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Autonomous Industrial Vehicles: From the Laboratory to the Factory Floor

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Editors:
Roger Bostelman
Elena Messina

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Foreword

THIS COMPILATION OF Selected Technical Papers, STP1594, *Autonomous Industrial Vehicles: From the Laboratory to the Factory Floor*, contains peer-reviewed papers that were presented at a workshop held May 26–30, 2015, in Seattle, Washington, USA. The workshop was sponsored by ASTM International Committee F45 on Driverless Automatic Guided Industrial Vehicles.

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Overview

Automatic guided vehicles (AGVs) were one of the earliest applications for mobile robots. The first AGVs were deployed in the 1950s to transport materials in large facilities and warehouses. Mobile robot capabilities have advanced significantly in the past decades. This progress is due in large part to researchers at technical universities who have made tremendous strides in applying computer control and sensors to mobile platforms for uses in applications such as manufacturing, health care, military, and emergency response. As industrial vehicles gained more capabilities, the “A” in AGV began to transition from “automatic” to “automated” in informal usage. This mirrors the progress in guided vehicles in areas such as safety sensing and reacting. Further advancements in mobile robotics, such as in more general-purpose sensing, planning, communications, and control, are paving the way for an era where the “A” stands for “autonomous.” This evolution in onboard intelligence has greatly expanded the potential scope of applications for AGVs and thus raised the need for standard means of measuring performance.

A new committee was formed under ASTM International to develop these missing standards for measuring, describing, and characterizing performance for this new breed of AGVs. ASTM’s Committee F45 on “Driverless Automatic Guided Industrial Vehicles” (<http://www.astm.org/COMMITTEE/F45.htm>) is scoped to include standardized nomenclature and definitions of terms, recommended practices, guides, test methods, specifications, and performance standards for AGVs. These new performance standards will complement the ongoing work in AGV safety standards by the Industrial Truck Standards Development Foundation [1], the British Standards Institution [2], and others. F45 is addressing areas that are important for potential AGV users to understand when making purchase and task application decisions. Therefore, the committee is divided into five technical subcommittees that focus on the key areas of interest for the community:

- F45.01 Environmental Effects
- F45.02 Docking and Navigation
- F45.03 Object Detection and Protection
- F45.04 Communication and Integration
- F45.91 Terminology

The first event organized by the ASTM F45 Committee was a workshop intended to foster communication between researchers and practitioners and was held at the

2015 Institute of Electrical and Electronic Engineers International Conference on Robotics and Automation (ICRA). Organized by Roger Bostelman of the National Institute of Standards and Technology and Pat Picariello from ASTM International, the workshop “Autonomous Industrial Vehicles: From the Laboratory to the Factory Floor” solicited researcher input for the development of consensus standards and sought to educate researchers about a standards-based mechanism for rapid technology transfer from the laboratory to industry.

This book comprises expanded versions of selected papers presented at the ICRA workshop. The workshop and this book feature perspectives from related standards efforts, industry needs, and cutting-edge research. The first chapter, “Towards Development of an Automated Guided Vehicle Intelligence Level Performance Standard” by Bostelman and Messina, sets the stage by reviewing standards development for other mobile robot application domains, such as emergency response, and suggests approaches for tackling performance measurement for intelligent AGVs. The authors discuss examples of performance standards that could be used for vehicle navigation performance and for perception systems (which would be key components of intelligent vehicles).

Norton and Yanco’s chapter, entitled “Preliminary Development of a Test Method for Obstacle Detection and Avoidance in Industrial Environments,” builds on the first chapter by documenting the process for developing a test method. Their process starts with building an understanding of the deployment environment through the development of a taxonomy of relevant obstacles. The key characteristics are abstracted to create reconfigurable artifacts for conducting tests that are representative of robot tasks. Statistical significance of performance data and other key aspects necessary for successful test methods are also considered.

One of the challenges of deploying AGVs in unstructured facilities is the possibility of obstacles appearing not just on the ground but also above the floor. To broaden obstacle detection capabilities, Hedenberg and Åstrand implemented time of flight and structured light sensors on an unmanned vehicle and conducted several experiments to characterize the performance of this sensing combination in the laboratory and in an industrial setting. The results of their experiments are presented in “3D Sensors on Driverless Trucks for Detection of Overhanging Objects in the Pathway,” which discusses the implications of using these sensors in real-world settings.

In the chapter “Multi-AGV Systems in Shared Industrial Environments: Advanced Sensing and Control Techniques for Enhanced Safety and Improved Efficiency,” Sabbatini et al. tackle the complexities of multiple AGVs operating in unstructured environments. They do so through fusion of sensor data from the different vehicles. The fused data produces a global environment representation that is updated in real-time and is used for assigning missions to AGVs and supporting path planning and obstacle avoidance.

Theobald and Heger’s chapter considers the transition from research capabilities to implementations in industry from an incremental perspective. Their chapter, entitled “The Safety-to-Autonomy Curve: An Incremental Approach to Introducing Automation to the Workforce,” proposes gradual implementation of automation for robotic systems. Starting with the deployment of the necessary safety systems, which include sensing and supporting algorithms, the authors advocate leveraging the sensor data from the safety systems to accumulate information and knowledge about the environment and humans. Thus, the robots learn how to navigate and behave on an ongoing basis, building confidence in the industry to allow incremental adoption.

The criticality of robust sensing to enable advanced performance and safety for AGVs heightens the importance of measuring how well a sensor system performs. Performance test methods must have a basis for comparison to a reference—or ground truth—system that is typically ten times better than the system under test. The chapter by Bostelman et al., “Dynamic Metrology Performance Measurement of a Six Degrees-of-Freedom Tracking System Used in Smart Manufacturing,” describes a method for evaluating the accuracy of a potential ground truth system.

The chapter “Harmonization of Research and Development Activities Toward Standardization in the Automated Warehousing Systems” by Kovačić et al. highlights the role of standards in bridging research and commercialization. Their work describes a European Commission project in advancing automated warehousing through a set of freely navigating AGVs in large-scale facilities. The authors discuss performance standards and benchmarks that can enable technology transfer from the laboratory to industry.

The book’s final chapter, “Recommendations for Autonomous Industrial Vehicle Performance Standards,” by Bostelman, summarizes and synthesizes a discussion session that was held at the ICRA workshop. The findings from the workshop presented in this chapter are meant to inform the standardization efforts under ASTM Committee F45 and accelerate the infusion of intelligence so as to enable autonomous guided vehicles.

References

- [1] ANSI/ITSDF B56.5:2012, Safety Standard for Driverless, Automatic Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles, November 2012, <http://www.itsdf.org>
- [2] British Standard Safety of Industrial Trucks—Driverless Trucks and Their Systems. Technical Report BS EN 1525, 1998.

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