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DEVELOPMENT OF COMMITTEE MACHINE MODELS FOR MULTIPLE RESPONSE OPTIMIZATION PROBLEMS

SEYED JAFAR GOLESTANEH

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By

SEYED JAFAR GOLESTANEH

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the requirement for the degree of Doctor of Philosophy

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DEDICATION

I dedicate this thesis to my wife

for her patience, endless support

and encouragement.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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Chairman: **Napsiah Bt. Ismail, PhD**
Faculty: **Engineering**

Multiple response optimization (MRO) problems need to optimize several response variables simultaneously. Three phases are considered to solve MRO problems and they include design of experiments, modeling, and optimization. Committee Machine (CM) is a group of some experts such as some Artificial Neural Networks (ANNs) or other mathematical models that can be used in modeling phase of MRO problem solving. There are several methods in two categories to solve MRO problems. The first category includes premier methods such as Response Surface Methodology (RSM) and Taguchi method and the second one includes newer methods like hybrid methods of ANNs and Genetic Algorithm (GA). Each of these methods has deficiencies. RSM uses quadratic polynomial in modeling phase and it is not an accurate modeling tool because all problems including curvilinearity do not fit and compatible to a quadratic polynomial. Responses of Taguchi are restricted to be selected from defined levels of input variables and newer hybrid methods use only one ANN in modeling. As usual, to evaluate the responses of each methodology, Global Desirability (GD) function is used as performance metrics. Higher GD for responses means superior performance for methodology and in MRO it is needed to introduce the new methods to obtain responses with more accuracy and higher Global Desirability. Methodology of the current research is an overall methodology that includes five methodologies. Four methodologies are to make four different CM models to solve MRO problems. The fifth methodology proposes the final algorithm which uses four CM models together to solve MRO problems. Accordingly, GD is computed for all design points of experiments. Then, eight different models are made as CM experts including seven well-known ANNs and one multi-linear regression (MLR) model based on experiments design points. CM models are in four types of categories including Sequential Combination Model (SCM), Optimum Combination Model (OCM), Point Approach Model (PAM), and Mixed Combination Model (MCM). Depending on each CM model, two to eight numbers of experts will participate. The weights of all CM models are obtained by GA with object minimum Root Mean Squire Error (RMSE). This is the modeling phase. Then, in the optimization phase, GA searches best responses for each Committee Machine model

with object maximum Global Desirability. For each response, the nearest experiment point number is determined according to x's and y's Euclidean distances. Five MRO case studies were selected from the literature and one real case study was selected from industry. The results showed optimum points can happen in all CM groups. The results showed that MCMs have less difference in GD between model and real responses in comparison with SCMs. However, SCMs may yield good responses. So, it is necessary to get all MCMs and SCMs responses. Furthermore, each response that is nearest to the point number for x's and y's is the same as experiments point number with highest GD and has a difference of less than 3%. Consequently, current algorithm helps to find a set of accurate responses. Implementation of the current algorithm on case 1, a wire-bonding problem, shows response surface methodology yields Global Desirability equal to 0.31, while neural networks model offers GD equal to 0.42, and usual Committee Machine has obtained GD of 0.48 and finally current algorithm offers Global Desirability equal to 0.52. The results represent Global Desirability of proposed algorithm is equal or higher than GD of case studies. Final conclusion shows that comparison between the results of Committee Machine and its experts in case studies indicate that Global Desirability of CM is equal to or higher than its experts, and proposed algorithm can be applied to solve different MRO problems in industry and scientific areas.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN BAGI JAWATANKUASA MODEL MESIN KEPADA MASALAH PELBAGAI PENGOPTIMUMAN RESPONS

Oleh

SEYED JAFAR GOLESTANEH

Mei 2014

Pengerusi: **Napsiah Bt. Ismail, PhD**
Fakulti: **Kejuruteraan**

Masalah Pengoptimuman Pelbagai Respons (MRO) perlu mengoptimumkan beberapa pembolehubah respons secara serentak. Tiga fasa telah dikenalpasti untuk menyelesaikan masalah MRO, iaitu, rekabentuk eksperimen, pemodelan dan pengoptimuman. Jawatankuasa mesin (CM) adalah satu kumpulan beberapa pakar seperti beberapa jaringan neural tiruan (ANNs) atau model matematik yang lain yang boleh digunakan dalam fasa pemodelan bagi penyelesaian masalah MRO. Terdapat beberapa kaedah untuk menyelesaikan masalah MRO termasuklah kaedah premier seperti metodologi respon permukaan (RSM) dan kaedah terbaru seperti kaedah hybrid bagi ANNs dan algorithma genetik (GA). Setiap kaedah ini mempunyai kekurangan masing-masing. RSM menggunakan polinomial kuadratik dalam fasa pemodelan dan ianya bukanlah peralatan pemodelan yang tepat kerana kesemua masalah termasuklah kelengkungan linear adalah tidak sepadan dan tidak sesuai kepada polinomial kuadratik . Seperti biasa, untuk menilai respon bagi setiap metodologi, kebolehinginan global (GD) berfungsi untuk digunakan sebagai metrik prestasi. GD yang lebih tinggi bermaksud prestasi yang lebih baik bagi metodologi dan masalah utama dalam subjek MRO adalah memperkenalkan kaedah terbaru dalam mendapatkan respon yang lebih tepat dengan kebolehinginan global yang lebih tinggi. Metodologi bagi kajian ini adalah keseluruhan metodologi yang termasuk lima metodologi. Empat metodologi adalah merangkumi empat model CM yang berbeza untuk menyelesaikan masalah MRO. Metodologi kelima mencadangkan algoritma yang terakhir yang mana menggunakan empat model CM bersama-sama untuk menyelesaikan masalah MRO. Sewajarnya, GD telah dikira kepada semua puncak rekabentuk eksperimen. Kemudian lapan model berbeza telah dibuat sebagai pakar CM termasuklah tujuh ANNs yang terkenal dan satu model regresi multi-linear (MLR) berdasarkan kepada puncak rekabentuk eksperimen. Model CM termasuk kepada empat kategori: model kombinasi berjujukan (SCM), model kombinasi optimum (OCM), model pendekatan poin (PAM), dan model kombinasi campuran (MCM). Bebanan bagi model CM telah diperolehi dengan algoritma genetik dengan objek minimum RMSE. Ini adalah fasa pemodelan. Kemudian dalam fasa pengoptimuman, GA mencari respon terbaik bagi setiap model jawatankuasa mesin dengan objek GD yang

tertinggi. Bagi setiap respon, bilangan puncak eksperimen yang terdekat telah dikenalpasti berdasarkan kepada jarak Euclidean x’s dan y’s. Lima kajian kes MRO telah dipilih daripada kajian terdahulu dan satu kajian kes sebenar telah dipilih daripada industri. Hasil kajian menunjukkan poin pengoptimuman telah terjadi bagi kesemua kumpulan CM. Hasil kajian, seperti biasa, menunjukkan yang MCM mempunyai perbezaan yang kurang dalam GD antara model dan respon sebenar dalam perbandingan dengan SCM. Walaubagaimanapun, SCM boleh menghasilkan respon yang baik. Jadi, adalah menjadi sangat penting untuk mendapatkan semua respon MCM dan SCM . Tambahan lagi, bagi setiap respon yang mana ianya adalah bilangan poin yang terdekat bagi x's dan y's adalah sama dengan bilangan poin eksperimen dengan GD paling tinggi dengan perbezaan kurang daripada 3%. Oleh yang sedemikian, algoritma terkini membantu untuk mencari satu set respon yang tepat. Pelaksanaan bagi algoritma terkini dalam kes pertama, yang mana masalah pengikatan dawai, menunjukkan respon metodologi permukaan telah menghasilkan GD sama dengan 0.31, manakala model jaringan neural menawarkan GD bersamaan kepada 0.42, jawatankuasa mesin yang biasa memperolehi GD bagi 0.47 dan akhirnya algoritma terkini menawarkan kebolehinginan global bersamaan kepada 0.52. Sebagai kesimpulannya, perbandingan antara hasil kajian daripada jawatankuasa mesin dan pakar mereka dalam kajian kes, menunjukkan kebolehinginan global bagi CM adalah bersamaan atau lebih tinggi daripada pakarnya. Algoritma yang dicadangkan boleh digunakan bagi menyelesaikan pelbagai masalah MRO dalam bidang industri dan saintifik.

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APPROVAL

I certify that a Thesis Examination Committee has met on 23rd May 2014 to conduct the final examination of Seyed Jafar Golestaneh on his thesis entitled "Development of Committee Machine models for multiple response optimization problems" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Shamsuddin b. Sulaiman , PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

B.T Hang Tuah b. Baharudin, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

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Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Pham Duc Truong, PhD
Professor
School of Mechanical Engineering
University of Birmingham
England
(External Examiner)

NORITAH OMAR, PhD
Associate Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 21 July 2014

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Datin Napsiah bt. Ismail, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Tang Sai Hong, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Mohd Khairol Anuar b. Mohd Ariffin, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Hassan Moslemi Naeini
Associate Professor
Faculty of Engineering
Tarbiat Modarres University
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Declaration by graduate student

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This is to confirm that:

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Signature: _____
Name of Member of Supervisory Committee: Assoc. Prof. Dr. Tang Sai Hong

Signature: _____
Name of Member of Supervisory Committee: Assoc. Prof. Dr. Mohd Khairol Anuar b. Mohd Ariffin

Signature: _____
Name of Member of Supervisory Committee: Assoc. Prof. Dr. Hassan Moslemi Naeini

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