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Data mining approaches for modeling complex electronic circuit design activities

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Abstract

A printed circuit board (PCB) is an essential part of modern electronic circuits. It is made of a flat panel of insulating materials with patterned copper foils that act as electric pathways for various components such as ICs, diodes, capacitors, resistors, and coils. The size of PCBs has been shrinking over the years, while the number of components mounted on these boards has increased considerably. This trend makes the design and fabrication of PCBs ever more difficult. At the beginning of design cycles, it is important to estimate the time to complete the steps required accurately, based on many factors such as the required parts, approximate board size and shape, and a rough sketch of schematics. Current approach uses multiple linear regression (MLR) technique for time and cost estimations. However, the need for accurate predictive models continues to grow as the technology becomes more advanced. In this paper, we analyze a large volume of historical PCB design data, extract some important variables, and develop predictive models based on the extracted variables using a data mining approach. The data mining approach uses an adaptive support vector regression (ASVR) technique; the benchmark model used is the MLR technique currently being used in the industry. The strengths of SVR for this data include its ability to represent data in high-dimensional space through kernel functions. The computational results show that a data mining approach is a better prediction technique for this data. Our approach reduces computation time and enhances the practical applications of the SVR technique.

Keywords: PCB; Support vector regression; Electronic circuit design; Adaptive modeling; Predictive modeling

1. Introduction

A printed circuit board is an essential part of modern electronic circuits. It is used virtually in every electronic product, such as, computers, automobiles, TVs, radios, aircraft, spaceship, robots, and household appliances. PCBs are made of a flat panel of insulating material with a pattern drawn in a copper foil (layer) acting as an electric pathways (for electrical signals, currents, and voltage) for various components including

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ICs, diodes, capacitors, resistors, coils, installed on the board by soldering (Alexson, 1993). PCBs can have a single layer or multiple layers depending on the intended functions and the complexity of the board. Multilayer PCBs are more expensive and complex than a single-layer board, but the advantages of putting several single-layer boards (as many as 24 layers) into one compact form make them more prominent (Kear, 1987). The fabrication processes of PCBs mainly consist of six steps: schematic, layout, image transfer, etching, drilling, soldering, and assembling (Alexson, 1993). Schematic is a two-dimensional diagram that describes a circuit's components and how they interconnect. From the schematic, a layer (pattern) is generated and the pattern is etched in a copper foil (through image transfer) that is attached on a board. After etching, mounting holes for the components are drilled at proper locations. Components are then inserted into the holes and soldered. For multilayer PCBs, some holes are plated with conductive materials to establish electrical connections between layers. Finally, completed boards are tested and inspected. Since there are no messy connecting wires between components, PCBs are generally compact and durable. The size of PCBs has been shrinking over the years, while the number of components mounted on the boards has increased considerably. This trend (densely packed PCBs with very narrow connection lines) makes the design and fabrication of PCBs ever more difficult.

In this study, a complex array of electronic circuit design activities in the *design phase* is considered. The data have been collected over a 12-year period at RC Inc. by the PCB Design Division. The PCB design process starts when the company receives customer specifications (either commercial or military). The electrical engineers carry out the initial design synthesis by determining several crucial factors, such as required parts, approximate board size and shape, and a rough sketch of schematics. The initial design is usually incomplete and imprecise; therefore, no exact part numbers, size, and layout of the board are specified. The electrical engineers then give the initial design and the customer specifications to the PCB design team. Depending on the complexity and the timeline for the completion of the board design, a number of electrical engineers and PCB designers are teamed up and assigned to a particular PCB board and worked together throughout the design, simulation, fabrication, assembly, test, and final delivery to the customers. The timeline is based on either a task oriented or a schedule-oriented design. When the design is schedule oriented, there is a particular deadline for the design so that the design could be finished before the due date. From the design to the delivery, it is a sequential and iterative process. Any problems relating to the board design and fabrication have to be reworked (referred to as a recovery process), retested, and verified until the engineers are absolutely confident about the performance of the board. The test procedures of the board are vigorous, including (but not a comprehensive list) jolting and vibration test, electrical shock test, thermal stability test, power surge test, and magnetic interference test. Fig. 1 represents a typical PCB development cycle: initiation, interaction, design and analysis, and production.

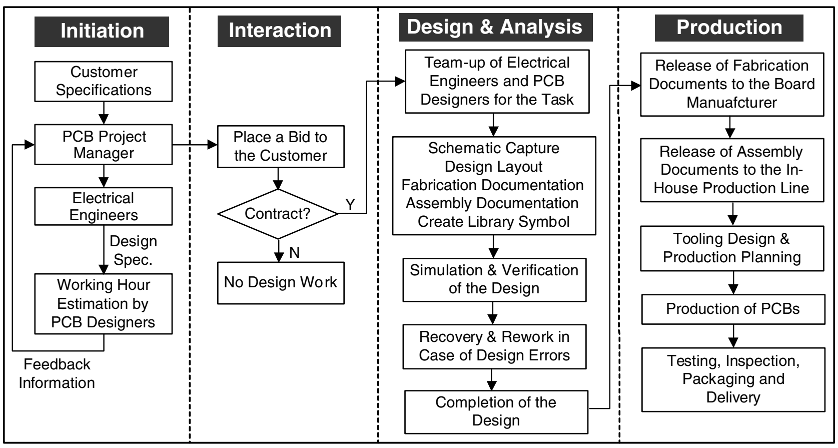

Fig. 1. The PCB development cycle.