Robotics in Mexican Agriculture, Current Situation and Perspectives

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Abstract The increase in population in the country is doing indispensable automation of agriculture in order to feed a growing population with a workforce that has migrated to the cities and the United States. Situation that threatens food security of the country, forcing to look for alternatives to solve the problem of food production, being the only solution is to increase productivity, because the agricultural frontier already the limit. Agricultural mechanization is the only way to dramatically increase productivity, being that in the XXI century is to be applied at the highest level, automation and robotics. In the country's efforts are minimal research and development of agricultural robotics. Being in full disadvantage to countries like Brazil, Argentina and Chile have already started research in this segment of robotics. It must start encouraging the creation of groups among the leading universities in research on robotics as the IPN, UNAM, IPN- CINVESTAV Tamaulipas and IPN-CINVESTAV Saltillo, Technological University of the Mixteca, University of Guanajuato and agricultural research institutions like INIFAP, COLPOS, and Antonio Narro Agrarian Autonomous University. So the experience and capacity of research institutionson robotics and research institutions in agricultural sciences to advance the development of this discipline in Mexico would take advantage. As the aims of this paper review the status of the applications of the robotics in Mexican agriculture and perspectives for the future and show that Mexico needs to make efforts research in robotics in agriculture is lagging as considerably.

Keywords Mexico; Agriculture; Agricultural mechanization; Robotics

Introduction

Mexico has 1 million 964 000 374 km$^2$ of land area and has 121 million in habitants. Agricultural acreage in Mexico has remained relatively constant over the last 25 years by about 20 million hectares. For 2014 is 22.2 million hectares. Agriculture employs 5.6 million people. (http://www.siap.gob.mx/atlas2015/index.html).

Commercial agricultural products mostly come from three areas of the country, the tropics of the Gulf of Mexico and Chiapas Highlands, the irrigated lands of the north and northwest and the Bajio region in central Mexico. The most profitable tropical crops are coffee and sugarcane. Coffee is exported but sugarcane is mostly for domestic consumption. Other important tropical crops are fruits such as bananas, pineapples and mangoes as well as cacao and rice. Vanilla is still also grown, which is native to Mexico. Cotton is an important crop in the export agricultural areas of the Soconusco in Chiapas and in the north of Mexico. Traditional farming methods with small plots worked by families and small communities still dominate in many regions especially those with large indigenous populations such as the Southern Plateau. In these areas the main crops are corn, beans as in the Mesoamerican period. Many peasants still survive on subsistence agriculture earning cash by selling excess crops in local markets, especially in central and southern Mexico. (http://www.britannica.com/place/Mexico).

The increase in population in the country is doing indispensable automation of agriculture in order to feed a growing population with a workforce that has migrated to the cities and the United States. Situation that threatens food security of the country, forcing to look for alternatives to solve the problem of food production, being the only solution is to increase productivity, because the agricultural frontier already the limit. Agricultural mechanization is the only way to dramatically increase productivity, being that in the XXI century is to be applied at the highest level, automation and robotics. Currently developed countries are advanced in this area, in Latin
America, Argentina, Brazil and Chile are making efforts on robotics in agriculture. In the country's efforts are minimal. As the aims of this paper review the status of the applications of the robotics in Mexican agriculture and perspectives for the future and show that Mexico needs to make efforts research in robotics in agriculture is lagging as considerably.

Materials and Methods
This study was conducted through exploratory, descriptive and bibliographic methodological process. These methods were adequate because the objective was to describe and point out the state of agriculture robotics in Mexico.

Results and Discussion
Agricultural robotics
A robot is a machine that can be programmed and reprogrammed to do certain task and usually consist of a manipulator such as claw, hand, or tool attached to a mobile body or a stationary platform. The word Robot came from the Czech word "robota", which means forced labor, or work: It was first used in the play R.U.R., Rossum’s Universal Robots, written in 1921 by a Czech playwright named Karel Capek. Issac Asimov was the first person to use the term “robotics” in "runaround" a short history published in 1942. Robots can be; 1. Autonomous; robots work completely under the control of a computer program. They often use sensors to gather data about their surroundings in order to navigate. 2. Tele-Controlled: robots work under the control of humans and/or computer programs. 3. Remote-controlled: robots are controlled by humans with a controlled such as a joystick or other hand-held device. Agricultural robotics is the logical proliferation of automation technology into bio systems such as agriculture, forestry, greenhouse, horticulture, etc. (Yaghoubi, 2013).

Application of Agricultural Mobile Robots is a strong tendency, mainly in the European Union, the USA and Japan, (Tabile, 2011). Thus, the range of applications in agriculture will continue in the coming years, as a natural phase of agricultural mechanization. (Llamas, 2014).

The application of agricultural machinery in precision agriculture has experienced an increase in investment and research due to the use of robotics applications in the machinery design and task executions. Precision autonomous farming is the operation, guidance, and control of autonomous machines to carry out agricultural tasks. It motivates agricultural robotics. It is expected that, in the near future, autonomous vehicles will be at the heart of all precision agriculture applications. The goal of agricultural robotics is more than just the application of robotics technologies to agriculture. Currently, most of the automatic agricultural vehicles used for weed detection, agrochemical dispersal, terrain leveling, irrigation, etc. are manned. An autonomous performance of such vehicles will allow for the continuous supervision of the field, since information regarding the environment can be autonomously acquired, and the vehicle can then perform its task accordingly. (Auat Cheein, 2013).

Simply put, it can be said that the potential benefits of robotics are the increase in the quantity and quality of products and improved management of natural resources through the efficient use of inputs. Despite propose a high technology and not very accessible to most productive systems of family farming solution, robotics and precision farming technology basically leverage the increase in production and energy value of grain with a focused management and located in the application of inputs. This more efficient management provides a performance culture that tends to get the greatest productive capacity of the stands, often increasing the average grain yield in two and a half tons per hectare (2.5 t/ha) for up to eight (8 t/ha), in the case of wheat. (Inamasu, 2010; Hackenhaar, 2015)

Archila (2013) reports that there different approaches to robotics application in agriculture by different universities, laboratorizes and industries around the world.

With fully-automated farms in the future, robots can perform all the tasks like mowing, fertilizing, monitoring of pests and diseases, harvesting, tilling, etc. This also enables the farmers to just supervise the robots without the
need to operate them. The key aspects of automated farms are the following:

- It facilitates operation in the farm
- It improves safety
- It allows selective harvesting
- It sustains domestic agriculture
- It reduces chemical usage and labor needs
- It enables plant-level management
- It assists in precision pest management
- It helps small family farmers by enabling small farms to compete globally.

**Robotics in Mexico**

In both extensive agriculture and protected agriculture required from much workforce and equipment, due to increased production volumes required, making it necessary to develop new systems (Robotics in agriculture) to improve the efficiency of equipment used in farming, which consist of combining computer technologies, electronics and mechanics available to develop smarter, more efficient machines that can make agricultural activities correctly. Young Mexicans are taking the first steps to end the technological dependence of the country in the area of robotics, as they have emerged triumphant in international competitions and are focusing on new areas such as aerial robotics, animatronics and artificial intelligence. In the country there is still no own robotics industry because companies do not want to wait the time national engineers would soon develop a device of this type, except when they can buy immediately in another nation. Derived from this, a large part of industrial robots used in Mexico are foreign-made and placed the country as the ninth most important for the sale of the equipment market. (Hernandez, 2015, www.excelsior.com.mx/hacker/2015/08/24/1041785).

Robotics is available to the country. Unlike other scientific areas where a substantial investment of resources to compete globally and where the technology is decades ahead of the national reality, the development of robotics in the country to reach required, and that most of the technology is available for development and also has worked in robotics in major research centers and major universities in the country for several years. This means we have the same opportunities to generate added value. Its development, however, requires an injection of resources to focus adequately create the conditions in the country to catch and train human resources to sustain and give continuity to the area. (Morales, 2009, ccc.inaoep.mx/~emorales/Papers/2009/eduardo.pdf).

Compared with countries like; China approximately 3500 robots installed in 2004, with 12 000 USA, European Union 29 000 and Japan 37,000 robots; Mexico is far below optimum level only reached the figure of just 900 robots. In the opinion of experts, our country should not only focus on the typical implementation of robots industries such as manufacturing or biomedical, but to reach other areas of interest such as security, education, food, renewable energy and conservation of environment. (http://archivo.eluniversal.com.mx/finanzas/95090.html). The technology promises to be the mainspring of the industry in Mexico whether supports adequately. Bionic arms, robots seeking oil at sea, drones, gloves with sensors that help move the hand to the disabled. With adequate investment these Mexican inventions in the area of robotics could be put to use in the future to facilitate daily life and also help the economic growth of the country to adequately invest in the segment. (Maldonado, 2009, www.cnnexpansion.com/tecnologia/2009/08/18/la-robotica-podria-hacer-crecer-a-mexico).

Although Mexico has a prominent role in world robotics competitions in our country this branch is marked by scarce resources for science and technology and lack of developers. (Sanchez, 2012, ELECONOMISTA.COM.MX/TECNOCIENTIA/2012/05/04/ROBOTICA-MEXICO-POCOS-RECURSOS-DESARROLLADORES).

Robotics in Mexico, begins with a robot almost forgotten that once was important to test the capabilities of a didactic processor designed in 1985 by researchers from Argentina, Brazil, Colombia, Spain and Mexico. We are talking about Don Cuco "El Guapo" a pianist robot was designed and built in the Department of Microelectronics
of the Autonomous University of Puebla in Mexico in August 1992 by a team of 30 researchers and 20 students from different disciplines, under the direction of Alejandro Melendez Pedroza. What handsome is due to its transparent design humanoid designed by the sculptor Gloria Erika Weimer and its construction (which took 10 months) aimed to demonstrate an application of the ILA 9200 processor for the Universal Exposition in Seville (1992). This robot was one of the pioneers of robotics in Mexico, later would come more advanced robots as the TPR-8 PLC of the National Autonomous University of Mexico and recently MexONE Center for Research and Advanced Studies (Guadalajara), which is expected to soon walk and climb stairs. Meanwhile students and the Polytechnic University of Chiapas and the National Polytechnic Institute still bearing the name of Mexico high in international events such as Robocup and Robogames. (https://www.fayerwayer.com/2010/09/100-cuco-el-guapo-pionero-de-la-robotica-en-mexico/).

Young Mexicans are taking the first steps to end the technological dependence of the country in the area of robotics, as they have emerged triumphant in international competitions and are focusing on new areas such as aerial robotics, animatronics and artificial intelligence. In the country there is still no own robotics industry because companies do not want to wait the time national engineers would soon develop a device of this type, except when they can buy immediately in another nation. Derived from this, a large part of industrial robots used in Mexico are foreign-made and placed the country as the ninth largest market for the sale of such equipment.(Hernandez, 2015, www.excelsior.com.mx/hacker/2015/08/24/1041785).

Agricultural robotics in Mexico

Redesign the irrigation robot BCC Cpmbi Boom, for which analyze the variables; measures overall working speed gear motor type, pump type, water consumption in nozzles, pressure waterpipes, transport system, etc. perform static, dynamic, hydraulic load, to obtain superior characteristics in actual robot operation (Hernandez, 2007).

Lack of young farmers capable of climbing palms requires of a robot for harvesting coconuts fruits. For the construction of the robot, a structure was design that could adapt easily to the trunk of the tree (inclination, height and diameter). The structure has a crank-connecting rod system that is capable of climbing the palm tree and carries at the same time a motor, a battery and a camera witch all together weighs 7 kg. The systems of artificial vision includes a camera IP that takes images to recognize the robot position. An algorithm that detects ellipses identifies the presence of coconut. The rod-crank mechanism used despite being very rustic, was effective for climb the robot on the palm. It also helps reduce the presence of motors on the robot, greatly reducing the amount of electronic devices on its control. (Ramirez, 2013).

It has been made the calculus of a two freedom degree robotic arm equipped with a video camera for recording desired images of plants. Images will be sent to a computer for its analysis (Llamas, 2014). The robotic arm calculated mounted on a turntable, which can also rise to the height that the crop needed, is suitable for generating trajectories whose geometry will vary, as the plant grows and its shape is changing at different stages from his development.

Many other tasks in agriculture in greenhouses can be made with robots. Past literature has reported many successful cases about crops in greenhouses. The main function of greenhouses is to recreate and keep adequate and controlled conditions of light, humidity, temperature, carbon dioxide, and pesticides, among others, in a confined space to growth plants for diverse purposes. However, those conditions can be potentially harmful to humans that work in greenhouses. An alternative to overcome this is the application of robotics in those agricultural sites, adequately applying Artificial Intelligence and mechanical subsystems that are part of a robot. (Garcia, 2007).

A group of students at the Technological Institute of Querétaro (ITQ, for its acronym in Spanish) created the prototype of a robotic solar vehicle that improves the sowing and reforestation works through programming trajectories. The robotic car was designed with a mechanism that can plow the crop field and thus speed up the process. The vehicle is aligned with a dispenser, which enables to sow the seeds that are then covered by a shovel installed in the bottom of the device, the student in Mechatronic Engineering explained. "Even, this robot can also
be used on agricultural land, because it can make planting processes efficient, the vehicle can be used automatically. Highlighted that the robot efficiently performs the planting times compared with traditional methods, because it can be programmed with a computer. By time managing we mean that this robotic vehicle can work non-stop. Usually in agriculture, a workday does not have a fixed schedule, it can be more than eight hours, which causes that people working in the field require more rest periods. For correctly using the robot, conducting a preliminary analysis of the land on which it will work is necessary in order to program the vehicle and thus establish the trajectories for the sowing. The prospects of this project are to plant pines, in the case of forests. Regarding agriculture, the design of this prototype is intended for planting tomatoes, peas and corn (http://www.starmedia.us/news/24h/students-create-solar-vehicle-to-improve-crops-in-the-countryside.html).

### Table 1 Robotics education in Mexico Several sources

| Institution                                      | Degree                                                                 |
|-------------------------------------------------|------------------------------------------------------------------------|
| IPN-CINVESTAV Tamaulipas                        | Masters and Ph.D. in Engineering with research in "Robotics and Vision" |
| Mixteca Technological University                | Masters and Ph.D. in Robotics                                           |
| IPN-CINVESTAV Saltillo                          | Masters and Ph.D. in Robotics and Advanced Manufacturing with research in Robotics |
| National Polytechnic Institute                  | Bachelor Science in Robotics and Doctorate in robotics systems and mechatronics |
| Institute Technology of Monterrey                | Bachelor engineering degree in digital systems and robotics             |
| National Autonomous University of Mexico         | Master's and Ph.D. in Electrical engineering research line control and robotics |
| Panamericana University                         | Specialization in robotics                                             |
| Autonomous University of Aguascalientes          | Bachelor Science in Robotics Engineering                                |
| Polytechnic University of Guanajueto            | Bachelor Science in Robotics Engineering                                |
| Polytechnic University of Tulancingo            | Bachelor Science in Robotics Engineering                                |
| Polytechnic University Bicentennial             | Bachelor Science in Robotics Engineering                                |
| Popular Autonomous University of Puebla         | Mechatronics Ph.D. with research in Robotics                            |
| State University of Guanajuato                  | Mechanical engineering Ph.D. with research in Robotics                 |

### Robotics agriculture in Latin America

#### Argentina

Proposes a technique of autonomous navigation and mapping in an olive grove by a robot-cell, which has laser frontal environmental information and the exact location of the extremes olive plantation only (Gimenez, 2015, www.secyt.frba.utn.edu.ar/gia/trabajosviiijar/jar8_submission_15.pdf). The method is based on solving an optimization problem with nonlinear constraints, which reduce errors inherent in the measurement step, and ensure efficient reconstruction of the map of planting posteriori. The technique provides satisfactory results and has great potential for future improvements.

Design of a robotic greenhouse, which involves basically the greenhouse and a mobile robot interacting with the physical environment (collecting data and acting on plants) (Garro, 2011). Thus, the main contribution is related to taking practical experience and generalize it by applying well-proven techniques to the development of CPS. In Argentina, Engineers of the Automation Institute of the National University of San Juan (UNSJ for its acronym in Spanish), Dr. Ricardo Carelli, Ing. Franco Penizzotto, Ing. Orlando Alvarez, Ing. Marcos Ayala, Dr. Carlos Soria working for some time in a small automaton for agricultural work. This work began with the purchase of a commercial quad which she underwent some modifications so you can automatically move through the field and, thus, control cultures without possessing a human driver. It is very light and, being fully automated, need not be handled by one person, lightening average 80 kg, allowing it to move between crops without damage. In first instance vehicle automation was done by modifying various parts mechanical and adding all the necessary electronics, including: sensors, computers, control systems, laser vision cameras, odometers, etc. In addition, they also put a GPS to get around in fields very accurate. The form second stage, in which you work at the moment, it is adding all sensors to know the situation of each particular crop, allowing once the entire field area, it may
generate a map application. In addition, you can recognize whether any pest or if crops are sick or if they need watering (http://www.actualidadgadget.com/robot-argentino-para-los-cultivos/).

Automatic phenotyping platform, developed in Argentina, through the innovative design of great simplicity of operation that lowers the cost of construction, operation and maintenance, through an original system of linear feed it very simple to expand. It was developed by the Biotec Soja Surto evaluate a considerable number of genotypes at a time and minimize the experimental mistake (Aguirrezabal, 2011, www.mercosooja2011.com.ar/site/wp-content/imagenes/AGUIRREZABAL-WESTERGAARD-BORSANI.pdf).

Brazil

In Brazil the core of the agricultural robotics group was born in 1999 in an Embrapa research project from the need to develop vehicles to support research in the agricultural environment. The Brazilian Agricultural Research Corporation (EMBRAPA Portuguese acronym of Empresa Brasileira de Pesquisa Agropecuária). The group was established since 2002, with a doctoral work of the EESC / USP which proposed the development of a mobile agricultural robot architecture. The Agricultural Robotics Group of the EESC / USP / Embrapa is the pioneer in Brazil in the study of mobile agricultural robots. Located in the "Center for Teaching and Research in Automation and Simulation" from the "Department Mechanical Engineering" of the "School of Engineering of São Carlos" from the "University of São Paulo" (NEPAS - EESC - USP) and has the guidance and support Embrapa Instrumentation in San Carlos (http://www.nepas.eesc.usp.br/roboticaagricola/).

Held in Brazil a study showed the possibility of the robot application for carrying out remote sensing in agricultural environments. (Tabile, 2011). Initially the possible areas of activity and the main consumer markets have been identified. The operations that could be performed as well as the most important features that make up the agricultural environment have been defined. With these data the technical options available have been selected, in view of the set of parameters of operation, and among those, the one that best fits the prerequisites of the project. Computational modeling and later simulation and validation of the structure designed by specific software have been performed. With the manufacture of the platform it has been possible to find that the methodology used to develop the agricultural robot has been efficient, according to all the needs.

A current trend in the agricultural area is the development of mobile robots and autonomous vehicles for Precision Agriculture (PA). One of the major challenges in the design of these robots is the development of the electronic architecture for the control of the devices. (Paciencia, 2012). In a joint project among research institutions and a private company in Brazil a multifunctional robotic platform for information acquisition in PA is being designed. This platform has as main characteristics four-wheel propulsion and independent steering, adjustable width, span of 1.80 m in height, diesel engine, hydraulic system, and a CAN-based networked control system (NCS). Presents a NCS solution for the platform guidance by the four-wheel hydraulic steering distributed control. The control strategy, centered on the robot manipulators control theory, is based on the difference between the desired and actual position and considering the angular speed of the wheels. The results demonstrate that the NCS was simple and efficient, providing suitable steering performance for the platform guidance. Even though the simplicity of the NCS solution developed, it also overcame some verified control challenges in the robot guidance system design such as the hydraulic system delay, nonlinearities in the steering actuators, and inertia in the steering system due the friction of different terrains.

Colombia

Development and implementation of a mobileplatform forcollectionoforanges. Developing the prototype of a robot platform for orange collection based on Arduino. (Tovar, 2014).

Romero (2014) made a research on the implementation of ICT (information and communications technology) and electronics technologies in the agricultural field for optimum land use, making use of a mobile prototype with GPS (Global Positioning System) and sensor temperature and relative humidity for industrial use, plus take advantage
the arduino platform as a means of information acquisition and processing, hand LabView programming platform and Wireless Communication Channel.

Chile
In Chile the Industrial and Autonomous Robotics Research Group and Advanced Center of Electrical and Electronic Engineering are facing the challenges of robotics in agriculture in Chile from both a research and an innovation perspective. Performing work on orchard characterization and tree top volume estimation, thermal characterization, SLAM (Simultaneous Localization and Mapping) in GPS denied environments, service units and navigation in agricultural environments, service units, modeling, simulation and control of skid steer mobile manipulators, design of skid steer mobile robots, path planning for agricultural mobile robots (Auat Cheein, 2015, www.fieldrobot.com/ieeeras/Downloads/20150710-ChileanGroup-Presentation.pdf).

Discussion
In the table 2 show the work has done by the Latin American countries in the area of agricultural robotics. The results show that in Latin American countries like Argentina, Brazil, Chile, Colombia, there is an interest and understands the importance of robotics and its application in agriculture, developed countries are advanced in all matters of technology is not new, what is important is that in the aforementioned countries have been created specifically for research groups on agricultural robotics research, which is the specific case of Chile with the creation of the Autonomous Robotics and Industrial Research Group and Advanced Center of Electrical and Electronic Engineering in the case of Brazil their respective group; Center for Teaching and Research in Automation and Simulation, NEPAS (Núcleo de Ensino e Pesquisa em Automação e Simulação for its acronym in Portuguese) in Agricultural Research Brazilian agricultural research company (EMBRAPA for its acronym in Portuguese) and National Agricultural Technology Institute (INTA for its acronym in Spanish) in Argentina and in Chile the Industrial and Autonomous Robotics Research are working to respect our country because of the low priority given to the primary sector as an engine for development, and the lack vision of the state, industry and

| COUNTRY and reference | ROBOT | INSTITUTION                                      |
|-----------------------|-------|-------------------------------------------------|
| Brazil                | SKINNY Platform data collector and reflectance sensors to measure nitrogen levels at various stages of the maize crop. | EMBRAPA                                      |
| Brazil                | VAA Platform robotics, autonomous navigation | EMBRAPA 2004 – set. 2006 agricultural machinery Jacto and EMBRAPA 2010-2012 |
| Brazil                | Agribot modular robotic platform agricultural area | EMBRAPA                                      |
| Argentina             | Trakür. Guided platform for applications of pesticides. | INTA                                         |
| Argentina             | Robot-cell autonomous navigation and mapping in an olive grove | Automation Institute of the National University of San Juan (UNSJ) |
| Argentina             | Robotic greenhouse | INTA                                         |
| Argentina             | Small automaton for agricultural work | Automation Institute of the National University of San Juan (UNSJ) |
| Argentina             | Automatic phenotyping platform | Biotec Soja Sur                              |
| Colombia              | Mobile platform for collecting oranges | Catholic University of Colombia               |
| Colombia              | Agricultural mobile prototype | University of the Llanos                     |
| Chile                 | Design of skid steer mobile robots, path planning for agricultural mobile robots | Industrial and Autonomous Robotics Research Group |
research groups as this segment of robotics is almost forgotten because as evidenced by the review performed it is minimal work on the matter. This situation can be revised in the short term because the country has a world-class infrastructure both physical and human in the area of robotics, it proves contests world robotic football, that experience should be used simultaneously to create robot to help food production, and in turn help reduce poverty among subsistence farmers in the country. As show in the table 1, there are institutions with education in the three levels, bachelor, master and doctorate of high standards that can be used to boost agricultural robotics in the country, just you need to make the decision that these programs include the research oriented to agriculture robotics.

**Conclusions and Recommendations**

In Mexico is minimal the research and development of agricultural robotics. Being in full disadvantage to countries like Brazil, Argentina and Chile have already started research in this segment of robotics. It must start encouraging the creation of groups among the leading universities in research on robotics as the National Polytechnic Institute (IPN for its acronym in Spanish), National Autonomous University of Mexico (UNAM for its acronym in Spanish), IPN-CINVESTAV Tamaulipas and IPN-CINVESTAV Saltillo, Technological University of the Mixteca, University of Guanajuato and agricultural research institutions like National Institute of Forestry, Agricultural and Livestock Research(INIFAP for its acronym in Spanish), Postgraduate College (COLPOS for its acronym in Spanish)and Antonio Narro Agrarian Autonomous University. So the experience and capacity of research institutions on robotics and research institutions in agricultural sciences to advance the development of this discipline in Mexico would take advantage. If the corresponding measures are carried out prospects of agricultural robotics will be more promising in Mexico.

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