chatter plant

APPLIED DESIGN

Universidad Politécnica de Valencia
Valencia UPV iGEM 2017

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

VALENCIA UPV iGEM

1. CHATTERPLANT APPLIED DESIGN

Nowadays, most fruits and vegetables come to the cities either from intensive farming or greenhouses. Current concerns of the world made several proposes to reduce the impact that human activities have on its society and the environment. This field is no exception.

On this basis ChatterPlant looks to contribute in changing into new sustainable agriculture. Going further and **controlling every single aspect of plant growth**. Since SynBio and other cutting-edge researches usually get stuck laboratory benches, a real application point-of-view is mandatory for an accurate development of an innovative project. However, although we got diverse SynBio tool to internally regulate plants, we faced a lack of implementation.

Thus, an integrated control system was essential in order to carry our SynBio technology to current society. A finely detailed hardware device and a refined software tool were both key features in developing our multidisciplinary project in the best.

2. BACKGROUND ANALYSIS

Our muse of inspiration was closer than we thought, nature, open agriculture and a combination of similar projects built the pillars of our main idea.

2.1. BIOART AND CUTTING-EDGE TECHNOLOGIES

Nature always has inspired artists throughout Art History, but art can also aid biology via symbiosis between both fields. Different art movements have integrated biology with avant-garde art techniques, conceiving cutting-edge bioart concepts, such as molecular and scientific photography, transgenic performances or microbiology exhibitions. In order to analyse bioart background, Salomé Cuesta, a UPV fine arts teacher, guided us where art and biology meet.

2.2. STATE-OF-THE-ART AGRICULTURE TECHNOLOGIES

To date, other projects have risen to try shaking up this situation with revolutionary concepts of agriculture such us:

- MIT Media Lab Open Agriculture Initiative, is on an objective to create affordable, more economical, and more innovative future food systems, controlling environmental conditions.
- AeroFarms, who have patented an aeroponic growing system for faster harvest cycles predictable results, superior food safety and less environmental impact.
- High technology's greenhouses, as automated and self-regulated plant growth system.

Among these proposals highlights Open agriculture, which pretends to develop a controlled-environmental agriculture engineering platforms called "food computers". This device automatically controls different parameters, optimizing the growth conditions of the plant seeking to decrease losses alike pest damages. Inside the confined space climate conditions are automated, meeting the users requirements and desires.

However, this Food Computers only controls external factors. Some of the problems related to crops are solved, but substantial ones still exist. In many instances it is unlikely to stop a pest since their hardware cannot be 100% isolated.

Valencia UPV team realized SynBio offers all the possibilities to carry plant growth control to a higher level.

3. CHATTERPLANT INTEGRATED SYSTEM TO CONTROL PLANT GROWTH PROCESS

ChatterPlant is proposed as a SynBio-based solution to control plant growth in both genetical and environmental way. A bidirectional communication is mandatory to

establish a properly system. Other technologies only provide the manage of environmental conditions, keeping away from a total control system.

In order to achieve that control, we designed ChatterBox, an specific device that regulates precisely plant growth conditions while enables a bidirectional human-plant interaction. Merging both SynBio and cutting-edge technologies in greenhouses, thorough control of plant processes is achieved.

Following bullets summarize main converging points between SynBio circuits and ChatterBox:

- Optogenetic switch enables to intervene in plant development by regulating its genetic profile. Systems' activation/deactivation is carried out by "Optogenetic" lamps, equipped with red/far-red wavelengths.

- Color code sensor circuit which flags the presence of specific plant stresses contains different AND gates. In normal basis, ΦC31 recombinase is being expressed in the plant and the stress-inducible promoter is always inverted. In this case, the circuit is inactivated and there will be any change in plant. If plant is under stress, phenotypic color variation is detected with the integrated camera and a specific recognition software, so the appropriate actions could be taken accordingly.

Adding to this, ChatterBox is able to regulate temperature, humidity and illumination as well as NFT hydroponic system is used to manage irrigation, oxygenation and crop nutrition. Besides in order to connect the ChatterBox to the user, a human - machine interface was developed, this opens the communication between both agents. Having this is possible to monitorize the inner environment of the device and control it to obtain the desired conditions.

4. FINELY DESIGN

Furthermore, a proper graphic design was proposed to bring our main stakeholders a more friendly and attractive project.

This work is aimed at a wide public that includes not only people interested in Science and Synthetic Biology, but people from all study areas. In order to easy spreading, a fancy graphic design was developed with the aim of bringing closer the new agriculture to urban environment.

For instance, the design of Chatterplant's logo combines three main concepts: plants, red light and hardware. The resulting image represents a geometric device inspired by our hardware Chatterbox combined with the idea of integrating SynBio technology. Likewise, digital illustration has been one of the techniques used in the graphic representation of the project. This highly visual way of expressing concepts has made the project more opened and easily understandable to the general public. Therefore, an innovative design was applied to help in developing a SynBio-based solution.

Gathering both proper graphic design and controlling external factors as regulating plant's features allow us increasing plant versatility and adaptative capacity. With those plenty possibilities our group had the chance to study current and future practices.

5. CHATTERPLANT APPLICATIONS

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Every competent project aims to overcome real problems with a suitable solution. ChatterPlant studied numerous opportunities to introduce the project in our society. It has been considered both actual as future applications.

5.1. CURRENT APPLICATIONS

Scale-up technology

As the real aspiration of our project is food production, scalability is an essential element, therefore current studies main objective is to estimate the average implementation cost of Chatterbox. Two different scenarios are proposed: Chatterbox implanted in cities at consumer level (100-1000 m^2); and a large-scale adaptation for great productions (1000-10.000 m^2). To scale Chatterbox, all costs were measured per square meter.

The data managed in this study, attached to this section, should be taken as an approximation and never as fixed and unquestionable values. With the previous data it's deduced that, in spite of the difference of cost existing in both models, the execution cost respect to a current greenhouse do not differ so much, converting Chatterbox like a reality in the short term, accessible and with different applicability.

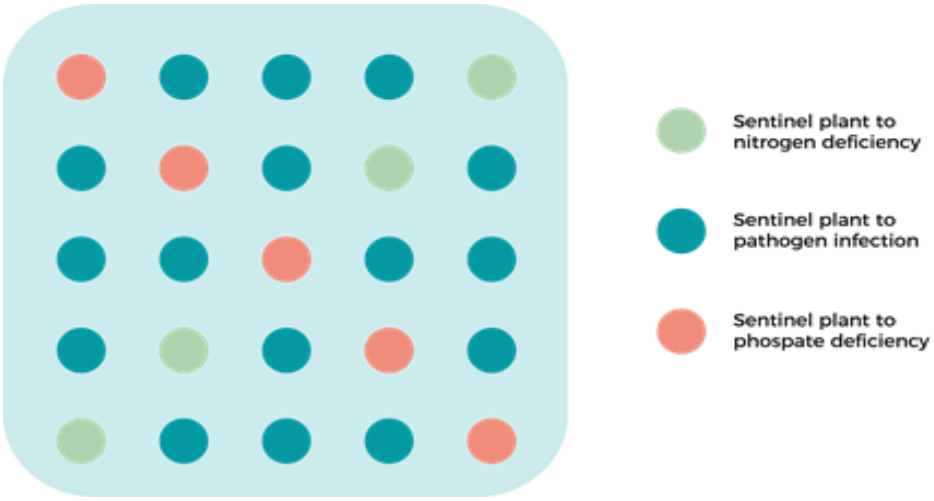
Ornamental

With ChatterPlant, we can modify plant metabolism to fit our needs. Starting a regular type of plant, we can achieve different final phenotypes. For example, we can have plants with diferents flower colors.

Nonetheless, in the integrated human practices, we contacted with Marta Vázquez to obtain knowledge about greenhouse necessities. As it can be seen in its interview with more detail, it could suppose and advantage obtaining a higher control over the plant. It could be interesting to put all the flowers of a given greenhouse at the same time of its lifecycle. In this case, the ornamental plants have to integrate the optogenetic switch in order to induce the required processes. As a consequence, it is obtained a higher production and a reduction of losses.

Sentinel plants:

Combining control over climatic conditions and SynBio, ChatterPlant strives increasing to the maximum the control of the crop through distinct color protein expression. In this context, our project could be applied through the innovative concept of sentinel plants. With the aim of controlling those conditions, we propose a diagonal system of sentinel plants in order to cover the maximum area possible (Figure 1).



Sentinel plants will be able to warn us if any plant suffers a given stress prematurely.

Figure 1. Graphic representation of a possible sentinel plants distribution.

Pathogen infections are the major cause of diseases in greenhouse crops. Being aware of its repercussions, our team suggests that the entire number of plants located inside the ChatterBox incorporate the pathogen detection system to increase detection control. Bearing that in mind, we solved our problems using a steroid injector in order to trigger a color code genetic circuit that accelerates a response and

allows applying corrective measures sooner.

The main problem with current preventive systems is that they normally deal with applying pesticides or fertilisers over crops, without even knowing if there's a real threat to the plants. This means a major waste of resources. Besides this, residues ultimately pollute and damage the environment. Furthermore, identifying plant damage requires plenty of time. This one is critical since some vectors and deficiencies spread among the whole crop rapidly and produce significant symptoms. Do we have any way to know whether the plants are stressed or not?

Sentinel plants seem the solution: They simplify the stress diagnosis task. Changes in leaves color will make the detection easier. Sentinels would be another plant in the crop, but they react to different stimuli. Distributing them over the land will make easier to know which regions are problematic. According to the number, type and position of sentinels that show a certain color, farmers can decide which solution has to apply and how big the problem is.

Education.

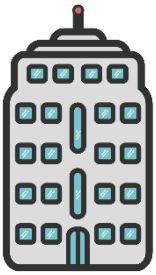
An interview with David Jorge, the Delegate of Students of the Universitat Politècnica de València (UPV) and student of the School of Agricultural Engineering and Environment took place. There, an idea to complete the new technologies education of Agricultural Engineering degree arose.

In order to tackle this situation, a group of 'Spontaneous Generation' was proposed to be created, inside a program which embraces the major part of students groups in UPV. Thus, ChatterPlant and Open Agriculture devices were considered to complement the student's education, contributing not only in agriculture itself but also in social areas.

5.1. FUTURE APPLICATIONS: ARCHITECTURE AND SOCIAL CHANGE

After studying the social acceptance of ChatterPlant, it was considered how it could affect to the evolution of the cities. In the next 20 years, society could radically change. FAO have really interesting studies and predictions about it. In them, it is shown the evolution of the cities to transform into megacities. If the pilot project works, ChatterPlant could bring different benefits to future society in different ways like:

- Climate and temporary-independent cultivation.
- Higher quality of the product.
- Reduction of fruits and vegetables shipping from productor places to far consumption cities.



Gathering all this information, we realize that we had to contact with architects. It was thought that contacting with architects involved in 'Asociación de Sostenibilidad y Arquitectura' (ASA) an urbanism association focused on working with sustainability, would be necessary. That is why two meetings were performed. Firstly, a meeting with Daniel Ayala (link), vocal of the association was performed, and secondly a meeting with Eva Álvarez (link), architect and teacher of our university, also member of the Spanish association of sustainability and architecture were done. The main conclusion obtained was:

- Application of ChatterPlant in communities to make them self-sufficient, obtaining more sustainable cities.

This application could be carried out in several ways:

- In private houses and communities.
- In neighborhoods.
- In business with the scaling up of the project.
- In public buildings as the next step of Urban Orchards.

This possibility was studied. Implantation of ChatterPlant could be done in building basements, in special community rooms, in a given building of a neighborhood, to make all of them self-sufficient. Another possibility is having a business with a large ChatterPlant extensions to feed a great part of the city. Finally, in every free space of urban environment. This last possibility was thought as the evolution of Urban Orchards in the way that it is not necessary to have a ground to cultivate, if you have a ChatterBox you can cultivate everywhere.

To obtain more ideas, we went to 'International Seminar on Urban Form' (ISUF), a widely-known congress about urbanism in where we contacted with architects that gave us more ideas about sustainability. We were very interested in the speech of June Komisar and Joe Nasr from Ryerson University (Canada), which told us about introducing ChatterPlant in rooftops.

Gathering the ideas together, we realize that it cannot be predicted all the possible ChatterPlant future applications. Nonetheless, we hope to help in the development of future self-sufficient cities by bringing closer the agriculture to everyone with ChatterPlant.

6. CHATTERPLANT APPLICATIONS

In order to study the potential applications of ChatterPlant, first we explained why ChatterBox is essential in ChatterPlant project. Secondly, a study of close relationed areas was done. Finally, the innovative SynBio concepts that ChatterPlant could contribute to society were evaluated. Gathering all the information, the possible current and future applications were considered.

Bearing all this in mind, these are the obtained conclusions:

- ChatterBox is necessary in ChatterPlant project because of the accessibility and control it brings.
- ChatterPlant SynBio circuits improve the control over the plant development and behavior, in a more sustainable manner than other solutions.
- Future ChatterPlant applications will be based on making houses, communities and neighborhoods self-sufficient.

We aspire to fully apply ChatterPlant in urban environment, obtaining an innovative sustainable approach in agriculture, and bringing it closer to the population.