Computers in Industry 47 (2002) 239–254

COMPUTERS IN INDUSTRY

www.elsevier.com/locate/compind

An object-oriented approach to the concurrent engineering of electronics assemblies

Wen-Yau Liang[a,*], Peter O'Grady[b]

[a]Department of Information Management, Da-Yeh University, Changhua, Taiwan, ROC

[b]Department of Industrial Engineering, University of Iowa, Iowa City, IA 52242, USA

Received 9 September 1998; accepted 7 February 2001

Abstract

An electronics assembly (EA) can be regarded as the backbone of electronic or electro-mechanical products, where its functions are implemented by combining components and their interconnections on a substrate plate. The design of EAs is relatively complex and encompasses the consideration of many diverse considerations. This paper is concerned with the central area of electronic assemblies component selection (EACS), and with considering constraints at this stage to avoid multiple repetitions of the design process. The main task is to take the requirements and constraints, together with a set of possible electronics components, and then to select a subset of these components to satisfy the requirements (functional, physical, ...) and constraints, while minimizing or maximizing the objective function. The use of such EACS promises substantial benefits but its successful implementation is hampered by the lack of a suitable formalism, particularly where, as is often the case, participants are geographically separated. The work presented in this paper is focused on how to represent EACS, where the participants may be remote, and how to implement it in a formal and systematic way. A representation formalism is proposed for that purpose. This paper first overviews the EACS process. A formalism for EACS is then presented. An Internet network-based implementation of this formalism is described that uses the Internet to support EACS, and an example is used to illustrate the implementation. The main contributions of this paper are three-fold. First, the design domain of electronics assemblies is described. Second, a formalism for EACS is presented. Third, the use of this formalism is illustrated with an Internet-based implementation showing how the formalism can be used for a specific problem.

Keywords: Electronics assembly; Design process; Concurrent engineering; Object-oriented approach

1. Introduction

An electronics assembly (EA) is a part of an electronic or electro-mechanical system. An electronics assembly is a backbone of electronic or electro-mechanical products, where its functions are implemented by combining components and their interconnections (conductors) on a substrate plate. It provides a rigid base for mounting electronics components and conductors for connecting them. The most significant role of EAs is that they separate electrical functions from other parts of the system, giving modularity to the system. The design of EAs is relatively complex and encompasses the consideration of many diverse considerations and this complexity is compounded by the relatively high rate of technology change in EAs

* Corresponding author. Tel.: +886-4-8528469; fax: +886-4-8528466.
E-mail address: wyliang@mail.dyu.edu.tw (W.-Y. Liang).

0166-3615/02/$ – see front matter
PII: S0166-3615(01)00144-0

Nomenclature

$\{\cdot\}$	set
$[\cdot]$	subset
$[\cdot]_{\mathrm{f}}$	feasible subset
$\langle\rangle$	order set
$\{\cdot\}_{\mathrm{u}}$	unsatisfied set
$\{\cdot\}_{\mathrm{s}}$	satisfied set
C_i	constraints
k	generation/iteration
z	location of design object
$o_{i,j}^{l}(z)$	design object i with attribute j from location z selected at design model l
$M_{i,j}^{l}(z)$	design module i with attribute j from location z selected at design model l
n	number of design objects in S_l^k
m	number of design models in population
$R_{\mathrm{o,p}}$	functional requirement o with attribute p
S	design model S
New S (S')	new design model S
V_l^k	objective function, where $V_l^k = f(S_l^k)$
O	object: physical design objects
A	object: design algorithms
R	object: requirements
C	object: constraints
E	object: evaluation schema
P	object: selection

where new technologies continue to emerge at a seemingly increasing rate.

A typical EA design process can be described as follows [1,2] (Fig. 1). A designer starts by analyzing a schematic diagram (*engineering analysis*). The schematic symbols in the diagram are converted to physical components (*component selection*) and the components are placed on a board (*placement*). Based on the selected components, board characteristics such as size, thickness, and type are determined (*board selection*). Then, and conductors are routed between the components and other elements (*conductor routing*). The next step is to finally check the design (*evaluation and checking*). Ideally, at each stage, the design is checked against a set of constraints that concern various concurrent engineering activities such as assembly, printing, drilling, and testing. If some design rules are violated, the design is modified and the design rules are checked again. This iterative process continues until the result is satisfactory.

The primary *input* to EA design is a schematic diagram, which is a schematic capture of the circuit information. The main *output* is a master artwork, which is a scaled configuration of the EA and from which the master pattern is photographically produced [3]. Most commercial CAD system (such as Mentor by Mentor Graphics, CADSTAR for Windows and VISULA NT by Zuken-Redac,) can fully perform this design process and manually select the parts/components from component library, which intend to be genetic. Recently, Nakamura and Kikuno [4] also have done related research. A simple transformation mechanism and a large number of alternatives characterize the transformation process. However, the number of possible mapping may be large since several vendors often supply various types of components which perform the same functionality. Typically, the solution space is continuous in most dimensions and the solution points are densely populated. However, the shape of the solution space is usually complicated by a large number of manufacturing constraints, and designers will then have to return to earlier design stages to make some necessary changes. One repercus-

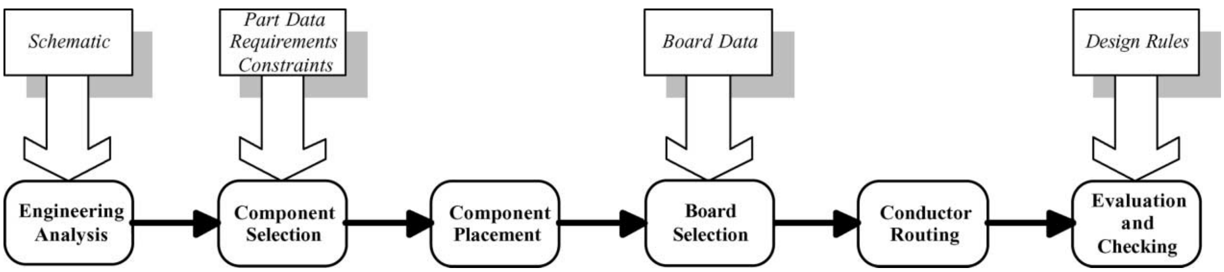

Fig. 1. The EA design process.