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PRM Based Motion Planning for Sequencing of Remote Laser Processing Tasks

Sigurd Lazic Villumsen[a,*] Morten Kristiansen[a]

[a]*Aalborg Universitet, Fibigerstræde 16, Aalborg 9220, Denmark*

Abstract

The mechanical system used for remote laser processing can contain as much as 9 degrees of freedom (DOF). In this paper, a sample based motion planning algorithm for such remote laser processing equipment is presented. By construction robot configurations through a sampling strategy redundancy is inherently taken into account and the path is ensured to comply with laser processing constraints. A test showed that the algorithm was capable of finding 1277/1280 possible paths in 2000 iterations for a 9 DOF mechanical system. These 1277 paths were represented in matrix form which can be used for sequencing of laser processing tasks.

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Keywords: Remote laser cutting; Remote laser welding; Production planning; Scheduling ; Redundancy; Robotics; Motion planning; Path planning

1. Introduction and state of the art

In the last decade the field of remote laser processing has received a great deal of attention from the scientific community [1,2]. This is especially evident for remote laser welding (RLW) which has the potential to reduce cycle times significantly when compared to e.g. traditional resistance spot welding [3]. One of the benefits of remote laser

* Corresponding author. Tel.: +45 30130852.
E-mail address: sv@m-tech.aau.dk

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processing is that the beam can be moved over the work piece by embedding galvanometer driven mirrors in the processing head [4].

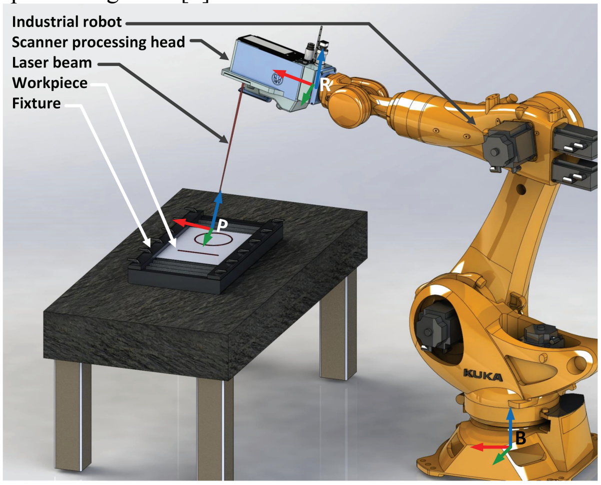

Fig. 1. A KUKA Quantec KR 120 R2500 pro mounted with an Arges remote welding elephant head. Notice the position of the three frames, the base frame B, the robot frame R and the processing frame P.

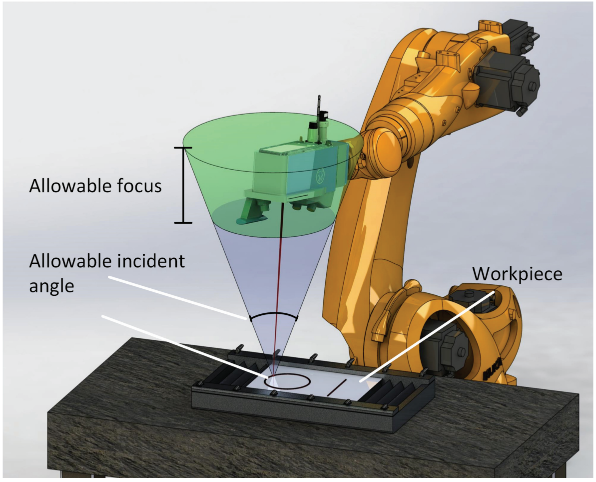

Fig. 2. The region in which the scanner cutting processing head can be situated and still yield a stable process.

Such actuated processing heads are generally referred to as scanner heads as they are capable of scanning the beam over the work piece with very high velocities. In the scientific literature such scanner heads are often mounted on industrial robots to combine the reach and flexibility of the robot with the capabilities of the scanner head. Such a setup is depicted in Fig. 1. The mechanical complexity of the system makes efficient on-line programming difficult. This means that an off-line programming approach needs to be utilized when generating the robot and scanner head programs. Such off- line programming approaches have already been presented in the scientific literature for remote laser welding (RLW) and remote laser cutting (RLC).

An on-line programming system for RLW with conventional optics is presented in [5]. By using a simple solver for the traveling salesman problem (TSP) an initial path is generated. This initial path is then improved and modified by changing the laser incident angle. The Cartesian distance is used as the cost function minimized by the TSP solver.

A combined planning system for RLW and RLC is presented in [6–8]. The planning system works by identifying regions around each task that enables the cutting head to reach the cutting kerf. These circular regions are denoted scan circles and are connected by straight lines. Paths are connected by using the traveling salesman algorithm. By utilizing scan circles it is however limited to 2D shapes, and as paths are connected by straight lines optimality cannot be guaranteed. Also the working field of the laser is limited to a circle and the level of redundancy of the robot and scanner system is not utilized to its full extent.

An integrated approach to rough cut path planning and task sequencing for RLW with scanner mirrors is presented in [9–11]. Access volumes in the shape of truncated cones are defined around entry and Exit points of weld seams. These access volumes are constrained by two parameters, the allowable incident angle of the laser beam and by the allowable focus range. Redundancy is handled by fixing a joint to ”mid-range” value.

In [12] an approach to planning of remote laser welding tasks for an articulated robot mounted with scanner mirrors is presented. It is based on robot configuration clusters that allows for welding of the seam in a task. One cluster is defined for each task and a generalized travelling salesman problem (GTSP) solver connects these clusters by the shortest path. Here redundancy is taken into account explicitly, but robot motions are not allowed while processing. Even though the above frameworks show promising results, they all, except [12], treat the problem of task sequencing and robot motion planning in Cartesian space. Also, redundancy with respect to the processing task is not handled explicitly. In [12] redundancy is taken into account, but the robot is not allowed to move while processing the weld seams. To expand the concept of the GTSP approach used in [12] to allow for movements of the

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