Report on Habilitation Thesis of Dr. Miroslav Kvassay, University of Zilina

Frank Coolen, Department of Mathematical Sciences, Durham University, Durham, UK
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The Habilitation Thesis presented by Dr. Miroslav Kvassay is entitled *Reliability Analysis of Complex Systems based on Logic Differential Calculus*. It presents, in a concise but clear and complete manner, a substantial amount of novel theory in the field of system reliability. The work has been performed by the author, and forms part of collaborative research with some colleagues and students. The work has also been presented in a number papers, all in well recognized journals and conference proceedings. Let me state my conclusion, before going into details:

Conclusion and recommendation: *The work presented by Dr. Kvassay in this Habilitation Thesis is of high theoretical quality and has practical relevance. It is clear evidence of excellence in mathematical theory of system reliability. Based on this thesis, and the wider evidence provided to me, I have no hesitation in recommending Dr. Kvassay to be allowed to defend his thesis, and after successful defence (which I strongly expect to be the case), for him to be awarded the title 'Associate Professor'.*

This thesis contains interesting contributions to the field of system reliability, in particular it develops methods based on logic differential calculus. This is a specific approach on which the Zilina group, including Dr. Kvassay, are well-recognized research leaders. It is an attractive approach which uses powerful mathematical methods for solving interesting questions. The thesis introduces the approach clearly in Chapter 2, after a basic introduction to system reliability in Chapter 1. Thereafter the main novel material is presented.

Chapter 3 considers importance measures, which quantify the overall importance of components in a system. I regard this as the nicest part of the thesis, as it is intuitively logical that derivatives are useful for this topic yet the approach presented in the thesis has not been used by other researchers, although this is an area of much active research.

Chapter 4 considers topological analysis, where general aspects of the reliability of systems are considered by only considering the structure of the system, so not taking specific component failure time distributions into account. Also here the presented logic differential calculus turns out to be a powerful tool and it enables fast computations.

Chapter 5 has a more applied nature, focussing on logic circuits. Again here, the proposed approach has computational advantages.Throughout, it is shown that the proposed method can be used for binary state and for multi-state systems, which is a great practical advantage as many real-world systems are multi-state, with either components having multiple states, the system functioning having multi states, or both.

I have also been asked to consider the further evidence provided in relation to the proposed promotion of Dr. Kvassay to Associate Professor. It is clear that he satisfies all the stated requirements. He has made, and clearly continues to make, a strong overall contribution to the University of Zilina and to the wider academic community. He works on the interface of Mathematics, Statistics and Engineering, and it is not easy to find strong academics in this area, so the Unviersity of

Zilina is to be congratulated on having such a strong academic coming through its ranks. I would also like to put the case for promotion for Dr. Kvassay in international perspective. If he were to be considered for the similar promotion at Durham University, I believe that he would have a very strong case, in particular because I deem him to be at least as well advanced in his scientific career as some colleagues who have recently been promoted to Associate Professor. In addition, I have been asked to comment on a few habilitation cases in recent years (Germany, Austria, and two similar confirmation of permanent position in the US), and Dr. Kvassay's case is certainly comparable with those cases, and I would say clearly stronger than two of them.

I regret that I cannot be present at the defence of the thesis. Perhaps it is allowed for me to pose a few questions that I would have been interested to discuss with Dr. Kvassay, mainly to explore the wider possibilities of the proposed theory and its relation to other theories. These questions are as follows:

1. Throughout the thesis, the emphasis is said to be on developing methods for large systems. What are large systems? So, what makes a system 'large', and in particular what makes a system large enough for the presented methods to perform better than alternative methods? I note that the included systems in the thesis are mosly not large, I understand that they are included to explain the workings of the method in a style as one would do in tutorials on this material. But how easy is it to apply the method to systems of, say, a few hundred components?

2. Chapter 4 considers the topology of the system. Another approach that does this is the use of the system signature, as presented by Francesco Samaniego, and more recently the survival signature as presented by Frank Coolen and Tahani Coolen-Maturi. Does the presented approach have advantages over signature-based approaches? Could the two approaches be combined?

3. For many practical applications, the reliability quantification is important but is not the end point. For example, one may need to take costs into account when considering planning for maintenance, inspections and levels of spare parts. Can the proposed methodology be generalized to scenarios where costs are important, or would generalization not be needed and is the method already capable of supporting such decisions? In particular, there are importance measures that take aspects of resilience (maintenance opportunities etc) into account; can the proposed method be used similarly?

As mentioned, I would not expect clear answers to these questions, but I would have been interested in the opportunity to discuss them with Dr. Kvassay, and indeed I hope to have the opportunity in the future.