Modeling system for 3D reconstruction of the growth of the Oryza sativa L rice variety.

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***Abstract*—The study of plant growth through modeling and reconstruction has proven to be a very important tool in plant breeding processes to evaluate the phenotypic expression of new varieties, in addition to registering their growth and functioning. In this work, we present a 3D modeling system of the growth of the rice variety Oryza sativa L. Its utility is to be used in order to contribute to the main objective of the OMICAS P4 project (platform for high-resolution multiscale genotyping), especially in the development of a complete 3D modeling that allows to evaluate the potential of the plant.**

From morphological variables of the plant, it is sought to reconstruct it by means of mathematical models and graphic computation in such a way that information can be obtained to be able to evaluate new varieties of rice, under different conditions, for this the selected model will be adapted to a language programming and specialized software

Key words: Plant breeding, Modeling, Plant reconstruction, Oryza sativa L, Morphology, Computer graphics, L systems, Pre-processing, OpenAlea, Json, Growth models, Fractals.

I. Introduction

It is estimated that the world demand for food will grow considerably in the future: according to studies carried out in 2015 by TechnoServe, it is estimated that by 2050 the global demand for food will grow 70 % [1]. Faced with this problem, plant breeding is a solution since it allows altering or modifying the inheritance of plants and thus obtaining new varieties that adapt to specific conditions and have better performance. [2].

The OMICAS project seeks to contribute through the improvement of agricultural varieties in search of a higher yield and a smaller environmental footprint" [p. 17]. To speed up the evaluation of new varieties, within the same OMICAS project the creation of a multimodal platform for the phenotyping of the crop is proposed (P4).

To contribute to this objective, a system divided into two phases is proposed as shown in Figure1.The first phase (capture) will be in charge of obtaining morphological data; its main tool for the development of this phase is PlantCV. This data will be fundamental in phase two (modeling) and will be sent by a JSON data format, which is a light format for data exchange, light and easy to use both for reading and writing, since it uses the code JavaScript as a data model [3].

Together with the data collected in the literature, on the morphology of the rice plant and phase 1, these are used as bases to carry out the modeling, to carry out this process, the OpenAlea tool is used, which presents different modules and libraries designed for the modeling of plant architectures [4].

In the same way, for the modeling of the plant, the morphology of the rice plant is investigated in depth, from this it was possible to obtain growth rules for the different organs of the plant, necessary to generate the L systems. These systems handle a grammar formal parallel derivation, a set of rules and symbols mainly used to model the growth process of plants, in this case of the rice plant Oriza sativa L [5]. Similarly, the proposal is based on growth models from important studies already carried out by Watanabe [6].

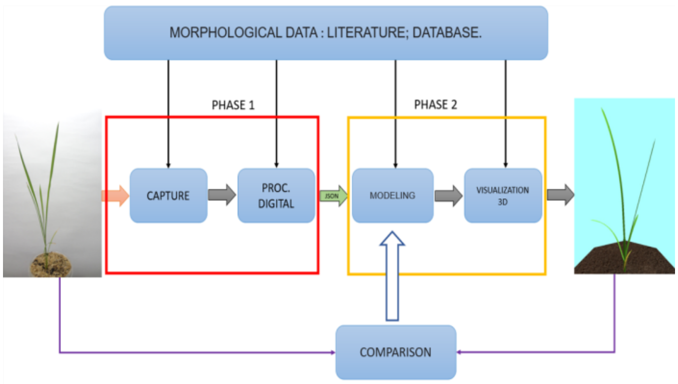

Figure 1. Project phases

II. Methodology

Figure 2 is a representation of phase 2 in which the stages that are developed to achieve the simulation of the growth of the rice plant are shown.

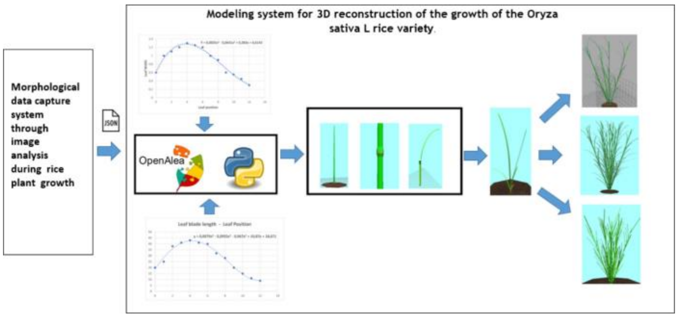

Figure 2. Stages of phase 2 of the project

For the development of the project, it is essential to carry out a deep and detailed investigation of the morphology of the rice plant, this includes understanding the development and function of each part of the plant, in the same way it is necessary to understand the effect that the different variables environmental factors have on the growth of rice. With all this, the different stages of rice growth could be understood, this information was consulted in Peñas J, Reyero L [7], Víctor D, Luis E Berrío, Roger E Charry [8], Velázquez J, Rosales A, Rodr´ıguez H. Salas R [9] and Olmos S. [10].

To synthesize this information, tables were made, in which each of the stages is explained, the changes that the development of the plant has from the appearance of the first leaf, called coleoptile, until the development of the primary, secondary and tertiary tillers. . (These tables are available in the annexes of the article). From the respective analyzes equations were generated, these equations help to describe the behavior of the leaves, which the rice plant has in each of the stages of development, an example graphs and equations can be seen in Figure 3.

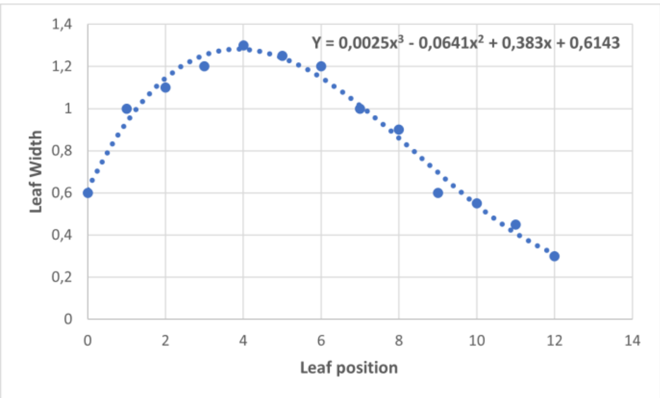

Figure 3. Graph of the length of the leaf with respect to its nodal position.

These graphs and formulas helped determine how the leaves grow, depending on the node in which they develop.

As can be seen in Figure 2 , A tool is used to model plant structures, called OpenAlea, an open source software based on Python, whose function is the modeling of plant architecture. Openalea includes modules for the analysis, visualization and modeling of the growth and functioning of the different parts of a plant. [4]

This tool is based on the theory of fractals or L systems, which consists of a set of rules and symbols which are executed in an iterative manner, they are mainly used to model the growth process of plants. [11]

The algorithm implemented in the Openalea L-py module is based on the model described in Watanabe T, Hannan J [6], together with the implementation of the formulas obtained for the development of the leaves and information on the effect of the climate on the growth of the rice plant.

For the connection between the capture phase and the modeling phase, it was agreed to use the .JSON format for the transmission of morphological information. This is due to its ease of writing and reading the file, because it is much lighter in transmissions, and because it has a high processing speed, it also has compatibility with Python [3].Next, you can see how the file is written and read.

Structure of the .JSON file: As can be seen in Figure 4 , for the structure of the .JSON file, the json library is imported and different arrangements are created for the different stages of development of the rice plant Oryza sativa L. These arrangements are made up of variables, which will be received as input in the stage of modeling.

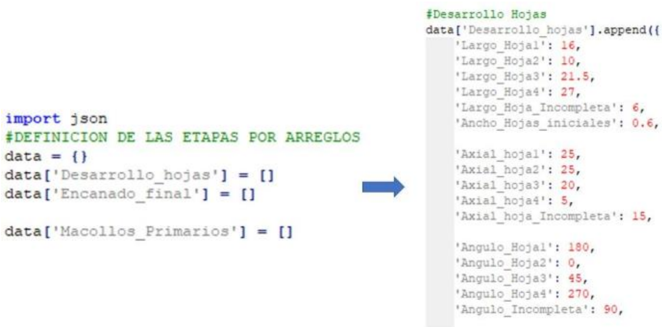

Figure 4. Structure of the .JSON file

For the reading stage, the algorithm present in Figure is developed 5, which is being used to read and connect the capture and modeling phase, so that it uses the parameters obtained in the first phase.

```
with open('data.json') as file:
    data = json.load(file)


    for var in data['Desarrollo_hojas']:

      Largo_Hoja1=var['Largo_Hoja1']
      Largo_Hoja2=var['Largo_Hoja2']
      Largo_Hoja3=var['Largo_Hoja3']
      Largo_Hoja4=var['Largo_Hoja4']
      Largo_Hoja_Incompleta= var['Largo_Hoja_Incompleta']

      Ancho_Hojas_iniciales = var['Ancho_Hojas_iniciales']


      Axial_hoja1=var['Axial_hoja1']
      Axial_hoja2=var['Axial_hoja2']
      Axial_hoja3=var['Axial_hoja3']
      Axial_hoja4=var['Axial_hoja4']
      Axial_hoja_Incompleta=var['Axial_hoja_Incompleta']

      Angulo_Hoja1=var['Angulo_Hoja1']
      Angulo_Hoja2=var['Angulo_Hoja2']
      Angulo_Hoja3=var['Angulo_Hoja3']
      Angulo_Hoja4=var['Angulo_Hoja4']
      Angulo_Incompleta=var['Angulo_Incompleta']

      Altura_Tallo_Hoja1= var['Altura_Tallo_Hoja1']
      Altura_Tallo_Hoja2= var['Altura_Tallo_Hoja2']
      Altura_Tallo_Hoja3= var['Altura_Tallo_Hoja3']
      Altura_Tallo_Hoja4= var['Altura_Tallo_Hoja4']
      Altura_TalloHoja_Incompleta= var['Altura_TalloHoja_Incompleta']
```

Figure 5. Reading .JSON file

Below are some models of the organs of the rice plant, which were developed with one of the OpenAlea panels.

In the figure 6 it can be seen that, for the model of the leaves, the bezier curves are used, which are used to represent irregular shapes in figures, in this case they are used to represent the structure of the leaves; **a** is the curve that the sheet will form, with **b** the outline of the sheet is obtained, since the sheet is considered to be symmetrical and with **c** the cross section of the sheet [12], this can be related to figure 7.

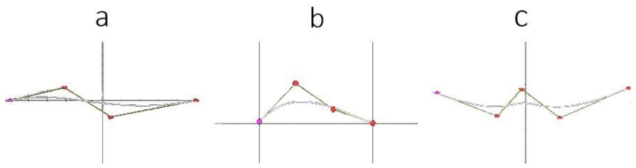

Figure 6. Bezier curves for the representation of the leaves

Figure 7 shows the graphical representation of the sheet, seen from different perspectives.
Here, **a** is the shape of the leaf, in **b** you can see the outline of the leaf and in **c** the cross section.

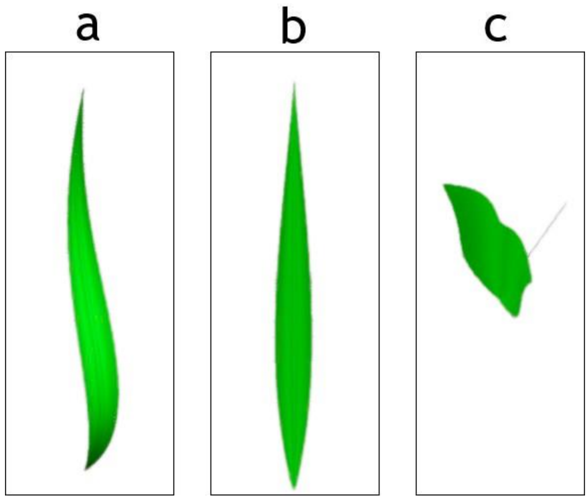

Figure 7. Rice leaf simulation

In Figure 8 you can see a representation of the modeling of the nodes and internodes of the rice plant.

Figure 8. Node simulation

This is how the final model of the rice plant is obtained, models of each organ of the plant structure are made, and by means of growth rules, variables that affect its development, morphological data and different iterations, these structures are developed in the course of the simulation.

III. Design

In Figure 9, you can see the structure of the program that was created for the simulation. First we have a block that imports the data from the .json file that has the morphological data sent by phase 1 of the project, additionally in this block, some morphological data that will be used in the preprocessing block are predefined.

The processing block is necessary, since OpenAlea does not use the dedicated GPU card, which causes a delay in the simulation. This preprocessing block does all the necessary calculations, data such as the length of the leaves, the angles of the tillers and leaves, the size of the tillers, among others, are calculated. This block helps the animation to be more fluid.

The values obtained in the preprocessing are used to create the leaves, the nodes and the internodes of the plant. Morphological rules are also created that define the number of tillers, the shape and the color of the leaves.

The models of the different parts of the plant are put together using the morphological rules to create a complete growth model of the plant, which is animated using visualea, this is one of the OPENALEA tools.

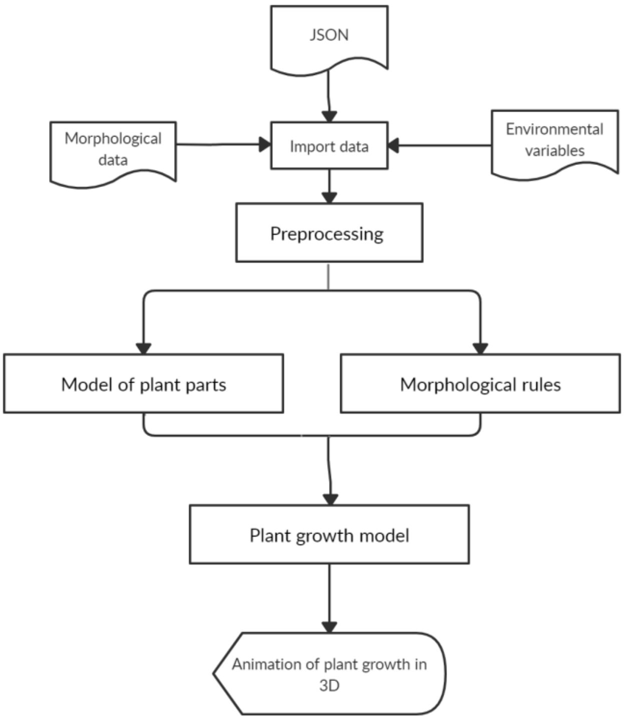

Figure 9. Program structure

IV. Resultados

Figure 10 shows the result of the simulation of the first stage of rice growth; This simulation was done by receiving some data from phase 1 of the project.

Figure 10. Simulation of the rice plant in its early stages

In Figure 11 the results of 3 simulations are observed, each one with different planting density levels; It should be remembered that the higher the sowing density the number of rice tillers will be lower.
In **a** the planting density was high so the number of tillers is less than that of **b** where the planting density is medium, and finally in **c** the planting density is low so the number of tillers is greater.

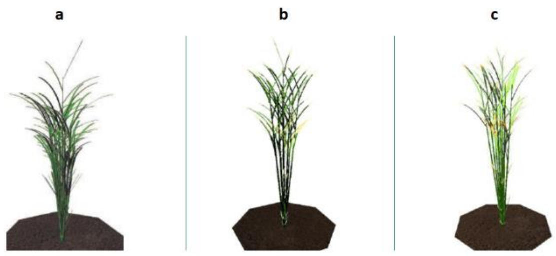

Figure 11. Simulation of the growth of the rice plant in different environments

V. Conclusions

- For the development of the project, OpenAlea is a fundamental key to achieve the proposed objectives. OpenAlea is an open source project, aimed mainly at the plant research community, its modules and libraries are based on Python, to analyze, visualize and model the operation and growth of a plant architecture.

  having good functionalities for plant modeling, OpenAlea has some flaws in the use of components from the same PC. It was possible to show that the tool is not compatible with integrated video cards (essential for graphic simulations), this results in the low number of frames per second at the time of simulation. Due to this, it is necessary to carry out preprocessing, in order to improve simulation times.

- For the union of the two phases, the JSON data format was used. Both for writing and reading, it is possible to verify its simplicity when generating algorithms. Due to the support of small loads, it has high processing speeds, which could help future projects to work with data instantly.

- Knowing in depth the morphology of a plant architecture, in this case of the rice plant, is necessary to obtain growth rules, growth models or environmental variables that modify its development.

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