Computer-Aided Design 67–68 (2015) 58–86

Contents lists available at ScienceDirect

Computer-Aided Design

journal homepage: www.elsevier.com/locate/cad

Review

Review and taxonomies of assembly and disassembly path planning problems and approaches☆

Somayé Ghandi, Ellips Masehian *

Faculty of Engineering, Tarbiat Modares University, Tehran, 14115-143, Iran

HIGHLIGHTS

- State-of-the-art review of the Assembly/Disassembly Path Planning (APP/DAPP) field.
- New taxonomies for categorizing APP/DAPP problem types and solution methods.
- Critical discussions on research trends, applications and open problems in APP/DAPP.

ARTICLE INFO

Article history:
Received 22 June 2014
Accepted 1 May 2015

Keywords:
Assembly planning
Assembly path planning
Disassembly path planning
Taxonomy

ABSTRACT

Assembly Planning (AP) is one of the most important elements of process planning in manufacturing industries, and is defined as the process of creating a detailed assembly plan to craft a whole product from separate parts considering the final product geometry, available resources, fixture design, feeder and tool descriptions, etc. AP has three main subproblems: (1) Assembly Sequence Planning (ASP), in which a sequence of collision-free operations is computed for bringing assembly parts together, (2) Assembly Line Balancing (ALB), in which some groups of subassemblies are formed and assigned to assembly stations in a way that their workloads are balanced, and (3) Assembly Path Planning (APP), in which collision-free paths for adding parts to a subassembly are computed. Each of the above subproblems has a disassembly version, creating DASP, DALB, and DAPP problems. All of the above problems have proven to be either NP-hard or NP-Complete, and many researches have been conducted to solve them efficiently. While some surveys and reviews exist on the ASP/DASP and ALB/DALB problems, no comprehensive survey exists for APP/DAPP problems, despite their important role in the design process of products as invaluable tools for deploying concurrent engineering, end-of-life processing, maintenance and repair, and decreasing the cost and time of manufacturing products. This paper investigates the relations between the above six subproblems and reviews the state-of-the-art of the APP and DAPP problems and their solution approaches. Through two new taxonomies the properties and categories of APP/DAPP problems and solution approaches are identified and described, the characteristics and applications of the reviewed 60 most relevant works are exposed and analyzed comprehensively, and open problems in the field are identified.

Contents

☆ This paper has been recommended for acceptance by Ming C. Lin.

* Corresponding author.
E-mail addresses: s.ghandibidgoli@modares.ac.ir (S. Ghandi), masehian@modares.ac.ir (E. Masehian).

http://dx.doi.org/10.1016/j.cad.2015.05.001

1. Introduction

Assembly Planning (AP) is the process of creating a detailed assembly plan to craft a whole product from separate parts by taking into account the final product geometry, available resources to manufacture that product, fixture design, feeder and tool descriptions, etc. Assembly planning is one of the most important processes in manufacturing products since assembly processes use up to 50% of the total production time and more than 20% of the total manufacturing cost [1]. So, efficient assembly plans can reduce manufacturing time and costs significantly. The Assembly Planning problem has been shown to be an NP-complete problem [2] and covers three main subproblems: Assembly Sequence Planning, Assembly Line Balancing, and Assembly Path Planning.

The *Assembly Sequence Planning* (ASP) problem concerns with finding a sequence of collision-free operations $o_1, \dots, o_n$ that bring the assembly parts $p_1, \dots, p_n$ together, having given the geometry of the final product A and the positions of parts in the final product. A systematic overview on the ASP is presented in [3], which includes a survey of the elements of sequence planning, such as finding a feasible sequence, determining an optimal sequence according to one or more operational criteria, representing the space of feasible assembly sequences in different ways, applying search and optimization algorithms, and satisfying precedence constraints existing between subassemblies. The ASP problem is classified as an NP-hard problem and so cannot be solved in polynomial time [4]. The complexity of finding an optimal sequence increases linearly with the size of the space of all potential assembly sequences in the case of exhaustive search. However, when all created sequences with the assembly sequence planner are linear and monotone, the number of assembly operations equals the number of parts, n, and therefore the total number of potential sequences is given by the permutations of parts, $n!$. Assuming that all the sequences created by the assembly sequence planner are monotone, the size of the solution space amounts to $(2n-2)!/(n-1)!$, and if non-monotone sequences are considered as well, the number of potential sequences will be infinite [5].

The *Assembly Line Balancing* (ALB) problem deals with partitioning the total assembly operations into a set of n elementary tasks o_i $(i = 1, \dots, n)$ with times t_i, and assigning them to m assembly workstations w_k $(k = 1, \dots, m)$ such that in all workstations approximately equal assembly times are spent and the precedence constraints between operations are satisfied. Assuming that the set S_k of tasks is assigned to the workstation k, the assembly time of that workstation equals $t(S_k) = \sum_{j \in S_k} t_j$. The ALB problem is also NP-hard [6], and can be divided into two categories: Simple Assembly Line Balancing Problem (SALBP), and Generalized Assembly Line Balancing Problem (GALBP). SALBP is appropriate for modeling assembly lines with all their input parameters deterministically known, which produce a unique model of a single product (i.e., serial assembly lines) [7]. On the other hand, GALBP is appropriate for balancing more complex lines such as parallel, U-shaped, mixed-shaped, and two-sided lines with stochastic dependent processing times [8]. A survey on researches in ASP and SALBP that have applied soft computing approaches is presented in [9], covering the years 2001 to 2011. Soft computing approaches are useful for ASP and ALB optimization because they are able to handle more complex and large size problems with numerous constraints.

The *Assembly Path Planning* (APP) problem considers generating sequences of positions for parts $p_1, \dots, p_n$ of a final product A with known geometries, from an initial (disassembled) position to the final (assembled) position, in the form of paths $\tau_1, \dots, \tau_n$ that contain no collisions between assembled and disassembled parts and with obstacles $o_1, \dots, o_r$ in a workspace $W \in \Re^2$ or $\Re^3$. The