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Workstation configuration and process planning for RLW operations

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Abstract

The application of Remote Laser Welding (RLW) has become an attractive assembly technology in various branches of industry, as it offers higher efficiency at lower costs compared to traditional Resistance Spot Welding (RSW) when high volumes of sheet metal assemblies are to be produced. However, the introduction of RLW technology raises multiple new issues in designing the configuration, the layout, and the behavior of the assembly system. Since configuring an RLW workstation and planning the welding process are closely interrelated problems, a hierarchical decision process must be applied where configuration and planning go hand in hand. The paper presents a hierarchical workflow for workstation configuration and process planning for RLW operations, and proposes methods for solving the decision problems related to each step of this workflow. A software toolbox is introduced that has been developed to facilitate a semi-automatic, mixed-initiative workstation design and to guide the expert user throughout the configuration, planning, programming, evaluation, and simulation of the RLW workstation. A case study from the automotive industry is presented, where the software tools developed are applied to configuring and planning the behavior of an RLW workstation that replaces RSW technology in assembling a car door.

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1. Introduction

The technology of remote laser welding (RLW) is an emerging option for replacing traditional resistance spot welding (RSW) in industrial applications, as it offers numerous advantages and introduces new opportunities in product design and assembly. The RLW process consists in welding by heat delivered by a laser beam emitted from a laser head. In contrast to earlier laser welding technologies, the focal length of the laser beam in RLW is higher, typically around 1 meter [1], and the beam is deflected and delivered by a scanner system. The scanner system is composed of two mirrors which are mounted to the end effector of an industrial robot via rotary joints [2].

This concise description of the technology comprises the most notable differences between RLW and RSW, from which the advances and difficulties of utilizing RLW stem. While RSW requires contact and access to both sides of the materials to be joined by a large welding gun, RLW enables contactless welding with single-sided access in the narrow line of the laser beam [3, 4]. The better accessibility of the stitches allows higher freedom in part design, which can be turned into end products that serve better the market needs, e.g., lighter yet stiffer car bodies [5]. Combined with increased focal length, the size of the resulting working volume is suitable for enclosing large workpieces, e.g., car body components [2]. Furthermore, the components of the scanner system that are responsible for focusing and guiding the laser beam have low inertia, which allows high-speed beam positioning and

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movement. This not only increases the welding speed but also decreases the non-productive times of the welding process, resulting in a significant reduction in cycle time [2, 4, 6].

Considering the advantages of the technology, application of RLW is prevailing in car body manufacturing. However, in contrast to the technological benefits offered, introducing RLW into manufacturing requires a high initial investment due to the cost of the laser source, the scanner system, and the complex fixture [7]. In order to make RLW a financially feasible alternative of RSW, the higher investment costs have to be returned by cycle time reduction [2, 4, 8].

The paper investigates the problem of workstation configuration and planning for RLW, and proposes an integrated workflow for solving it, together with efficient methods and a decision support tool for each step of the workflow. The paper is structured as follows. In the next section, a detailed problem statement is given. In Section 3, an integrated decision workflow is introduced, and methods are proposed for solving the decision problems related to each step of the workflow. Section 4 introduces a novel representation that captures the evolution of the workstation configuration and the motion plan throughout the workflow, terminating in the final robot program code. Section 5 provides implementation details and presents the application of the developed tools in a case study. Finally, conclusions are drawn.

2. Problem statement

RLW operations are executed in a dedicated *workstation.* Throughout the paper, we assume that the workstation contains a single RLW robot, and one workpiece is processed at a time. Below, we define the problem of configuring an RLW workstation and planning its processes in order to be able to solve a specified assembly process by RLW [9].

The inputs of the problem are product related: geometric models of the workpiece and the fixture, as well as the structured description of the welding operation. The operation consists of two sub-operations: dimpling, i.e., producing small "bumps" that maintain the gap between the metal sheets assembled; and welding disjoint stitches (linear or circular) that join the sheets. Furthermore, constraints defined by the surrounding manufacturing system of the workstation also have to be provided as an input.

The defined inputs specify constraints (e.g., in terms of size, geometric arrangement) which have to be satisfied and optimization objectives (minimizing costs, cycle time) for the task of configuration and process planning. These together form a complex task composed of a set of subproblems. Solving these subproblems requires different engineering principles to be adopted.

The variety of decisions to be made, such as component selection, placement, and motion planning, requires a decomposition approach, and an adequate workflow that structures these decisions. In our research, the workflow has two main tracks: one responsible for workstation configuration and another for process planning and off-line robot programming.

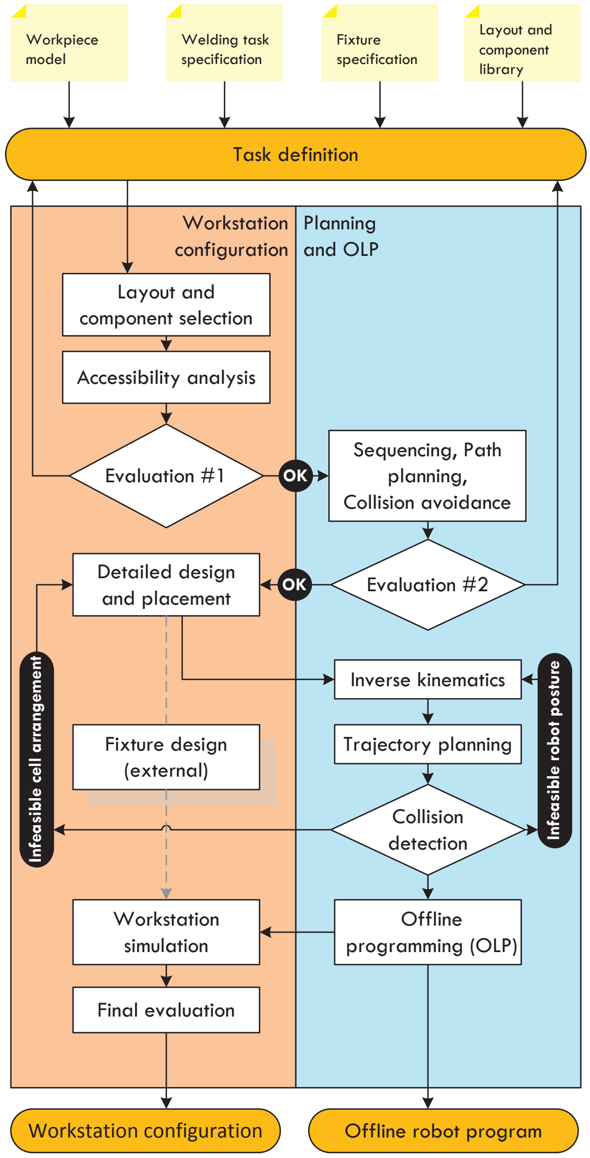

Fig. 1. The defined integrated workflow displays the two main tracks and the components of the solution.

Along with decomposition, defining a workflow which supports the hierarchical refinement of the solution is also desirable as it offers a step-by-step evolution of the solution. Application of generic representation methods provides better connectivity between the components of the solution.

Supporting mixed-initiative problem solving allows human interaction, which is desirable since uncaptured pieces of expert knowledge can also be utilized in the course of a complex solution process. However, this demands a proper graphical user interface and short response times from the solution.