* 1. Abstract

Abstract section of the paper, the position of the work in terms of contributing a theoretical approach, computational method or fabrication technique (or combinations of these) should be clearly and concisely stated. The results of the research and major contributions should be briefly stated. The abstract should be a maximum of 250 words.

* 1. Introduction and Backgrounds

The objectives of the work are to be stated and placed within the context of relevant research. The research can reflect the author's previous work, but should also cite original sources that led to the development of their specific body of research. Proper references to journal articles and/or conference papers must be used when describing the precedent work. It is expected that a Short Paper will have a more condensed description of precedent and background work, consolidated into the Introduction section.

* 1. Methods

In the Methods section, the novel techniques developed in the work should be stated so that they can be understood and reproduced by someone in the field of computational design and digital fabrication

* 1. Results and Discussion

For the Results and Discussion, the outcome of the work should be clearly described and depicted. The author's work should be placed in the context of computational design and indicate its contribution to previously cited work. Authors must provide a critical summation of their research offering successes and failures in relation to the original hypothesis. It is expected that a Short Paper will focus more on the discreet outcomes of the work, over its larger implications to the field of computational design.

* 1. Conclusions

The Conclusion section should describe the future development of the work and provide a reasonable projection of the research into future applications. Such propositions should be grounded in the precedents that were originally stated in the hypothesis for the research.

SYMBIOTIC ASSOCIATIONS

a research about the digital impact on soil remediation

* 1. Abstract

*+ methods to look at biology*

*+ mycelium case*

*+ apparatus*

*+ technical definition of the methodology*

*+ possible implication of conclusions*

Biology has established in recent years as a crucial contributor in the definition of design strategies. The observation of biological phenomena becomes indeed the first method to extract patterns for the deconstruction and assembly of multiple behaviors connected to specific environmental conditions. A clear workflow of digitalization of those physical outputs becomes indeed necessary to establish accurately specific growing patterns. Mushrooms haven already been involved into several design process mainly for their structural characteristics defined by a lightweight fibrous constitution and their fast mycelium growing abilities. In all recent experimentations involving mycelium, a scientific method of data collection have not be defined. The research developed for the workshop Symbiotic Associations focused on the construction of physical apparatuses hosting oyster mushrooms, belonging to the family of Pleurotus species. From every machine data have been extracted through photogrammetric techniques and then parsed according to the physical information stored in the point cloud, using computational methods to recalculate principal growing directions. The influences of temperature and nutritional conditions on the mycelium growth were part of the variables tested during the conduction of the experiment. This research is focused towards the definition of a catalog of growing conditions established through a rigorous observation empowered by computational methods. The overall experiment is part of a larger research implementing the contribution of digital fabrication and computational techniques in the biological process of soil remediation involving mushrooms, commonly defined as mycoremediation.

* 1. Introduction and Backgrounds

*+ Problem of contamination*

*+ Food Production*

*+ Mycoremediation*

*+ Drone Technology / Nero*

*+ Glocal*

Symbiotic Associations is a research addressing the problem of soil contamination. Also described as land pollution, it refers to degradation or destruction of earth’s surface and soil, directly or indirectly as a result of human activities. [Soil](http://www.britannica.com/science/soil) consists of a mixture of unconsolidated mineral and rock fragments ([gravel](http://www.britannica.com/science/gravel), [sand](http://www.britannica.com/science/sand), [silt](http://www.britannica.com/science/silt), and [clay](http://www.britannica.com/science/clay-mineral)) formed from natural [weathering](http://www.britannica.com/science/weathering-geology) processes. Gravel and sand formations are porous and permeable, allowing the free flow of water through the pores or spaces between the particles. Land Pollution has led, in fact, to a series of issues that we have come to realize in recent times, after decades of neglect. The increasing numbers of barren land plots and the decreasing numbers of forest cover is at an alarming ratio. The dominant types of land degradation across the dry lands are water and wind erosion – often the result of overgrazing, unsustainable agricultural and water management practices, and the over-exploitation of vegetative cover. In turn, these are driven by rapid population growth, urbanization and poverty, which force rural communities to adopt non-sustainable land use practices. Climate change is making it even harder to cope, increasing vulnerability to crop failures and poor livestock productivity. In agriculture, toxic levels of various elements pollute the groundwater as a result of excessive fertilizer application (e.g., nitrates and phosphates), and through leaching of naturally occurring trace elements in the soil after irrigation (e.g., selenium). Pollution of both water and soil poses a significant hazard to human health. Finding suitable treatment technologies to clean up contaminated water and soil is not easy. Many technologies that are available are usually very expensive. Because the need for practical and cost-effective procedures for cleaning up contaminated water and soil is so great, Symbiotic Associations research is focused on achieving this goal through the study of process involved in soil pollution and analyze the best solution to apply. Essential contribution is devoted to the right selection of strategies to recover contaminated soil. The choice is based of knowledge of basic principles of soil characteristics and analysis of pollutants speciation and bioavailability. In this research we question the possibility of designing and predicting soil remediation by digitally exploring and experimenting several processes of soil decontaminations. Contemporary tools allow, in fact, to study, through hardware and software, biological behaviors based on the extraction and interpretation of real time data. This research is meant to explore the possible implementation of physical computing, computational design and digital fabrication techniques in the design and optimization of the most efficient soil remediation strategy. This research will be structured on the data collected from a single or a family of apparatuses. An apparatus consist in any equipment used during data collection (such as computers or eye-tracking devices). Materials include scripts, surveys, or software used for data collection (not data analysis). Our hypothesis is that using those information we’ll be able to introduce additional methods to perform programmed soil decontamination, mixing digital fabrication and rapid prototyping techniques.

* 1. Methods

*+ Research Protocol: digital and analog*

*+ Apparatus*

*+ Substratum*

*+ 3d scanning*

*+ Point cloud construction*

*+ Reading data*

*+ Parsing the cloud*

*+ Extracting growing pattern*

The research for Symbiotic Association starts with a precise protocol establishing the rules of observation through constant loops of analog inputs into digital information related to the mycelium growth. The research protocol is structured in different steps mainly organized among analog and computational operations. The first part is focused on the definition of a digitally fabricated apparatus for the observation of the mycelium. Once built, the next step is the generation of a point clouds from series of pictures taken to the model. The computational studies starts with the reconstruction of those clouds using an external software (agisoft), followed by the analysis of the cloud done parsing the data based on a specific color range made in rhino/grasshopper3d. The observation is concluded by applying an octree subdivision to the parsed cloud in order to extract the main vectors defining the growing directions of the mycelium. The following description of the research will focus on the explanation of each single step mentioned above. In order to establish a scientific process of research, we tested different apparatus with the intention to define the best method for data collection. Each apparatus was a combination of different digital fabrication processes. During the study in fact we developed different types each based on a combination of digital fabrication techniques. The first one was a 3dprinted hexaedra structure with four faces capped with laser cutted metacrilatic plates. Between those faces a grid of thin strings were inserted in order to offer a continuous surface distributed in multiple direction where the mycelium could possibly grow. This first apparatus indeed resulted quite difficult to use for the generation of the point cloud since the space was very narrow and the strong symmetry of the structure was generating strong noise for a correct point rebuild. During the workshop we had the opportunity to build other machines, each with a specific observation focus, testing different substratum or grid structures. The substrate consisted of straw, which was infused with a mix of water and honey to add complex sugars as a nutrient base for the mycelium. This substrate was inoculated with grains pawn of Pleurotus ostreatus, at a ratio of about 20% of the total substrate mass. The inoculation took place around a bunsenburner gas flame to ensure a sterile working environment. Colonization of the different substrates was complete after 2 to 3 weeks, and produced mushrooms after 5 weeks since inoculation. In some cases we added pla plastic from 3d printing material in order to observe the possible decomposition of the material by the mycelium. During the overall process the machines used were commercial 3dprinters and trotec laser cutter. As for the photogrammetry process, the collection of images was performed using a Nikon D3200 with a 50mm f1.8 lens and 25 megapixels. For the analysis and construction of the 3dmensional model, all procedures were based on Agisoft, a stand-alone software that performs photogrammetric processing of digital images and generates 3d spatial data. As stated in the manual description, Agisoft operates with arbitrary images and is efficient in both controlled and uncontrolled conditions. Image alignment and 3d model reconstruction are fully automated operations which we also tested during the workshop with successful results in both outdoor and indoor conditions. In order to get precise results, given the level of accuracy needed for our analysis, we took around 30 to 50 pictures for every observation. Processing time for every reconstruction took an average amount of time around 30 minutes each, between building dense clouds and generating meshes. Once the cloud was generated, the entire process shifted to Rhino-Grasshopper3d. Here, the main grasshopper3d add-on used was Volvox library, developed as a part of DURAARK project at the Center for Information Technology and Architecture (CITA) by Henrik Leander Evers and Mateusz Zwierzycki. Volvox is a smart library which enables to create, edit and analyze Point Cloud data. This library imports directly all .e57 formats which can be easily exported using Agisoft. Volvox allows to work with a large amount of points and enables to perform multiple operations regardless the quantity of data stored in each file. Once in grasshopper we established a color range associated with the mycelium. This set of points is afterwards organized in the 3dmensional space by converting each band from RGB values to XYZ coordinates. This set of points in then converted in a bounding box to test the inclusion of the entire Point Cloud list of points. This operation is crucial for the final selection of those points associated to the mycelium. The final outputs are a boolean list of values which are used to cull the starting list of data from the Cloud. All points still available in the list are finally used for an octree subdivision which organize all data in the main eight quads of the 3dmensional space recursively subdividing according to a minimum set of points each cube can contain. Finally from the overall amount of cubes generated for each single quad in the 3dmensional space, we extract the main vectors representing the main growing direction for the mycelium. This overall operation intend to generate a time-based behavior which can be overlapped with a series of multiple one and define an accurate growing pattern.

* 1. Results and Discussion

*+ Amount of Data processed*

*+ Contribution to previous work*

*+ Results and original hypothesis*

Symbiotic Associations went through several iterations of apparatuses and different data collection methods which resulted in a great amount of data processed. This data collection represent a substantial improvement from previous experiment connected to mycelium research. From a single observation we collected more than 50 pictures, generating in agisoft a parse cloud of 56.000 points, converted finally in a dense cloud of more than 1.6 million points. Thanks to the Volvox library this cloud was afterwards processed in grasshopper where we were able to parse the amount of points associated to mycelium obtaining percentage and growing direction translated in vectors. Collecting this information is in fact crucial to predict behaviors for the organisms that can be used to inform multiple design strategies. The first hypothesis to achieve similar results have been accomplished following the procedure detailed in this paper. Nonetheless it was proven very difficult to collect data from the first apparatus we designed and constructed. The difficulty was mainly related to the structure and accessibility of the camera in the internal part and the ability in Agisoft to rebuild very narrow and symmetric environments. Agisoft software based on image processing relay heavily on the amount of pixels each image can store. That said becomes very expensive to rely this process to multiple cameras attached to each single face of the apparatus, since hd cameras have an important costs which doesn't even guarantee a higher level of resolution for the 3d scanning process. Since this first assumption was proven wrong the result was collecting picture manually for each observation. For further developments of this research, this code should be the first one to implement.

* 1. Conclusions

*+ Future development*

*+ Possible applications*

This set of data can absolutely be used to inform other methods of observation and studies associated not only to the mycelium research but to all possible image-based observations on living organisms. In a wider picture it also encourage the future implication of 3d scanning techniques in the definition of patterns or color based analysis performed on physical supports. At this stage the research resulted in an interesting process, yet to be optimize by automating many of the steps which are now more comprehensible as separated entities. Picture collection can be performed by a robotic arm rotating around the apparatus. Image reconstruction is good enough using Agisoft, but can be optimize by culling all information related to parts of the picture we don't actually need to consider. Even if this operation is possible in Agisoft, the method allowed in the software is very inaccurate and time consuming, since it mostly rely on manual correction of the pictures. For the computational methods implemented in grasshopper it has to be written an interface where to store and access all information generated during the process. This interface should be accessible online and open to other researchers developing similar studies. The interface should allow to upload data automatically from the pictures and allow a proper data visualization service to overlap different analysis generated. From another point of view the end-goal of our research is to test the impact of mycelium growth on a contaminated soil.

Our next generation of apparatuses will be focus on monitoring mycoremediation adding ph sensors, humidity sensors, thermal cameras, to the data set already present in the research presented in this paper. This future study will be part of a complete research merging computational methods to traditional apparatus used for the observation of bio-reactions. The results obtained by the entire process will converge in a series of small items hosting mycelium and the substratum. We'll involve those small bio-cells in a wider aerial robotic research involving drones, focused on empowering reforestation and food production on dry or contaminated lands.

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