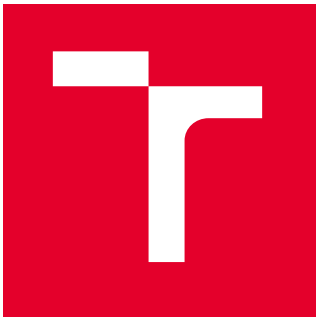

BRNO UNIVERSITY OF TECHNOLOGY

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

FACULTY OF MECHANICAL ENGINEERING

FAKULTA STROJNÍHO INŽENÝRSTVÍ

INSTITUTE OF AUTOMATION AND COMPUTER SCIENCE

ÚSTAV AUTOMATIZACE A INFORMATIKY

DESIGN OF AN ADVANCED ROBOTIC CELL IN THE CONTEXT OF INDUSTRY 4.0

NÁVRH POKROČILÉ ROBOTICKÉ BUŇKY V KONTEXTU PRŮMYSLU 4.0

DOCTORAL THESIS

DIZERTAČNÍ PRÁCE

AUTHOR — **Ing. Roman Parák**

AUTOR PRÁCE

SUPERVISOR — **prof. Ing. Radomil Matoušek, Ph.D.**

ŠKOLITEL

BRNO 2023

Abstract

Text ...

Keywords

keyword 1, keyword 2, etc.

Abstrakt

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Klíčová slova

klíčové slovo 1, klíčové slovo 2, atd.

Bibliographic Citation

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Declaration of Authorship

I declare that I have written my doctoral thesis on the theme of "Design of Advanced Methods in the Field of Industrial Robotics, Fitting into the Concept of Industry 4.0" independently, under the guidance of the doctoral thesis supervisor, and using the technical literature and other sources of information, which are all quoted in the thesis and detailed in the list of literature at the end of the thesis.

As the author of the doctoral thesis, I furthermore declare that, as regards the creation of this doctoral thesis, I have not infringed any copyright. In particular, I have not unlawfully encroached on anyone's personal and/or ownership rights, and I am fully aware of the consequences in the case of breaking Regulation S 11 and the following of the Copyright Act No. 121/2000 Sb., and of the rights related to intellectual property rights and changes in some Acts (Intellectual Property Act) and formulated in later regulations, inclusive of the possible consequences resulting from the provisions of Criminal Act No. 40/2009 Sb., Section 2, Head VI, Part 4.

February 29, 2024

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Date Ing. Roman Parák

Preface

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Acknowledgements

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Contents

CHAPTER 1

Introduction

"An automated machine that does just one thing is not a robot. It is simply automation. A robot should have the capability of handling a range of jobs at a factory."

— Joseph Engelberger (1925 - 2015), *"The Father of Robotics"*

Text ...

CHAPTER 2

Current State in the Field of Industry 4.0

The following chapter introduces the state of the art in Industry 4.0, the basic vision of which was first presented in 2011 by Professor Wolfgang Wahlster at the Hannover Messe trade fair in Germany [1]. A detailed concept of the Fourth Industrial Revolution was later presented at the same fair in 2013 [2].

2.1 History of the Industrial Revolution

In this section, we briefly discuss the history of the rise of the Fourth Industrial Revolution (Industry 4.0), which began in the late 18th century and continues to the present day. The historical process of the sequence of industrial revolutions with key pillars is depicted in Figure 2.1.

The First Industrial Revolution

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The Second Industrial Revolution

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The Third Industrial Revolution

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The Fourth Industrial Revolution

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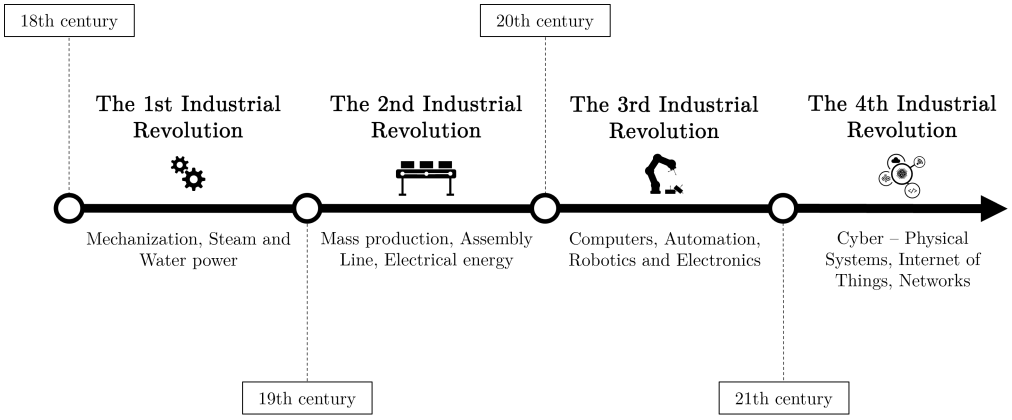

Figure 2.1: A visualization of the historical process of industrial revolutions that began in the 18th century and continues to the present day.

2.2 The Characteristics of the Fourth Industrial Revolution

As the title implies, the following section introduces the characteristics of the Fourth Industrial Revolution.

The concept of the Fourth Industrial Revolution is based on the nine main pillars (see Fig. 2.2) [3], which together form the core idea of the digitization of industry.

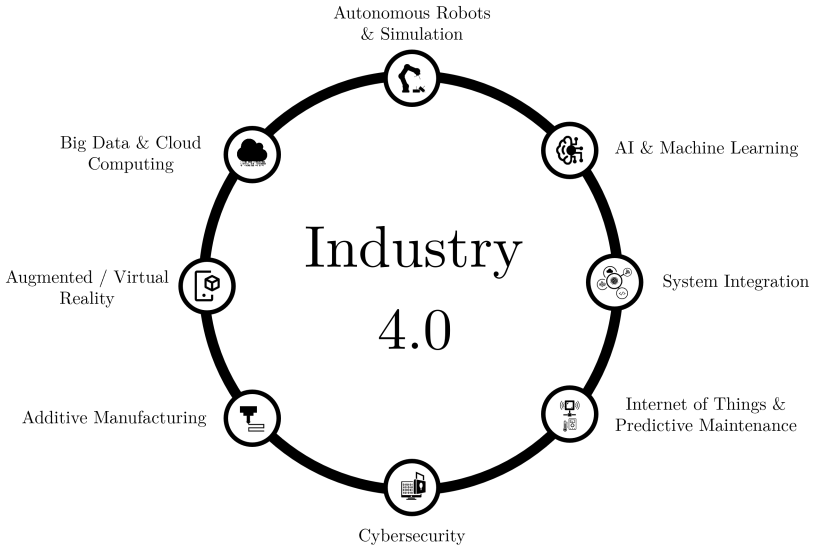

Figure 2.2: The nine main pillars of the concept of the Fourth Industrial Revolution.

Industry 4.0 encompasses six design principles in its characteristics, namely modularity, interoperability, etc. (see below for other principles) [4, 5, 6]. These principles are referred

to as "design principles" because they contribute to the design or transition process from Industry 3.0 to Industry 4.0.

The main design principles of Industry 4.0

(a) Modularity

The principle of modularity refers to customization and adaptation to different requirements. This principle offers scalability, flexibility, and the ability to upgrade or replace specific components without affecting the entire system.

(b) Interoperability

The principle of interoperability refers to the fact that a cyber-physical system (CPS) comprises intelligent machines and intelligent storage systems and facilities capable of autonomously exchanging information, initiating actions, and controlling each other independently. This involves standardizing communication protocols and data formats to ensure compatibility among different components and technologies.

(c) Decentralization

The principle of decentralization refers to the fact that different components and machines can make autonomous decisions based on real-time data, reducing the need for a central controller. Only in cases of failure are tasks delegated to a higher level.

(d) Real-time capability

The principle of real-time capability refers to the ability of systems, manufacturing processes, and intelligent machines to operate and respond to events in real time or near-real time.

(e) Virtualization

The principle of virtualization refers to the creation of virtual representations or simulations of physical entities, processes, or systems within the industrial environment. The sensor data is linked to virtual plant models and simulation models. Thus, a virtual copy of the physical world can be created.

(f) Service orientation

The principle of service orientation emphasizes the organization and delivery of functionality as services, marking a shift from merely selling products to offering integrated products and services that provide more value to the customer. This involves the use of SOA architecture (Service-Oriented Architectures).

2.3 The main pillars of Industry 4.0

In this section, we briefly introduce the main pillars of the Fourth Industrial Revolution, which are illustrated in Figure 2.2 in the previous section. Since some key pillars, such

as artificial intelligence and machine learning, system integration, autonomous robots, and simulation, are more important than others for the practical implementation of the presented thesis, we will focus more attention on them.

2.3.1 Artificial Intelligence and Machine Learning

Text ...

2.3.2 System Integration

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2.3.3 Autonomous Robots and Simulation

Text ...

2.3.4 Other Pillars

Text ...

Internet of Things and Predictive Maintenance

Text ...

Cybersecurity

Text ...

Additive Manufacturing

Text ...

Augmented / Virtual Reality

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Big Data and Cloud Computing

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2.4 Testbeds for Industry 4.0 in the Czech Republic and the Surrounding Countries

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2.5 Forecasting the Future Landscape of the Industry

Text ...

CHAPTER 3

Kinematics

Text ...

CHAPTER 4

Robot Motion Planning and Control

Text ...

CHAPTER 5

Versatile Intelligent Robotic Workstation

Text ...

CHAPTER 6

Conclusion

"If you want to improve something, you must first understand it. The combination of theoretical and practical knowledge is not an option, it is a must."

— Roman Parak

Text ...

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Appendix A: Activities within Doctoral Studies

Text ...

Appendix B: Source Codes

"Active participation within the open-source community, not only as a user but also as a contributor, is essential to ensuring continued growth."

— Roman Parak

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