The *Mobile MEASURE* Metrology Knowledge Schema: an Artificial Intelligence Reasoning over Metrology

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Abstract. Mobile devices offer measuring capabilities using embedded or connected sensors. Development teams find many uses of those in order to retrieve data that enables to capture the execution context of applications. Considering that performed measurements might be used in rigorous contexts ; measurement procedures are critical and must produce reliable results.
The definition of correct measurement procedures requires to handle the rules specified by metrology. Such expertise is rarely found in development teams.
We present here how to implement the *sub_SI*, a basic Knowledge Representation encoding specific rules and knowledge of the metrology. This works as an expert system able to reason and answer questions about simple systems of units. The capabilities of the *Metrology Knowledge Schema*, an extension of the presented work are presented. It is dedicated to the validation of measurement procedures accordingly to users defined system of units.

Keywords: Knowledge Representation, First Order Logic, Metrology, Reasoning

1 Introduction

In the last decade happened the emergence of mobile platforms. They are now powerful devices able to perform a lot of computing tasks and connected to either local or distant networks with different communication technologies. In addition, they embed plenty of measuring devices [1]. Those capabilities make them the perfect support for measurement assistants ; applications dedicated to the assistance of specific end users measuring processes. Those guide the user in the execution of a specific measurement procedure, indicating how to perform the different measurements with either embedded or communicating sensors, performing automated computation, dedicated to answer the user needs.

In this context, Actimage GmbH[3], the partner of those researches, wants to develop a set of applications dedicated to assist operators in mobility contexts. Examples of applications would be to estimate a solar panel installation cost or to diagnose an industrial facility. Those applications require : to produce the specific quantities the user needs, to handle the user-specific instruments and methods and to retrieve not traditional "*measurements*" (client data, colors, design type, ...)

The development of any of those applications requires expertise in software development and in metrology [2–4]. Each of those applications present similarities ; they

[3] http://www.actimage.de

are built on a measurement procedure, highly customisable and must conform to the metrology rules. In order to maximise the confidence in the measurement and reduce the development time, a Model Driven Engineering platform has been proposed in previous work [5]. This platform, named mobile MEASURE, describes concepts and tools to model, validate and execute measurement assistants.

This paper briefly describes what Knowledge Representations [6] are. It then presents how to use First Order Logic to model a simple coherent system of units. At last, presents the reasoning capabilities of the existing *Metrology Knowledge Schema* (MKS) ; the metrology semantics validation Knowledge Representation implemented in the context of the mobile MEASURE platform.

2 Knowledge Representations

A Knowledge Representation (KR) is a numerical encoding of a specific domain knowledge. This encoding enables to share the knowledge and to reason over the domain as a human being would. The most used approach is the mathematical logic.

KR hold elements and relations between the elements. From this point of view, they are identical to basics of relational databases. Nevertheless KR also holds complex relations which bind elements and relations. Those describe the rules of the domain to encode. KR description languages are associated with strong semantics derived from mathematical logic. The association of this semantics and an inference engine allows for reasoning over the whole set of entities and rules described. The reasoning deduces relations that are not explicitly expressed in the KR [7]. The association of a KR and an inference engine is usually called an expert system. This approach was the premise of the first Artificial Intelligence (AI) using the LISP and Prolog Languages and it is still employed widely.

3 Encoding a Simple System of Units

The International System of Units (SI) paper [3] describes the system of units rules. In this paper we will focus on the creation of a really simple system. Hence we will use a subset of the SI entities and rules to describe our system, the *sub_SI*. The *sub_SI* holds several units. A unit is a reference enabling to encode a real-world event into a quantity. The different kinds of events that can be encoded (length, mass, ...) are named dimensions. We consider that units are either declared as a dimension reference or directly related to an existing unit. Relations between dimensions, conversions of units, prefixes, aliases, unit compositions, dimensional analysis and representational theory of measurement are out of the scope of this paper.

Table 1 lists First Order Logic terms and predicates to model the described *sub_SI* set of rules. Then, using the defined set of predicates, table 2 defines a small system of units with length and time dimensions and some units in each of them.

From the predicates *is_ref_dim(d,u)* and *is_ref_unit(u,v)* it is possible to describe a tree that has a unit reference as root and all other units of the dimension as nodes. It is then possible to add a complex recursive rule *unit_dim(u,d)*from which the dimension of every unit can be deduced :

$$\forall u, d \; is\_ref\_dim(d, u) \Rightarrow unit\_dim(u, d) \tag{1}$$

$$\forall u, v, d \; unit\_dim(v, d) \wedge is\_ref\_unit(v, u) \Rightarrow unit\_dim(u, d) \tag{2}$$

Table 1. Termes and predicates to model the *sub_SI*

Variables	**Description**
u, v, d, ...	are any variable
Predicates	**Description**
is_unit(u)	u is a unit
is_dim(d)	d is a dimension
is_ref_dim(d,u)	defines the unit u as a reference for dimension d
is_ref_unit(u,v)	defines the unit v as a reference for unit u

Table 2. A *sub_SI* instance description

is_base_dim(length)	is_base_dim(time)
is_unit(metre)	is_unit(mile)
is_unit(inch)	is_unit(second)
is_ref_dim(length, metre)	
is_ref_dim(time, second)	
is_ref_unit(metre, mile)	
is_ref_dim(mile,inch))	

The *sub_SI* KR described here can be implemented using Prolog's Horn clauses. Using the inference engine it is then possible to request the produced expert system to get answers to the following questions : does that dimension or unit exists ; what is the dimension of that unit ; what are all the units for that dimension ; what unit defines a given one or what units are defined by a given one.

Generating a system with more units or dimensions is straightforward. The current KR is then able to model any system of units compliant to our *sub_SI* set of rules.

4 The Metrology Knowledge Schema

The *Metrology Knowledge Schema* (MKS) is the evolution of the previous section KR. It has to be able to define if a measurement procedure is valid or not accordingly to the semantics of metrology. Our previous work present how an expert system ; based upon a FOL KR can be employed to validate specific domain processes [8].

To answer to those requests ; the MKS models the dimensional analysis brought by the metrology standards and the measurement scales analysis brought by the representational theory of measurement. Both analysis are brought as complex rules.

In order to handle any kind of units and correct dimensional analysis ; base and composed dimensions have been defined. Also, a set of rule is specified to enable units composition with : prefixes, aliases, unit powers, units product, units quotient. Such units can be parsed to deduce the dimension of any unit ; which combined with the constraints brought by dimensional analysis enables to validate any kind of unit operation.

Using the measurement scales analysis enables to constrain the set of operations that can be performed on a specific quantity. Thanks to those constraints it is possible to define new dimensions that are out of the SI. Indeed, it becomes possible to handle ordered (e.g. IQ tests or school grades) or categorised (e.g. colors, human gender) quantities.

5 Conclusions

This paper presents an overview of the Artificial Intelligence researches performed in the context of the Mobile MEASURE project ; a project financed by the German BMWI as an AIF Projekt in the context of the *Zentrales Innovationsprogramm Mittelstand.* The objective of the project is the creation of a development platform based on Model Driven Engineering concepts able to model, validate and execute mobile measurement assistants. The presented research is focussed on the validation of the measurement procedures implied in those measurement assistants.

First, the paper presents the Mobile Measure project context. Second, it describes briefly what are Knowledge Representations and how to use them. These notions are employed in the following section to model a KR able to hold a system of units constrained by a reduced set of rules called the *sub_SI.* A set of entities is proposed to describe an instance of a system and its reasoning capabilities are described. Last, the paper summarizes the current state of the Metrology Knowledge Schema ; which is the current version of the Mobile MEASURE measurement procedure validation Knowledge Representation.

Further works imply the development of a web api that enables any user to request an instance of a system of units in the MKS. With such capabilities ; the MKS will be an autonomous micro-service that can answer metrological queries. Then, an expected evolution will be to enable the system to be dynamic ; an administrator will have access to the API in order to modify the instance of the system in order to either populate it or specialize it ; depending on the field of application of the measurement assistant. Also, we recognize that it is currently difficult to follow explicitly describe the current MKS instance and its behavior when asserting that a measurement procedure is valid or when a quantity conversion is performed. Hence, we are looking for integrating the API with a web interface that will be used as a pedagogical platform to explain the MKS inference process.

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