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Block assembly planning in shipbuilding using case-based reasoning

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Abstract

A process planning system using case-based reasoning (CBR) is developed for block assembly in shipbuilding. A block assembly planning problem is modeled as a constraint satisfaction problem where the precedence relations between operations are considered constraints. In order to find similar cases, we propose two similarity coefficients for finding similar cases and for finding similar relations. Due to the limited number of operation types, the process planning system first matches the parts of the problem and those of the case-based on their roles in the assembly, and then it matches the relations related to the matched part–pairs. The parts involved in more operations are considered first. The process planning system is applied to simple examples for verification and comparison. An interface system is also developed for extracting information from CAD model, for preparing data for process planning, and for visually verifying the assembly sequence.

Keywords: Block assembly; Process plan; Case-based reasoning; Similarity coefficient; Constraint satisfaction problem

1. Introduction

Process planning is an activity to translate the design information specified in the drawing or CAD model into manufacturing information such as operations, set-ups, jig and fixtures, tools, processing conditions, and machines. It also estimates operation time, and publishes the result as operation sheets. Since the number of process planning experts is decreasing and manual process planning can be subjective and inconsistent, there have been enormous efforts to build knowledge base and computer aided process planning (CAPP) systems based on it. CAPP systems can be categorized into three types: variant type, generative type and automatic type. A variant type CAPP system generates the process plan of a part by modifying the process plans of similar part. Sometimes it refers to multiple process plans of multiple parts. It is considered practical by industries since it utilizes domain knowledge that is implicitly stored in existing process plans. A generative CAPP system selects operations based on the manufacturing features of part, and it determines the sequence of operations using a knowledge base. The knowledge base can have various forms, but regardless of its form it contains knowledge about matching between manufacturing features and operations, and the precedence among the operations. Automatic CAPP system incorporates feature recognition function that automatically generates inputs for CAPP system, usually a generative system, by recognizing manufacturing features stored in CAD model.

While many researches on CAPP have been reported in machining area, there are, however, few researches reported in other area such as in block assembly in shipbuilding industry. Ship hulls are built with hundreds of blocks. A hull block consists of skin plates, longitudinals, and transverses (Okumoto & Matsuzaki, 1997). Assembly process consist of three kinds of operations (Fig. 1): butt welding (butt), fitting through other parts (through), and fillet welding (fillet). Because the rationale of process

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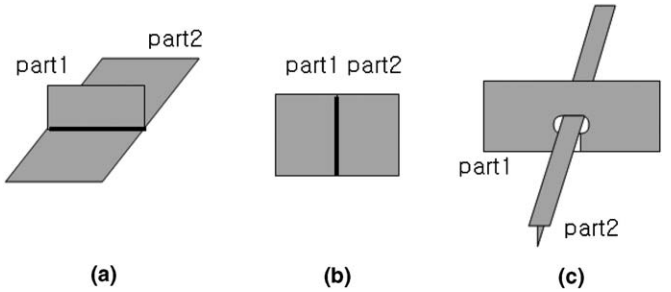

Fig. 1. Joint types. (a) Fillet (p1, p2) (b) butt (p1, p2) (c) through (p1, p2).

sequencing based on interference, deformation, and know-how cannot be easily formulated, human experts with experience determine the sequence. Naturally, the assembly plan can be different from person to person. Therefore, it is imperative to make the assembly plan consistent to improve the productivity. It is also important to have a system to automatically generate alternative assembly plans in order to automate the block assembly shop. Cho, Sun, and Oh (1999) developed an expert system for block operation planning system in which the system can determine welding postures, welding methods, and welding machines. Cho, Lee, and Chung (1996) earlier developed a block assembly planning system for bigger blocks which may require turnovers. They used a case-base reasoning (CBR) approach using a descriptive indexing scheme (Maher, Balachandran, & Zhang, 1995) in which cases are divided into several groups based on the ship types, the hull shapes, and block numbers. In determining the assembly sequence, blocks in a similar group are retrieved to find similar blocks. The similar group is easily identified since they are already categorized by attributes. This approach is effective but the types of problems it can solve are limited.

We present a CBR CAPP system for automatic assembly planning for small blocks. In our system, topological relationship between parts are considered so that blocks from different ship types and from different areas in the ships can be retrieved. An expert system shell CLIPS (available from: http://www.ghg.net/clips/CLIPS.html) is used in implementing the proposed approaches.

2. Block assembly process planning system

The ship blocks have different shapes depending on the types and shapes of ships and therefore their assembly sequences tend to be different. The blocks comprising one ship have different shapes depending on their positions in the ship. For example, the midship of bulk carrier consists of several blocks such as double bottoms, hopper tanks, side structures, topside tanks, deck structures, and bulkheads (Park & Kang, 1999). Nonetheless, blocks are basically built with plates, girders, and stiffeners. A feasible assembly sequence is determined by avoiding interference among parts, and by minimizing the deformation during welding to maintain the tolerances and geometrical tolerances of block.

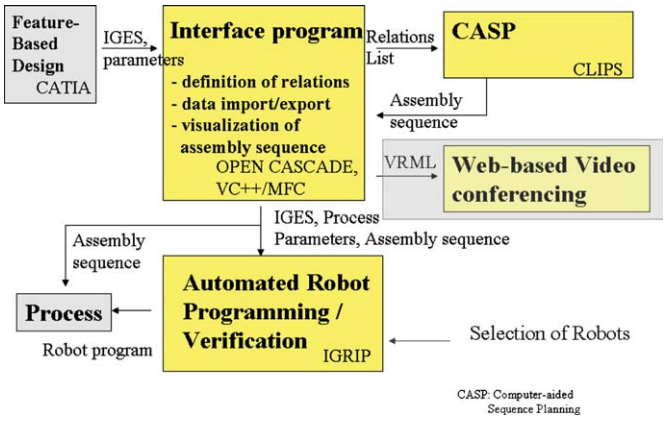

Fig. 2. Block assembly planning system.

In this research, we build a case base in which process planning examples for unit blocks are formulated as constraint-satisfaction problems and we develop a process planning system using the case base. The overall system is shown in Fig. 2. First, BOM (bill of materials) data of the block model are extracted from the CAD model with which the relations between parts are defined in the interface program. With the relations defined, CASP (computer aided sequence planner) determines the assembly sequence using case-based reasoning. After the assembly plan is verified, robot programs for welding operations are generated. Robot module is under development and is not described in this paper.

3. Case-based reasoning

In CBR approaches, knowledge is stored as cases. A case is defined by the problem definition part and the solution part. A CBR system solves a problem by finding similar cases and adapting the retrieved solutions (Kolodner & Leake, 1996). CBR approaches have been applied to many engineering problems such as manufacturing process design, inspection, and knowledge management (Liao, 2005). In order to make search process easier, case base is built with various indexing schemes. Indexing schemes can be grouped into descriptive schemes and relationship schemes (Maher et al., 1995). With descriptive schemes, cases are categorized first based on the attribute values and stored by groups in the case base. Tsai, Chiu, and Chen, 2005 used a descriptive scheme in which they clustered cases and assigned a representative case, which they called a vintage case, for each group. The distances between the problem and the vintage cases in a vector space consisting of attributes were used in finding a similar group. Relationship scheme focuses on the structural relationship between attributes. It uses FBS (function, behavior, structure) model, causal relationship model, or qualitative model to represent the structural relationships. If a relationship scheme is used, we may utilize cases from other domain as long as the cases have the same structural relationship. For instance, we can refer to a case from