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► To cite this version:

Olimpia Hoinaru, Julie Beugin, Juliette Marais. Contribution to a terminology related to dependability for the qualification of an on-board satellite-based system. 2th ICTIS conference, International Conference on Transportation Information and Safety, Jun 2013, Wuhan, China. p333-339. hal-00853771

HAL Id: hal-00853771

<https://hal.science/hal-00853771>

Submitted on 11 Sep 2023

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Contribution to a terminology related to dependability for the qualification of an on-board satellite-based system

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ABSTRACT

This paper aims at presenting the research work of formalisation of dependability-related localisation attributes within the framework of the European project QualiSaR. Processing of natural language is used with the aim of creating a structure of dependability and safety-related terms for evaluating automated systems in general and satellite positioning performances more specifically. The attribute hierarchy developed is managed by the help of iglos, an NLP tool (Natural Language Processing). The standardisation objective of this research work consists of making a proposal for an international standard, which describes satellite-based system quality criteria understandable by transportation communities.

1. INTRODUCTION

Diverse transportation applications are today based on satellite localisation techniques, using essentially the GPS system, as for instance, fleet management, driver assistance or passenger information. For the moment, given the currently delivered performances, GNSS (Global Navigation Satellite Systems) are only integrated in non-safety-related applications for which incorrect estimated positions are not dangerous for the users. The arrival of the European GNSS Galileo and EGNOS will lead to tremendous enhancements in safety, ecology, and efficiency fields for land transportations. Due to new signal properties allowing new accuracy and integrity performances to be provided on a continuous period of time, satellite positioning services are envisaged in safety-related applications (e.g. in enhanced Advanced Driver Assistance Systems-ADAS for the road domain or, in train traffic management for the railway domain). For now, these services cannot be used in the road and rail safety applications as there is no standardised process to qualify them. The *QualiSaR* project proposes to develop such a qualification process by means of

the development of a reference measurement system and also by means of creating a terminology of metrological and dependability-related localisation performances. The latter aspect is related to the construction of well-founded terminologies that allows misunderstanding to be avoided when applying the process.

Metrology only covers one dimension of measurement quality. Its focus relies on accuracy measurement. Reliability, Availability, Maintainability, and Safety (RAMS), on the other hand, are essential aspects in holistically evaluating a system. While these two fields of terminology provide standards for evaluating systems in general, there is of course a broad field of terminological knowledge concerning GNSS as well as geo-referencing and localisation to be processed. The chosen approach in the project is to formalise the previously mentioned standards and knowledge as interrelated attribute hierarchies.

The present paper discusses particularly our work on the terminology related to the standardised terms describing dependability issues, and the terminology derived from GNSS related research and engineering. This is in the line of the research conducted on the formalisation of a metamodel of a linguistic sign with the aim of analysing satellite-based localisation system specifications (Manz et al., 2009). This semantic metamodel will be reminded in the second section of the article. It is implemented in the *iglos* tool developed at the iVA-Institute for Traffic Safety and Automation Engineering (Braunschweig, Germany). *iglos* allows the formalisation of terminological structures and is used in this work for structuring generic dependability-related terms and for structuring terms qualifying the dependability performances of satellite-based positioning systems. These two steps are explained in the third and fourth sections. The last section presents a conclusion and states the perspectives envisaged for future work.

2. GENERIC MODEL FOR THE FORMALISATION OF TERMS

This section reminds the generic model of formalisation of terms as described in (Manz et al., 2009). It is based on a tripartite semantic model and constitutes thus a meta-linguistic model of a linguistic sign. It comprises the following constituents: the designation i.e. the concept representation (linguistic, symbolic, by formulas), the actual 'concept' and the linguistic variety i.e. the context of use. This choice is motivated by the fact that natural language has several properties like vagueness or ambiguity, which will negatively affect processes of language reception in those contexts that need to rely on specificity and precision.

The intelligent glossary *iglos* helps modelling terminologies. The *iglos* model for analysing terms is based on the tripartite semantic model. Additionally, the above model of linguistic sign is expanded by adding attribute hierarchies to the definition. Attribute hierarchies are based on semantic feature theory and they allow

for lexeme comparability based on numerical values. The hierarchy uses four levels: property, characteristic, quantity and value. These levels permit to precisely distinguish semantically similar terms based on semantic features and allows for identification of potential ambiguities. An important task during the *QualiSaR* process is to compare the new terminology with already standardised terminologies. Figure 1 shows the generic hierarchy for describing a term in *iglos*.

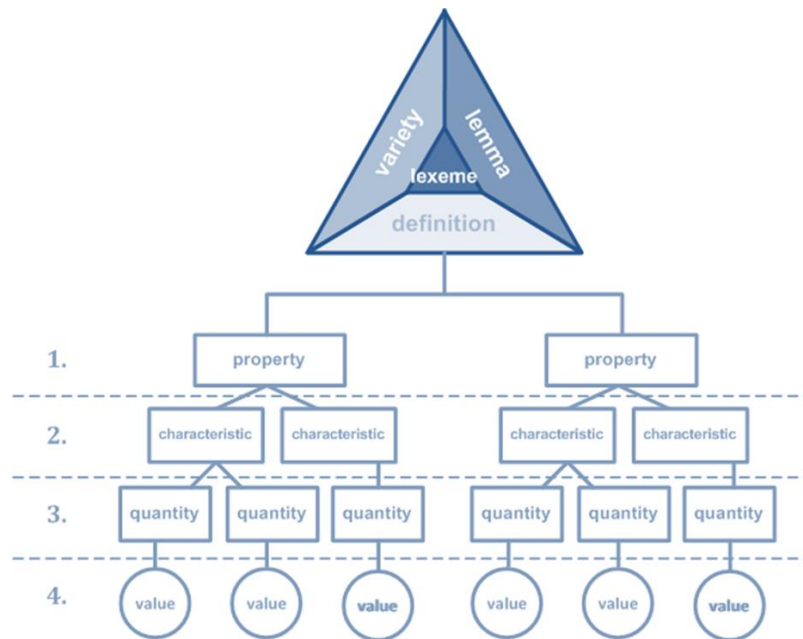


Fig.1 Generic hierarchy for describing a term in *iglos*

Relations among terms are also practised in *iglos*. Apart from typically linguistic relations like homonymy and synonymy, the *iglos* tool is intended to capture other types of relations as well (ex. “isPartOf” for the Part and Whole relation type, “hasHyponym” for the Super-ordination relation type). These are especially based on specific domain knowledge and capture the connections that are said to hold between the objects, which the lexemes refer to. The next sections present how we used this model for describing dependability and satellite-based localisation performances.

3. STRUCTURING OF GENERIC DEPENDABILITY TERMS

This section concentrates on the dependability attributes associated to any automated system. The objective is to obtain a generic terminological structure characterising the system dependability. In the next section, we will focus on the terms denoting the dependability performances of satellite-based localisation systems. The first part of the terms constitutes the more generic part in the study of the dependability-related terms. The second part is also a study on the identification

of dependability and safety performances and other related terms in the domain of satellite-based navigation.

3.1. The context of dependability and safety assessment

Dependability and safety assessments are used in road and railway systems for qualifying new systems realising safety operations. They are described in the EN 50126 standard (prEN 50126, 2011) for the railway transport field and in the ISO 26262 standard (ISO26262, 2009) for the road transport field. These two kinds of assessments are interdependent and are often run together during RAMS management activities (Reliability, Availability, Maintainability, and Safety). At each stage of the development process of such transportation systems, demonstrations of compliance with RAMS requirements are provided using recommended techniques and methods (such as Failure Mode Effects and Criticality Analysis, Preliminary Risk Analysis, Fault Trees, Reliability Block Diagrams, SIL allocation, Markov Analysis). Two types of outputs can be produced at each development phase to prove that RAMS requirements were satisfied and correctly traced throughout the product life cycle. The outputs related to dependability (RAM) concern the management of performances in operating conditions and are based on a “RAM program”. The outputs that integrate the “safety plan” concern risk analysis and management using specific requirements in terms of SIL (Safety Integrity Level). This safety plan also includes audits, description of roles and responsibilities. These activities related to RAMS were processed in the framework of the terminology.

3.2. Construction of the terminological structure

We have chosen to also define some of the terms that are employed in the definitions of the dependability attributes (such as failure, requirement, etc), and this for a better understanding for the potential users of the final terminological database. We also defined notions related to safety, as they characterise the quality of a system additionally to those linked to dependability, and notions linked to dependability assessment (ex: failure analysis, causal analysis, validation). The standardised terms describing dependability issues were analysed and introduced into the terminology created with *iglos* according to the model for the formalisation of terms presented in section 2. For each term, a lexeme was created. Each lexeme consists of:

- the denomination of the concept
- the linguistic variety standing for the contex/ domain in which the term is used
- the definition of the term
- relations with other lexemes.

The attributes of the dependability terms describe performances of the automated systems. Judging within the context of the life cycle of an automated system, these performances describe requirements that have to be accomplished in all the phases of the life cycle.

4. STRUCTURING OF SPECIFIC DEPENDABILITY TERMS RELATED TO SATELLITE-BASED LOCALISATION SYSTEMS

This section is related to the performances expected in output of a localisation unit, especially a localisation unit that uses GPS and/or Galileo signals. These performances characterise the quality of positioning data. This part of the project only aims at analysing the positioning data obtained from the treatment of satellite signals by the receiver. In addition to that, we also provided some terms concerning the SIS (acronym for “Signal In Space”) that can be identified within the linguistic variety “satellite-based positioning dependability”, and some others concerning navigation (the “GNSS” variety).

4.1. Context of the application of RAMS activities to satellite-based navigation system

Demonstrations of compliance with RAMS requirements, especially the evaluation of RAMS performances, serve for the proof of safety and for the proof of dependability (RAM) of a system. In the case of emerging technologies intended for safety issues like satellite-based navigation technologies, these activities are difficult to accomplish. Especially, difficulties are encountered when trying to define the performances of the positioning function realised by the embedded system. Indeed, RAMS attributes are used to qualify new system and also, GNSS have their own attributes. These ones define performances related to accuracy, availability, continuity and integrity. In the *QualiSaR* project, we identified and defined the terms used to describe these performances. No equivalent concepts are defined in the railway domain or in the road domain. However, in (Filip et al., 2008), we demonstrated that an analogy between the two classes of quality criteria is possible in the railway domain.

4.2. Construction of the terminological structure

This section contains information about the creation of the second part of the terminology, the one containing the terminology derived from GNSS-related research and engineering. The metalinguistic model of formalisation of this part of the terminology is the same as the one used to describe the dependability performances of automated systems.

These terms were introduced in the *QualiSaR* instance gathered under the

varieties: “GNSS” and “satellite-based positioning dependability” where the latter is entrenched in the former. The GNSS variety contains terms concerning the whole GNSS system including all the services that it provides, and that for comprehension reasons. The “satellite-based positioning dependability” variety identifies terms describing the performances of the positioning service as from a user’s point of view. It is the way that the receiver interprets the information and it calculates its position. We have used the term “positioning service” for the output of the localisation unit and not “localisation service”. Indeed, the definition of the “localisation” term does not appear in any reference documents we have studied and also, some experts in GNSS we have contacted have more or less ambiguous empirical definitions of this term.

Accordingly, the denomination of the variety was chosen to be “satellite-based positioning dependability” in order to specify the performances of the positioning service. The second figure contains a semantic network constructed within the framework of that part of the ontology specifying performances and other aspects of a satellite-based positioning system.

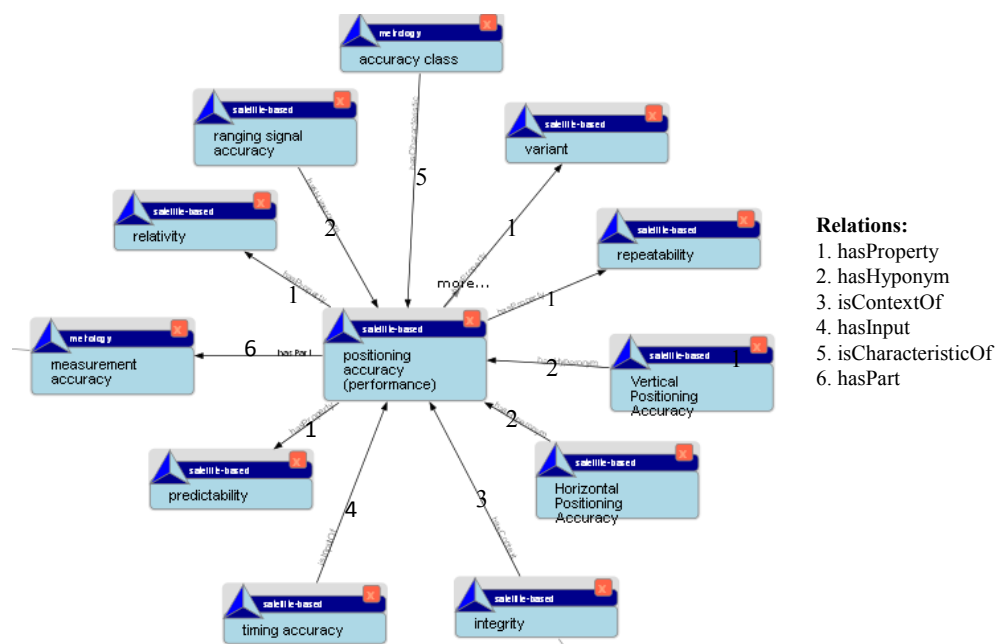


Fig. 2 Semantic network with *property* and *characteristic* relations

This example highlights, among others, terms and relations describing characteristics and properties of the positioning accuracy performance.

CONCLUSION AND PERSPECTIVES

The present paper aimed at providing an overview of our work of processing and structuring of terms describing the quality of GNSS. A terminological ontology was built using the NLP software *iglos* in order to have a graph structure.

Prospects of continuation of this work are envisaged. Relations between the database containing the built terminology on metrology and the dependability-related terminology are envisaged for future work. They will be built on the basis of the need to converge metrology, dependability and safety databases in order to obtain a terminology meant to be a key element for the qualification of a solution able to operate GNSS services in safety applications of transportation.

ACKNOWLEDGMENTS

This research work was conducted for the *QualiSaR* project within the framework of the FP7 (European Framework Programme) and financed by the EU.

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