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AUTOMATED SYSTEM FOR THE PROCESS OF ARTIFICIAL RAIN GENERATION

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1 ABSTRACT

Different models of rainfall simulators have been developed over time, and the use of electronics has allowed achieving higher levels of production and control. On this subject, the aim is to present the development of a technical system for automated generation of simulated rain. The study was divided into two stages. In the first stage, the development of the automated system for generating simulated rain was carried out. In the second stage, tests were conducted to verify the functioning of the proposed system. The result are: (i) concept of the system developed is compound by a sensor of flow rate, pressure and temperature, digital display, interface cable of computer and four buttons that allows the setup of the simulated rain (the plot of land, time and volume of water to produce the simulated rain). It can be programmed up to 240 parcel, maximum time each experiment of 240 minutes and the volume of rain according to the pump used. (ii) to check the functioning of the electronic system, a test in the laboratory was done. During the automated operation, the system measured pressure (kPa), water flow (L min^{-1}), temperature (ºC), and time (minute). The operation was evaluated and it was concluded that it enable the automated generation of simulated rain and that under the experimental conditions studied (without the influence of wind, natural rain or sun), the 17 repetitions totaled 510 minutes of experiments, in which time the prototype showed neither failures in programming or measurement errors of the sensors.

Keywords: automation, electronics, simulated rainfall, hydrology, water and soil.

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SISTEMA AUTOMATIZADO PARA O PROCESSO DE GERAÇÃO DE CHUVA ARTIFICIAL

2 RESUMO

Diferentes modelos de simuladores de chuva foram desenvolvidos ao longo do tempo, e a utilização de sistemas eletrônicos permitiu alcançar maiores níveis de produção e controle.

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Sobre este tema, o objetivo é apresentar o desenvolvimento de um sistema técnico para geração automática de chuva artificial. O estudo foi dividido em duas etapas. Na primeira, foi desenvolvido o sistema automático para geração de chuva simulada. Na segunda etapa, foram realizados testes para verificar o funcionamento do sistema proposto. Os resultados são: (i) o conceito do sistema desenvolvido é composto por um sensor de vazão do fluído, pressão e temperatura, um mostrador digital, cabo de interface do computador e quatro botões que permitem a configuração da chuva simulada (parcela, tempo e o volume de água para produzir a chuva simulada). Pode ser programado até 240 parcelas, tempo máximo de cada experimento de 240 minutos e o volume de chuva de acordo com a bomba utilizada. (ii) para verificar o funcionamento do sistema eletrônico, foi realizado testes em laboratório. Durante a operação automatizada, o sistema mediu a pressão (kPa), vazão (L min^{-1}), temperatura (ºC) e o tempo (minutos). A operação foi avaliada e conclui-se que o sistema desenvolvido possibilitou a geração automatizada de chuva simulada e, nas condições experimentais estudadas (sem influência do vento, chuva natural e sol), as 17 repetições totalizaram 510 minutos de experimentos, o sistema proposto não apresentou falhas na programação ou erros de medição dos sensores.

Palavras-chave: automação, eletrônica, chuva simulada, hidrologia, água e solo.

3 INTRODUCTION

The rains have an important role in the hydrological cycle (VALIPOUR, 2016). However, in many countries the water scarcity has been seen as a problem for agriculture, so, a deeper knowledge about more depth about the hydrological cycle allows to assist in the management of water resources (VALIPOUR; SEFIDKOUHI; ESLAMIAN, 2015).

In agriculture, the management of water resources is indispensable and is related to different aspects: efficiency of irrigation, ground salinity, water economy, sustainable development; management of ground water and cultivation productivity. (VALIPOUR, 2015b).

Knowing the influence of rains on ground surface is important for auxiliary in the land use management (VALIPOUR, 2016). Therefore, studies have been aimed to predict and analyze to perform with goal of predict and analyze rains precipitation, among them, Valipour (2016) used different techniques (Non-linear AutoRegressive Neural Network - NARNN and e Non-linear Input-Output - NIO) to predict the annual precipitation of rainfall in the region of Iran. A software was developed with the techniques and calibrated with historical data of the rains collected in 27 stations between the years of 1968 to 2009.

In countries of Asian and Oceania, which represents more than 60% of world population, the handling of irrigation is indispensable because of the limitations of water resources.

Therefor Valipour (2015a) has been performed irrigation handling studies in these regions about the handling of irrigation and concluded that New Zealand is the country that has the best rate. In Iran region Valipour and Eslamian (2014), it was performed studies with the goal of analyzing the behavior of evaporation, consisting of water loss of an ecosystem caused by evaporation from the ground and transpiration from plants, under the influence of different temperatures.

In constant search for knowledge, researchers have been using mathematical models since 1980 aiming to predict and simulate different scenarios and estimate regions and periods of dry or excessive rains to obtain better use of rains for agriculture (VALIPOUR; SEFIDKOUHI; ESLAMIAN, 2015). In studies about surface irrigation, there are four different mathematical models that allow simulating different scenarios, full hydrodynamic (HD), zero inertia (ZI), kinematic wave (KW) and volume balance (VB). The most complete and accurate model is HD, which uses a set of equations that integrates mass and conservation of energy allowing you to use this model in many cases to calibrate the other (VALIPOUR; SEFIDKOUHI; ESLAMIAN, 2015). In addition to the mathematical models, the use of models such as ARMA (Auto Regressive Moving Average) has been used to predict rains, being successfully used to estimate flooding in real time (VALIPOUR; BANIHABIB; BEHBAHANI, 2013).

With the objective of performing different studies related to rain and its effects, rainfall simulators were developed. Rain simulators are devices that contribute to several researches and studies. Various models of rain simulators were developed to meet the specific needs of each experiment (MEYER and MCCUNE, 1958; SWANSON, 1965; PALL et al., 1983; ALVES SOBRINHO, 1997; NORTON and SAVABI, 2010; BERTOL, I.; BERTOL, C.; BARBOSA, 2012).

According to different existing views, the design of a generic model becomes complex, due to the variation of the plot, minimum and maximum intensity and kinetic energy of the artificial raindrop (SANTOS, 2015). Several studies were performed using systems that generate artificial rains, mainly in the areas of water erosion (BAGATINI et al., 2011; GARBIATE et al., 2011; NUNES and CASSOL, 2011; PORTELA et al., 2011; VOLK and COGO, 2014), surface runoff (SPORH et al., 2009; BRAMORSKI et al., 2012; CARVALHO et al., 2012; SILVA et al., 2012; PINHEIRO et al., 2013; OLIVEIRA et al., 2013; ABRANTES; LIMA; MONTENEGRO, 2015 and RODRIGUES et al., 2015) and the persistence of phytosanitary products (BASTIANI et al., 2000; NEVES; FOLONI; PITELLI, 2002; CAMPOS et al., 2010; PEREIRA et al., 2010; PEDRINHO JUNIOR et al. 2012a and PEDRINHO JUNIOR et al. 2012b).

The use of rain simulators allows the reduction of labor and time required for data collection. Conducting experiments using the natural rainfall requires many repetitions with the same intensity characteristics. This requires lots of people to be involved, resulting in high costs, which often leads to the discontinuation of experiments, therefore, compromising the historical data series (BERTOL, I.; BERTOL, C.; BARBOSA, 2012).

The increasing automation in agricultural equipment and machinery through electronic systems has provided a revolution in data management and operational control (ANTUNIASSI and BOLLER, 2011). It also contributed to improving quality, reducing waste, increasing productivity and supports planning and decision-making towards greater competitiveness (TERUEL, 2010).

Automation is an irreversible evolutionary process that provides speed and accuracy in performing tasks and therefore increases productivity (SILVEIRA and SANTOS, 1998).

From an engineering point of view, the rainfall simulator is a device that performs the function of artificially producing the characteristics of natural rainfall, requiring the definition of a function of automated generation of artificial rain.

In this context, the definition of the design specifications for a technical system for the automated generation of artificial rain is an essential activity. This definition is done through a systematic and progressive process, using product plan, customer requirements and within these, obtained the requirements and product design specifications (BACK et al., 2008). Commonly, these definitions are the main activities of the informational design phase (FONSECA, 2000; BACK et al., 2008; ROMANO, 2013).

During this phase, different attributes should be considered: functionality, ergonomics, safety, reliability, modularity, aesthetic, legality, among others. In combination with customer requirements, the design requirements are obtained, which indicate how each of the customer requirements can be met, representing measurable technical and physical aspects of the product (FONSECA, 2000). From these definitions, a technical system can be designed.

In this context, the aim is to present the development of a technical system for the automated generation of artificial rain.

4 MATERIALS AND METHODS

First, of all, the customers' requirements were defined, which were identified from previous analysis on rain simulators available in literature. Determining customer requirements allowed their conversion into design requirements (metrics and measurement units) and design specifications (metrics, measurement units and target value), constituting the informational project phase.

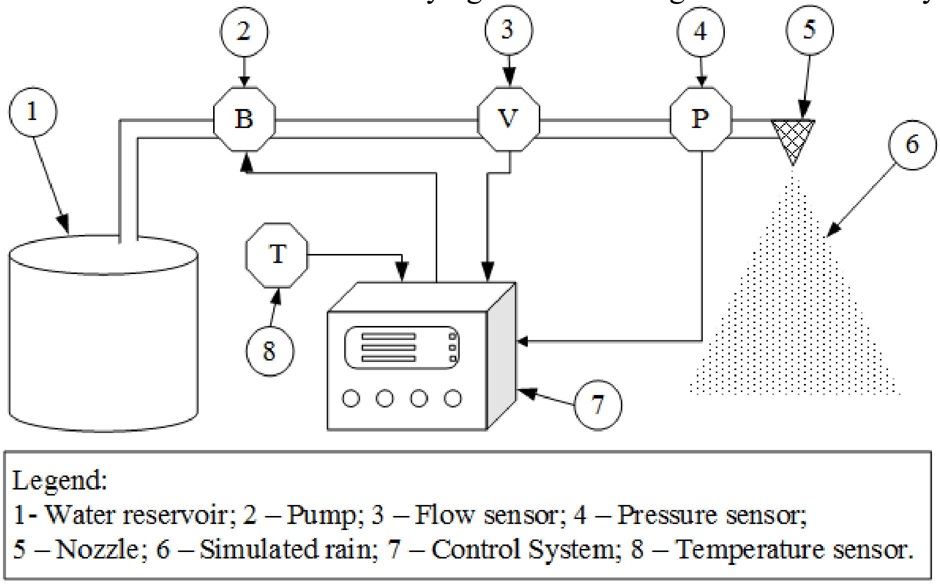
The second step was the definition of the architecture of the electronics system, basically consisting of choosing between centralized or distributed architecture. In the context of the project centralized architecture was selected, as it combines all processing elements in a single center.

The third step was the preparation of a block diagram, which shows in a flow chart the programming logic of the electronic system. By means of a standard formalism, the chart represents the start and end (ellipse), data processing (rectangle), manual data input (parallelogram) and decision-making (diamond), interconnected by arrows indicating the information flow (arrow).

The electronic system was assembled using a microcontroller PIC18F4520 model, which allowed integrating the sensors necessary to meet the design specifications.

At this second stage, a laboratory test bed was set up (Figure 1) to check the functioning of the electronic system. 17 repetitions were carried out in an environment with no influence of wind, natural rain or sun, totaling 510 minutes of simulation of artificial rain.

Figure 1. Scheme of the test bench for verifying the functioning of the electronic system.



Legend:
1- Water reservoir; 2 – Pump; 3 – Flow sensor; 4 – Pressure sensor;
5 – Nozzle; 6 – Simulated rain; 7 – Control System; 8 – Temperature sensor.

The hydraulic system comprises a diaphragm pump SEAFLO SFDP1-050-060-51 model with a maximum flow rate of 18.9 L m^{-1}, fed by a tank with a 200-liter capacity; the water outlet is through a nozzle spray FullJet Fl-15VS model.

Table 1 lists the materials used for assembling the test bench. Five models of connectors were used, thus avoiding the switching or reversing of wires.

Table 1. Materials used.

Material	Model	Specification
Flow sensor	YF-S201	1 to 30 liters per minute
Pressure sensor	MPX4250Gp	maximum 250 Kilopascal
Temperature sensor	DS 1822	-55ºC to 125ºC
Actuated pump 12V	SEAFLOW (SFDP1-050-060-51)	maximum 18,1 liters per minute maximum pressure 480 Kilopascal
Standardized Connections	Jack P4/J4 Jack P10/J10 DB9 male DB9 female Jack RCA female	-----
Reservoir	Steel drum	200 liters

5 RESULTS AND DISCUSSION

Corresponding to the first stage of the study, the development of the automated system for generating artificial rain, customer requirements, design requirements and design specifications are presented in Table 2.

Table 2. Informational design phase results.

Customer requirement	Design requirement	Design specifications	
		Metric	**Target Value**
1. Measure flow of water	1. Flow	1. Flow	30 liter per minute
2. Tracking of tests	2. Storage capacity	2. Data storage	1 megabyte
3. Measure pressure	3. Pressure	3. Pressure	500 Kilopascal
4. Easy to assemble	4. Standard interfaces	4. Number of standardized connections	90 percent
5. Low maintenance costs	5. Standardized components	5. Number of standardized components	90 percent
6. Easy Maintenance	6. Time for maintenance	6. Time for maintenance	< 2 hours
7. System with low voltage triggered controller	7. Operating voltage	7. Operating voltage of the control system	12 direct current
8. Low voltage powered pump	8. Operating voltage	8. Operating voltage of the pump	12 direct current
9. Communication with microcomputer	9. Standard interfaces	9. Serial interface	9 pins
10. Measure temperature	10. Temperature	10. Temperature	70 degrees Celsius
11. Easy configuration	11. Number of data entries	11. Number of data entries	5 units
12. Easy to operate	12. Number of buttons	12. Number of buttons	5 units

The first three design specifications establish the measurement of flow, pressure and storage of data for automated generation of artificial rain. The pressure and flow are directly linked to the intensity of rain that needs to be produced, and the parameters of storage used in each experiment enables tracking the simulation.

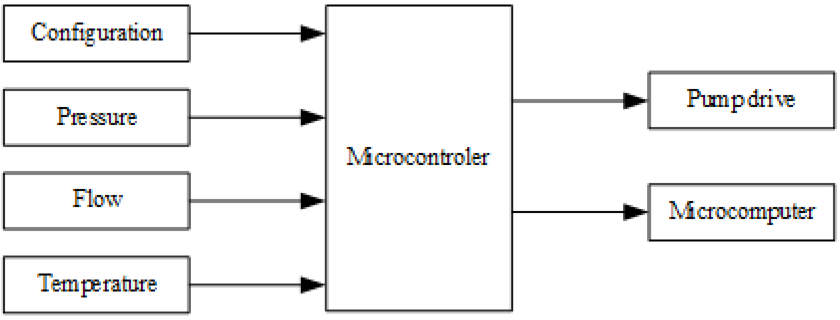
The system operates at 12 Vcc (direct current) voltage powered by an automotive battery, allowing the using of the field simulator without the need of use a fixed power network.

The temperature is a specification which does not influence the process of generating artificial rain, however, in the irrigation, Keller & Bliesner (1990) mention the importance of knowing the ambient temperature due to evaporation losses and drag, which may vary between 5 and 10%, and, in extreme conditions, can occur even bigger losses. Thus, it was used a temperature sensor that allows the user to check the ambient temperature and make the decision about when to carry out the experiments.

The specifications of standardized components, the number of data inputs and the number of buttons are characteristics related to the use and operation of the proposed system when looking at the lowest number of tasks needed to perform artificial rain. The serial interface allows the user to export the data to a computer where they are stored in order to register and prepare a history of rainfall produced by the system.

Figure 2 shows the electronic architecture of the automated system for generating artificial rain. A centralized architecture was selected in order to group data acquisition, processing and data storage on a single microprocessor system.

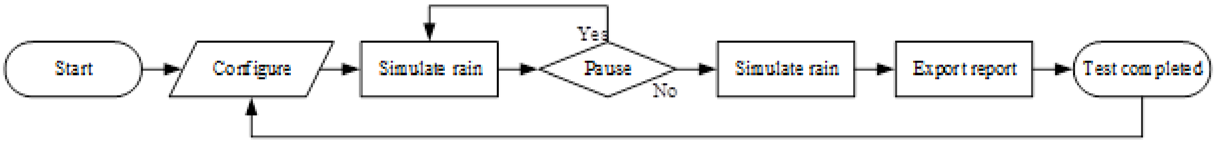
Figure 2. Centralized electronic architecture.



Source: Adapted from Santos (2015).

The block diagram (Figure 3) corresponds with the information flow of the system, enabling the use of the programming language C. The programmed system allows the user to perform the setting by means of 4 buttons, and the information is showed on a digital display with dynamic menu. The system was also programmed to export reports that include the programmed parameters and the values measured by the sensors.

Figure 3. Block diagram for automated generation of artificial rain.

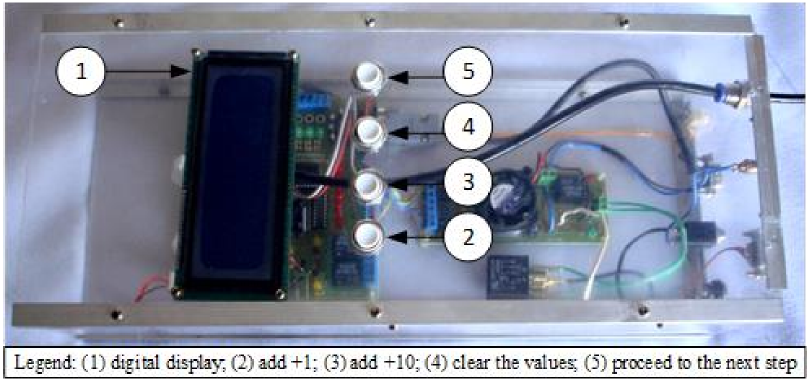


Source: Adapted from Santos (2015).

Configuration is performed by manual data input (MDI). The user enters the plot identification, rain duration (minutes) and intensity (mm h^{-1}). The microcontroller system allows the realization of different intensities in artificial rain, by means of signal variation that is sent to the pump and to the microcomputer in the form of data reports as well.

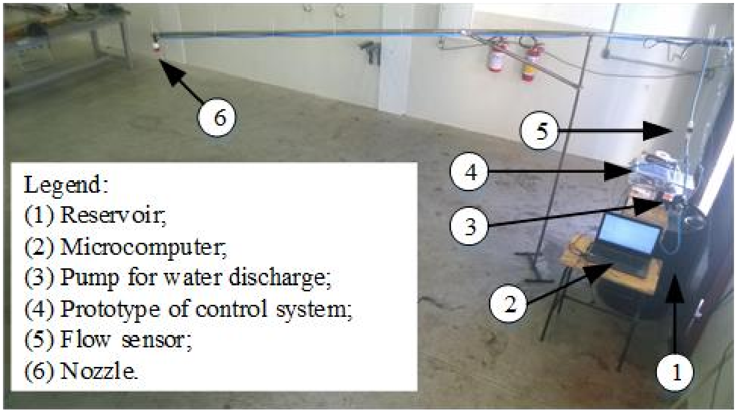
During the next step, the assembly of the electronics prototype was carried out (Figure 4), consisting of (1) the digital display, the add +1 button (2), the add +10 button (3), the button (4), to clear the values on the digital display, and the button (5), which allows to proceed to the next step. The ability to add +1 or +10 allows two ways to set the desired value of the simulated rainfall volume. If you skip a step, an audible noise and visual alert (on the digital display) will show the need to define the parameter.

Figure 4. Electronics prototype assembled.



Regarding to the second stage, checking the functioning of the electronic system, the assembled test bench is shown in Figure 5. Flow, pressure and temperature sensors have been previously calibrated.

Figure 5. Bench tests to check the electronics system.



On the test bench, the first set parameter is to identify the plot – “número da parcela” – (Figure 6A), the second parameter is the duration of simulation time – “tempo de ensaio” – (Figure 6B) and the third parameter is the intensity of rain – “volume de chuva” – (6C).

Figure 6. Digital display at stage set plot (A), at stage setup time (B) and at stage configure volume (C).

numero da parcela
parcela = 0
+1 +10 CLEAR OK

tempo de ensaio
tempo = 0 min
+1 +10 CLEAR OK

volume de chuva
volume = 0 mm
+1 +10 CLEAR OK

The user can program up to 240 plots. The maximum time that the electronic system allows you to set is 240 minutes and the maximum intensity corresponds with the pump flow capacity.

In the programming a function, was inserted that allows the user to pause the experiment at any time during execution, so allowing the analysis and decision-making of information, and continuation of the simulated rain from the paused point.

A report was generated for each repetition allowing to analyze the functioning of the proposed system. Figure 7 shows the report template that the electronic system automatically generates and sends to a PC serial cable. The electronic system updates the values of each sensor every 60 s.

Figure 7. Report automatically generated by electronic system

```
CONNECTED

Experiment configuration
Parcel = 2; volume = 60mm; time = 30 minutes

RAINING

Experiment conditions
Pressure = 174kPa; Flow rate = 08,94l/min; Temperature = 32,50ºC
Experiment conditions
Pressure = 174kPa; Flow rate = 09,07l/min; Temperature = 32,87ºC
...
Experiment conditions
Pressure = 174kPa; Flow rate = 09,07l/min; Temperature = 34,06ºC
Experiment conditions
Pressure = 174kPa; Flow rate = 09,13l/min; Temperature = 34,18ºC

Pause in 15min0s

RESTART RAIN

Experiment conditions
Pressure = 174kPa; Flow rate = 09,40l/min; Temperature = 34,81ºC
Experiment conditions
Pressure = 174kPa; Flow rate = 09,82l/min; Temperature = 35,25ºC
...
Experiment conditions
Pressure = 174kPa; Flow rate = 09,05l/min; Temperature = 31,50ºC
Experiment conditions
Pressure = 174kPa; Flow rate = 09,09l/min; Temperature = 32,25ºC

EXPERIMENT COMPLETED
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The use of automated equipment at the industry or in agriculture has as advantages the reduce costs with manpower, it increases quality and consistency of the product and also increases the security and remote monitoring (GROOVER, 2011).

In this context, the advantages presented by the system are: lower operating costs, because it's necessary smaller number of people involved; smaller loss of material (water); the monitoring of pressure and flow rate, the system allowed operator to use the volume required for each experiment; the data inserted by operator and the measured data by sensors are showed on digital display; possibility it can be paused the experiments; tracking of information through reports generated by the system and, increase quality of experiments through the control of the parameters involved in the simulated rain generation process.

In the system suggested, it was observed some sources of haziness that can be consider as disadvantage. The conception is an open mesh system. In the other words, the software does not automatically correct the pressure and flow variations measured by the sensors. doesn't have an automatic mechanism to operate in the system with goal to correct occasional variations. Other disadvantage is in the flow rate in the system, where the rotation of the pump is directly proportional for a voltage and regulating the power supply, the experiment and in consequence the data got only will be constant and reliable if the source has a good regulation.

Another disadvantage is necessary the power supply with constant voltage, if the power supply in the system failure the experiment should be discard, the system suggested may also introduces data loss inherent of the analog to the digital signal conversion. This can happen in the flow sensor, whose data are measure every 6 seconds.

The experiment reproduces faithfully the designed layout of the test bench. During the tests, the production of artificial rainfall and the behavior as the behavior of each system element was observed. There wasn't any malfunction detected relating to the different programming steps for the process of generating artificial rain, making it possible to track the involved parameters through the generated report.

6 CONCLUSIONS

The developed system enabled the generation of artificial rainfall by programming the parameters for the identification of the plot, duration of the simulation and the rain intensity.

In the studied experimental conditions (without the influence of wind, natural rain and sun), the 17 repetitions totaled 510 minutes of experiments, with the prototype showing no failures in programming and sensors and remaining stable during the experiments.

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