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Review Article

Industrial, Collaborative and Mobile Robotics in Latin America: Review of Mechatronic Technologies for Advanced Automation

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Abstract

Mechatronics and Robotics (MaR) have recently gained importance in product development and manufacturing settings and applications. Therefore, the Center for Space Emerging Technologies (C-SET) has managed an international multi-disciplinary study to present, historically, the first Latin American general review of industrial, collaborative, and mobile robotics, with the support of North American and European researchers and institutions. The methodology is developed by considering literature extracted from Scopus, Web of Science, and Aerospace Research Central and adding reports written by companies and government organizations. This describes the state-of-the-art of MaR until the year 2023 in the 3 Sub-Regions: North America, Central America, and South America, having achieved important results related to the academy, industry, government, and entrepreneurship; thus, the statistics shown in this manuscript are unique. Also, this article explores the potential for further work and advantages described by robotic companies such as ABB, KUKA, and Mecademic and the use of the Robot Operating System (ROS) in order to promote research, development, and innovation. In addition, the integration with industry 4.0 and digital manufacturing, architecture and construction, aerospace, smart agriculture, artificial intelligence, and computational social science (human-robot interaction) is analyzed to show the promising features of these growing tech areas, considering the improvements to increase production, manufacturing, and education in the Region. Finally, regarding the information presented, Latin America is considered an important location for investments to increase production and product development, taking into account the further proposal for the creation of the LATAM Consortium for Advanced Robotics and Mechatronics, which could support and work on roboethics and education/R+D+I law and regulations in the Region.

Keywords:

Mechatronics;
Robotics;
Industry;
Automation;
Human-Robot Interaction;
Latin America.

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1- Introduction

Over the last few years, the mass production and industrial competitiveness of Latin America have increased internationally, generating a motivation to improve the quality of the products and services in the industrial sectors. The implementation of state-of-the-art technologies that integrate the fourth industrial revolution encompasses technologies that interact, such as data science, artificial intelligence, or the IoT (Internet of Things), to meet the highest levels of quality demand of information, productivity, efficiency, security, and profitability [1–3]. The data generated allows us to monitor the quality of a product. It is worth mentioning that industry 4.0 is not to replace people; it is to improve product quality since there are processes that cannot be replaced. Robotics is key to the success of Industry 4.0 [4]. An industrial robot is a reprogrammable multifunctional manipulator capable of moving materials, parts, tools, or special devices according to variable trajectories and performing various tasks. There are robots with more advanced functions, which integrate vision to carry out inspections or precision adjustments. Collaborative robotics is designed to interact with people safely. The potential of robotics in the industrial sector is immense due to the various tasks to which it has been applied, among which are: robotic welding, foundry handling, mold handling, and plastic molding handling, among others.

Working with robots brings flexibility, safety, and protection to operators against harsh environments and dangerous work. Robots can perform functions without loss of production due to failures, fatigue, coordination, or planning problems [5, 6]. Thanks to Industry 4.0, this has been favored for the productive development of any country and the consolidation of production chains. Still, in various countries, it is necessary to increase their level of industrialization through activities that improve their competitiveness and promote sectors with high added value, providing a generation of jobs and greater absorption and technological integration [7, 8]. For this reason, it is essential to mention the need to increase industrialization by integrating automation and robotics in the industrial sector. Initially, the investment could be high; however, the benefits that this integration constitutes will be genuinely representative since greater production will be obtained in less time, operational costs will be reduced, and the most demanding quality and safety standards of each country will be met, generating a strategy for the digital transformation of any country [9, 10].

Therefore, this paper consisted of a review with three objectives, summarized as: (1) Present the first science manuscript in history, where the main technical and research data about the state-of-the-art of robotics in Latin America is shown. (2) Multi-Collaborative study between international robotics institutions that integrates the academy and industry. (3) Show the most important and growing fields of robotics development in Latin America. Then, following an introduction, the rest of the paper is structured as: Section 2 states the methodology used for data analysis, then Section 3 presents the context of robotics and automation in Latin America. Section 4 shows the exponential innovations made by robot manufacturers and software platforms. Section 5 describes the present and future of high performance in robotics, which exhibits advanced applications around the world that can be proposed to be implemented in the Region. Finally, the paper ends with a conclusion and future insights.

2- Materials and Methods

This study has been undertaken as a general literature review based on the original guidelines proposed by Kitchenham [11]. Thereby, the following principal question was raised: what are the advances and outcomes in the applications of robotics in Latin America? The main contribution of this work is to have a better knowledge of this developing technology and, thus, with this highly specialized group of authors with professional backgrounds in engineering and science, be able to promote their concomitant use as industrial, collaborative, and mobile mechatronic systems. The objectives are aligned with the support of PICOC criteria (population, intervention, comparison, outcomes, and context).

Table 1 shows the (PICOC) structure of this research [12]. The analysis was conducted from December 2021 to January 2023, and EndNote was used for reference management. To start the search, an appropriate combination of Data Bases has been chosen to increase the likelihood of finding highly relevant articles. The foremost predominant literature is looked for in the widest possible selection of publications. The references are found in: Scopus, Web of Science, and Aerospace Research Central. In addition, some government/company reports are used for the identification of robotics applications.

Table 1. Summary of PICOC

Population	The literature on robotic system applications in Latin America
Intervention	Industrial, collaborative, and mobile robots
Comparison	Robotics in some countries of Latin America, such as Argentina, Chile, Colombia, Mexico, Panamá and Central America, and Peru.
Outcomes	Robotic applications considering Industry 4.0 and Digital Manufacturing, Architecture, and Construction, Aerospace, Smart Agriculture, and Artificial Intelligence and Computational Social Science applications
Context	Studies in industry and academia, small and large data sets

3- Robotics and Automation in Latin America

3-1- Argentina

This section depicts a general overview of the status of industrial robotics in Argentina. In the country, the current indicator is 18 robots per 10,000 workers, and the commercial demand is about 400 average annual sales, which are mostly concentrated in the automotive industry, the first to incorporate this technology. Other applications are: a) Forging transfer of parts, b) Electronic assembly, c) Finishing of parts and surfaces, d) Application of adhesives, e) Inspection and quality control, f) Arc welding, g) Loading, and unloading of machines, h) Painting and enameling, i) Assembly of parts, j) Plastic molding, k) Polishing, l) Machining, m) Spot welding. According to the IMD World Competitiveness Yearbook 2022 (WCY) [13], Argentina is ranked in the 62nd position. The International Robotics Federation (IRF) presents a report based on available data broken down by application and by industry shown in Table 2 [14], big companies in Argentina use a lot of robotics in their industrial plants. Those, have well-trained engineers capable of identifying what each new operation requires to turn it into a more flexible and automatic by installing robots and peripheral equipment [15].

Table 2. Distribution of the use of robots by industry applications [16]

Industry	Quantity
Food and Drinks	147
Textiles	2
Wood and Furniture	2
Paper	13
Plastics and Chemicals	75
Glass, Ceramics, and Related	8
Metal	437
Electricity/Electronics	8
Automotive	1313
Other Vehicles	2
Other Branches	51
Total	**2058**

Nowadays, small and middle-size companies (PYMES), where the engineers are responsible for making the "ROI And Financial" analysis (based on technical training programs [17]), require the following activities: a) Inspecting the production line, b) Requesting for information about their manufacturing process, c) Designing technical proposals to achieve the goals, d) Preparing the engineering documentation required to provide the robot and its peripheral components, e) Assembling the complete robotic cell, f) Programming and start-up machine operation, g) Providing a very practical training course for the owner [18].

Currently, about 30,000 robots are already performing agricultural tasks around the world, and more than 1,000 of them are working in Argentina. Experts in precision agriculture at “Instituto Nacional de Tecnología Agropecuaria – INTA”, at Concepción del Uruguay, maintain that agricultural activity remains the least digitized segment of the world economy. Argentina is currently in 13th place in the development of technologies for agriculture, among the 194 countries of the United Nations [19]. Experts agree that the best way to measure which are the countries with the most robots in their plants is by counting the units for every 10,000 active employees, where Argentina occupies 36th place with 16 units [20].

Universities have contributed a lot to this aspect by providing training at different levels, for example, “Universidad Tecnológica Nacional at Facultad Regional Córdoba” creates a robotics program [21], and also a robotics school at Misiones [22]. The National State and Provinces, drive Robotics from the disclosure of Industry 4.0 through grants and programs such as Cordoba 4.0 [23]. The Robotics and Educational Technology program is an initiative of the Federal Council for Science and Technology, to promote the use of robotics in the classroom and the tools offered by new technologies for innovative and collaborative learning [24-26].

3-2- Chile

This section depicts a general overview of the status of industrial robotics in Chile. To the best knowledge of the authors, there is no formal study or statistical analysis of industrial robotics in this country. Despite having several years of autonomous mining trucks, industrial robotics is still not extensive enough in the country, given that it lacks a strategy for guiding and fostering this kind of technological adoption [27-30]. Nevertheless, there are surging new initiatives such as the national policies for artificial intelligence which intend to define strategic guidelines for this kind of technological development and include industrial robotics as one of their 8 objectives [31].

According to the IMD World Competitiveness Yearbook 2022 (WCY) [13], Chile is ranked in the 45th position with the industry mainly related to mining, telecommunications, fishing, and retail sectors. Although according to the International Federation of Robotics (IFR) [32], there are about 200 industrial robots installed in Chile, there are certain national laws that encourage industrial robots’ usage for supporting human tasks such as Law 20949 [33], which lowers the maximum payload for workers from 50 to 25 kgs, and just if manual manipulation is unavoidable, so it is expected to motivate a continuous growth of robot’s installations. Although there is little detailed information about how industrial robots are distributed along with the country, there are 14 observations for Chile having a mean of 220 imports according to Comtrade (United Nations International Trade Statistics Database) and a mean of 4.9 industrial robots according to IFR installations, with a 56% of Pearson correlation between both databases for import quantities and 87.6% of Pearson correlation for import values according to [34], as shown in Table 3.

Table 3. Imported quantities based on 14 observations [34]

Organization	Mean	Standard Deviation	Minimum	Maximum
IFR	4.9	4.5	0	16
COMTRADE	220	315.9	8	899

According to data available directly on Comtrade for imports to Chile related to “Machinery and mechanical appliances; industrial robots, N.E.C. or included” with HS (Harmonized System) commodity code 847950, obtaining data from 1997 up to 2021 as shown in Figure 1, there is sustained growth of technological equipment for automation applications.

The principal activities of industrial robotics are in the northern part of Chile, specifically in mining led by Mining Industry Robotics Solution (MIRS) [35], whose main solutions are: a) Robotic starting sheet stripping machine, b) Robotic sampler for truck or rail concentrates, c) Robotic cathode stripping machine, d) Robotic furnace tapping sampling and plugging, e) Robotic sampler from maxibag, f) Robotic baseplate polishing machine, g) Robotic sag mill bolt removal and torquing [36].

In the middle part of the country, the main production is from the food and beverage industries, with some local integrators: Roboris [37], Robotec [38], Pat [39], Austral-Robotics [40], whose principal robotic cells provided by them are: a) Robotic Palletizing Cells of bag, boxes, bottles, b) Robotic Pallet Manage on distribution centers, c) Robotic welding cells. In southern regions working with Salmon Industry as a main productive sector, there are some local integrators: Pat [39], Austral-Robotics [40], whose principal robotic cells provided by them are: a) Robotic palletizing cells (20-25kg), b) Robotic Maxibags / Big bag lines (1250 kg) [41-43].

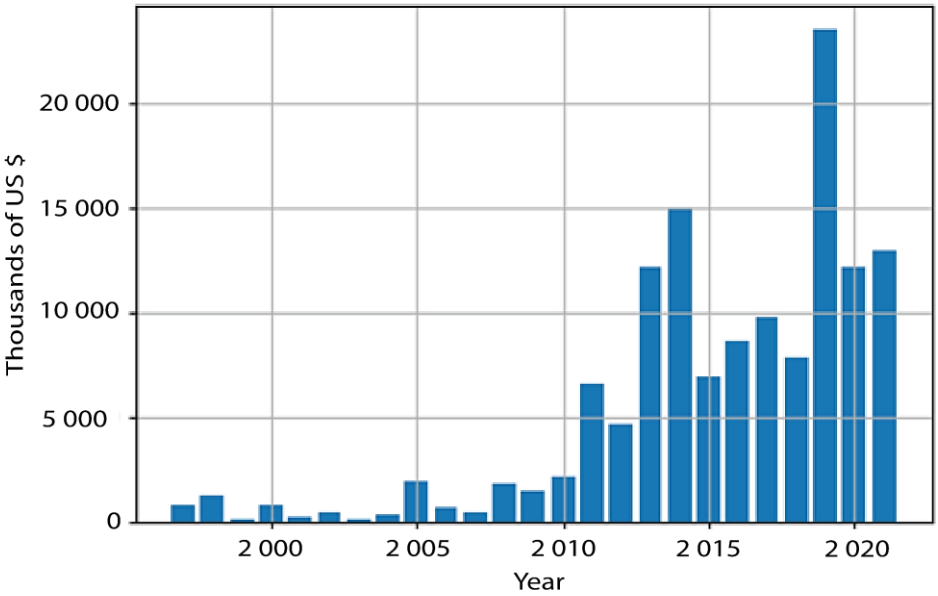

Figure 1. **Trade Value for machinery and mechanical appliances and industrial robots' imports to Chile per year**

3-3- Colombia

According to the IMD World Competitiveness Yearbook 2022 (WCY) [13], Colombia is ranked in the 57th position, which is mainly based on petroleum, manufacturing, coffee growing, pisciculture, and services; there are installed some automation systems most of them without robots. The "Reportero Industrial" magazine [44, 45], shows that almost 500 industrial robots are installed in the Colombian industry, taking into account that there are no automotive and electronics industries for global production [32]. Among the industrial robots installed and reported in LATAM, Colombia has only 116 [16] (shown in Figure 2) classified by applications, which are focused mainly on plastic and chemical product production; and the automotive industry at the General Motors plant.

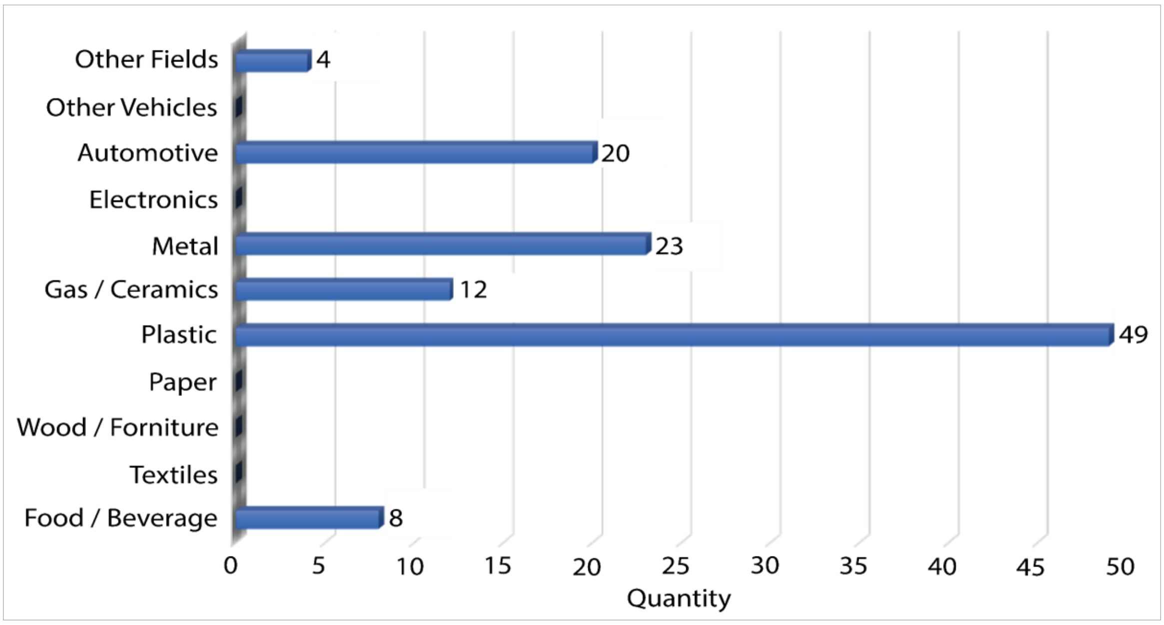

Figure 2. **Number of Robots by Industry [3]**

At the industrial level, despite there are almost 80 robotics companies registered that sell robots and components. A current survey made by 3 companies, which install industrial robots in Colombia, explains the data in Figure 3, where: i) FESTO shows 16 robots, ii) Robotika 40 robots, and iii) CAV Robotics 50 robots; further. FESTO has installed robots in academic environments such as the following: a) SENA-10 Mitsubishi robots, b) University Javeriana-1 Mitsubishi robot, c) 1 KUKA robot, d) 1 UR robots; e) University Agustiniana-1 Mitsubishi robot; f) ETITC-1 Mitsubishi robot; g) University El Bosque-1 Mitsubishi robot. Also, Robotika worked in maintenance, programming, and support tasks for 96 industrial robots around Colombia states.

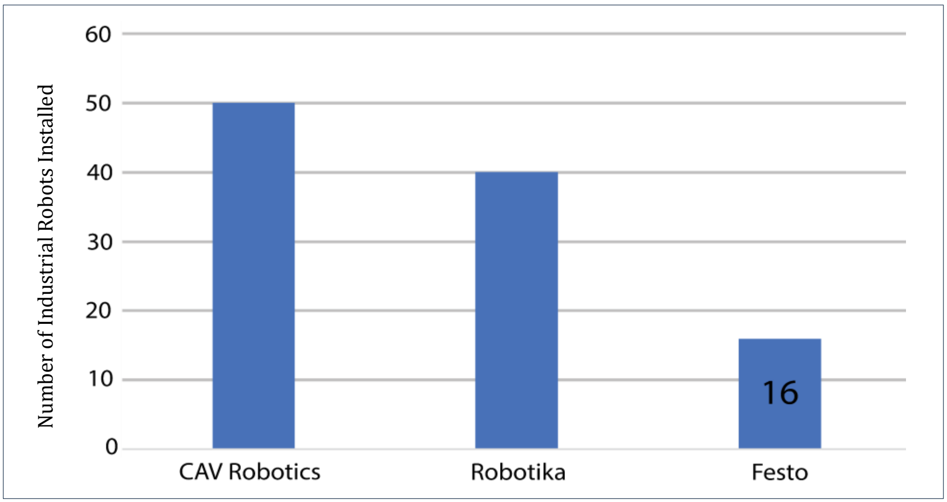

Figure 3. Colombian Companies – Number of Industrial Robots Installed

At University Labs and Technological Institutes, there are some industrial robots installed. The student's work is addressed to robotic foundations workshops, research, and innovation with private companies and the defense sector: integrating artificial intelligence to mounting tasks with industrial robots [46]. At UNAD, there are more than 20 Intellitek industrial robots installed. Besides, the National University of Colombia has around 10 ABB robots. ICRA is a mobile robotics start-up, and it has developed an autonomous mobile robot for floor cleaning of large spaces such as supermarkets or airports, called BOGBOT, and some robots for private companies such as front desk autonomous robots, luggage carrying robots, and robot for flower producers Agroindustry Company [47, 48]. On the STEAM and education projects, ICRA has been able to mentor FRC (FIRST Robotics Competition) team CIP 6001 (Colombian Innovation Program) in 2017 where the team was Rank 1 with a record of 12-4-2 and won the Team Spirit Award sponsored by FCA Foundation [49] and again in 2019 winning the Judge's award [50].

Finally, the robotics sector is very active at the academic scale, and there are a motivation for service robots too, such as: a) A space rover for the University Rover Challenge [51], b) the ROBOCOL initiative by Andes University [52], c) the KIWIBOT company with delivery robots [53], d) Robotics 4.0, a new company which is focused on service Robotics solution development [54], which have delivered more than 50 academic robots (patented locally) to many universities and academic entities in Colombia; and it had directed 2 service robots developments, one for Medical sector; and other for Renewable Energy sector, all of them developed in LATAM. The industrial sector is at its starting phase, the growing trend is due to the economic reactivation policies, and Enterprise innovation [55-57].

3-4- Mexico

This section shows a general review of the status of industrial robotics in Mexico. It has been found that there does not exist a formal study and analysis regarding the actual status of industrial robots, statistics, and applications in different regions in Mexico. This country occupies the 55th position in the IMD World Competitiveness Yearbook 2022 (WCY) [13]. Also, it is among the top 5 largest economies in Latin America [58]. The main industry sectors are vehicles, computer equipment, electrical apparatuses, plastic, and rubber among others. Manufacturing is one of the most relevant economic activities in Mexico, being the automotive sector the most attractive for investments in some regions in the country [59]. This implies a certain level of maturity in technical capabilities such as automation. The Economist Intelligence Unit reports an automation readiness index of a set of 25 countries where Mexico is positioned in the 22nd [60]. In that sense, Mexico also faces the challenge that manufacturing countries have. Moving from traditional automation to smart manufacturing automation, which is needed to achieve personalized goods [61]. This challenge requires among other things, the installation of industrial robotics. Additionally, the main industrial areas where robots are applied in manufacturing are the automotive industry and electronics assembly [62].

Regarding the industrial robotics infrastructure in Mexico, there is little detailed information to identify the status of industrial robotics in the different regions. According to the International Federation of Robotics (IFR) report, Mexico occupies 11th place in the world ranking for robot installation in 2020, with a total of 3,400 units [32]. Other sources of information such as industrial magazines and news agencies had published some data regarding the industrial robot sector. Castro reported that Mexico occupies the 2nd place in robotics installations growth in America with a total of 40,300 units [63]. On the other hand, the industrial magazine Mexico Industry publishes an article where they report robotics data from a census study in San Luis Potosí [64]. Concerning industrial robotics imports data [65], Figure 4 shows the states of Mexico with more investment in robotics during the 2016-2020 period and Figure 5 presents the origin of these imports. The available data regarding industrial robotics in Mexico is difficult to investigate. A more detailed study as presented by Svaco et al. [66] is recommended to present a complete scenario of industrial robotics in Mexico [67, 68].

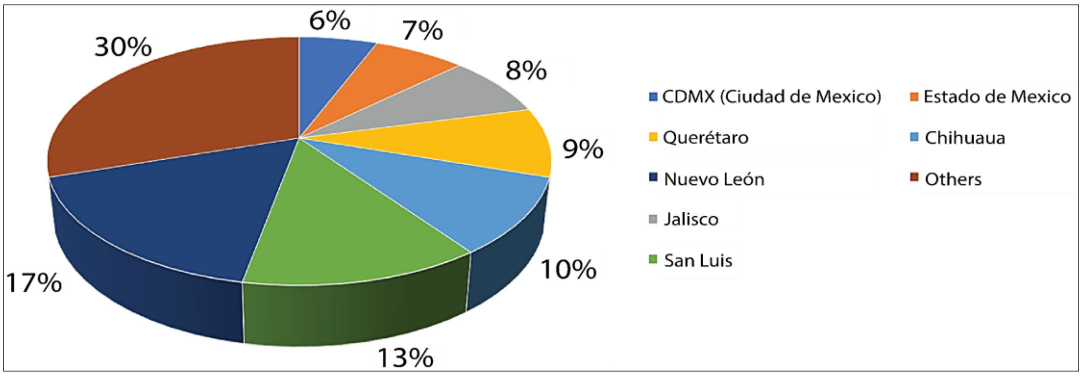

Figure 4. Robotics Investment in the Mexican States 2016-2020

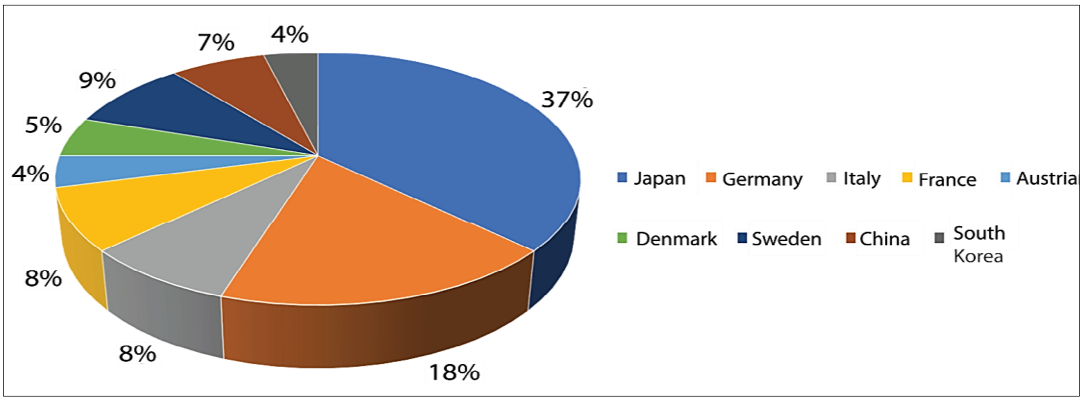

Figure 5. Mexico - Robotics Imports by Country 2017-2019

Education efforts toward teaching robotics in Mexico have been growing since the year 2000. According to Savage et al. [69], the Mexican Robotics Federation (FMR) conformed by several Mexican universities had organized robot competitions focused on high school and undergraduate students. An increasing interest in robotics among young students is evident considering the growing number of students participating in robotics contests in regional, national, and international phases [70].

3-5- Panama and Central America

Due to the advantage of its geographical position, the Republic of Panama has strengthened the tertiary sector of the economy compared to others, which means that few companies are developing the industrial sector. According to a software expert from the international company GBM [71]: "in Panama, the adoption of the robotization process is reaching 5 to 10 percent." The main robotic project applications are: a) Control of gantry cranes, for welding and underwater cleaning of ships [72-74], b) Food industry and agribusiness [75]. On the other hand, the development of a logistics hub, the advancement of industry 4.0, artificial intelligence, and professionals specialized in robotics and automation [76], give the country the real possibility of leading automation in Central America (Table 4). This country occupies the 56th position in the Heritage Foundation-Economic Freedom Status, Ranking 2022 [77].

Table 4. Panama and Central America – Industrial Robotics

	Characteristics
1	From elementary school, the use of robotics and participation in related regional or global events are promoted among students
2	Use of non-governmental organizations to develop the sector, as in Costa Rica the case of the Investment Promotion Agency (CINDE)
3	Packaging processes are the ones that most use industrial robots in the area
4	Multinational manufacturers and distributors of industrial robots are represented in the region

In addition, Costa Rica occupies the 55th position in the Heritage Foundation-Economic Freedom Status, Ranking 2022 [78]. The presence of free zones allows large multinational companies to become interested in investment and expansion. The business area is very varied, there is a presence of industries focused on the design and manufacture of medical devices, software and hardware development, agribusiness, food, or engineering solutions, which generate great contributions to the country through technological growth, knowledge, innovation, and reactivation of economic development. The maximum benchmark is the Coyol Free Zone, which has been recognized by The European magazine as the Best Free Zone in Latin America and the Caribbean for the second consecutive year in 2021 [79]. It is possible due to strategic alliances with educational centers in the national territory, where engineering programs such as

Mechatronics Engineering [80], master's degrees, and technical courses taught by the Instituto Tecnológico de Costa Rica (TEC) [81] stand out, and the manufacturing training by the National Learning Institute (INA) [82]. In terms of robotics at the industrial level, these companies allow continuous development of technology and work in various types of processes. It is estimated that in Costa Rica there are 64% of companies in the service sector are currently in the process of adopting robotics [83], pending a beneficial technological leap in its production. In addition, MicroTech stands out and its manufacturing center with approximately 350 employers with the potential to produce up to 1 billion parts per year [84], has been present for 22 years and is internationally recognized for its high innovation capabilities and confidence in the automotive, medical device, aerospace and other industries with high demand [85]. In the case of Central America, according to Reportero Industrial Magazine [86]: the data is even much lower, and the integration of robots in manufacturing processes is minimal, this is mainly due to the lack of investment by businesses, as a result of fear of income or no return of investment. This means that companies in Latin America do not increase and diversify production, slowing down their growth and limiting their competitiveness.

Most of the installed industrial robots correspond to refurbished robots used in the food industry. Some asbestos Cement Industries located in El Salvador, Honduras, and Costa Rica use large-scale industrial robots to handle heavy materials [87, 88]. In a similar case, in Guatemala, some companies manufacture ceramic floors and integrate robots into their processes. In addition, Costa Rica integrates robots into the electronics industry, being the main country in Central America that uses robots in its manufacturing processes. In the case of the Academy, at least one university in each Central American country has industrial robots for teaching-learning in careers such as Mechatronics Engineering, while the use of robotics has been introduced from an early age in education, for example, Belize [89, 90]. On the other hand, there are very specific cases in the beverage industry where industrial robots are used to automate their processes. In general, most industrial robots in Central America operate in the food, beverage, metalworking, construction, and electronic device industries. Even though the use of industrial robots is very low in Central America, it is Costa Rica, followed by El Salvador, which leads with the largest number of installed industrial robots (Table 5). This country occupies the 90th position in the Heritage Foundation-Economic Freedom Status, Ranking 2022 [91].

Table 5. El Salvador – Industrial Robot Applications

Field/Industry	Installed (Percentage)
Metal-Mechanics	13%
Food	26%
Construction	37%
Education	11%
Paper and Packaging	8%
Textile	5%

3-6- Peru

This section depicts a general overview of the state of industrial robotics in Peru. It has been found that there is no national registry of companies that include industrial robots in their processes. This country occupies the 54th position in the IMD World Competitiveness Yearbook 2022 (WCY) [13]. According to the National Society of Industries, the main industry sectors in Peru are Mining and Refining of Minerals, Oil Extraction and Refining, Gas Extraction and Liquefaction, Fishing and Fish Processing, Cement, Textiles, Beer, and Soft Drinks [92]. Peru is a member of the Pacific Alliance together with Chile, Colombia, and Mexico, an alliance that seeks to achieve the free movement of goods, services, capital, and people and promote greater growth, development, and competitiveness of the economies of the member countries [93]. Mecanos Automation S.A.C., founded in 2012, is a pioneer company in industrial robotics integration. It has developed some applications in the country, involving 2 fields: a) Stand-Alone Robot: Robot Hardware, Robot controller, Programming unit (console). b) Robotic Cell: robot, tooling, sensors, safety measures, and software. According to selected data from this company, there is a statistics about the 4 main applications of Industrial Robotics in Peru (in the year 2021, there could be other robots that are currently under installation development in the country). It is shown in Figure 6.

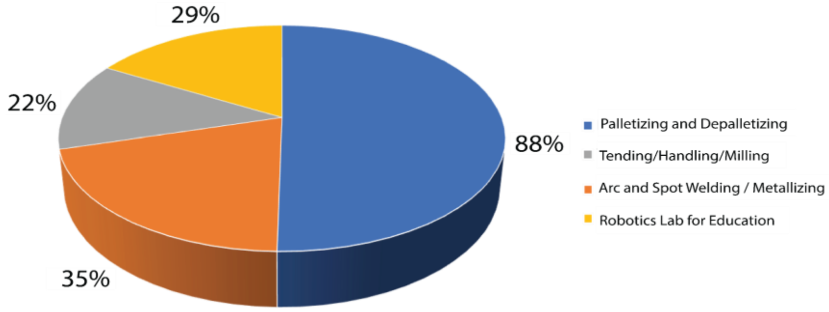

Figure 6. Main Industrial Robotic Applications – 2021

1) Palletizing and Depalletizing (robots: 60 - 470 Kg Payload), (Provinces: Lima, Arequipa, Trujillo, Piura). Applied to Industries, such as for: a) Beverage (beer, bottled water, and soft drinks). b) Packaged food (milk: tetrapak/cans, noodles, oils: bottles/cans, cookies: boxes. c) cleaning (detergent bags). d) Bricks and ceramics. e) Lubricant packaging. 2) Arc and Spot Welding / Metallizing (robots: 5 - 16 Kg Payload). Applied in Industries, such as for: a) GMAW - MIG / MAG welding (structural steel, LAF / LAC, mining components). b) Spot welding of light furniture. c) Metallizing (coating of concrete pieces). 3) Tending / Handling / Milling. Applied in Industries, such as: a) Folding, CNC machines (metal sheet bending). b) Cathode plates (cathodes). c) Pick / Place steel balls on a hydraulic press (mining). 4) Robotics Lab for Education. Applied on: a) Universities: ai) Public: UNI - FANUC robots; UNAC – Amatrol robot. aii) Private: URP – Mitsubishi robot at CIM Lab; UTP / UPC / UCSM Arequipa have KUKA robots; PUCP – Kuka robot at CETAM. (Purpose: Welding, Manipulation, FABLAB). b) Technical Institutes: SENATI / TECSUP – Kuka robots [94-99], 5) Biomedical applications [100-106]. Consequently, the Institutions state that is important to include subjects of industrial robotics in Mechatronics Engineering Programs and related branches [106, 107], because robots raise productivity in all industries, thereby increasing the labor demand [108-111].

4- Exponential Innovations by Robot Manufacturers and Software Platforms

4-1- ABB

Globally the usage of industrial robots has increased exponentially during the past 10 years in response to the need for enhanced productivity and competitiveness, in consequence, many of the "old" traditional factories have been updating their manufacturing processes to more flexible and adaptable automation solutions which in many cases include industrial and collaborative robots commonly known as "cobots". More robots are being used now for many different tasks that historically used to be done by a human operator, so, it is expected that in the future, workers will need to develop different skills to be able to share tasks and even work alongside cobots, this will require a new wave of engineers better prepared in schools and universities to be able to implement fully robotic systems with new developing technologies such as artificial intelligence, virtual and augmented reality and remote assistance over the cloud [112].

In Latin America, the potential usage of industrial and collaborative robots for a variety of applications is quite extensive in many market segments ranging from F&B, cosmetics, logistics, pharma, plastics, metals, electronics, household appliances and going also to automotive manufacturers and their parts suppliers. ABB as a robot manufacturer is offering one of the most extensive product lines including robots and cobots which will be a key component in this everyday growing automated world. One of the key players in this evolution is the ABB GoFa™ cobot which is an easy-to-use, fast, and intelligently safe robot that was designed with first-time users in mind (Figure 7) [113].

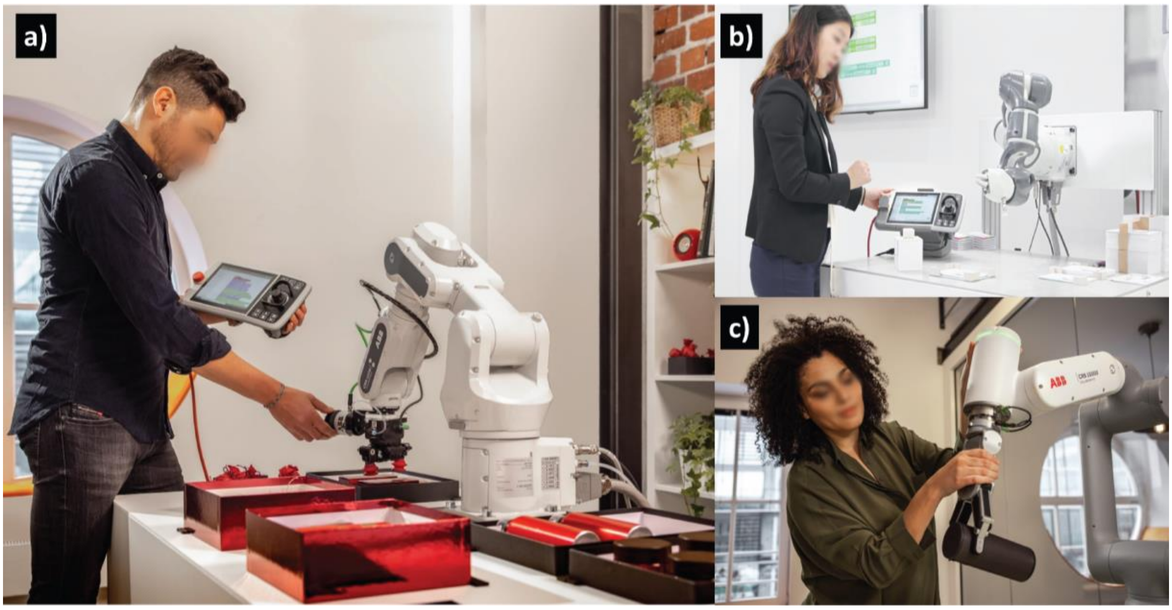

Figure 7. **ABB Robots: a) SWIFTI™ CRB 1100 [114], b) IRB 14050 YuMi® [115], c) GoFa™ CRB 15000 [116]**

4-2- KUKA

KUKA is working in many sectors in Latin America, but our goal is to revolutionize the production sector in the entire region. This is the only company that can provide after-sales service and guarantees its equipment thanks to its delegations, in Buenos Aires (Argentina), San Pablo (Brazil), and San Luis de Potosí (Mexico), the other countries are supported by official distributors trained at the headquarters of KUKA Germany (Ausburg) and for all this, the staff can provide a quality service in Latin America. Kuka is committed to training at universities and professional training centers distributed throughout the region. These centers have the latest KUKA robotic technology, thanks to agreements that have been reached to train the engineers of the future [117]. Training is key in the development of technology and KUKA offers quality education for companies that want to implement robotics in their countries, with training centers located in Argentina, Brazil, and Mexico, and in the other countries, it has also the same technology thanks to official distributors in order to obtain the same robot certifications. Due to this commitment to training, today there are more than 20 Official System Partners distributed throughout Latin America.

Automation and robotics have had different developments depending on the industry, the political moment of each country, laws on imports, risk prevention, and labor relations. That is why we are going to talk about the introduction of robotics in Latin America, but structuring it in different regions, the First region will be the southern cone, the next the other countries of South America except for Brazil, and finally Central America. The next few years will be very important for the growth of robotics in the region because the objective of the companies will be the export of goods and equipment with added value to compete with the rest of the countries of the world (Figure 8).

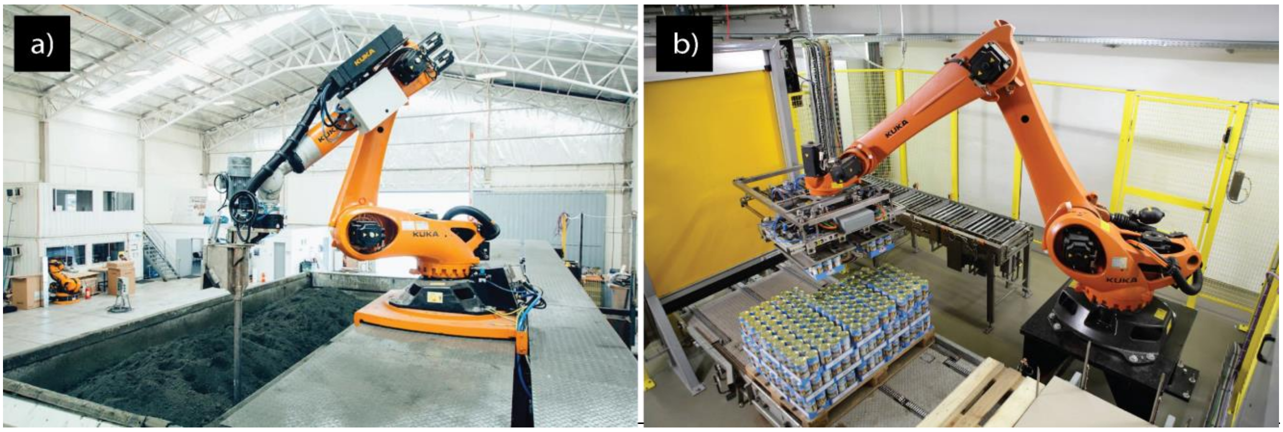

Figure 8. KUKA Robots: a) KR180 R 3500 K [118], b) KR 180 R3200 PA [119]

4-2-1- Southern Cone

Is made up of Argentina, Chile, Paraguay, and Uruguay. In this region the growth of the automotive industry at the end of the twentieth century makes that robots begin to be used in the assembly lines of automobiles, this provides powerful industrial manufacturing and very well prepared technologically to undertake different projects that arrived at the plants of the Auto. The main applications that were robotized at first were those of arc welding and resistance welding, which were necessary to give that quality and repeatability to the manufactured cars. Today Argentina has a very robotic industrial fabric, although far from European countries, North America, South Korea, Thailand, Japan, and Singapore. This ratio also shows that the main robotic countries are very competitive and exporting countries, in addition to being countries with unemployment rates below 5%. Chile has had strong automation in two very important industries in the country, mining, and the agri-food sector, for several years. MIRS, a local engineering company, has installed more than 50 robots in different mining applications. MIRS has managed to export these solutions to the whole world, showing that the engineering in Mining of Chile, are pioneers in this industry. The other export sector in Chile is the agri-food sector, and the example of agricultural Garces that exports cherries to the US, are benchmarks in automation in this sector. Uruguay and Paraguay are beginning to robotize their factories, they are far behind Argentina and Chile, but they are accelerating automation in power plants.

4-2-2- Andean Region

It is made up of the following countries, Ecuador, Peru, Colombia, Venezuela, and Bolivia. In these countries, robotization is very incipient, and very few robots are imported per year, although it should be noted that, Colombia, Peru, and Ecuador, are training many engineers in the area of robotics because their universities have prepared for industry 4.0, with very important investments in the equipment of the main robot brands. The main industries that are being automated in these countries are mining, suppliers of parts for the automotive sector, and the agri-food sector.

4-2-3- Central America

There are little data on the imports of robots that are being produced in the industries of these countries, but Costa Rica has positioned itself as an industrial reference in the region for the ease of exporting its products and for the investments received by American multinationals in the pharmaceutical sector and is having a very large development in this area, creating an important industrial fabric and improving the experience of robotization in its factories.

4-3- Mecademic

Having studied what the automation industry offers, what it needs, and what it was missing, we seek to be the first point of access into robotics for companies looking to automate for the first time, as well as an ongoing solution for already automated organizations. Mecademic Robotics is committed to making the use of small industrial robots more accessible by breaking down barriers and obstacles to entry into the world of automation. All our robots are plug & work automation components with a tiny footprint, low overall cost, and are easy to integrate and operate.

Our flagship robot, the Meca500 (Figure 9), is a slave component rather than a complex stand-alone system making it very easy to incorporate into any automation application. Users greatly benefit from the simplicity and lower costs, as our robots don't require any training courses, software installations, additional option purchases, or regular maintenance. Most importantly, Mecademic robots consume less than 30 W on average, no more than a typical laptop computer. As a robot manufacturing company, Mecademic is also committed to the environment and future generations. All our robots are designed, manufactured, and assembled in Montreal, Canada, using the industry’s highest-quality components. They are built entirely from aluminum, with all waste chips recycled, using minimal energy and eco-friendly machine working fluid. Our products have the distinction of being the world’s smallest, most compact, and most precise industrial robot arms [120].

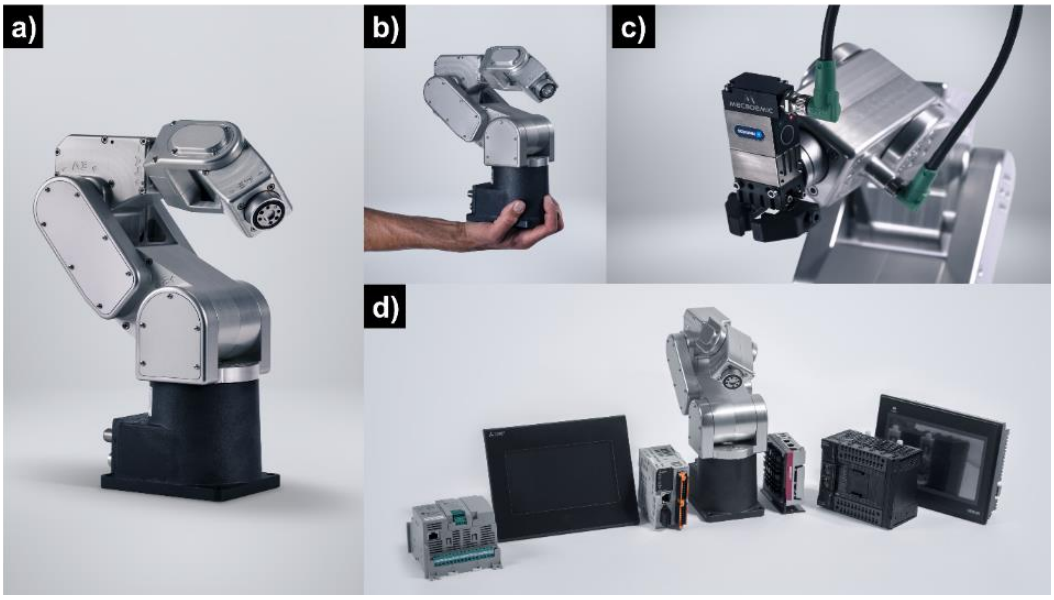

Figure 9. Mecademic Robot: a) Meca500 Robot Arm [121], b) Small Size, c-d) End-Effector and accessories [122, 123]

4-4- Robot Operating System (ROS) and Advanced Robotics

ROS [124] (Robot Operating System) is the current standard in robot programming. It is not an operating system that replaces Linux or Windows but a middleware that increases the system's capabilities to develop Robotic applications. ROS was born in 2006 within the STAIR Project [125], from which Willow Garage was born, and later the OpenSource Robotics Foundation [126], which is the foundation that coordinates the distribution of software and promotes its adoption by the ROS community. ROS is fundamentally Open Source, which fosters the creation of a community made up of thousands of developers, organizations, companies, and universities (Figure 10).

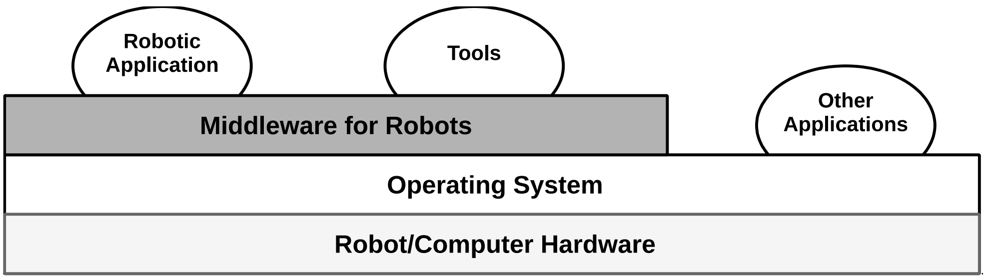

Figure 10. Software layers in a Robotics Application

ROS provides libraries, standards, tools, documentation, and resources to create robotic applications. These robotic applications are formed by collaborating nodes, forming a computation graph (Figure 11). Nodes can publish or subscribe to data and receive synchronous (services) or asynchronous (actions) requests. Drivers to access sensors or command motors are nodes in this graph. Part of this graph can be developed independently or reused by other developers in the ROS community. The essential aspect of this scheme is standardization. There are specific structures and methodologies for developing software in ROS, which allows for easy reuse of third-party code or understanding and collaboration on other projects. Data formats are standard, allowing software reuse. For example, the format of a message containing an image is standard. All drivers for all cameras in ROS produce data in the same format. Many tools or programs can subscribe to this message format.

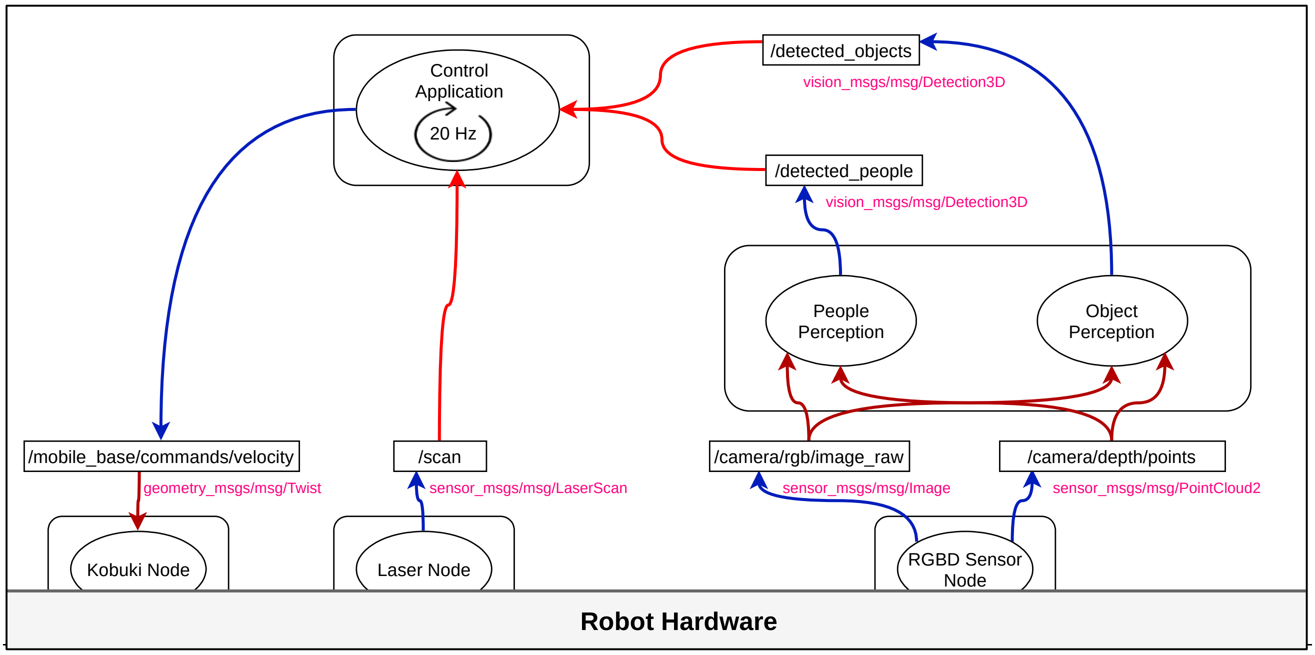

Figure 11. Computation Graph of a smart robot behavior for the Kobuki robot [127]

In recent years, ROS has evolved into a second version, ROS2 [128], which is a complete redesign [129] that incorporates aspects required by critical environments and industrial areas such as communications through DDS, Security, multiplatform, embedded software, or real-time. In ROS, remarkable communities contribute to a federal model for developing packages, highlighting Nav2 [130, 131] as a reference package for robot navigation, PlanSys2 [132, 133] for planning in Artificial Intelligence, or MoveIt [134, 135] for manipulation or diffusion in specific environments such as ROS Industrial [136] or ROS Agriculture [137]. All manufacturers of robots, sensors, or actuators are interested in developing their ROS packages, as they are aware that this makes them more attractive. ROS runs into mobile robots, robotic arms, space robots, self-driving cars, submarines, drones, or any robot that can be programmed (Figure 12).

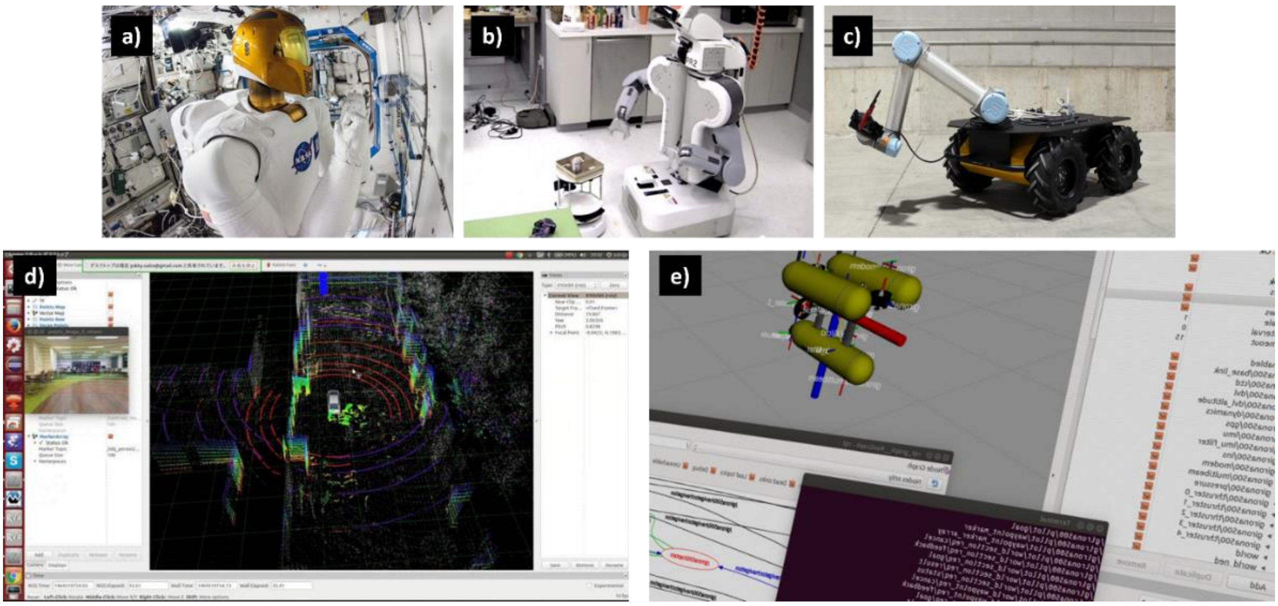

Figure 12. Robots using ROS. a) The Robonaut at ISS [138], b) PR2 [139] and Turtlebot2 [140], c) A mobile base with a robotic arm [141], d) An autonomous car, and e) A submarine robot

5- Present and Future of High Performance in Robotics

5-1- Industry 4.0 and Digital Manufacturing

Industry 4.0 (I4.0) refers to a digital initiative that uses advanced technologies throughout the organizations' value chains to interconnect processes, people, and products [142, 143]. Due to this digital interconnection, Digital Manufacturing (DM) is evolving into a "smart" factory centered on a digital system. In the DM environment, enabling technologies are connected to the Internet to design, redesign, and analyze the enterprises' processes and products [144, 145].

Nowadays, autonomous robots are being used in manufacturing since they can interact with other devices and make autonomous decisions using algorithms [146]. Specifically, cobots are incorporated into manufacturing processes to safely interact with humans in their workplace, supporting their daily tasks [147, 148]. Although human-robot collaboration increases productivity and competitiveness through the operations' improvement [149, 150], challenges such as uncertainty, acceptance, trust, and confidentiality are acknowledged [151, 152]. Moreover, to reach the expected benefits, cobots need to be interconnected with other "smart" devices and people to ensure real-time decision-making, which implies connectivity and data analysis challenges [153-155]. Therefore, using cobots in manufacturing generates process transformations, technology adoption, and individual, departmental, and organizational changes [156, 157].

Consequently, enterprises will require guidelines to adopt I4.0 toward human-robot interaction in digital systems and help them keep their advancements and investments aligned with their strategic transformation plan [158]. Furthermore, due to the high investment in adopting robots, it would be relevant to make an exhaustive analysis using engineering economy tools and concepts of process efficiency in order to determine where it is appropriate to place them and substantiate their benefits. Figure 13 provides a general visualization of the main stages in an I4.0 and DM process.

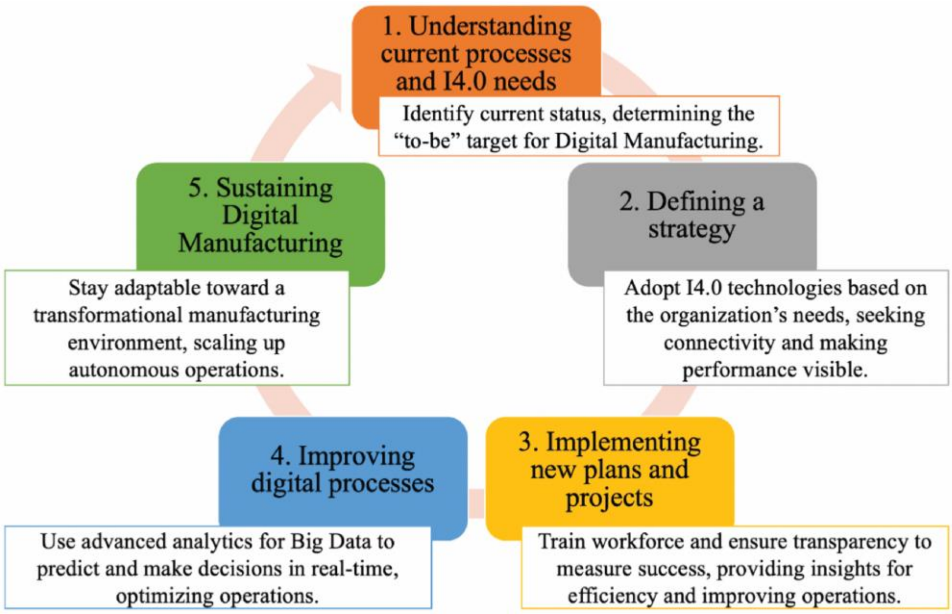

Figure 13. Main stages in an I4.0 and DM process

5-2- Robotics for Architecture and Construction

The construction industry is a historically complex sector. In the late 20th century, the increasing difficulty to establish efficient practices became largely evident, indicating the need for a deep reassessment of its foundation. Moreover, the slow growth of the architecture, engineering, and construction (AEC) sector compared to other sectors is evident in terms of productivity [159] and in the failure of planning mechanisms and the inability of plans to represent the reality of on-site construction [160-162]. In such a framework, a strong impact is foreseen in the next few years for companies introducing advanced automation systems. Automation - alongside the global need for new and updated infrastructure and better and more affordable housing - can help shape the future direction of the industry [163, 164]. The key will be anticipating and preparing for the shift, partly by developing new skills in the current and future workforce [165, 166].

Within this context, the Master in Robotics and Advanced Construction (MRAC), directed by Alexandre Dubor and Aldo Sollazzo at the Institute of Advanced Architecture of Catalonia (IAAC), investigates the emerging design and market opportunities arising from novel robotic and advanced manufacturing systems, focusing on expanding the application of automation and robotics in the AEC sectors. The program is organized through three terms, each of them specifically tailored to address contemporary challenges: design to manufacturing, sensing and data analytics, and human-machine interactions. Through seminars, workshops, and research studios, the Master seeks to investigate innovative solutions involving students in hands-on research. Over its first four editions, students developed solutions integrating vision-based systems to redefine management and logistic operations as part of the AEC sector. The master is training a new generation of experts in the field, which will lead the digital transformation of the AEC sector through the introduction of automation (Figure 14).

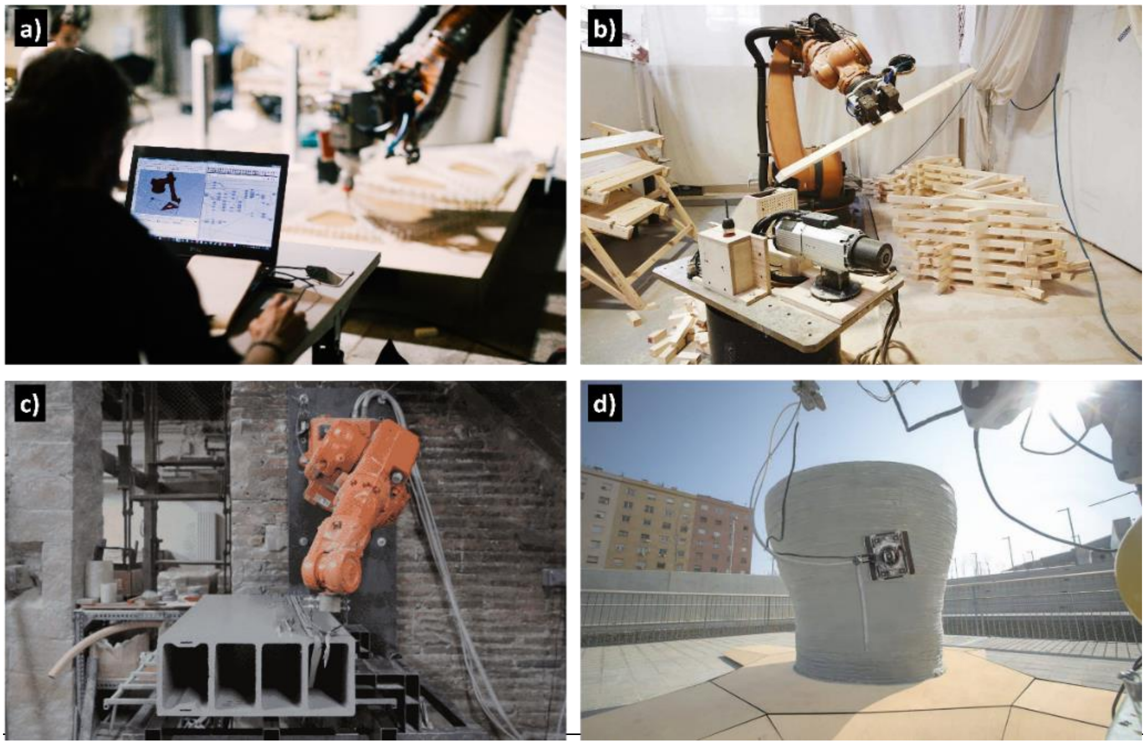

Figure 14. **Construction Robots Applications: a) Parametric design and fabrication. b) Prefabricated wood structure. c) Custom ceramic facades. d) On-site 3D printing. Used with permission from IAAC and Cumella Copyright**

5-3- Robotics for Aerospace Industry

Robotics and Automation have been used for many years in the Aerospace Industry since it was deployed in 1937 by Thomas Speller of Gemcor Corp. It was the ability to apply clamp load during drilling before installing a rivet that enabled wider deployment. This process minimized burrs and eliminated SWARF at the joint interface during drilling ensuring structural fatigue and fluid-tight joints. From modest beginnings, this technology included bolted joints, composite materials, and major assembly. However, its continued use will require changes to aircraft design and a new approach. Historically, major players have planned, invested, installed, and implemented numerous solutions to meet increasing market demand for their products. The industry has grown tremendously, and the entire world has adopted robotic technologies where global aerospace markets (Figure 14) are expected to reach USD$7.23 billion by 2030 from US$2.84 billion in 2021-2022 [167]. Currently, aircraft assembly presents specific challenges posed by automation systems, including aircraft design, requalification, large manual content, access, and tight tolerances. Space exploration has benefited from these lessons learned and has applied them to numerous missions to Mars (Figure 15), the Moon, and other celestial bodies [168-172], where there is an important development of robots that simulates some features of biomimicry and biomechanics to improve locomotion in extreme environments [173-177], called bioinspired robots.

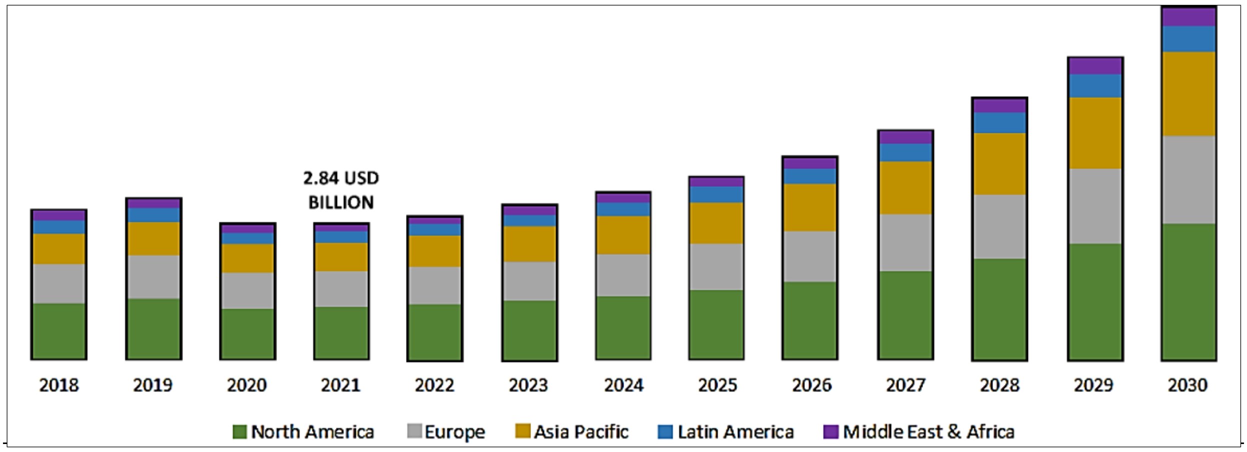

Figure 15. **Aerospace Robotics Market Size, By Region 2018 – 230 (USD Billion) [178]**

However, many challenges remain for automated aircraft assembly, including fastener variation and different material combinations that require more research, testing, and qualification. The industry recognizes that design has a key role to play in enabling automation (Figure 16). Solutions must overcome the need for dedicated equipment allowing them to be shared between assembly jigs; moved between floor levels and access to either side of the airframe. Therefore, higher quality, reduced tooling, and production costs have been obtained compared with manual methods [179-181]. In contrast to the automotive industry, automation in aerospace in both manufacturing and mission operations need to be much broader covering processes that may be described as dangerous or un-ergonomic; repetitive or dirty. Moreover, despite the general reduction in the cost of computing power, there is still a heavy reliance on traditional CNC controllers within aircraft automation, rather than on adopting lower-cost robotic controllers and PLCs. Solutions may incorporate sensing and measurement systems to validate position or ensure quality [182-184].

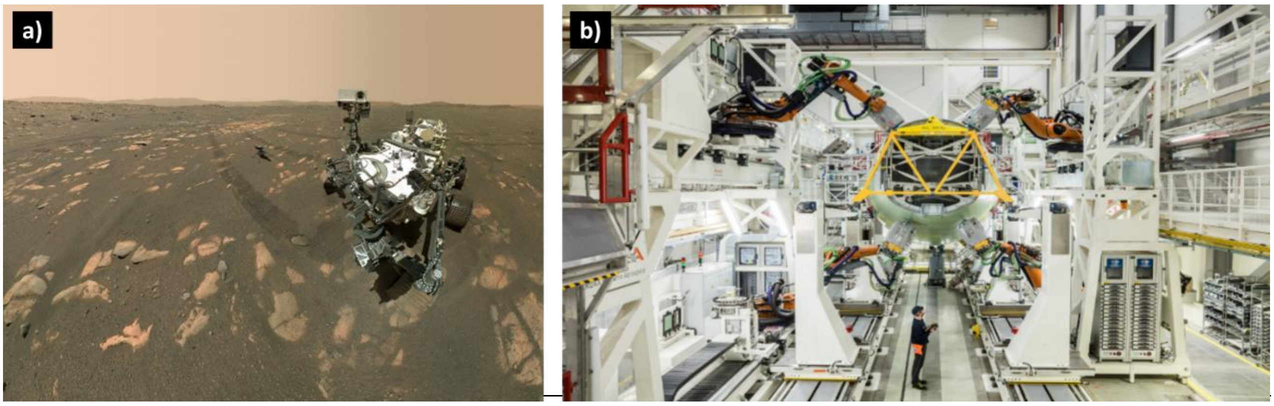

Figure 16. Aerospace applications: a) Perseverance Rover and WATSON (NASA/JPL [185]), b) Airbus Finkenwerder (Hamburg) H245 A320 production line (Airbus [186])

In this context, Latin America has a vast potential to become not only a large-scale manufacturing and integration hub for aerospace components but also be in charge of their design. The selection of Costa Rica as one of Intel's main manufacturing locations is a well-known case study of the impact high technology investment had in the region [187]. Before 1996, Costa Rica's major exports were agricultural-based (coffee, bananas, etc.) however, after Intel Costa Rica started its operations in 1997, net exports and the economy as a whole grew at a significantly higher rate. Additionally, STEM education improved and a domino effect in direct investment attraction to the country increased the number of companies involved in the manufacturing of high technology: healthcare components, software development, and even space-related start-ups. The country's gross domestic product (GDP) also has grown significantly, and Costa Rican nationals now design the Intel chips used worldwide. Similar examples exist across Latin America making it one of the most well-positioned locations to invest and manufacture aerospace components.

5-4- Smart Agriculture

The demands of a growing population and a developing global economy will require an increase in agricultural yield of 70% over the next 30 years [188]. However, this achievement is jeopardized by the limited extension of agricultural lands, the prospect of climate change, and the need to reduce inputs to guarantee the sustainability of agricultural systems. The need to create efficient and productive agricultural systems has motivated the growth of precision agriculture (PA) and the adoption of new technologies that are autonomous, disruptive, and data-intensive (Figure 1). This has led to the agricultural sector undergoing a spectacular digital transformation [189]. The role of GNSS is fundamental in the absolute positioning and has enabled specific applications in agriculture, with four of which the authors are very closely involved: (1) precision crop protection, (2) variable rate application, (3) agricultural UAVs, and (4) autonomous tractors, robots or UGV.

Precise spraying distribution and smart mechanical weed control equipment can range from field/region level to Drop-On-Demand technology or individual plant with savings of over 75% [190, 191]. The basic components of these weed control systems involve electronics, sensors, mechatronics, computer vision, navigation control devices, and computer decision support systems. These integrated and functioning systems allow it to be said that herbicide application or physical removal of weeds is more accurate and efficient. Achieving sustainable intensive agriculture requires a better adjustment of the inputs used (seeds, nutrients, water, etc.). Specific farm tools based on historical satellite imagery, using vegetation indices, together with other remote sensing tools closer to the crop, make it possible today to establish different management zones on a plot [192]. Management zones are a breakthrough in the field of precision farming, however, even more so will be automated management zones using new artificial intelligence techniques. Such demarcated zones could then be used to supply various inputs in the field using variable-rate methods.

Particularly relevant is the role that UAVs are playing in agriculture over the last few years (Figure 17-a). They are becoming a powerful management tool in crop fields and are enabling farmers to reap the benefits of precision agriculture [193]. This has been possible due to their advantages as compared to terrestrial or other sensing platforms, such as their high flexibility to fly at low altitudes to collect detailed crop information, ease of operation, availability of high-resolution images, acquisition of data on demand, and, foremost because their cost has been significantly reduced [194]. In this sense, the use of UAVs has rapidly expanded for the determination of multiple agronomic traits, such as LAI using RGB and multi-spectral imagery [195], physiological indicators based on hyperspectral images [196], and chlorophyll fluorescence [197], plant disease detection [198], 3D reconstructing for phenotyping purposes [199], and others. Additionally, in Latin America, a microgravity machine for space agriculture is under development with bio-automation fundamentals [200-202], and a bioreactor was built to establish conditions of carbon dioxide concentration levels, atmospheric pressure, temperature, Martian cycles of day and night, hyperaridity, and UV radiation (Figure 17b).

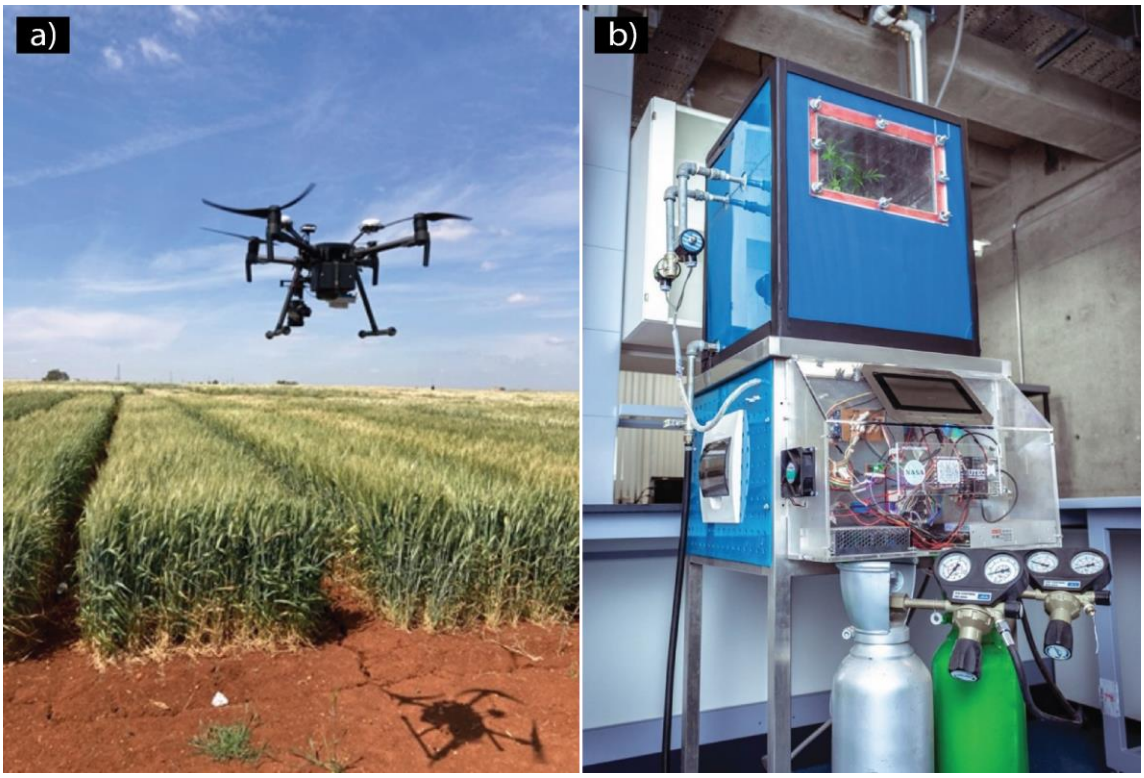

Figure 17. a) Experimental plots of different cultivars of cereal that are evaluated using drone technology, b) Controlled environment agriculture system for space applications by UTEC [203]

When it comes to ground robotics, we can see that robotic systems and related technologies are growing rapidly, while costs are decreasing compared to the benefits that they offer [201, 202, 204]. These ground systems require a certain degree of intelligence to realize the agriculture tasks, which may even involve coordination with operators [205]. For weed control by robotic systems, the integration of perception systems, to detect and classify weeds should be considered. Once the weeds have been detected, the treatment has to be carried out by an implement that can use different mechanisms for weed control. Weed control by mechanical weeding and precision spraying is possibly one of the most demanded tasks on autonomous agricultural platforms. In this respect, weed spraying by automated and/or robotic systems has yielded acceptable results and has reduced herbicide use by varying percentages depending on the automated spraying systems used, the type of crop, and the structure of the environment (Figure 18). In addition, in Latin America was proposed a mechatronics design of a tripteron cartesian-parallel agricultural robot mounted on a 4-wheeled mobile platform to perform seed sowing activity, shown in Figure 19 [204], which is a promising approach for agriculture and forestry (according to the World Bank) [206].

Figure 18. A fleet of autonomous sprayers working in a coordinated manner developed by SwarmFarm Inc [207]

Figure 19. Mechatronics Design of Agricultural Robot [204]

Another very interesting approach is the precise treatment of weeds with heterogeneous fleets of small robots, centrally coordinated or distributed, which can even collaborate with operators. In recent years, some research groups in conjunction with agricultural and technology companies have invested time and effort in developing robot fleets that integrate fleet supervision and planning [208-210]. Thus, a fleet approach requires the integration of supervision systems [211] to monitor the work that each of the robots performs during the joint execution of the agricultural task or mission. It is also essential to have a planner that allows for defining an optimal route for each robot, as well as the task it must perform during the route, ensuring full coverage of the different weed stands [211-213]. And, on the other hand, the supervision system may be distributed, so that there will be modules of the system running on the robot itself capable of detecting, analyzing in real time the information provided by the robot's sensors and subsystems, faults that in some cases can be resolved by the robot itself. Other supervision modules will have a view of the whole, being able to detect problems involving two or more robots. These last modules will run on a base station computer where at least one operator will follow the execution of the agricultural task by the fleet of robots through a Graphical User Interface (GUI) that receives real-time information from all the robots in the fleet. Precision agriculture and robotics are enabling factors for enhancing the adoption of best management practices and achieving sustainable intensive agriculture.

5-5-Artificial Intelligence and Computational Social Science

Artificial Intelligence (A.I.) gets a bad reputation as it is rarely properly understood in its entirety [214]. Historically, it is common to see A.I. portrayed in the media and public discourse as the imitation of those features that we identify as human. Although this is partially true, the avant-garde computer scientists that pushed intelligent computers have focused on any capable activity for the machine; not only those we possess [215, 216]. A.I. aims at the development of higher-level processing of information and decision-making such as abstraction, perception, recognition, or learning by experience [215, 216]. The A.I. field thus is recognized by great achievements like IBM's Deep Blue versus Kasparov, alpha vs Go champion, or the impressive prediction power of deep learning [215-217]. With the inclusion of physical robots or simply unseen algorithms, industries around the world have adopted A.I. or have faced an increasingly AI-driven market. Table 6 shows the results of A.I. adoption in several industries according to a McKinsey survey in 2020. This survey also reveals that around half of the participants claimed that their organization used A.I. at least in one business function [218-221].

To accurately represent the unique potential, it is important to include other major fields of artificial intelligence. For robotics and alternative views on social systems, these contributions rely on the computational development of autonomous agents that interact with their environment, for example, human-robot collaboration [222]. Robotics, from an A.I. perspective, has focused on the capability of an independent agent to interact with its environment for a specific task. In this field, engineering and computer science have been central to developing electro-mechanical systems, which entails a complicated relationship between sensors, actuators, and an effective collection of algorithms as an intermediary. Another applied focus of A.I. is its use for public policy or social good, which has received considerable attention from governments and public institutions [223, 224]. The large Latin-American drive for digitalization has seen support to develop A.I.-based solutions, facing the main challenges of subpar digital infrastructure, STEM education, and inequity in the use of A.I. benefits [223, 225, 226].

Table 6. **A.I. adoption in the industry by sector and activity [218]**

Activity	Sector	Percentage (%)
AI-based enhancements of products	Product and/or service development	24
Product-feature optimization	Product and/or service development	21
Service-operation optimization	Service operations	24
Predictive service and interventions	Service operations	19
Customer-service analytics	Marketing and sales	17
Customer segmentation	Marketing and sales	14
Risk modeling and analytics	Risk management	16
Fraud and debt analytics	Risk management	12
Yield, energy, and/or throughput optimization	Manufacturing	15
Predictive maintenance	Manufacturing	12
Optimization of talent management	Human resources	10
Performance management	Human resources	7
Logistics-network optimization	Supply-chain management	9
Inventory and parts optimization	Supply-chain management	9
Capital allocation	Strategy and corporate finance	8
Merge and Acquisition support	Strategy and corporate finance	6

A general evaluation of the penetration of A.I. at the regional level shows the major impact seen so far is the use of machine learning, and its higher performance derivative, deep learning. The utilization of some of these low-cost applications of A.I. has been predominant considering the limited resources in the region [227]. The diffusion of data science applications has permeated into commercial and industrial activity, while A.I. research and development appear to be truncated. According to the Technology Report from MIT, the application of A.I. in Latin America has been adopted by a considerable fraction of businesses, but new research and entrepreneurship have been limited by talent migration [227]. Furthermore, the differences with societies that have an advanced A.I. ecosystem can bring direct challenges to its development. For example, regulatory practices like the EU's General Data Protection Regulation present an additional challenge to Latin American countries without sufficient institutional infrastructure. Overall, there is a considerable effort to support A.I. in Latin America [218, 223, 227–229], and the limitations today can benefit from continuous work on national policies and regional collaborations.

6- Conclusion and Future Insights

This paper states: a) the first science manuscript in history, where the main technical and research data about the state-of-the-art of robotics in Latin America is shown; b) a multi-collaborative study between international robotics institutions that integrate the academy and industry; c) the most important and growing fields of robotics development in Latin America. The study context describes Mechatronics and Robotics (MaR) as the main and most important field that brings the best opportunities for Industry 5.0 implementation, which includes industrial, collaborative, and mobile robotics. Therefore, Latin America is achieving important outcomes related to the academy, industry, government, and entrepreneurship. In addition, the exponential innovations of MaR have great expectations that will provide enhanced benefits in the future. Thus, the research and development of these technologies show a potential impact with the integration of Industry 4.0 and Digital Manufacturing, Architecture and Construction, Aerospace, Smart Agriculture, and Artificial Intelligence and Computational Social Science, in order to promote new job open positions for human-robotic collaborative tasks to maximize productivity and accuracy.

To our knowledge, there are not any published data in Scopus or Web of Science about the number of robots used in many countries in Latin America, so the most important contribution of this manuscript is that the authors looked for the information by asking some companies and government organizations, achieving the successful results shown in Section 3. In addition, three growing robotic companies have been taking the manufacturing market: ABB and Kuka; on the other hand, Mecademic is showing great relevance in the field of education (kinematics and dynamics); hence, Robot Operating System (ROS) has shown high versatility on simulation of diverse locomotion and manipulation tasks. Furthermore, there is one type of robot that is getting interest in the science community; it is called a bio-inspired robot, which is a system with biological characteristics, usually similar to animals. Due to its flexibility and exoskeleton morphological configuration, it is used for exploration and aerospace applications. Finally, regarding the information presented, Latin America is considered an important location for investments to increase production and product development, taking into account the further proposal for the creation of the LATAM Consortium for Advanced Robotics and Mechatronics, which could support and work on roboethics and education/R+D+I law and regulations in the Region. This paper is expected to be the most important guide for the future of robotics in Latin America.

7- Declarations

7-1- Author Contributions

Data will be made available on request.

7-2- Data Availability Statement

Data sharing is not applicable to this article.

7-3- Funding

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7-5- Institutional Review Board Statement

Not applicable.

7-6- Informed Consent Statement

Not applicable.

7-7- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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