1 Introduction

Chapter 1 reviews definitions and classifications of industrial robots.

1 Introduction: Sources and methods

1.1 CONTENTS, ACCESS TO DATA FOR PREVIOUS YEARS, AND CONTACT

The annual publication “World Robotics Industrial Robots: Statistics, Market Analysis, Forecasts and Case Studies” covers **multipurpose industrial robots** as defined in section 1.7. Whenever this study refers to “robots” it means “multipurpose industrial robots”.

From 2000 to 2008, World Robotics included statistics on service robots as a separate chapter. Since 2009, the companion publication “World Robotics Service Robots” has been covering service robots (see section 1.7 for delimitation of industrial robots).

World Robotics Industrial Robots contains data on robot installations by **type, country, industry** and **application**. The data is collected from nearly all industrial robot suppliers worldwide either as primary data or as secondary data through national robotics associations. Therefore, World Robotics Industrial Robots covers the global industrial robot market. The publication also provides estimates of the operational stock of industrial robots at year-end.

Chapter 1 contains **definitions, classifications,** and **general methodological remarks.**

Chapter 2 analyzes the **worldwide spread of industrial robots from 2016 to 2021.** It contains **summary tables** of the world robot stock and the global robot supply by country, by application, or by industry. For the Republic of China, the United States, Japan, Germany and the Republic of Korea, the **value of the robot market, and the average unit prices of robots** are calculated and an estimate of the **total world market** value of industrial robot sales is deduced.

The chapter also contains analyses on the development of **industrial robot densities** (number of robots in operation per 10,000 employees) in the manufacturing industry of over 40 countries and in the automotive versus the general industry (manufacturing without automotive) for over 20 countries.

Chapter 3 presents statistical data on industrial robots for some 40 **countries**. The market analyses provide a discussion of the present situation and deduce a forecast of future robot installations for major markets.

Chapter 4 discusses technological trends, market trends, and presents the forecast for the ongoing year and the next three years.

Finally, **chapter 5** of World Robotics Industrial Robots provides a selection of case studies or use cases of actual robot installations from different countries and industries. These case studies illustrate the effects of robots on costs, production and employment and indicate the overall profitability of robot investments. They demonstrate how robots can solve specific problems, how such solutions have been obtained and what the implications are.

How to get access

The present issue of World Robotics as well as access to the World Robotics database that contains historic data (in some cases dating back to 1993), can be ordered at www.worldrobotics.org.

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For questions concerning the purchase or delivery of World Robotics, please contact the distributor:

VDMA Verlag, verlag@vdma.org, www.vdma-verlag.com

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1.2 DATA SOURCES, REVISIONS, RELIABILITY, AND VALIDITY

1.2.1 SOURCES

World Robotics Industrial Robots statistics rely on primary and secondary data.

The **primary source** is data on robot installations by country, industry, and application that nearly all major industrial robot suppliers worldwide report to the IFR Statistical Department directly.

Several national robotics associations collect data on their national robot markets and provide their results as **secondary data** to the IFR. This data is used to validate the IFR primary data, thus ensuring data quality. It is also used to fill in the missing information of companies not reporting to the IFR directly. The final statistics provided in this publication and in the online database is therefore the **consolidated primary and secondary data**.

The submission of statistical data on industrial robots is mandatory for robot suppliers (IFR Constitution § C3.4) and national robot associations (IFR Constitution § C3.3) in the IFR. All other robot suppliers are invited to participate directly as a primary source or indirectly through national associations.

Since 2015, the Korean Association of Robot Industry (KAR) has been providing data on Korean production, imports, and exports. Before 2015, the Korean Machine Tool Manufacturers Association (KOMMA) provided the data on the Korean robot companies' sales in the Republic of Korea.

The Japanese Robot Association (JARA) provides consolidated global data for Japanese companies' robot shipments in compliance with the IFR industry and application classifications. They also provide Japanese production, imports and exports. Until 2017, JARA contributed national statistics for Japan including exports. The information was refined using data that the IFR Statistical Department received directly from European subsidiaries of Japanese companies and for North America by results from A3 order statistics. JARA also reports the operational stock of robots in Japan. When working with historic data (access is included in the Premium version of World Robotics), note that there is a break in the time series for data on Japan between 2000 and 2001 resulting from international harmonization of definitions and coverage of statistics.

The Association for Advancing Automation (A3, formerly: Robotic Industries Association, RIA) provides data on North America. The statistics report shipment data from North American companies in compliance with the IFR industry and application classifications. Primary data, not included in the A3 statistics and JARA data on exports or Japanese suppliers to North America, supplement this data. Until and including 2010, data was available only for North America (Canada, Mexico, United States) as a whole. From 2004 to 2010, data on North America was based on the consolidated data of robot suppliers worldwide and JARA. Before 2004, the annual data for North America only comprised what was reported to RIA by its member companies.

Since 2013, the Chinese Robot Industry Alliance (CRIA) provides installations of Chinese robot suppliers in compliance with the IFR industry and application classifications. Since the reporting year 2018, CRIA also reports export data of Chinese suppliers, but only by country and type. Due to legal requirements, CRIA can only report member statistics.

IFR also gratefully appreciates the support of the national robotics associations of Spain (AER), Italy (SIRI), Sweden (SWIRA), and Chinese Taipei (TAIROA).

Prior 2004, country reports relied exclusively on data of national robot associations. This holds true for Denmark, Finland, France, Germany, Italy, Japan, Rep. of Korea, North America, Norway, and Spain. Reports on other countries were based on data provided by only a few robot suppliers. In 2005, robot suppliers reported consolidated data classified by country, industry, or application for the first time. This facilitated more detailed reports on countries that do not have a national robotics association.

For sources of **employment data** and methods of computing robot densities, see chapter 2.5.1.

1.2.2 QUALITY, RELIABILITY, AND VALIDITY

IFR Statistical Department considers the high-quality data to be valid and reliable for the following reasons:

IFR Statistical Department provides definitions and delimitations of robot types, industries and applications to all primary and secondary data sources to ensure data reliability.

The objective of World Robotics Industrial Robots is a comprehensive overview of the dissemination of industrial robots globally. The main indicator is the number of robots newly installed per year. The implications of some companies and associations counting “shipments” instead of “installations” are discussed in chapter 1.5. For some countries there is also information on sales in monetary units available. IFR Statistical Department considers these indicators a valid measure of robot dissemination.

The data presented in World Robotics Industrial Robots covers almost the whole population. This is ensured by permanent market observation and cooperation with national robotics associations. The availability of primary and secondary data sources enables IFR Statistical Department to check the data for consistency. This makes the data reliable.

1.2.3 DATA REVISIONS SINCE THE PREVIOUS EDITION

Minor revisions: World Robotics Industrial Robots statistical data on robot installations in previous years is updated if new information becomes available. Therefore, some of the numbers in the current issue might differ slightly from numbers published in previous issues. This holds true especially for the robot density data, because the employment data which is used to compute robot densities is only available with a large time lag. Thus, employment data is often preliminary or estimated and must be revised later.

Major revisions: The Chinese Robot Industry Alliance (CRIA) has substantially increased its membership base and provided revised data on domestic installations and exports from 2018 onwards. This revised data has been incorporated into World Robotics Industrial Robots 2022.

1.3 COMPLIANCE

IFR Statistical Department ensures the confidentiality of individual company data and compliance with antitrust regulations. Access to raw data is strictly limited to IFR Statistical Department staff. IFR Statistical Department will never provide company-level data to third parties neither outside nor inside the IFR. This means that IFR Statistical Department publishes only aggregated data by country, by industry, or by application. IFR Statistical Department will not reveal data if a data point consists of less than four observations greater zero. This is to prevent mathematical retrieval of company-level data.

Please note that this rule may lead to seemingly inconsistent data, because columns or rows may not necessarily add up to the sums reported. In addition, time series data may seem incomplete, especially in small markets, because in some years data can be revealed and in others it cannot.

IFR Statistical Department applies two different mechanisms to ensure compliance.

Mechanism 1 (M1): Reclassification

If a data point is non-compliant, the data is reclassified data to an “unspecified” class on the same hierarchy level. If it is already in an “unspecified” class, it is reclassified to a superior hierarchy level until the most generic level is reached. Figures 1.2 and 1.3 display the reclassification levels for data by application and data by industry.

Example: Assume in country A data in application class 111 (metal casting) consists of data from just 3 different companies. This data point is non-compliant. The data will be counted in class 120 (handling unspecified) instead of 111, and a zero will be displayed in class 111. If the data in class 120 this is still non-compliant, the data is reclassified to class 999 (unspecified).

Mechanism 2 (M2): Supression

Data by application and industry will not be displayed for a specific country, but at an aggregate level, e.g. a country group. The application of this mechanism is pre-selected by IFR Statistical Department. It is usually done for small markets, where all or nearly all applications or industries would be subject to M1, so that it is not meaningful to provide the data using M1. Figure 1.1 displays the aggregation levels used.

Example: Australia and New Zealand both have low installation counts. Applying M1 to these markets would result in all the data being reported as industry and application “unspecified”. Under M2, the data is aggregated to country group Australia/New Zealand, which yields more observations per industry class or application class.

Figures 1.1, 1.2, and 1.3 show how data points from the different classes are aggregated upon compliance violation. Descriptions of IFR application classes, IFR industry classes, and IFR geographical units can be found in chapters 1.11, 1.10, and 1.12.

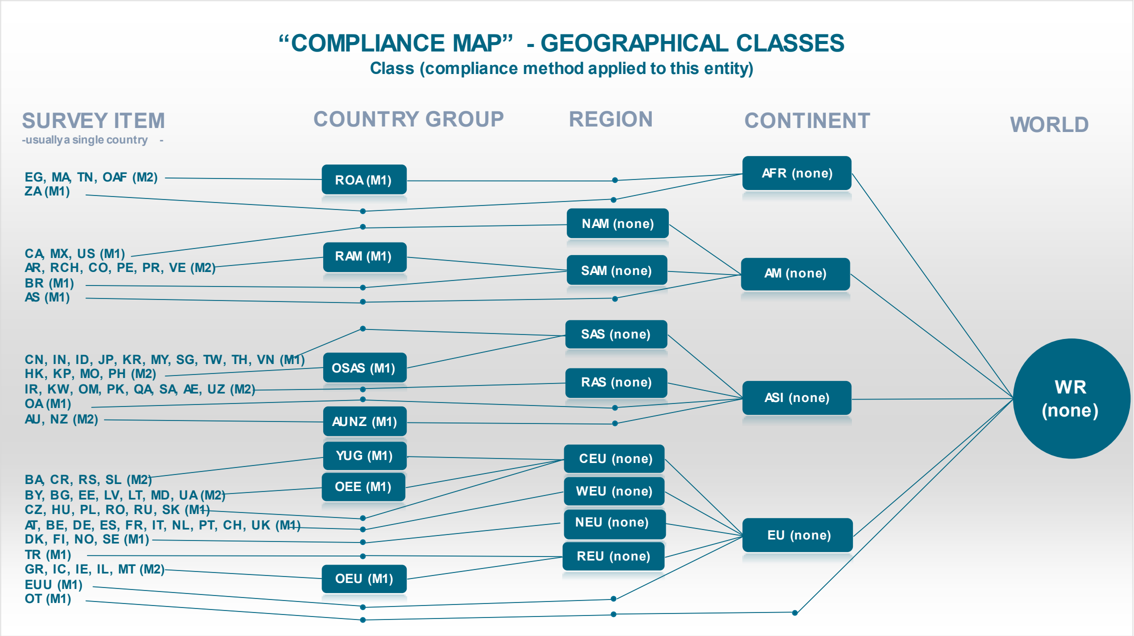

Figure 1.1: Compliance re-classification of data by geographical class.

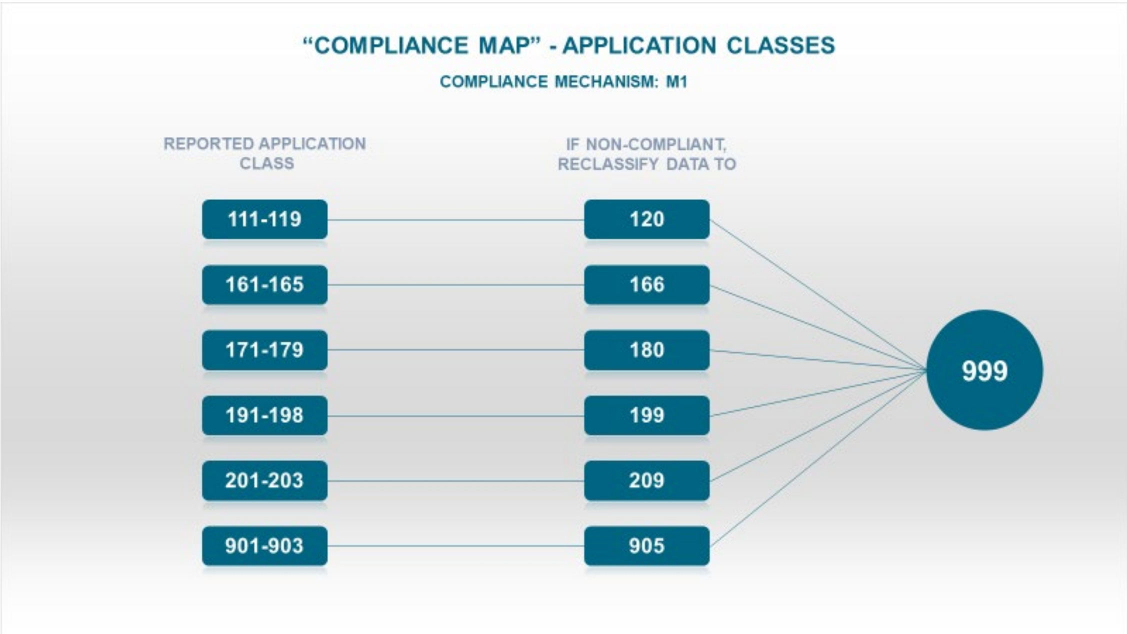

Figure 1.2: Compliance re-classification of data by application class.

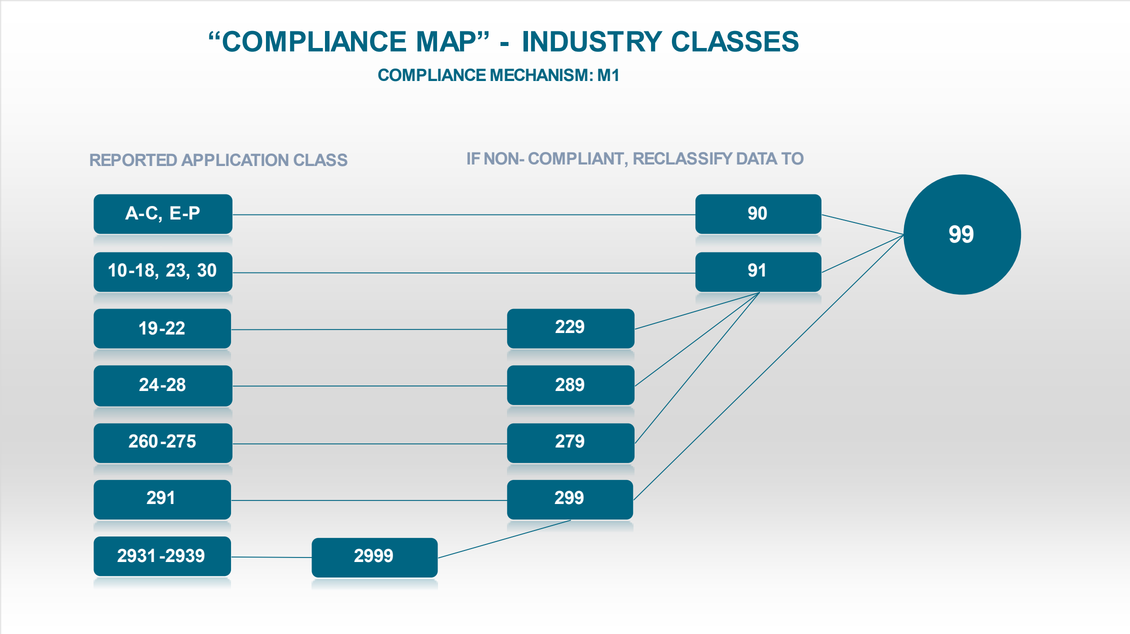

Figure 1.3: Compliance re-classification of data by industry class.

1.4 FORECASTS

Forecasts of investments in industrial robots, presented in chapter 4, are derived as the consolidated assessment of:

- economic factors
- technological progress
- expert opinions of some of the leading robot manufacturers, major robot users and national robotics associations

1.5 DEFINITION OF “SHIPMENTS” AND “INSTALLATIONS”

IFR surveys annual installations of industrial robots. However, as a compromise between the theoretical idea of counting the actual installation of the robot at the customer’s site and the practical data availability which often refers to the shipment of the robot, reporting of shipment data is also accepted. Note that shipment and installation data might differ for several reasons: A geographical measurement bias might occur for instance, if - without the knowledge of the producer- a reseller or integrator installs a robot in a different country than the producer shipped it to. The time of installation might be subject to measurement bias if a robot is shipped, but not installed in the same year, e.g. because it is still en route or went to the inventory or is work-in-progress at the integrator’s site.

1.6 DEFINITION OF "OPERATIONAL STOCK"

The operational stock of robots measures the number of robots currently deployed. JARA calculates and provides this number for Japan. For other countries, IFR Statistical Department calculates the operational stock **assuming an average service life of 12 years with an immediate withdrawal from service afterwards.** This assumption was investigated in an UNECE/IFR pilot study, carried out in 2000 among some major robot companies (see annex B in **World Robotics 2001**).[5] This investigation suggested that an assumption of 12 years of average life span might be too conservative and that the average service life was closer to 15 years. On the other hand, German tax authorities suggest in their standard depreciation schedules an average service life of 5 years for robots in the automotive industry and 6 years for robots in the mechanical engineering industry. Similarly, useful life of class 80.0C "Robotics" is 5 years in the American tax law. Of course, robots may be refurbished and appreciated, so the standard depreciation schedule rather underestimates the service life. Nevertheless, the differences (5, 12 or 15 years) are substantial and need further investigation. Presumably, there are substantial differences depending on industry, application, and type of robot. In the meantime, the operational stock is calculated as the sum of robot installations over 12 years.

[5] For several years IFR and the United Nations Economic Commission for Europe UNECE have cooperated closely in the compilation, processing and analysis of worldwide statistics on industrial robots. In 2005, the full responsibility for World Robotics was transferred to IFR Statistical Department.

1.7 DEFINITIONS: "ROBOT", "SERVICE ROBOT", "INDUSTRIAL ROBOT"

1.7.1 STATEMENT ON REVISED ISO VOCABULARY DEFINITIONS (ISO 8373:2021)

In December 2021, ISO published a revised version of their robotics vocabulary definitions standard 8373. A first investigation of this updated standard by IFR Statistical Department did not reveal any major implication for IFR industrial robot statistics. The IFR Robot Supplier Committee will be discussing the revised vocabulary definitions in one of their future meetings and decide if adjustments to IFR definitions are necessary.

As the most recent survey had been conducted under the same definitions as in previous years, the following sections are still citing ISO 8373:2012.

1.7.2 ISO 8373:2012 VOCABULARY DEFINITIONS

ISO 8373:2012 "*defines terms used in relation with robots and robotic devices operating in both industrial and non-industrial environments*" (§ 1). These vocabulary definitions relate to both, industrial and service robotics.[6] This section describes the ISO definitions needed to understand IFR classifications schemes, IFR industrial robot statistics, and the delimitation to IFR service robot statistics.

According to ISO 8373:2012, a **robot** is an "*actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks*" (§ 2.6). Actuated mechanisms that are lacking the number of programmable axes or that are fully teleoperated (no degree of autonomy) but satisfy the definitions of industrial or service robots otherwise, are called **robotic devices** (§ 2.8).

Note 2 to § 2.6 determines that **the classification into industrial robot or service robot is done according to its intended application**. Industrial robots are robots "*for use in industrial automation applications*" (§ 2.9), while a service robot "*performs useful tasks for humans or equipment excluding industrial automation applications*" (§ 2.10).

Note 2 to § 2.10 explicitly states that **the mechanical type/kinematics of a robot is insufficient to distinguish industrial robots from service robots**. Hence, by ISO definition, the application is a sufficient criterion to distinguish industrial from service robots but the kinematics are not.

An **industrial robot** is an "*automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications*" (§ 2.9).

That is, industrial robots have **at least three axes** (directions used to specify the robot motion in a linear or rotary mode, § 4.3) and they satisfy all of the following:

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[6] ISO 8373:2012 Robots and robotic devices - Vocabulary; http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=55890.

- **Automatically controlled**: The robot control system operates in accordance with the task program (§ 5.3.10.1). The task program is a set of instructions for motion and auxiliary functions that define the specific intended task (§ 5.1.1). The opposite of automatically controlled operation is manual operation, where a human operator uses input devices (e.g. joysticks or pushbuttons) to control the motions of the machine (§ 5.3.10.2).
- **Reprogrammable** (§ 2.4): designed so that the programmed motions or auxiliary functions can be changed **without physical alteration**. Physical alterations are alterations of the mechanical system. This does not include storage media, ROMs, etc. (§ 2.3).
- **Multipurpose** (§ 2.5): capable of being adapted to a different application with physical alteration.
- **Manipulator** (§ 2.1): machine for the purpose of grasping and/or moving objects like pieces or tools. The end effector is not part of the manipulator (§ 2.1, Note 2).
- **Fixed in place or mobile**: The robot can be mounted to a stationary point but it can also be mounted to a non-stationary point, e.g. railways. Note: In the past few years, the combination of robot arms (articulated robots) and Autonomous Mobile Robots (AMR) became popular. See the following section for the statistical treatment of such combinations.

1.7.3 DEVIATIONS OF IFR DEFINITIONS FROM ISO DEFINITIONS AND IFR REFINEMENTS OF ISO DEFINITIONS –INDUSTRIAL ROBOTS

IFR generally defines robots according to ISO 8373:2012. There are, however, some details that by IFR experience are not helpful to unambiguously distinguish the different robot categories or that might be in contrast to the primary goal of IFR statistics – which is to provide information on the robotics industry to the robotics industry. IFR industrial robot statistics will therefore deviate from ISO definitions in specific details described in this section.

Delimitation of industrial robots and service robots

IFR generally adopts the ISO criteria that define the application in industrial automation applications versus non-industrial automation as sufficient to classify a robot as industrial versus service robot, while the kinematic is not a sufficient criterion. Unfortunately, **ISO 8373:2012, § 2.10 note 1** mentions only a few examples but does not provide a full list of industrial automation applications. IFR therefore developed their own application classification schemes for industrial robots (see chapter 1.11) and service robots (see World Robotics Service Robots). These classifications schemes have been developed in IFR's Robot Supplier Committee and IFR's Service Robot Group. The IFR Robot Supplier Committee has also defined **kinematic robot types typically and mainly found in industrial robotics** (see chapter 1.9). By ISO definition, the kinematic type is not a sufficient criterion to qualify a robot as industrial robot. However, the Robot Supplier Committee decided to **include all robots of typically industrial kinematic type in the industrial robot statistics**. Robots with an industrial robot kinematic that are in service applications are therefore counted in both statistics: In IFR industrial robot statistics such cases are counted in application class 905 ("other applications") as well as in their actual application class in IFR service robot statistics.

The term **autonomous mobile robots** (AMR) is not defined in ISO 8373:2012 and there seems to be a wide range of products running under this label. Usually AMR is used for mobile robots as defined by § 2.13: A mobile robot is a robot that is able to travel under its own control. Sometimes, these AMR are used in industrial environments but usually they neither have three axes nor do they have manipulation capabilities. Therefore, they do not satisfy the definition of an industrial robot but should be considered as mobile platforms (§ 3.18). **IFR classifies AMR as service robots**. If the AMR is equipped with a robot arm (i.e. an articulated robot), **IFR statistics count the manipulator as an industrial robot and the platform as a service robot.**

1.7.4 IFR DEFINITION: MULTIPURPOSE INDUSTRIAL ROBOT

AN INDUSTRIAL ROBOT IS AN

- AUTOMATICALLY CONTROLLED,
- REPROGRAMMABLE,
- MULTIPURPOSE
- MANIPULATOR THAT IS
- PROGRAMMABLE IN AT LEAST THREE AXES, AND
- EITHER FIXED IN PLACE OR MOBILE, AND
- INTENDED FOR AND TYPICALLY USED IN INDUSTRIAL AUTOMATION APPLICATIONS.

INDUSTRIAL ROBOTS ARE USUALLY (BUT NOT EXCLUSIVELY) OF ONE OF THE FOLLOWING KINEMATIC TYPES:

- ARTICULATED
- CARTESIAN/LINEAR/GANTRY
- CYLINDRICAL
- SPHERICAL
- PARALLEL/DELTA
- SCARA

1.8 SCOPE OF IFR INDUSTRIAL ROBOT STATISTICS

IFR industrial robot statistics count multipurpose industrial robots as defined in the previous chapter, only. **Robotic devices** are excluded.[7] IFR industrial robot statistics generally exclude **dedicated industrial robots**. Dedicated industrial robots are industrial robots specifically designed for and controlled by a special machine. However, industrial robots with an own control system and not controlled by the machine are included, even if they are dedicated for a special machine.

Examples of dedicated industrial robots excluded from the statistics are:

- Equipment dedicated for loading/unloading of machine tools
- Dedicated assembling equipment, e.g. for assembling on printed circuit boards
- Integrated Circuit Handlers (pick and place)
- Automated storage and retrieval systems

Wafer handlers have their own control system and are **included** in the industrial robot statistics. Wafers handlers can be articulated, cartesian, cylindrical or SCARA robots. They are reported in the IFR application class 902 “cleanroom for semiconductors”.

Flat panel handlers are included, too. These are mainly articulated robots and they are reported in the application class 901 “cleanroom for FPD”.

[7] This is in contrast to IFR service robot statistics, which include robotic devices under specific conditions.

1.9 IFR DEFINITION OF ROBOT TYPES

The IFR Robot Supplier Committee decided in 2004 that robot types should be classified by their mechanical structure.

Classification by mechanical structure:

- **Articulated robot**: a robot whose arm has at least three rotary joints
- **Cartesian (linear/gantry) robot**: robot whose arm has three prismatic joints and whose axes are correlated with a cartesian coordinate system
- **Cylindrical robot**: a robot whose axes form a cylindrical coordinate system
- **Parallel robot**: a robot whose arms have concurrent prismatic or rotary joints
- **SCARA robot**: a robot, which has two parallel rotary joints to provide compliance in a plane
- **Others**: Robots not covered by one of the above classes

Figures 1.4 illustrates the mechanical configuration and kinematics of these types of robots.

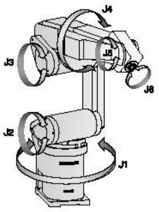
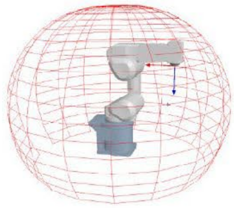
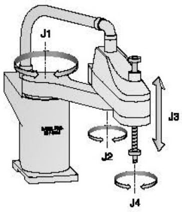
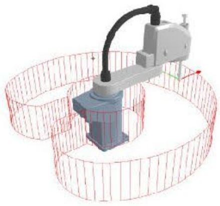
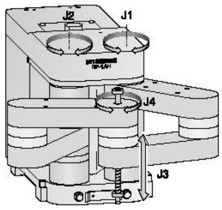
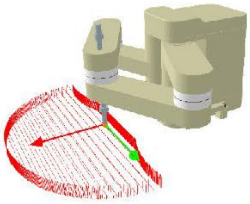
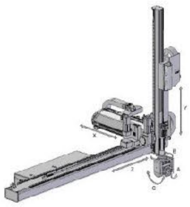
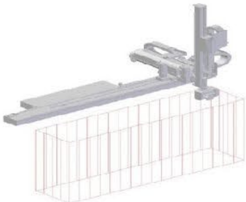
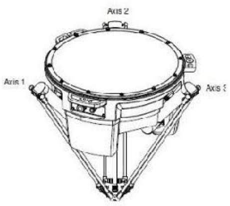
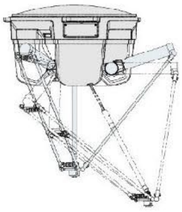
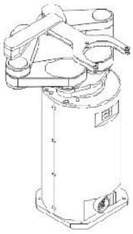
Principle	Kinematic Structure	Photo
Articulated Robot 		
SCARA Robot 		
SCARA Robot 		
Cartesian Robot 		
Parallel Robot 		
Cylindrical Robot 		

Figure 1.4: Classification of industrial robots by mechanical structure

Examples of articulated robots:

©NACHI

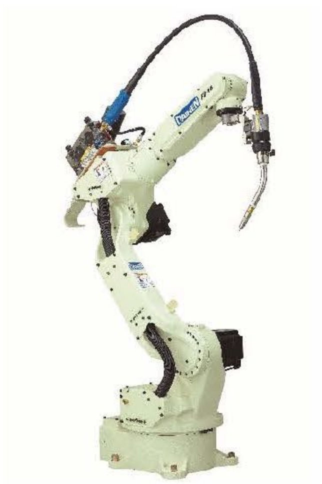
©FANUC

Flexible mounting possibilities – optimized working range

©ABB

©EPSON

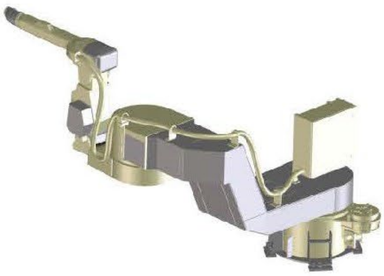
Welding Robot



©DAIHEN

©KUKA

Examples of articulated robots:



©Dürr

The Swingarm is an articulated robot combined with SCARA elements

Different dualarm robots

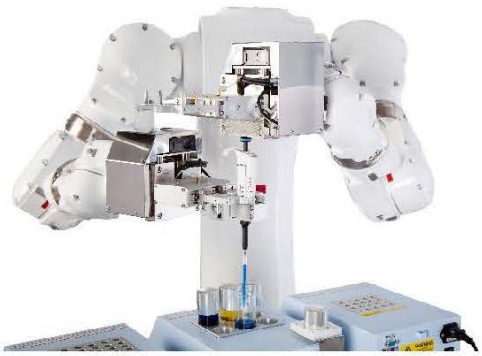
©Universal Robots

©EPSON

©Comau

©ABB

©Schunk



©YASKAWA

Examples of applications of articulated robots:

Handling for metal casting

©Comau

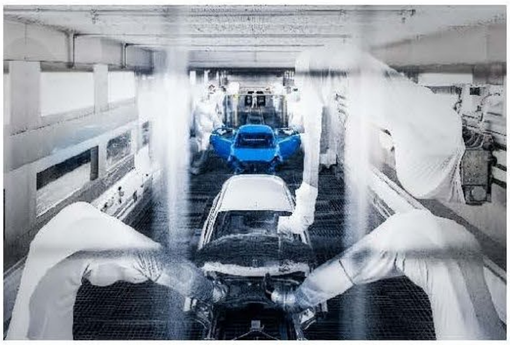
Packaging

©Kawasaki

Welding

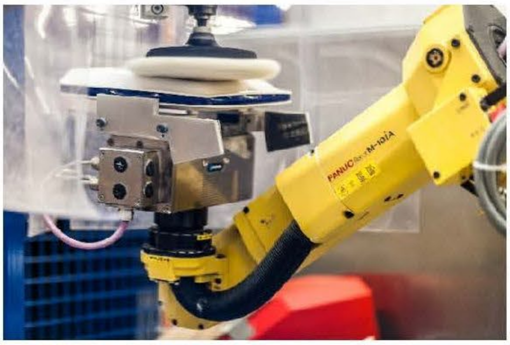
©Valk Welding

Painting



©DÜRR

Polishing



©FANUC

Machine Feeding

©Schunk

Sealing

©DÜRR

Grinding

©OnRobot

Material Handling

©KUKA

Examples of applications of articulated robots:

FDP handling	Wafer handler
	

Examples of SCARA robots and their applications:

 ©FANUC	 ©EPSON
 ©Omron	Assembly  ©EPSON

Examples of linear/Cartesian/gantry robots:

Linear robot

©Wittmann

Gantry robot

©GÜDEL

Examples of applications of cartesian robots:

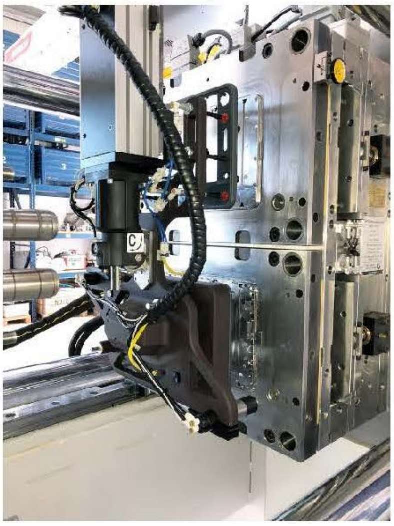
Material Handling

©GÜDEL

Material Handling

©GÜDEL

Machine feeding



©Wittmann

Handling for plastic moulding

©Wittmann

Examples of parallel robots:

©Omron

©FANUC

Examples of applications of parallel robots:

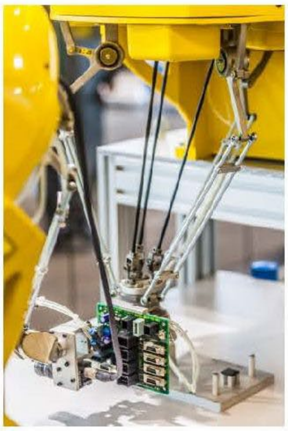
Picking and Placing

©Omron

Assembly

©ABB

Handling



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Picking and Placing

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1.10 IFR CLASSIFICATION OF INDUSTRIES

Starting with World Robotics 2010, data by customer industry has been reported using the IFR industry classification scheme. IFR industry classes are related to and derived from the International Standard Industrial Classification of All Economic Activities (ISIC) revision 4 scheme. It does, however, not exactly to correspond ISIC revision 4. Classes with minor robot installation counts were aggregated and classes that include major customer industries (automotive in particular) were further divided to provide more detail (see table 1.1). Prior 2010, data was presented according to ISIC revision 2 or 3. All earlier data was transferred to the new classification scheme.

Table 1.1

IFR class	Categories, divisions and classes of economic activities, ISIC, rev. 4	Definitions
A-B	Agriculture, hunting and forestry; fishing	Crop and animal production, hunting and related service activities, forestry and logging, fishing and aquaculture
C	Mining and quarrying	Mining of coal and lignite, extraction of crude petroleum and natural gas, mining of metal ores, mining support service
D	Manufacturing	
10-12	Food products and beverages; Tobacco products	
13-15	Textiles, leather, wearing apparel	Textiles; Wearing apparel; dressing & dyeing of fur; Luggage, handbags, saddlery, harness and footwear
16	Wood and wood products (incl. furniture)	Manufacture of wood, products of wood (incl. wood furniture) and products of cork
17-18	Paper and paper products, publishing & printing	Manufacture of pulp, paper and converted paper production, printing of products, such as newspapers, books, periodicals, business forms, greeting cards, and other materials, and associated support activities, such as bookbinding, plate- making services, and data imaging; reproduction of recorded media, such as compact discs, video recordings, software on discs or tapes, records etc.
19-22	Plastic and chemical products	
19	Chemical products, pharmaceuticals, cosmetics	Manufacture of basic pharmaceutical products and pharmaceutical preparations. This includes also the manufacture of medicinal chemical and botanical products
20-21	Unspecified chemical, petrolium products	Transformation of crude petroleum and coal into usable products, transformation of organic and inorganic raw materials by a chemical process and the formation of products
22	Rubber and plastic products without automotive parts*	(e.g. rubber tires, plastic plates, foils, pipes, bags, boxes, doors, etc.) rubber and plastic parts for motor vehicles should be reported in 29.3.2
23	Glass, ceramics, stone, mineral products n.e.c. (without automotive parts*)	Manufacture of intermediate and final products from mined or quarried non-metallic minerals, such as sand, gravel, stone or clay, manufacture of glass, flat glass ceramic and glass products, clinkers, plasters, etc.
24-28	Metal	
24	Basic metals (iron, steel, aluminium, copper, chrome)	e.g. iron, steel, aluminium, copper, chrome etc.
25	Metal products (without automotive parts*), except machinery and equipment	e.g. metal furniture, tanks, metal doors, forging, pressing, stamping and roll forming of metal, nails, pins, hand tools, etc.
28	Industrial machinery	e.g. machinery for food processing and packaging, machine tools, industrial equipment, rubber and plastic machinery, industrial cleaning machines, agricultural and forestry machinery, construction machinery etc.

Sources: IFR

Table 1.1 (continued)

IFR class	Categories, divisions and classes of economic activities, ISIC, rev. 4	Definitions
26-27	Electrical/electronics	
275	Household/ domestic appliances	(e.g. refrigerators, vacuum cleaners, lawn mowers, lamps, ovens, shavers, vacuum cleaners, etc.)
271	Electrical machinery and apparatus n.e.c. (without automotive parts*)	Manufacture of power, distribution and specialty transformers; electric motors, generators and motor generator sets; switchgear and switchboard apparatus; relays and industrial controls, batteries and accumulators; manufacture of current-carrying wiring devices and non current- carrying wiring devices for wiring electrical circuits regardless of material, fiber optic cables and insulating of wires; manufacture of electric light bulbs and tubes and parts and components thereof (except glass blanks for electric light bulbs), electric lighting fixtures and lighting fixture components (except current-carrying wiring devices) For electrical/electronic parts for motor vehicles, see class 2933.
260	Electronic components/devices	Manufacture of electronic capacitors and resistors, microprocessors, bare printed circuit boards, electron tubes, electronic connectors, integrated circuits (analog, digital or hybrid), diodes, transistors and related discrete devices, inductors (e.g. chokes, coils, transformers), electronic component type, electronic crystals and crystal assemblies, solenoids, switches and transducers for electronic applications, interface cards (e.g. sound, video, controllers, network, modems), printer cables, monitor cables, USB cables, connectors etc.
261	Semiconductors, LCD, LED (incl solar cells and solar thermal collectors)	Manufacture of dice or wafers, semiconductor, finished or semi- finished and of display components (plasma, polymer, LCD), light emitting diods (LED), including solar cells and solar thermal collectors
262	Computers and peripheral equipment	Manufacture of desktop, laptop, main frame computers and hand-held computers (e.g. PDA), magnetic disk drives, flash drives and other storage devices,optical (e.g. CD-RW, CD- ROM, DVD-ROM, DVD-RW) disk drives, printers, monitors, keyboards, all types of mice, joysticks, and trackball accessories, dedicated computer terminals, computer servers, scanners, including bar code scanners, smart card readers, virtual reality helmets, computer projectors (video beamers), computer terminals, like automatic teller machines (ATM's), point-of-sale (POS) terminals, not mechanically operated, of multi-function office equipment, such as fax-scanner-copier combinations
263	Info communication equipment domestic and professional (TV, radio, CD, DVD-Players, pagers, mobile phones, VTR etc.) without automotive parts*	Manufacture of video cassette recorders and duplicating equipment, televisions, television monitors and displays,audio recording and duplicating systems, stereo equipment, radio receivers, speaker systems household-type video cameras, jukeboxes, amplifiers for musical instruments and public address systems, microphones, CD and DVD players, karaoke machines, headphones (e.g. radio, stereo, computer), video game consoles Manufacture of pagers, cellular phones, mobile communication equipment, telephone and facsimile equipment, incl. telephone answering machines, data communications equipment, such as bridges, routers, and gateways, transmitting and receiving antenna, cable television equipment, radio and television studio and broadcasting equipment, including television cameras, modems, carrier equipment, burglar and fire alarm systems, sending signals to a control station, radio and television transmitters, infrared devices (e.g. remote controls)
265	Medical, precision and optical instruments	Manufacture of measuring, testing, navigating and control equipment for various industrial and non-industrial purposes, including time-based measuring devices such as watches and clocks and related devices; manufacture of irradiation, electromedical and electrotherapeutic equipment, manufacture of optical instruments and photographic equipment
279	Electrical machinery unspecified	Electrical/electronic products that do not fit into 26-27 or 2933 or the exact class is unknown
29	Automotive	
291	Motor vehicles, motor vehicle engines and bodies	Manufacture of cars, trucks, buses and their engines, manufacture of bodies (coachwork) for motor vehicles, manufacture of trailers and semitrailers
293	Parts and accessories for motor vehicles:	
2931	Metal products	metal parts of motor vehicles (e.g. brakes, gearboxes, axles, road wheels, suspension shock absorbers, radiators, silencers, exhaust pipes, catalytic converters, clutches, steering wheels, steering columns and steering boxes)
2932	Rubber and plastic	tyres, plastic parts of motor vehicles (e.g. bumpers, dashboards)
2933	Electrical/electronics	electrical/electronic parts of motor vehicles (e.g. generators, alternators, spark plugs, ignition wiring harnesses, power window and door systems, assembly of purchased gauges into instrument panels, voltage regulators, navigation systems, communication equipment, electric motors; switchboard apparatus; relays, batteries and accumulators;airbags
2934	Glass	auto glass
2939	Other	car seats, safety belts, airbags
2999	Parts and accessories unspecified	Parts and accessories for motor vehicles do not fit into 2931-2939 or the exact class is unknown
299	Automotive unspecified	Automotive manufacturing that does not fit into 291 or 293 or the exact class is unknown
30	Other transport equipment	e.g. ships, locomotives, aeroplanes, spacecraft vehicles
91	All other manufacturing branches	
E	**Electricity, gas and water supply**	
F	**Construction**	**General construction and specialized construction activities for buildings and civil engineering works. It includes new work, repair, additions and alterations, the erection of prefabricated buildings or structures on the site and also construction of a temporary nature**
P	**Education, research and development**	
90	All other non-manufacturing branches	
99	Unspecified	Customer industry is unknown

Source: IFR

1.11 IFR CLASSIFICATION OF APPLICATIONS

The current IFR application classification scheme was originally presented in 2004. In World Robotics 2020, the branch of "assembling and disassembling" was simplified (see table 1.2). This upper-level class now only consists of the classes "assembling" and "disassembling" (and "assembling and disassembling unspecified"). All earlier data was transferred into the revised classification scheme.

Table 1.2

IFR Class	Application area	Definitions
110	**Handling operations/machine tending**	**Assistant processes for the primary operation (the robot doesn't process the main operation directly)**
111	Handling operations for metal casting	including die-casting
112	Handling operations for plastic molding	also inserting operations for injection molding
113	Handling operations for stamping/forging/bending	
114	Handling operations at machine tools	
115	Machine tending for other processes	e.g. handling during assembly, handling operations during glas or ceramics production or food production Robots that handle workpieces at an external welding TCP (i.e. MIG/MAG torch or spot gun) need to be reported in the appropriate welding classification (i.e. 161 for arc welding or 162 for spot welding) and shall not be counted to the classification of handling operations.
116	Handling operations for measurement, inspection, testing	triage, quality inspection, calibrating
117	Handling operations for palletizing	all sectors, all kinds and sizes of pallets
118	Handling operations for packaging, picking and placing	e.g. operations during primary and secondary packaging
119	Material Handling n.e.c.	e.g. transposing, handling during sandcasting
120	Handling operations/machine tending unspecified	the exact IFR 11X class is unknown
160	**Welding and soldering**	**all materials**
161	Arc welding	
162	Spot welding	
163	Laser welding	
164	Other welding	e.g. ultrasonic welding, gas welding, plasma welding
165	Soldering	
166	Welding and soldering unspecified	the exact IFR 16X class is unknown
170	**Dispensing**	
171	Painting and enamelling	area-measured application of lacquer (surface coat)
172	Application of adhesive, sealing material or similar material	spot-wise and line-wise
179	Dispensing others/spraying others	e.g. powder coating, application of mould release agent, area-measured application of adhesive, spraying of wax
180	Dispensing unspecified	the exact IFR 17X class is unknown
190	**Processing**	**enduring changing, the robot leads the workpiece or the tool, material removal**
191	Laser cutting	
192	Water jet cutting	
193	Mechanical cutting/grinding/deburring/milling/polishing	
198	Other processing	e.g. gas/plasma cutting, drilling, bending, punching, shearing
199	Processing unspecified	the exact IFR 19X class is unknown
200	**Assembling and disassembling**	**enduring positioning of elements**
201	Assembling	assembling, mounting,screw/nut-driving, clinching, reveting, bonding
203	Disassembling	recycling, removal of cover after processing
209	Assembling and disassembling unspecified	the exact IFR 20X class is unknown
900	**Others**	
901	Cleanroom for FPD	Cleanroom applications for flat-panel displays
902	Cleanroom for semiconductors	Cleanroom applications for semiconductors
903	Cleanroom for others	Other cleanroom applications
905	Others	Applications that were not mentioned before, including applications that are considered as service robotics
999	**Unspecified**	**the application is unknown**

Source: IFR

1.12 IFR GEOGRAPHY CLASSIFICATION

The primary intention and motivation of IFR industrial robot statistics is to create information about the robotics industry for the robotics industry. Therefore, IFR created a geography classification scheme that represent relevant robotics markets rather than political or cultural territories.

There are currently 76 geographical units surveyed. These survey items are the lowest-level geographical units in the IFR geographical classification scheme. They are often, but not necessarily, congruent to countries.

The analysis and evaluation of the survey data aggregates the geographical units along several hierarchy levels. Each survey item is assigned to a continent and all continents form the world, which is the top hierarchy level. Sometimes it is necessary or meaningful to define intermediate hierarchy levels, but not all survey items use all these intermediate levels. These levels may represent relevant markets, or they may be necessary to satisfy compliance rules (see chapter 1.3). The full hierarchy is (from lowest to highest level):

Survey item → country group → region → continent → world

Figure 1.1 in chapter 1.3 shows the assignment of survey items from bottom to top. Therefore, this chapter only describes the names and abbreviations used to describe geographical units. World Robotics Premium customers can find this list including the superior hierarchy level as a CSV download in the “reporting” section of my.worldrobotics.org.

Table 1.3

IFR geography classification		
Survey items		
IFR code	**Geographical unit**	**Superior item**
AE	United Arab Emirates	RAS
AR	Argentina	RAM
AT	Austria	WEU
AU	Australia	AUNZ
BA	Bosnia-Herzegowina	YUG
BE	Belgium	WEU
BG	Bulgaria	OEE
BR	Brazil	SAM
BY	Belarus	OEE
CA	Canada	NAM
CH	Switzerland	WEU
CN	China	SAS
CO	Colombia	RAM
CR	Croatia	YUG
CZ	Czech Republic	CEU
DE	Germany	WEU
DK	Denmark	NEU
EE	Estonia	OEE
EG	Egypt	ROA
ES	Spain	WEU

Table 1.3 (continued)

IFR geography classification		
Survey items		
IFR code	Geographical unit	Superior item
FI	Finland	NEU
FR	France	WEU
GR	Greece	OEU
HK	Hong Kong	OSAS
HU	Hungary	CEU
IC	Iceland	OEU
ID	Indonesia	SAS
IE	Ireland	OEU
IL	Israel	OEU
IN	India	SAS
IR	Iran	RAS
IT	Italy	WEU
JP	Japan	SAS
KP	North Korea	OSAS
KR	Rep. of Korea	SAS
KW	Kuwait	RAS
LT	Lithuania	OEE
LV	Latvia	OEE
MA	Morocco	ROA
MD	Moldova	OEE
MO	Macau	OSAS
MT	Malta	OEU
MX	Mexico	NAM
MY	Malaysia	SAS
NL	Netherlands	WEU
NO	Norway	NEU
NZ	New Zealand	AUNZ
OA	Other Asia	ASI
OAF	Other Africa	ROA
OM	Oman	RAS
OT	Others not specified	WR
PE	Peru	RAM
PH	Philippines	OSAS
PK	Pakistan	RAS
PL	Poland	CEU
PR	Puerto Rico	RAM
PT	Portugal	WEU
QA	Quatar	RAS
RCH	Chile	RAM
RO	Romania	CEU
RS	Serbia	YUG
RU	Russian Federation	CEU
SA	Saudi Arabia	RAS
SE	Sweden	NEU
SG	Singapore	SAS
SK	Slovakia	CEU
SL	Slovenia	YUG
TH	Thailand	SAS

Table 1.3 (continued)

IFR geography classification		
Survey items		
IFR code	**Geographical unit**	**Superior item**
TN	Tunisia	ROA
TR	Turkey	REU
TW	Chinese Taipei	SAS
UA	Ukraine	OEE
UK	United Kingdom	WEU
US	United States	NAM
UZ	Uzbekistan	RAS
VE	Venezuela	RAM
VN	Vietnam	SAS
ZA	South Africa	AFR
Country groups		
IFR code	**Geographical unit**	**Superior item**
AUNZ	Australia/New Zealand	ASI
EUU	Europe unspecified	EU
OEE	other Eastern Europe	CEU
OEU	all other European countries	REU
OSAS	other South/East Asia	SAS
RAM	Rest of South America	SAM
ROA	Rest of Africa	AFR
YUG	Balkan Countries	CEU
Regions		
IFR code	**Geographical unit**	**Superior item**
NAM	North America	AM
SAM	South America	AM
AS	America, not specified	AM
SAS	South East Asia	ASI
RAS	Rest of Asia	ASI
CEU	Central/Eastern Europe	EU
WEU	Western Europe	EU
NEU	Nordic Countries	EU
REU	Rest of Europe	EU
Continents		
IFR code	**Geographical unit**	**Superior item**
AFR	Africa	WR
AM	America	WR
ASI	Asia/Australia	WR
EU	Europe	WR
Top level		
IFR code	**Geographical unit**	**Superior item**
WR	World	-

Source: IFR

1.13 DISTRIBUTION AND SALES CHANNELS FOR INDUSTRIAL ROBOTS AND THEIR IMPACT ON IFR DATA COLLECTION

This chapter sheds light on the distribution and sales channels found in the industrial robotics industry. It is supposed to help readers who are new to the industry to understand the different ways robots may take from their production to the installation at the end user's site. It will also provide some background knowledge that is helpful to understand and interpret IFR industrial robot statistics.

The content of this chapter is based on interviews and material received from robot suppliers (robot producers, component suppliers, system integrators). The channels describe different setups that can generally be found in the industry. There may always be individual projects or use cases that deviate from the sketched channels.

The terms "distribution channel" and "sales channel" are closely related and may intersect, depending on the definition. In this chapter, distribution channel will refer to the stations a robot takes physically, while sales channel refers to the communication method used between vendor and customer.

1.13.1 DEFINITION OF THE MARKET PLAYERS

- ROBOT PRODUCERS: COMPANIES THAT BUILD INDUSTRIAL ROBOTS.
- DISTRIBUTORS ("RESELLERS"): COMPANIES THAT BUY ROBOTS FROM ROBOT PRODUCERS IN ORDER TO SELL THESE ROBOTS WITHOUT ANY CHANGE OR WITH ONLY MINOR CHANGE (E.G. ADDITIONAL COMPONENTS).
- SYSTEM INTEGRATORS ("INTEGRATORS"): SYSTEM INTEGRATORS BUY ROBOTS AND OTHER AUTOMATION GEAR TO BUILD COMPLEX AUTOMATION SOLUTIONS. SYSTEM INTEGRATORS CAN BUILD EITHER STANDARD SOLUTIONS (PRE-CONFIGURED SOLUTIONS FOR SPECIFIC APPLICATIONS, E.G. WELDING CELLS, MACHINE TOOLS) OR CUSTOMIZED SOLUTIONS, TAILORED TO AN INDIVIDUAL END USER'S SPECIFICATIONS AND NEEDS (SPECIAL ENGINEERING).
- END USERS (OR "USERS"): THE END USER OF THE ROBOT; THE POINT OF INSTALLATION (POI).

NOTE: THE TERM "CUSTOMER" DESCRIBES A DOWNSTREAM MARKET PLAYER. THE TERM "VENDOR" DESCRIBES AN UPSTREAM MARKET PLAYER.

1.13.2 DISTRIBUTION CHANNELS

There are four different types of distributions channels found in industrial robotics:

- **Distribution channel 1: Directly to end user:**
  The robot producer sells and ships directly to the end user. The end user may hire a system integrator to install these robots. Today, many robot suppliers offer intuitive or hand-guided programming or offer collections of generic programs for different applications in online databases. This may render the service of a system integrator obsolete, particularly in the case of simple tasks and environments that do not require the robot to be embedded in a complex setup.
- **Distribution channel 2: To system integrator**
  The robot producer sells and ships to a system integrator. The system integrator delivers a turnkey solution to the end user. This turnkey solution includes one or

more robots alongside other automation gear, e.g. conveyors and machine tools. Often the robot producer puts the end user in contact with the integrator to develop a solution for the specific use case. Depending on the specific case, the robot producer may or may not have the project lead and be more or less closely involved.

- **Distribution channel 3: Retail**
  In this setup, the robot producer sells and ships to a reseller or distributer. This distributor sells and ships to the end user. There is no direct contact from the robot producer to the end user.
- **Distribution channel 4: Wholesale**
  This channel involves four parties: The robot producer sells to a wholesale distributor, who sells to a system integrator or retailer. The system integrator sells to the end user. There are two intermediaries between the robot producer and the end user, so there is no direct contact between robot producer and end user.

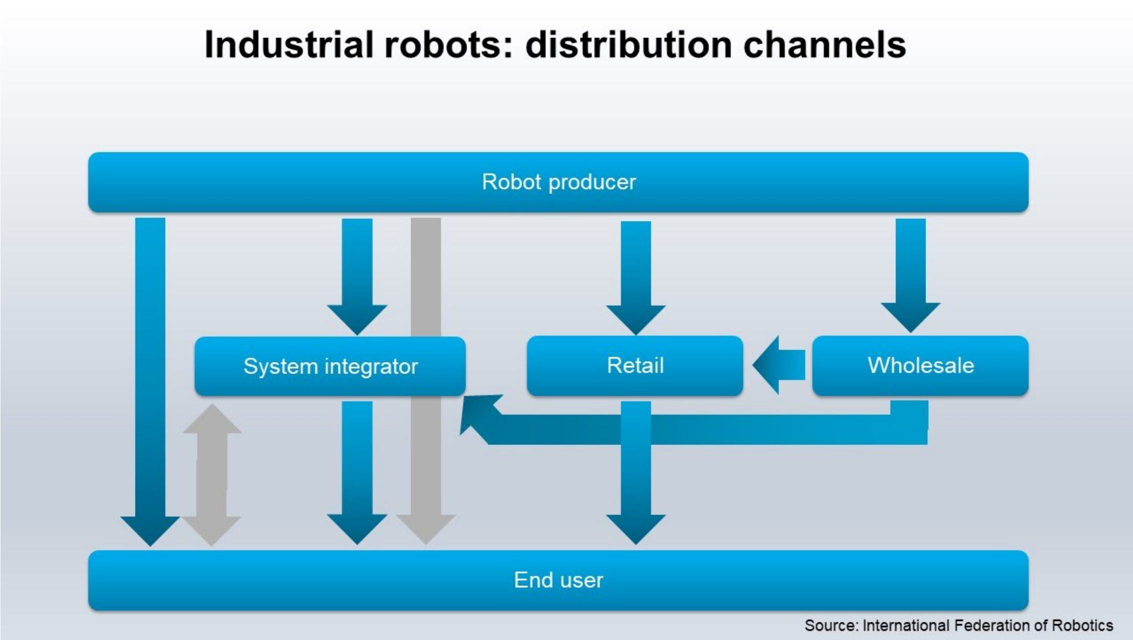

Figure 1.5: Distribution channels for industrial robots

1.13.3 SALES CHANNELS

The communication between vendors and customers in the industrial robot market can take the following forms:

- **Sales channel 1: Sales representative**
  The vendor has sales representatives who talk to customers, assess their needs, and suggest one or more solutions for the specific use case.
- **Sales channel 2: Online B2B order system**
  The vendor negotiates a quota of robots that the customer can call forward using a digital interface. This channel is common in the relationship of robot producers and large system integrators or resellers, but it could also be offered by resellers

for large customers. A sales representative is only involved in the negotiation of the contract but not in the processing of the call.

- **Sales channel 3: Web shop**
  The vendor offers a web shop through which the customer can order. This setup can be used by robot producers for factory sales but also by system integrators (for standardized products), retail, and wholesale.

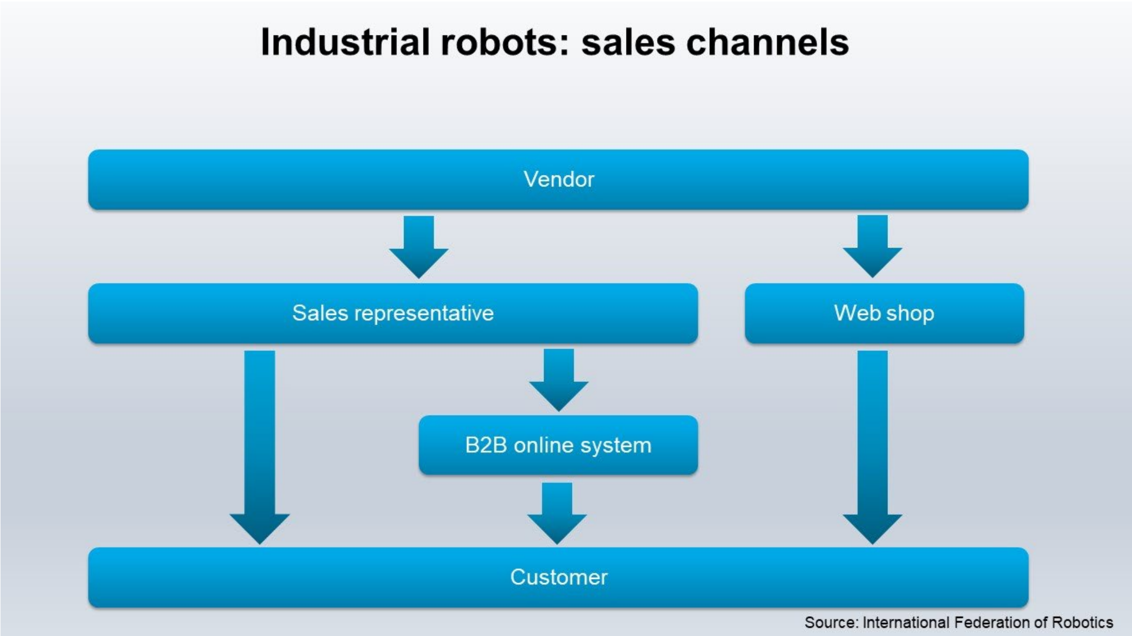

Figure 1.5: Sales channels for industrial robots

1.13.4 DATA COLLECTION FOR IFR INDUSTRIAL ROBOT STATISTICS

IFR Statistical Department relies on data provided by robot producers, either directly to IFR (primary data) or through national robotics associations (secondary data). Robot producers are encouraged to track their sales through all distribution and sales channels to obtain the statistical information on the point of installation (POI: geographic destination, application, and industry) for each unit. Shipment data should only be used as a second-best option if installation data is not available because the timing and the geographic destination might deviate from the actual installation date and location. Such deviations will translate into biased operational stocks and biased robot densities, as these indicators are computed from the installation data.

There are different challenges associated with data tracking in the different channels.

Counter-intuitively, collecting statistical data on robots distributed through channel 1 is not the easiest exercise. These robots are often easy-to-program models that the user configures and programs herself. Information on the application might not be easy to retrieve. On the other hand, using shipment instead of installation data is a good alternative because it is rather unlikely that end users hold a robot inventory or export the units to another country. The case is different for large customers. These customers are sufficiently large to have their own in-house expertise to configure and install the robots. In these cases, statistical data can be retrieved if the customer provides it to the robot producer.

For units distributed through channel 2, robot suppliers rely on the cooperation of system integrators to obtain data on the POI. There are numerous integrators worldwide. Many of them are specialized in the models of one or two robot suppliers and there are often close and trusty business relationships between robot suppliers and system integrators. It is common that large system integrators contract for a specific annual quota to be delivered on demand (sales channel 2). These integrators often place orders directly into the robot supplier's order system, without sales managers being involved in the transaction. If the statistical information is not requested automatically by the order system, it must be retrieved afterwards. Also, the accuracy of this data can hardly be verified, and the data will not be available if the integrator refuses to cooperate (e.g., because of non-disclosure agreements with the end user). Using shipment instead of installation data is error-prone in this channel because systems are often exported so that the actual destination of the installation is different from the shipment destination. Vertical integration is a promising variant for statistics in this channel: Many robot suppliers offer system integration, too. In this case, there is a direct contact to the end users and all the required statistical information is available.

Robots distributed through retailers (channel 3) seem to be a particular burden for statistics. While the shipment destination is clear, the further whereabouts are largely unknown. Retailers could export the robots, causing an incorrect geographical attribution if shipment data is used instead of installation data. The time attribution could be biased if the retailer holds inventory. Application and end user's industry are mainly unknown. Much like in the case of system integrators, robot suppliers need to rely on the retailer's cooperation. But unlike system integrators, retailers might not possess all the required information, either. In the case of wholesale models (channel 4), the challenges of channels 2 and 3 are combined.