Business Modeling of a Measurement-based Context: A Methodological Process

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Abstract: A measurement-based context is a working environment where measurements, i.e. quantitative information from measured quantities, represent a fundamental component and are relevant for behaviors, decisions and scenario modeling. In such a context, the Rational Unified Process has been customized in order to improve the methodological approach for the business modeling. The aspects considered concern the analysis of the involved stakeholders, the measurements concepts to be shared among them and the way this sharing can be realized for suitable use of the information deriving from measurements. The effects of this study in terms of definition of the business modeling team, insertion of some specific input documents and increase of ability of transferring the real physical meaning of the measurement information in the business modeling process are discussed. The methodological improvements contributing to an aware cooperation among stakeholders involved are argued.

1 INTRODUCTION

Nowadays measurements, i.e. quantitative information from measured quantities, represent a fundamental component of Enterprise Information Systems (EIS) and they play a key role in organizations (D'Emilia, 2014a).

A measurement-based context is intended as a scenario where measurement data assume a great relevance with respect to industrial behaviors, decisions and models describing the applications to be faced. When this situation has to be faced, care should be paid with reference to the peculiarity meaning and characteristics of quantities and numbers deriving from measurement activity; in fact, their meaning is definitely different from what the numerical data represent referring to the "general" data management (e.g. bills, accounting and/or administrative records and documents) (Paolone, 2008a). Moreover, this difference increases with the amount of processing operations, derived from experimental data.

Obviously, in both cases (measurement data on one hand, and general data on the other hand) numbers representing quantitative entities have to be managed, but both meaning and characteristics are quite different.

In fact, first of all, measurement data are strongly connected to the physical reality, since they quantify the physical quantities, i.e. the entities able to quantitatively represent and describe the physical phenomena. Furthermore, measurement numbers should be completed by the indication of the measurement uncertainty, which is itself a direct derivation of the characteristics of the real situation where measurements are realized; these characteristics are generally difficult to model, therefore the real situation is intrinsically complex and casual. On the contrary, the numbers of bills or of accounting documents (just to refer to the above example) represent deterministic data, deriving from operational and/or commercial procedures, that are conventional.

A further aspect to be taken into account is the human attitude towards casual situations: generally, the possibility of acting and thinking with a deterministic point of view without probabilistic considerations is by far preferred. On the other hand, the intrinsic random nature of measurement data cannot be neglected: they are the final result of an operational process which is affected by many factors of different type (technical, environmental, operational, instrumental). In this way, they

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represent the effective scenario where the measurements are made. Facing a random situation appears to be an unavoidable requirement.

Therefore, business modeling must highlight this difference. In other words, we believe that business modeling should correctly take into account the role of measurements in the EIS. In fact, if previously and correctly validated, measurements are credited to the ability to provide objective information based on physical elements. Measurements and their uncertainty represent engineering parameters, able to model the systems and the processes of interest, from both technical and economic point of view, these latters intended to be, for example, investments in measurement instrumentation or in personnel metrological training and education.

Some approaches that consider, as common practice in modeling processes, the engagement of anyone who has some specialized knowledge of the business object [e.g., (Robertson, 2012)] exist in literature; they give general guidelines to manage expert contributions regardless of the adopted modeling approach. Unfortunately, in our daily experience, measurements are too often incorrectly endorsed, managed and used and they lose the great part of their informative content. For this reason, if business modeling is not able to involve the specific contributions coming from measurements (such as their innate randomness nature), a relevant part of its operating capability is strongly reduced.

A tailoring of the methodological approach for business modeling of measurement-based context is needed. A possible way to get this result, avoiding a misunderstanding of measurement information, is to approach in a systematic way the EIS modeling in a measurement-based context.

In the present paper, taking advantage of the high versatility of the RUP process (Kruchten, 2003a) (RUP, 2001) a customized solution of the process is proposed, aimed to the integration of some basic metrological concepts into the process itself. Section 2 describes the state of the art about the business modeling in the EIS, by means of a methodological modification referring to the Business modeling discipline. Section 3 introduces the general measurement concepts to be considered priority for the business modeling allowing us to individuate a first approximation class of metrological core-concepts, useful for a conscious treatment of a measurement-based context. Section 4 describes the proposed methodological process including the specific funcions of each involved stakeholder and section 5 outlines conclusions and future work.

2 STATE OF THE ART

Modern software development processes are invariably iterative and incremental (Maciaszek, 2007). There are many variants of the typical iterative and incremental development process. Among the main variants, according to (Maciaszek, 2004), we can include:

- The Rational Unified Process;
- The model-driven architecture (MDA);
- The agile development process.

Going ahead with the research activity started in (D'Emilia, 2014a) (D'Emilia, 2014b), trying to improve and ensure the continuity between business modeling, system modeling, design, and implementation according to the model driven paradigm also in the specific measurement-based context, we focus on the RUP software engineering process, especially on the business modeling discipline.

2.1 Business Modeling in the Rational Unified Process

The Rational Unified Process is an iterative and incremental software engineering process developed originally by Rational Software, and then by IBM. It is a disciplined approach that helps who is involved in a software engineering development process to assign and manage tasks and responsibilities within a development organization (RUP, 2001). Its goal is to ensure the production of high-quality software that meets the needs of its end-users, within a predictable schedule and budget (Kruchten, 2003b) (Jacobson, 1999).

The RUP is not only a guide for how to effectively use the Unified Modeling Language (UML) but also it provides detailed and practical guidance through all phases of the software development life cycle. The Rational Unified Process enhances team productivity by providing easy access to a knowledge base with guidelines, templates and tool mentors for all critical development activities. By sharing with all the team members the same knowledge base, it is able to ensure that all team members share a common language, process and view of how to develop software. It is very important to underline that no single process is suitable for all software development. Therefore the RUP process has been thought to be tailored to suit a wide variety of projects and organizations (Kruchten, 2003b) and to be varied to accommodate different real life situations providing effective support for configuring the process to suit the needs of a given organization. For this reason, also in a measurement-based context, we decided to use the RUP based approach introduced in (Paolone, 2008b) (Paolone, 2009).

The process can be described in two dimensions (Figure 1):

- the horizontal axis represents time and shows the dynamic aspect of the process as it is enacted, and it is expressed in terms of cycles, phases, iterations, and milestones;
- the vertical axis represents the static aspect of the process: how it is described in terms of activities, artefacts, workers and workflows.

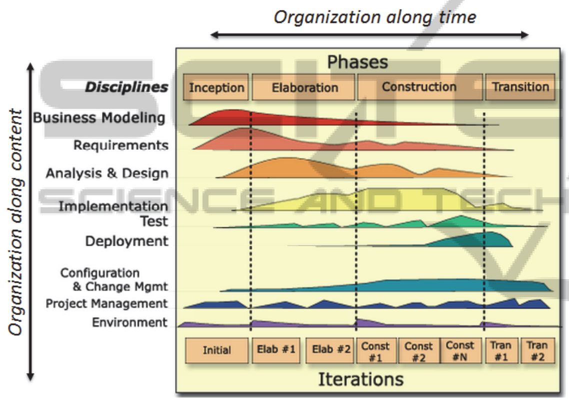

Figure 1: The RUP: overview (SCE, 2015).

For the purpose of this paper, the most important phase is the inception phase. During the inception phase the business case for the system and the project scope limits are established. This involves identifying all use cases and describing a few significant ones (the most important or the most complex ones). The outcomes of the inception phase are several documents such as a vision document expressing a general vision of the core project's requirements, an initial (partial) use-case model, an initial (and optional) project glossary that can be expressed as a domain model, and so on. The process is also described by meaningful sequences of activities that produce some valuable result and show interactions between workers: the workflows. The RUP proposes the most essential type of workflows in the process as the Core Workflows (Figure 1): those workflows are revisited again and again throughout the project lifecycle.

For the purpose of this paper we are very interested in the business modeling discipline (Figure 2).

A good business modeling permits to understand the structure and the dynamics of the target organization and ensures that customers, end users, and developers have a common understanding of the target organization.

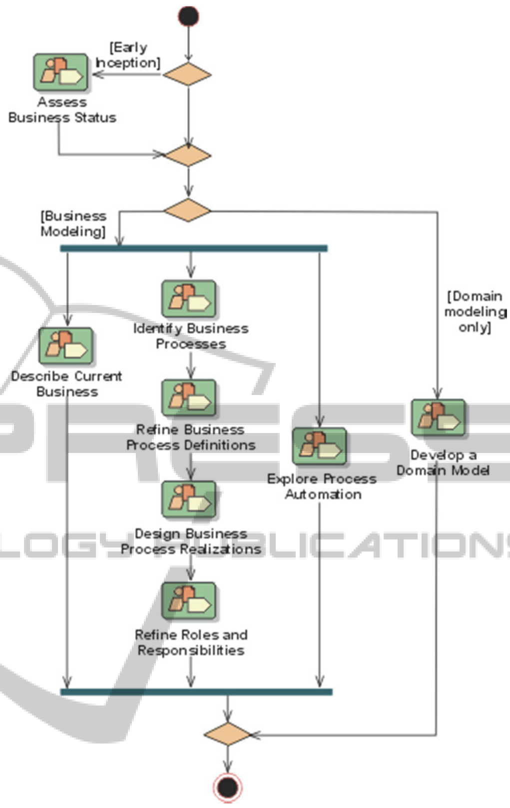

Figure 2: Business modeling discipline: overview (Kruchten, 2003b).

The main roles involved in the business modeling are:

- The Business-Process Analyst: that leads and coordinates business use-case modeling by outlining and delimiting the organization being modelled;
- The Business Designer: that details the specification of a part of the organization by describing one or several business use cases, determines the business workers and business entities needed to realize a business use case, and also how they work together to achieve the realization.

Also involved in this discipline are:

- Stakeholders, who represent various parts of the organization and provide input and review (end-users and customer);
- The Business Reviewer, who reviews the resulting artefacts.

3 PRIORITY MEASUREMENT CONCEPTS FOR THE BUSINESS MODELING

In a business modeling that is carried out in a measurement-based context, it seems to be necessary to identify the basic concepts of measurements to be taken into account; these basic concepts should be defined and described with the aim of sharing their true physical meaning and usefulness with all the actors of the modeling itself, taking care about all the specific aspects linked to the measurement data. These aspects should be known by all project stakeholders.

The effort of addressing the definitions to the modeling process is expected to improve the efficaciousness of the modeling procedures in a very large range of possible applications of industrial interest.

The authors are aware that the technical and professional background of people involved in these applications is usually different between each other; for this reason the methodological approach has to be faced very carefully and it has to be intended as a first step to be possibly extended in the future. It is to be noticed that customers also should be involved in this action of sharing the physical meaning of concepts, for a good transfer of their requirements to the business modeling experts.

Furthermore, the authors are conscious that the VIM - International Vocabulary of Metrology (JCGM, 2012) is the "address", where the correct definitions of metrological terms are found, in particular if the need of general validity of definitions is considered.

The aim of sharing the basic metrological concepts with the stakeholders involved in business modeling, probably requires that the definition of concepts to be used in this specific task are fitted to their typical professional background; the physical meaning of experienced practice will be also able and useful to suggest a few formal, and not substantial, modifications with respect to the standard approach of VIM (D'Emilia, 2015).

In the following, the bases of the methodology are defined in order to draw a sort of guide lines supporting conscious and rigorous management and analysis of measurement data, during the modeling process.

For a complete sharing of the measurement theory, many concepts must be treated and considered. In this section only a preliminary number of arguments is analyzed.

The selection criteria mainly refer to these aspects:

- *meaningfulness* and *relevance* of the concepts with reference to typical decisional situations and to the relationships between all the possible actors involved in the industrial processes (supplier/customer, for instance);
- *physical representativeness* and *possibility of being transferred* into the business modeling actions, preserving good consciousness of all the involved actors in the business modeling itself;
- *general interest* of the concepts for different applications and possibility of realizing guide lines of industrial inter-sectorial validity.

A simple and coarse example is now described, in order to underline the importance of correctly using the metrological concepts in an engineering application of industrial safety.

A tank is considered in an industrial plant; its working model requires that the safety valve has to be open by a control system when the *real pressure* of the fluid is 2.0 bar, in order to avoid structural problems of the tank itself. If a typical measurement configuration is considered, the control system is driven by a pressure transducer with a measuring range of 4.0 bar; furthermore, the whole measuring uncertainty is 0.1 bar with a level of confidence in the order of 95% and the pressure transducer has been calibrated before use. In this case, if the *measured pressure* by the transducer is 1.9 bar, a probability of 2.5% can be assumed that the limit pressure of 2.0 bar was overcome in the tank. If this level of risk is considered acceptable, the control system must open the valve when the *measured pressure* is 1.9 bar.

In a latter case, if the opening of the safety valve is set in correspondence of a *measured pressure* of 2.0 bar, with a threshold set in a deterministic manner, it has to be assumed a probability of 50 % that the limit pressure of 2.0 bar was overcome in the tank at the opening of the valve.

It is quite evident that the latter approach is remarkably less safe, even though this consciousness is difficult to be shared with people not expert of measurements. In this case the needed concept is the expanded uncertainty and it will be discussed hereinafter.

In this first step of the methodological approach, being at a very general level, both theoretical concepts and procedures will be analyzed together.

The priority metrological concepts and procedures are re-elaborated and presented in the following trying to underline the practical relevance of them:

- **True value:** the unique value representing the physical quantity to be measured in an exhaustive manner; if the actor refers to it and the operational and/or decisional models are correct and completely valid, the selected actions realize the right solution of the problem. Furthermore, if all the actors involved in any situation refer to it, no misunderstanding can occur, being the target exactly the same.

It is to be pointed out that the knowledge of the *true value* involves the availability of a very large (theoretically infinite) amount of information about the problem; in practical cases it is obviously impossible to get it by preliminary considerations or by the measurement process.

Typically, the answer to the question "what's the true value?" should be given according to the indication of an interval of values comprising the true value with a given *level of confidence*.

The half-amplitude of this interval corresponds to the *expanded uncertainty* obtained from the *standard uncertainty*. This approach requires that measurements are not affected by any *systematic error*; this result is achieved if any measuring instrument is calibrated before use.

Usually this way of operating is fully satisfactory from a practical point of view, even though it appears complicated.

- **Measurement uncertainty:** it represents the variability of measurements, being all the values ascribing to the quantity to be measured. The variability is strictly depending on the reality of the measurement process. All the aspects influence it, like performances of instrumentation and correction of the *systematic measurement error*, skill of the operator, simplified models and assumptions, environmental conditions, … The *standard uncertainty* is the statistical indicator of it, representing the operating context where measurements are carried out. As a rule of thumb, it increases as the approximations, the simplifications and the limitations with respect to any aspect, increase;
- **Expanded measurement uncertainty:** it is the way to combine the datum expressing the measurement and the *level of confidence*: it defines the interval around the measurement datum where you are confident the *true value* is, with a given *level of confidence*.
  It is to be noted that an engineering answer should give an indication of the relevant *level of confidence*. This information has to be treated as an engineering parameter, to be optimized by a trade-off procedure. In most cases, decisions and actions to be carried on could change depending on the acceptable *level of confidence* of reaching the set objectives; in fact, the resources and the requested investments depend on the *level of confidence*;
- **Systematic measurement error:** it represents the systematic difference of all measurements with respect to the situation the *systematic measurement error* does not occur.
  To be absolutely avoided for more reasons: the target of measurements is varied with respect to the *true value* and, furthermore, the systematic variation is remarkable with respect to the random variability.
  Both these conditions are very detrimental for the usefulness of the measurement, the former making useless statistical operation usually adopted for improving quality of measurements (mean of repeated measurements), the latter since standard procedures loss their meaning;
- **Level of confidence:** fraction from 0 to 1 of the values reasonably ascribed to the quantity to be measured being in the interval defined by the *expanded uncertainty*. In other words, it is the probability that the *true value* of the quantity is included in the interval defined by the *expanded uncertainty*;
- **Calibration:** procedure to estimate the *systematic measurement error* and the *calibration uncertainty* with reference to defined conditions. By using these estimates, the *systematic measurement error* could be corrected in measurements and the *measurement uncertainty* also in operating or field conditions can be estimated, by further data processing.

Only by guaranteeing that a *calibration* has been realized before measurements, the previous methodological approach can be assumed; provided that the measuring devices are calibrated, the measurements are expected to give reliable information for typical practical purposes, like the conformity check of products/processes and the validation of theoretical models for industrial process control.

4 A RUP INSTANCE FOR A MEASUREMENT-BASED CONTEXT

Agreed the strategic importance of information derived from measured values and their peculiarities, and acknowledged in literature there are very few examples that can be supportive (Wen, 2009), we are going to define a first step towards the definition of a RUP-based modeling approach to be used in contexts in which measurement data are central. The modeling approach we are going to propose is independent of the specific scope but applicable to a whole class of application contexts: the measurement-based contexts.

Our experience suggests that modeling a software system supporting an organization working within a measurement-based context, where information derives from data that are pure expression of physical concepts, needs to be treated differently from those the information derives from a conceptual modeling of the reality (e.g., measurement data are conceptually different from data treated in invoices). Data expressing the value of a measured quantity have the burden of representing physical aspects and, as such, need to be treated as not to lose meaning. Therefore we believe it is necessary a substantial change in managing the information arising from measurement. So, in modeling those systems, we believe a paradigm change is needed. The first step towards a paradigm shift in the methodological approach concerns a change in the business modeling: the business-modeling team must have the awareness of measurement's peculiarities and of the need for such a paradigm change in their treatment.

Any RUP-based software development approach considers the business modeling disciplines in the inception phase. The purpose of this workflow is to:

- describe the initial requirements;
- discriminate the critical business use cases of the system (that is the primary scenarios of the behaviour that will drive the system's functionality);
- assess the status of the organization and develop a first understanding of the goals and objectives of the target organization.

Upon all these items, stakeholders and the business-modeling team should agree.

At this stage, the RUP requires a close interaction among business analysis roles (Business-Process Analysts, Business Designers and Business Reviewers) and, mainly, two stakeholders: Customer and End-User.

Leveraging the great capacity for customization provided by the RUP and the chance to tailor it to the specific context's needs, our proposal provides for the introduction of a new stakeholder at an early stage of development, already: we call this stakeholder the *Measurement Expert*.

The *Measurement Expert*, in this context, is a crucial stakeholder. She/he not only deeply knows measurement and the metrology (regardless of the particular application context) but has a good practice too. From these skills the need of her/ his participation comes: the theoretical knowledge on one hand, the more practice on the other allow her/ him to analyze the impacts and the correctness of the measurement regardless of the specific practical case. For this reasons, we believe it is necessary and unavoidable to insist on the participation of this stakeholder in all the business modeling activities.

It is important that underlining the insertion of the *Measurement Expert* stakeholder does not represent a competence increase but rather a change in the process. It is not a technical addition, inherent to a single practical case but a methodological change impacting on an entire class of problems. In fact, measurements can concern several scopes of application and our proposal does not bind to any specific application area but has the aim to concern the general use of measurement data.

It should also be clarified that, as it might seem at first sight, the *Measurement Expert* is not a Domain Expert (that is an expert in functional aspects of processes and supporting systems) but she/he is an expert of metrology and measurement. So, she/he not necessarily must deeply know the specific application context but she/he must be able to manage measurement data and to understand information deriving from them. The presence of the *Measurement Expert* is necessary because generally, in our daily experience, End Users and Customers do not have any adequate sensitivity about the proper handling and use of measurement data. This is because they have different perspectives on the problem and different needs that must be addressed.

Finally, it is moreover important to emphasize that the understanding of the actual meaning of the measurements also allows the early detection of possible sources of error due, for example, to an excessive demand for information related to measurements. A typical example is the claim, by the management, to make decisions based on threshold values, rather than on bands - thus ignoring the basic principles of measurements (in particular, the true value concept). This kind of errors, being related to some conceptual aspects or misunderstandings about the data interpretation, are very impactful in the project management because it is difficult to detect and mitigate them. Even on this, thanks to its peculiar skills, the *Measurement Expert* has a positive effect.

The *Measurement Expert*'s tasks are:

- sharing the concepts of measurement with the business analysis team (Section 3);
- as regards the understanding of metrological concept, being the link between business analysis team, Customers and End-Users;
- keeping the focus on the physical characteristics of the measurement data;
- helping in early detection of problems and/or potential errors in the use of information derived from measurements;
- actively participating in the review activities of the business use-case model and the business object model.

In order to achieve an effective business model, as to be a reliable starting point for the next analysis phase, it is therefore clear the need to involve the *Measurement Expert* in all the workflow details provided for the business modeling discipline (see Figure 2).

The set of core concepts meticulously studied and developed by the working group (composed of software engineers and measurement and instrumentation engineers) (see Section 3) must be made available as an *input* document supporting the modeling activities (*Measurement core-concepts document*). In it, the basic concepts are presented in a formally and conceptually correct way but enriched with specific competences and actual experiences that could support others stakeholders in the understanding of their importance. Because of its importance, this document should be considered a fundamental input for the business modeling process when it is carried out in a measurement-based context.

By way of example, figure 3 shows the *Measurement core-concepts document* and the *Measurement-expert* stakeholder in the *Assess Business Status workflow detail*, part of figure 2.

Looking at figure 3 and at the other workflows details considered in the business modeling discipline (Figure 2) it is clear that the insertion of the *Measurement Expert* stakeholder and the *Measurement core-concepts document*, produces, in cascade, positive effects on the construction of all the documents and artefacts that make up the business model.

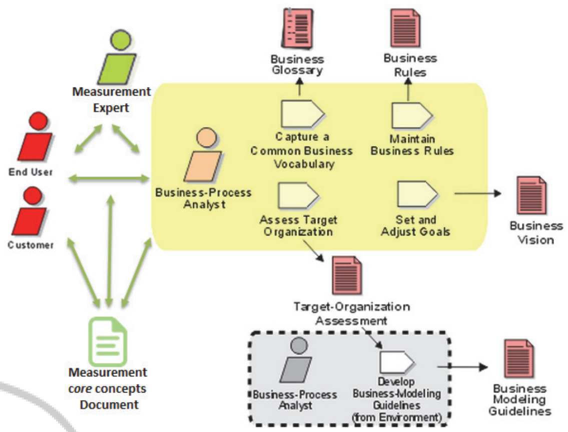

Figure 3: The modified Assess Business Status workflow detail.

As an example, the industrial safety case proposed in Section 3 has been modeled by two different teams having similar skills. The first one involved in the business modeling mainly the *customer*, the *domanin experts* and the *end-users*. The latter one also involved the *Measurement Expert* and shared the *Measurement core-concepts document* with all stakeholders. The *document* allowed sharing the measurement basic concepts necessary to manage the measurement-based decisional process. Comparing the produced artifacts it is clear the second team produced a more accurate and conceptually correct business model. For example the *business event* (construct used to clearly define the conditions under which the event occurs) named *HighPressure* (see Figure 4) is described with reference to the desidered *Confidence Level* (as it is correct from an engineering and operating point ov view). Simply taking into account a threshold value it would have been an incomplete solution with respect to the safety application; the prevention of risk requires a probabilistic approach being impossible achieving a zero-probability risk solution. This *business event* was also in detail described by a supporting Activity Diagram.

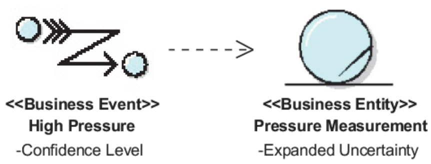

Figure 4: The business event called High Pressure.

The proposed approach has been also positively tested in the industrial context presented in (D'Emilia, 2014a) (D'Emilia, 2014b) and it allowed to increase the reliability and the effectiveness of the implemented decisional process.

5 CONCLUSIONS AND FUTURE WORK

In this paper a methodological approach has been set to customize the business modeling discipline in a measurement-based context.

The RUP process has been tailored to this purpose, leading us to the following main results:

- identification and description of priority metrological concepts useful for the business modeling in a measurement-based context;
- insertion of the *Measurement Expert* as a crucial stakeholder in the business modeling discipline carried out in the inception phase. His role is different from a general Domain Expert role;
- insertion of a specific input document (the *Measurement core concept document*) supporting an efficient and effective sharing of the measurement concepts with the business modeling team.

These results represent an effective, even though preliminary, contribution to an aware cooperation among stakeholders involved in business modeling of a measurement-based context. The improved cooperation will contribute to a better interpretration of the information deriving from measurement data.

The attention is paid to the inception phase so far, nevertheless according to the proposed methodological approach, the *Measurement Expert* is also expected to give a contribution in the next RUP phases: the elaboration, the construction and the transition ones. Future work will focus on the evaluation of these perspectives.

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