Measurement Task Ontology

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Abstract. *Measurement is a key process in several domains. Although it has particularities according to the application domain, part of the knowledge related to the measurement process is common to all of them. This paper presents the Measurement Task Ontology (MTO), which establishes a common conceptualization regarding core aspects of measurement. MTO addresses behavioral aspects of the measurement process and extends the Core Ontology on Measurement, combining both domain and task-related aspects of measurement. As evaluation of MTO, we described a real-world case scenario regarding a laboratory test, showing that MTO is capable of representing real world situations.*

Keywords: *Measurement, Ontology, Task Ontology*

1. Introduction

Measurement is an important subject in various domains, since it provides information for getting conclusions and making decisions. Part of the knowledge related to measurement remains unchanged across different application domains. However, depending on the application domain, measurement presents some particularities.

There are several standards and references about measurement. Some of them focus on general aspects, such as VIM (2012), which determines a vocabulary about measurement as an attempt to standardize terminology across different domains. Others focus on specific domains (e.g., [ISO, 2007], which concerns Software Measurement), to address particularities when measurement is applied in their context. When analyzing different standards and references, it is possible to identify common concepts, although the terminology used is largely distinct. It is not rare finding in different references the same concept being designated by different terms and the same term being used to refer to different concepts.

To deal with these semantic problems, we need a common conceptualization about measurement. Ontologies are acknowledged as being quite appropriate to solve conceptual ambiguities and knowledge vagueness. An ontology is a formal representation of a common conceptualization of a universe of discourse [Guarino, 1998]. Therefore, it is a useful instrument for reducing conceptual ambiguities and inconsistencies, and for making knowledge structures clearer. Ontologies can focus on describing the concepts of a domain (domain ontologies) or describing general knowledge about processes that may occur in several application domains (task ontologies).

Aiming to establish a common conceptualization regarding the core aspects of measurement, Barcellos *et al*. (2014) proposed the Core Ontology on Measurement (COM). COM is a core ontology in the sense that it provides a precise definition of the structural knowledge in the measurement field that spans across several application domains. However, COM does not cover aspects that are common in more complex measurements, such as sampling and measurement analysis through successive data analysis. Moreover, COM represents only structural knowledge and does not clearly address behavioral aspects describing the measurement process, by identifying its activities and the flow between them, their inputs, outputs and actors involved in their execution. To reach a semantic agreement in a broader sense, it is important to achieve a common understanding regarding both domain (structural) and task-related (behavioral) aspects of measurement [Barcellos *et al.*, 2013]. Therefore, in this paper we propose the Measurement Task Ontology (MTO), which describes behavioral aspects of the measurement process and extends COM to deal with application domains in which measurement involves sampling and measurement analysis through successive data analysis.

This paper is organized as follows. Section 2 provides the background for the paper, discussing briefly measurement and ontologies. Section 3 presents the Measurement Task Ontology. Section 4 evaluates MTO by showing that the ontology is capable of describing factual situations. Section 5 discusses related works. Finally, Section 6 presents our final considerations.

2. Background

Measurement can be defined as a set of actions aiming to characterize an entity by analyzing values attributed to its properties. The main activities involved in measurement are planning, execution and analysis. During planning, the entities to be measured are identified (e.g., objects, phenomena), as well as the properties to be measured (e.g., size, cost), the measures to be used to quantify those properties (e.g., size in meters), and how measurement of each measure should be carried out (e.g., the area of a square object must be measured by applying the formula $a=s^2$, where s is the side length). Decisions regarding which entities and properties are to be measured and which measures are to be used should be driven by goals. Once measurement is planned, it can be performed. Measurement execution consists in collecting data for the measures by applying measurement procedures. Finally, measurement analysis comprises analyzing collected data, thus providing basis for problem solving or decision making [VIM, 2012] [ISO, 2007].

Measurement occurs in various application domains. Thus, there are key concepts and activities present in all of them. Ontologies can be built to make explicit this common conceptualization, since they describe the information semantics and turn its content explicit [Wache, 2001].

According to Guarino (1998), ontologies can be classified according to their generality level into: *foundational ontologies*, which describe very general concepts, such as object, event, etc.; *domain ontologies*, which describe the conceptualization related to a generic domain (e.g., medicine, law); *task ontologies*, which describe the conceptualization related to a generic task (such as diagnosis and sale); and *application ontologies* that describe concepts dependent on a particular domain and task. Although the use of domain ontologies has become increasingly common, the use of task ontologies is rarer. Task ontologies are important because they contextualize the concepts defined in domain ontologies assigning meaning to services, functionalities, activities, flows, and related information [Martins and Falbo*,* 2008].

Task ontologies should capture two major kinds of knowledge [Martins and Falbo, 2008]: (i) task decomposition, including control flow, and (ii) knowledge roles played by entities from the domain in the fulfillment of the task. These two kinds of knowledge are very inter-related, although they capture different views of a task. In fact, they represent different modeling aspects, i.e. different dimension of modeling that emphasizes particular views of the same portion of the reality. Thus, we need different models for representing them. Martins and Falbo (2008) proposed the use of two UML diagrams for representing task ontologies: activity diagrams, capturing task decomposition into sub-tasks and how knowledge roles act in their fulfillment; and class diagrams, modeling the concepts involved and their relation. We follow this proposal to represent our ontology.

In the next section, we present the Measurement Task Ontology, which describes aspects of these two perspectives of the measurement process. It is worthwhile to point out that, although we use the term "task ontology", which is already consecrated in the field of ontologies, in fact we are talking about a process ontology, in the sense that we are interested in describing the measurement process as a whole, and not tasks with low granularity level. Moreover, we should emphasize that our ontology is a reference ontology, i.e., a special kind of conceptual model representing a model of consensus within a community. It is a solution-independent specification with the aim of making a clear and precise description of entities in the universe of discourse, for the purposes of communication, learning and problem-solving. We are not interested in an implementation of this ontology for purposes of reasoning, for instance. As advocated by Guizzardi (2007), a reference ontology should be developed taking truly ontological distinctions into account, i.e. a reference ontology should be grounded in a foundational ontology. Thus, our task ontology is developed grounded in the Unified Foundational Ontology (UFO) [Guizzardi, 2005] [Guizzardi, 2008]. Due to space limitations, in this paper we present only the core fragment of our ontology. Moreover, deeper discussions about the use of UFO to ground our ontology are out of scope of this paper. Discussions in this regard can be found in [Barcellos *et al*., 2014].

3. MTO: Measurement Task Ontology

As a process ontology, MTO is supposed to answer the following competency questions: (i) Which are the activities of the measurement process? (ii) Who is responsible for performing them? (iii) How the activities are decomposed into sub-activities? (iv) What is the control flow between them? (v) What are the inputs and outputs of each activity?

Following the guidelines given in [Martins *et al.,* 2008], for capturing the conceptualization involved in the measurement process, we developed two conceptual models: a behavioral model (Subsection 3.1) and a structural conceptual model (Subsection 3.2).

3.1 MTO Behavioral Model

Figure 1 presents the main activities of the measurement process and the roles responsible for performing each activity. Although four out of five activities in the diagram (activities identified with) are decomposed into sub-activities, in this paper, due to space limitation, we show only the decomposition of the "Plan Measurement Process" activity (see Figure 2). In fact, all the activities shown in both diagrams (figures 1 and 2) are complex actions in the sense of UFO. In UFO [Guizzardi *et al.,* 2008], actions are intentional events. Complex actions are actions involving the participation of different agents and objects. Every activity of the MTO behavioral models has the participation of one agent and of one or more objects.

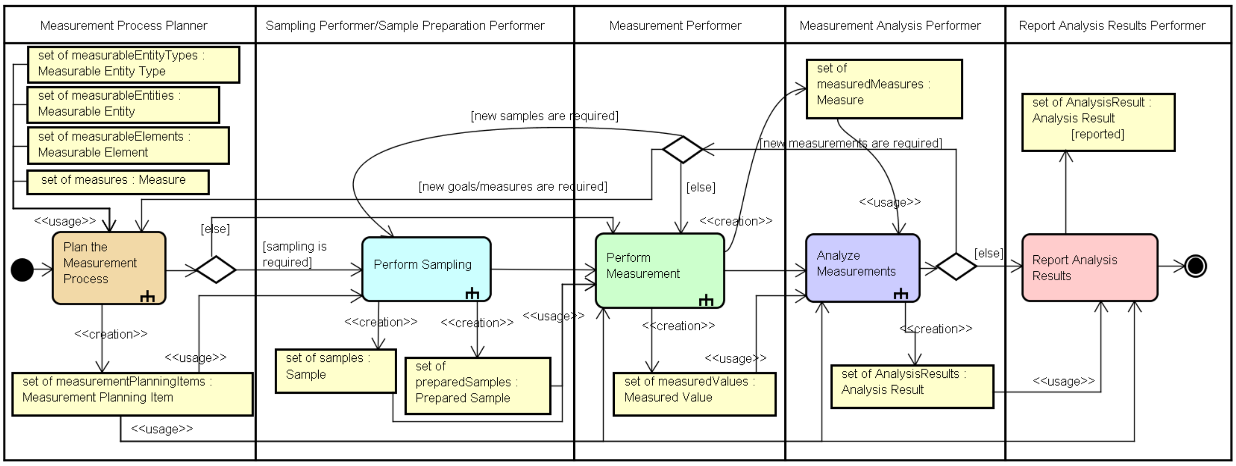

Figure 1. Overview of the Measurement Process

The models also present some stereotypes alongside to the object flows to capture distinctions made in UFO [Guizzardi *et al.,* 2008] related to object participation in actions, namely: *creation*, indicating that an object is created by the action; *change*, indicating that some property of the object changed; and *usage*, when the object is used without changing any of its properties. Since the behavioral model presents a complex process with non-linear flows, there are also decision nodes responsible for bypassing some activities and also returning to previous ones if needed. Next, the measurement process is described. In the text, activities are written in **bold**. *Italics* is used to identify actors that perform the activities and objects participating in the activities as input or output. The objects involved in the behavioral models represent instances of concepts of the MTO structural model. Some of the objects cited in the text are not illustrated in the figures for sake of legibility.

The measurement process starts with the *Measurement Process Planner* performing the **Plan the Measurement Process** activity. In this activity, the *Measurement Process Planner* plans how other activities of the measurement process (namely, Perform Sampling, Perform Measurement and Analyze Measurements) should be performed. Its main result is a set of *Measurement Planning Items.* A *Measurement Planning Item* defines the plan to be followed to perform the measurement process by specifying, according to the goals to be achieved, what is to be measured (i.e., the *Measurable Entity Type* (e.g., Person, River) or the *Measurable Entity* (e.g., John, Amazonas River) and its *Measurable Element* (e.g., cholesterol, turbidity)); which *Measure* is to be used (e.g., cholesterol in mg/dl, turbidity in Nephelometric Turbidity Units); which procedures are to be adopted in each measurement-related activity; which device types (or devices) are to be used in them; and who are responsible for performing each of them. Figure 2 details this activity.

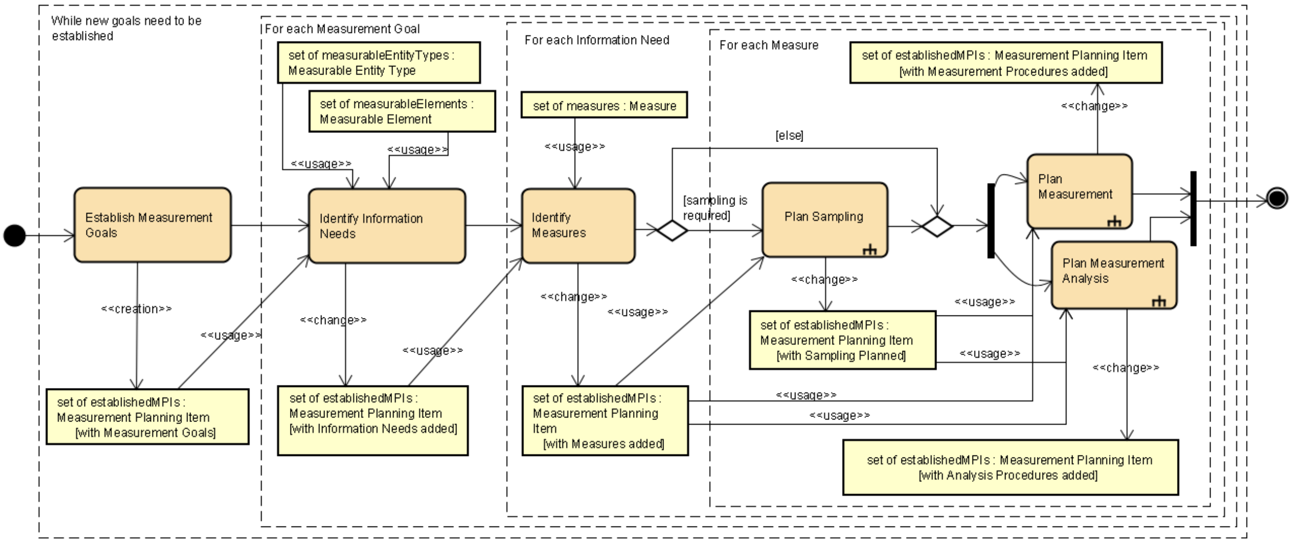

Figure 2. Detailing of Plan the Measurement Process

Measurement should be driven by goals [VIM, 2012] [ISO, 2007]. Therefore, the first activity of Plan the Measurement Process is **Establish Measurement Goals**, where the goals to be achieved through measurement are defined (for example, a doctor can have the goal "check John's health"). The output of this activity is a set of *Measurement Planning Items*, which at this time specify only the *Measurement Goals* to be achieved. The next activity is **Identify Information Needs**, when information needed to achieve the established goals are identified and added to the respective *Measurement Planning Items*.

For example, to achieve the goal "check John's health", the doctor may need to know "what is John's cholesterol level" and "what is John's blood pressure". The inputs for this activity are *Measurable Entity Types* (or *Measurable Entities*) and *Measurable Elements,* which indicate, respectively, the entities that can be characterized in the measurement process and their properties that can be measured. For example, the above cited information needs refer to the measurable entity John and to its measurable elements cholesterol and blood pressure. As shown in Figure 2, after being created, *Measurement Planning Items are* updated in each activity with new information defined in that activity and thus it serves as an input for the succeeding activity. Thereby, after the **Identify Information Needs** activity, the *Measurement Planning Items* contain the *Measurement Goals* previously established and the related *Information Needs*.

Once defined the goals to be achieved and the information needs to be met, the next activity is **Identify Measures**, in which the *Measures* to be used to provide the information needs are identified. For example, the measures "cholesterol in mg/dl" and "blood pressure in mmHg" could be used to meet the information needs previously cited.

In some circumstances, it may be necessary to collect and prepare samples to be used in the next activities of the measurement process. For example, to measure the cholesterol of a person, a blood sample must be collected and prepared. When this is the case, the next activity in Plan the Measurement Process is **Plan Sampling**. This activity refers to planning how samples will be collected and, if necessary, how they will be prepared for measurement. In this activity, the planner defines *Sampling* and *Sample*

Preparation Responsible, *Sampling* and *Sample Preparation Procedures* to be adopted, and *Sampling* and *Sample Preparation Device Types* (or *Devices*) to be used. This information is added to the respective *Measurement Planning Item*, updating it.

Once sampling is planned, or if sampling is not needed, the next activities are **Plan Measurement** and **Plan Measurement Analysis**. The former refers to planning how a measure should be measured. That is, it defines the *Measurement Responsible*, the *Measurement Procedure* to be adopted and the *Measurement Device Types* (or *Devices*) to be used. Analogously, the later concerns planning how collected data should be analyzed to get conclusions. It defines the *Measurement Analysis Responsible*, the *Measurement Analysis Procedure* to be adopted and the *Measurement Analysis Device Types* (or *Devices*) to be used. After each of these activities, the respective *Measurement Planning Item* is updated with the information accordingly.

It is possible to notice that, when planning a measurement-related activity, there is a pattern of information that must be defined: the responsible for performing the activity, the procedures to be adopted and the device types (or devices) to be used. The responsible refers to the person (e.g., Mary), organization (e.g., Lab A) or role (e.g., Doctor) responsible for the activity. Procedures describe how the activity should be performed and they can require the use of device types (e.g., Weight Balance) or specific devices (e.g., Mary's weight balance). For example, the measurement procedure to measure the blood pressure in mmHg using the device type Blood Pressure Aneroid Monitor could be "put the stethoscope earpieces into your ears; place the stethoscope disk on the inside of the crease of the patience elbow; inflate the cuff at a rapid rate by squeezing the rubber bulb; slightly loosen the valve and slowly let some air out of the cuff; read the systolic pressure looking at the pointer on the dial when you listen the heartbeat; read the diastolic pressure looking at the pointer on the dial when you stop listening the heartbeat".

After performing the **Plan the Measurement Process** activity, *Measurement Planning Items* are fully set, i.e. the measurement process is planned, and the planned activities can be now performed. Thus, if sampling is needed, the *Sampling Performer* **Performs Sampling** (see Figure 1). Although not shown in the figure, this activity is composed of three activities. First, a *Measurement Planning Item* is selected (**Select Measurement Planning Item for Sampling**). Thus, samples are collected (**Collect Sample**) and, if necessary, the *Sample Preparation Performer* prepares them (**Prepare Sample**) according to the sample planning defined in the *Measurement Planning Item*. **Collect Sample** refers to obtain a sample from which data will be collected (e.g., obtain a blood sample of a person aiming to collect data to measure her cholesterol). **Prepare Sample** consists of performing specific procedures to make a sample ready for measurement. For example, it may be needed to freeze a sample before collecting data from it. The main result of this activity are *Samples*, when it is necessary only to collect samples, or *Prepared Samples*, when it is also necessary to prepare them.

Following **Perform Sampling** (or **Plan the Measurement Process**, if samples are not required), the *Measurement Performer* must **Perform Measurement**, which consists in, first, **Selecting Measurement Planning Item for Measurement**. Next, if data will be collected from a sample, the *Measurement Performer* **Selects Sample for Measurement**. Finally, she **Collects Data**, according to the measurement plan contained in the selected *Measurement Planning Item*. The main result of this activity is a set of *Measured Values*, i.e., the collected data.

Once data is collected, the *Measurement Analysis Performer* **Analyzes Measurements**. Like **Perform Sampling** and **Perform Measurement**, this activity is decomposed in others. Its main purpose is to provide information to get conclusions and support decision making. Therefore, analysis should be carried out driven by goals. Hence, its first activity is **Identify Goal for Analysis**, when the goal to which information will be provided is identified. Thus, it is necessary to **Select Measures for Analysis**, when the measures able to provide information related to the goal are selected, and **Select Data for Analysis**, when data collected for the selected measures (i.e., measured values) are selected. Finally, the *Measurement Analysis Performer* **Analyzes Measurements**, when data regarding the selected measures are analyzed, producing *Analysis Results*. After analyzing data, the *Measurement Analysis Performer* may need further analysis, which can involve the need to: (i) analyze the same dataset using different analysis procedures, (ii) include other measures and data in the analysis or (iii) establish new goals to be analyzed. All these situations are addressed by returning to different activities of the Measurement Process. At the end, the *Analysis Results* are reported by the *Report Analysis Results Performer* in the **Report Analysis Results** activity.

3.2 MTO Structural Model

The structural model of MTO is an extension of COM [Barcellos *et al*., 2014] by including mainly concepts to address aspects related to sampling, which were not considered in the first version of COM. Figure 3 presents a fragment of the structural model of the MTO, focusing on more central concepts. After the figure, we briefly describe the concepts. In the text, the concepts are written in **bold** in the first time they are cited. Concepts from UFO that are used to ground MTO concepts are written in *italics*. Deeper discussions about the use of UFO to ground some concepts can be found in [Barcellos *et al*., 2014].

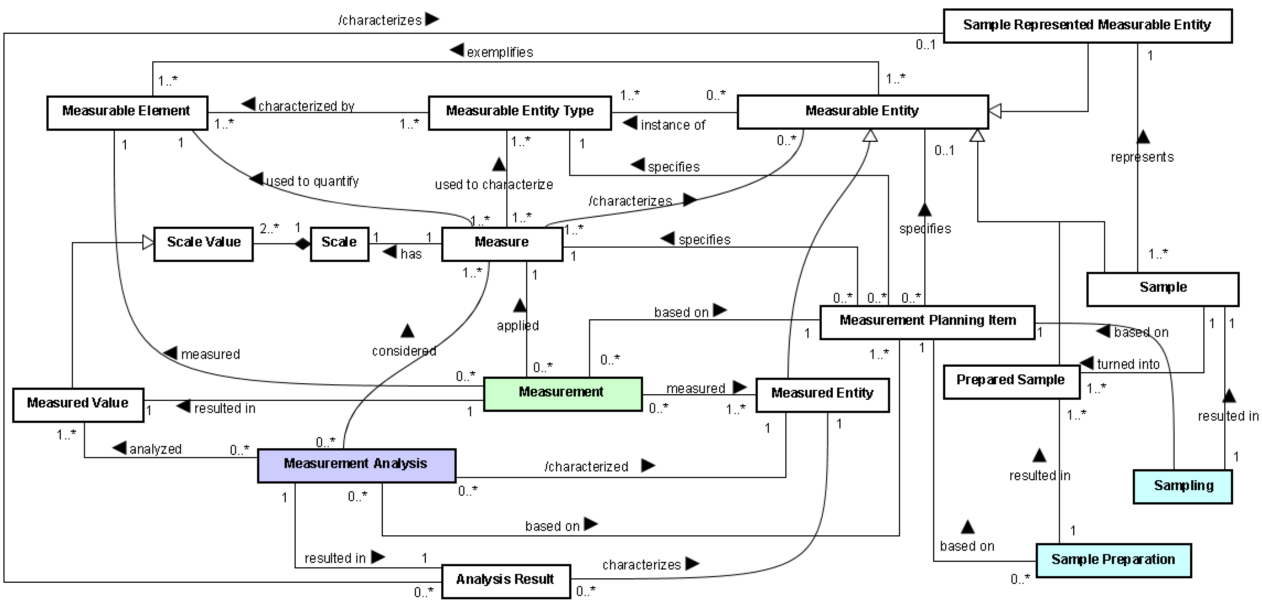

Figure 3. Fragment of the Structural Model of MTO

A **Measurable Entity** is anything that can be measured, such as a person, a river or an artifact. Given its very general nature, Measurable Entity corresponds to *Individual* in UFO. Measurable Entity is instance of **Measurable Entity Type** (e.g., Person, River, Artifact), a *First Order Universal* in UFO. Measurable Entity Types are characterized by at least one *Measurable Quality Universal*, here so-called **Measurable Element** (e.g., Person can be characterized by weight, high, blood pressure, etc.). **Measures** are used to quantify Measurable Elements and to characterize Measurable Entity Types. For instance, the measure weight in kilograms can be used to quantify the measurable element weight of measurable entities of the type Person. Measure is a *Function* in UFO in the sense that it maps an instance of Measurable Element to a value (the **Measured Value**). Measures have **Scales** (*Measurement Reference Structure*) composed of **Scale Values** (*Measurement Reference Region*), which are the possible values to be associated by the measure to a measurable element. For example, weight in kilograms has a scale composed of positive real numbers.

As explained in the behavioral model description, **Measurement Planning Item** specifies information about the planning of each measurement-related activity (the goal to be achieved, the information needs to be met, the measurable entity type and its measurable element to be measured, the measure to be used, the procedures to be adopted in each measurement-related activity, the device types (or devices) to be used in them, and the responsible for each activity). For sake of better visualization, from these concepts, in Figure 2, we show only Measure, Measurable Entity Type and Measurable Element.

Activities addressed in the behavioral model (namely, Sampling, Sample Preparation, Measurement and Measurement Analysis) are represented as *Events* in the structural model. The colors used in the concepts representing these events in the structural model (Figure 3) are the same used in the activities in the behavioral model (Figure 1), showing their correspondence. Sampling, Sample Preparation and Measurement are performed based on a Measurement Planning Item. **Sampling** results in a **Sample**, which is a Measurable Entity that after **Sample Preparation** is turned into a set of **Prepared Samples**. A Sample is a proxy for a Measurable Entity, said a **Sample Represented Measurable Entity**. In other words, a Sample represents a Sample Represented Measurable Entity, which is the Measurable Entity characterized by the sample. For example, a blood sample represents a person, since by measuring the blood sample it is possible to characterize that person.

Measurement measured a **Measurable Element** of the **Measured Entity** (the role played by the Measurable Entity when it was measured) and resulted in a **Measured Value**. Finally, **Measurement Analysis** analyzed Measured Values and resulted in an **Analysis Result** that characterizes the Measured Entity.

4. MTO Evaluation

To evaluate MTO, we used it to describe a real-world case scenario regarding a Laboratory Test. In this section, we show how MTO can be used to represent a real case of a HDL Cholesterol Test in which a doctor asked for a HDL Cholesterol Test of Ricardo and used its results to make decisions about Ricardo's health. In the following, we describe the measurement process followed in this scenario. In the text, we use **bold** to identify the performed activities of the measurement process and *italics* to identify their performers. After the description, we present the objects (i.e., concepts instances) involved in the process.

Ricardo's doctor had the goal of "verifying Ricardo's cardiological-related conditions" and for that he needed to know, among others, Ricardo's HDL Cholesterol level. This started the measurement process. Based on that goal and information need, the doctor asked for a test to measure HDL Cholesterol in mg/dL using the Bichromatic Enzymatic method, which establishes the procedures to be adopted to collect sample, prepare it, measure it and analyze collected data according to reference values. By doing that, the Ricardo's doctor (*Measurement Process Planner*) performed the **Plan Measurement Process** activity.

After the medical appointment, Ricardo went to the laboratory Lab A and a nursing technician (*Sampling Performer*) **Performed Sampling** (more specifically, she **Collected Sample**) by collecting his blood sample using the established procedure. Later, a biomedical technician (*Sample Preparation Performer*) **Prepared Sample**, by adopting the established procedure to extract blood serum from the blood sample. After that, another biomedical technician (*Measurement Performer*) **Performed Measurement** by collecting data about Ricardo's cholesterol from the blood serum, also according to the established procedure. The laboratory's responsible doctor (*Measurement Analysis Performer*) evaluated the collected data and compared them with reference values (i.e., she performed the **Analyze Measurement** activity). Finally, the Lab A (*Report Analysis Results Performer*) **Reported Analysis Results** through a document handed in to Ricardo. Ricardo showed the test results to his doctor, who got information about Ricardo's HDL Cholesterol level and made decisions about Ricardo's health. Figure 4 shows a fragment of Ricardo's cholesterol test. Next, Table1 presents the instantiation of MTO's structural model, focusing on the objects involved in the described scenario. Measurement-related activities and performers are not shown in the table because they were indicated in the text.

CHOLESTEROL HDL				**51 mg/dL**
BICHROMATIC ENZYMATIC				
	RECOMMENDED VALUES		(mg/dL)	
.		DESIRED	ACCEPTABLE	NOT RECOMMENDED
ADULTS	:	>55	35 – 55	< 35
2 to 19 years old:	DESIRED >= 45.0			

Figure 4. Fragment of the Ricardo's HDL Cholesterol Test

Table 1. MTO Instantiation

MTO	Laboratory Test Scenario
Measurement Goal	Verifying Ricardo's cardiological-related conditions
Information Need	What is Ricardo's HDL Cholesterol level?
Measurable Entity Type	Person; Blood
Measurable Entity	Ricardo;Ricardo's Blood Serum
Measurable Element	HDL Cholesterol
Measure	HDL Cholesterol in mg/dL
Scale	Scale made up of positive integer numbers
Scale Value	Positive Integer Numbers

Table 1. MTO Instantiation (cont.)

MTO	Laboratory Test Scenario
Sampling/ Sample Preparation / Measurement/ Measurement Analysis Procedure	Bichromatic Enzymatic method
Measurable Planning Item	Combination of information presented in the previous concepts
Sample	Ricardo's Blood Sample
Prepared Sample	Ricardo's Blood Serum Sample
Sample Represented Measurable Entity	Ricardo
Measured Value	51 mg/dL
Measured Entity	Ricardo; Ricardo's Blood Serum after measurement
Analysis Result	Acceptable

5. Related Works

In the literature there are works proposing ontologies and conceptual models to the measurement domain. For example, the TOVE Measurement Ontology (TMO) [Kim *et al*., 2007] is a measurement core ontology for Semantic Web applications. TMO addresses concepts related to: (i) measurement system, which deals with attributes that can be measured, samples, and quality requirements; (ii) measurement activities, which deals with data collection, inspection and test; and (iii) measurement points, addressing measured values and their conformance to the quality requirements. There is some equivalence between TMO and MTO concepts (e.g., measure and measurable element), although different terms are used in some cases. However, TMO does not address some aspects covered by MTO, such as measurement goal, scale, procedures, among others. Moreover, TMO does not explore some relations between concepts. For instance, in TMO there is no relation between measure and measured attribute (equivalent to Measurable Element in MTO).

ISO 19156 (2011) defines a conceptual schema for observations and measurements. It focuses on measurement in the context of environmental sampling, defining a common set of sampling feature types classified primarily by topological dimension, as well as samples for observations away from its natural surroundings. Like MTO, it defines sampling-related concepts such as Sampling Method (Sampling Procedure in MTO), Sampled Feature (Sample in MTO) and Sampling Time. Even though the last concept is not explicitly mentioned in MTO models, it is also covered because Sampling is an event in UFO, thus it also brings information regarding time within it. However, although ISO 19156 addresses sampling aspects, it does not properly cover other core aspects of measurement and it is applied to a specific domain.

Olsina and Martin (2003) proposed an ontology for software metrics and indicators. Although focusing on software measurement aspects, the ontology is quite general and includes some core concepts defined in MTO (sometimes using different terms) such as Measurement, Measurable Entity, Measurable Element and Measure. Later, Becker *et al*. (2015) used a generic process ontology to semantically enrich the terms of the Olsina and Martin's ontology by means of stereotypes. As a result, Becker *et al*. categorized measurement-related concepts in the process context. For example, Measurement was categorized as Task and Metric (equivalent to Measure in MTO) as Method. However, this is not enough to describe the behavioral aspect of the measurement process.

In summary, apart from TMO and MTO, none of the cited works is concerned with a comprehensive and common conceptualization about measurement. Moreover, the cited works focus only on structural aspects, while MTO addresses both structural (domain) and task-related (behavioral) aspects of the measurement process.

6. Final Considerations

Measurement occurs in many application domains. There are various standards and references about measurement and in some of them it is possible to identify common knowledge, although the terminology used is distinct. Since ontologies are acknowledged as being quite appropriate to solve conceptual ambiguities and knowledge vagueness, we proposed MTO (Measurement Task Ontology) aiming to provide a conceptualization to enable to reach a semantic agreement in a broader sense, i.e., by achieving a common understanding regarding both domain (structural) and task-related (behavioral) aspects of measurement.

Being a task ontology, MTO defines behavioral and structural models. The structural model is an extension of the Core Ontology on Measurement (COM) [Barcellos *et al*., 2014]. Since COM does not cover aspects that are common in more complex measurements, such as sampling and measurement analysis through successive data analysis and also does not address behavioral aspects describing the measurement process, there was a need to represent the measurement process under a behavioral perspective and to cover concepts involved in this process and not addressed in COM [Barcellos *et al*., 2014].

MTO has been evaluated through instantiation of real-world case scenarios. In this paper, we showed the instantiation involving a HDL cholesterol test. The scenario was properly instantiated, providing initial evidence that the ontology is able to represent real word situations.

MTO provides a conceptualization about measurement that can be used in several domains. Moreover, MTO can be specialized to deal with particularities of measurement applied to specific domains. MTO can be used for knowledge workers and can also serve as a reference model to solve interoperability issues, such as standards harmonization and systems integration. As future work, we intend to use MTO as a reference model to integrate data from different sources in an Environmental Quality Research Project.

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