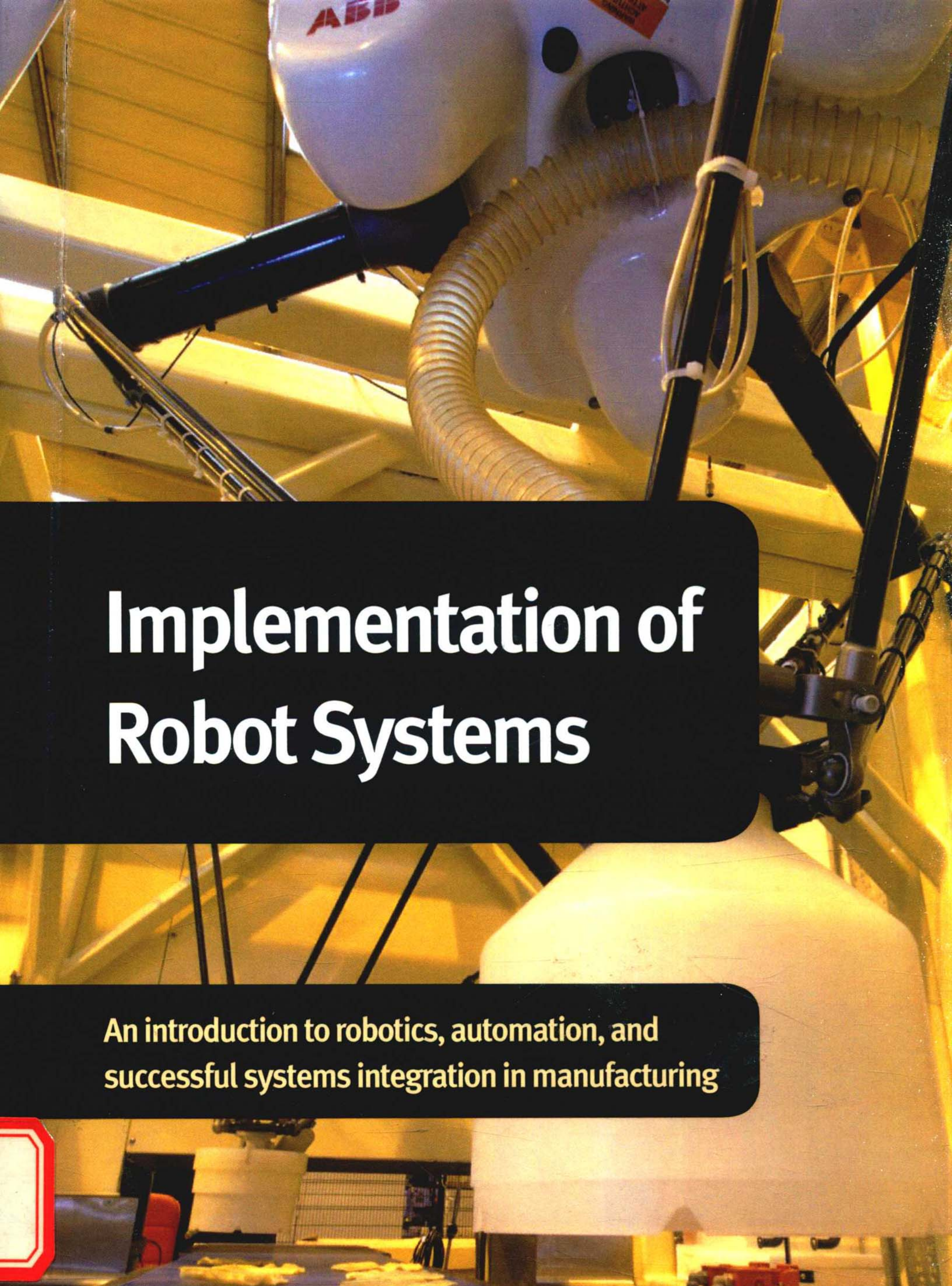

Implementation of Robot Systems

An introduction to robotics, automation, and successful systems integration in manufacturing

Mike Wilson

B H

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MIKE WILSON

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Finally, thank you to my wife Elena, for her patience and support, throughout the writing of this book.

DEDICATION

This book is dedicated with love, to my wife Elena and my three daughters, Rosie, Robyn, and Emily.

ABOUT THE AUTHOR

Mike Wilson has worked in the robotics industry for over 30 years. He qualified with a masters degree in Industrial Robotics from Cranfield University in 1982.

His initial experience was within the British Leyland car company working on the development and implementation of robot systems, particularly for adhesive, sealant, and paint applications. In 1988, he moved into sales, initially with Torsteknik (which ultimately became part of Yaskawa), selling robotic welding systems to a range of automotive component and metal fabrication businesses in the UK. This was followed by a move to GMF (which became Fanuc Robotics), where he initially concentrated on the automotive sector followed by general sales management, finally becoming UK managing director, responsible for all aspects of the business including sales, finance, engineering, and customer service.

This was followed by 6 years with Meta Vision Systems, a venture capital-backed UK business focussed on vision guidance systems for robots and welding machines. This period included the acquisition and subsequent integration of two competitors, one based in Montreal and the other in the UK. Over 95% of Meta's business was outside the UK, which resulted in many visits to overseas customers, particularly throughout Europe, India, and North America.

In 2005, Mike started his own business providing consultancy services to manufacturing companies and automation suppliers, as well as training. This included projects for Italian, Korean, Dutch, and UK companies, retention as an expert witness for a number of disputes, as well as teaching on behalf of Warwick University. In 2012, Mike joined ABB Robotics in the UK in a sales management role.

Throughout his career, Mike has also been very active in trade associations and other related organisations in the UK. He has been involved with the British Automation and Robot Association since 1991, serving as chairman since 2009. He has also been the chairman of the International Federation of Robotics for the period 2000–2003, the only chairman to be elected for two consecutive terms.

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CHAPTER 1

Introduction

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Abstract

This chapter outlines the contents of the book and provides a brief history of automation, differentiating between process and discrete automation. To this end, the chapter surveys the history of industrial robots from the first installation in the 1960s onward, outlining the key milestones in the development of industrial robot technology. The chapter also discusses the development of robot applications, particularly those driven by the automotive industry, as well as the effects of robot use on employment.

Keywords: Industrial robots, Discrete automation, Factory automation, Unimation, PUMA, Robot density

The advent of industrial robots in the 1960s heralded an exciting period for manufacturing engineers. These machines provided them an opportunity to automate activities in ways that had previously been infeasible. In 1961, General Motors first applied an industrial robot in a manufacturing process. Since that time, robotic technology has developed at a fast pace, and today's robots are very different from the first machines in terms of performance, capability, and cost. Over 2 million robots have been installed across many industrial sectors, and a whole new automation sector has developed. These robots have provided significant benefits to manufacturing businesses and consumers alike. There are many challenges involved in achieving successful applications, however, and over the last 50 years, those who have led the way have learnt many lessons.

The challenges are largely caused by the limitations of robots in comparison with humans. Although they can perform many manufacturing tasks as well as, or even better than, humans, robots do not presently have the same sensing capabilities and intelligence as humans do. Therefore, to achieve a successful application, these limitations have to be considered, and the application must be designed to allow the robot to perform the task successfully.

This book provides a practical guide for engineers and students hoping to achieve successful robot implementation. It is not intended to provide exhaustive details of robot technology or how robots operate or are programmed. It is intended to convey lessons learnt from experience, offering guidance particularly to those who are new to the application of robots. The fear of problems and unfulfilled expectations is often the largest barrier to the introduction of robots. Even given the current population of robots, many companies throughout the world can still benefit from adopting this technology. Their reticence to incorporate robotics is largely due to a fear of the unknown, a view that robots are "fine for the automotive industry but they are not for us". This mistaken view holds back the growth and profitability of many companies that have not embraced robot technology nor gained the benefits it can bring.

1.1 SCOPE

As mentioned above, this book is intended to be a guide to the practical application of robot systems. Many academic books describe the development and current technologies of robotics. Many examples of applications are also supplied by robot manufacturers and system integrators via the internet. Yet, few sources cover all the important aspects of the implementation of robot systems. Many experts have developed this knowledge through experience, but most have not had the time to impart this experience to others in this way.

In the following pages, we introduce automation. Knowledge of automation varies across different industry sectors. Therefore, it is important to understand when robots are appropriate and, most importantly, when they are not. The term *robot* also conjures up many different images from simple handling devices to intelligent humanoid machines. So, we provide an explanation for the term *industrial robot*, which then defines the context for this book.

Although we do not intend to provide a deep understanding of robot technology, we do offer an introduction to the benefits of using robots, as well as robot configurations, performance, and characteristics. This knowledge is required as a starting point for all applications because it serves as the basis for selecting a suitable robot for a particular application. This is covered in Chapter 2.

A robot consists of a mechanical device, typically an arm and its associated controller. On its own, this device can achieve nothing. In order to perform an application, a robot must be built into a system that includes many other devices. Chapter 3 provides a brief outline of the most important equipment that can be used around a robot.

Chapter 4 then reviews typical applications. Again, we do not intend this review to be exhaustive. Instead it provides examples of a range of robot applications throughout various different industry sectors. These are used to illustrate the main issues that must be addressed when implementing a robot solution, particularly those issues relevant to a specific sector or application.

The remainder of the book outlines a step-by-step process that can be followed in order to achieve a successful application. First, in Chapter 5, we discuss the initial process of developing the solution, although the process is normally iterative, with the actual solution often not finalised until the financial justification has been developed. A key element of any successful implementation is the definition of the system specification. In most cases, a company subcontracts the actual implementation of the robot solution to an external supplier, such as a system integrator, and this supplier must have a clear understanding of both the requirements for the system and the constraints under which it is to perform. These are defined in the User Requirements Specification. Without this specification, the chance of failure is greatly increased due to the lack of a clear understanding between the customer and supplier. The purpose of the user requirements specification is to convey this information, and we discuss the development of this key document in Chapter 6.

Of course, the implementation of a robot system must provide benefits to the end user. These benefits are often financial, and the financial justification must be clearly identified at the commencement of the project. Normally, a company will not proceed with the purchase of a robot system, as with most other capital investments, unless the financial justification is viable. For this reason the final decision maker, within the end user, requires a compelling financial justification. Therefore, the development of this justification is as important as the engineering design of the solution. This is not just a case of determining labour savings. Robot systems also provide many other benefits that can be quantified financially. In many cases, robot systems are not implemented, because the justification does not satisfy the financial requirements of the business. However, a detailed analysis presented in the correct way can improve the justification. This is covered in Chapter 7.

All successful projects require a methodical approach to project planning and management. In this respect, robot systems implementation is no different, although specific issues must be addressed, particularly for those companies undertaking an initial implementation of robot technology. Chapter 8 provides a guide to the successful implementation of a robot system from the initial project plan, through supplier selection to the installation and operation of the robot system. In particular, the chapter considers common problems and how they can be avoided.

Finally, Chapter 9 summarises the implementation process. This chapter also provides some thoughts as to how engineers and companies that are new to robot technologies might benefit from the development of an automation strategy. This strategy offers a plan from which manufacturers can develop their expertise and automation use as part of the overall company goals.

1.2 INTRODUCTION TO AUTOMATION

Automation can be defined as "automatically controlled operation of an apparatus, process, or system by mechanical or electronic devices that take the place of human labour". Basically, automation is the replacement of man by machine for the performance of tasks, and it can provide movement, data gathering, and decision making. Automation therefore covers a very wide array of devices, machines, and systems ranging from simple pick-and-place operations to the complex monitoring and control systems used for nuclear power plants.

Industrial automation originated with the Industrial Revolution and the invention of the steam engine by James Watt in 1769. This was followed by the Jacquard punch card-controlled loom in 1801 and the cam-programmable lathe in 1830. These early industrial machines can be more appropriately defined as mechanisation because they were exclusively mechanical devices with little programmability. In 1908, Henry Ford introduced mass production with the Model T, and Morris Motors in the UK further enhanced this process in 1923 by employing the automatic transfer machine. The first truly programmable devices did not appear until the 1950s, with the development of the numerically controlled machine tool at MIT. General Motors installed the first industrial robot in 1961 and the first programmable logic controller in 1969. The first industrial network, the Manufacturing Automation Protocol was conceived in 1985, and all of these developments have led to the automation systems in use today.

Robots are a particular form of automation. To understand the role robots can play within a manufacturing facility, one must distinguish between the different types of automation. The first major distinction is between process and discrete automation. Discrete, or factory, automation provides the rapid execution of intermittent movements. This frequently involves the highly dynamic motion of large machine parts that must be moved and positioned with great precision. The overall production plant generally consists of numbers of machines from different manufacturers that are often independently automated. In contrast, process automation is designed for continuous processes. The plant normally consists of closed systems of pumps used to move media through pipes and valves connecting containers in which materials are added and mixing and temperature control takes place. In simple terms, discrete automation is normally associated with individual parts, whereas process automation controls fluids.

The control systems for chemical plants and oil refineries provide examples of process automation. The facilities used by the automotive industry represent discrete automation, and some facilities in the food and beverage sector require both forms of automation. In these facilities, process automation provides the basic product (such as milk), and factory automation then provides the handling when the product has been put into discrete packages, the bottles or cartons.

Therefore, robots are a form of discrete or factory automation. Within this group the types of automation can be categorised as hard or soft automation. Hard automation is dedicated to a specific task, and, as a result, it is highly optimised to the performance of that task. It has little flexibility but can operate at very high speeds. An excellent example of hard automation is cigarette-manufacturing machinery. Soft automation provides flexibility. It can either handle different types of product through the same equipment or be reprogrammed to perform different tasks or operate on different products. The trade-off is often performance, in that soft automation is not as optimised, and therefore, it cannot achieve the same output as dedicated, hard automation. Robots are a very flexible form of soft automation because the basic robot can be applied to many different types of application.

1.3 EVOLUTION OF ROBOTS

The word "robot" was first used by the Czech playwright Karel Capek in his play "Rossum's Universal Robots". It is derived from the Czech word "robota" meaning slave labour. This science fiction play, from 1920, portrayed robots as intelligent machines serving their human masters but ultimately taking over the world. The popular concept of robots has emerged from this beginning. Other writers developed the ideas further. In particular, in the 1940s, Isaac Asmiov created three laws of robotics to govern the operation of his fictional robots (Engelberger, 1980):

1. Robots must not injure humans, or through inaction, allow a human being to come to harm.
2. Robots must obey the orders given by human beings except where such orders would conflict with the first law.
3. Robots must protect their own existence as long as this does not conflict with the first or second law.

Although these laws are fictional, they do provide the basis used by many current researchers developing robot intelligence and human–robot interaction.

Robots come in many forms. Due to the high profile of fictional robots, such as C3PO from *Star Wars*, the public often associates robots with intelligent, humanoid devices, but the reality of current robot technologies is very different. The robot community categorises robots into two distinct application areas, service robots and industrial robots. Service robots are being developed for a wide range of applications, including unmanned aircraft for the military, machines for milking cows, robot surgeons, search and rescue robots, robot vacuum cleaners, and educational and toy robots. Due to the wide range of applications and environments in which they operate, the machines vary greatly in terms of size, performance, technology, and cost. The use of service robots is a growing market, largely addressed by companies other than those that supply the industrial sector. There is some cross over in terms of technologies with industrial robots, but the machines are very different.

This book focuses on the use of robots in the industrial sector. These machines have been developed to meet the needs of industry and therefore they have much less variation than do service robots. The following is an accepted definition (ISO 8373) for an industrial robot (International Federation of Robotics, 2013).

> *An automatically controlled, re-programmable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.*

This provides a distinction between robots and other automation devices such as pick-and-place units, machine tools, and storage-and-retrieval systems.

The industrial robot industry began in 1956 with the formation of Unimation by Joseph Engelberger and George Devol. Devol had previously registered the patent "Programmed Article Transfer", and together, they developed the first industrial robot, the Unimate (Figure 1.1). Unimation installed the first robot into industry for the stacking of die cast parts at the General Motors plant in Trenton, New Jersey. This robot was a hydraulically driven arm that followed step-by-step instructions stored on a magnetic drum. The first major installation was again at General Motors, in this

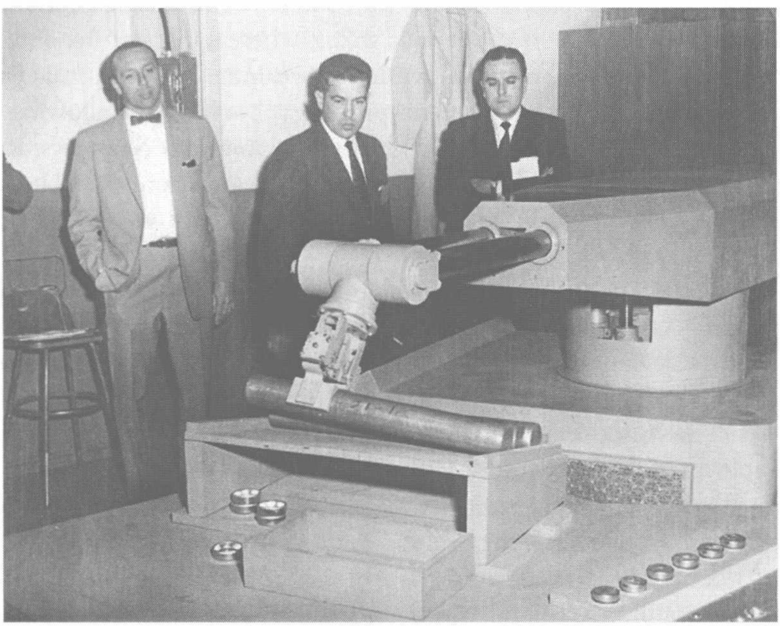

Figure 1.1 First Unimate.