1 Introduction

Chapter 1 reviews definitions and classifications of industrial robots and service robots.

1 Introduction: Sources and methods

1.1 COMPLIANCE

The IFR Statistical Department ensures the confidentiality of individual company data. Access to raw data is strictly limited to IFR Statistical Department staff. The IFR Statistical Department will never provide company-level data to third parties neither outside nor inside the IFR. This means that the IFR Statistical Department publishes only aggregated data by country, by industry, or by application area. The IFR Statistical Department will not reveal data if a number consists of less than four observations. This is to prevent mathematical retrieval of company-level data. If there are less than four reports, the numbers will be added to “all others” or “unspecified”. This rule has been applied since 2015.

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.

1.2 COVERAGE, ACCESS TO DATA FOR PREVIOUS YEARS AND CONTACT

The annual publication “World Robotics Industrial Robots: Statistics, Market Analysis, Forecasts, Case Studies and Profitability of Robot Investments” 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” covers 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 and supplemented with data provided by several national robot 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 2013 to 2018.** 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 contains **forecasts** for the world industrial robot market **2019-2022** as well as major trends in customer industries and main countries.

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 manufacturing 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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1.3 DATA SOURCES, REVISIONS, RELIABILITY AND VALIDITY

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 industrial robot suppliers worldwide report to the IFR Statistical Department directly. If a table or graph does not mention a specific source, it means that it is primary data and the source is "IFR Statistical Department".

Several national robot 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.

Since 2015, the Korean Association of Robot Industry (KAR) has been providing data on Korean production, imports and exports. Before, 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 RIA 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 Robotic Industries Association (RIA) provides data on North America. The statistics report installation data from North American companies in compliance with the IFR industry and application classifications. Primary data not included in the RIA statistics and JARA data on exports to North America supplement this data. Until 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.

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)

Quality, reliability and validity

The IFR Statistical Department considers the high-quality data to be valid and reliable.

The IFR Statistical Department provides definitions and delimitations of robot types, industries and applications for 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. For some countries there is also information on sales in monetary units available. The IFR Statistical Department considers these indicators to be 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 the IFR Statistical Department to check the data for consistency.

Revisions

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 rather large time lag. Thus, employment data is often preliminary or estimated and must be revised later.

In the processing of this vast statistical material, errors are inevitable. The IFR Statistical Department would be most grateful for a notification, if the reader happened to find such an error.

Major revisions: The current issue of World Robotics Industrial Robots does not contain major revisions. The most important major revision of the past was a downwards revision of the robot stock of the former USSR that affected the robot stock before 2007. The data originated from the end of the 1980s and early 1990s before the transition of the economic system. In view of the profound industrial restructuring, it can be suspected that a large share of those robots had been taken out of operation – some of the reported units probably were never taken into operation. Some 80% of the 1990 robot stock consisted of simple sequence-controlled robots.

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 robot associations

1.5 DEFINITION OF "SHIPMENTS" AND "INSTALLATIONS"

World Robotics Industrial Robots uses the words "shipments" and "installations" of industrial robots synonymously. This is 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. Note that shipment and installation data might differ for several reasons. Geographical deviations might for instance occur, if - without the knowledge of the producer- a reseller installs a robot in a different country than the producer shipped it to. The time of installation might be assigned earlier if a robot is shipped, but not installed at year-end, e.g. because it is en route or went to the inventory or is work-in-progress at the integrator.

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, the 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**).[3] This investigation suggested that an assumption of 12 years of average life span might be too conservative and that the average life/ 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.

[3] 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 the IFR Statistical Department.

1.7 DEFINITIONS AND CLASSIFICATIONS

1.7.1 INDUSTRIAL ROBOTS DEFINITION (ISO 8373:2012) AND DELIMITATION

World Robotics Industrial Robots presents statistics on the production, imports, exports and installations/shipments of industrial robots (at least three or more axes) as described in ISO 8372:2012:

INDUSTRIAL ROBOT AS DEFINED BY ISO 8373:2012:

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

The terms used in the definition above mean:

- Reprogrammable: designed so that the programmed motions or auxiliary functions can be changed without physical alteration;
- Multipurpose: capable of being adapted to a different application with physical alteration;
- Physical alteration: alteration of the mechanical system (the mechanical system does not include storage media, ROMs, etc.)
- Axis: direction used to specify the robot motion in a linear or rotary mode

Figures 1.1 shows examples of robot types which are covered by this definition and hence included in the surveys.

A robot which has its own control system and is not controlled by the machine should be included in the statistics, although it may be dedicated for a special machine. Other dedicated industrial robots should not be included in the statistics.

- Wafer handlers have their own control system and should be included in the statistics of industrial robots. Wafers handlers can be articulated, cartesian, cylindrical or SCARA robots. Irrespective of the type of robots they are reported in the application “cleanroom for semiconductors”.

- Flat panel handlers should also be included. They are mainly articulated robots. Irrespective of the type of robots they are reported in the application “cleanroom for FPD”.

Examples of dedicated industrial robots that should not be included in the international survey are:

- Equipment dedicated for loading/unloading of machine tools
- Dedicated assembly equipment, e.g. for assembly on printed circuit boards
- Integrated Circuit Handlers (pick and place)
- Automated storage and retrieval systems
- Automated guided vehicles (AGVs) (see “World Robotics Service Robots”)

The submission of statistics on industrial robots is mandatory for IFR member associations.

1.7.2 DEFINITIONS OF ROBOT TYPES

In agreement with the robot suppliers, robots should be classified only by mechanical structure as of 2004.

Classification by mechanical structure:

- Linear robots (including cartesian and gantry robots)
- SCARA robots
- Articulated robots
- Parallel/delta robots
- Cylindrical robots
- Others
- Not classified

Figures 1.1 illustrates the mechanical configuration of these types of robots.

The number of axes should be understood as the basic feature supplied by the producer and not axes added later by the user.

Robots broken down by mechanical structure are based on the following definitions:

Cartesian robot: robot whose arm has three prismatic joints and whose axes are correlated with a cartesian coordinate system

SCARA robot: a robot, which has two parallel rotary joints to provide compliance in a plane

Articulated robot: a robot whose arm has at least three rotary joints

Parallel/Delta robot: a robot whose arms have concurrent prismatic or rotary joints

Cylindrical robot: a robot whose axes form a cylindrical coordinate system

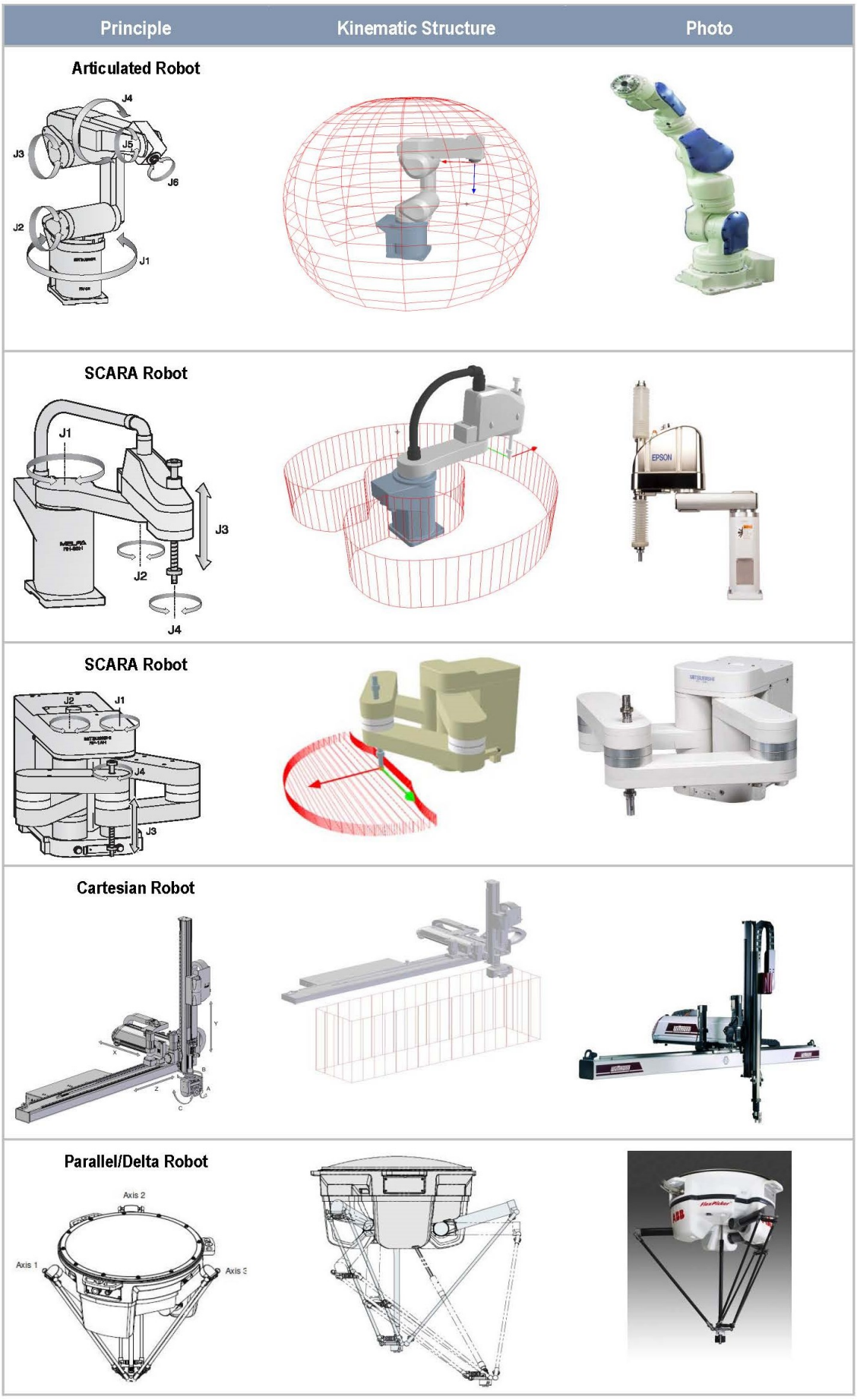


Figure 1.1: Classification of industrial robots by mechanical structure

Examples of articulated robots:

©NACHI

©FANUC

Flexible mounting possibilities – optimized working range

©ABB

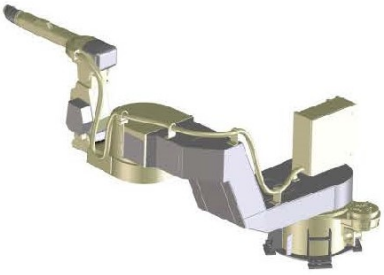
©EPSON

Welding Robot

©DAIHEN

©KUKA

Examples of articulated robots:



©Dürr

The Swingarm is an articulated robot combined with SCARA elements

Different dualarm robots

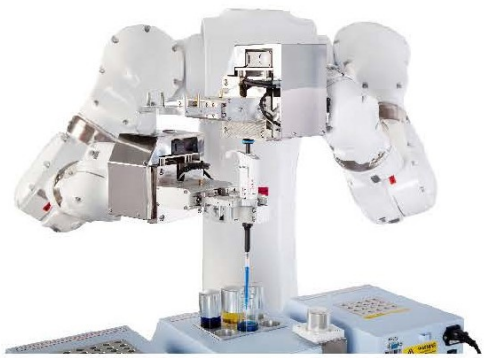
©Universal Robots

©EPSON

©Comau

©ABB

©Schunk



©YASKAWA

Examples of applications of articulated robots:

Handling for metal casting

©Comau

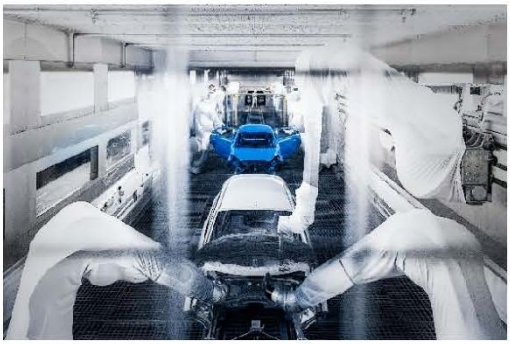
Packaging

©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:

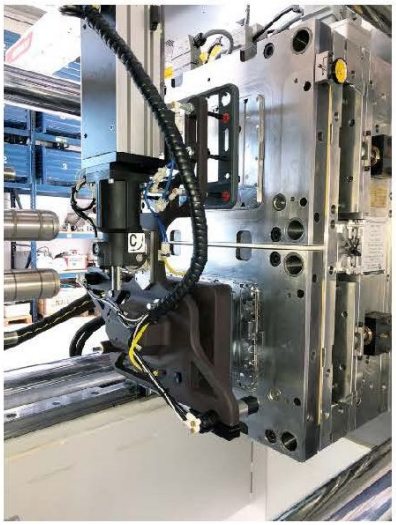
Material Handling

©GÜDEL

Material Handling

©GÜDEL

Machine feeding



©Wittmann

Handling for plastic moulding

©Wittmann

Examples of parallel robots:

©Omron

©FANUC

Examples of applications of parallel robots:

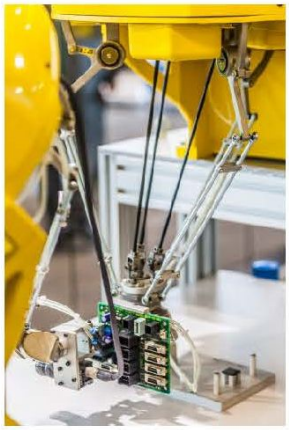
Picking and Placing

©Omron

Assembly

©ABB

Handling



©FANUC

Picking and Placing

©FANUC

1.7.3 CLASSIFICATION OF INDUSTRIES

Starting from the 2010 issue, data broken down by industrial branches is reported based on the International Standard Industrial Classification of All Economic Activities (ISIC) revision 4. The categories do not correspond exactly to the ISIC rev4. In previous issues, data was presented according to ISIC revision 2 or 3. In conjunction with the change of classification system, the number of branches to be surveyed by the IFR questionnaire was extended, reflecting the need for deeper analysis of the distribution of robots. (see table 1.1). All earlier data was transferred into this classification.

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)
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
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)
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
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	

Sources: IFR

1.7.4 CLASSIFICATION OF APPLICATIONS

From 2004, the applications have been revised in agreement with the robot suppliers. All earlier data was transferred into the revised classification. The table 1.2 below shows the type of classification, by application areas.

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 moulding	also inserting operations for injection moulding
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
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	
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 to conserve)
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
200	**Assembling and disassembling**	**enduring positioning of elements**
201	Fixing, press-fitting	screw/nut-driving, clinching, reveting, bonding
202	Assembling/ mounting/ inserting	also temporarily positioning to facilitate the assembling process
203	Disassembling	recycling, removal of cover after processing
208	Other assembling	not mentioned before
900	**Others**	
901	Cleanroom for FPD	
902	Cleanroom for semiconductors	
903	Cleanroom for others	
905	Others	not mentioned before
999	**Unspecified**	**the application is unknown**

Sources: IFR