Key Factors of Dependability of Mechatronic Units
- Mechatronic Dependability -

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Abstract

Serious accidents in the last years, e.g. Concorde disaster, long-distance train ICE 3rd generation, and countless and increasing rates of call-back actions of automobiles because of failures, underline the necessity for systematic dependability analysis and integrative dependability design. The different technological areas (mechanics, electronics, information and communication technology) and a wide concept of trustworthiness (dependability) that subsumes reliability, availability, safety and security under "real-world" constraints have to be regarded and integrated. One key solving the problems is the adequate definition and stringent use of this definition during the whole development cycle. The following questions have to be answered: What is understood by the term mechatronic dependability? What are the key factors of Mechatronic Dependability? The key factors are put together to form a framework for mechatronic dependability evaluation and design.

1. Introduction

Today, complex systems strongly integrate components of different fields of technology such as mechanics, electronics, sensors, actuators, embedded computers as well as distributed networking, to form a mechatronic unit. Asking experts from industry and universities, what they do understand by the term "dependability of mechatronic units", different and incomprehensible answers are given. This is not a surprise, because up till now, cooperating individual units of the specific fields of technology were independently analysed and designed.

The term dependability was established by the fault tolerance community for computer systems with high reliability and safety requirements. Since it describes reliability and safety related questions more comprehensively than the single terms reliability and safety do, the idea is to extend dependability to mechatronic components and systems.

2. A Definition of Dependability of Mechatronic Units

Definitions of the term dependability for computer systems with high reliability and safety requirements for example can be found in (Laprie 1991, Laprie 1995, Misra 1993, Pradhan 1995, Avizienis 2001).

With regard to design, operation, and maintenance of mechatronic units, dependability is defined as following (Kochs 2004) based on and extending the well known definitions:

Dependability of mechatronic units is defined as the qualitative and quantitative assessment of degree of performance of reliability and safety related predefinitions taking into consideration all relevant influencing factors (attributes).

By this definition, it will be expressed, to what extent (... degree ...) humans can rely on the considered unit, taken into consideration all relevant influencing factors, which are the key factors of mechatronic dependability. Thus, all determining characteristics of the different technological fields of mechatronic units and the „real-world" constraints have to be explicitly regarded and considered.

3. A Framework of Dependability Considerations of Mechatronic Units

Fig. 1 shows the suggested framework. Based on the intention of the above definition, the activities (framed), their effect directions (arrows), and the results at the interfaces (dashed lines) are represented.

The result of a dependability evaluation is given by the definition as "... the qualitative and quantitative assessment of degree of performance of reliability and safety related predefinitions taking into consideration all relevant influencing factors ...". The result manifests itself in the interface (c) in fig. 1. In each

case, the dependability depends on the predefinitions[1-6] on the left side. The predefinitions 2 to 6 are usually necessary for the analysis of the influencing factors[7].

The influencing factors[7] summarize all the values, which can affect the dependability of the unit. Reliability and safety related analysis of all relevant influencing factors - including their identification - is the most difficult task of a dependability evaluation.

The different technological areas, e.g. mechanics, electronics, computers, and communications are taken into consideration by the term "technological influencing factors[7] ", real-world constraints, e.g. commonmode failures by the term „internal influencing factors[7] ", and so on.

The influencing factors comprise all the relevant technological features (attributes) of the unit and the "real-world constraints" which influence essentially the dependability. They are the key factors of dependability analysis and design.

Influencing factors can be evaluated qualitatively e.g. by text descriptions, and quantitative e.g. by quantities, measurements, or metrics. The result of the analysis of the influencing factors is a reliability and safety related specification (interface (b) in the fig. 1), which forms a basis of the phases modelling[8] , calculation[9] and assessment[10] of dependability. If the requirements are not fullfilled (interface (c)), then the design[11] has to be modified (e.g. fault tolerance structure - interface (d)).

4. Integration of Dependability in the V-Model

The new development guideline (VDI 2003) of mechatronic units, proposes a V-model as one possible organisational framework for the development of mechatronic units. The development cycle consists of three levels: analysis, raw design, and fine design on the left branch and integration (e.g. mechanics, electronics and informatics), validation, and verification on the right branch of the V-model.

Dependability has to be considered at the beginning of the product development, that means in the analysis phase, and the raw and fine design phase, as an integrated part of each development level. Most often, customer requirements are given implicitly or explicitly by the relevant guidelines, regulations and experience just before the first analysis steps will be started. Therefore, dependability analysis and design have to be integrated in the left branch and dependability integration, validation, and verification in the right branch of the V-model, step by step.

The V-model can be iterated several times until a product fulfills the specification and the dependability predefinitions, affected by the influencing factors (key factors).

Considering dependability in the V-model means that the framework of fig. 1 is applied during the whole development cycle, either in a very rough version in the beginning analysis and design phase (e.g. with uncertain key factors) or in a detailed version at the "end" of the verification and validation phase.

5. Conclusion

The dependability of a mechatronic unit always is referred to the predefinitions taking into consideration all relevant influencing factors (key-factors). They have to analysed carefully and as completely as possible, since dependability mainly depends on these factors.

The proposed definition of dependability of mechatronic units leads to extensive consequences according to modelling, calculation, and assessment. The different technological areas e.g. mechanics, hydraulics, electronics, sensors, actors, information, communication, and computer technology, and last but not least human- machine interactions are "meshed" in a complex manner resulting from their functional cooperation.

6. Bibliography

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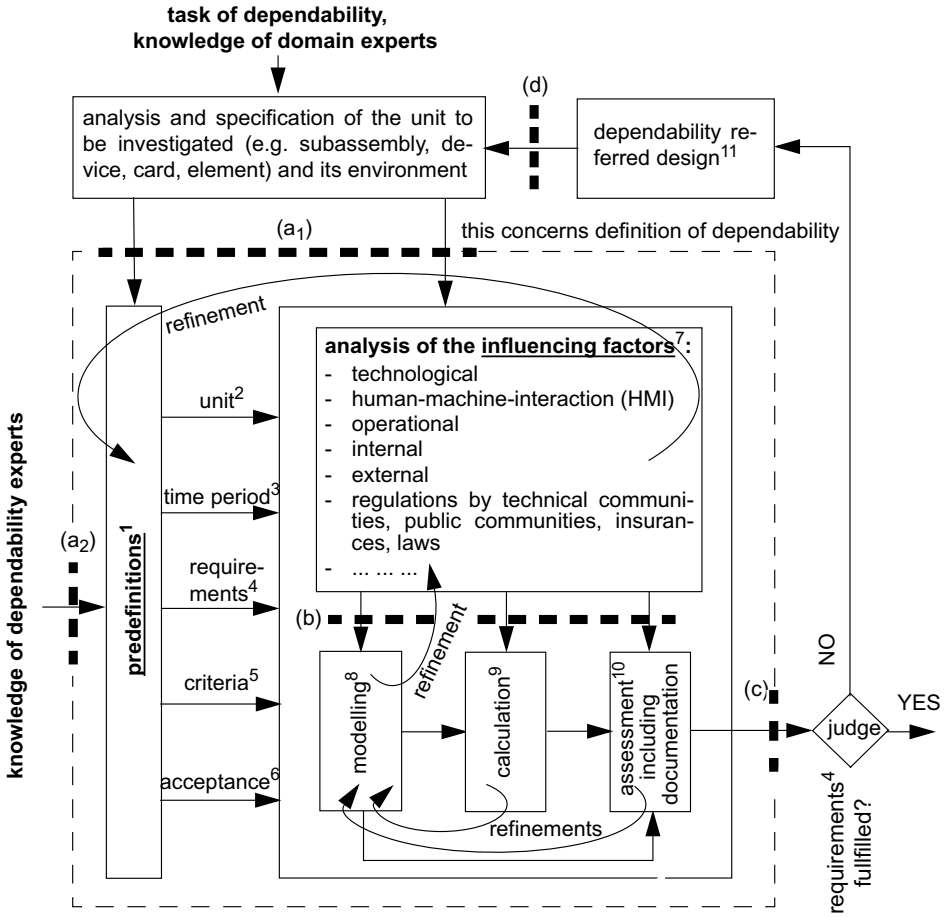

Figure 1: Framework of dependability evaluation of mechatronic units.

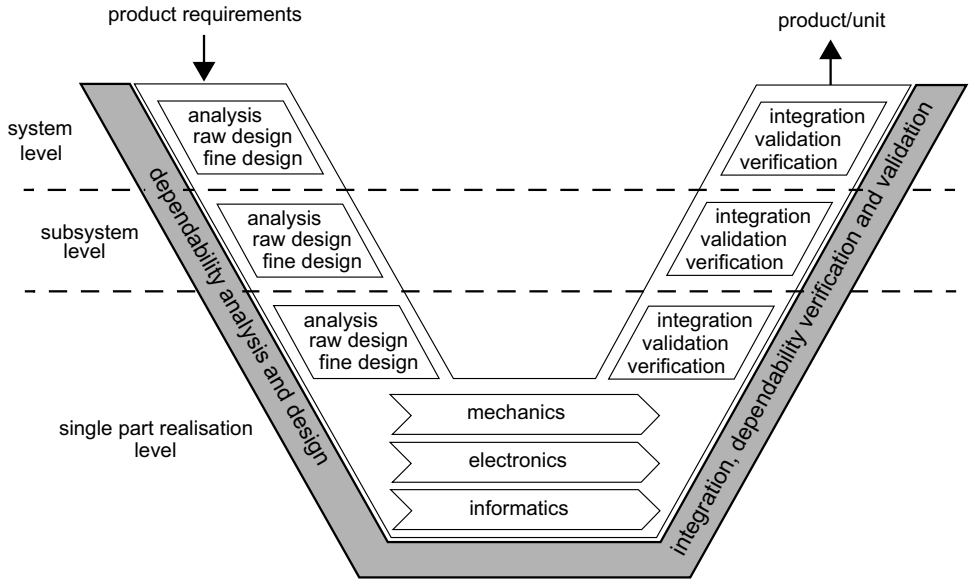

Figure 2: Integration of dependability methodology in the V-model of the new German VDI 2206 guideline (proposal, 2003) for the development of mechatronic units.