APPLICATION OF OPTIMIZATION APPROACH FOR MARINE SHIPS CONTROL PROBLEMS

Thesis submitted by Ms. Wang Hongbo, PhD candidate
for the degree of PhD in technical sciences
05.13.01 - system analysis, control and information processing
(Applied mathematics and control processes)

Review Report

By Prof. Dr.-Ing. Zaojian Zou

1. Research Significance of the Thesis

The continuous development of science and technology has provided the favorable condition for the development of shipping industry. In 2015, the world trade by sea has exceeded ten billion tonnages, accounts for over 80% of the total world merchandise trade. This fact indicates that sea transportation is vital to the world economy. However, the maritime environment is complex and varied, which brings a huge challenge for the efficiency and safety of sea transportation. According the statistics and surveys on marine accidents of IMO, during 2006-2011, the actual number of maritime accidents of various ships reached 3583, with 2869 dead and missing. Marine accidents bring not only the loss and damage of goods and ships, but also put every crew member at risk of death and loss of life. Therefore, it is especially important and urgent to apply advanced and reliable modern control technology to solve the problems such as safe manoeuvring, sea-keeping and route design in the course of ship navigation.

This thesis has described the significance of the present study from the following aspects:

1) The operational particularity of the ship motion control system. That is, there exists the problem of multiple conditions.

2) In designing the control system, some concessions must be made with respect to the control quality for all operating conditions because the requirements of different control indexes are almost on the contrary. A simplest concession is to design a unified control law to guarantee the control quality for all operating conditions; however it will limit some improvements of some control index for a certain operating condition. In order to avoid this situation, the second kind of concession is to design separately the locally independent control law for a certain operational condition. The drawback of this scheme is that when switching among different operating conditions, the reliability of the system will be reduced. The third option is the scheme investigated in the present thesis. This is a quality assurance method for multi-objective control of dynamic process. It divides the control law into two parts: the first part is a control law established for all operating conditions, while the second part satisfies the special requirements for each independent operating condition.

3) Most relevant studies focused on the feed-back optimization design approach applied only one time under laboratory condition. There are little applications for full-scale ships.

4) The existing search approaches for the adjustable elements in the structure of multi-objective control algorithm are either of unsatisfying in effect or too complicated.

5) With respect to the problems such as autopilot, roll stabilization system and route planning, implement of simple and feasible engineering approach for multi-objective control law should be searched for. It should present the approximately optimal solution, and can be directly obtained in the course of navigation.

Combining the above factors, this thesis has considered the conditions realized on land and the limited computer resources, improved the original motion control law and realized the ship-based computation algorithm. These are of great realistic significance.

2. Consistency of the Thesis Title with the Contents

The following research works are accomplished in this thesis:

1) Consideration of the particularity in applying the optimization approach to design the multi-objective control law of ship motions.

2) Theoretical basis of the approach to search the approximately optimal adjustable elements of ship motion multi-objective control law under various conditions.

3) Development of the design approach and algorithm design for multi-objective control law of ship's autopilot under wave condition.

4) Design of the dynamic calibrator in the multi-objective control law of roll stabilization system and algorithm generation under wave condition.

5) Development of the route optimization method for ocean-going vessels and algorithm design with consideration of weather condition forecast.

6) In order to show the practicability and efficiency of the design approach proposed in this thesis, various specific examples for ship motion control are given.

The contents of the thesis fully demonstrate the characteristics of optimization, practical application etc. in the title of the thesis. It can be seen that the title has extracted the essence of the thesis.

3. Innovation and Scientific Contributions

The innovative work of this thesis is the new engineering design method for the multi-objective control law of ship motions which ensures the motion quality of closed loop system. The practical application value is that the design has considered the various possibilities of directly using the control law in the course of ship's voyage, and can solve a series of problems in a targeted way.

In order to verify the efficiency of the multi-objective control law, this thesis presents a large number of specific examples to demonstrate for various types of ships. The author strives to make the basic principles and methods described in the thesis to be applied to directly guide the engineering practice.

This thesis includes four parts: the Introduction, three chapters of main body, the Conclusions and the References.

After making a detail analysis on the literatures published by domestic and overseas authors working in the present field, this thesis has put forward its design philosophy, i.e., the

multi-objective control algorithm for ship motion.

Chapter 1 mainly deals with the key algorithm in the ship autopilot. i.e., the control algorithm for course keeping based on multi-objective negative feedback. Firstly, the author introduced the mathematical models of ship motion, including the model of wave disturbances. Then the author described the motion conditions of the three possible close-loop control systems and the requirements of their performance indexes, such as the time of transient phase, the accuracy and the number of oscillation. Also the concrete composition of the multi-objective structures is given. Finally, the computational algorithm is designed with respect to different operational conditions, and the concrete implement steps and the graphical simulation results are presented.

In Chapter 2, analysis design of the control law for the automatic ship roll stabilization system is conducted, and the computer simulation algorithm is realized. Similarly, the mathematical model of the control system for ship roll motion and the physical dimensions of a ship are presented. On this basis, the single roll control problem without considering course keeping is firstly investigated, where two cases, the "efficient" case and the "accurate" case, are distinguished according to the different optimization objects. Then, to solve the problem of not in accord with reality when considering only the roll control while neglecting the effect of rudder to roll motion, research on integrated control law for course keeping and roll stabilization is carried out. Both the "efficient" case and the "accurate" case are also considered, where in the "accurate" case, two cases, i.e., roll stabilization by rudder and joint roll stabilization by rudder and fin are studied. Not only the concrete implement steps of the algorithm is presented, but also the simulation results of the values of control signals and control variables after 1000s when the calibrator is switched in are presented to verify the validity of the algorithm. The control effects of the algorithm are visibly demonstrated.

In Chapter 3, the automatic routing problem of ocean-going vessels with weather condition forecast is investigated. Firstly, the optimization objective, i.e., minimum fuel consumption, shortest sailing time and arriving on time, of route planning is determined. Starting with parameterization of the routes, analysis of the static obstruction (such as land, shoal or safety requirements) and the dynamic restriction condition (meteorological condition), set of the permitted routes and quality criteria for the routes, etc., isochrone method, A* algorithm and genetic algorithm are applied respectively to obtain the allowed route which is then optimized. As in the first two chapters, the simulation results of the algorithm are demonstrated with specific examples.

All these suffice to prove that this thesis shows us in every respect from a scientific point of view the complexity of this research topic. Its research significance, innovation, practical and theoretical values have been enough proven and beyond doubt. This research work is accomplished based on the accumulated extensive experience in scientific research and engineering. It is highly appreciated that this study has aroused our keen interest in this research topic.

Up to now, 26 papers by the author related to this thesis can be retrieved in SCOPUS. The author has attended many international conferences and presented papers with methods and conclusions consistent with those in this thesis. These papers reflect that the author has obtained some research achievements in the present field.

On the other hand, just as all innovative works, in the research work presented to us

there also exit some problems, such as

1) In Chapter 1, page 166, the directions of the coordinate system is not consistent with those in Chapter 2. Although the coordinate system in Chapter 2 is the conventional body-fixed coordinate system, the directions of the coordinate system should be shown for analysis purposes.

2) In Chapter 1 and Chapter 2, corresponding example is presented for each algorithm, and the simulation results are intuitional and visible. In Chapter 3, however, searching the permitted routes and optimizing the routes by applying isochrone method, A* algorithm and genetic algorithm are presented, but no simulation results are presented for each algorithm.

3) Eq. (2.3.6) is wrong.

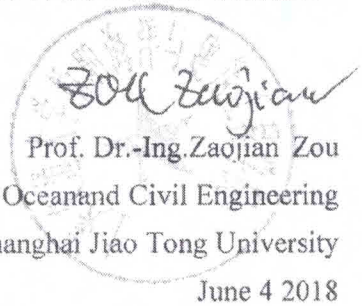
4) Page 162, the number of cited reference appears 116, but in face there are only 92 references.

5) Page 243, the labels of Fig. 3.1.1 should be on the same page as the figure.

6) Some English words are not accurately used, and should be corrected..

In a word, the thesis submitted by Wang Hongbo on the topic of "Application of optimization approach for marine ships control problems" corresponds to the basic requirements as specified in the Order of 01.09.2016 No. 6821/1 "Concerning the Procedure for conferring SPbU Academic Degree"; The seeker Wang Hongbo deserves to be granted the SPbU PhD degree in technical sciences, specialty 05.13.01 – system analysis, control and information processing.

Member of the Defense Committee



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от 28.04.2018 *№* _____
на № _____ *от* _____

О необходимости внесения в ФИС сведений
о результатах признания ученых степеней в СПбГУ

В дополнение к моему заключению по данному вопросу, которое было представлено ранее (оно также направлялось для сведения первому проректору И.А. Дементьеву) и стало основанием для формулирования поручения Ю.В. Пенову о подготовке письма с запросом разъяснений по данной ситуации в адрес Министерства образования и науки Российской Федерации могу сообщить следующее.

Согласно п. 1 ст. 6.2 Федерального закона от 23.08.1996 №127-ФЗ «О науке и государственной научно-технической политике» «Под признанием в Российской Федерации иностранных ученых степеней, иностранных ученых званий понимается официальное подтверждение значимости иностранных ученых степеней, иностранных ученых званий в целях обеспечения доступа их обладателей к профессиональной деятельности в Российской Федерации, предоставления их обладателям профессиональных и (или) иных предусмотренных международными договорами Российской Федерации и законодательством Российской Федерации прав.» Это относится в равной степени к любой процедуре признания, действующей в Российской Федерации в соответствии с указанным законом – все они являются в равной степени «официальными» независимо от того, кто именно уполномочен Федеральным законом принимать соответствующее решение (Правительство РФ, Минобрнауки России или отдельные вузы и государственные академии наук). Что же касается представленной Ю.В. Пеновым информации о том, что полномочиями вносить соответствующие сведения в Федеральную информационную систему государственной научной аттестации обладает только Министерство образования и науки РФ, то я полностью с этим согласен и полагаю, что наш приказ нуждается в корректировке в этой части – соответствующие сведения должны направляться не в Национальный информационный центр, указанный в п. 5 ст. 6.2 Федерального закона от 23.08.1996 №127-ФЗ, а в Минобрнауки России.

Причина, по которой в нашем приказе имеется эта частная ошибка, полагаю, следующая: приказ был издан за 1 месяц до выхода в свет Постановления Правительства РФ от 18.11.2013 №1035 «О федеральной информационной системе государственной научной аттестации» (которое

вступило в силу с 01.01.2014) и почти за 3 года до издания Приказа Минобрнауки России от 27.06.2016 №749 «Об утверждении Порядка предоставления информации о государственной научной аттестации для включения в федеральную информационную систему государственной научной аттестации», из содержания которых и стало понятным распределение функций в указанной сфере. Почему изменения в наш приказ не были внесены ранее и почему никто из ответственных должностных лиц не отследил появления указанных выше нормативных документов, я не знаю. При этом сама по себе практика, когда государственный орган самостоятельно вносит в определенную федеральную информационную систему сведения, представленные другими субъектами, является распространенной – например, можно вспомнить о Федеральной информационной системе «Реестр федерального имущества», поэтому я не согласен с выводами Ю.В. Пенова о том, что раз сведения по вопросам признания вносятся в соответствующую ФИС вносятся только Минобрнауки России, то сведения о нашей работе по признанию ученых степеней вноситься в эту федеральную информационную систему не должны (никаких других аргументов в его заключении не приводится).

На основании изложенного, предлагаю:

а) либо внести изменение в наш приказ и направить в Минобрнауки России соответствующие сведения, указав, что они направляются в целях внесения в федеральную информационную систему государственной научной аттестации;

б) либо направить в Минобрнауки России запрос о том, как и в каком порядке нам следует представлять указанные сведения;

в) либо направить в Минобрнауки России запрос о том, необходимо ли нам представлять указанные сведения.

При этом полагаю, что запрос в любом случае необходим ради предупреждения в будущем возможных проблем, если окажется, что мы обязаны исполнять указанные выше требования закона, но не исполняли их. Мне больше всего нравится вариант с абстрактным запросом: законом предоставлено право, существует такая система, обязаны ли представлять сведения в эту систему в рамках реализации этого права? Учитывая информацию Ю.В. Пенова, нам, скорее всего, просто откажут и все. После чего мы положим этот ответ в дело, внесем изменение в приказ (исключив обязанность по направлению информации о результатах признания) и закроем вопрос.

Первый заместитель по правовым вопросам
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28.04.2018