UNIVERSITI PUTRA MALAYSIA

OPTIMIZING TREE PLANTING AREAS THROUGH INTEGER PROGRAMMING AND IMPROVED GENETIC ALGORITHM

ISMADI BIN MD BADARUDIN

FSKTM 2012 6

OPTIMIZING TREE PLANTING AREAS THROUGH INTEGER PROGRAMMING AND IMPROVED GENETIC ALGORITHM

By

ISMADI BIN MD BADARUDIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

October 2012

Dedicated to my beloved wife, children and parents

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

OPTIMIZING TREE PLANTING AREAS THROUGH INTEGER PROGRAMMING AND IMPROVED GENETIC ALGORITHM

By

ISMADI BIN MD BADARUDIN

October 2012

Chairman: Associate Professor Abu Bakar bin Md Sultan, PhD

Faculty: Computer Science and Information Technology

The simulation of planting lining design relative to possible solutions of dividing an area to blocks (block division) and selecting planting lining direction towards optimizing tree planting areas is a complex problem. To analyze the huge number of possible solutions with uncertain results manually will lead to unanswered decision of the optimal result determination. Therefore, a hybrid algorithm through an incorporation of Integer Programming and Improved Genetic Algorithm was proposed for planting lining design. The algorithmic solution with some strategies mainly focuses on efficiency. Planting lining design selection in oil palm planting areas involves the comparison of the three techniques namely technique-1 which is to handle 60^0 planting direction from baseline, technique-2 which is to choose the best planting lining direction in an area and technique-3 which is to obtain optimal block division. Then the best planting lining directions are assigned into the blocks. The decision based on the highest number of trees is promoted among the three techniques.

The process of block division and determining the optimal number of trees require a series of analysis. The possible solutions rely on the number of blocks or the number of shapes that represent the blocks, where an increase in both numbers influences the rising time for analysis. Previous strategies by cell representation promote excessive time to generate solution for large areas, whereas two methods of best-fit called Bottom Left to Right first and Bottom Left to Top first promote result inconsistency and require more time in analyzing solution.

Therefore, the two strategies consisting line representation and combined best-fit methods were introduced to solve two issues respectively; the issues are to count tree number according to planting lining directions and to decide block division. Meanwhile, the improvement in Genetic Algorithm is focused on the strategies of specific random value, deterministic crossover and deterministic mutation. In addition, the strategy of control mechanism was applied in hybrid algorithm.

With the aim of evaluating the algorithm efficiency, comparisons between the proposed strategies and the previous strategies were conducted. The result of line representation promoting less iteration numbers indicates that time usage is more efficient. More number of optimal solutions in combined best-fit methods and the rejection of infeasible chromosomes in Genetic Algorithm are significant factors to be better efficiency. Moreover, the implementation of control mechanism in order to skip the expected same solution occurs, expedited the processing time. These proposed strategies were applied in an application named the Lining Layout Planning by Intelligent Computerized System. This application generates possible solutions for planting lining design. Analysis results from coordinate dataset shows that the selection of planting lining techniques for areas less than 10 hectare is difficult to predict but for the larger areas, results showed that the technique-3 is more consistent to produce the best tree density. While, the results of FELCRA dataset show

through technique-2 or technique-3 produces higher number than common practice which allows 143 trees/ha.

In conclusion, the hybrid algorithm based solution strategies improved efficiency with convincing results, therefore, this will assist planners for better decision making to optimize area to achieve more trees to be planted. The model solution and empirical result are important for the selection of planting lining design. The experimental results on the datasets within the actual coordinates of areas are not only confirmed as theoretical results but also prove that it can be applied in practice. In addition, the revealed results contribute to the new perspective of designing planting lining for area optimization by computerized system.

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

MENGOPTIMUM KAWASAN PENANAMAN POKOK MELALUI PENGATURCARAAN INTEGER DAN PENAMBAHBAIKAN ALGORITMA GENETIK

Oleh

ISMADI BIN MD BADARUDIN

Oktober 2012

Pengerusi: **Profesor Madya Abu Bakar bin Md Sultan, PhD**

Fakulti: **Sains Komputer dan Teknologi Maklumat**

Simulasi reka bentuk baris tanaman berkaitan kepada kemungkinan penyelesaian dari pemecahan satu kawasan kepada blok (pembahagian blok) dan pemilihan arah baris tanaman untuk pengoptimuman kawasan penanaman pokok adalah satu masalah yang kompleks. Untuk menganalisa bilangan kemungkinan penyelesaian yang besar dengan ketidakpastian keputusan secara manual akan membawa kepada keputusan yang gagal dijawab dalam penentuan keputusan optimum. Oleh itu, satu algoritma hibrid melalui gabungan dari Pengaturcaraan Integer dan Penambahbaikan Algoritma Genetik dicadangkan untuk reka bentuk baris tanaman. Penyelesaian algoritma dengan beberapa strategi memfokuskan kepada kecekapan. Pemilihan reka bentuk baris tanaman dalam kawasan penanaman kelapa sawit melibatkan perbandingan dari tiga teknik dengan nama teknik-1 adalah untuk mengendalikan 60^0 arah perbarisan daripada garisan asas, teknik-2 adalah untuk memilih arah baris tanaman yang terbaik dan teknik-3 adalah untuk memperolehi pembahagian blok-blok yang optimum. Kemudian arah baris tanaman yang terbaik diaplikasikan di dalam blok-blok. Keputusan penyelesaian berdasarkan kepada bilangan pokok terbanyak dihasilkan di kalangan tiga teknik.

Process pembahagian blok dan mengenalpasti bilangan optimum pokok memerlukan satu siri analisis. Kemungkinan penyelesaian bergantung kepada bilangan blok atau bilangan bentuk yang mewakili blok di mana pertambahan bilangan dari kedua-dua mempengaruhi peningkatan masa untuk analisa. Strategi terdahulu dengan perwakilan sel (*cell representation*) menghasilkan masa yang berlebihan untuk menjana penyelesaian bagi kawasan yang besar, manakala dua kaedah dari *best-fit* dipanggil *Bottom Left to Right first* dan *Bottom Left to Top first* menghasilkan keputuan yang tidak konsisten dan memerlukan lebih masa dalam penganalisaan keputusan.

Oleh itu, dua strategi terdiri dari perwakilan garisan (*line representation*) dan kombinasi kaedah *best-fit* telah diperkenalkan untuk menyelesaikan dua isu iaitu pengiraan bilangan pokok berdasarkan arah baris tanaman dan untuk menentukan pembahagian blok. Sementara itu, penambahbaikan dalam Algoritma Genetik difokuskan ke atas strategi-strategi dari nilai rawak yang spesifik, *deterministic crossover* dan *deterministic mutation*. Di samping itu, makanisma kawalan dilaksanakan dalam algoritma hibrid.

Dengan matlamat menilai kecekapan algoritma, perbandingan antara strategi yang dicadangkan dengan strategi sebelumnya telah dijalankan. Keputusan dari perwakilan garisan telah menghasilkan bilangan iterasi yang lebih rendah untuk analisa menandakan penggunaan masa adalah lebih efisyen. Lebih banyak bilangan untuk penyelesaian yang optima dalam kombinasi kaedah *best-fit* dan penghapusan kromosom yang tidak praktikal (*infeasible chromosomes*) dalam Algoritma Genetik merupakan faktor yang signifikan untuk kecekapan yang lebih baik. Tambahan, pelaksanaan makanisma kawalan dengan mengabaikan kromosom yang dijangka memberi keputusan sama, telah mempercepatkan masa pemprosesan. Strategi yang dicadangkan ini digunakan dalam aplikasi yang dinamakan *Lining Layout Planning by Intelligent Computerized System*. Aplikasi ini menjana kemungkinan penyelesaian untuk pemilihan reka bentuk baris tanaman. Keputusan analisis

dari set data koordinat menunjukkan pemilihan teknik baris tanaman untuk kawasan yang kurang 10 hektar adalah sukar diramalkan tetapi untuk kawasan yang lebih luas, keputusan menunjukan teknik-3 adalah lebih konsisten untuk menghasilkan kepadatan pokok yang terbaik. Sementara itu, keputusan dari set data FELCRA menunjukan melalui teknik-2 atau teknik-3 menghasilkan bilangan yang lebih tinggi dari praktis biasa yang membenarkan 143 pokok per hektar.

Sebagai kesimpulan, algoritma hibrid berdasarkan strategi penyelesaian telah meningkatkan kecekapan dengan keputusan yang meyakinkan, oleh itu, ini membantu perancang dalam membuat keputusan yang lebih baik untuk mengoptimumkan kawasan dan mencapai lebih banyak pokok untuk ditanam. Model penyelesaian dan keputusan secara empirikal adalah penting untuk pemilihan reka bentuk baris tanaman. Hasil eksperimen ke atas set data untuk kawasan sebenar memberi indikator bahawa keputusan bukan sekadar teori tetapi membuktikan juga bahawa ia boleh digunakan secara praktikal. Tambahan lagi, keputusan yang didedahkan menyumbang kepada perspektif baru dalam mereka bentuk baris tanaman bagi pengoptimuman kawasan dengan sistem berkomputer.

.

ACKNOWLEDGEMENTS

In the name of ALLAH, that the most Gracious, most Merciful and Him alone is Worthy of all praise. I would like to thank God for giving me the strength and motivation to successfully complete this thesis.

First and foremost, a special thanks and my sincere gratitude to my supervisor Associate Professor Dr. Abu Bakar bin Md Sultan for his patient guidance, encouragement, valuable suggestions, ideas and advice. Through the course of my study, he was always available to support my study.

Secondly, I would like to express my thanks and appreciation to the Supervisory Committee Members, Associate Professor Dr. Md Nasir bin Sulaiman, Associate Professor Dr. Ali bin Mamat and Professor Dr. Mahmud bin Tengku Muda Mohamed for their contributions of precious suggestions, advice and comments throughout making this study a success.

Thirdly, I would like to gratefully acknowledge Universiti Putra Malayia (UPM) for providing a very conducive and motivating place for study, Universiti Teknologi MARA (UiTM) and Ministry of Higher Education (MOHE), Malaysia for sponsoring my study. In addition, this study was registered under the Fundamental Research Grant Scheme (FRGS) fully funded by MOHE. I would also like to express my appreciation and thanks to the Malaysian Federal Land Consolidation and Rehabilitation Authority (FELCRA), the Malaysian Federal Land Development Authority (FELDA) and the University Agriculture Park Department of UPM for giving us very good support and corporation in acquiring information. I would also like to convey my thanks to my colleagues who have been involved directly or indirectly for their continuous help.

Finally, I would like to express my gratefulness and thanks to my family and parents for supporting me during my study. To my wife, thanks for her compassion and company most of the time; and for her patience and moral support during the duration of my PhD programme.

Ismadi Md Badarudin
2012

APPROVAL

I certify that a Thesis Examination Committee has met on 3 October 2012 to conduct the final examination of Ismadi bin Md Badarudin on his Doctor of Philosophy thesis entitled "**Optimizing Tree Planting Areas Through Integer Programming And Improved Genetic Algorithm**" 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 degree of Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Shyamala Doraisamy, PhD
Associate Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Chairman)

Ramlan bin Mahmod, PhD
Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Internal Examiner)

Razali bin Yaakob, PhD
Senior Lecturer
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Internal Examiner)

Ajith Abraham, PhD
Professor
Information Technology for Innovations - EU Center of Excellence
Faculty of Electrical Engineering and Computer Science
Czech Republic
(External Examiner)

SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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 the Supervisory Committee were as follows:

Abu Bakar bin Md Sultan, PhD
Associate Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Chairman)

Md Nasir bin Sulaiman, PhD
Associate Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Member)

Ali bin Mamat, PhD
Associate Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Member)

Mahmud bin Tengku Muda Mohamed, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

_____

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotation and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, for any other degree at Universiti Putra Malaysia or other institutions.

_____

ISMADI BIN MD BADARUDIN

Date: 3 October 2012

TABLE OF CONTENTS