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Multifunctional Robot at low cost for small farms

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ABSTRACT: *In this study was developed a three-dimensional robotic device, equipped with a system of actuators, sensors, and controllers to do the individual irrigation of plants in low-cost greenhouses for family farming. After the development were carried out the data collection in the field. In the data analyzing, reported that there was no statistical difference between means for manual irrigation and robotics in the development of agronomic variables of stem height, stem diameter and number of leaves, concluding that the robotic irrigation promoted a lower coefficient of variation and a lower standard deviation in the samples.*
Key words: *agricultural robotics, water irrigation, cartesian robot.*

Robô multifunctional de baixo custo para agricultura familiar

RESUMO: *O objetivo deste trabalho foi desenvolver um dispositivo robótico tridimensional, dotado de um sistema de atuadores, sensores e controladores para realizar a irrigação individual de plantas em estufas agrícolas de baixo custo para a agricultura familiar. Após o desenvolvimento foram realizadas as coletas de dados em campo, analisando-se os dados, constatou-se que não houve diferença estatística entre médias para a irrigação manual e robótica no desenvolvimento das variáveis agronômicas de altura de caule, diâmetro de caule e número de folhas, podendo concluir que a irrigação robotizada promoveu um menor coeficiente de variação e um menor desvio padrão nas amostras coletadas.*
Palavras-chave: *robótica na agricultura, irrigação, robô cartesiano.*

The rural population of Brazil has reduced since agricultural activities are not attractive, which accentuated rural exodus and so, a shortage of workers (ALVES, 2006). Agricultural mechanization can meet the need for labor, but with the high cost of agricultural equipment the small farmer does not have enough resources to acquire appropriate technologies, as a result, its production is inefficient, then there is a need to introduce low-cost technological systems to aid in the production capacity of these farmers. Modern agriculture requires advanced methods to increase the productivity in a quantitative and qualitative way. Application of new technologies such as sensors, actuators, and processors can to increase the efficiency and reliability and so to integrate new applications in agriculture (BODUR et al., 2012). In this context, the use robots are an alternative to cut costs and increase efficiency. Basic concept of a robot is presented as an agent capable of performing tasks that change the physical space with the use of actuators and equipped with sensors, allowing him to perceive the environment (RUSSEL & NORVING, 2004).

Robotics in an agricultural environment is a complex activity, due to the uncertainty inherent in environment. Disadvantage of existing systems is the lack of robustness for these uncertainties (HIREMATH et al., 2014). Development of robotics in agriculture, in general, is slow but persistent (XUE et al., 2012). BELFORTE et al. (2006) affirmed that the most advanced technologies and the latest scientific research results have been widely applied to agriculture to improve the quality of products and to increase productivity, an example is given by the climate control that can be applied in greenhouses.

This paper was carried out with the aim of developing a robotic device capable of interacting in a three-dimensional plane with an actuator system, sensors, and controllers to do irrigation in low-cost greenhouses for a family farm. This system was built and it has been tested, applied in

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irrigation of bean crop in a greenhouse. The system comprises a robotic mechanism with the setup of a Cartesian geometry three axes and with computer intelligence that performs individual irrigation of plants in greenhouses, based on the reference evapotranspiration. This system can be divided into: mechanical structure, drive systems for locomotion, system of control, sensing and irrigation. Figure 1 showed the diagram of the robotic system. All parts of the robotic system were installed in a greenhouse on the Meteorological Station, in Agricultural Science Center dependencies of the Universidade Federal do Ceará in Fortaleza - CE, Brazil, geographically at 3°44' south latitude and 38°34' west longitude and 24 meters of sea level. The moving parts are controlled for a microcontroller, based on sensory information, manipulating electromechanical devices in the execution of sequential movements, contained in an external memory device or SD card, where after positioning the end effector is measured and applied to the volume of water required to irrigate plants. The main robot control is implemented by an electronic platform, where they are connected with a relay module to drive the loads and motors, there is a reader module of memory cards and the sensors of inductive position. There is a communication interface board controller. In the construction of the mechanical structure it was used rectangular metal tubes 50x20mm with 1.20mm wall such tubes are attached with fixing elements with the purpose of forming a track system, which will compose the axes X and Y and Z systems. The axis movement is produced by DC motor coupled to an axle reducer of type worm crown; the shaft end of the gear was fixed in plastic gears, which engaged with a set of racks connected in series and fixed in a metal structure.

The robot design requirement was the use of materials, instrumentation, and supplies of easy acquisition and low price in the market. This goal was achieved from studies on the possibility of replacing conventional materials in robotics for common materials in the automotive commerce and residential instrumentation. All materials used are inexpensive and easy to buy in the market, which are important factors in the production process scale and in the final cost of the product, given that must be purchased by farmers with low capital to invest in agricultural mechanization. Table 1 has the values of materials and tools acquired for the construction of the irrigator robot prototype, with a total value of US$ 538.00 for the construction of the prototype, these values can be reduced when production occurs in the multifunctional robot series.

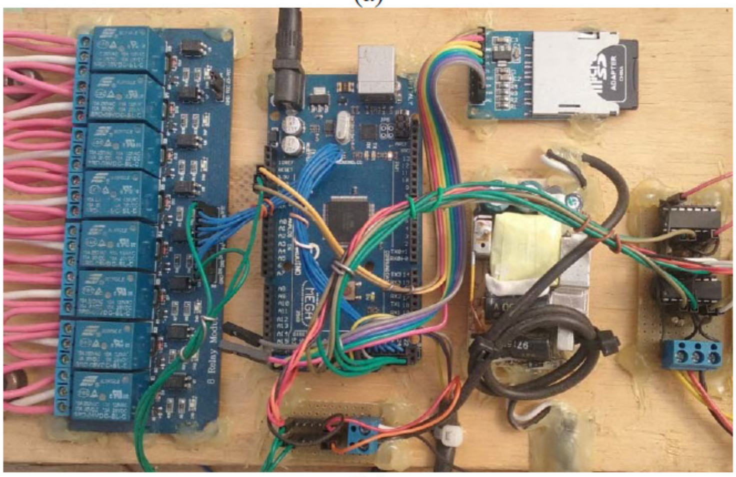
Currently in most of the microcontrollers market, there is an C language compilers for creating software, which allowed a shorter time in the development of new applications due to the facilities offered by the programming language. Another interesting fact is the possibility to make changes from one system to another with great ease (PEREIRA, 2003). The main robot control is implemented by an Arduino® Mega platform 2560, figure 1 (c), where it connects the relay module to drive the loads like motors, reader module memory cards, position sensors, sensors applied inductive as described above, being a communication interface with the driver of water plate in high-level application. The control software was designed by Python® language.

Water meter consisted of PVC tube having an internal diameter of 98mm and 400mm of height, closed at both ends, in the upper part passes through a hole of 10mm diameter a metal rod threaded 500mm long with a diameter of 8mm and a thread pitch of 1mm with proper sealing to prevent possible leakage, both sensors connected to Arduino® One. After all developments, it was built the robot shown in figure 1.

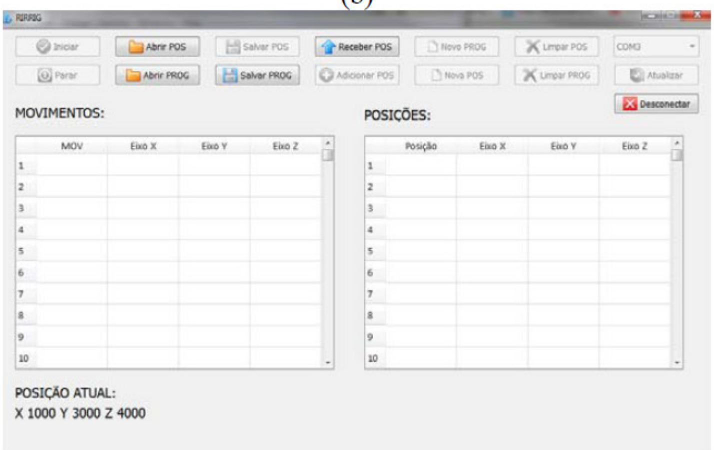
With all hardware and software in accordance with the goals, pre-tests were performed. After several corrections campaign measuring of robot performance in irrigation function was performed and compared with manual irrigation. This method of irrigation was chosen to avoid positive or negative trends with respect to conventional irrigation systems, both micro sprinkler as drip, so we could assess a manual irrigation very well controlled compared to irrigation performed by RIRRIG. The data collected on the stem of plants irrigated by the robot and manually were the mean was 22.99mm and 22.67 for manual irrigation and robotics respectively, the largest standard deviation was 1.02 with 4.54% of the largest coefficient of variation was for manual irrigation. The significance value of 0.100, reported by using the MINITAB statistical software 17®, with a value of 5% de significance, concluded that these hypothesis should not be rejected, so there is not significant difference between treatments. Results taken for the diameter of bean stem in robotic and manual tests are presented using descriptive analysis where it can be observed that the average diameter was 2.97mm, standard deviation of 0.084 and 2.82% coefficient of variation for robotics irrigation, as for manual irrigation the average value reporte was 2.92, standard deviation 0,182 and coefficient of variation 6,25%.

Based on the standard deviation values and coefficient of variation, the stem diameter of the bean was sensitive to the type of irrigation, showing that robotic irrigation was most right, because with

(a)



(b)



(c)

Figure 1 - (a) Robot RIRRIG, (b) Control devices, (c) Graphic interface of controller.
Source: author (2016).

Table 1 - Material costs and tool used in construction of prototype.

	Company	Model	Value (US$)
Motors	Bosch	CEP 006 WMO 310	125.00
Sensors	JNG	LM8-3002NA	66.00
Metal structure	Aço Cearense	Galvanized Metalon	69.00
Controllers	Arduino	Uno e Mega	27.00
Pumps	GAPbr®	AG0004	10.00
Driven Drives	OEM	B60	33.00
Electric cable	SIL Fios e Cabos Elétricos	Flexible Cable 1,5mm²	14.00
Electronic Components	-	-	83.00
Power supply	Goldentec	Power Supply ATX 450 W	58.00
Pipes	Vonder	Transparent hose 1/4”	3.00
Pinion gear and rack	Patola	Rack modulus 4 e pinion modulus 4	50.00
Total			US$ 538.00

Source: author (2015).

this method the lowest values were obtained. When irrigated by the robot the bean has a smaller variation in stem diameter, one of the elements that give such a result is repeatability. NIKU (2013) affirmed that this measure (repeatability) is the ability of the robotic manipulator to me the same position when the movement is repeated many times, but many factors can disrupt this ability as overhead actuators: miscommunication between devices and bad-position of the sensors.

The data acquisition on the number of leaves per plant were carried out and the following results mean was reported for the robot: the value of 4.76 with a standard deviation of 0.487 and 10.27% of coefficient of variation.

The average value of the number of leaves of the samples for plants irrigated manually is 4,580 leaves per plant, with a higher coefficient of variation compared with the irrigated by the machine and a greater standard deviation. In the analysis of variance, the value P value is greater than the adopted significance level of 0.05 and concluded that there is not difference in the number of leaves of plants irrigated by the robot and manually.

There is a tendency to modernize the agricultural sector and agricultural mechanization has been a key part in this process (NOGUEIRA, 2001). Today mechanization in family farming faces a large lack of equipment, in the semi-arid region, there is one tractor to 2.100 hectares (OLIVEIRA & PEREIRA, 2010). Public policy can foster the modernization of the family farm sector, through direct actions by the government or by creating favorable conditions for investments in technology (NOGUEIRA, 2001).

In the process of implementation of robotic technology systems, it is needed to promote training for the farmers, about operation, periodic maintenance, fault detection and safe operation of the equipment and its electrical components to avoid accidents arising from lack of technical knowledge used in the prototype and thus eliminating the need for skilled labor for operation and maintenance. Another striking point provided by the automation of agricultural management is a reduction of intense work activities, repetitive and stressful, which the family farmer is subjected in their daily lives.

The robot has an impact socially positively because it supplies the lack of workers and removes the rural jobs that degrade their physical health. In the industrial sector the deployment of robotic systems is necessary to remain on the market to do greater productivity and raise the qualitative parameters of its products, offering the consumer market at the lowest possible cost, but the hand replacement by robotics promotes a significant reduction in jobs offered by the industrial sector. Conversely, the agricultural sector suffers from lack of workers and the robotics comes as a benefit because it enables the replacement of human labor.

CONCLUSION

The implementation of robotics in this research was presented as an option to complement or even replacement the workers for the agricultural management as it requires minimum operator intervention to come into operation. The real possibility of producing a robot with affordable price to the Brazilian small farmer was reported. In the study, there was no statistical difference between means for manual irrigation and robotics in the development of agronomic variables of stem height, stem diameter, and number of leaves. Robotic irrigation promoted a lower coefficient of variation and a lower standard deviation in the samples.

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