THERMAL AND AREA OPTIMIZATION FOR COMPONENT PLACEMENT ON PCB DESIGN USING INVERSE GENETIC ALGORITHM

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Dedicated to my beloved parents, my able governor of Kano State in person of Engr. Dr. Rabi'u Musa Kwankwaso, my brothers and sisters, and my friends for their supports and prayers toward making this work a success. May Allah (S.W.T) reward you abundently.

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ABSTRACT

Considering the current trend of compact designs which are mostly multiobjective in nature, proper arrangement of components has become a basic necessity so as to have optimal management of heat generation and dissipation. In this work, *Inverse Genetic Algorithm (IGA)* optimization has been adopted in order to achieve optimal placement of components on printed circuit board (PCB). The objective functions are the PCB area and temperature of each component while the constraint parameters are; to avoid the overlapping of components, the maximum allowable PCB area is $(120 \times 193.4)\,mm^2$, thermal connections were internally set, and the manufacturer allowable temperature for the ICs must be more than the components optimal temperature. In the conventional *Forward Genetic Algorithm (FGA)* optimization, the individual fitness of components are generated through the GA process. The IGA approach on the other hand, allows the user to set the desired fitness, so that the GA process will try to approach these set values. Hence, the IGA has two major advantages over FGA; the first being a reduction in the overall computational time and the other is the freedom of choosing the desired fitness (i.e. ability to manipulate the GA output). The objectives of this work includes; development of an IGA search Engine, minimization of the thermal profile of components based on thermal resistance network and the area of PCB, and comparison of the proposed IGA and FGA performances. From the simulation results, the IGA has successfully minimized the thermal profile and area of PCB by 0.78% and 1.28% respectively. The CPU-time has also been minimised by 15.56%.

ABSTRAK

Mengambil kira tren semasa rekabentuk kompak yang kebanyakannya mempunyai beberapa objektif, penyusunan komponen secara terperinci menjadi salah satu kemestian asas agar ianya mempunyai pengurusan optimum terhadap penghasilan dan pembuangan haba. Memaksimumkan pengurusan melalui pendekatan *Inverse Genetic Algorithm (IGA)* telah digunakan untuk mencapai susunan komponen secara optimum ke papan litar bercetak (PCB). Fungsi objektif adalah PCB dan suhu setiap komponen, disamping mengambil kira aspek yang perlu dielakkan seperti pertindihan komponen serta saiz maksimum untuk PCB adalah $(120 \times 193.4)\,mm^2$. Penyambungan haba telah ditetapkan dan pengilang meletakkan tetapan suhu untuk ICs harus lebih tinggi daripada suhu optimum komponen. Dalam teknik optimum *Forward Genetic Algorithm (FGA)* secara konvensional, kesesuaian setiap komponen dihasilkan melalui proses GA. Manakala, melalui pendekatan IGA, ianya membolehkan pengguna untuk menetapkan sendiri kesesuaian komponen dan hanya selepas itu proses GA akan mencapai nilai set yang ditetapkan oleh pengguna. Tambahan pula, IGA mempunyai dua kelebihan utama berbanding FGA; pertama adalah pengurangan masa untuk membuat perkiraan dan kedua adalah kebebasan pengguna untuk memilih nilai kesesuaian yang diinginkan (cth. kebolehan memanipulasi output GA). Objektif kajian ini termasuk; mengurangkan profil haba untuk komponen melalui asas rangkaian rintanga haba, mengurangkan saiz PCB dan perbezaan prestasi antara FGA dan IGA melalui penempatan komponen secara optimum. Melalui hasil simulasi, proses IGA telah dapat mengurangkan 0.78% profil haba dan 1.28% saiz PCB. Masa pengiraan juga dapat dikurangkan sebanyak 15.56%.

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LIST OF ABBREVATIONS

PCB	-	Printed Circuit Board
FOP	-	Forward Optimization Problems
IOP	-	Inverse Optimization Problems
GA	-	Genetic Algorithm
FGA	-	Forward Genetic Algorithm
IGA	-	Inverse Genetic Algorithm
FO	-	Forward Optimization
IO	-	Inverse Optimization
AGGA	-	A General Genetic A lgorithm
MOGA	-	Multi-objective Genetic Algorithm
SOGA	-	Self-Organising Genetic Algorithm
EMI	-	Electromagnetic Interference

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Printed Circuit Boards (PCBs) being the bedrock of modern electronics designs, is available in almost all electronics devices. It is available in cars, aeroplanes, mobile phones, computers, robotics e.t.c. These devices are part and parcel of everyday life. It has therefore become necessary to ensure an optimal arrangement of components on PCBs so as to get the best system performance.

Various optimization techniques have been used for components placement on PCB designs such as in [1]–[5]. However, the most common among these techniques is the use of Evolutionary Algorithms. In addition, Genetic Algorithms are the most widely used among the Evolutionary Algorithms as seen in [6]–[16]. Genetic Algorithms have the advantage that they rarely get trapped in the suboptimal region (i.e. Local maxima or minima) as compared to the traditional gradient approach. This is for the reason that information from diverse regions in the search space is used. Consequently, the GA can travel from a suboptimal region if it finds better fitness values in some other regions within the search space [17]. Other methods previousely used include Particle Swamp Optimization as in [16], [18] and numerical analysis such as in [19]–[23]. Several other methods have been used by many researchers. In general, optimal management of heat generation and dissipation is the primary aim of components placement optimization. In order to achieve this aim, the heat generating electronics components need to be positioned properly on the PCB. This will help in prolonging the life span of device.

The Genetic Algorithm, which is the most commonly used in the field of components placement optimization and many other fields, has failed to allow the designer to have a specific desired solution (i.e. the designer can not modify the GA’s optput to suite the design needs). In this study, an Inverse Genetic Algorithm (IGA) has been proposed to solve the above problem, and then used it for thermal and Area optimization for components placement on PCB design. The proposed IGA is discussed in Chapter 3.

1.2 Background of the Study

Generally speaking, components placement on PCB has a huge influence on its electrical, mechanical as well as its thermal properties due to the fact that different components have different thermal characteristics. The components sizes also play an important role in the study of thermal characteristics of PCBs. Placement of components on PCB has a significant effect on its junction temperature which consequently affects the total PCB thermal distribution. Optimal components placement on PCB will help in minimizing the generated heat through even distribution. Random placement of components on the other hand will cause more heat generation, thereby affecting the overall system performance.

Obviously, compact designs are the order of the day. These designs require proper components positioning due to the large number of components being placed in smaller areas with various interconnections between them, therefore, fewer surface for effective heat dissipation. To have a reliable and durable system, heat generation and dissipation should be managed optimally.

Conventional forward Genetic Algorithm along side other optimization techniques such as Particle Swamp optimization have been previously been used in the optimization of electronic components placement on PCB design such as in [2], [5], [7], [22], [24]–[29] and [3], [30], [31]. However, these approaches produce a final optimal design in which the user has to accept, and can not modify the results to suite certain specific needs. In practice, there is a need for the designer to have total control on the output of the optimization so that certain design needs can be more precisely reached. This can be achieved by using the Inverse Genetic Algorithm (IGA) proposed in this work.

1.3 Problem Statement

In practice, the temperature of components will increase while operating which may lead to poor system performance. However, this problem can be optimally managed through proper placement of components. Many studies have focused on tracking the shortest distance between components in an effort to optimize components placement on PCB [3], [7], [12], [24], [27], [32]. This study focuses on the thermal problem in electronic components placement on PCB design by considering the temperature of each component and the Area of PCB as the parameters to be optimized.

In the conventional forward optimization problem (FOP), the actual desired optimal solution might not necessarily always be achievable. To solve the problem of using the near optimal solution, an inverse optimization technique is introduced, so that the designer can choose the desired optimal value which can be used to locate the various variables that will lead to the chosen optima. In other words, in practice, there is a need for the designer to have total control on the output of the optimization, so that certain design needs can be more precisely reached and IGA is here to give just that.

1.4 Objectives

The objectives of this Project are;

i. To develop an optimization search engine using Inverse Genetic Algorithm (IGA) approach for components placement on PCB design.

ii. To minimize the thermal profile of components based on thermal resistance network and the Area of PCB.

iii. To compare the performances of conventional forward GA and Inverse GA approaches.

1.5 Scope of Study

Optimization of components placement on PCB is a complex optimization problem that can be affected by many factors. The scope of this study includes;

i. Only two variables (Temperature of each component and Area of PCB) are considered in this study
ii. To study both forward and inverse optimization approaches
iii. To develop an Inverse Genetic Algorithm optimization programs
iv. To study the relationship between Thermal Resistance Network and electronic components
v. To compare the performances of FO and IO techniques

1.6 Significance

Heat generated by electronic components during operation is a major threat to the overall life span of the electronic devices. Optimal placement of components in these devices will help to reduce this heat generation to a barest minimum, thereby ensuring the overall reliability and performance of the devices.

1.7 Project report Structure and Organization

This Project report is divided into five Chapters. The overview of this work is presented in Chapter 1, where the thermal problem of electronic components placement on PCBs as well as Optimization were discussed. The problem statement, objectives, scope, and significance of this work came last in this Chapter.

In Chapter 2, various optimization methods, AGGA, MOGA, Bayesian inversion and Inverse optimization are presented, followed by reviews on previous related works.

In Chapter 3, forward optimization and the proposed inverse optimization techniques are presented. The methodology employed has been thoroughly discussed herein.

Results and discussion are presented in Chapter 4. Comparisons between the conventional FGA and the proposed IGA optimization approaches are also presented in this Chapter.

Conclusion as well as recommendation for future works are presented in Chapter 5. This Chapter concludes the whole work with respect to the objective achieved.

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