Facets of a Discourse Analysis of Safety Requirements

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Abstract. In this paper, we provide a linguistic analysis and an implementation of the discourse structure of safety requirements within the framework of the <TextCoop> discourse semantics platform. The main structures are introduced and a detailed evaluation is carried out.

Understanding the contents of requirements is a major objective to be able to automatically organize them, develop traceability, explore overlaps or various types of contradictions, extract their scope and themes, explore semantic and dependency relations between requirements, etc. Even if requirements follow in some context precise authoring recommendations, they often have a complex language structure, with a large diversity of expression modes and nuances. This is in particular the case for a subclass of requirements: safety requirements that include public safety regulations as well as business rules.

Discourse analysis allows the recognition of the backbone of a requirement: how it is organized (in the case of safety requirements: context, conditions, warnings and hints, actions to realize, expectations, goals, etc.). Then, a semantic analysis of the contents of each structure allows to get a more precise information. This article explores the discourse analysis of requirements within the context of the LELIE project which is briefly presented below.

1 The LELIE project

The main goal of the ANR LELIE project is to produce an analysis, a model and a piece of software based on language processing and artificial intelligence that detects and analyses potential risky situations in technical documents. Risks (health, ecology) Risks emerge in particular when these documents are not correctly written, not updated or contain gaps in safety recommendations. This is a very frequent situation in almost any kind of technical document. We concentrate on procedural documents e.g. [2] and on requirements, e.g. [3], which are, by large, the main types of technical documents. Given a set of procedures over a certain domain produced by a company, and possibly given some domain knowledge (ontology or terminology and lexical), the challenge is to annotate procedures wherever potential risks are identified. Procedure authors are then invited to revise these documents.

Requirements, in particular those related to safety, often exhibit complex language structures which make their understanding and concrete use quite challenging especially in emergency situations. For example, it is quite frequent to observe in an instruction several negations, pronouns, complex cross-references and embedded conditions.

Safety requirements are oriented towards action: little space should be left to personal interpretations resulting from gaps or misunderstandings. It is therefore crucial to analyse their structure, get an adequate understanding of their contents and possibly suggest some writing revisions.

To overcome this situation, from original safety requirements, a number of organizations and industries reformulated and customized them for specific activities and users (e.g. the French INRS). Authoring norms have also emerged, e.g. EEC norms for chemical product storage and uses. Besides public regulations, safety requirements also include a number of business requirements associated with certain types of products (e.g. chemicals) or activities. In spite of several levels of reformulation and validation, safety requirements remain quite complex to use.

Our goals in the long term are:
- to detect inappropriate ways of authoring requirements: complex expressions, implicit elements (e.g. verb arguments), references, scoping difficulties, inappropriate terminology or granularity levels, inappropriate style w.r.t. domain authoring norms,
- to make the semantic contents of requiremements more accessible and explicit to users, via contents elicitation,
- to propose a more accurate level of theme extraction and indexing, e.g. to possibly help to reformulate of re-structure sets of requirements, or to improve traceability,
- to develop techniques for (partial) overlap and inconsistency checking, via lexical and textual inference,
- to develop a model for the confrontation of safety requirements with procedures (of maintenance, production, installation) in order, on simple cases, to detect whether safety precautions as stated in requirements, are indeed clearly specified in procedures, at the correct place.

2 Safety Requirements

To manage the difficulty of such a task, we first focus on the discourse analysis of safety requirements from a number of use cases we have defined, characterized by various types of authoring constraints, functional levels, application domains and target users with various levels of expertise. Most requirements make heavy use of domain knowledge: it is here restricted to equipment and product ontologies.

We constructed a development corpus for requirements in French (English is ongoing and is quite similar) from the following types of sources:
- Large public or professionals: *paint scouring, wood lathe uses, electric welding, charging batteries, cooking for groups, working on high positions (roofs), maintenance of agricultural engines*, etc.
- Professionals: *isolated worker, working in cold areas, working in noisy environments, food processing tasks and precautions, oil spill and evacuation plans, X-ray equipments uses, fire in oil refineries, security in nuclear plants, radiation biosafety, various chemical product manipulations, plastic fiber uses,* etc.

Documents come from public administrations (French, EEC, Canadian) and companies (transportation, energy, food processing, etc.). Finally, the corpus concerns sev-

eral types of activity: standard uses and production, emergency situations, installation, maintenance, storage, etc.

Our corpus is composed at the moment of 460 requirements, i.e. a total of about 550 pages of plain text. Pictures and graphics are not taken into account at this stage, however, they are not so frequent and are essentially meant to improve understanding.

3 Discourse Structures of Requirements

The standard form of a safety requirement is composed of three fields, outlining its business or functional structure. These fields are linguistically distinct but they are often interleaved throughout the whole document:

- **The Context of application** field roughly indicates when the actions that follow are relevant and must be carried out. It may have several forms, which are often quite elliptic: (1) title-subtitles hierarchy, which can have several forms, e.g. general statements (*Isolated worker, working in cold areas*), or (2) conditional expressions (*if you use nitric acid, when using ...*). Besides these central elements, this field may also contains definitions, various types of restrictions of application, general purpose information, reformulations, comments, references to legal or business information, and a number of general purpose warnings and advice.
- **The Actor** field is in general very simple. For complex requirements, several types of actors may be required, in that case, each instruction indicates who is doing what.
- **The Action** field is basically composed of instructions and specific warnings and advice. These may be associated with 'low level' discourse structures such as definitions, illustrations, reformulations, concessions, etc. For requirements covering complex activities, this field may be decomposed into several functional fields (identified via subtitles) which are treated sequentially, in particular: (1) actions per equipment or product used, or (2) actions for a given equipment per type of use, e.g.: direct use, maintenance, cleaning, storage, training and supervision. For more casual users, a 'you should do / you must never do' classification is sometimes adopted. Some Action fields end by a 'Remember' or 'Advice Plus' section.

In the remainder of this paper, we investigate the linguistic structure of the main discourse structures we have identified in safety requirements. These structures are implemented as rules in the <TextCoop> environment, our platform for discourse semantic analysis [9,10]. It is used to process the discourse structure of various types of documents [1]. <TextCoop> is based on a linguistic and logic-based approach to discourse analysis: it provides a logic-based language (Dislog) and an environment for authoring rules and developing lexical resources [8]. It also allows the integration of knowledge and reasoning within the rules, which is an important feature to resolve structure ambiguities, accurate content analysis and scoping problems [11]. Source documents are in general in Word, Visio, or XML, sometimes in pdf.

4 The discourse structure of safety requirements

In a theory of discourse such as the RST [4, 5, 6, 7], relations are binary: a satellite is bound to a kernel (e.g. an illustration with what it illustrates). Identifying and precisely

characterizing these structures is in general quite challenging. Much better results can be expected on specific textual genres with limited complexity, which is the case for procedures and requirements. At the moment the following discourse structures have been identified and characterized in detail for requirements, these have been adapted from our work on explanation analysis [1]:

- **title** (9 rules), basically typographic considerations are used, titles are often very elliptic with missing verb or object. If not made explicit, the title hierarchy is difficult to identify. It gives the general purpose of the requirement at stake.
- **instructions** (15 rules) are based on the fact that they contain an action verb often in the infinitive or imperative form; they express the 'what to do' in requirements,
- **advice** (27 rules) and **warnings** (23 rules) are complex structures from argumentation theory, they are formed of a statement and one or more supports [10,11], a warning indicates a danger or the need to care very much about an action, the support(s) indicates the risks if not carefully realized. An advice is more optional in nature: it indicates ways to improve the result of an action or ways to realize it e.g. more comfortably; its support(s) indicates the level and nature of the gain. Advice therefore introduce a specific subclass of requirements, with a different orientation.
- **illustration** (20 rules) is often associated with an element within an instruction, to better characterize it,
- **restatement** (12 rules) is a way to shed a different light on a statement,
- **purpose** (9 rules), often embedded into instructions, develops low-level motivations,
- **condition** (13 rules) ranges over one or a few instructions, it defines restrictions of application or use,
- **circumstance** (15 rules) indicates the environment in which an action must be carried out,
- **frame** (17 rules) is more general than condition or circumstance: it scopes over the entire document or a whole section and specifies the context of application,
- **concession** (8 rules) is not very frequent, it is used to indicate an alternative to an action, it is often very constrained,
- **elaboration** (19 rules) is a high-level discourse relation, it is also not very frequent in requirements (but more frequent in procedures), it is mainly used to focus on an action and to develop it when its realization may be difficult for some users,
- **definition** (9 rules) appears mainly in the Context field of the requirement,
- **goal** (14 rules) may be high level and plays the role of a title, it may also be associated with a group of instructions where it indicates their objectives, from that point of view it is stronger than the purpose relation,
- some forms of **causes** (11 rules) which develops forms close to argument supports but in structures others that warnings and advice.

Here is a short example that illustrates the kind of analysis which is realized:

<requirement> <title> Monitoring safe operation of industrial trucks </title>
<warning> Working practices should be monitored by a responsible supervisor to ensure that safe systems of work are followed. </warning>
<purpose> This list is a basic guide - <elaboration> it is not exhaustive and is not intended to be a substitute for the guidance and training. </elaboration> </purpose>

<subtitle1> Operators should always: </subtitle1>
<instruction> observe floor loading limits - <restatement> find out the weight of the laden truck. </restatement> </instruction>
<instruction> plan their way first. </instruction>
<warning> ensure the load is not wider than the width of the gangways.</warning>
<instruction> watch out for pedestrians and bystanders. </instruction> ....
<illustration>(see paragraph 390-394)</illustration>. </instruction> ...
<subtitle1> Operators should never: </subtitle1>
<warning> lift loads that exceed the truck's rated capacity. </warning>
<warning> travel with a bulky load obscuring vision. </warning>
<warning> travel on soft ground <concession> unless the industrial truck is suitable for this purpose </concession>. </warning> ....
<subtitle1> Remember: </subtitle1>
<warning> never allow unauthorised people to operate the industrial truck. </warning>
</requirement>

5 Results and performances

An important feature of our description is that it mainly requires domain independent linguistic resources. Discourse rules, over various domains, require the following resources (due to space limitations a subset of relations are mentioned below):

structure	discourse marker	connector	negation	pronouns	prepo-sition	punctuation, typography
instruction						X
advice concl.				X		
advice support		X		X		
warning concl.			X	X	X	
warning support		X	X	X	X	
illustration	X					X
restatement	X					X
purpose		X				X
condition		X				X
circumstance		X				X

structure	modals, auxiliaries	action verbs and verb classes (7100)	adverbs (75)	expr. with polarity (290)	adhoc (360)	know-ledge
instruction	X	action verbs	X			
advice concl.	X	communication	X		X	
advice support	X	change verbs		positive	X	
warning concl.	X	communication	X		X	
warning support	X	change verbs		negative	X	
illustration	X	X			X	X
restatement	X	epistemic			X	X
purpose					X	X
condition						X
circumstance	X				X	

From a test corpus (62 requirements, about 31 500 words), with the same distribution as for the development corpus, we have the following coverage and accuracy rates, expressed in terms of recall and precision. Our strategy was to favor precision over recall. The following figures are based on a comparison of the system performances w.r.t. manual annotations. A structure is correct if it is correctly identified and well delimited.

structure	number manually annotated	precision (%)	recall (%)
instruction	554	98	96
advice concl.	49	87	76
advice support	42	91	82
warning concl.	112	91	88
warning support	88	93	90
illustration	38	92	87
restatement	47	86	79
purpose	101	89	86
condition	168	93	82
circumstance	121	95	92

6 Perspectives

We have here developed the analysis of the discourse structure of safety requirements with the purpose of improving risk analysis in the industrial procedures they apply to. This is the first step before realizing contents and coherence controls. This analysis should improve requirement understanding, and to explore overlaps or contradictions, relations between requirements and how to enhance traceability.

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