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Extended liaison as an interface between product and process model in assembly

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ABSTRACT

This paper describes the use of liaison to better integrate product model and assembly process model so as to enable sharing of design and assembly process information in a common integrated form and reason about them. Liaison can be viewed as a set, usually a pair, of features in proximity with which process information can be associated. A liaison is defined as a set of geometric entities on the parts being assembled and relations between these geometric entities. Liaisons have been defined for riveting, welding, bolt fastening, screw fastening, adhesive bonding (gluing) and blind fastening processes. The liaison captures process specific information through attributes associated with it. The attributes are associated with process details at varying levels of abstraction. A data structure for liaison has been developed to cluster the attributes of the liaison based on the level of abstraction. As information about the liaisons is not explicitly available in either the part model or the assembly model, algorithms have been developed for extracting liaisons from the assembly model. The use of liaison is proposed to enable both the construction of process model as the product model is fleshed out, as well as maintaining integrity of both product and process models as the inevitable changes happen to both design and the manufacturing environment during the product lifecycle. Results from aerospace and automotive domains have been provided to illustrate and validate the use of liaisons.

1. Introduction

Liaison has been used in manufacturing planning research as a means to capture mating relationship between parts in an assembly. Over the years other entities such as port [1], mating features [2], assembly joint [3], and assembly features [4] have also been proposed for the same purpose. All these entities have been primarily used to capture mating relationship between parts in an assembly and in some cases the kinematics of the mating relationship. In a product assembly, components maintain mutual contact. Assembly process brings components in desirable contact configurations and guarantees their persistence during the operation of the product. Geometric shape and extent of the contacting interface makes the components amenable to specific assembly process. In this paper, the concept of liaison has been extended to also capture this information and thereby enable tighter integration of product and process information. This integration is increasingly becoming relevant as the assembly process is geographically separated from the part design and production facilities. It is therefore important to formally represent information related to the assembly process. This can then be used to understand and flag the impact of changes in the part on the process and vice versa. In the remainder of the paper, the term liaison refers to the extended liaison and only the attributes introduced for the extended capabilities are discussed.

Hitherto, liaison (or the equivalent terms such as joint, port etc.) would only capture the kinematic relationship between two parts [5] without any consideration of how the liaisons are assembled. This is because most of these representations were motivated by the problem of either assembly sequence planning [2,4] or checking validity of the assembly (in terms of the degrees of freedom left in each part in the assembly) [6]. Both these problems could be addressed without consideration of the assembly processes that could be used to assemble the parts.

This paper presents a representation of liaison that enables capturing process related information and enables reasoning about the process. Presently, while the designer is responsible for defining the mating regions between parts or sub-assemblies in an assembly, the actual process to be used to realize them is only specified at a very high level of abstraction and the details are left to the manufacturing planning group. Much of this information is decided based on the experience of the process planner of the process related information (even those that are available in the design) are not integrated with the product model. Rather, these are available in separate drawing, usually more than one, called *process sheets*. The process related information therefore, is

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diffuse and not amenable to computer based reasoning. A formal structure is required to enable tighter integration between the product model and the process information. The extended liaison provides this structure.

As mentioned earlier, prior art in the use of liaisons use it to only capture and represent mating relationships. Information such as location, type of attachment is typically captured in the liaison. There have been a few attempts [3,7] to capture process type (to be used to realize the liaison). But even in these cases only the process label is captured and other information relevant to further flesh out the process model are not captured. For example, welding could be associated with a joint or liaison. However, for obtaining a process model it is important to have information regarding the type of joint/groove, and the geometry of the groove. For instance, this information is necessary for deciding the number of passes required. A formal structure to represent geometry, extent and other features relevant to the process is not available at present. Moreover, most of the currently available commercial CAD systems do not represent liaison in the assembly explicitly. Two main research issues are—a representation for the liaison that allows a tight connection between the product model and the process model and automatic extraction of the liaison information from a model of the assembly.

Liaison is defined as a collection of geometric entities across parts in an assembly that is associated with one or more assembly process. In the past the entities constituting the liaison would only capture features in proximity without capturing the details of these features that enable association with the process. The liaison captures process specific information through attributes defined. In the present research, liaisons have been defined for assembly processes, such as riveting, welding, bolt fastening, screw fastening, adhesive bonding (gluing) and blind fastening processes. It may be noted that this information stored is in addition to the information normally stored in the liaison as used by Lohse et al. [8] and Kim et al. [3]. A data structure for liaison has been developed. At the highest level of abstraction, a liaison may be associated with more than one type of assembly process. As more and more details (attributes) of the liaison become available, each liaison then is associated with only one assembly process. As information about the liaisons is not explicitly available in either the part model or the assembly model, algorithms have been developed for extracting liaisons from the assembly model. The use of liaison is proposed to enable both the construction of process model as the product model is fleshed out, maintaining integrity of both product and process models as the inevitable changes happen to both design and the manufacturing environment during the product lifecycle.

It is envisaged that the extended liaison will be a part of the OAM product model [9]. The OAM was developed to capture product information pertaining to assembly that would enable its use across the product life-cycle.

The remainder of the paper is organized as follows. Section 2 reviews related work in the literature. The liaison is then introduced in Section 3 along with the definition of its attributes. Representation of the liaison in a product model is then discussed in Section 4 along with an implementation. Extraction of the liaison from a CAD model of the assembly is presented in Section 5. The paper concludes with a discussion of the contributions and the applications of liaison in the integrating product and process models.

2. Review of related work

This section reviews the literature pertaining to the representation and extraction of liaison.

In the assembly planning literature, mating between the components is basically referred as liaison. Several definitions of liaison are available in the literature considering the geometric relationship between components. Work on liaison in the literature originated from two different but eventually related objectives. One body of work was motivated by the need to automate assembly planning and validation. The second was driven by the need to develop product information models as opposed to data models capturing only geometric or shape information.

As mentioned earlier entities such as port [1], mating features [2], assembly joint [3], and assembly features [4] have been used to carry assembly specific information. These information typically include the mating regions, type of contact (thread, planar surface), nature of degrees of freedom (rotation/translation), type of attachment (rigid attachment/conditional attachment), and nature of constraints between the parts in an assembly at each contact or connection region.

Liaison has been used in the form of a graph in assembly sequence planning [6,10]. Lee [6] categorized liaison between parts as floating liaison (attachment), rigid liaison (force fit, welding or connector) and firm liaison (glue or screw).

Holland and Bronsvoort [4] defined assembly features where the assembly features contain information about handling and connection specific information. The handling feature contains feeding, fixturing, grippers and matching grasping areas. The connection feature carries information regarding form feature types, final position, insertion position, insertion path, tolerances, internal freedom of motion, and geometric refinements. However the assembly feature has no connection to the actual joining process.

In product information modeling, the objective has been to represent the function and behavior of the artifact in addition to its form. The Open Assembly Model (OAM) [9] is a product model proposed to support assembly operations. The OAM uses port as the interface between entities in the artifact. The connection class in OAM represents the connection between artifacts that are physically connected. In another study, Singh and Bettig [1] considered assembly port as a group of low level geometric entities, and undergo mating constraint for joining the parts in a CAD assembly.

In all of the work discussed above, the liaison (or its equivalent port, feature) do not consider the assembly process that would be used to realize the liaison. There have been some efforts in capturing process related information in the liaison. That is, the liaison also carries some information about the process to use to realize the liaison. In an early study, Lee [6] categorized liaison depending on the "intersection" types into floating liaison (attachment), rigid liaison (force fit, welding or connector) and firm liaison (glue or screw). This achieved the connection with the process enabling identification of the process at a very high level. Some researchers defined assembly features considering the assembly processes associated with it. Xiaoming and Pingan [11] have proposed an assembly relational model (ARM), consisting of assembly, components and liaisons. Liaison is used to describe the geometric relationships between components in terms of contact, constraint, and interference matrices. Xiaoming and Pingan [11] defined liaison as the relationship between two connected or contacted component as well as the operation needed to assemble them. Mascle et al. [12] defined the assembly features using any geometric (a sub-face) or technological (a process) or functional (describes the product's function as an allowance or a liaison) information assigned to a face, a part or a sub-assembly. They have considered processes like welding, gluing, tightening and keying for creation of liaison. However, the processes are identified by the user. Coma et al. [13] defined assembly feature (AF) as any topological, geometrical, technological or functional information