

I. IDENTIFIKAČNÍ ÚDAJE

Název práce:	Multi-agent System Distributed Sensor Fusion Algorithms
Jméno autora:	Shaondip Bhattacharya
Typ práce:	diplomová
Fakulta/ústav:	Fakulta elektrotechnická (FEL)
Katedra/ústav:	Katedra Řidici Techniky
Vedoucí práce:	Kristian Hengster Movric, PhD
Pracoviště vedoucího práce:	Katedra Řidici Techniky

II. HODNOCENÍ JEDNOTLIVÝCH KRITÉRIÍ

Zadání	průměrně náročné
<i>Hodnocení náročnosti zadání závěrečné práce.</i>	
This thesis addresses the assigned tasks mainly in their simpler instances, but there is plenty of room for further extensions, and for analysis of more complicated cases, based on the presented results and achievable along the lines mentioned in the text. .	

Splnění zadání	splněno
<i>Posuďte, zda předložená závěrečná práce splňuje zadání. V komentáři případně uveďte body zadání, které nebyly zcela splněny, nebo zda je práce oproti zadání rozšířena. Nebylo-li zadání zcela splněno, pokuste se posoudit závažnost, dopady a případně i příčiny jednotlivých nedostatků.</i>	
As assigned, the thesis investigates sensor fusion and estimation under uncertainties within networked multi-agent systems. This topic thus brings together two very dynamic fields of current research interest; sensor fusion and multi-agent cooperation. The thesis is self-contained in that it gives introductory chapters, Chapter 1 and 2, presenting the required theoretical background. The subsequent developments, in Chapters 3 and 4, include novel special types of synchronization algorithms, involving single-integrator agents as well as agents with possibly more complicated dynamics. Several different algorithms are studied, both in discrete-time and continuous-time, which asymptotically achieve sensor fusion from multiple information sources of varying reliability through distributed synchronization. Statistical analysis was carried out to examine the properties of signals resulting at each agent as a consequence of applied algorithms.	

Aktivita a samostatnost při zpracování práce	A - výborně
<i>Posuďte, zda byl student během řešení aktivní, zda dodržoval dohodnuté termíny, jestli své řešení průběžně konzultoval a zda byl na konzultace dostatečně připraven. Posuďte schopnost studenta samostatně tvůrčí práce.</i>	
Through his work the author demonstrated understanding of the background material at a level sufficient for further independent research. For example, he completed a proof of a generalized variant of a result whose more specialized form was familiar from the literature, (Proposition 1), and he carried out a detailed statistical treatment of the time-series obtained from numerical simulations.	

Odborná úroveň	A - výborně
<i>Posuďte úroveň odbornosti závěrečné práce, využití znalostí získaných studiem a z odborné literatury, využití podkladů a dat získaných z praxe.</i>	
The student successfully mastered and incorporated into the body of the thesis relevant current literature on stochastic signals, Bayesian sensor fusion and cooperative control. The conducted numerical simulations made the student draw independent conclusions on performance of the studied algorithms.	

Formální a jazyková úroveň, rozsah práce	A - výborně
<i>Posuďte správnost používání formálních zápisů obsažených v práci. Posuďte typografickou a jazykovou stránku.</i>	
The level of English language used is satisfactory.	

Výběr zdrojů, korektnost citací	A - výborně
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Vyjádřete se k aktivitě studenta při získávání a využívání studijních materiálů k řešení závěrečné práce. Charakterizujte výběr pramenů. Posuďte, zda student využil všechny relevantní zdroje. Ověřte, zda jsou všechny převzaté prvky řádně odlišeny od vlastních výsledků a úvah, zda nedošlo k porušení citační etiky a zda jsou bibliografické citace úplné a v souladu s citačními zvyklostmi a normami.

All relevant literature is consulted. The background references chosen cover the pertinent fields of random signals and noise and cooperative control. Journal papers reporting most recent results on distributed observation were consulted and referred to. The required theoretical background and results have all been properly cited. No ethical violations were found.

Další komentáře a hodnocení

Vyjádřete se k úrovni dosažených hlavních výsledků závěrečné práce, např. k úrovni teoretických výsledků, nebo k úrovni a funkčnosti technického nebo programového vytvořeného řešení, publikačním výstupům, experimentální zručnosti apod.

The research topics assigned are of current interest for a wider scientific and engineering community in that they bring together results in cooperative control/estimation on distributed networks and sensor fusion methods for information sources of differing reliability. This thesis offers a contribution to those fields with future routes of extension possible. The student has demonstrated the ability to treat the encountered problems using theoretical as well as numerical methods.

III. CELKOVÉ HODNOCENÍ A NÁVRH KLASIFIKACE

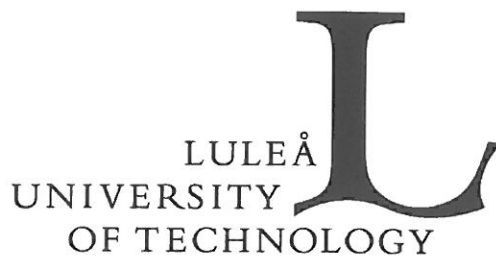
Shrňte aspekty závěrečné práce, které nejvíce ovlivnily Vaše celkové hodnocení.

Mr. Shaondip Bhattacharya successfully used the existing results, familiar from the literature, to develop original extensions applicable to distributed sensor fusion through networked multi-agent systems. These results are, to my knowledge, novel and of considerable engineering interest. During his work, the student thus demonstrated an ability to work independently and arrive at correct conclusions from conducted research. It is for that reason that I recommend the grade below.

Předloženou závěrečnou práci hodnotím klasifikačním stupněm **A - výborně**.

Datum: 5.6.2017

Podpis: Kristian Hengster Movric



Czech Technical University
Faculty of Electrical Engineering
Department of Control Engineering
Examination board

CTU Diploma Project Review
Kiruna, June 7 2017

Division of Space Technology
Department of Computer Science, Electrical
and Space Engineering
Luleå University of Technology

✉ Box 848 – SE-98 128 Kiruna - Sweden
Phone +46 980 79100
Fax +46 980 79190
Email anita.enmark@ltu.se

CTU Diploma Project review- 2nd reviewer's evaluation of master thesis with title
"Multi-agent System Distributed Sensor Fusion Algorithms" by Space Master student Shaondip
Bhattacharya.

I find that the goal of the thesis project well fulfills the requirements of a master thesis in space technology. The work concerns sensor fusion using a graph model and comparing different methods with variants including a novel state update algorithm.

Comparison simulations are performed using two input signals (a DC and a harmonic function of a given frequency) with additive Gaussian white noise and a model graph consisting of 6 nodes (sensing and no-sensing). The thesis includes a mathematical background part introducing relevant basic concepts to the reader and also the theoretical development of the novel algorithm.

The sensor responses are visualized in graphs and output variances for a given set of sensor initial states and input variances are calculated followed by a short qualitative comparison in terms of better or worse performance. It is not completely clear from the report, but I, as a reviewer has interpreted the discussion regarding simulation results as based on "one shot" (i.e not Monte Carlo). For the oral presentation it would be good to clarify this since it is of importance for the validity of the discussion regarding the results if it is based on single scenarios or not. Also a more extensive discussion regarding the results for the Luenberger observer should have been included.

The thesis also present coupling graphs for state covariance and cross correlation. This parts of the thesis I consider the weakest. The discussion on the results is qualitative, and it is very difficult for the reader to interpret the differences between the methods from the graphs and the following discussion. For example why is fig 4.24 symmetric and 4.23 non-symmetric. A phase lag is seen in this graph. Comments on this?

The output noise is also discussed. The author claims that since the input noise is Gaussian white noise with a Dirac auto-correlation function, the output shows filtered colored noise (filtered by the system). Even if the input noise at each sensor is one draft from such a process, the auto-correlation function for each draft will not be a Dirac function. The same holds for the output noise. In order to see whether the noise is colored or not you have to use many drafts to estimate the statistics.

From the thesis it is not clear whether the novel algorithm is given to the student or independently developed by him. Based on the review above I recommend to grade the thesis by C(good). If the student, during the oral presentation, shows that the novel algorithm proposal and mathematical analysis is his own independent work the grade should be increased.

This review serves solely for the purposes of the diploma project defense at CTU. LTU official evaluation for the SpaceMaster double degree will follow the thesis defense and may differ from this review report and suggested grade.

Dr. Anita Enmark
Luleå University of Technology