Zeynep Bacınoğlu and Ömer Halil Çavuşoğlu

(Paper): **EXPLORING THE POTENTIALS OF NATURE INSPIRED APPROACHES IN ARCHITECTURAL DESIGN THROUGH COMPUTATIONAL MODELS OF SEED GROWTH**

Topic: Architecture

Authors:
Zeynep Bacınoğlu*
Ömer Çavuşoğlu*
Sema Alaçam*
* ITU, Graduate School of University of Science Engineering and Technology, Department of Informatics, Architectural Design Computing Grad. Prog.
www.mimarliktabilisim.itu.edu.tr

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[1] http://news.bbc.co.uk/2/hi/8473316.stm
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Abstract:
The use of nature as a source of inspiration is a well established concept in architecture. The past few decades have seen computational approaches that have brought out new ways of thinking during the architectural design process. The observation of living organisms and natural systems have inspired novel computational models such as cellular automata, L-systems and genetic algorithms and refined simulations of growth patterns in nature and swarm behavior. Even more recently, designers have developed unique approaches in their exploratory process that have gone beyond replicating natural systems through predefined approaches, instead analysing these systems as processes and as ecosystems that consist of complex interactions. Two notable instances of the latter approach have been the way that the growth of slime mold, viewed as a process has provided information to Tokyo Rail designers[1] and the way the growth process of trees has been used as an ecosystem metaphor in the design of the Groningen Stadsbalkon[2]. In this paper, we discuss the potential of nature inspired design processes in idea generation and form finding in the architectural design process, through a series of experiments based on the computability of seed growth.
The experimental setup consists of square glass mats of width 8cm, at top which cress and arugula seeds are placed. The growth of these seeds is photographed and videotaped from above . This data is then converted into a matrix based definition system and used in the Processing. The experiment is repeated with different amounts of seeds. We use the overlaid matrix system to abstract out the co-ordination of the germinated seeds, the direction of the growth process and the denseness of growth. We then analyze the correlation between the number of seeds used and these parameters.

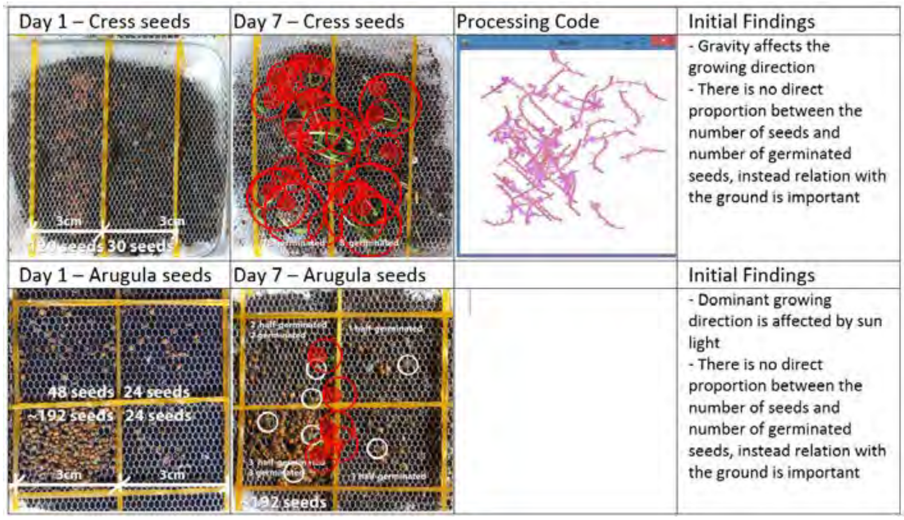


Figure: Growing process of different seeds

***Contact:* zeynepbacinoglu@gmail.com**

Keywords: Nature inspired design, computability, growth process, form finding, biomimetics

Exploring the Potential of Nature Inspired Processes in Architecture through Computational Models of Seed Growth

Res. Assist. Saadet Zeynep Bacınoğlu[1], Res. Assist. Ömer Halil Çavuşoğlu[2], Res. Assist. Sema Alaçam[3]

[1,2,3] *Graduate School of Science, Engineering and Technology, Department of Informatics, Architectural Design Computing Graduate Program, Istanbul Technical University, Istanbul, Turkey*
www.mimarliktabilisim.itu.edu.tr
[1]*zeynepbacinoglu@gmail.com*, [2]*posta@omercavusoglu.com*, [3]*alacams@itu.edu.tr*

Abstract

The use of nature as a source of inspiration is a well-established concept in architecture. The past few decades have seen computational approaches that have brought out new ways of approaching the architectural design process. Designers have developed unique approaches in their exploratory process that have gone beyond replicating natural systems through predefined approaches, instead analysing these systems as processes and as ecosystems that consist of complex interactions. In this paper, we discuss the potential of nature inspired design processes in idea generation and form finding during the architectural design process, through a series of experiments based on the modelling and computability of seed growth.

1. Introduction

"For artists communication with nature remains the most essential condition. The artist is human; himself nature, part of nature within natural space" (Paul Klee, 1953:7, first edition in 1925).

We aim to discuss that how Nature becomes a source of intuition and it provides a layout for generating design ideas. Our approach to considering Nature as a layout for design is related to Deleuze's notion of the "plane of becoming" which considers all of life as a process of becoming, instead of a singular imitation or analogy [2] .The term 'Nature' refers to the organic and inorganic entities and beings in a broader sense. In this paper, however, when we mention "Nature inspired" design approaches, we limit ourselves to living organisms.

The observation of living organisms and Natural systems has inspired numerous approaches such as Voronoi Diagrams [3], Cellular Automata [4], Evolutionary Computing [5], Fractals [6], Evolutionary Programming [7], L-systems [8], Genetic Algorithms [9], Swarm Behaviour [10], among others. There has however been a lag of a few decades in the adoption of these Nature inspired computational approaches in architectural discourse [11- 16]. The successful adoption of such approaches in architectural design is a subtle and challenging problem. Improperly done, they carry the risk of becoming a collection of concrete methods that are isolated and context free. Simpleminded adoptions could lead to boilerplate techniques that are merely used for the purposes of routine design. However, Nature inspired computational approaches have the potential to bring novelty to the discourse of architectural design, if we regard these as a way of thinking and reasoning; in Deleuze and Guattari's words, as a generative way of being and becoming [2]. In other words, Nature can be regarded as a 'counterpoint', constituting the relationships between different planes, forming compounds of sensations and blocs, which together determine 'becoming'. As Ballantyne proposes, *"...it is not just these determinate melodic compounds, however, that constitute nature; an infinite symphonic plane of composition"* [17].

We argue that direct observation of Nature, together with Roudavski's notion of 'reverse engineering' [18], is crucial for architects to gain an intuitive experience for Nature inspired computational approaches. Direct observation of Nature is important in terms of the dialogue between the designer and the above referenced computational processes. Dialogue between designer and Nature promotes diverse actions such as abstraction, conceptualization, exploration and calculation. This encounter makes possible design thinking in terms of a reflection-action' [19] or a 'seeing -calculation' cycle [20]. It has been argued that direct experiments on the complex mechanism of plant morphogenesis are difficult and time consuming, which is why developmental biologists have come to increasingly rely on mathematical and computational models [18]. We believe however, that this time consuming activity of direct experimentation on plant morphogenesis is highly important for architects; as Snodgrass and Coyne remark "Creativity is not matter. It is open-ended, wasteful and often misses the mark" [21].

In this paper, we aim to investigate the potential of nature inspired design processes in idea generation and form finding during the architectural design process. In Section 2, we discuss a few distinctive architectural examples and design approaches which deal with nature either as a process or as an ecosystem consisting of complex interactions. In Section 3, we present our own explorations based on a series of experiments on the dynamics of seed growth.

2. From Form Towards Formation: Computability of the Flux

"By extension, the meaning of a concept depends on a context (or the horizon) within which it occurs; but this context is made up of the concepts to the concepts to which it gives meaning" [21].

Abstraction is the way of differentiating within an existing context and constituting new ones. While looking at Nature, the action of abstracting might occur at different levels; one may abstract analogically, metaphorically, conceptually, geometrically or formally. Each assumption translates existing meanings into a new context and therefore creates new meanings in new contexts. The richness of the domain of initial assumptions and incidental actions influence the fruitfulness of idea generation in architectural design process. First published in 1925 in a booklet for Bauhaus students, Klee's drawing of the point process is shown in *Figure 1.a-e* [1].

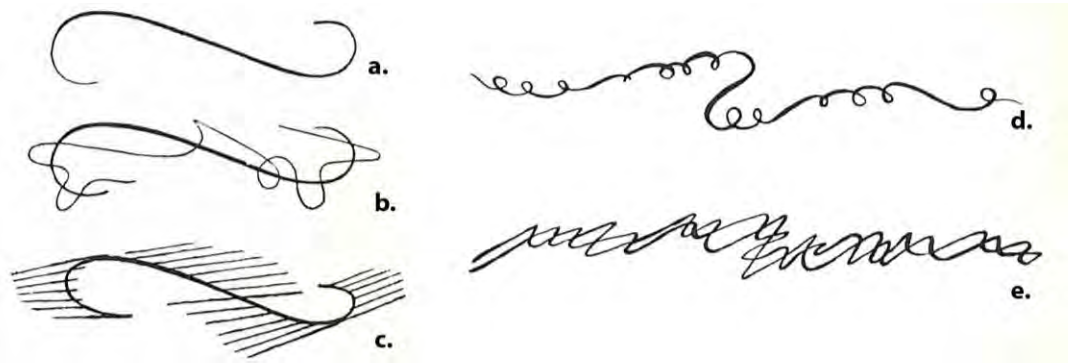


Figure 1.a: An Active walk by a point agent; Figure 1.b – 1.c: "The same line accompanied by complementary forms"; Figure 1d: "Same line circumscribing itself"; Figure 1.e: Two lines moving around an imaginary main line" [1].

Hanlon defines five composition rules in architecture, shown in Figure 2.a-2.e [22]. The same static image can be represented via different concepts such as a numeric representation consisting of 3 major and 2 minor lobs (Figure 2.a), as an angular division (Figure 2b). In Figure 2.c we see proportional comparison; Figure 2.d involves a triple hierarchy and the fifth one incorporates orthogonal orientation [22]. **In addition to** Hanlon's representations, we have added a further ten possible ways of abstraction (Figure 2.f- Figure 2.o).

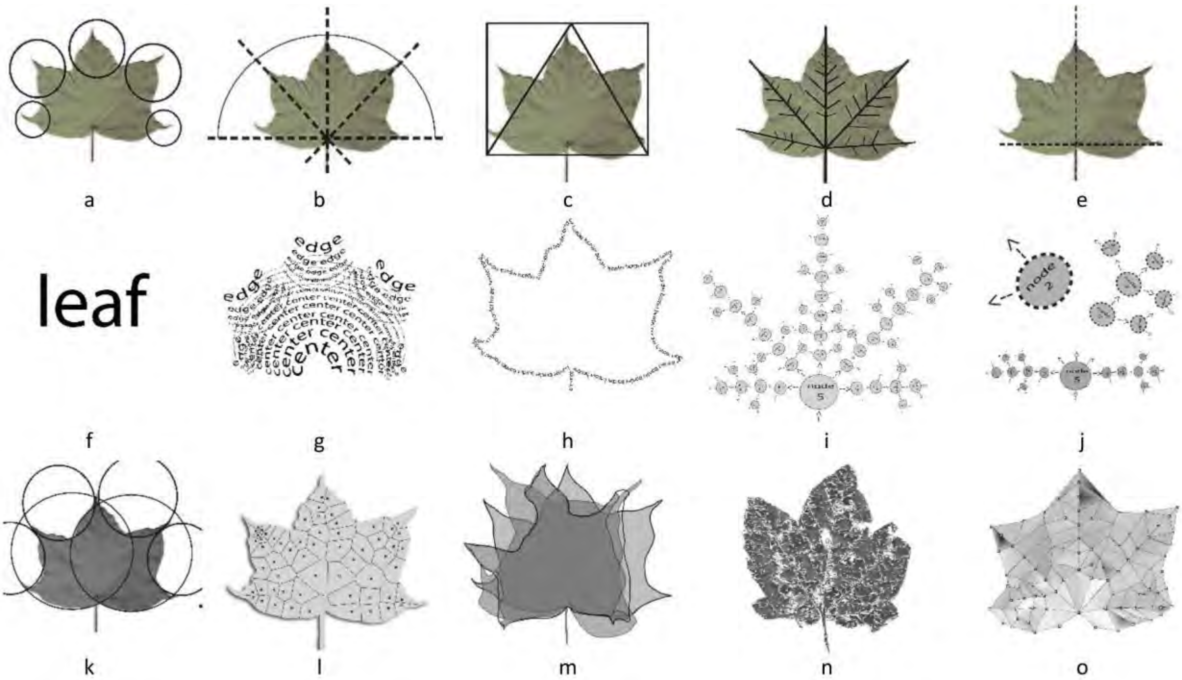


Figure 2.a-2.e: Redrawn of Hanlon's diagrams [22].Figure 2.f: Verbal expression, Figure 2.g: Conceptual representation, Figure 2h: Contour; Figure 2.i: Branching; Figure 2.j: Self-similarity; Figure 2.k: Geometric abstractions via reading negative; Figure 2.l: Voronoi diagrams; Figure 2.m: Process of drying; Figure 2.n: Deterioration; Figure 2.o: Triangulated mesh.

Dealing with natural processes as a formation, Thompson [23] describes the dynamics of growth and physical processes, not only as initial geometric representations but also as a set of transformation rules *(Figure 3.a and 5.b).*

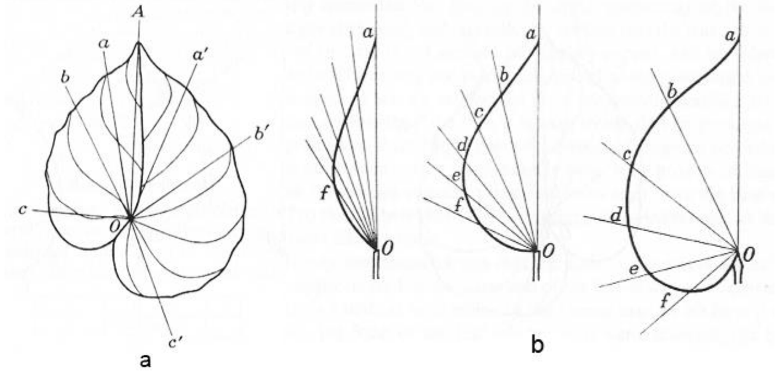


Figure 3.a-b: Growth of a leaf of Begonia Daedalea [23].

Thompson [23] conceives form not as a given, but as a product of dynamic forces that are shaped by flows of energy and stages of growth; he demonstrates new working methods for understanding the influence of physical forces on the environment *(Figure 4.a-c).*

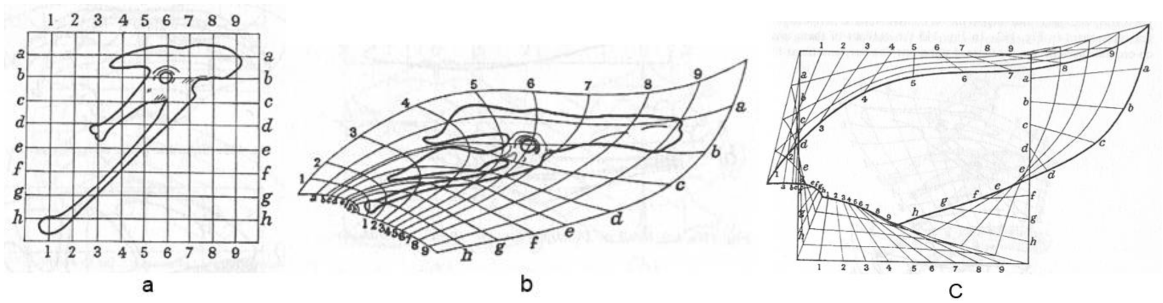
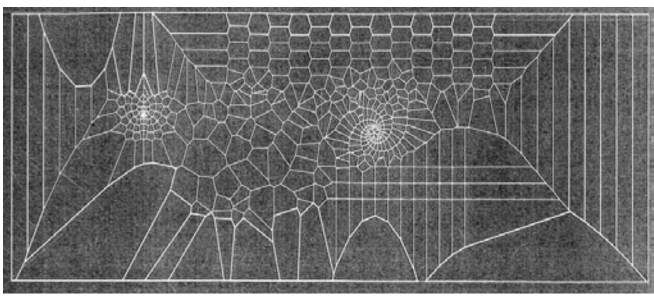


Figure 4.a-c: Method of coordinate, digitation of morphological transformation [23].



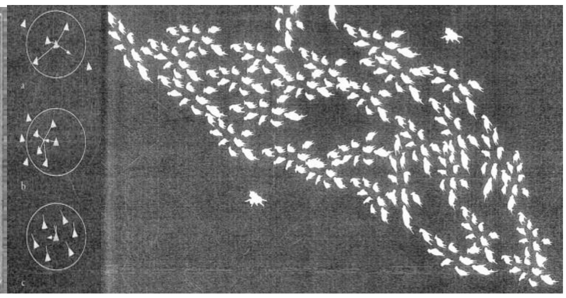


Figure 5: “Tiling” [24]. Figure 6: “Recipe for tiling, cracking, flocking, blending, weaving, packing, spiralling” [24].

Aranda and Lasch merge observations of biological processes with algorithmic design thinking by creating flexible and adaptable representations of formation which take into account responses to outer forces [24]. They claim that these representations of formation are both adequate to “liquefy the form organisations” and “create the potential for crystallization” [24]. For instance, they describe how natural phenomena such as the flocking rule can simulate crowd behaviour *(Figure 5)*.

In another celebrated example, the Groningen Stadsbalkon project, metaphoric abstraction is integrated with the earlier phases of design process to develop a digital analysis tool [13, 25]. The Stadsbalkon project utilized the metaphor of the “Column forest” in the form finding process; the columns are assumed as particles of a swarm system which is understood to be able to grow, shrink, split or die [13]. Each particle then tries to grow, constrained by the interaction with other columns(particles) located in its neighbourhood [13].

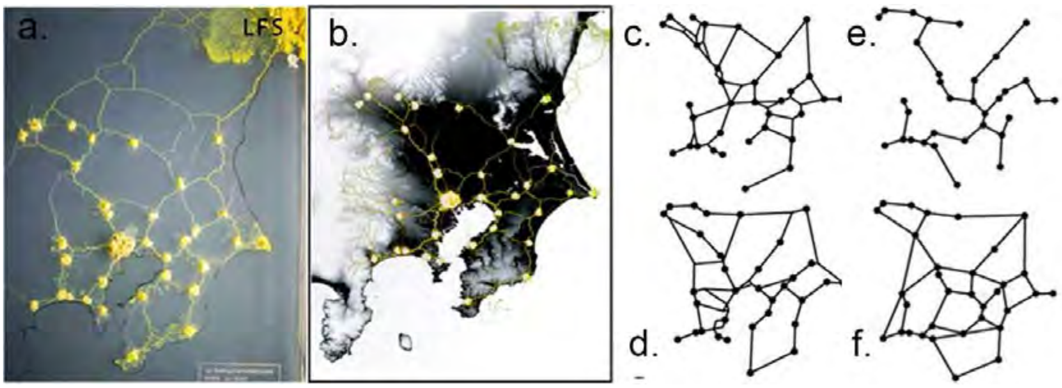


Figure 7.a-f: Slime Mold dispersion and its computational model[26].

A biologically inspired mathematical model was developed for the Tokyo Railway system based on the complex growth mechanism of slime mold. Slime mold grows and spreads as an interconnected network in its foraging strategy to discover new resources[26-28]. As shown in *Figure 7.a-f*, an experimental setup in which a plate covered with gel, representing the Kanto region, along with food sources representing cities to be connected to Tokyo was used[26]. The slime mold spreads in search of food and the pattern of growth was used as input in the design process. Beyond some differences in relation with the geographic features such as reduction of mountains and lakes, the ubiquitous character of a transport network was translated from the experimental model into the design model [26], from one domain to another.

Apart from taking nature into consideration as a process or as an ecosystem consisting of complex interactions, there has been some recent research [29-31] on alternative computational processes supporting the generation of form, based on the interaction between material and environment. Oxman approaches ‘form’ as a result of the matching between material parameters and their corresponding environmental constraints [29] (a derivative of natural behavioural formation) Kotnik and Weinststock use the potential of material properties for unfolding a generative logic of form finding in their projects [31]. They integrate the adaptation of the form and the distribution of material in response to the forces acting upon them. However, Menges states “even in design computation, materiality is still conceived as a passive property of form rather than as an active form generator. But unlike CAD, the underlying logic of computational design offers the possibility of synthesising virtual form generation and physical materialisation in architectural design” [30]. Menges actuates material information in exploratory computational design processes through the example of performative wood works shaped by the information of fiber density and direction[30].

3. Case Study: Computational Models of Seed Growth

3.1 Methodology

We started our experiment setup with six different seed alternatives and observed their growth for one week. Next, we updated our environmental setup with cress and arugula seeds and prepared a new set up by controlling the number of seeds in order to observe the effect of a change in density *(Figure 8).* We measured the growth numerically as well as through diagrams, sketches and time based photography. We decided to use a matrix based definition and then repeated the same experiment with the seeds lined up in a 2D matrix. We used the overlaid matrix system to abstract out the co-ordination of the germinated seeds, the direction of the growth process and the density of growth. We then analyzed the correlation between the number of seeds used and the utilized parameters and visualized and analyzed the data we collected.

3.2 Constraint of Experimental Study

The experimental setup consists of physical, time and media constraints, which we related to the captured data. As a physical contraint square glass mats of width 8cm were used, atop which cress and arugula seeds were placed. The growth of these seeds was photographed and videotaped from above every 4 minutes. The same experiment was repeated with different setups such as randomly distributed seeds sequentially 200-600-3000 in each mat *(Figure 8.a-c)*; matrix ordered in 6x6-8x8-12x12 and 3x3-6x6- 9x9 (Figure 9.a-c). We observed each growth process for 7 days.

Figure 8.a-b-c: Image of cress and arugula seeds sequentially belonging 2nd day, 4th day and 7th day after germination.

Figure 9.a-b-c: 2nd, 4th and 7th day of cress (above) and arugula (below) seeds which are located in a matrix of 6x6; 8x8 and 12x12 seeds.

3.3 Observations and Findings

We prepared an experiment setup with cress and arugula seeds and observed their germination process for 7 days. To achieve coherent information, we repeated the experiment under the same conditions, but with different seed types and density to measure how germination, growth and interaction of the seed were affected. In our experimental setup we encountered new and unexpected phenomena, notably a circular movement pattern as well as complex behaviour of seeds. In Coyne's words, we "played" with our findings in a computational environment and benefited from them as an initial context.

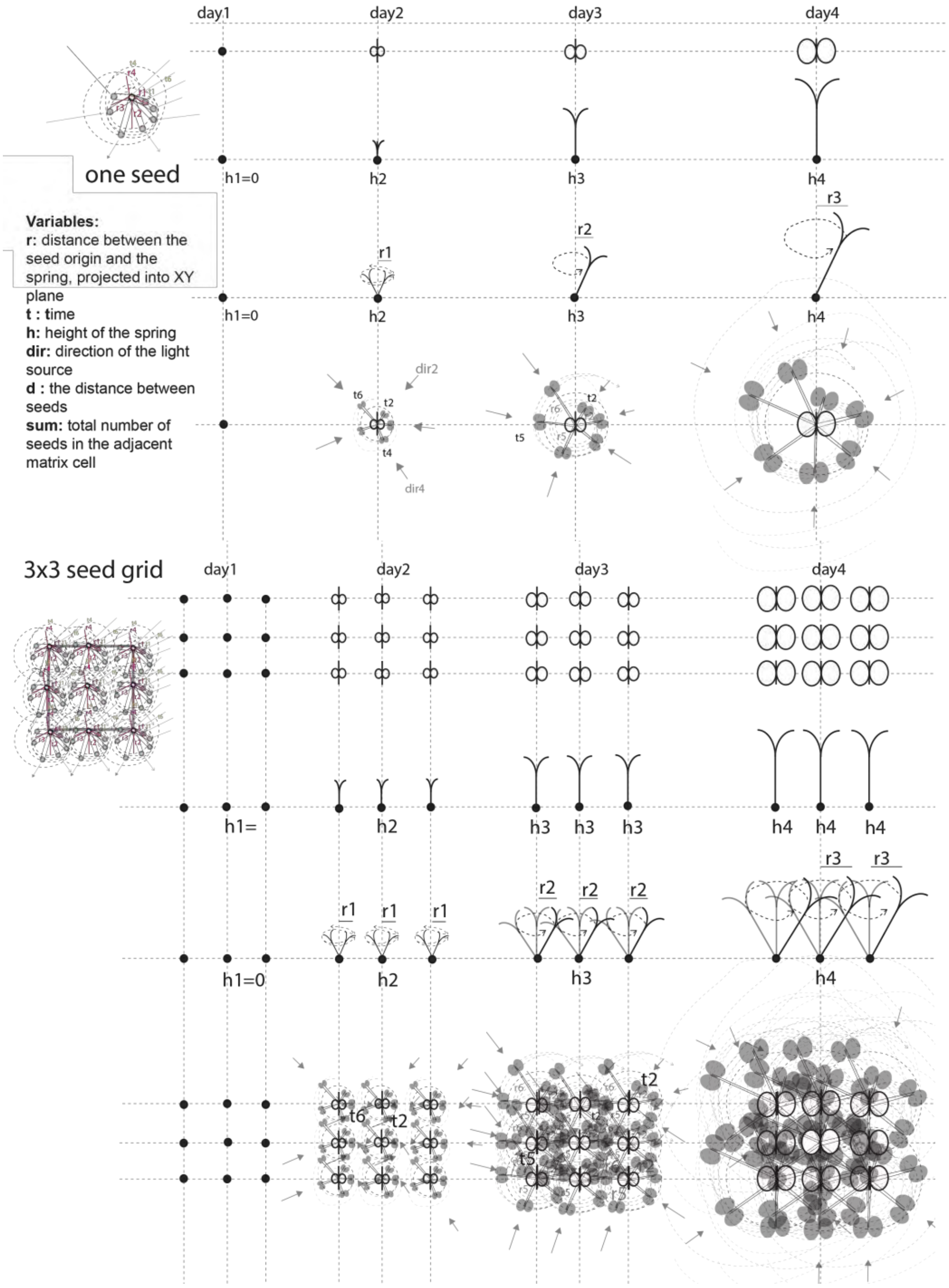


Figure 10: Illustration of growing process of arugula seeds

3.4 Computational Models

3.4.1 Grid Deformation

Each value in the two dimensional matrix represents information about one seed's growth condition (as explained in Section 3.2). First we applied existing values as an increment dependent on a coefficient variable. We assumed that whenever one seed starts to grow, it requires more area. We decided to represent this situation as a repulsion force that translates the neighbour meshes. This translation was calculated in both horizontal and vertical directions *(Figure 12).* The coordinate of the meshes was reorganised proportionally with the values defined in the 2D arrays (*Figure 11 and Figure 12)* .The translation rules, defined in Figure 12, are applied to the data file (.txt) which consists of seeds' germination situation.

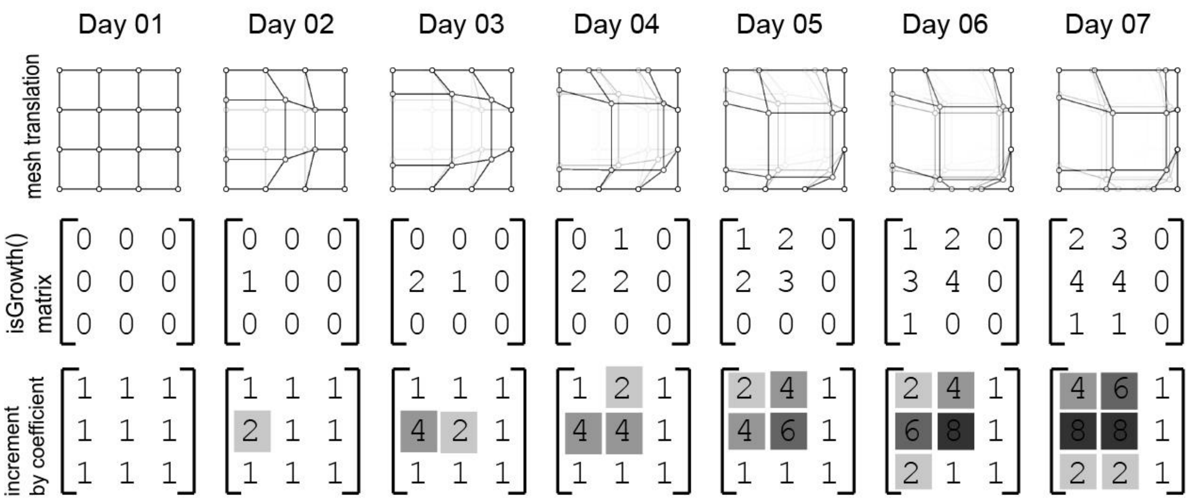


Figure 11: Time Based Grid Deformation Through Mesh Translation

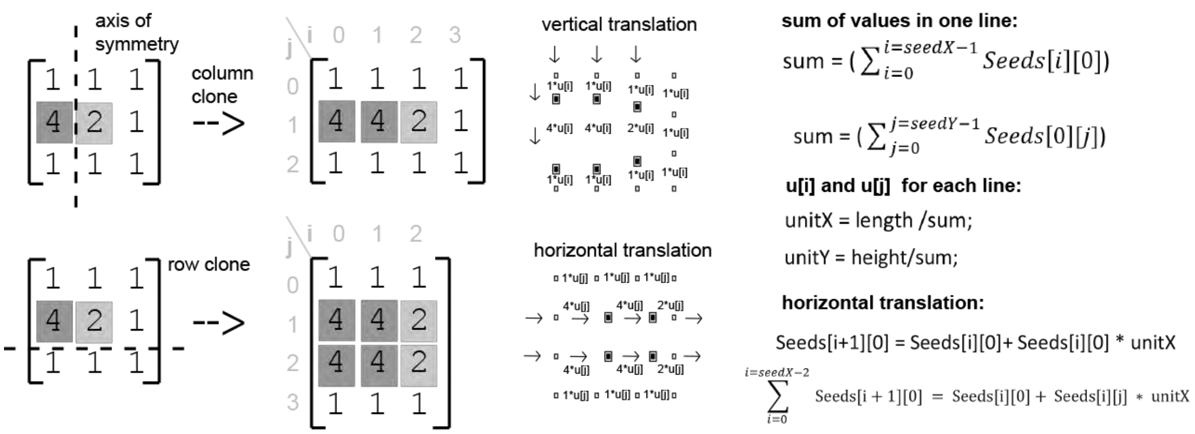


Figure 12: Translation rules

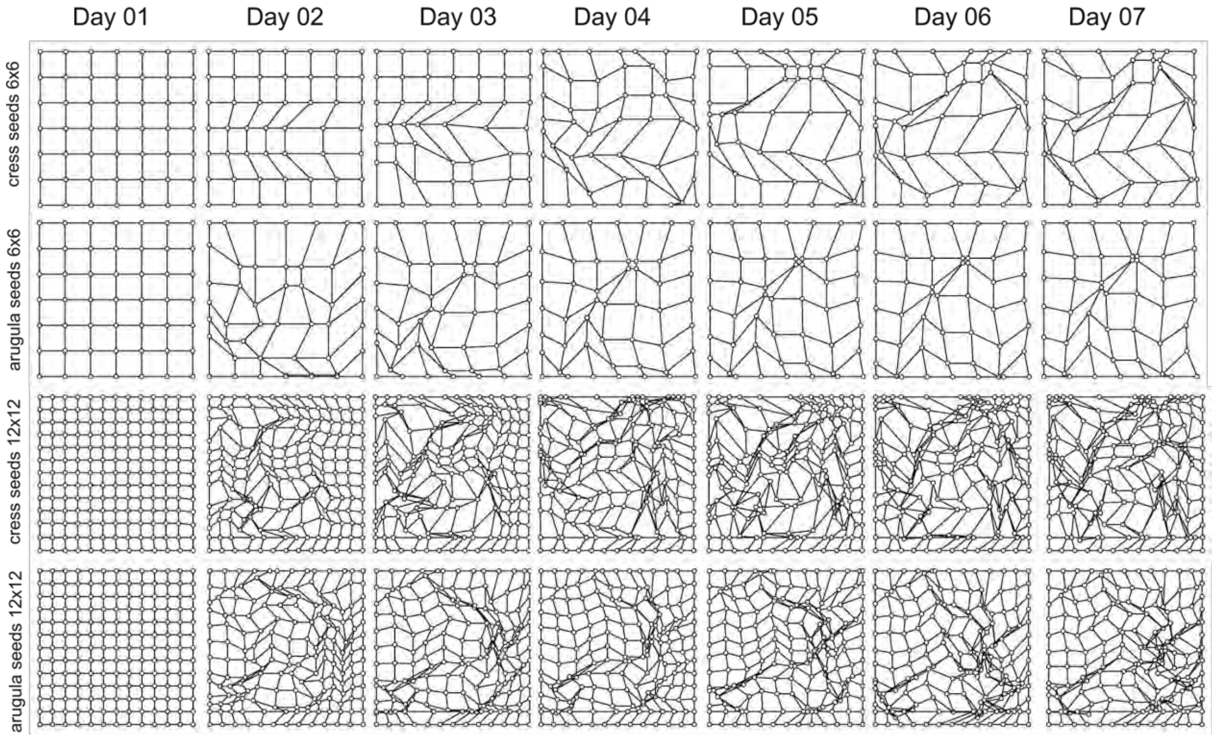


Figure 13: Time Based Grid Deformation through Mesh Translation

3.4.2 Object Based Modelling

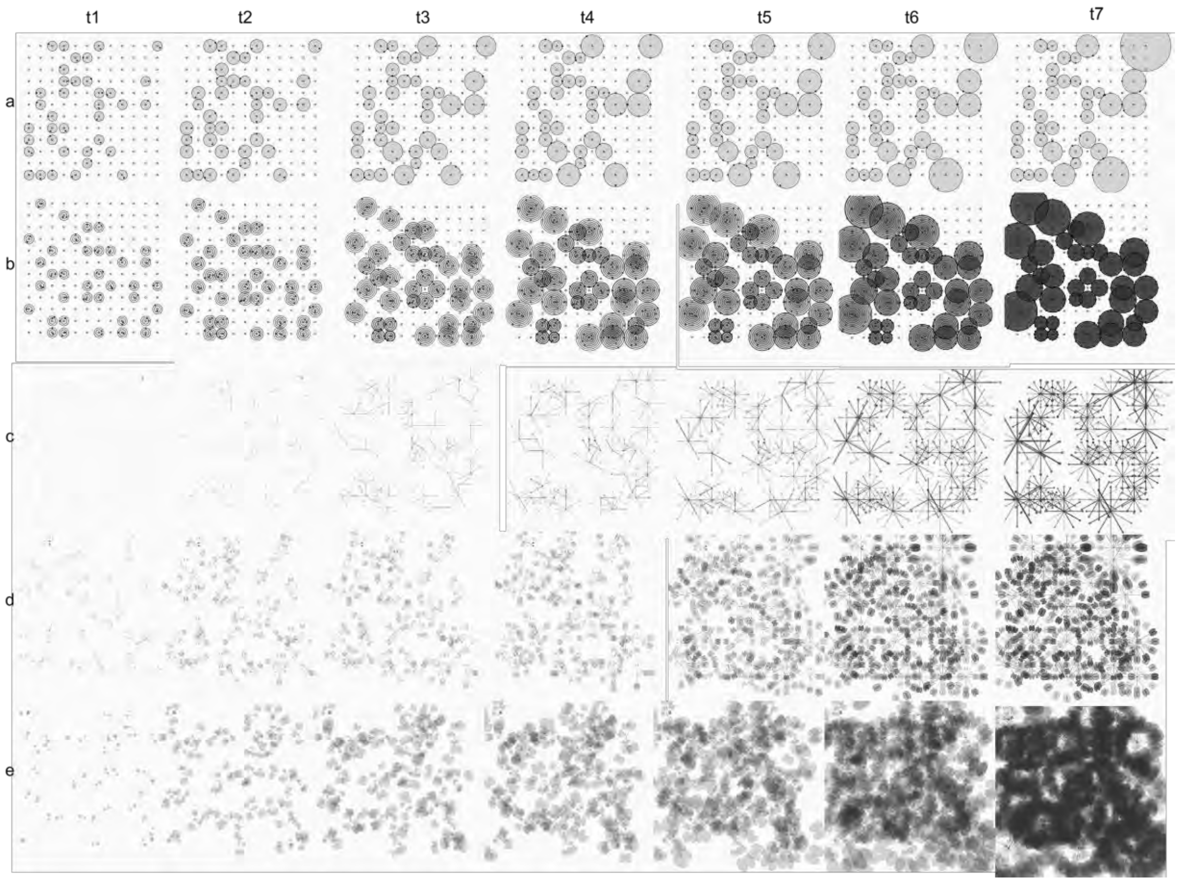


Figure 14: Alternative representations for the simulation process of seed growth

We defined each seed as an object with specific properties and functions in Processing environment. Each seed is considered to be able to “grow()”, sprout()” , “moveCircular()” and they are also expected to control the distance and intersection condition via “collisionControl()” function and “display()” the defined images . The same class definition is used in the alternatives shown in *Figure 14*. The initial coordinates of the seeds are assumed as fixed points and the springs make circular movement. The number of the seeds (s), whether overlaps are allowed or not and the density of germination are the variables that can be changed easily.

4. Discussion

In this paper, our goal is to indicate the potential of directly observing living organisms and using these observations as inspiration during the form finding and idea generation stages in nature inspired computational design approaches. Instead of merely using clearly defined existing Nature inspired methods, we argue that while observing Natural processes it is important to explore relations intuitively and constitute new ones through the observed context with a subjective vocabulary and subjective assumptions. Therefore, the cycle of observation, abstraction, constitution of assumptions and translation of the observed data into digital media provides a reflective, explorative and interpretative experience. In other words, Nature becomes a source of intuition and provides a layout for generating design ideas; such interaction with Nature may be considered, in effect, a way of thinking. With this in mind, we tried to explore the principles of seed growing process through a case study.

A seed exists both as an entity and as an element of an ecosystem which exhibits complex interactions. While growing, a sprout interacts not only with other sprouts, but also with the soil, the source of light and the density around itself. When we reconsider these ways of becoming through new analogies and metaphors, we encounter novelties that enhance our understanding of the original process. For example, when we model the requirement of area for growth by the seed as a repulsive force that affects the grid system, the representation of forces constitutes a topological folding which can be used further as a layout for spatial diagrams or evolution processes in an urban setting in terms of population increase.

5. Acknowledgement

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