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Implementación de un Robot Cuadrúpedo para Monitoreo de Temperatura, Humedad del Suelo y Gases, en Cultivos de Tomate en Invernaderos

Implementation of a Quadrupedo Robot for Monitoring Temperature, Soil Humidity and Gases, In Tomato Crops in Greenhouses

Implementação de um Robô Quadrupedo para Monitoramento de Temperatura, Umidade e Gases do Solo, em Cultivos de Tomate em Estufas

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Resumen

Desde la antigüedad, el uso de las fases lunares se ha convertido en una técnica fundamental para el cultivo de diferentes productos. Pero las fases lunares no son lo único a tener en cuenta a la hora de cultivar plantas. Uno de los principales problemas en el cultivo del tomate se debe a factores climáticos como la alta HR, favorece el desarrollo de enfermedades aéreas, rajado del fruto y dificulta la fertilización, actualmente a medida que avanza la tecnología la optimización de los cultivos se ha convertido en un estudio frecuente, por lo que el diseño de un robot cuadrúpedo para el control y seguimiento en diferentes fechas y horarios en las fases lunares, para la adquisición de datos en la primera etapa de control el robot analizará el suelo en base a la producción vegetal utilizando el Software Solidwords, para la adquisición de datos de humedad y gases en el invernadero con las semillas cultivadas en fases lunares y sobre el crecimiento de las plantas, se colocó un sensor QT135 que ayudará a monitorear los gases producidos por la composta orgánica.
Palabras clave: cuadrúpedo; fases lunares; sensores; supervisión..

Abstract

Since ancient times, the use of the lunar phases has become a fundamental technique for the cultivation of different products. But the lunar phases are not the only thing to be taken into account when growing plants. One of the main problems in tomato cultivation is due to climatic factors such as high RH, favors the development of aerial diseases, cracking of the fruit and hinders fertilization, currently as technology advances the optimization of crops has become a frequent study, so the design of a quadrupedal robot was proposed for the control and monitoring at different dates and times in the lunar phases, for the acquisition of data in the first stage of control the robot will analyze the soil based on plant production using the Solidwords Software, for the acquisition of data on humidity and gases in the greenhouse with the seeds grown in lunar phases and on the growth of the plants, a QT135 sensor was placed that will help monitoring of gases produced by organic compost.
Keywords: quadruped; lunar phases; sensors; monitoring..

Resumo

Desde a antiguidade, o uso das fases lunares tornou-se uma técnica fundamental para o cultivo de diferentes produtos. Mas as fases lunares não são a única coisa a ser levada em consideração ao cultivar plantas. Um dos principais problemas na cultura do tomateiro se deve a fatores climáticos como a alta UR, favorece o desenvolvimento de doenças aéreas, rachadura do fruto e dificulta a adubação, atualmente com o avanço da tecnologia a otimização das lavouras tem se tornado um estudo frequente, por isso o planejamento de um robô quadrúpede foi proposto para o controle e monitoramento em diferentes datas e horários nas fases lunares, para a aquisição de dados na primeira etapa de controle o robô irá analisar o solo com base na produção vegetal utilizando o Software Solidwords, para a aquisição de dados de umidade e gases na estufa com as sementes cultivadas em fases lunares e sobre o crescimento das plantas, foi colocado um sensor QT135 que auxiliará no monitoramento dos gases produzidos pelo composto orgânico.

Palavras-chave: quadrúpede; fases lunares; sensores; monitoramento..

Introduction

The optimization of crops in a closed environment, using multiple practices, has become a permanent study, both for the productive sector as well as for the student sector, since this study will be reflected in the final product of the crop.

Among the wide range of commercialized horticultural spices, tomato is one of the most important, both in terms of production, distribution and consumption. Likewise, for a better quality and productivity of tomato, it is of utmost importance to control certain parameters, with good temperature control and plenty of light. One of the main problems in tomato cultivation is due to climatic factors such as high RH, which favors the development of airborne diseases, cracking of the fruit and hinders fertilization, because the pollen is compacted, aborting part of the flowers, low light level, negatively affects the processes of flowering, fertilization and vegetative development of the plant and contributes to the development of fungi; high temperatures, above 45ºC are lethal, above 35ºC affect fruiting, due to poor ovule development and the development of the plant in general and of the root system in particular. Or low temperatures produce a physiopathology called "Catface" or pistillate woody scar. (Ponce, et al, 2012)

Tomatoes grow best at temperatures of 21 to 27 °C (70 to 80 °F) during the day and temperatures of 16 to 18 °C (60 to 65 °F) during the night. The ideal is to regulate the temperature at the lowest point of this range on cloudy days and raise it to the highest point (or even a little higher) on sunny and clear days. Therefore, it is of interest to the scientific community to know if it is possible to control the temperature, humidity and amount of gases in a tomato greenhouse by using quadrupeds, as well as to analyze the possible effects due to lunar phases. Since ancient times, the use of lunar phases has become a fundamental technique for the cultivation of different products. The belief that the lunar phases are fundamental in the development and production of the plant has become an enigma.

At present, as technology advances, crop optimization has become a frequent study, thus multiple stages of control and monitoring of the environment have been implemented, these controls have somehow allowed the final product to be of good quality and suitable for human consumption. The objective to develop will be the implementation of a quadruped robot to monitor soil moisture and gases emitted by the organic compost, in the tomato crop planted in a closed environment in different lunar phases located in the Instituto Superior Pedagógico Martha Bucaram de Roldós Bilingüe Intercultural, through the design of the quadruped robot, its control and data acquisition stage, the cultivation of tomato seeds in the different lunar phases, the identification of the type of organic waste that can be used for crops in closed environments, the quantification of soil moisture and organic compost in the greenhouse as well as the level of gases emitted by the use of organic waste in the greenhouse, an evaluation of the efficiency of the prototype in monitoring moisture and gas for crop growth and the comparison of the quality of tomatoes planted in different lunar stages.

Materials and Methods

Design the quadruped robot, its control stage and data acquisition.

It is required to determine the adequate design of the quadruped robot, in which 2 important aspects were taken into consideration, the first one is its control stage and the second one is the data acquisition stage.

1) Control stage

For an adequate control stage was designed taking into account the aspects of the terrain in which the prototype will move, analyzing that it must be for a soil considered for vegetable production, it was decided to design a quadruped prototype, each of the parts are designed in SolidWorks software for its applications in the management of structural design of 3D parts.

Once the appropriate prototype was obtained, the material and technology in which the prototype would be manufactured was analyzed, it was considered that the prototype should be friendly with the land to be monitored, therefore it should not present materials that will harm the growth of plants, Therefore, it was decided to manufacture them in PLA (Polylactic Acid), this material is biodegradable and is made of corn splints, which makes it harmless to the touch and does not present any damage. The technology used to manufacture the pieces is known as 3D printing, which refers to the superposition of layers of PLA plastic until the desired shape of the different pieces of the prototype is achieved.

Analyzed and designed the structure of locomotion and manufacturing materials of the prototype is necessary to design the necessary electronics that will be the brain of the prototype, for the development of the PCB" Printed Circuit Board" was made in perforated Bakelite for its ease of realization of electronic circuits and low cost.

Together with the analysis of the electronic components of locomotion that the prototype is going to use, it was decided to use servomotors for their high level of torque, which will help the prototype to perform better in this type of terrain, The servomotors work by means of PWM cycles (Pulse Width Modulation) which depending on the range of pulse width that is sent to the servomotor, the same managed to position with an accuracy in degrees of rotation, to create the PWM pulse we opted for programming based on the Arduino software to have an extensive range of information and in addition to being free hardware and software.

2) Data Acquisition Stage

Humidity and gases are fundamental factors in plant growth, so the prototype comes with a QT135 sensor which will help to monitor the gases produced by the organic compost, while for humidity the DHT11 sensor was used, which by means of contact technology will measure the soil humidity of each of the samples taken from the greenhouse.

Once corroborated that all the electronic board is working correctly, we proceeded to the manufacture of the PCB in professional development software, to give the final finish to the circuit and that it does not present failures at the time of the field tests, as professional electronic development software was taken into consideration using Proteus 8.5 since making a comparison of design programs, Proteus shows a higher speed of design presentation compared to three softwares, which consume much aspects of computer technology, in terms of the aspects that should be considered for the computer in which it will be designed.

In addition, the control stage included a visualization stage, which was incorporated wirelessly through Bluethoth communication, and through this communication the values of humidity and gases monitored in the field were received and visualized.

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Growing tomato seeds in different moon phases

The greenhouse was built on land suitable for cultivation and easily accessible, with a wooden base covered with a three-layer extruded polyethylene plastic sheet, with additives against UV radiation, for agricultural applications, providing high light transmission, flexibility and moderate resistance to climatic factors. ("Plástico para invernadero - Plásticos Jaramillo | Plásticos en Ecuador", 2021), of the area.

For seed sowing, a perforated plastic seedbed was used for seed germination and then transplanting was carried out in the greenhouse.

Identify what type of organic wastes can be used for indoor cultivation.

The use of organic solid waste is a very important process that is part of the Integrated Solid Waste Management System. For this reason, we searched through bibliographic information and comparing different reliable sources, which are the best compost for closed environments, looking for compost that does not acidify the soil or the plant, and that does not generate greenhouse gases or harbor harmful vectors for tomato growth.

Once the best compost for closed environments was bibliographically identified, the following steps were taken:

1. The organic compost bin was made, which is simply the box or container in which the different layers of waste were added to form the homemade compost.
2. Organic waste was collected in conjunction with the 3rd semester students of the Environmental Measurement and Monitoring course generated in the ISPIB MBR.
3. Organic waste not suitable for composting was separated.
4. We added the residues obtained by layering different products or wastes, such as vegetable and fruit peelings, twigs and dry leaves from hedges or plants that we have pruned, coffee, eggshells, etc.
5. The compost was watered because it needs a certain degree of humidity to be able to form the handmade fertilizer that will enrich our organic crops. This way, it will be worried that the humidity penetrates in the different layers that were added to the compost.
6. The compost was turned every 15 days in order to generate aeration in the compost.
7. The compost was left to rest for 3 months to obtain a mature compost ready for use.

At the end of the composting process, it was used to improve the growth and quality of the tomato plants.

Quantify soil moisture and organic compost in the greenhouse.

With the help of the quadruped robot, the amount of soil moisture and compost used prior to planting was measured. It was used as a base information that indicated which are the areas of higher humidity for the crop so that a better quality of tomato can be obtained and also indicated which are the areas that require more water at the time of irrigation.

Quantify the level of gases emitted by organic waste uses in the greenhouse.

The quadruped robot measured the amount of greenhouse gases and biogas resulting from the composting of organic fertilizers.

Once the measurements were taken, isoline maps were designed using ArcGIS software to indicate the areas with the greatest impact in terms of the level of gases emitted by the waste, and a comparison was made with other studies of tomato crops.

Evaluate the efficiency of the prototype in monitoring moisture and gas for crop growth.

For the evaluation of the prototype, 2 fundamental cases of the prototype were analyzed, firstly, the locomotion and secondly, the monitoring of the sensors.

To evaluate the efficiency of the locomotion of the prototype, several locomotion tests were performed in various sectors of the greenhouse demonstrating the ability to move the robot, thus showing the efficiency of the movement and programming of the prototype, while to evaluate the efficiency of monitoring, the measurements emitted by each of the sensors were analyzed, comparing the results obtained in the different sensors versus measuring devices dedicated to environmental monitoring of crops or studies previously conducted in areas of tomato crops.

Comparison of the quality of tomato sown at different lunar stages.

We want to know the quality of tomato from a crop in a closed environment planted in different lunar phases. Samples were taken from different crops and a comparison was made between them and the degree of affectation according to the phase. The amount of humidity and gases to which the crop was exposed was also considered.

Results

Design the quadruped robot, its control stage and data acquisition.

The mechanical development of the prototype was carried out in Solidwork 2014, since this tool allows us to virtualize and model figures in 3D, with the ability to analyze the respective movements of each joint of the quadruped.

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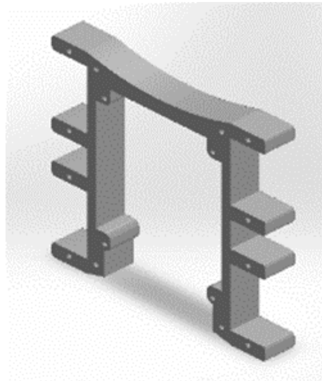

Figure. 1. Servo support (Body)

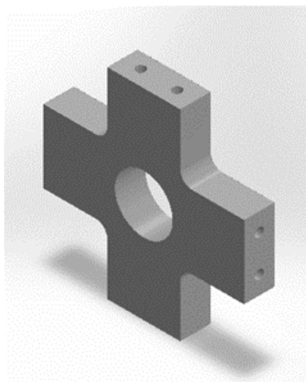

Figure. 2. Support servo couplings with legs

A total of 19 pieces were designed to form the entire structure of the prototype.

For the development of the 3D printing, the institute's own printer was used.

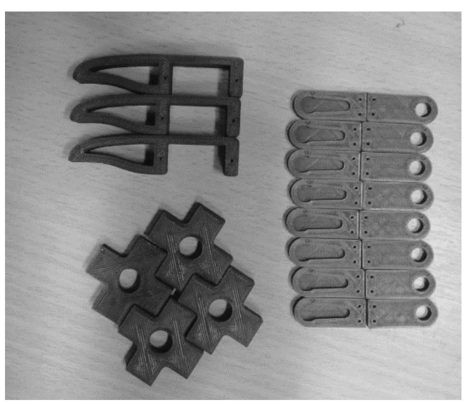

Figure. 3. Parts of the prototype legs

Thanks to the contribution of the institute's 3D printer, the different parts of the prototype were created, which will eventually become a didactic material for some of the institute's semesters.

Quadruped Robot Design

Once the design was developed in Solidwork 2014 and the parts were printed in 3D, we proceeded with the assembly of the structure. For the assembly we used M3*12 mm screws, and towerpro SG92 servos of 2.5kg were used for each of the joints.

The prototype has 8 degrees of freedom each limb with 2 degrees for better mobility.

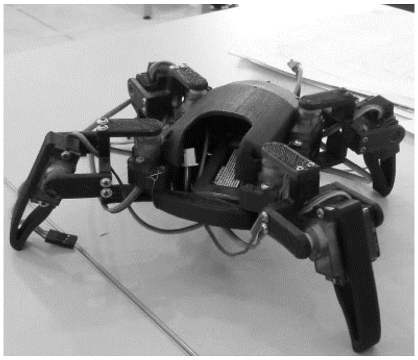

Figure. 4. Prototype of armed Quadruped Robot

Control Stage

The control stage in its first stage was designed in a perforated Bakelite which is for didactic methods and to focus on the performance of locomotion of the prototype.

In the second stage, a bakelite was designed in the CNC machine and properly focused on the performance of the prototype.

Data Acquisition

The Arduino platform was used for the data acquisition, since we wanted to implement a prototype that could be used for further links with the students.

Once the prototype was assembled in perforated Bakelite, we could start the programming stage to delimit the degrees of each of the servos.

Prototype programming.

We proceeded to develop the programming, which consisted of four movements.

- Forward movement.
- Backward movement.

- Left Rotation.
- Right Rotation.

In order to achieve the necessary sequences of movements, a scheme of the movements and the arrangement of the servomotors was made.

It was taken into account that the following steps are used for the forward movement, with small modifications the other movements will be achieved, backward movement and their respective right and left rotations.

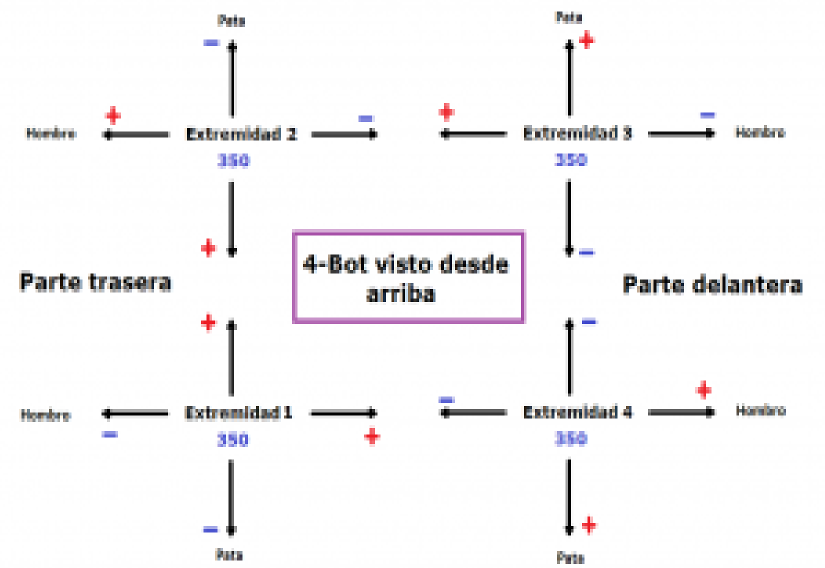

Figure. 5. Arrangement of the extremities for movement.

Cultivar las semillas de tomate en las diferentes fases lunares

Se The seeds were sown in an EPS (expanded polystyrene) seedbed, which is suitable for seed germination.

The seedbed has 210 spaces which will be divided into the 4 lunar phases:

1. New Moon (42 spaces)
2. Crescent Moon (63 spaces)
3. Full Moon (63 spaces)
4. Waning Quarter Moon (42 spaces)

This way of distributing the spaces was decided because phases 1 and 4 are not good for harvesting and phases 2 and 3 were considered more spaces in order to have an adequate seedbed for the greenhouse.

Identify what type of organic wastes can be used for indoor cultivation.

Through bibliographic information it has been determined that citrus organic waste is not suitable for planting in greenhouses because it acidifies the soil and generates many odors and gases, making the quality of the compost unsuitable for planting tomatoes, so these wastes have been separated in the collection and collection of organic waste.

The collection and separation of organic waste was done in conjunction with the students of the 3rd Semester of Environmental Measurement and Monitoring, from the solid waste management course.

Once the compost was matured and ready, it was applied to the soil where the tomato sprouts were planted and transplanted according to the lunar phase.

Quantify soil moisture, temperature and the level of gases emitted by organic waste uses in the greenhouse.

With the help of the Quadruped, temperature, humidity and gases emitted were monitored and controlled, and 15 readings were obtained for the five monitored variables, which were measured in a closed environment. Since repeatability can be expressed quantitatively, depending on the dispersion characteristics of the results, isoline maps were made with the readings obtained to visibly identify the critical points in each analysis.

The readings obtained with the monitoring and control module are shown in Table 1. It should be noted that as a result of the analysis it was obtained that the readings taken by the sensors show little variability as reported, so the error committed in the measurement of the variables is minimal. The repeatability for each of the variables is less than 10%, and it is concluded that the measurement system is acceptable due to its stability. (Llamosa, 2007).

LONGITUD	LATITUD	TEMPERATURA	HUMEDAD	CO-mg/m3	OZONO-ug/m3	Nox-mg/m3
289037,32	7801,62	20,14	78,00	0,33	43,53	21,20
289037,31	7801,62	21,00	78,00	0,33	43,53	21,20
289037,31	7801,62	21,00	80,00	0,34	43,53	21,20
289036,32	7802,55	20,24	77,00	0,34	43,53	21,20
289033,43	7802,98	20,34	76,00	0,34	43,00	21,20
289033,84	7802,81	20,34	77,00	0,33	43,00	21,20
289033,13	7802,12	21,00	80,00	0,33	43,00	21,20
289033,02	7802,17	21,01	73,00	0,33	42,46	21,20
289035,07	7801,35	21,05	73,00	0,33	42,46	21,20
289037,32	7799,54	20,15	70,00	0,34	43,00	21,20
289037,33	7799,72	20,90	70,00	0,33	43,00	21,20
289037,21	7799,41	22,01	75,00	0,34	43,00	21,20
289037,22	7799,33	22,01	85,00	0,34	42,99	21,20
289037,71	7798,79	21,05	78,00	0,32	42,99	21,20
289037,82	7798,63	21,05	78,00	0,32	42,99	21,20

Table 1. Values of the variables analyzed in the growth of tomato.

It was obtained that soil moisture is at an average of 76.53% which favors the growth of tomato. There were areas that through the use of the quadruped could be evidenced as critical areas for their low values and a more frequent irrigation was chosen, being able to normalize the amount of existing humidity, thus remaining with minimum values of 70% to maximum values of 80% humidity, as shown in Fig. 6, where the points with lighter colors are those where there is less moisture and likewise those with darker blue colors are where there is more soil moisture.

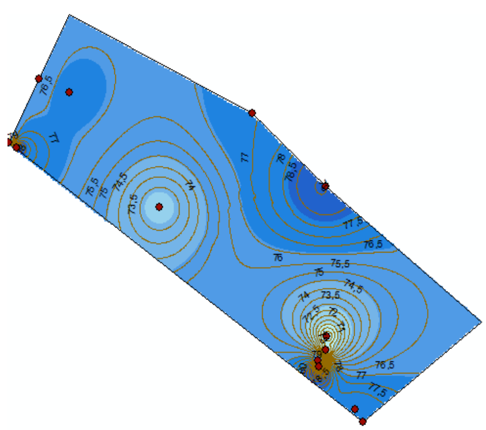

Figure. 6. Soil Moisture Level

The temperature of the environment, in spite of being a closed environment, was maintained at an average of 20.89°C. This temperature helps to obtain better tomato growth and it was evident that the highest temperatures were 22.90° and the lowest were 20.04; this is indicated in Fig. 7 where the blue colors show the lowest temperatures and the cream and orange colors show the highest temperatures.

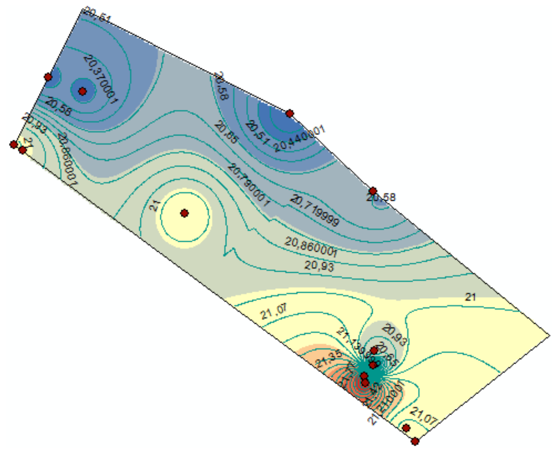

Figure. 7. Temperature level

The CO2 gases in the environment were measured in the same way with the help of the quadruped and an average of 0.33 mg/m3 was obtained. This amount of gases is minimal, so it is not significant in the growth of the tomato; it was calculated that the highest amount was 0.34 mg/m3 and the lowest was 0.32 mg/m3; this is indicated in figure. 8, which has a scale of gray colors referring to the environmental contamination that the tomato could produce, noting that the darkest colors are where the highest amount of CO2 exists. It should be emphasized that the measurement of the same, gave to notice that the cultivation of tomatoes does not cause environmental pollution by CO2 because the amount produced is minimal.

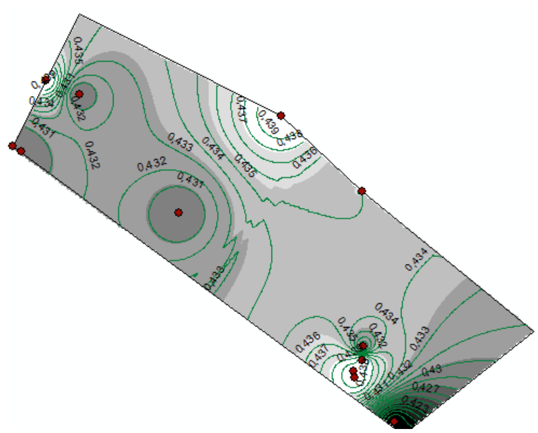

Figure. 8. CO2 level

The other gases measured with the help of the quadruped such as ozone and NOx were not analyzed because there is no variation between their data, but it can be indicated that they had values of 43.07 ug/m3 for ozone and 21.20 mg/m3 for NOx. These gases did not interfere with adequate tomato growth.

Evaluate the efficiency of the prototype in monitoring moisture and gas for crop growth.

Locomotive Performance Tests

a. Dry Ground

The locomotion of the quadruped robot has been designed to have 8 degrees of freedom, 2 degrees of freedom for each limb, at the moment of placing it in the greenhouse in a dry sector we have shown that the locomotion of the prototype is adequate due to the fact that the soil is compact, thus reducing the census time and avoiding the intervention of the human hand.

Figure. 9. Locomotion on dry ground

b. Wet Ground

The locomotion of the prototype, in spite of its 8 degrees of freedom, is affected when the ground is excessively wet because the ground is not stable, evidenced by an increase in the monitoring time of the sensors and in any case it has been necessary to intervene to help it in its locomotion.

Figure. 10. Locomotion on wet ground

A. Sensor monitoring performance test

For the corresponding efficiency tests of the prototype we must take into account that the sensors capture data within 4 seconds.

The expertise acquired during the implementation of the device will involve an estimated 15 samples in 60 seconds to verify range, failures and device configuration.

a. *Data acquisition repeatability test.*

For the test, approximately 15 samples will be taken from each of the sensors to determine the respective levels of temperature, gas and humidity detected by the sensors at different distances from the plant.

b. *Data acquisition a 40 cm*

The first test was performed at a distance of 40 cm from the plant.

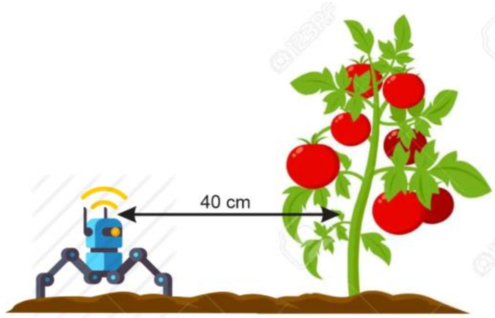

Figure. 9. Sensors at a monitoring distance of 40cm.

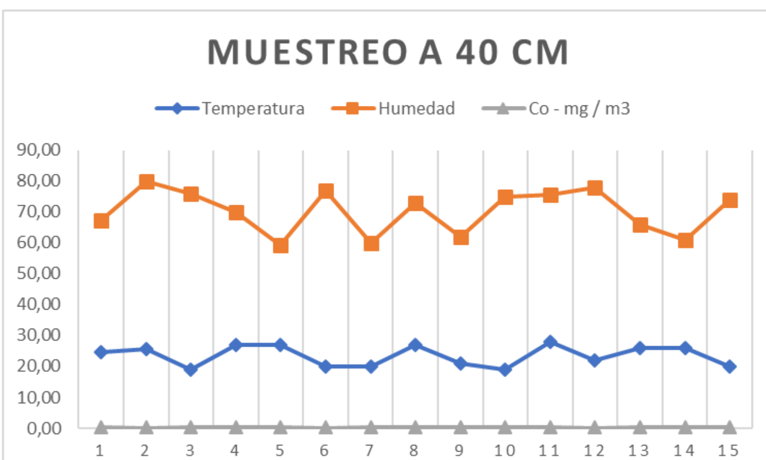

Figure. 10. Samples taken at a monitoring distance of 40cm.

c. *Data acquisition at 20 cm*

The second test was performed at a distance of 20 cm from the plant.

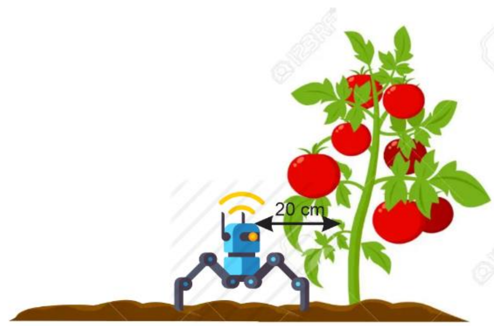

Figure. 11. Sensors at 20cm monitoring distance

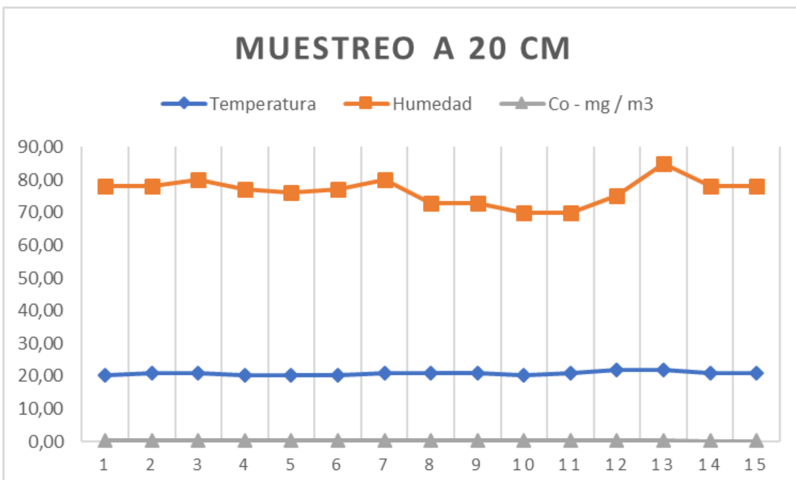

Figure. 12. Samples taken at a monitoring distance of 20cm.

Comparison of the quality of tomato sown at different lunar stages.

The lunar phases are associated with atmospheric precipitation, as well as in the circulation of plant sap. Thun (1988), states that after more than twenty years of scientific research, he found evidence of a rhythm related to the passage of the moon in its orbit through the signs of the zodiac and these in relation to the phases. This rhythm causes plants to accentuate the growth of one or another of its parts (root, leaf, flower or fruit), depending on the day of planting.

However, it must be considered that each cultivation site has different characteristics: climatic conditions, soil properties, pests, among others, which directly and indirectly affect the crop.

Soil moisture is an important factor in each crop, since if this factor is too low or too high, plant growth, development, growth and production will be seriously affected. The effect on each plant depends on the type of crop.

Figure. 13. Tomatoes in new moon

During the first lunar phase (new moon), the sap is concentrated in the root, presents a low growth, in agriculture is considered as a cycle of rest, the plants planted during this phase have very few leaves and the fruit development is quite slow and fails to have an adequate size.

Figure. 14. Tomatoes in crescent

The cultivation carried out during the second lunar phase (fourth crescent) was more favorable, since the fruits were of average size and the plants had adequate foliage. Traditionally, this lunar phase is considered a suitable phase for cultivation, since the sap circulates towards the upper part of the canopy, ideal for balanced growth.

Figura. 15. Tomatoes in full moon

Farmers consider that, during the full moon, plant growth is quite fast, since the sap is concentrated in the upper part of the plant, the ripening of the fruit during this stage, developed very irregular within the crop.

Plants planted during the fourth lunar phase failed to ripen, but this is attributed to pest factors.

Discussion

The research is oriented to know how the lunar phases are related to tomato cultivation, as well as the factors of humidity and CO2 gases. During the execution, cultivation was carried out in four lunar phases: new moon, crescent, full moon and waning quarter.

Seed germination was carried out in a plastic seedbed, during this process the seeds sown in full moon, have an accelerated growth, while those sown in waning quarter the growth is unbalanced, when the transplanting process was carried out it was noticed that their roots are quite weak as well as their stems, the plant tends to bend, The sprouts planted in the fourth crescent phase have a balanced growth, it must be clearly understood that the lunar phases are not the only factor that can affect the germination or the quality of its sprouts, there are other factors such as soil quality,

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amount of oxygen in the place destined for germination, as well as the humidity of the soil in the seedbed.

The circulation of the hexapod robot inside the greenhouse has difficulties due to the soft texture that the soil of the crop must have, which causes it to be buried, causing it to be immobilized when the soil is very humid. Compared to other measurement systems, this robot has the advantage that the measurement and monitoring is done directly on the plant or in the rows, which allows sectoring the water irrigation.

Data collection with this prototype consists of burying a humidity sensor in the soil, once the reading is obtained, it is sent via Bluetooth to a cell phone. In later applications, it could work with a wifi module to increase the range of sending data to a computer for data processing.

The results obtained by the quadruped robot in the tomato crop show that the temperature obtained by the quadruped robot used for this study shows average temperature values of 20.89 °C and 76, 53 % humidity as main control values, while in the greenhouse gases the data obtained are on average for carbon monoxide 0.33 mg/m3, for ozone 43.07 ug/ m3 and finally for NOx an average value of 21.20 mg/m3. These data agree with the data obtained in the research "IMPLEMENTATION OF A WIRELESS ELECTRONIC PROTOTYPE FOR MONITORING, WARNING AND CONTROL OF POLLUTANT GASES IN ARTESANAL GREENHOUSES" where a wireless electronic prototype for monitoring, warning and control of polluting gases in artisanal greenhouses has been used to measure data of the variables NH3, CO, O3, NOx and temperature, showing the following average values. NOx = 26.26 mg/m3, Ozone = 48.01 ug/ m3, Carbon monoxide = 0.43 mg/m3 and temperature of 20.02 °C, with these data it can be seen that the values taken by the quadruped robot are similar to those of the prototype used, at the same time these values are in the range established bibliographically as a recommendation for the adequate growth of tomato in greenhouses. The implementation of automated systems to measure and control growth and cultivation parameters in greenhouses can help to have a better result in the plant and fruit planted.

Conclusions

A quadruped robot was implemented to control the parameters of Temperature, Humidity, Carbon Monoxide, Ozone and NOx, considering pollutant gases that may be present in the use of greenhouses for tomato cultivation. It was designed in Solidwork 2014 and printed in 3D, it was verified that the system does not introduce errors in the data measurement, by calibrating the gas sensors.

Bibliographic studies were carried out for the elaboration of compost for the improvement of the soil where it will be cultivated, it was obtained that citrus residues do not contribute to the quality of the compost; therefore, compost was elaborated without this type of residues.

210 plants were planted in a seedbed, which were divided into the 4 lunar phases: New Moon (42 plants), Crescent Moon (63 plants), Full Moon (63 plants) and Waning Quarter Moon (42 plants). Afterwards, these plants were transplanted and with the help of the quadruped robot, temperature, humidity and greenhouse gases (CO, O3 and NOx) were monitored, obtaining an average temperature value of 20.89 °C and 76.53 % humidity as the main control values, while for greenhouse gases the data obtained were an average of 0.33 mg/m3 for carbon monoxide, 43.07 ug/ m3 for ozone and finally an average value of 21.20 mg/m3 for NOx. The measurement of these data helped to maintain areas of soil with the necessary amount of moisture and adequate ventilation for tomato growth in greenhouses, the values of greenhouse gases did not influence the proper growth of tomatoes.

The locomotion of the prototype, in spite of its 8 degrees of freedom, is affected when the ground is excessively humid since the ground is not stable, evidenced an increase in the monitoring time of the sensors and in any case it has been necessary to intervene to help it in its locomotion, the prototype took a time of 4 seconds to measure, and the results were verified during 1 hour, the data were taken at 20 and 40 cm of distance with the plant, it can be concluded that the quadruped robot works with great efficiency.

The plants that had the best results were those planted in the second lunar phase (fourth crescent), this phase was more favorable, obtaining fruits of larger size compared to those of more lunar phases and adequate foliage.

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Conflicts of Interest

There is no conflict of interest in this research.

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