A Communication Tool Between Designers and Accidentologists for the Development of Safety Systems

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Abstract: Designers and accidentologists have to collaborate in order to develop new safety systems. Accidentologists recognize *Accident Scenario* as a powerful tool to provide designers with the required knowledge about accident. However, an accident scenario has to be presented in a way that both designers and accidentologists can understand and use. The fact that designers and accidentologists do not share the same viewpoints, neither the same models to analyze an accident, nor the same technical language makes their communication a complex task in a design process. To address this issue, we use the *systemic approach* (a complex system modelling approach) to develop a new methodology allowing constructing multi-view accident scenarios.

Keywords: safety system development, accident scenario, systemic approach, multi-view modelling, complex system modelling.

Introduction

Several approaches, methods and tools exist in the literature to support designers developing new systems and functions. Functional Analysis and Query Functional Deployment (QFD) for example allow a designer to structure his design. However, these methods suppose that the main functions (functions related to the requirements) exist. Therefore, these methods only allow the deployment of the main functions and the structuring of the design space. When one deals with new systems development, the primary need is a tool to build the design space. In other words, we need tools to define functions to be realized in technical solutions. According to our records, there is a lack of research in literature dealing with this issue.

Our research is carried out in the LAB (Laboratory of Accidentology, Biomechanics and Human Behaviour), which is a shared laboratory between the two main French car manufacturers, PSA (Peugeot-Citroën) and Renault. This research is intended to provide safety system designers with accidentlogy knowledge to allow them to understand accident behaviour and therefore to develop new road safety systems.

Developing safety system is a complex task due to the fact that several disciplines have to be combined to achieve it. Indeed, designers who are generally specialized in mechanics and electronics, collaborate with accidentologists who are specialized in mechanics, biomechanics, ergonomics, infrastructure and psychology. Hence, the main issue consists of making possible the communication between these different skills.

In the LAB, brainstorming sessions are one of the means used to allow the communication between accidentologists and designers. The aim of these sessions is to understand the accident mechanisms and to propose new road safety counter-measures that designers may use as an input to elaborate new safety systems. However, there are many issues that have to be addressed in order to carry out successful brainstorming session:

- Designers and accidentologists do not share the same viewpoints, neither the same models to analyze an accident, nor the same technical language. For instance, a psychologist focuses more on the driver's information processing aspects whereas a designer is more interested in the mechanical aspects;
- There are many different approaches and viewpoints that can be used to analyse a road accident in order to understand the failure mechanisms. Some of these approaches focus on the accident's causal aspect. Others focus on the accident's sequential aspect (Brenac, 1997; Brenac and Fleury, 1999), or on the human mechanisms of error production and of information processing (Fuller and Santos, 2002; Van Elslande and Alberton, 1997). Some studies in cognitive psychology analyze the driver's behaviour as a

process of skill learning and automatization (Summala, 2000), or as a risk management process (Fuller, 2000). Thus, each of these approaches focuses on a specific aspect of the accident. However, when considering the complexity of the accident, several approaches should be combined in order to handle this complexity;

- Another difficulty that designers and accidentologists are facing when they work together in brainstorming sessions is related to the nature and forms of the accident data colleted in the databases. Indeed, using the thousands of accidents characterized by hundreds of attributes is a hard, time-consuming and thereby inefficient task.

Hence, the aim of our paper is to elaborate a tool intended to represent accidentology knowledge in a way that designers and accidentologists can use. In other words, we aim at developing a tool that represents accidentology knowledge for each operator in his own viewpoint. This may make easier and more efficient the communication between the various skills involved in safety system development.

In the first section of this paper, we present an overview of the use of accident scenarios as a communication tool between designers and accidentologistes. In the second and third sections we present respectively the systemic approach and its use to integrate different viewpoints stemming from designers and accidentologists in design process.

Accident Scenarios: a Powerful Interface Between Designers and Accidentologists

A scenario is a prototypical behaviour of a group of subjects or objects (customers, accidents, users, etc.) with similarities. Scenario-based approaches are used in several fields (Leite et al., 2000). For instance, in economy and finance, scenarios are used to anticipate market behaviour and thereby to perform adequate plans to address economical issues. Scenarios are also used in risk analysis in project management, nuclear installation etc. (Scheringer et al., 2001). They allow risk anticipation and handling. They are also used in software engineering as a tool to understand the user behaviour in order to anticipate the different software use-case (Caroll, 1995,1998; Gandon and Dieng, 2001; Jarke et al., 1998).

Accidentologists assume that similar accident factors entail similar safety countermeasures (Brenac and Megherbi, 1996; Fleury et al., 1991; Van Elslande and Alberton, 1997). Based on this assumption, accidentologists in the LAB recognize *Accident Scenario* (AS) as a powerful tool to provide safety system developers with the required knowledge. In Figure 1, we present an accident scenario example. It is a synthetic description of 30 road accidents. It is one of 18 scenarios we elaborated using a sample of 750 road accidents.

4% of accidents in the database concern the following situation: *"The accident happened at a junction of two main roads. The weather was sunny and the road surface was dry. A driver came up to the roundabout at the junction. He did not know which direction he had to take, and was concentrating on the road signs. As he reached the roundabout, he glanced left quickly, and thinking that the road was clear, pulled out. He declared his speed to be about 20 km/h. The crash barrier that runs round the middle of the roundabout reduces the visibility of vehicles coming from the left."*

Figure 1 - Example of an accident scenario.

Obviously, using the scenario presented in Figure 1 in a brainstorming session for example is easier than using the 30 accidents summarized by this scenario. Indeed, each accident in the data base is characterized by 900 attributes and thereby the use of the detailed cases is time-consuming and inefficient. Hence, accident scenario provides accidentologists and designers with a synthetic description of a group of accident with an adequate granularity level. Thus, instead of using 750 detailed accident cases in discussing session between accidentologists and designers, we use only 18 scenarios summarizing the different accident cases.

To elaborate such scenarios, several researches were carried out in literature. In (Brenac and Megherbi, 1996; Fleury *et al.*, 1991; Van Elslande and Alberton, 1997), the authors propose an expert approach: expert clusters accidents manually according to their similarity. Next, he elaborates a synthetic description for each cluster. However, this approach has some drawbacks related to the fact that expertise is expensive and scenarios depend on the expert viewpoint and discipline. Moreover, different granularity levels and ways of representing accident scenarios exist. Indeed, several models may be used to present accident

scenario. A *Driver-Vehicle-Environment (DVE) model* may be used to describe what happened to each of these three components (i.e. driver, vehicle and environment). *Information processing model* is another model that can be used to represent accident scenarios (Van Elslande and Alberton, 1997). It consists of describing the scenarios according to the following steps: *perception*, *diagnosis*, *prognosis*, *decision* and *action*. A *sequential model* that presents accident as a sequence of five steps (*normal driving step*, *failure step*, *emergency step* and *crash step*) may also be used (Brenac and Fleury, 1999).
Other studies propose data-mining techniques in order to elaborate accident scenarios. In (Chovan et al., 1994; Najm et al., 2001; Sohn and Lee, 2003; Sohn and Shin, 2001), authors propose classification techniques to elaborate accident configurations. (Page, 2002; Page et al., 2004) propose clustering techniques to perform accident scenarios. However, data-mining techniques suffer from some drawbacks: the interpretation of the statistical clusters is a hard task for experts.
We propose the combination of the expert and the data-mining approaches. Concretely, we propose to apply clustering techniques[1] to regroup similar accidents. In a second step, we perform a projection of the obtained cluster according to chosen viewpoints. Thus, we allow the interpretation of accident scenarios as well as their representation according to the viewpoints and models that accidentologists and designers may chose (DVE model, sequential model, information processing model, etc.).
The main issue is: *how to identify the different viewpoints and models that are relevant to analyze road accident in order to define new countermeasures*? To address this issue, we propose to use the systemic (also called cybernetic) approach (Ashby, 1965; Le Moigne, 1974; Von Foerster, 1995) in order to identify the relevant viewpoints and models.

A Systemic Approach for Viewpoints Integration

Behaviour in road accidents is complex. This is not due to the number of components involved in the accident occurrence, neither the number of variables interacting during the accident. Most of all, it is the non-linearity and the impossibility to predict the DVE system behaviour that entails this complexity. This unpredictability is notably due to the fact that human actions are strongly involved in accident causation, and that human behaviour is unpredictable. Furthermore, during the road accident, the DVE system performs some functions (i.e. perception, interpretation, anticipation, decision, action), which generate transformations (i.e. new situation, new interpretation, new purpose, new requirement, etc.), which in turn generate new functions and behaviours, etc. DVE behavior then be described through feedbacks and recursive loops. According to Miller's definition of a living system (Miller, 1995), the DVE is an open and living system as much as each component (i.e. driver, vehicle, infrastructure, traffic, etc.) is constantly interacting with its environment by means of information and matter-energy exchanges. Due to these feedbacks and recursive loops, it is impossible for designers and accidentologists to identify with exhaustiveness and certainty all the failures and dysfunction mechanisms occurring in a road accident.

Moreover, a same accident may be seen differently according to the analyst viewpoint. We assume that each expert in accidentology and each designer have an individual perception of the same phenomenon. Our assumption is based on constructivist foundations, which assume that knowledge depends on how the individual "constructs" meaning from her/his experience. A system, in a constructivist perspective, is recognized as a representation of reality seen by some people in a given context.

Our approach is then intended to identify and integrate the various viewpoints in accident scenarios construction and interpretation. For this purpose, we propose the *systemic approach* (Le Moigne, 1999) as a shared architecture between accidentologists and designers in order to understand and analyze accident scenarios.

The systemic approach assumes that to handle a complex behaviour, it is fundamental to make junction between the *ontological*, *functional*, *transformational* and *teleological* viewpoints (Le Moigne, 1999). We use these viewpoints to analyse accident behaviour:

[1] We used k-means algorithm (MacQueen, 1967).

- **The ontological viewpoint** (i.e. what is the system?): it allows a structure-oriented and contextual analysis of the system. In other words, it represents the sub-systems (the driver, infrastructure, traffic, ambient conditions, vehicle, etc.), their taxonomic groups, their contexts (the driver's professional status, family status, etc.), their structures, as well as the various interactions between these sub-systems and their components;
- **The functional viewpoint** (i.e. what does the system do?): it allows a function-oriented analysis of the system. It represents the global process of the DVE functioning during the road accident, which combines several procedures (perception, diagnostic, prognostic, decision and action) (Van Elslande et al., 1997);
- **The transformational (or evolutionary) viewpoint** (i.e. how does the system evolve? What does it become?): it allows a transformation-oriented analysis of the system. The DVE system behaviour can be described as an evolution that goes through several states. The transformational viewpoint integrates the accident's sequential and causal models developed by the INRETS and described in the next section (Brenac, 1997; Fleury et al., 2001);
- **The teleological (or intentional) viewpoint** (i.e. what is the goal or intention of the system?): it allows a goal-directed analysis of the accident. In other words, it assumes that each of the DVE system components or functions has to serve a purpose in an active context in order to ensure the safety of the DVE system.

In the next section, we show how to use the systemic viewpoints in order to provide accidentologists and designers with a multi-view analysis tool of accident scenarios.

A Multi-view Interpretation of Accident Scenario

Using the systemic viewpoints presented in the previous section, we developed a software that enables us to represent the same scenario according to different models specific to different fields, i.e. safety system design field and accidentology fields. Each scenario user has the possibility to represent the scenario according to his own model.

Our approach is described through the following steps:

1. Find and/or construct accident representation models according to each systemic viewpoint. For example, the *DVE model* is assigned to the ontological view. The *sequential model* is assigned to the transformational view. The *information processing model* is assigned to the functional view etc.
2. Each model is composed of one or more concepts. For example, "*Normal driving step*", "*Failure step*", "*Emergency step*" and "*Crash step*" are the concepts composing the *sequential model*. "*Perception*", "*Diagnosis*", "*Prognosis*", "*Decision*" and "*Action*" are the concepts composing the *information processing model* etc.
3. Each concept is characterized by one or more attributes. Each attribute may characterize many concepts in different models. For example, the attribute "*steering angle*" characterizes, at the same time, the concept "*Driver/Vehicle interaction*" in the *DVE model*, the concept "*Emergency*" in the *sequential model* and the concept "*Action*" in the *information processing model*. In a sense, the attributes classification according to the model concepts can be perceived as the construction of *metadata* since it is a "*data about data*". Figure 2 shows how we use XML to represent these metadata and how an attribute (e.g. "*steering angle*") is assigned to various concepts.

```xml
<?xml version="1.0"?>
<Accident_Metadata>
<Viewpoint>
  <ViewpointName> Ontological_View </ ViewpointName >
 <Model>
  <ModelName> DEV_Model </ModelName>
  ...
  <Concept>
      <ConceptName> Driver/Vehicle interaction </ ConceptName >
      <Attributs>
           Steering angle
      </Attributs>
  </Concept>
  ...
  </Model>
  </Viewpoint>
<Viewpoint>
  <ViewpointName> Functional_View </ ViewpointName >
 <Model>
  <ModelName> Information_Processing_Model </ModelName>
  ...
  <Concept>
      <ConceptName> Action </ ConceptName >
      <Attributs>
           Steering angle
      </Attributs>
  </Concept>
  ...
  </Model>
  </Viewpoint>
...
</ Accident_Metadata >
```

Figure 2- An XML representation of the metadata: each attribute is assigned to several concepts according to the various models.

4. Since the accident clusters are characterized by attributes and since these attributes are classified according to the different concepts in the different models, we can perform a multi-view projection of a scenario accordingly (see Figure 3).

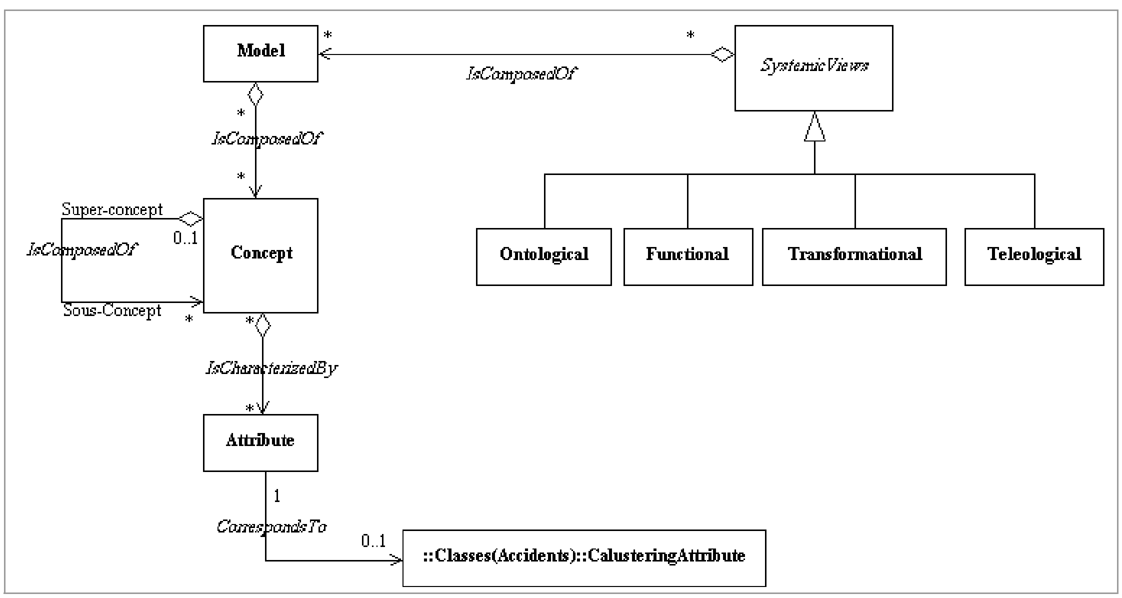

Figure 3 - The link between ASMEC and the clustering results: attributes in ASMEC correspond to attributes used in the clustering task.

Figure 4 shows the beginning of a table describing an accident cluster. Accidentologists and designers have to analyze each table using statistical features. Using our approach, we allow them to represent the same table (i.e. cluster) according to the different models (see Figure 5).

Clustering Attributes	Attribute modality	% of the modality in the study sample	% of the modality in the cluster
Crash_position	Offroad	26,64	96,72
Crash_Type	Rollover	21,76	78,69
Obstacle	Obstacle=ground	18,97	68,85
Number_Vehicles	Signle_Vehicle	29,15	72,13
Accid_situation	Control_Probl	32,50	73,77
Critic_task	Guidance_infrastr	15,62	44,26
Initial_event	External perturbation	5,72	22,95
Infrastructure_Typ	Straight line	24,83	49,18
Accid_Type	Pilotability	55,51	80,33
atmosphere conditions	Clear/Normal	55,79	80,33
Surface	Dry road surface	62,62	85,25
Accid. Position	Secondary road	47,98	70,49
Failure_Type	Action	9,07	22,95
Manœuvre	Lane_change_manoeuvre	6,14	18,03
Failure	failed_task	33,61	52,46
mask	No_Mask	65,13	81,97
critini	Perte_contrôle_tr_8#	17,85	32,79
failure_mecanism	Panic	5,72	14,75

Figure 4 - An example of an accident cluster.

	Driver	Vehicle	Environment	Driv/Veh	Driv/Env	Env/Veh
CVE Model	failed_task Lane_change_manoeuv external_perturbation typacc=pilotabilite driver_distraction Drug failure_mec=Panic failure_typ=Action	rollover Obstacl=ground	atmosph=clear/normal Dry_road_surf Secondary_road No_Mask driver_distraction straight_line	Control_Probl Dry_road_surf loss_lateral_control	Guidance_infrastr Dry_road_surf Lane_change_manoeuv	Obstacl=ground Dry_road_surf Single_Vehicle

	Permanent State	Normal Driving step	Failure step	Emergency step	Crash step
Sequential Model		atmosph=clear/normal Dry_road_surf Secondary_road straight_line	Control_Probl Guidance_infrastr No_Mask failed_task Single_Vehicle Lane_change_manoeuv driver_distraction	failure_mec=Panic	Obstacl=ground Dry_road_surf rollover Obstacl=ground Offroad

	Perception	Diagnostic	Prognostic	Decision	Action	Global
Inform. process. Model	No_Mask			failure_mec=Panic	fondef=Action failed_task loss_lateral_control	driver_distraction Drug/font>

	Navigation	Guidage latéral	Guidance longit.	Control latéral	longit. Control
Task Model	No_Mask	Guidance_infrastr straight_line	Guidance_infrastr	loss_lateral_control rollover	

Figure 5 - A multi-view projection of clusters.

Conclusion

Developing new safety systems requires the collaboration of designers and accidentologists. Brainstorming sessions are one of the means used in the LAB PSA Peugeot-Citroën and Renault to support the required collaboration. However, the various participants do not share the same viewpoint for accident analysis and understanding. Indeed, several models are used to analyze accident and this depends not only on the study objective, but also on the analyst specialty. A psychologist, for example, focuses more on the driver's information processing aspects whereas a designer is more interested in the mechanical aspects. This makes their communication hard and inefficient leading to a complex problem. Accident scenarios are one of the efficient tools allowing the required communication. However, even we use clustering techniques, the scenarios elaboration is time-consuming for experts. Moreover, these scenarios depend on the viewpoint of the expert performing them. Besides, they may be represented and interpreted according to several accident models that the various participants may used.

Using the *systemic (not systematic) approach*, we propose a multi-view architecture, which guides the user to identify the relevant models that may be used in accident analysis. It classifies the different models according to four viewpoints (ontological, functional, transformational and teleological). Then, we use an attribute-based approach to implement our approach. Concretely, we classify the attributes that characterize an accident according to the different concepts composing each identified relevant accident model. This allows us to represent automatically each accident scenario according to a specific model that users (accidentologists and/or designers) choose.

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