Process Conceptual Base for Enriching a Measurement and Evaluation Ontology

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Abstract. In this work, we specify and discuss the main terms, properties and relationships for the process domain taking also into account the relevant related literature. A practical usefulness of the built process ontology is to enrich the measurement and evaluation domain terms with stereotypes, e.g. a measurement is a task, a measure is an outcome, and a metric is a method from the process standpoint. The augmented conceptual framework, i.e. measurement and evaluation terms plus process terms, has also a positive impact on the GOCAME (*Goal-Oriented Context-Aware Measurement and Evaluation*) strategy capabilities since ensures terminological uniformity and verifiability to process and method specifications. To illustrate and discuss the new situation, an example of process specification for elementary evaluation is shown.

Keywords. Measurement, Evaluation, Process Ontology, GOCAME Strategy.

1. Introduction

Aimed at implementing measurement and evaluation (M&E) projects and programs in a systematic way, software and web organizations need to establish explicitly a set of activities and methods to specify, collect, store, and use measures and indicators. Moreover, for performing more effective analysis, recommendation and decision-making processes, the design of metrics and indicators and the consistent usage of their values that can be repeatable and comparable among the organization's projects should be assured. To pursue programs with these features organizations need well-established and integrated strategies [1]. An integrated M&E strategy should support simultaneously at least the following three capabilities: i) a *M&E conceptual base and framework*; ii) *specifications of M&E process views*; and, iii) *specifications of methods*.

Considering the above core capabilities, we have built the GOCAME (*Goal-Oriented Context-Aware Measurement and Evaluation*) strategy. GOCAME's first capability is the C-INCAMI (*Contextual-Information Need, Concept model, Attribute, Metric and Indicator*) conceptual base and framework [2], which explicitly and formally specifies the M&E concepts, properties, relationships and constraints, in addition to their grouping into components. GOCAME's second capability -the M&E process views specification [3]-, is aimed at assuring repeatability in performing activities and consistency of results. A process specification usually describes a set of activities, tasks, inputs and outputs, interdependencies, artifacts, roles, and so forth. Besides, a process specification can consider different process views such as functional, behavioral, informational and organizational [4]. In our opinion, process specifications should primarily state what to do rather than indicate the particular methods and tools used by specific activity descriptions. The third GOCAME capability allows to assign systematically particular ways (i.e. well-defined methods) to perform M&E tasks.

Looking at the first capability, i.e. the C-INCAMI conceptual base and framework, we observed a potential opportunity for improvement with regard to the previously developed M&E components. Specifically, we have observed that many M&E domain terms are related to many process domain terms, but these were not explicitly modeled and linked. For example, a measurement -from the M&E domain standpoint- is a task -from the process domain viewpoint-, likewise a metric is a method, a measure is an outcome, etc., as we discuss later on. So the C-INCAMI conceptual framework, particularly the M&E components were enriched semantically with process terms.

In a recent work [5], we have introduced a process conceptual base to enrich C-INCAMI. In this paper, we thoroughly specify the process ontology, i.e. the definition of the process key terms, and their main attributes and relationships. Then, we model (enrich) M&E terms with process terms. Additionally, we illustrate how the process concepts linked to the M&E concepts by means of stereotypes help to build better specifications for M&E process views and their verifiability. To gauge and discuss the new situation, an example of process specification for the "calculate elementary indicators" activity is shown.

The remainder of this article is organized as follows. Section 2 analyzes related work in the light of process conceptual bases, and describes our motivation. Then, Section 3 presents the developed process ontology. Section 4 shows the enhancement made to the GOCAME´s conceptual framework; also illustrates its practical impact on the process specification capability by examples. Finally, concluding remarks and future work are outlined.

2. Related Work and Motivation

Looking at process related work, we observe to some extent a mismatch in terminological bases and in the semantic of concepts and relationships. It seems that so far there is no broad and unanimous consensus on all key terms and their meaning for the process domain.

Among pioneers in defining process terminologies are for instance Feiler & Humphrey [6], Conradi *et al.* [7] and Lonchamp [8]. In these works a set of basic terms are defined. In [6] authors recognize that many terms will suffer an evolutionary change and other terms will be added in the future. In [7], the activity term is defined but not in [6], while the task term is not taken into account in [7]. However in [8], a clear distinction between task and activity is proposed, i.e. an activity is planned, while a task is scheduled -with human, technological and monetary resources- and enacted.

Another quoted work in process domain is the ISO 12207 standard [9]. Like in the abovementioned works, it has a glossary of terms but also presents a diagram where the relationships between the process, activity and task terms are depicted. According to this diagram, a process can group other processes, and can also contain at least one activity; in turn, an activity can group one or more related tasks.

Additionally, there are works where authors identify relationships among the process terms, as in Acuña *et al.* [10] and Esteban & Olsina [11]. In [11] authors identify concepts and their relationships, as well as attributes for each term. Moreover, they include the method term not used in other related works. This term is linked to the process domain since specifies 'how' to implement or carry out the description of an activity.

In an effort to standardize the process domain terms, OMG (*Object Management Group*) developed SPEM (*Software & Systems Process Engineering Meta-Model Specification*), a meta-model of process engineering as well as a conceptual framework, which provides the concepts necessary to model, document and manage processes [12]. SPEM focuses on defining a generic framework for process modeling. Note that in SPEM a process is defined as a special type of activity, so that the hierarchy between activity and process differs from that in ISO 12207, where a process groups activities, and an activity groups tasks.

Another worth mentioning work is [13] in which Bringuente *et al.* define a Software Process Ontology (SPO) that contains concepts such as organization and project including also the concepts of project planning and scheduling. It is based on UFO (*Unified Foundational Ontology*) [14], which provides robustness to SPO -as indicated by authors. However, we observe some semantic inconsistencies as for example: in the SPO version documented in Guizzardi *et al.* [14], authors show that hardware resource, software resource and human resource inherit from resource, while in [13] a human resource is not a resource. This happened since a resource represented in SPO is an object in UFO, and given that a human resource cannot be an object from the semantic standpoint, then they decided to remove such a link. On the other hand, SPO uses terminology which to a some extent differs from recognized standards in the process area such as SPEM [12], CMMI [15] and ISO 12207 [9]. For example, instead of using the work product term authors use artifact, not making distinction with outcome and service terms. Also they do not use the task term but rather the atomic activity term.

Besides, some authors of SPO developed a software quality ontology [16], which is related to SPO [17]. It is divided into three sub-ontologies, namely: quality models, measurement, and evaluation. Regarding the measurement sub-ontology [16], we observe an ambiguity in using the measure term, since sometimes it refers to the value produced by a measurement, while sometimes to the instrument (procedure) for obtaining such a value. This semantic duality of the measure term is also observed in CMMI [15], ISO 15939 [18], and ISO 25000 [19]. Instead, we make a clear distinction between measure and metric terms, linking them also to our process ontology -as we discuss in sub-section 4.2. On the other hand, Barcellos *et al.* [16] use the measurable element term to refer to measurable properties of an entity; however, the widely used term in the M&E literature [18, 19, 20] is attribute or property. Also, context terms are not included in the software quality ontology, as we did in [21].

Regarding the motivation, in previous works we have developed a M&E ontology

[22] and specified the M&E process [3] from different views [4]. We observe that some M&E ontology terms are related to process domain terms, for example, a measurement is a task, a measure is an outcome, and a metric is a method, as we discuss later on. So there exists an opportunity to enrich semantically the M&E ontology with process terms. Reviewing process relevant literature we observe there is no broad and unanimous consensus on all key terms and their meaning for the process domain, as analyzed above. Hence, we have re-built the process conceptual base documented in [11] -which had been based on seminal works such as Feiler & Humphrey [6] and Lonchamp [8], amongst others- considering now recent, well-known contributions in process domain such as SPEM, CMMI and ISO 12207.

3. The Process Conceptual Base

For building the process conceptual base, elements from an ontology were used. These include the key domain concepts, their definitions, relationships, and attributes. As per [23], an ontology with these features is called light-weight ontology, as opposed to heavy-weight ontology, which also includes axioms and restrictions.

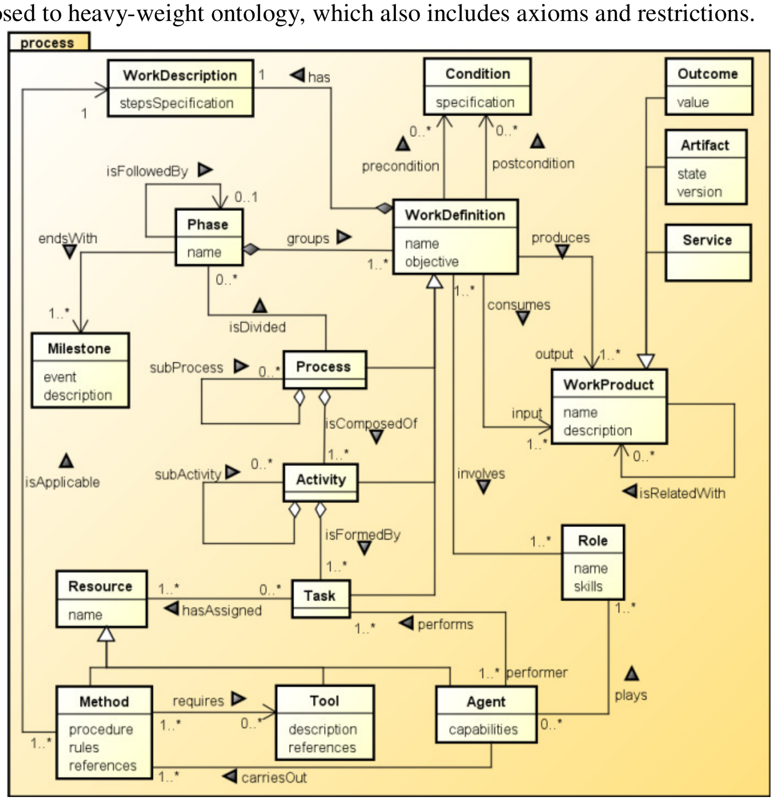

Figure 1. Terms and relationships for the Process component.

Figure 1 depicts the process component, which includes the proposed terms, relationships and attributes. Also, the process ontology terms are defined in Table 1 and their attributes and relationships are defined in Tables 2 and 3, respectively.

Table 1. Definition of Process terms, which are included in Figure 1.

Process Term	Definition
Activity	It is a **Work Definition** that is formed by an interrelated set of sub-activities and **Tasks**. Note 1: A sub-activity is an **Activity** at a lower granularity level. Note 2: In engineering projects, while **Activities** are planned, **Tasks** are scheduled and enacted.
Agent	Performer assigned to a **Task** in compliance with a **Role**. Note 1: An **Agent** can be human or automated.
Artifact	It is a tangible or intangible, versionable **Work Product**, which can be delivered.
Condition	Situation that must be achieved at the beginning (pre-condition) or ending (post-condition) of a **Work Definition** realization.
Method	Specific and particular way to perform the specified steps in the description of a **Work Definition**. Note 1: The specific and particular way of a **Method** –i.e. *how* the described steps in a work definition should be made- is represented by a procedure and rules.
Milestone	A meaningful event. Note 1: A **Milestone** represents for instance a **Phase** finalization.
Outcome	It is an intangible, storable and processable **Work Product**.
Phase	A group of strongly-related **Work Definitions** defined in a given order. Note 1: A **Phase** ends with a **Milestone**. Note 2: In a phase the **Work Definitions** are **Processes** and/or **Activities**.
Process	It is a **Work Definition** that is composed of an interrelated set of sub-processes and activities. Note 1: A sub-process is a **Process** at a lower granularity level.
Resource	Asset assigned to perform a **Task**. Note 1: An asset is an entity with added value for an organization.
Role	A set of skills that ought to own an **Agent** to perform a **Work Definition**. Note 1: Skills include abilities, competencies and responsibilities.
Service	It is an intangible, non-storable and deliverable **Work Product**.
Task	It is an atomic **Work Definition**, which cannot be decomposed. Note 1: Conversely to an **Activity** and **Process**, a **Resource** is assigned (scheduled) to a **Task**, e.g. **Resources** such as a **Method**, **Agent**, etc.
Tool	Instrument that facilitates the execution of a **Method**. Note 1: An instrument can be physical (hardware), computerized (software) or a mix of both types.
Work Definition	Abstract entity which describes the work by means of consumed and produced **Work Products**, **Conditions** and involved **Roles**. Note 1: Work represents a **Process**, an **Activity** or a **Task**.
Work Description	Specification of the steps for achieving the objective of a **Work Definition**. Note 1: The specification of the steps is a set of general actions –both **Activities** and **Tasks**- or a transformation function. It represents *what* should be done instead of *how* it should be performed. Note 2: The specification of the description of a **Work Definition** can be formal, semi-formal or informal as for example the natural language.
Work Product	A product that is consumed or produced by a **Work Definition**.

Core terms in this ontology are *Process*, *Activity* and *Task*. Specifically, a process is composed of sub-processes or activities, and in turn an activity is formed by sub-activities or tasks. A task is an atomic element that cannot be decomposed. Note that the semantic given to these three terms is compliant with the meaning given in ISO 12207. Additionally, we include the *Phase* concept, which represents a group of strongly-related processes or activities defined in a given order.

While the process, activity and task terms have slightly different semantics, they do share common properties such as *name*, *objective*, and *Work Description*. Also they involve common *Roles*, *Work Products*, and *Conditions* -both *preconditions* and *postconditions* (see definitions in Table 3). The high-level *Work Definition* concept -which embraces the common semantic of process, activity and task terms- is defined in Table 1 as an "*abstract entity which describes the work by means of consumed and produced Work Products, Conditions and involved Roles*". Thus, process, activity and task terms are different specializations of it. Note that the *Work Definition* term is also used in SPEM.

Another key concept in our process ontology is *Work Product*. In turn, *Outcome*, *Artifact* and *Service* are kinds of work products (see Figure 1). Outcome is defined in Table 1 as "*an intangible, storable and processable Work Product*", while artifact "*is a tangible or intangible, versionable Work Product, which can be delivered*". Lastly, the service term is defined as "*an intangible, non-storable and deliverable Work Product*". The definition of service is based on the CMMI related term.

Table 2. Process ontology: Attribute definition

Concept	Attribute	Definition
Agent	**capabilities**	Set of abilities that the agent has.
Artifact	**state**	Situation or state in which the artifact is.
	Version	Unique identifier which indicates the level of evolution of an artifact.
Condition	**specification**	Unambiguous specification of constraints or circumstances that must be achieved.
Method	**procedure**	Arranged set of method instructions or operations which specifies how the steps of a description of a work definition must be performed.
	rules	Set of principles, conditions, heuristics, axioms, etc. associated to the procedure.
	references	Cite to bibliographical or URL resources, where authoritative and additional information for a given method can be consulted.
Milestone	**event**	Name of the event which indicates a milestone.
	description	An unambiguous textual statement describing the event.
Outcome	**value**	Numerical or categorical result.
Phase	**name**	Name of a phase to be identified.
Resource	**name**	Name of a resource to be identified.
Role	**name**	Name of a role to be identified.
	Skills	Set of capabilities, competencies and responsibilities of a role.
Tool	**Description**	An unambiguous textual statement describing the tool.
	references	Cite to bibliographical or URL resources, where authoritative and additional information for a given tool can be consulted.
Work Definition	**Name**	Name of a work definition to be identified.
	Objective	Aim or end to be reached.
Work Description	**stepsSpecification**	Specification of steps to be followed in order to achieve the work definition objective. Note: Steps can be generic actions e.g., for a process, or concrete instructions e.g., for a task.
Work Product	**Name**	Name of a work product to be identified.
	description	An unambiguous textual statement describing the work product.

On the other hand, a work definition has a *Work Description*, which specifies the steps for achieving its *objective*. It represents 'what' should be done instead of 'how' it should be performed. The semantic of 'how' is represented by the *Method* term, i.e. the specific and particular way to perform the specified steps e.g. in a task. Note in Figure 1 that a method concept has the *procedure* and *rules* attributes, which are defined in Table 2. This explicit link between Method (the 'how') and Work Description (the 'what') is not made as clear in other proposals as in ours.

Contrary to a process or activity, a task is scheduled and enacted. Hence it has allocated *Resources* such as a *Method*, *Tool* as well as an *Agent* (i.e. a performer playing a *Role*). Resource is defined as an "*asset assigned to perform a Task*".

Table 3. Process ontology: Relationships definition

Name	Definition
carriesOut	An agent carries out one or more methods.
consumes	In order to achieve its objective, a work definition consumes one or more work products.
endsWith	A phase ends with the occurrence of one or more milestones.
Groups	A phase groups one or more work definitions.
Has	A work definition has a work description in which specifies what to do for achieving its objective.
has Assigned	A task has assigned resources for its enactment.
involves	A work definition involves one or more roles. In turn, a role may participate in one or more work definitions.
isApplicable	A method is applicable to a description of a work definition. In turn, to a work description can be applied none or several methods.
isComposedOf	A process is composed of one or more activities.
isDivided	A process is divided in none or several phases.
isFollowedBy	A phase is followed by none or one phase.
isFormedBy	An activity is formed by one or more tasks.
isRelatedWith	A work product is related with none or several work products. Note 1: The relationship among work products can be of different types such as inheritance, aggregation, composition, etc.
Performs	An agent performs one or more assigned tasks. In turn, a task is performed by one or more agents.
plays	An agent plays one or more roles. In turn, a role is played by none or several agents.
Postcondition	A work definition may have associated conditions which must be accomplished at the end of its realization to be considered finished. Note 1: A post-condition defines any kind of constraint that must evaluate to true before the work described for the work definition can be declared completed or finished and which other work definition might depend upon.
precondition	A work definition may have associated conditions which must be accomplished before its initiation. Note 1: A pre-condition defines any kind of constraint that must evaluate to true before the work described for the work definition can start.
produces	A work definition produces (modifies, create) one or more work products.
requires	A method requires to use none or several tools.
subActivity	An activity is formed by none or several more specific activities, named sub-activities.
subProcess	A process is formed by none or several more specific processes, named sub-processes.

Ultimately, this process conceptual base -one of the contributions indicated in the Introduction Section-, contains the key concepts which are capable to enrich semantically many M&E domain terms as we analyze below.

4. Enriching a M&E Ontology

In the next sub-section, we summarize the GOCAME strategy and its three capabilities, namely: i) the M&E conceptual framework, ii) the process specification, and iii) the specification of methods. Then, in sub-section 4.2 the enriched M&E conceptual framework is shown. Finally, in sub-section 4.3, we illustrate a practical impact of this improvement on process specifications.

4.1. GOCAME Overview

GOCAME is a multi-purpose M&E strategy that follows a goal-oriented and context-sensitive approach in defining M&E projects. It is based on the abovementioned three capabilities, which are summarized below.

Firstly, GOCAME has its M&E terminological base defined as an ontology [22], from which the C-INCAMI conceptual framework emerges. This domain model allows a common vocabulary which is shared among the organization's projects lending to more consistent results and analysis across projects. C-INCAMI is structured in six components, namely (next M&E terms highlighted in italic are in Figure 3):

i) M&E project component, which allows specifying the management data for M&E projects;

ii) Nonfunctional requirements component, which allows specifying the Information Need for a given purpose and the user viewpoint related to an Entity and quality focus. The focus is represented by a Concept Model (e.g. a quality model) which includes *Calculable Concepts* (i.e. characteristics), *sub-concepts* (i.e. sub-characteristics) and associated *Attributes*. Attributes are measurable properties of an entity category under analysis;

iii) Context component, which describes the relevant Context through Context properties which are attributes;

iv) Measurement component, which allows specifying *Direct* and *Indirect Metrics* used by *Direct* and *Indirect Measurement* tasks that produce *Base* and *Derived Measures* respectively;

v) Evaluation component, which allows specifying the *Evaluation* task through *Indicators*, which interpret attributes and calculable concepts for a non-functional requirements tree. Two types of indicators are distinguished: *Elementary Indicators* which evaluate lower-level requirements (attributes), and, *Derived Indicators*, which evaluate higher-level requirements, i.e. sub-characteristics and characteristics; and

vi) Analysis and Recommendation component, which supports data and information analysis in order to provide recommendations.

Secondly, GOCAME has a well-defined M&E process specification [3], which is composed of six main activities as shown in Figure 2. These activities are: (A1) *Define Non-functional Requirements*; (A2) *Design the Measurement*; (A3) *Implement the Measurement*; (A4) *Design the Evaluation*; (A5) *Implement the Evaluation*; and (A6) *Analyze and Recommend*. The M&E process is specified using the SPEM language [12]. We can look at Figure 2 that concepts defined in the M&E terminological base (Figure 3) are also reused in the process model, such as *Metric*, *Measure* and *Indicator*, amongst others.

Lastly, GOCAME is supported by different method specifications. This provides for instance the 'how' (i.e. the metrics) for measurement, the 'how' for evaluation, which comprises elementary and derived indicator specifications, etc. GOCAME includes a set of methods, techniques and tools to carry out the description of activities.

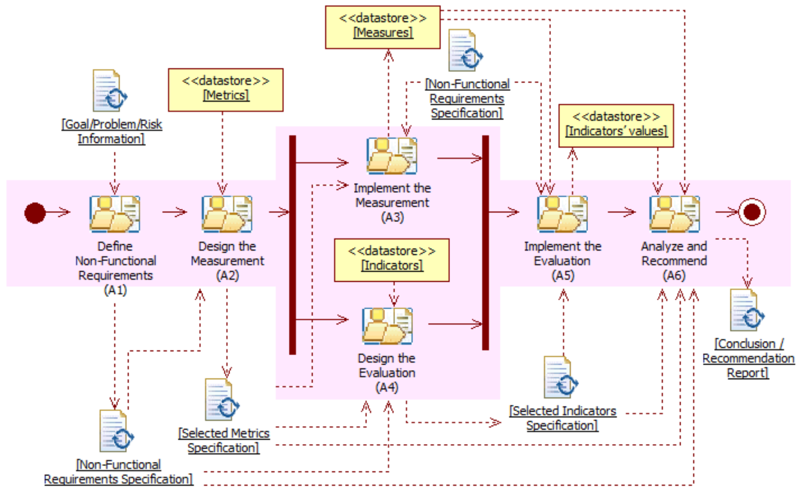

Figure 2. The functional and behavioral process views of GOCAME.

4.2. Adding more Semantic to M&E Components

To augment and improve the GOCAME strategy, we use our process ontology for adding more semantic to the C-INCAMI former terms. The introduced terms from the process ontology are used as stereotypes in the C-INCAMI framework. A stereotype is an UML modeling element, which is an extensibility mechanism [24]. They are applied e.g., to diagram elements or relationships indicating additional meaning.

In our case, we have employed the process terms (Table 1) as stereotypes for enriching M&E terms. Figure 3 shows the *measurement* and *evaluation* components (introduced in sub-section 4.1) augmented with process terms and relationships. Examples of enriched terms are *Indicator* and *Metric* which are stereotyped with «`Method`». An indicator is "*the defined calculation procedure and scale in addition to the indicator model and decision criteria in order to provide an evaluation of a calculable concept or attribute with respect to a defined information need*" (see Table 4). Then, with the «`Method`» stereotype an indicator now includes the semantic of a method, which is defined as the "*specific and particular way to perform the specified steps in the description of a Work Definition*". So an indicator specifies *how* should be made the described steps (*what*) of an evaluation task. Thus, if we look at the *procedure* and *rules* attributes of the *Method* term in Figure 1, the *Indicator* has both a *Calculation Procedure* as procedure and a *Scale* and a set of *Decision Criterion* as rules, as shown in Figure 3.

Consequently, many of the former M&E term definitions [2] have been updated to reflect this new situation. Also new terms such as *Direct Measurement*, *Indirect*

Measurement, *Base Measure*, *Derived Measure*, etc. have emerged in order to have greater terminological completeness and detail. All these adapted definitions and/or new terms as well the links to process terms are shown in Table 4.

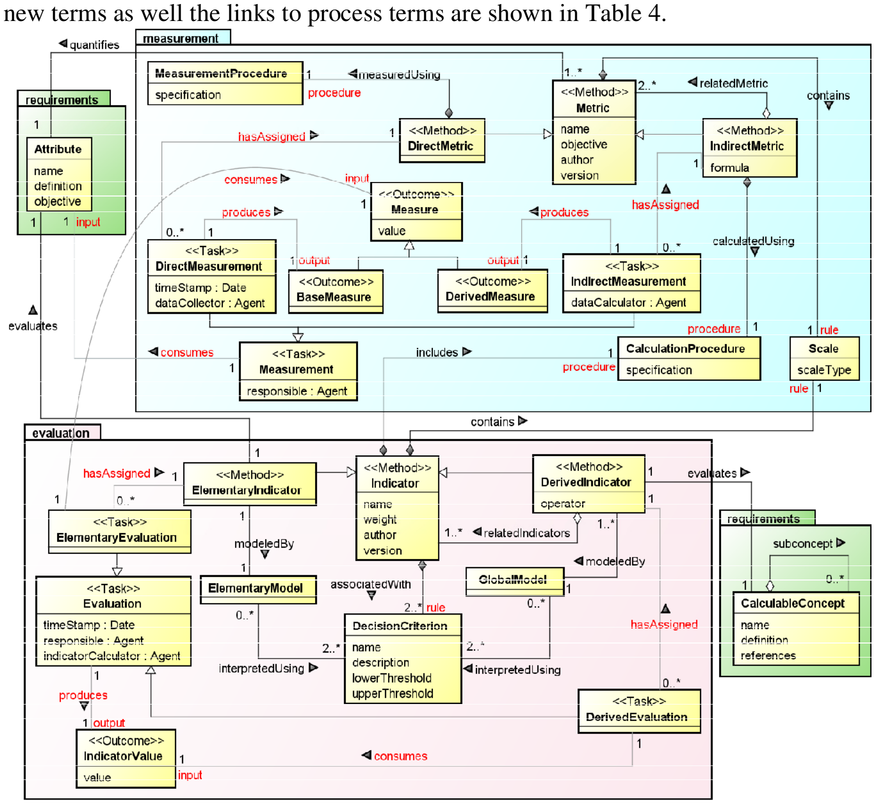

Figure 3. Main concepts and relationships for Measurement and Evaluation Components enriched with process stereotypes.

Table 4. Definition of M&E terms, which are semantically enriched with process terms.

M&E Term	Definition	Process Term
	Measurement Term	
Base Measure	A measure that does not depend upon other measure.	Outcome
Calculation Procedure	Set of established and ordered instructions of an indirect metric or indicator that indicates how the described steps in an indirect measurement or evaluation task should be carried out.	procedure in Method
Derived Measure	A measure that is derived from other measures.	Outcome
Direct Measurement	Measurement that produces a base measure.	Task
Direct Metric	A metric of an attribute that does not depend upon a metric of any other attribute	Method
Indirect Measurement	Measurement that produces a derived measure.	Task
Indirect Metric	A metric of an attribute that depends of metrics of other attributes.	Method

Measure	The number or category assigned to an attribute of an entity by making a measurement. Note 1: It is the measurement output that represents an outcome as work product.	Outcome
Measurement	A task that uses a metric in order to produce a measure's value. Note 1: This task quantifies an attribute by producing a measure as outcome.	Task
Measurement Procedure	Set of established and ordered instructions of a direct metric that indicates how the described steps in a direct measurement task should be carried out.	procedure in Method
Metric	The defined measurement or calculation procedure and the scale. Note 1: A metric is a method which is applicable to the description of a measurement task.	Method
	Evaluation Term	
Derived Evaluation	Evaluation that produces an indicator's value by assessing a calculable concept.	Task
Derived Indicator	An indicator that is derived from other indicators to evaluate a calculable concept.	Method
Elementary Evaluation	Evaluation that produces an indicator's value by assessing an attribute. Note 1: An attribute is a non-functional elementary requirement from the evaluation standpoint.	Task
Elementary Indicator	An indicator that does not depend upon other indicators to evaluate an attribute.	Method
Evaluation	A task that uses an indicator in order to produce an indicator's value.	Task
Indicator	The defined calculation procedure and scale in addition to the indicator model and decision criteria in order to provide an evaluation of a calculable concept or attribute with respect to a defined information need. Note 1: An indicator is a method which is applicable to the description of an evaluation task.	Method
Indicator Value	The number or category assigned to a calculable concept or attribute by making an evaluation. Note 1: It is the evaluation output that represents an outcome as work product.	Outcome

On the other hand, to increase the consistency between M&E and process components, some relationships among M&E terms have been adapted accordingly, as depicted in Figure 3. For instance, we added the *consumes* relationship between *Elementary Evaluation* and *Measure* terms. Thus an Elementary Evaluation task *consumes* a Measure of an attribute (as input) and *produces* an Indicator Value (as output). Note that the added or renamed relations are highlighted in gray and red text.

The augmented conceptual framework has also a positive impact on the other strategy capabilities since ensures terminological uniformity to process and method specifications while strengthening the verifiability. Next, for illustration purposes, we show excerpts of process specifications regarding the new situation.

4.3. Using the Updated M&E Components for Process Specification

GOCAME process specification capability embraces different process views, namely: functional, behavioral, informational and organizational. Figure 2 depicts the M&E process stressing the functional and behavioral perspectives. While the functional view represents what activities/tasks should be performed -as well as the inputs and outputs (work products) that will be consumed and produced-, the behavioral view models the dynamics of the process i.e., sequences, parallelisms, iterations, feedback loops, among other aspects.

The updated M&E components have a practical impact on the process views specification since allow to develop process models more consistent and verifiable semantically. To illustrate this, a sub-activity from A5 (in Figure 2) is described. The *Calculate Elementary Indicators* sub-activity implies executing, iteratively, the Elementary Evaluation task for each attribute´s measure. Figure 4 shows that each Elementary Evaluation task execution consumes an attribute´s measure, from Measures datastore, and produces an indicator´s value, which is stored in the Indicator´s values datastore. In order to perform the Elementary Evaluation the Indicator Calculator must follow the calculation procedure and rules described in the assigned Elementary Indicator. Note that each Elementary Indicator was previously added to the Selected Indicators Specification artifact in the A4 activity.

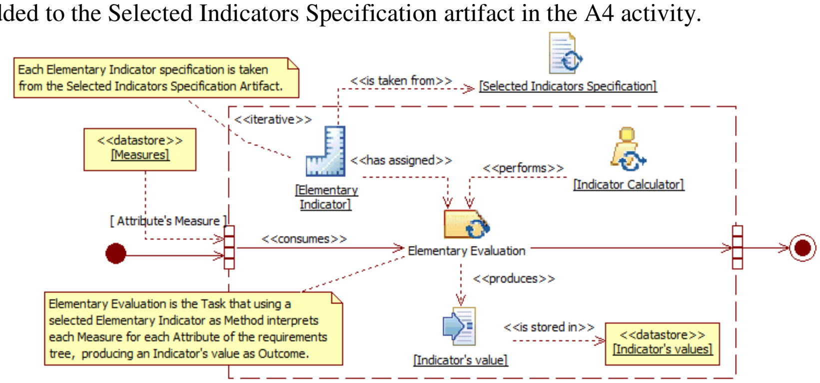

Figure 4. SPEM diagram for the *Calculate Elementary Indicators* activity.

The consistency of the above diagram can be checked by verifying the process specification (Figure 4) with the augmented C-INCAMI conceptual base (Figure 3). For instance, the Elementary Evaluation task consumes an attribute´s measure and produces an indicator´s value. This specification is consistent semantically when verified against the C-INCAMI evaluation component, since the *Elementary Evaluation* term -enriched with the «`Task`» stereotype- is associated to the *Measure* term with the *consumes* relationship, and to the *Indicator Value* term with the *produces* relationship. Moreover, the produced indicator´s value which is modeled as an outcome is consistent with the *Indicator Value* term in Figure 3, which in turn is enriched with the «`Outcome`» stereotype. Remember that outcome is defined (in Table 1) as "*an intangible, storable and processable Work Product*". Therefore an indicator´s value can be stored in the *Indicator´s values* datastore and can be used as a processable item for the A6 (Analyze and Recommend) activity.

Additionally, Figure 4 shows that the Elementary Evaluation task *has assigned* an elementary indicator. This is consistent with the augmented M&E conceptual base since the *Elementary Evaluation* term is related to *Elementary Indicator* by the *has Assigned* relationship in Figure 3. Furthermore, an *Elementary Indicator* has the semantic of a `Method` (as reflected in Table 4), which in turn is a *Resource* (as shown in Figure 1).

On the other hand, the augmented M&E components have also a positive impact for the GOCAME methods specification capability introduced in sub-section 4.1. For example, a metric and an elementary indicator are now methods explicitly. So, when storing and retrieving their templates from Metrics or Indicators repositories (in Figure 2), all the associated metadata as measurement/calculation procedures in addition to rules such as scale, scale types, decision criteria can be verified for consistency. Ultimately, a metric or indicator specifies *how* should be implemented the work description (i.e. *what*) of a measurement or evaluation task.

5. Concluding Remarks

In a previous research, we have developed the integrated GOCAME strategy which relies on three pillars or capabilities viz. C-INCAMI M&E conceptual framework, M&E process view specifications, and M&E method specifications. With the purpose to enrich semantically the M&E conceptual framework with process terms, different literature for the process domain were analyzed in Section 2. This review exposes that so far there is no broad and unanimous consensus on all key terms and their meaning.

Taking into account this concern, in the present work, a process conceptual base structured in an ontology was specified. Term, attribute and relationship definitions in the documented ontology consider recent and well-known contributions in the process domain such as SPEM, CMMI, and ISO 12207, among others. The ultimate aim was to enrich and augment the former M&E ontology with the new process ontology by means of UML stereotypes. Note that in this paper we have emphasized the process ontology and its applicability to the M&E domain terminology rather than the ontology construction process itself (as we did in [22]).

Finally, as an added value of the enriched and augmented M&E components, the practical impact on the terminological consistency and verifiability for specifications of methods and process views -the other two GOCAME capabilities- has been analyzed in sub-section 4.3.

As a future line of research, we envision to develop both the strategy and project ontologies. For instance, a M&E strategy can be applied for concrete M&E projects to address different information needs at different organizational levels. Given that a project can be defined as an "endeavor with defined start and finish dates undertaken to create, maintain and evaluate a work product in accordance with specified resources and requirements", a reader can surmise that both the process and M&E ontologies can be reused in this future work.

References

1. Papa, F.: Toward the Improvement of an M&E Strategy from a Comparative Study. In LNCS 7703, Springer: Current Trends in Web Engineering, ICWE Int'l Workshops, M. Grossniklauss and M. Wimmer (Eds.), pp. 189-203, (2012)
2. Olsina, L., Papa, F., Molina, H.: How to Measure and Evaluate Web Applications in a Consistent Way. In Springer HCIS book Web Engineering: Modeling and Implementing Web Applications; Rossi, Pastor, Schwabe, and Olsina (Eds.), pp. 385-420, (2008)
3. Becker, P., Lew, P., Olsina, L.: Specifying Process Views for a Measurement, Evaluation and Improvement Strategy. Advances in Software Engineering, Software Quality Assurance Methodologies and Techniques, Vol. 2012, pp. 1-27, (2012)
4. Curtis, B., Kellner, M., Over, J.: Process Modelling. Com. of ACM , 35 (9), pp. 75-90,

(1992)
5. Becker, P., Papa, F., Olsina, L. Enhancing the Conceptual Framework Capability for a Measurement and Evaluation Strategy, LNCS 8295. Springer, Q.Z. Sheng and J. Kjeldskov (Eds.): ICWE 2013 Workshops, Aalborg, Denmark, pp. 104–116, (2013)
6. Feiler, P.H., Humphrey, W.S.: Software Process Development and Enactment: Concepts and Definitions. International Conference of Software Process (ICSP). Berlin, Germany: IEEE Computer Society, pp. 28-40, (1993)
7. Conradi, R., Fernström, C., & Fuggetta, A. A Conceptual Framework for Evolving Software Processes. SIGSOFT Softw. Eng. Notes , 18 (4), 26-35, (1993)
8. Lonchamp, J.: A Structured Conceptual and Terminological Framework for Software Process Engineering. International Conference on the Software Process (ICSP). Berlin, Germany: IEEE Computer Society Press. pp. 41-53, (1993)
9. ISO/IEC 12207: Systems and software engineering - Software life cycle processes. (2008)
10. Acuña, S., De Antonio, A., Ferré, X., López, M., & Maté, L. The Software Process: Modeling, Evaluation and Improvement. In S. K. Chang, Handbook of Software Engineering and Knowledge Engineering. World Scientific Publishing Company, Vol.1, pp. 193-237, (2001)
11. Esteban, N., & Olsina, L. Hacia un Catálogo de Actividades para el Desarrollo de Sitios y Aplicaciones Web. En Proceedings del VI Workshop Iberoamericano de Ingeniería de Requisitos y Ambientes Software (IDEAS), (2003)
12. OMG-SPEM: Software & Systems Process Engineering Meta-Model Specification V2.0. (2008)
13. Bringuente, A., Falbo, R., Guizzardi, G.: Using a Foundational Ontology for Reengineering a Software Process Ontology. Journal of Information and Data Management, Vol. 2, pp. 511-526, (2011)
14. Guizzardi, G., Falbo, R., Guizzardi, R.: Grounding Software Domain Ontologies in the Unified Foundational Ontology (UFO): The case of the ODE Software Process Ontology. En Proceedings de la XI Conferencia Iberoamericana de Software Engineering (CIbSE 2008), pp. 127-140, (2008)
15. CMMI Product Team: CMMI for Development. Accessed by 21 Feb, 2014, from SEI, Carnegie Mellon University: http://resources.sei.cmu.edu/library/asset-view.cfm?assetID=9661, Ver. 1.3, CMU/SEI-2010-TR-033, (2010)
16. Barcellos M.P., Falbo R., Dal Moro R.: A Well-Founded Software Measurement Ontology. Proceedings of the Sixth International Conference FOIS 2010, A. Galton and R. Mizoguchi (Eds.). IOS Press, Amsterdam, The Netherlands, pp. 213-226, (2010)
17. Moro, R.D., Falbo, R.A.: Uma Ontologia para o Domínio de Qualidade de Software com Foco em Produtos e Processos de Software. In Proc. of the 3rd Workshop on Ontologies and Metamodels for Software and Data Engineering (WOMSDE'08), Campinas, Brazil, pp. 37-48, (2008)
18. ISO/IEC 15939: Software Engineering - Software Measurement Process. (2002)
19. ISO/IEC 25000: Software Engineering - Software product Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE. (2005)
20. ISO/IEC 14598-5:IT - Software product evaluation - Part 5: Process for evaluators. (1998)
21. Molina H.; Olsina L.; Systematic Support for Measurement and Evaluation in Software Projects, In CD of XVI Conferencia Iberoamericana en Software Engineering (CIbSE'13), Montevideo, Uruguay, pp 1-14, ISBN: 978-9974-8379-2-8, (2013)
22. Olsina, L., Martin, M.: Ontology for Software Metrics and Indicators. Journal of Web Engineering, Rinton Press, US, 2(4), pp. 262-281, (2004)
23. Corcho, O., Fernández-López, M., & Gómez-Pérez, A. Methodologies, tools and languages for building ontologies. Where is their meeting point? Data & Knowledge Engineering 46(1), 41–64, (2003)
24. OMG-UML: Unified Modeling Language, Superstructure, v2.3. (2010)