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Method and software application to assist in the conceptual design of aircraft final assembly lines

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ABSTRACT

The decision-making process during the conceptual design of aircraft final assembly lines requires of software applications to assist industrialization engineers. This work proposes a method, a supporting model and ad-hoc software development to address that issue. The proposed method divides the problem of the assembly process definition into four parts: logistic plan definition, assembly line definition, layout design and evaluation of complete solutions. The proposed approach is implemented in a prototype software application that is integrated within a commercial software system widely used in the aerospace sector. Feasible design solutions, which are created by the user interactively, are evaluated and ranked with a Fuzzy Logic based multi criteria utility. A case study shows the feasibility of the proposed approach.
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1. Introduction

Literature shows the relevance of the assembly process within the aircraft lifecycle. In aircraft manufacturing projects, the assembly has a big impact on the production volume and cost, where the latter is estimated as nearly as the 30% of the total cost [1–4]. Ultimately, the execution of assembly processes, manually or automatically, requires work instructions and/or robot programs. To be able to generate them, designers work collaboratively along the functional and industrial design process [5–10]. Collaborative working procedures are developed to integrate teams and processes. Although, still there are issues related to project management and software tools capabilities and interoperability, the aim is to create a common industrial Digital Mock Up (iDMU) [5–12].

The definition of the assembly process can be structured into three main top-level tasks: create conceptual assembly process, define assembly process and develop detailed assembly process [4]. The latter task deals with the definition of the basic assembly tasks, the documentation to be used by the assembly personnel and the programs to be used in the automatic machines. The execution of the two prior top-level tasks is necessary to define the lowest level assembly information. Precisely, the 'create conceptual assembly process' task defines the scope of this work.

One key objective of the collaborative approach is to integrate the functional design and the industrial design from the very beginning. This implies, starting the conceptual assembly process design when the product is still at an early development state [4,7,8,13]. Industrial design decision-making is a challenge when implications are difficult to be evaluated due to the product and processes low definition state [13].

Scientific literature acknowledges the need to support industrial engineers during the definition of the assembly process at any of the previously mentioned three top-level tasks [15–19]; additional references can be found in [4,13]. In the aerospace sector, at the conceptual assembly process phase, the main objective of the industrial decision-making process is to evaluate alternatives for the aircraft final assembly line (FAL) [4,10,13,20]. Taking these works as an antecedent, there are four main contributions presented in this paper. The first one is the method to guide the designer by splitting the conceptual assembly definition into: logistic plan, assembly line, layout and evaluation. The second one is the extension of the aircraft assembly line conceptual design model to support such a guidance method. The third one is the enhancement of the cost model by considering an activity-based approach to evaluate both transport and assembly cost. The fourth contribution is the adoption of a multi-criteria evaluation method, which considers time, cost and resource usage-efficiency, to support the decision-making process.

The proposed method aims to support the conceptual design of aircraft FAL based on static workstations. The following features characterize this kind of FAL. FALs are mostly designed as synchronous [14], i.e. all the workstations have the same cycle time

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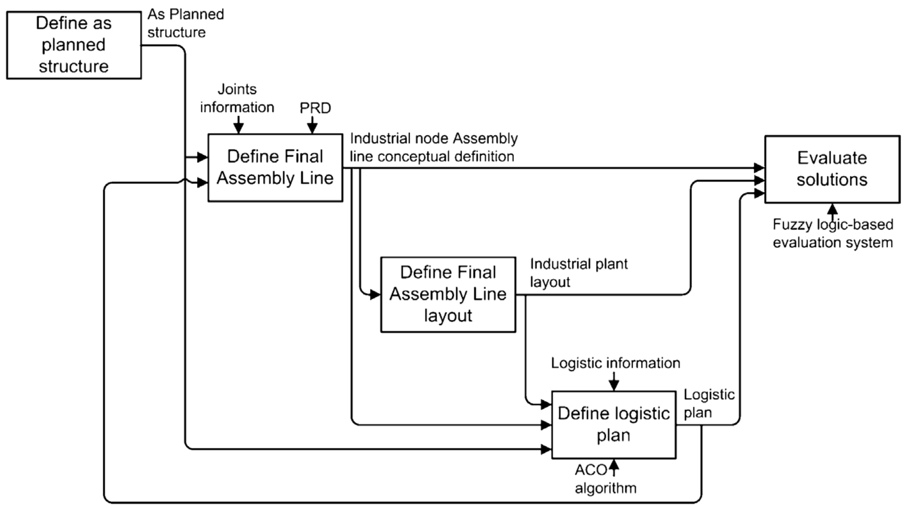

Fig. 1. Sequence of tasks of the proposed method.

[16,19]. Assembly operations are performed manually in a high percentage [2–4], so the number of assigned worker and their hourly cost are key factors in manufacturing process costing [29,30]. In addition, a FAL involves parts and subassemblies with large dimensions, which requires a careful distribution of spaces within the assembly line facilities [10,11].

Fig. 1 shows the method proposed in this work. Four main tasks are considered to create an assembly process conceptual design solution: definition of the product assembly structure (or as-planned structure), definition of the FAL, definition of the FAL layout and definition of the logistic plan. The last three activities must be completed following an iterative loop, as it is shown in Fig. 1. This ensures the feasibility of the solutions, since the different parts of the problem are coupled. A FAL configuration implies some resources requirements that have an impact on the FAL layout. The FAL layout determines space requirements has to be fulfilled by any available plant to be part of the network that defines the logistic plan. On the other hand, the logistic plan represents a big percentage of the total cost [31–34]. Therefore, it can be optimized in first place, and distributing the industrial workload into a set of plants. Then, a FAL configuration and layout can be defined considering the available surface of such plants as space constraints.

A feasible conceptual solution for the FAL is defined each time the tasks within the loop are completed at least once. Then, the solution can be evaluated using a multi-criteria Fuzzy Logic-based system. Several solutions, or variants of a single one, can be generated by executing the previously mentioned tasks. Then, they can be compared by the evaluation system to find the best one in terms of costs, time and efficiency in resources usage. Section 4 details the proposed method and its implementation.

To support the proposed method, an object-oriented Product, Process, Resources (PPR) meta-model was required. The created model (see Fig. 2) takes as antecedent, a prior model created to support industrialization conceptual design [4]. This antecedent PPR model was modified to fulfill the requirements of the proposed method and to be implemented in the commercial software system CATIA/DELMIA V5. Rules were defined to estimate costs and times parameters. As input initial data, a library of resources and processes is required for each assembly design specific case. Such a library is called processes and resources dictionary (PRD). Section 2 details the created models.

There are four main topics involved in this work. The first topic is assembly planning. Assembly planning deals with the definition of the product structure showing the main sub-assemblies to be built and the execution sequence. The second topic is assembly line definition. Assembly line definition comprises the definition of the assembly line concept; this implies defining the workstations, the joints to be executed in each workstation, allocating resources and estimating space requirements. The third topic to consider is the cost estimation for assembly line configurations, which is the purpose of cost models. The fourth topic is multi-criteria evaluation of assembly line configurations. Multi-criteria evaluation deals with the evaluation of alternatives when there are several parameters to be considered. The literature review is included across the paper within each section.

The paper is structured as follows: Section 2 presents the developed models. Section 4 shows the proposed method and its implementation in a prototype application. Section 5 shows a case study. Section 6 shows the results and the paper ends with the conclusions.

2. Developed models

This section describes the models created to support the proposed method. Such models are the basis for the development of a prototype application integrated within a commercial software system (CATIA/DELMIA V5).

2.1. Object oriented meta model

The information necessary for the defined approach is supported by a PPR model (Products, Processes and Resources), which was defined from the initial structure proposed by Mas et al. [4,13]. The initial structure was modified to generalize the model structure, to support the detailed properties of a FAL solution, mainly related to operations and resources, and to enhance the integration with DELMIA V5 native structure.

The original model was modified to work as a meta-model to generalize its structure. This way, one unique PPR model is used to support the information required by any particular case. It works as a base to develop any particular model dealing with processes and resources. The proposed method implements a specific model of processes and resources in the form of a dictionary. Table 1 shows an extract of the dictionary. Fig. 2 shows an UML class diagram of the created meta-model. Tables 2 and 3 show an extract of the specific information for a given case, which belongs to the case study presented in Section 5.

The final structure presents some variations from the initial proposal from Mas et al. [4,13]. Most of the properties are not directly associated as class attributes, but they are represented as objects

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