs, it is time to detail them using the selected representation format. At the TIM level, BPMN 2.0 is a natural selection, but modelling should begin at higher level (e.g. using Extended Actrigram * or GRAI GRID) in the case new enterprise services are to be deployed (natural case of MDSEA). In the case it is only supporting the transition towards an LSE (focus of the paper), then only the services assisting the osmosis processes are new, and TIM is an acceptable starting point. Nevertheless it is important to note that the use of an enterprise or software architect is recommended.

The membrane process is implemented as illustrated in Figure 6; it acts as a listener component that, at the time events are received, checks their context and nature (type of the event as discussed before) and decides whether an event is "osmiotic" or not. If it is the case, then corresponding osmosis process(es) is/are started. Otherwise, the system can decide to do nothing or to start an intra-world enterprise process needed to manage the event in the scope of the world that originated it. In the osmiotic case, a call to an intra-world process can happen aside the osmosis process; for example to react to a serious error in the real world the machine is stopped launching a RW process (intra-world) and the virtualization is started in parallel (inter-world).

4.5 Model-driven Generation of LSE Services

Having all the models recreated at the TIM level (Figure 6 extended with all details), one will already have specified the enterprise behaviour in a platform independent level. Hence, MDSEA enables the generation, though top-down model transformations, of the osmosis services necessary to have all the information integrated and accessible through the gates of the different worlds (with different views targeted for different actors). Agostinho et al. (2014), in his paper about MDSEA model transformations, goes into more detail how the information is generated with the detail necessary to reach an actual software service.

5 VIRTUALIZATION CASE IN MANUFACTURING

The overall reason to have VW is to allow users to

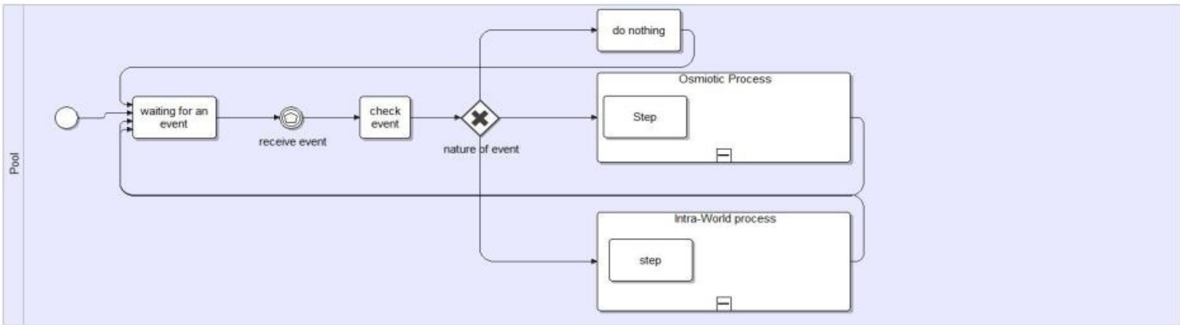

Figure 6: Membrane Monitoring of OSMOSIS events.

investigate hypothetical situations. In many cases these situations are investigated with the help of simulations that use models, which are linked to RW entities. The purpose of virtualization is, on the one hand to create virtual artefacts that represent or at least correspond to RW entities, and to provide the data, which allows re-creating virtual situations that are close to situations actually occurring in the real world. Important concepts for virtualization are therefore physical entities, measurement of physical entities, and (3D) models derived from RW entities.

Depending on whether the model of the VW already exists and does not need to be changed at the level of modelling, the process might run completely automated or completely manual, where manual does not means that is not computer supported with adequate modelling tools. In cases where no (or only a partial) model is available and a new model needs to be created, the process of virtualization needs to be executed by human experts. For example, it is possible to provide accurate 2D or 3D scans but without further modelling effort only the pure data can be visualized. Automated checks and processing might be done on this data. However, checks and processing needs to be predefined together, and with this the process of virtualization.

With respect to virtualization, the LSE aims at generic virtualization processes that can be flexibly instantiated for different situations. In many cases this might basically mean that the data the process is acting upon is coming from different RW entities.

5.1 RW Events

Real world events monitored by the membrane are correlated to (non–exhaustive list):

- HW execution system (danger, error, warning, advancement info, config. settings debug);
- SW execution system (running, error, warning);
- Structural measurement (strengthens measured, surface, 3D scan);
- Position (GPS positioning, logistic position);
- Environment (temperature, humidity, brightness, policy)
- Availability (broken/available/updated).

Some of the events are the starting point for both virtualisation and digitalisation processes while others are correlated to just one of the osmosis process.

5.2 Example

This section reports the *Activities* and *Services* that need to be executed and/or generated to support the virtualization process following certain events. “HW Danger” and also “HW Warning” are exemplified. For each process, the generic set of steps is detailed in the following form. Services, events or processes that need to be generated are indicated.

HW Exec DANGER Event Subsequent Steps:

1. Block the system (*internal process*)
2. Activate notification (*alarm event*) to the environment (human and/or things)
3. Activate safety procedure (*internal process*)
4. Collect data about environment (GPS positioning and tracing of objects people, information about positioning of object, settings of machineries) (*service*)
5. Save data (*service*)
6. Prepare session for the virtual recreation of the situation (*process*)
7. Inform target system in VW (*service*).

HW Exec WARNING Event Subsequent Steps:

1. Activate notification (*alarm event*) to the environment (human and/or things)
2. Collect data about execution (*service*)
3. Save data (*service*)
4. Prepare session for the virtual recreation of the situation (*process*)
5. Inform target system in VW (*service*).

The above sequences can be applied in multiple situations. The first one could be illustrated with a simple situation taken from a manufacturing shop floor environment, i.e., *"after an accident/incident, a what-if simulation of the manufacturing environment can be done in order to understand how the situation has been generated; verify if it has been well managed and better organize shop floor workplace and machineries configuration for the future*". We could illustrate the second with a warning in a production line. For instance "*an over threshold temperature of some components can be acceptable allowing the system to continue working (so remaining a warning without becoming an error) if the system is used with some constraints like, for example keeping a lower speed during execution. The constraints will be determined during what-if simulations and fed back to the system by augmentation process"*.

6 CONCLUDING REMARKS

The paper analysed the needs behind industry's digital transformation and how it can be capitalized by implementing the sensing and liquid enterprise concepts proposed by the FInES 2025 roadmap. The paper presented the status quo of the modelling and design of the OSMOSE liquid-sensing enterprise vision, as well as the realisation on the osmosis process and connected events and services.

The general modelling approach towards LSE osmosis processes realisation has been provided and MDSEA has been proposed. Due to the proximity of some of the inner construct behind manufacturing servitization design and LSE design, the model driven approach could be adapted to facilitate the transition between the traditional enterprise and the future LSE. The realisation of the activities, events handling, monitoring, recognition of osmosis, and the reaction by osmosis processes, is currently modelled at the MDSEA TIM level. Model transformations are applied to semi-automatically derive technology specific models and accommodate the specific needs of every enterprise and reach an actual software service that supports the LSE osmosis.

Implementing the OSMOSE digital transformation will provide companies the digital capabilities to capitalize on the FI and IoT, improving customer experience, operational process, business models. Next steps target the osmosis processes deployment into real pilots and further study on how to integration CEP middleware with the generated services is needed. Also governance models need to be studied for a proper realization of the LSE at the BSM level. Based on the feedback received, the final version of the modelling approach will be produced.

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