Review of the PhD thesis titled "*Model based fault diagnosis in networked linear time invariant systems*" written by Wijaya Kurniawan

In Wijaya Kurniawan's PhD thesis, the author aimed at fault diagnosis of networked linear time-invariant systems, for different application areas and different types of faults. In relation to linear time-invariant systems, one usually has the feeling that there is no more room for revolutionary scientific results in this field. On the other hand, one investigated problem class is fault diagnosis, which is an actively researched topic nowadays, wether it is related to robots, batteries, electrical networks, or other fields.

In light of this, it can certainly be said that *the choice of topic is current*, the methods used *correspond to internationally accepted research methods.* The thesis is basically an interesting and instructive material, from which I myself gained a lot of new knowledge.

In the following, I describe my general observations, criticisms and questions regarding the doctoral theses.

Format

The thesis has 82 pages of content, it has 93 pages including the reference list. The structure is well balanced, it consists of six chapters, the most important of which are chapters 3, 4 and 5, these contain the results underlying the theses. The dissertation has been written in English and the use of technical terms and professional language meets the expectations. Materials that are not closely related to the dissertation, but help the user's understanding, are included in the five-chapter appendix.

The formatting of the text and equations is elegant, and the use of notations is consistent. The list of abbreviations at the beginning of the thesis makes the life of the reader much easier.

The figures are generally well edited and straightforward. For figures containing several curves, it would have been better to use not only the color, but also the line style to distinguish the curves, as you did in the case of Fig 4.6 - Fig 4.9, this would have greatly improved the comprehensibility. In the three essential chapters, the size and style of the graphs are different, this is not tragic, but the thesis could have been made more aesthetic by applying a uniform style.

The thesis does not contain too many tables, they are generally adequate.

The candidate took into account and corrected almost all of my formal comments and suggestions regarding the version of the thesis submitted at the workplace debate. In light of these, I have no formal comments worth mentioning.

Content

In the beginning, I would like to state that I had the opportunity to read an interesting and valuable scientific work. The methods used during the research meet the standards expected by the international professional public. The thesis contains 163 independent references.

The thesis begins with a short introductory chapter in which the motivation and research aims are presented in three pages. Based on the reviewers' previous suggestion, clear research questions help the reader to understand the goal at the beginning of each chapter. However, it is not clear to me why the overviews at the beginning of the chapters and in section 1.1 (Background and motivations) were separated.

In the second chapter, the basic linear concepts necessary for understanding the thesis are introduced, such as linear time-invariant system models, networked systems, fault modelling, fault detection methods, and the chapter closes with linear observers.

Chapter 3 discusses the authors' research results on actuator and sensor fault diagnostics for robot platoons. The chapter starts with a focused literature review on the topic. The investigated case is the linear leader follower structure used in e.g. adaptive cruise control application, the author has extended a known state-space model of this problem with sensor-, and actuator faults and network disturbances. The sensor fault isolation is solved by a unknown input observer bank designed for each robot in the platoon. With this approach, only one fault can be isolated, i.e. it is assumed that there is only one fault at a time. For the actuator fault estimation problem, the author suggests a proportional-integral observer based solution. The proposed fault diagnosis methods are investigated using simulation experiments.

Chapter 4 begins with a brief review of the literature on the parameter fault diagnosis of heat exchange networks, and then in a short paragraph at the end of the chapter, he describes the essential differences between his own results and those found in the literature. However, there is almost no overlap between the articles referenced in the two sections, as if the motivational literature is not the same as the one to which we finally compare the result. Real world heat exchanger networks have junctions, that is why splitting and joining type junctions are assumed to be in the network. This raises the problem of sensor placement, i.e. where to put the given set (and type) of sensors in order to maximize the information obtained from the sensor measurements. The author uses signed directed graphs to analyze structural observability of the network. Two scenarios are investigated separately: one with joining and splitting connections and another one where a longitudinal fault diagnosis is to be solved.

Finally, chapter 5 the same heat exchanger network model is used for input fault diagnosis. Assuming linear segments, the steady states of the faulty and fault free cases can be investigated with the well known final va-

lue theorem for Laplace transform for each segments. Afterwards, a network graph-based fault isolation algorithm is proposed that uses the steady states of the segments for isolating the fault. As a next step, the method is extended with measurement noise, and finally, the fault estimation problem is solved using a linear state observer. The proposed methods are justified by simulation experiments.

The candidate summarized his scientific results in three theses, which are stated in chapter 6 of the dissertation. Since the theses are the results of the just summarized chapters 3, 4 and 5, I will refrain from summarizing them again. *I accept the contents of the three theses as the author's new scientific results.*

In general, it can be said that the work done is clearly visible from the thesis. At the end of the chapters, he compares the achieved results with those of others (albeit rather superficially), in this area the work has improved a lot compared to the previous version.

Thesis booklet

The thesis booklet is generally subject to the same comments as the dissertation. The ordering and the numbering of the own publications in the booklet is different from that of the dissertation.

Publications

Until now, Wijaya Kurniawan has presented his results at two prestigious international conferences, two accepted prestigious international journal articles and he also has an independent citation for his work according to the Hungarian Scientific Bibliography. To the best of my knowledge, these results meet the minimum requirements contained in the Doctoral Regulations of the University of Pannonia and supplemented by the Doctoral School of Information Science and Technology.

Questions

1. The results of Chapter 3 were developed for wheeled mobile robot platoons, which means a linear formation. How could the proposed sensor and actuator fault diagnosis methods be generalized for formations different from straight line, e.g. for vehicles moving in closed formations (square, triangle, etc.)?

2. It is clear that each thesis is strongly application-centric. Do you see potential application areas that are different from the current ones (robot sections, heat exchangers) but belong to a similar problem class as the ones investigated?

Summary

Based on the above, it can be concluded that the scientific activity of Wijaya Kurniawan meets the scientific requirements, so *after the successful public debate I recommend awarding him the Ph.D. degree.*

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