A Measurement-oriented Modelling Approach
A Step Forward

Giulio D'Emilia, Gaetanino Paolone, Emanuela Natale, Antonella Gaspari and Denis Del Villano
Department of Industrial and Information Engineering and of Economics, University of L'Aquila, L'Aquila, Italy

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Abstract: Measurements represent a fundamental component of Enterprise Information Systems and they play a key role in organizations. Their own languages, concepts and techniques, concerning how to approach and solve problems in modern industrial scenarios, inevitably characterize these two disciplines. This is why the question we posed is to get a methodology that allows us to analyse, model and implement software subsystems able to render really usable information concerning measurements, keeping their informative peculiarities unchanged. The final goal of our research is to define a Use Case-based methodological proposal for modeling the informative content of measurements and their usage that starts from the business model of an enterprise subsystem and achieves a software model able to satisfy the users' needs.

1 INTRODUCTION

It is generally acknowledged that designing and developing software systems is becoming increasingly complex. Fortunately, there are methodologies and tools (Sukaviriya et al., 2009) to tackle this demanding and, sometimes critical, challenge. For example, the methodology proposed in (Paolone et al., 2008a; 2008b; 2009) promotes the iterative and incremental development of complex software systems using a methodological framework that supports model-driven engineering. Such a methodology is inspired to the Rational Unified Process (RUP) (Kruchten, 2003) and it poses Use Cases (UC) at the centre of the modelling (UML, 2012).

Nowadays measurements, i.e. quantitative information from measured quantities, represent more and more a fundamental component of Enterprise Information Systems (EIS) and they play a key role in organizations. While the automation of decision-making processes based on measurements appears to be a great opportunity, on the other hand difficulties are presumable. There is the possibility of having a large amount of data coming from measurements to be integrated into the Business Information System that have their primary language and who are not always well spread throughout all departments of the business organizations. Moreover the source of information has an extremely wide variability, in the measuring system implementing methods and in the quality of measurements. There are concepts related to the variability that may give rise to content's smokiness and, then, computerization may be a useful solution. Another difficulty is that the operating conditions can have, from one case to another, completely different characteristics and connotations. This is why the question we posed is to get a methodology that allows us to analyse, model and implement software subsystems able to render really usable information concerning measurements, keeping their informative peculiarities unchanged. Please note that in literature there are very few examples that can be supportive (Wen Bilong et al., 2009). Studies aiming to compare foundations of measurement theory to software measurement (Carbone et al., 2008) do not appear, in fact, closer to these goals.

For an IT project to be successful, it must be as close as possible to business reality, in such a way that corporate users can find in the application (Zhao et al., 2007) the same modus operandi of their own function: each actor plays a set of UCs within the organization and does so regardless of automation. Today, UCs are at the core of modelling and developing software applications (Zelinka, Vrani´, 2009) (Duan, 2009) (Sukaviriya et al., 2009). The methodology appeared in (Paolone et al., 2009) is an

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instance of the proposal that empower to manage such a complexity through a layer of classes dedicated to UC automation. Their methodology examines the system behavioural aspects through a top-down process (such an approach is commonplace amidst software development methodologies), and then proceeds by means of stepwise refinements of the initial business model.

The final goal of our research is to define a methodological proposal for modeling the measurements and their usage that starts from the business model of an enterprise subsystem and achieves a software model able to satisfy the users' needs (i.e., that fully adheres to business processes). In line with this goal, the present contribution calls into question the convenience of using a top-down approach in business modeling, system modeling, design and implementation of a software system able to make available the expected information, arising from the measurements, to the management.

The next step (started with this position paper) adapts the approach proposed in (Paolone et al., 2008a, 2008b, 2009), transforming it in such a way that you can understand and design software application for the analysis of measurements starting from business system requirements. In summary, what we want to do is to extract UCs from the EIS and bring them into the computerized system (from Business Modeling to System Modeling) also in relation to the measurements to be carried out in any enterprise area, whether they are related to the production, power consumption or all other forms of detection.

The paper is organized as follows. Section 2 recalls essential elements of the methodology appeared in (Paolone et al., 2008a, 2008b, 2009) needed for understanding this work. Section 3 outlines essential characteristics of an EIS' subsystem dedicated to metering and its peculiarities in decision-making, regardless of the usage of computer. Section 4 starts the discussion about a possible transformation of the methodological process recalled in Section 2, which can lay a solid foundation for pursuing the aforementioned ultimate goal. Brief conclusions end the paper.

2 THE METHODOLOGY

The methodology introduced in (Paolone et al., 2008a; 2008b; 2009) allows to represent in detail two models: the business and the system model. Use case modeling and realization are the most important aspects of the methodology. The proposal is centered around four distinct layers (Figure 1) with an iterative and incremental approach that leads to the realization of a Business Use Case (BUC) into the software application through stepwise refinements. The first two layers of UC analysis are placed in the business modeling context: their objective is to get a complete representation of the given business reality. The next two layers are instead placed in the system modeling context with the objective of representing the software system. More in detail, they say that the first layer concerns BUCs analysis, which are then specialized by Business Use Case Realizations (BUCR) in the second layer. Afterwards, a *trace* operation is used to define the system UCs (third layer), which are then specialized by Use Case Realizations (UCR) (fourth layer). The latter ones can be implemented by Object Oriented classes.

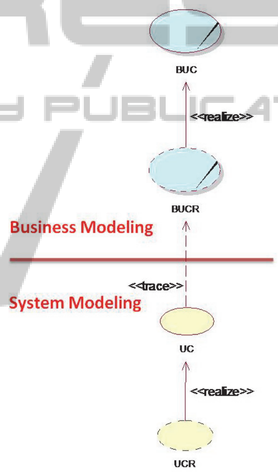

Figure 1: A sketch of the methodological layers.

Next, we describe the methodology in detail through a brief example referring to a real-life document management project for a bank, where every layer contains a type of UML diagram.

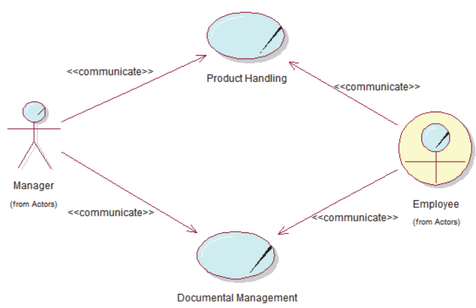

Figure 2: The BUC diagram (1st layer).

This example may be useful because, as we will show hereafter, what is being developed for a bank, which is a typical management case, can be applied to any industrial scenario.

Figure 2 shows a fragment of the BUC diagram, placed in the first layer of Figure 1.

The example shows how BUCs are used to express an actor/system interaction. For each BUC, we define the related BUCRs. Referring to the BUC `Documental Management`, Figure 3 proposes six BUCRs.

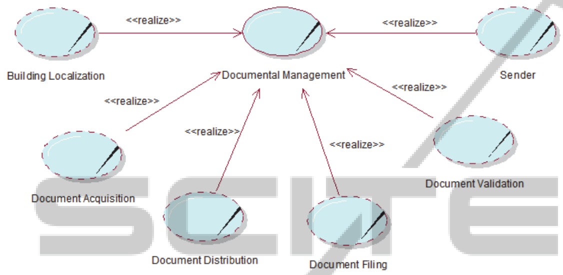

Figure 3: The BUC *realize* diagram (2nd layer).

After the business modelling phase, we analyse the part of the system that will be automated. The *trace* operation can introduce many system UCs for a single BUCR. For example, in `Documental Management`, the document acquisition can be done by the Bank, but also by Suppliers (see Figure 4). The output of the *trace* operation produces the system UCs in the third layer of Figure 1.

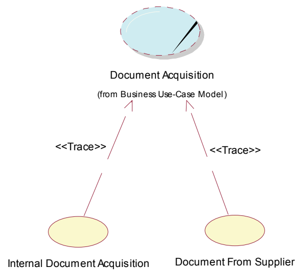

Figure 4: The use case *trace* diagram (3rd layer).

In the last phase of the subsystem behavioural analysis, we must identify at least one system UCR for each system UC. In this phase we also introduce some *technological* UCRs, such as `LinkFile`. For the sake of brevity, we don't present an example of system UCR diagram, but it should be straightforward to understand that this operation introduces a further refinement of the subsystem.

The current methodology has a strong industrial impact because it has been repeatedly applied in real projects reaching good results and its adoption has brought benefits both in terms of the engineering aspects of design and development time (Paolone et al., 2008a). Moreover, the methodology enables to build software systems with the help of a an existing Java-based framework that implements a Java class for each UCR and permits to ~~speeds~~ up software development.

In conclusion, it is possible to reaffirm that the methodological process is UC-driven, since the UC artefact exists both in the business model and system model, although it is represented by different stereotypes, and is also exported to code.

3 THE MEASUREMENT VIEWPOINT

Decision making requires both information and knowledge. Information (or its absence) is central to decision making (Beretta et al., 2012). In other circumstances the theory of measurement has alredy demonstrated to favor the ability to enter in the actual reality of the processes of interest (D'Emilia et al., 2014a). Therefore, information deriving from measurement data may play a key role in business decision making. In business management, it is important that decision is supported by appropriate tools, having the function to give the possibility to minimize the risk of underestimate and of errors to the called person to make a complex decision. In this sense, measurement uncertainty offers a considerable aid to quantify that risk, because it refers to the concept of the information reliability level (level of confidence).

In fact, if the data are accurate, i.e. closer to the "true quantity value" of the measured quantity, then they can be processed effectively creating an informative base with the following features:

- *shared*, i.e. integrated within business informative systems set in the specific industrial situation;
- *transparent*, i.e. objective and incontestable from the team members who participate to the decisional process;
- *significant*, i.e. consistent from the data quality viewpoint,
- *aware*, involving, in other words, an indication about the risk assumed by the decision maker, with reference to different alternative choices.

In that context, aiming the fulfillment of these features, the attention must be paid to several challenging aspects for both information systems and metrology disciplines. Without limiting the general nature of the foregoing, an interesting area of use of a decision-making strategy based on measurement uncertainty of data coming from the field, is referred to an energy case of optimization. In particular, with reference to an industry operating in the aeronautical sector, simple measurements allowed us to validate a predictive model of energy consumption, to be used for the definition of a cost effective strategy for energy saving (D'Emilia et al., 2014b).

In this context, the decision-making strategy provides for the possibility of having a management tool that, for example, is able to return alternately:

- the correspondence between a budget of improvement (I) and the target (t) that can be guaranteed, in front of a predetermined level of confidence (k) or risk deemed acceptable by the decision maker;
- the relation between a variable and adjustable improvement investment $\check{I}$ and the probability p(k') that a target set as t' is achieved.

In fact, in order to ensure, for the same investment I, and with a given level of confidence p(k) to achieve a given objective t, it is necessary that the model gives the value $\bar{m}$ as a solution, which is related to the target of a quantity t exactly equal to the measurement uncertainty of the model, U(m), according to the following logical implication:

$$\mathrm{p(t, I)\%} = \mathrm{p(k)} \rightarrow \bar{\mathrm{m}} = \mathrm{t} - \mathrm{U}(\bar{m})$$

with:

$$\mathrm{U}(\bar{m}) = \mathrm{k} * \mathrm{u}(\bar{m})$$

where:

p(t, I)%: probability of reaching the target t, with the investment I;

n : degrees of freedom;

k, k': coverage factors (with $n = \infty$);

p(k): probability (confidence level) associated with the model with the coverage factor k chosen;

t, t': target fixed or variable depending on investment;

m: indication of the consumption model validated, i.e. provided of its uncertainty, m = f (I);

$\bar{\mathrm{m}}$: indication of the model that is in new condition after the fixed investment I;

$\bar{\bar{\mathrm{m}}}$: indication of the model corresponding to the realization of the investment variable $\check{I}$;

u (m): standard uncertainty of the model;

U (m): expanded uncertainty of the model.

Furthermore it is possible to study the relationship, $\mathrm{p(k')} = \mathrm{f'}(\check{\mathrm{I}})$, between probability p(k') to reach the target and the required investment $\check{\mathrm{I}}$. In fact, in front of an investment $\check{\mathrm{I}}$ the model will return an indication $\bar{\bar{\mathrm{m}}} = \mathrm{f}\,(\check{\mathrm{I}})$ corresponding to a reduction in consumption plausibly less ambitious (i.e. $\bar{\bar{\mathrm{m}}} > \bar{\mathrm{m}}$), being: k'≠k.

4 THE APPROACH WE LOOK AT

Designing a large enterprise software application is a complex and articulated process since it represents the company automation. Particularly critical appears the identification of the UCs that illustrate the interaction modes of the end-users with the system according to the usual business workflows. It is important to emphasize that the usage of a methodology, in the context of software engineering, has a fundamental importance to dominate the complexity of computerized solution.

As described in previous sections, measurements represent a key element in decision making. BUCs and BUCRs detection is a critical factor for the success of software applications which aim to be strategic for the business management and that are inspired by measurements. As a first step towards the definition of a methodology for the analysis and design of software for decision making that is based on measurements, we apply the methodology mentioned in Section 2 to a real case. The case study is referred to an energy case of optimization within an avionics components' enterprise: the main goal is to reach the energy consumption optimization.

In the proposed approach, the business modeling activity starts, in close collaboration with the enterprise top management, from the detection of Organization Units involved in the IT project and then proceeds discovering their Business Systems (BS) and their Business Goals (BG). Four BSs were detected and analyzed: in the example discussed hereinafter we focus on one of them, the BS `EnergyManagementArea`, involved in reaching the BG named `EnergyConsumptionEfficiency`.

Inside every BS we identify Business Actors, BUCs and BUCRs, using the construct BUC to represent a single interaction mode between actors and the system and the construct BUCR to represent how business workers, business entities, and business events collaborate to perform a particular BUC (Johnston, 2004).

After a careful analysis of the Company, paying particular attention to information flow inside the BS

`EnergyManagementArea`, we identified several BUCs. In presenting our proposal, particularly interesting are the BUCs performed by the Business Worker `Energy Manager`, whose decisions are closely related to the measurements made on the field. Among those several BUCs, the most complex (from the knowledge-intensive point of view) is `ConsumptionTargetManagement`, realized by 3 BUCRs (Figure 5).

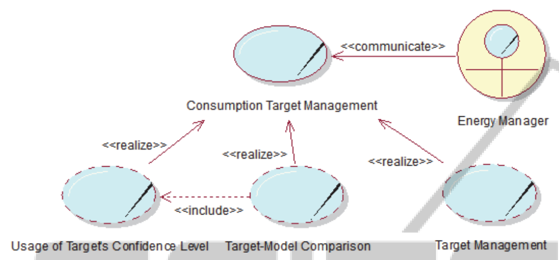

Figure 5: Part of the case study BUC realize diagram.

To better understand the logic flow and document knowledge aspects involved in knowledge-intensive BUCRs, we widely use Business Activity Diagrams (BAD) (where a Business Activity (BA) denotes an elementary business operation or a knowledge-intensive task) and a strong narrative description. The ability of UML BADs to effectively describe complex business processes (Russel et al., 2006) allows us to depict the inference process that permits the Business Actor to take a complex decision. A complex BA (that is an activity representing a number of intricate atomic tasks) may be depicted at different grain-size levels through the use of several BADs.

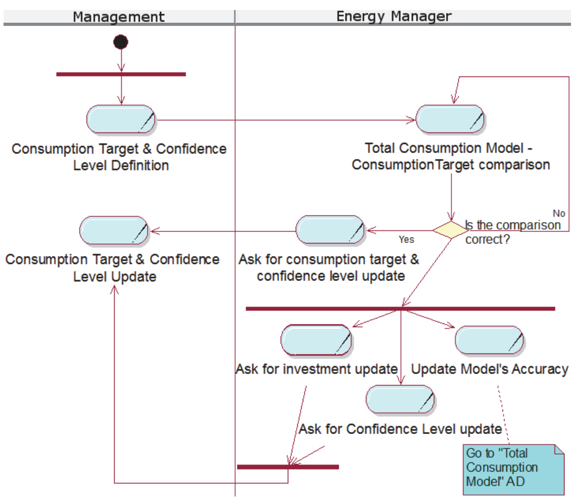

Figure 6: Part of the case study BA diagram.

For example, the BUCR `Target-Model Comparison` – representing the concepts expressed in Section 3 – was depicted using the BAD in Figure 6 (which is only a part of a larger diagram because of space limits) and also widely documented through a narrative specification.

During the execution of the business modeling discipline, as provided for by theory, the main Business Entities (BE) (representing a significant and persistent piece of information that is manipulated by Business Actors and Business Workers (Johnston, 2004)) were also identified and modelled.

Specific attention was paid to documenting classes of measurement-intensive business objects, i.e. those BEs strongly related to measurements. In their modeling, close attention was paid to maintain the peculiarities of measurement unchanged and well-marked, in order to grant a key role in business decision making to information deriving from measurement data. Figure 7 shows a portion of the BEs diagram

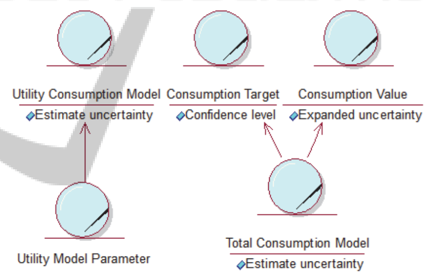

Figure 7: Case study Business Entities.

After the Business Analysis, a *trace* operation was performed: according to the methodology, we identified the BUCRs to be computerized and we *traced* them into System UCs (Figure 8).

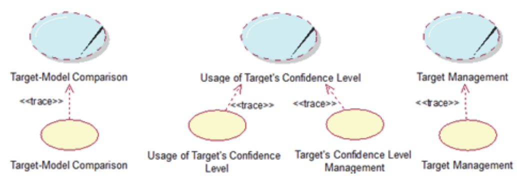

Figure 8: Part of the case study UC trace diagram.

In the same way, a *trace* operation was performed only on BEs needed for the computerization.

In the last phase of the subsystem behavioural analysis, we identified UCRs for each system UC. Each UCR was diagrammatically depicted in terms of scenarios: for the sake of brevity we will not present a figure of system UCR diagram.

5 CONCLUSIONS

At the end of the case study's modelling process we believe the proposed approach produces a good representation of the EIS to be computerized and a concrete image of subsystems to be automated. It is important to remark we achieved this firm belief in close collaboration with several stakeholders involved in various aspects into the project, mainly measurements experts, decision makers, IT-business analysts and software engineers. Therefore, in our opinion, the usage of this methodological approach, broadly integrated with the usage of BADs (mainly to represents business decision-making patterns) permits to improve the communications' quality between the various stakeholders involved in modelling and designing a measurement-intensive software system. Starting from the business modeling activity, the increase in the information's quality may help to reach a more effective system analysis and, at the end of the process, to build a software system as close as possible to business reality and fully able to reveal its decision-making patterns.

Finally, we believe this approach may become a first step in reducing the informative gap (concerning the correct usage and interpretation of measurements) between business management, software engineers and measurement experts, giving some preliminary solutions deriving from the fact that in the best of our knowledge, measurements are not correctly used into automated decision making processes as often the typical concepts of measurement (uncertainty, level of confidence, ...) are lost while being processed and made accessible to end-users. A change is needed in the usage of measurements in decision making processes modelling and computerization and the proposed top-down approach may be a first step in this change. Of course, to completely clarify how measurements need to be correctly used and interpreted within an automated decision-making process, requires that many aspects are further studied with reference to the business modelling, to the type of approach (top-down, bottom-up, mixed), to the procedures of in field transfer of the results, etc.)

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