Qing-long Wang, Zhi-xue Wang, Ting-ting Zhang, Wei-xing Zhu, 2017. A quality requirements model and verification approach for system of systems based on description logic. *Frontiers of Information Technology & Electronic Engineering*, **18**(3):346-361. http://dx.doi.org/10.1631/FITEE.1500309

A quality requirements model and verification approach for system of systems based on description logic

Key words: System of systems (SoS); Cloud model; Description logic (DL); Requirements verification

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Motivation

- Due to the rapid development of the society and industry, the developed information system is the result of many, autonomous, and heterogeneous constituent systems (CSs), having complex constitution and interactions that generate large-scale complex system of systems (SoS) .
- The System of systems engineering (SoSE) involves the complex procedure of translating capability needs into the high-level requirements for SoS and evaluating how the SoS quality requirements meet their capability needs.
- To solve the problem of modeling and verification, meta-models are proposed to refine both functional and non-functional characteristics of the SoS requirements.

Main idea

- Our theory provides a three-layer analysis framework of capability requirements to acquire the domain knowledge for V&V tasks, extends the UML Class and Association with fuzzy constructs in order to specify both functional and non-functional characteristics of SoS requirements.
- We introduce the fuzzy Description Logic to formalize the UML model, and offer an algorithm to convert the fuzzy UML models into the f-DL ontology so that the verification can be automated with a popular Description Logic (DL) reasoner such as Pellet.

Method

- A domain-specific modeling language is defined by extending unified modeling language (UML) class and association with fuzzy constructs to model the vague and uncertain concepts of the SoS quality requirements.
- The efficiency evaluation function of the cloud model is introduced to evaluate the efficiency of the SoS quality requirements.
- A concise algorithm transforms the fuzzy UML models into the description logic (DL) ontology so that the verification can be automated with a DL reasoner.

Major results

- An EEF based on the cloud model to address the problem of evaluating the efficiency countered in analyzing the quality requirements of SoS.

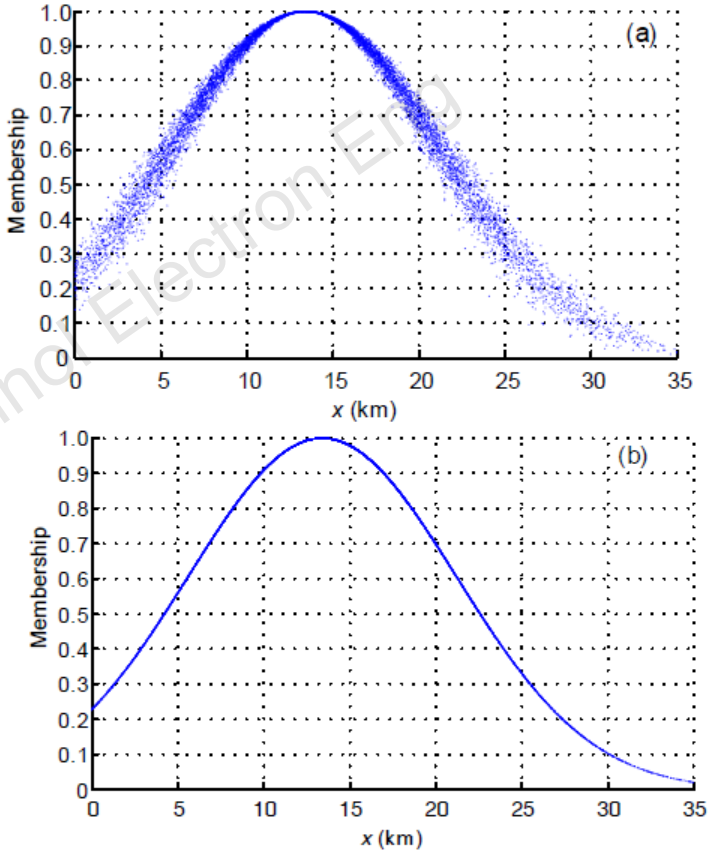

Fig. 5 Synthetic cloud model (a) and efficiency evaluation function of 'effectively intercept' (b) for a short-range air defense missile

Major results (Cont'd)

- Due to the extension of the UML profile, our approach inherits the strong description ability of high level abstraction.
- Our method introduces deduction reasoning with the finite space of state space.
- The verification efficiency is primarily determined by human interference, execution time, and operational cost in the verification process. Our method, which depends on human interference, is graded low.
- Careful analysis demonstrates that our approach facilitates reuse knowledge to acquire description ability, and has a modest degree of verification efficiency, compared to the other methods.

Conclusions

- This paper regards NFRs as quality requirements and proposes a modeling and verification approach countered in quality requirements analysis to facilitate stakeholders to adopt the appropriate quality to decrease the cost and risk in the developing procedure of SoS.
- The approach starts with quality requirements modeling and then extended UML with fuzzy constructs to address the problem of modeling the uncertain and vague concepts in quality requirements.