# Process Development for the Liquid-sensing Enterprise

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Abstract: Servitization and product-based services are used to support the integration of products and services with customers, enabling companies to maintain a competitive advantage in their markets. However, in order to achieve these capabilities is necessary to have flexible processes and services. The enterprise needs to become self and context aware to meet these new challenges, and with the Internet-of-Things development, resources can be shared across companies to reduce costs. Enterprise integration is an essential component of enterprise and service engineering but traditional modelling techniques need to evolve and become more dynamic, separating concerns but at the same time promoting knowledge reuse. This paper contributes to a more flexible environment for information systems and service development, proposing a model-driven framework for dynamic process development in the enterprise of the future. It applies the concept of the liquid-sensing enterprise following the Osmosis processes paradigm, supporting the enterprises to model and design their processes at business and technical level. With the support of a modelling toolbox the enterprises are able to parameterize their processes and accelerate the advancement from the design phase into services execution phase.

## 1 INTRODUCTION

In today's economy, to achieve customers' satisfaction, enterprises need to be able to deliver products tailored specifically to each customer's needs. However, this can result in a challenging environment that mixes manufacturing flexibility with constantly evolving information systems and services characterized by high volumes of information (Friedman, 2006). A single final manufactured product is often processed in many companies, countries, and crossing several systems in a collaborative process. Hence, a growing servitisation is shaping today's manufacturing sector (Baines and W. Lightfoot, 2013), enabling to focus on the services these companies are providing to the value chain or to the end customer.

Enterprise integration is an essential component of enterprise and service engineering (Panetto and Molina, 2008), concerning the usage of specific methods, models and tools to design and to continually maintain an enterprise and the services it provides constantly updated and integrated with the domain objectives. However, from a technical point of view, traditional information systems and service development techniques are rigid, designed from the planning stages with predefined functionality. This makes them less sustainable to face the dynamicity requested by the evolving market (Honour, 2008).

This concern is shared by a number of communities and is reflected in the 2025 roadmap for Future Internet Enterprise Systems (FInES Research Roadmap Task Force, 2012), which considers that today's business process modelling techniques do not appear adequate to address today's systems. Methods based on advanced modelling techniques and model-driven development are required to allow users to properly address different levels of concerns (from business goals to development), and at the same time reuse the knowledge acquired between modelling levels and teams. This idea was implemented in the OSMOSE Project (www.osmose-project.eu) with design and development of a reference architecture for modelling and managing the Liquid Sensing Enterprises (LSE) with the aim of design, execute and monitor the processes and services of enterprises. This architecture was designed having in mind the integration of the several components and



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services of an enterprise. This paper contributes to a more flexible environment for information systems and service development, proposing a model-driven framework for dynamic process development in the enterprise of the future, where business experts, system architects and developers are involved on the development process and can contribute to any design/re-design activity. This design follows the Osmosis processes paradigm, allowing the business experts to represent business process model at a high level, describing knowledge in terms of the enterprise of future notions of Real, Digital, and Virtual World activities. This facilitates transference of requirements to the technical experts and accelerates LSE services development.

The paper starts by presenting the liquid–sensing enterprise concept for the future enterprise, and in section 2 it recalls the model-driven paradigm developed previously, relating it the other related initiatives. Section 3 presents the process development framework proposed and developed with the support of the OSMOSE European project. Finally, section 4 presents the details about the proof-of-concept developed and section 5 draws the final considerations.

## 1.1 Liquid-sensing Enterprise

In face of the enduring economic crisis, shortness of resources, and increasing demands for customization and flexibility highlighted before, our enterprises are in need of innovative ideas to adapt to these changes and remain competitive. To meet these requirements, the concept of Sensing Liquid Enterprise was introduced as a fusion of the Sensing Enterprise (Santucci et al., 2012) with the fact that the enterprise is losing it fixed boundaries, in terms of human resources, markets, products and processes (FInES Cluster, 2010). Hence, the LSE is as an attempt to reconcile traditional (non Internet-driven) organisations with the tremendous possibilities offered by the cyber worlds where objects, equipment's, and technological infrastructures are shared by many exhibiting advanced networking and processing capabilities, actively cooperating in a sort of 'nervous system' (Arthur, 2011; FInES Cluster, 2010; Santucci et al., 2012; Moisescu & Sacala, 2016).

## 1.2 OSMOSE Metaphor and Processes

The OSMOsis applications for the Sensing Enterprise - OSMOSE (FP7 610905) project aimed at developing a reference architecture, a middleware and some prototypal applications for the Sensing-Liquid 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 (Agostinho et al., 2015). The worlds represent a way of organizing the structure of an entire manufacturing enterprise, and the business applications in three types of data management environments: **Real World (RW)** - related to data that comes directly from devices that is handled by physical components; **Digital World (DW)** - related to data management available in data and knowledge bases or Internet (big data); and **Virtual World (VW)** - related to specific management of data with the support of future projections or specific simulations (Spirito et al., 2014).

Following the LSE paradigm, osmosis processes are a special type of business processes used to moderate the information exchanged among the worlds. The six Osmosis processes considered are detailed in (Marques-Lucena et al., 2015):

- **Digitalization (RW-DW) –** Model and represent RW data in a computer-tractable form;
- **Actuation (DW-RW) –** Plan and implement highly distributed decision-making;
- **Enrichment (VW-DW) –** Extends the computational capabilities of the DW with annotations and projections coming from simulations and what-if hypothetical scenarios;
- **Simulation (DW-VW) –** Instantiate and run hypothetical VW scenarios based on historical data;
- **Virtualization (RW-VW) –** Provides real-time data for simulation of hypothetical simulations;
- **Augmentation (VW-RW) –** Annotates Real World objects with Virtual World information.

# 2 MODEL-DRIVEN PARADIGM FOR THE LSE

A business process can be seen as a *set of internal activities performed to serve a customer* (Jacobson et al., 1994). It is characterized by being: a purposed activity; carried out collaboratively by a group; it often crosses functional boundaries; it is invariably driven by outside agents or customers (Ould and Ould, 1995). This means that, to accomplish a business process, especially in manufacturing, it is necessary to involve several partners or user profiles, and manage knowledge across different boundaries of the enterprise (Zdravkovic et al., 2013), much alike the LSE.

To better align the implementation and support of a process lifecycle, a separation of concerns starting from business goals down to the consequent physical means to realize it is required (Ducq et al., 2012). It can be accomplished if a model driven approach is applied. Thus, instead of writing the code directly, such approach enables services to be firstly modelled with a high level of abstraction in a context independent way. The main advantages of applying model driven approaches are the improvement of the portability, interoperability and reusability through the architectural separation of concerns (Grangel et al., 2008).

The work presented in this paper was inspired by the one presented in (Ducq et al., 2012), which adapted the model driven concept to manufacturing services development, with the definition of Model Driven Service Engineering Architecture (MDSEA) concept. It followed the Model Driven Architecture (MDA) and Model Driven Interoperability (MDI) principles (Lemrabet et al., 2010), supporting the modelling stage and guiding the transformation from the business requirements (Business Service Model, BSM) into detailed specification of components that need to be implemented (Technology Specific Models, TSM). This approach proposes that each model, retrieved by the model transformation from an upper-level model, should use a dedicated service modelling language, which represents the system containing the level of description needed. MDSEA was the chosen method because is already oriented to the development of services for business processes and identifies the concepts IT, Physical Mean and Human used to describe the processes.

However, for such approach to be successfully applied to the LSE concept, it should be enriched with the capability of represent concerns related with the LSE-enabled real, digital and virtual worlds of the Liquid-Sensing Enterprise (Agostinho & Jardim-Goncalves, 2015). Following this requirement, three levels of abstraction where adapted from the MDSEA (see Figure 1):

- **Osmosis Business Models (OBM),** where the business case is defined. OBM extends the BSM in the sense that this abstraction level envisages meta-information not only about components (e.g. actors, resources, etc.) but also about activities and the world in which it is active (e.g. “schedule maintenance” is an activity from the DW and “clean machine” is from the RW), The representation of the world in each activity is called OBM Annotated, enabling the system to identify osmotic processes.
- **OSMOSE Technology Independent Models (OTIM),** that like the MDSEA TIM is complementing the upper level model with detailed technology independent functionally. OTIM is optimized for the osmostis processes representation, detailing such behaviour (OSMOSE membrane) and the interactions between the source and target world. For instance, in a digitalization process, OTIM represents three pools of activities (one the RW, one for the DW and one for the membrane).
- **OSMOSE Technology Specific Models (OTSM),** which is the last level and consists in the instantiation and parameterization of the identified activities with services needed for the the process execution.

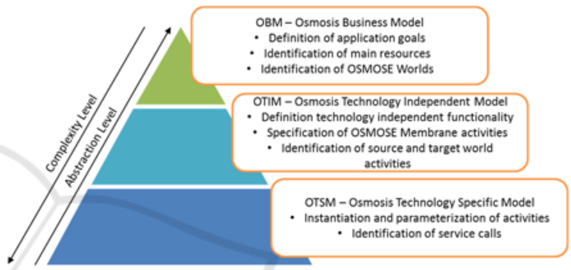


Figure 1: OSMOSE Process Design Methodology.

## 2.1 Discussion and Similar Approaches

The usage of model driven approaches applied to processes modelling is not a novelty *per se*. Several related works can be found in the literature. In the work presented in (Mili et al., 2004), the authors propose a method for classifying and specializing generic business processes. With that method, the authors aim to derive, from a catalogue of generic processes and process specialization operators, an enterprise-specific process, which corresponds closely to MDA’s computation independent models or CIMs. In (Bouchbout & Alimazighi, 2011), the authors propose a framework for Inter-Organizational Business Processes based on MDA. Thus, it considers three levels in a top-down manner: business (organizational), conceptual (logic) and technical (execution). Other relevant works are (Bouchbout et al., 2012; Rodríguez et al., 2010; Rodr’iguez et al., 2007).

Based on the presented successful applications of MDA techniques in processes modelling, the authors consider that LSE design could benefit from the methodology behind MDA and 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. This papers contributes to prove this hypothesis, continuing the work of (Marques-Lucena et al., 2016) and contributing to the implementation of the model-driven paradigm for the LSE. In detail, this work complements the existing ones, identifying a concrete LSE process development framework and updated models transformation methodology.

# 3 OSMOSIS PROCESS DEVELOPMENT FRAMEWORK

As introduced in section 1.2, the osmosis processes are a special type of process used to moderate the information exchange among the real, digital, and virtual worlds. When instantiated, these processes will enable to seamlessly integrate the LSE, connecting events across the 3 worlds, and triggering services to provide the enterprise full knowledge about its inner systems and interactions.

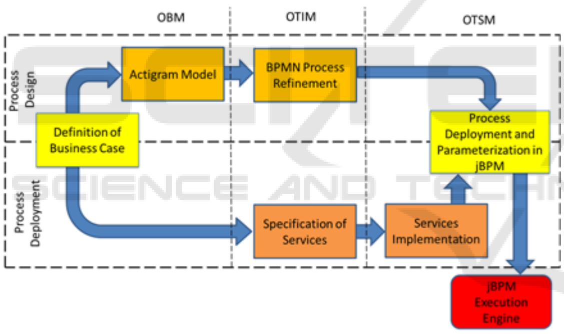


Figure 2: Overall Structure of Process Development.

The process design framework allows companies to take the most out of LSE and the OSMOSE project, being able to carefully plan the new business strategies or specify the new services clearly differentiating activities and events in different worlds. Next section describes how the process design methodology is combined with the services specification and deployment, used at execution time (Figure 2). It is divided into 2 phases, the **Process Design** and the **Process Deployment**.

## 3.1 Process Design

The Process Design starts with the Definition of Business Case, which is a high-level description of the business case/service to be implemented. It can be made in the form of textual description of the user story, or a more formal definition following models. After that and illustrated in Figure 3, the design of the Actigram Model is conducted (EA* (Extended Actigram Star) language is used (H. Bazoun, G. Zacharewicz, 2013)). It represents the initial part of the OBM level, starting with the specification of the enterprise, collecting meta-information about the organization and the resources (as illustrated in the upper figure of Figure 3).

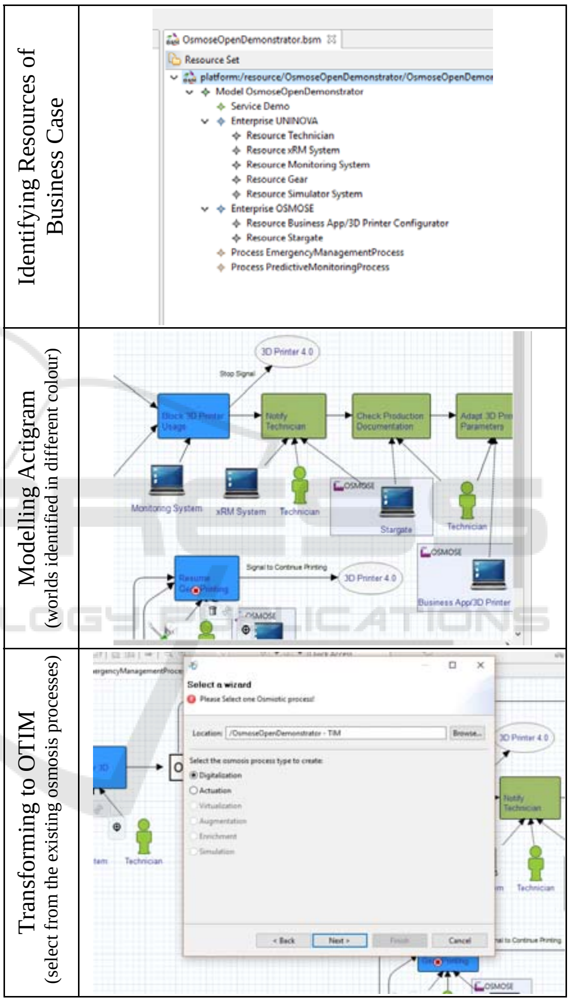


Figure 3: OBM Modelling Activities.

Then, it is specified the business perspective of the process model (as illustrated in the middle figure of Figure 3), by identifying the innovation requirements and expected behaviour. Using this model, the user visualizes in a simple form, which activities will go into processes between the different worlds. The worlds identification procedure at the OBM initiates the model-driven paradigm explained in section 2, enabling the system to identify osmosis processes and ask to the user the type of osmosis event that can occur (see last figure of Figure 3). This gives the possibility to change from the OBM level into the OTIM level, through an automated model transformation that transforms the Actigram into a 3-parts BPMN model (BPMN 2.0 is used to instantiate OTIM in this work) representing the OSMOSE membrane and the respective worlds processes. The transformation used in this process is described in section 3.1.2.

The next step is the BPMN Process Refinement; at this phase is possible to specify additional details for service integration and extended business logic. This represents the OTSM level of the methodology preparing the BPMNs for execution.

### 3.1.1 Algorithm for Osmosis Process Detection

To facilitate the identification of the osmosis processes between different OBM activities, the user should select to which world the activity belongs. This option changes the colour of the activity in the diagram, hence facilitating the visualization of the worlds by the user, and providing the system the necessary information for it to compute the existing osmosis processes in a single business case (see the middle part of Figure 2). When more than one exists, the user should address them separately in different OTIM models.

To support this process identification, an algorithm has been specified and implemented. It detects the world transitions and asks the user which osmosis process he wants to work on. This new feature improves the transformation between the EA* and BPMN instances of OBM and OTIM, following the concept presented in Figure 2. For example, looking to Figure 5, the algorithm is going to ask to user to select between two transitions (which correspond the transitions between Blue-Green and Green-Blue), i.e., Digitalization and an Actuation processes.

Figure 4 describes the algorithm dividing it into two phases. First phase is about the detection of the transitions between the worlds, and the second part about the detection of the Activities flow within the process. The algorithm reads the EA* diagram into a graph structure to search for world transitions. It does this by applying the following rules to the EA* model:

- A start and stop events needs to exist;
- At least one world transitions need to exist.

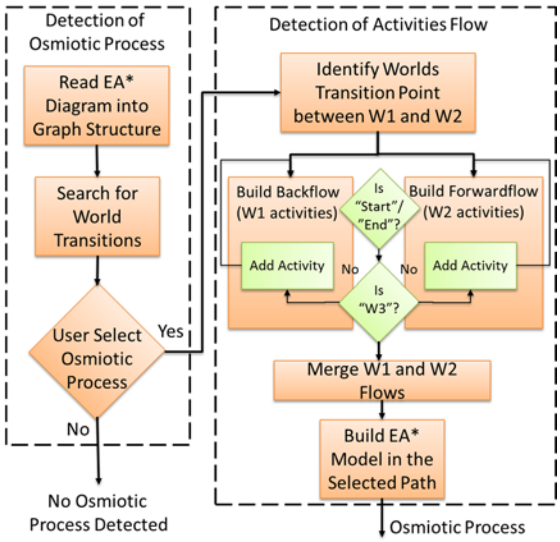


Figure 4: Algorithm for Osmosis Process Detection.

In the case of the model does not respect these rules, the algorithm is invalid.

After the user selects which osmosis process he wishes to further specify at OTIM, the second phase starts to iterate the graph and will identify all the Activity blocks that belong to the selected osmosis process. It starts detecting the Activities Blocks back and forth from the world transition point (e.g. RW->DW). It follows the graph until it detects the start/end of the diagram or a different world (RW backflow; DW forward flow). In the end, it merges the two flows into the osmosis EA* model to be transformed.

As in the first phase, there are also some rules:

- Detect if an activity is already included in the flow and stop the iteration (it avoids to repeat it the case the graph iterates through the same activity more than once),
- "And" or an "Or" connections points respect the same rules as the Activities.

### 3.1.2 EA* to BPMN 2.0 Transformation (Evolved)

To support the modelling and model transformation process, the authors continued to develop the MSEE's Toolbox for service modelling (H. Bazoun, G. Zacharewicz, 2013; Wiesner et al., 2014) which is using ATL (https://eclipse.org/atl/) engine to automatically execute the predefined transformation rules between OBM and OTIM models. Since, the MSEE Toolbox did not have the OSMOSE processes concept implemented, (Marques-Lucena et al., 2016) started to make the update which is here continued with the new transformation rules identified in Table 1.

Table 1: Summary of changes made in EA* to BPMN2.0 Transformation.

<table>
<tr><th colspan="2">Source Concept</th><th colspan="3">Target Concept</th></tr>
<tr><td colspan="2">EA* (OBM)</td><td colspan="3">BPMN2.0 (OTIM)</td></tr>
<tr><td rowspan="3">Resource</td><td>Material</td><td colspan="3">Data Object</td></tr>
<tr><td>Human</td><td colspan="3">Lane</td></tr>
<tr><td>IT</td><td colspan="3">Lane</td></tr>
<tr><td colspan="2" rowspan="7">Osmosis Process (Digitalization, Virtualization, etc…)</td><td rowspan="7">Pool</td><td rowspan="3">Source (Real, Digital, Virtual) world</td><td>End Event</td></tr>
<tr><td>Source Lanes</td></tr>
<tr><td>Source Tasks</td></tr>
<tr><td>Osmosis membrane</td><td>Predefined Pool, Events and Tasks</td></tr>
<tr><td rowspan="3">Target (Real, Digital, Virtual) world</td><td>Start Event</td></tr>
<tr><td>Target Lanes</td></tr>
<tr><td>Target Tasks</td></tr>
</table>

The changes made to the transformation are divided into two parts, the first one is related with the changes made in the resource, the first version of the Toolbox was made to do the transformation of the Human and IT resource, and at this moment the Material resource is also being contemplated. The second part is the big change, since at this moment each activity is being transformed into task and being allocated in the respective world. For example, in the case of being a Digitalization process, three different pools are created, one for the Real World, other for the Digital World, and the last for the Osmosis Membrane. Then in each pool is allocated the respective lanes (each lane represents the resource which is being used in that world), the tasks. In the case of the Start or End event is due to the rules of the BPMN, as each pool needs to have a start and an end event (missing in the previous version).

### 3.2 Process Deployment

The Process Deployment, as illustrated in the bottom part of Figure 2 is made to support process execution. In our implementation, the jBPM (Del Fabro et al., 2009) environment has been selected, since it is an open environment and being widely used by the community. A straight forward manner to start process execution is to use the jBPM Web console. This step represents the Code level in the model-driven paradigm.

The processes from the Toolbox are transformed into BPMN processes that are uploaded into the jBPM repository, from where they are deployed in the jBPM process execution engine. In the jBPM execution engine the processes can be further refined (OTSM) and executed, when they are eventually completed. For now, a command line interface is available for interacting with the jBPM git repository. The usual clone, commit, pull and push commands are used for download of the jBPM git repository content and to upload modifications or new process models appropriately. The address of the jBPM git repository is ssh://[username]@[host]:[port]/jbpm-playground.

During the preparation of the jBPM to execute the processes, it is necessary to specify and implement the services in order to get or set data used during the monitoring processes. The service part of the design framework can be handled in parallel with the OTIM and OTSM definition. These services are register in an enterprise service bus being available to entities in the OSMOSE architecture to invoke process execution of these services. With this approach, the services are available anytime to be used in the processes, allowing the system to have two types of services: a) Services for invoking process execution; and b) Services for delivering messages to specific processes which are already in execution. Indeed, the specification of user and service tasks begins to be detailed in the BPMN model at the OTIM level (see Figure 2). Then using a standard IDE (Integrated Development Environment) is possible to generate the skeleton of the code to be applied on the service tasks, which then needs to be finalized using the usual programming rules and approaches.

These services have to be specified and implemented mapping the input/output of the service specification to the input/output of the process.

## 4 OSMOSE OPEN DEMONSTRATOR

The process of the framework is a complete integrated process allowing, starting from a business case, to get to the conclusive execution of the Osmosis business processes. This section describes an example showing how the different steps of Figure 2 are instantiated to be used by a user. The reference scenario is the OSMOSE open demonstrator demonstrating the core steps to follow in terms of process modelling (applying the design framework), and at same time validating them.

## 4.1 Description of Business Case

The emergence of 3D Printers has made the market of customizable products grows exponentially, providing anyone (end user or manufacturing stakeholder) with the possibility to print a custom piece on demand. However, printers (especially low cost ones) are still far from being a reliable option due to production times, very delicate conditions and configuration, and high failure rates. Hence, depending on the size or quality of the piece, printing can take many hours, and whenever an undetected problem occurs in the printing process, in addition to the huge waste of time there is the amount of wasted raw material. For this reason, it is important to monitor the printing and ensure the best possible approach to save time and material in face to such situations.

In open demonstrator scenario, OSMOSE is applied to better manage the process of monitoring a standard 3D printer that is producing a gear, providing the solutions to handle predictive maintenance and emergency management. In an emergency situation, the printer has to stop to ensure that the current the work is not ruined, and potentially saving many working hours. Also, if it is possible to predict possible printing error or hardware failure, then maintenance procedure can be triggered, avoiding significant losses.

## 4.2 OBM Models – Business Actigram Instances

In this phase, the OSMOSE middleware framework enables to design and specify in a business-friendly interface, the activities that describe the different flows of monitoring 3D Printer process. The OSMOSE Process Modelling Toolbox is used to design and specify the OBM Model in EA* notation. For the specific user story described before, two main process flows have been identified: a) Emergency Management and b) Predictive Maintenance (only the Emergency Management example is going to be demonstrated in this paper).

Figure 5 depicts the high-level overview of the Emergency Management process, where sensors available in the printer are used to track and monitor the Gear printing, hence enabling to detect when and which problems occur. The sensors used for this process are the temperature sensor, accelerometer sensor, gas sensor and a panic button. Using these sensors, the idea is to develop a system capable of detecting the real world events bellow and managing the subsequent activities to prevent material waste:

- **Earthquake –** In this situation an accelerometer is used to detect abrupt oscillations to determine if it is an earthquake, stopping the production in the case of occurring one. This prevents the workers, product and the printer itself from damage (external to the earthquake);
- **Fire –** In this situation the temperature and gas sensors are used to detect a fire. This is made by validating a high temperature together with an increase of $CO_2$ in the air. In the case of detecting a fire the system stops the production;
- **Panic Button –** In the case of a dangerous situation (e.g. burnt hand in the printer bed; hand stuck in the printer, etc.) or if the worker identifies that the piece presents flaws during the printing, he/she can press the panic button in order to pause the production and resolve the situation;

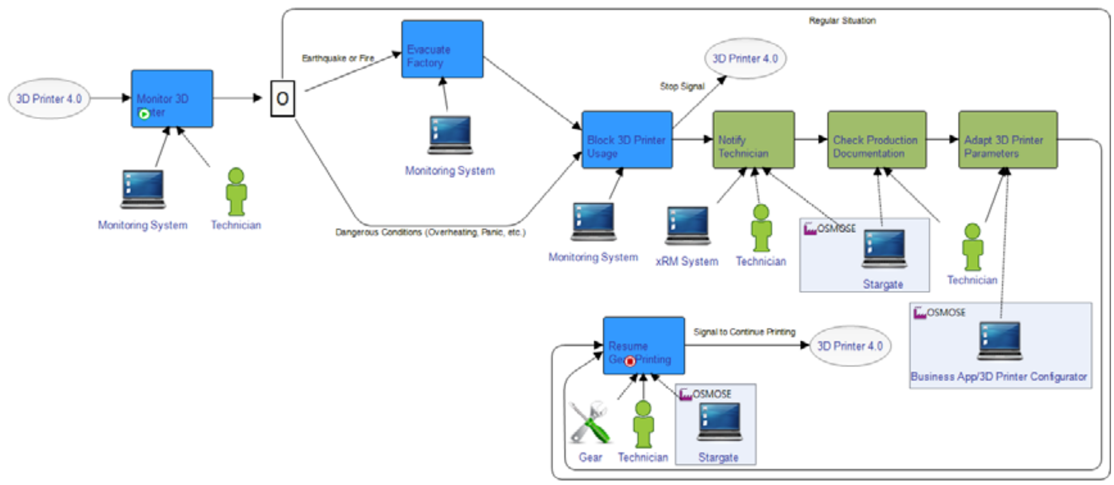


Figure 5: Actigram for an Emergency Management Process.

- **Printer Overheating Detection** – The system is prepared to detect whether the printer reaches very high temperatures, which can cause long term damage. This option prompts the user to check what is happening to the printer and if possible return it to the ideal temperature.

## 4.3 OTIM – BPMN Process Refinement

In this stage, one automatically derives BMPN2.0 Technical Models from the Actigram Business Process Models, reusing concepts already defined and simplifying the design of the detailed osmosis behaviour. Each BPMN process represents an Osmosis process defined.

Figure 5 represents the Actigram model of the Emergency Management process. By looking to the model, it is possible to identify two Osmosis Processes (a Digitalization Process – from blue to green activities - and an Actuation Process – from green to blue activities). Figure 6 represents the refined Digitalization process, defining the printer monitoring activities and identifying situations in which the system can block the printer (described in the previous section). It is possible to see that comparing with the Actigram model, this includes much more detail specified by the system architect.

At same time, OTIM describes the transition between worlds. In this case one can see that the Digitalization crosses the boundaries of the Real World into the Digital World going through the OSMOSE membrane (the transition is made by the detection of osmosis events).

Once, the process has identified the problem (real world event) and the printer is locked, the technician is notified and he becomes responsible to restore the production following a certain set of actions. This is an Actuation process that is not represented in this paper.

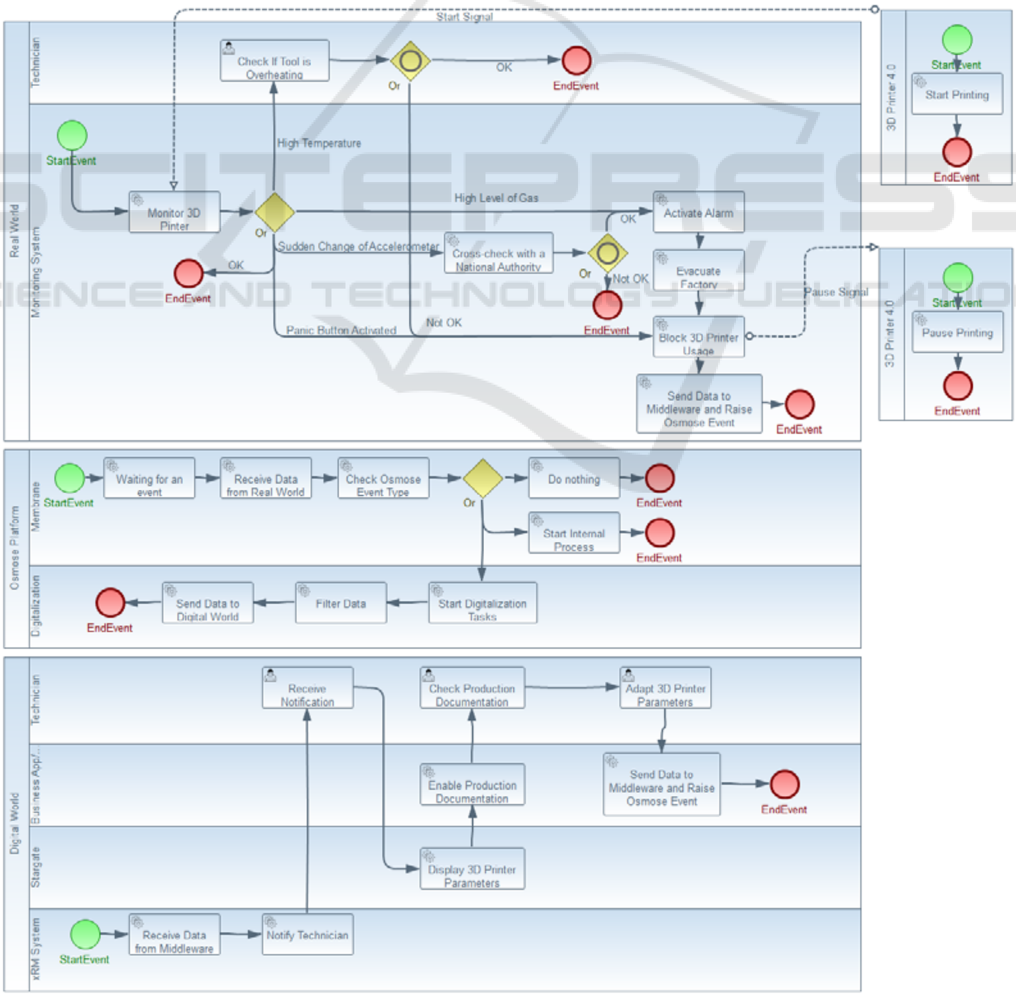


Figure 6: Digitalization Process to Notify Technician.

### 4.4 OTSM – BPMN Process Deployment and Parameterization in jBPM

The last phase is the implementation model, which is the refinement of the BPMN so that in can be executed in jBPM concurrently. In this model the configuration of the BPMN with the services and events is made, to be used in the run-time mode. The representation of the executable Real World processes is illustrated in Figure 7 (for space restrictions we did not include the DW and the OSMOSE membrane, where the model is complemented with more detail and ready to be launched and tested in jBPM, making the osmosis process runnable.

The process is divided into three different processes, as illustrated in Figure 7. In this case, the Digitalization process is going to be divided into, Real World, Osmosis World and Digital World processes. For each situation, it was needed to identify the services needed and configure them in the BPMN to be ready for execution. After this, it is ready for deployment and them for execution.

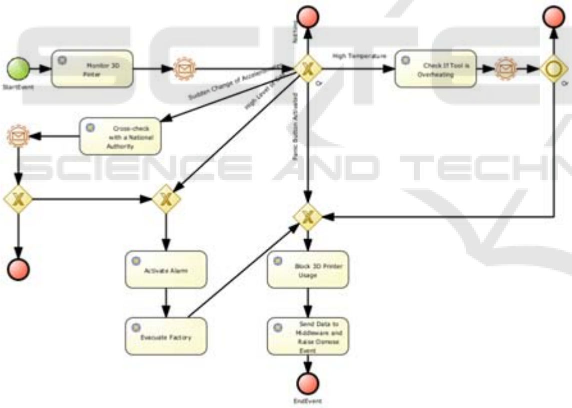


Figure 7: RW BPMN Emergency Management Process.

### 4.5 Open Demonstrator Process Execution

In this section, we briefly describe the execution of the processes in the jBPM process execution engine. It is important to note that this step requires that the ones described in the previous sections need to be properly designed and implemented.

Figure 8 shows a screen shot of the execution of the digitalization process in the emergency management. In the first image is represented the Real world process, and it is monitoring the 3D printer was started and the process waits for events from the monitoring. In this example (following the dark tasks), it was detected a high temperature in the extruder, in response the system blocks the printer, with this the Real world process ends.

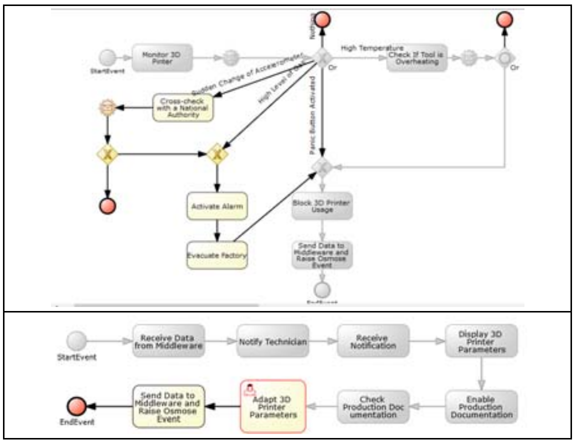


Figure 8: Execution of Real and Digital Worlds Emergency Management Process.

At this moment, the Osmosis Membrane started and it is executing the middleware actions to allow to proceed into the next phase of the Digitalization, which in this case is the Digital World Process. In the Digital world, the technician is notify about the possible problem and he is called to verify the state of the printer. Until the technician checks and detects the problem and solve it, the process is blocked until the user check the validation option. The process finish with the confirmation by the user, then it restarts to continue to monitor the printer.

## 5 CONCLUDING REMARKS

This paper presents the Osmosis Processes concept and its associated modelling challenges for the liquid-sensing enterprise. This objective was achieved by following the three-layer paradigm based on MSDEA approach, which the supports potential coordination and cooperation between multi-disciplinary teams. It starts by defining the process application goals, to identify the activities for each world, in a business and technical language, ending with the osmosis process execution.

The modelling tool was adapted from MSEE's project results. In (Marques-Lucena et al., 2016) was presented a first version of the OSMOSE Toolbox explained the changes made in the MSEE's tool to follow the need to model the osmosis processes concept, namely the interactions between worlds, and the middleware membrane decision logic. In this new version, the objective was to improve the experience of the user, by giving the option to specify the worlds in the EA* model, facilitating with this approach the redesign in the BPMN2.0 model. For that, it was needed to change the transformation code, improving the transformation and accelerate the design time. These changes allowed to include in the business process model a more detailed information about the involved worlds. It facilitated, technical teams, with their knowledge about the osmosis worlds' concept and technical modelling skills, to enrich the business process model with the osmosis behaviours and constrains. This new version of the Toolbox improved user experience as well as the integration between the business level and the technical level. The notion of the worlds in the transformation rules improved the resulting BPMN process, causing the user to make fewer changes in it. At same time, due to the fact that the Toolbox follows the MDA paradigm, it gives the capability (at the design phase of the processes models) to re-adapt over time, allowing to evolve when occurring a change in the process or service, which need to be changed.

As future work, the authors intend to enrich LSE environment tool with the osmosis events pallet, so the osmosis processes modelling can be facilitated. The authors also want to improve the deployment to jBPM, enabling the import of the BPMN directly to the jBPM reducing the time to execution and improving the instantiation and parametrization of the activities, since it is made at same level.

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## REFERENCES

Agostinho, C. & Jardim-Goncalves, R. (2015) Sustaining interoperability of networked liquid-sensing enterprises: A complex systems perspective. *Annual Reviews in Control*, 39, pp.128–143.

Agostinho, C., Sesana, M., Jardim-Gonçalves, R. & Gusmeroli, S. (2015) Model-driven Service Engineering Towards the Manufacturing Liquid-sensing Enterprise. In: *{MODELSWARD} 2015 - Proceedings of the 3rd International Conference on Model-Driven Engineering and Software Development, ESEO, Angers, Loire Valley, France, 9-11 February, 2015.* pp.608–617.

Arthur, W.B. (2011) The Second Economy. *McKinsey Quarterly*.

Baines, T. & W. Lightfoot, H. (2013) Servitization of the manufacturing firm. *International Journal of Operations & Production Management*, 34 (1), pp.2–35.

Bouchbout, K., Akoka, J. & Alimazighi, Z. (2012) An MDA-based framework for collaborative business process modelling. *Business Process Management Journal*, 18 (6), pp.919–948.

Bouchbout, K. & Alimazighi, Z. (2011) Inter-organizational business processes modelling framework. In: *ADBIS (2)*. pp.45–54.

Ducq, Y., Chen, D. & Alix, T. (2012) Principles of Servitization and Definition of an Architecture for Model Driven Service System Engineering. In: M. van Sinderen, P. Johnson, X. Xu, & G. Doumeingts eds. *Enterprise Interoperability*. Lecture Notes in Business Information Processing. Springer Berlin Heidelberg, pp.117–128.

Del Fabro, M.D., Albert, P., Bézivin, J. & Jouault, F. (2009) Achieving Rule Interoperability Using Chains of Model Transformations. In: pp.249–259.

FInES Cluster (2010) FINES Research Roadmap. *Retrieved, August*, 24, p.2013.

FInES Research Roadmap Task Force (2012) *FInESResearch Roadmap 2025: version 3.0*.

Friedman, T.L. (2006) *The World is flat : a brief history of the twenty-first century*. New York, Farrar, Straus and Giroux.

Grangel, R., Bigand, M. & Bourey, J.-P.J.P. (2008) A UML profile as support for transformation of business process models at enterprise level. *1st International Workshop on Model Driven Interoperability for Sustainable Information Systems, MDISIS 2008 - Held in Conjunction with the CAiSE 2008 Conference*, 340, pp.73–87.

H. Bazoun, G. Zacharewicz, Y.D. and H.B. (2013) Transformation of Extended Actigram Star to BPMN 2.0 in the frame of Model Driven Service Engineering Architecture. In: *Symposium on Theory of Modeling and Simulation (TMS/DEVS 2013)*. San Diego, USA.

Honour, E. (2008) Systems Engineering and Complexity. *INCOSE Insight*, 11 (1), p.20.

Jacobson, I., Ericsson, M. & Jacobson, A. (1994) *The Object Advantage: Business Process Reengineering with Object Technology*. New York, NY, USA, ACM Press/Addison-Wesley Publishing Co.

Lemrabet, Y., Bigand, M., Clin, D., Benkeltoum, N. & Bourey, J.-P. (2010) Model Driven Interoperability in Practice: Preliminary Evidences and Issues from an Industrial Project. In: *Proceedings of the First International Workshop on Model-Driven Interoperability*. MDI '10. New York, NY, USA, ACM, pp.3–9.

Marques-Lucena, C., Agostinho, C., Marcelino-Jesus, E., Sarraipa, J. & Jardim-Goncalves, R. (2015)

Collaborative Management of Requirements Using Semantic Wiki Modules. In: *Control Systems and Computer Science (CSCS), 2015 20th International Conference on*. pp.665–672.

Marques-Lucena, C., Ferreira, J., Sesana, M., Fischer, K. & Agostinho, C. (2016) Process Modelling Approach for the Liquid-Sensing Enterprise. In: *I-ESA'16 - Interoperability for Enterprise Systems and Applications*. Guimarães, Portugal.

Mili, H., Jaoude, G.B., Lefebvre, É. & Tremblay, G. (2004) Going beyond MDA: Business process modeling for software reuse. In: *Proceedings of the Workshop on Legacy Transformation: Capturing Business Knowledge from Legacy Systems-OOPSLA'2004*.

Moisescu, M.A. & Sacala, I.S. (2016) Towards the development of interoperable sensing systems for the future enterprise. *Journal of Intelligent Manufacturing*, 27 (1), pp.33–54.

Ould, M.A. & Ould, M.A. (1995) *Business processes: modelling and analysis for re-engineering and improvement*. Wiley Chichester.

Panetto, H. & Molina, A. (2008) Enterprise integration and interoperability in manufacturing systems: Trends and issues. *Computers in Industry*, 59 (7), pp.641–646.

Radder, L. & Louw, L. (1999) Mass customization and mass production. *The TQM Magazine*, 11 (1), pp.35–40.

Rodr'iguez, A., Fernández-Medina, E. & Piattini, M. (2007) Towards CIM to PIM Transformation: From Secure Business Processes Defined in BPMN to Use-Cases. In: G. Alonso, P. Dadam, & M. Rosemann eds. *Business Process Management: 5th International Conference, BPM 2007, Brisbane, Australia, September 24-28, 2007. Proceedings*. Berlin, Heidelberg, Springer Berlin Heidelberg, pp.408–415.

Rodríguez, A., de Guzmán, I.G.-R., Fernández-Medina, E. & Piattini, M. (2010) Semi-formal transformation of secure business processes into analysis class and use case models: An {MDA} approach. *Information and Software Technology*, 52 (9), pp.945–971.

Santucci, G., Martinez, C. & Vlad, D. (2012) The Sensing Enterprise. In: *In FInES Workshop at FIA 2012*. Available from: <http://www.theinternetofthings.eu/sites/default/files/%5Buser-name%5D/Sensing-enterprise.pdf>.

Spirito, M., Pastrone, C., Soldatos, J., Giaffreda, R., Doukas, C., Muñoz, L., Polidura, V.G., Gusmeroli, S., Sola, J. & Agostinho, C. (2014) Internet of Things Applications - Research and Innovation to Market Deployment (Chapter 7). In: O. Vermesan & P. Friess eds. *Internet of Things – From Research and Innovation to Market Deployment*. River Publishers, pp.243–286.

Wiesner, S., Guglielmina, C., Gusmeroli, S. & Doumeingts, G. (2014) *Manufacturing Service Ecosystem: Achievements of the European 7th Framework Programme FoF-ICT Project MSEE: Manufacturing Service Ecosystem (Grant No. 284860)*. Bremer Sch. http://www.verlag-mainz.de.

Zdravkovic, M., Panetto, H. & Trajanovic, M. (2013) Semantic Interoperability for Dynamic Product-Service. In: *International Conference on Information Systems and Technology (ICIST 2013)*. Kopaonik, Serbia.