

Methodical Approach for Analyzing Process Variables and Optimizing Boundary Conditions in Multi-Axis Robot Programs

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Abstract—This thesis discusses a methodology for analyzing and optimizing process variables in manufacturing systems with redundant DoFs. The main focus lies on a 6-DoF industrial robot that traverses a toolpath defined in 5-DoFs (X,Y,Z,A,B). This means that the rotation C, which represents the rotation around the tool symmetry axis, is a redundant DoF and can be chosen freely. The first part of the methodology covers the analysis of process variables, such as direction changes in the joints or the total travel of the joints. The goal is to understand how the redundant DoFs affect the robot's behavior and how they can be used to optimize user-selected process variables. The second part of the methodology proposes a procedure to optimize the user-selected process variables by properly constraining the redundant DoF. After modeling the robot in Python, validation is performed on multiple toolpaths. The results show that the redundant DoFs can significantly affect the process variables. By implementing a PSO algorithm, it is possible to find the ideal setting for the redundant DoFs, thus maximizing the process quality with respect to the process variables.

Index Terms—Industrial Robot, Redundant DoF, Milling, WAAM, Optimization

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- The word “data” is plural, not singular.
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An excellent style manual for science writers is [7].

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TABLE I
TABLE TYPE STYLES

Table Head	Table Column Head		
	<i>Table column subhead</i>	<i>Subhead</i>	<i>Subhead</i>
copy	More table copy ^a		

^aSample of a Table footnote.



Fig. 1. Example of a figure caption.

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ACKNOWLEDGMENT

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REFERENCES

Please number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first ...”

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the abstract or reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors’ names; do not use “et al.”. Papers that have not been published, even if they have been submitted for publication, should be cited as “unpublished” [4]. Papers that have been accepted for publication should be cited as “in press” [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

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