Intelligent Seam Tracking for Robotic Welding

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Intelligent Seam Tracking for Robotic Welding

With 75 Figures

Springer-Verlag
London Berlin Heidelberg New York
Paris Tokyo Hong Kong
Barcelona Budapest

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ISBN-13: 978-1-4471-2047-6 e-ISBN-13: 978-1-4471-2045-2
DOI: 10.1007/978-1-4471-2045-2

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

Softcover reprint of the hardcover 1st edition 1993

Typesetting: Camera ready by authors
69/3830—543210 Printed on acid-free paper

To our parents

SERIES EDITORS' FOREWORD

The series *Advances in Industrial Control* aims to report and encourage technology transfer in control engineering. The rapid development of control technology impacts all areas of the control discipline. New theory, new controllers, actuators, sensors, new industrial processes, computing methods, new applications, new philosophies, . . ., new challenges. Much of this development work resides in industrial reports, feasibility study papers and the reports of advanced collaborative projects. The series offers an opportunity for researchers to present an extended exposition of such new work in all aspects of industrial control for wider and rapid dissemination.

In the field of robotics, the classic repetitive manufacturing tasks which have been automated by robots are paint spraying and spot/seam welding for the car industry. This monograph reports advances in robotic science for the operation of seam welding. It presents a systematic treatment of the prevailing industrial technology and a new state of the art intelligent robotic seam welding prototype system on which the authors, Dr Nayak and Professor Ray, collaborated. The authors have made a determined effort to set their work in the context of international robotic seam welding research and conclude by reviewing seven other international prototype systems. The mix of specific research issues and the review of broader research activities reported makes this a particularly welcome contribution to the Series.

October, 1992

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PREFACE

Robotic welding is critical to welding automation in many industries. "Blind" robotic welding systems, however, cannot adapt to changes in the joint geometry which may occur due to a variety of reasons. For example, in systems following pretaught weld paths, in-process thermal distortion of the part during welding, part fixturing errors, and out-of-tolerance parts will shift the original weld path, leading to poor quality welds. Essential to accurate seam tracking is some form of joint sensing to adjust the welding torch position in realtime as it moves along the seam. Realtime seam tracking is attractive from the perspective of improving the weld quality and also reducing the process cycle time. In this monograph, we have addressed the technological aspects of adaptive, realtime, intelligent seam tracking for automation of the welding process in the context of three-dimensional (3D) seams.

The work reported in this monograph builds upon the research conducted during the course of project ARTIST (acronym for Adaptive, RealTime, Intelligent Seam Tracker) at the Applied Research Laboratory of the Pennsylvania State University, USA. The research project ARTIST was sponsored by the BMY Corporation of York, Pennsylvania, USA, and the Commonwealth of Pennsylvania to address requirements of welding steel and aluminium plates and castings used in the manufacture of heavy duty battlefield vehicles. A prototype version of ARTIST was designed and developed for tracking and welding planar seams. Since ARTIST was expected to encounter mostly slip joints during welding, the algorithms for seam tracking are predominantly based on the analysis of vee-grooves. The objective was to demonstrate the proof of concept, develop a prototype of a seam tracking system, and integrate it with the welding equipment for realtime operation.

The ARTIST system comprised of a six degree-of-freedom robot (PUMA 560 robot manipulator with Unimate controller), a laser profiling gage (Chesapeake Laser System), a PC-AT microcomputer serving as the supervisory controller, and welding equipment (Miller Electric Deltaweld 450 welding controller and a Miller Electric S54A wire feeder). At the end of the one year development period, the system was capable of tracking planar seams. The promising results motivated us to extend the scope of this system to tracking general 3D vee-jointed seams. Based on the data collected from real samples, we developed and tested algorithms for interpreting joint features in range images under conditions of variable position and orientation relationship between the sensor and the 3D seam. The analysis of seam tracking error is based on our experience with the operation of the ranging sensor and real joint geometries.

This monograph covers up-to-date and relevant work in the area of intelligent seam tracking. In contrast to many seam tracking systems that have been developed in the past for operation within well-defined working environments, this monograph primarily addresses the tracking of seams in unstructured environments. Essential to tracking seams within such an environment is some form of joint sensing. Chapter 2 provides an overview of the various sensing techniques while Chapter 3 covers the basic principles of processing intensity and range images for extracting and interpreting joint features, and the development of 3D seam environment models. Chapters 4 and 5 discuss the various coordinate frames and robot motion control issues related to seam tracking. Implementation details regarding development of a seam tracking system based on off-the-shelf components are presented in Chapter 6 and the various tracking errors are analyzed in Chapter 7. Finally an overview of the approaches used in existing seam tracking systems is presented in Chapter 8, and possible directions for future intelligent, realtime seam tracking are discussed in Chapter 9.

This monograph is directed towards readers who are interested in developing intelligent robotic applications. Although this work is presented in the context of seam tracking, the issues related to systems integration are general in nature and apply to other robotic applications as well.

November, 1992

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Acknowledgements

We are grateful to Mr. Henry Watson, Head of the Manufacturing Science and Technology department at the Applied Research Laboratory of the Pennsylvania State University, and the BMY Corporation, York, Pennsylvania, for their support during the initial phase of the ARTIST project. The hard work put in by Andy Vavreck to get this project going also deserves a lot of praise. Thanks are also due to Nancy Hahn and Prof. Gang Yu for providing the use of word processing facilities so crucial to the completion of this monograph. Finally, the support provided by the management at IBM Corporation, especially Ann Feicht and Peter Stoll, during the preparation of this monograph is highly appreciated.

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