Computation Biology and its use in Design.

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Transcription and translation of human DNA into Artificial life forms

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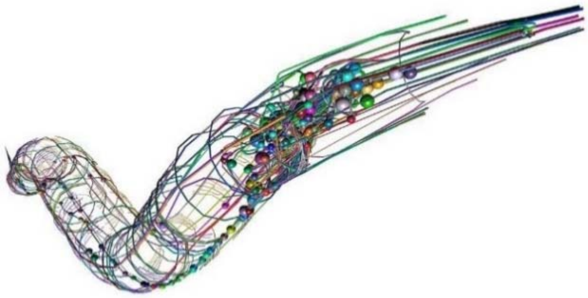
WE can study nature to find solutions to design problems. That's where inspiration comes from! We pick a solution already spotted somewhere in the organic world, that resembles our design problem, and use it in a constructive way. First, examining it, disassembling, sorting out conclusions and ideas discovered, then performing an act of 'reverse engineering' and putting it all together again, in a way that suits our design needs. Very simple ideas copied from nature can produce complexity and exhibit self-organization capabilities when applied in bigger scale and number. Computer algorithms of simulated artificial life help us to capture them, understand well and use where needed.

This paper resumes the graduation project for the spring of 2018 at Istituto Europeo di Design, Madrid (IED Madrid). We are going to perform experimentation and application of Artificial Life systems to the field of industrial design, with the goal of growing new forms and possibly personalized products using human DNA data. The experiments are done by simulation various A-Life systems (Morphogenesis, Evolution, Transcription, Translation etc.) on Grasshopper, a node-based visual programming language editor and Rhinoceros 3D.

1. CONTEXT

"It all began when I was reading a book by the British Biologist Richard Dawkins, the Blind Watchmaker. The Blind Watchmaker analogy made me question my beliefs, not as a religious but as a "Designer" or a "Creator" of products. The book explained how evolution and natural selection is capable of "designing" extraordinary and creative solutions by having rather rudimentary sets of instructions. And there started my curiosity about Artificial life..."

Artificial life (often abbreviated **ALife** or **A-Life**) studies the fundamental processes of living systems in artificial environments to gain a deeper understanding of the complex information processing that defines such systems. These topics are broad, but often include evolutionary dynamics, emergent properties of collective systems, biomimicry, as well as related issues about the philosophy of the nature of life and the use of lifelike properties in artistic works.



http://openworm.org/

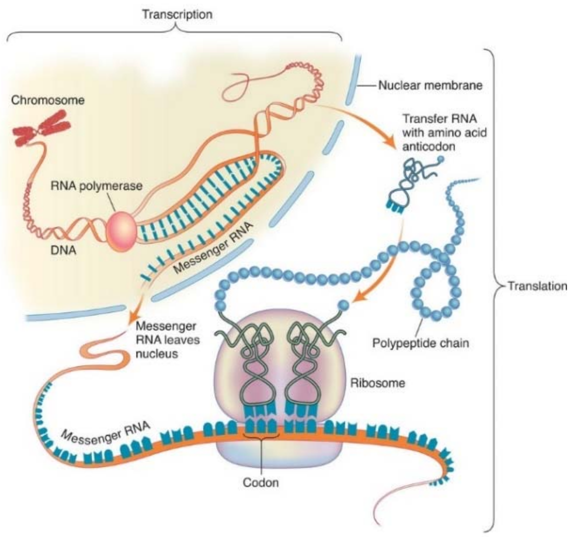
(OpenWorm is an open source project dedicated to creating the first virtual organism in a computer.)

The modelling philosophy of artificial life strongly differs from traditional modelling by studying not only "life-as-we-know-it" but also "life-as-it-might-be".

A traditional model of a biological system will focus on capturing its most important parameters. In contrast, an A-life modelling approach will generally seek to decipher the most simple and general principles underlying life and implement them in a simulation. The simulation then offers the possibility to analyse new and different lifelike systems.

2. SPECIFIC SUBJECT MATTER

Like almost all the cells in our bodies, the single new human cell formed by the fusion of sperm and ovum contain twenty-three pairs of chromosomes (half being contributed by each parent). Our forty-six chromosomes are made from 3 Billion DNA molecules. These are constructed out of four building blocks, or base; adenine (A), guanine (G), cytosine (C), and thymine (T). The DNA molecules are arranged in chains of bases (such as ACAATGC), forming long strings. Each base pair stores the equivalent of 2 binary digits of information.



https://www.atdbio.com/content/14/Transcription-Translation-and-Replication

(The central dogma, showing how information flows from DNA to RNA to protein)

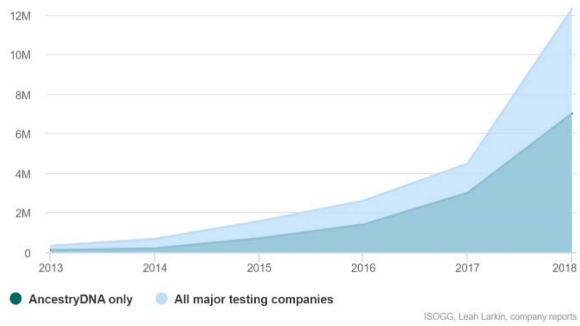
Artificial life system is a broad term. In this paper, we are going to look at some of the **experimentation** and **application** of A-Life systems to the field of **industrial design**, with the goal of **growing** new forms using **human DNA** data.

The efficiency of the process **directly** relates to the accuracy and approximation of the natural and artificial process.

3. CHALLENGE

3.1 Problem/Opportunity:

3.1.1 There is a growing trend in the number of people who have had their DNA analysed with direct-to-consumer genetic genealogy tests more than doubled during 2017 and now exceeds 12 million, according to industry estimates.



https://www.technologyreview.com/s/610233/2017-was-the-year-consumer-dna-testing-blew-up/
(2017 the year consumer DNA testing blew up)

3.1.2 On the other hand, mass personalisation is set to become a reality, with 36% of consumers saying they are interested in personalised products or services, according to research by the business advisory firm, Deloitte. Those under 40 are more interested, with 43% of 16-24-year olds and 46% of 25-30-year olds attracted to personalised goods and services. This desire contrasts with a relatively low take up so far, only one in six of consumers have ever bought these products or services.

https://www2.deloitte.com/uk/en/pages/press-releases/articles/one-in-three-consumers-wants-personalised-products.html)

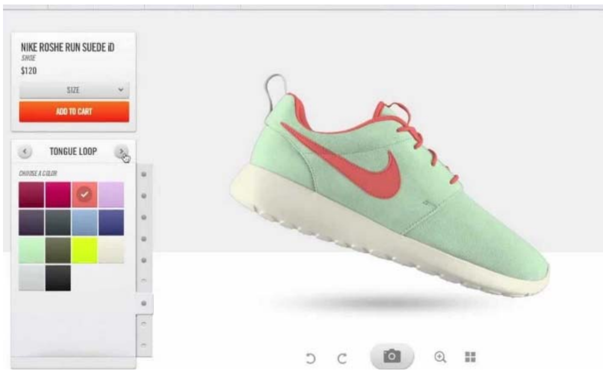
3.1.3 The general model of A-Life system is a rudimentary way of converting genotype to phenotype without going through the phase of growth, embryology, morphogenesis and evolution etc.

3.2 Causes & effects / consequences:

3.2.1 The cause for the dramatic decrease in price is due to advancement in the field of portable DNA sequencing machines. Hence the decrease in the acquisition cause an overall decrease in the price of sequencing. Also, a key factor is the amount of money spent on advertisements by companies like 23&Me and My Heritage.

3.2.2 The majority of shift has been due to advancement in the manufacturing process of products. It is much easier now to design a personalized product than it was a decade ago. Technologies like 3D printers, CNC machines are revolutionizing the sector of personalized products.

Personalization gives a product it´s soul by differentiation itself with product of its kind, which is highly appreciated by the young generation now a day. This makes the user stand out from the norm.



https://www.nike.com/
(An example of graphical personalization)

3.2.3 Once we start going through the processes required to replicate Artificial life systems on a digital platform, the complexity of the simulation exponentially grows out of hand. Although, with advancement in computing power and insights about the corresponding biological process, the field of A Life seems promising and interesting.

https://en.wikipedia.org/wiki/Evolved_antenna
(The 2006 NASA ST5 spacecraft antenna. This complicated shape was found by an evolutionary computer design program to create the best radiation pattern.)

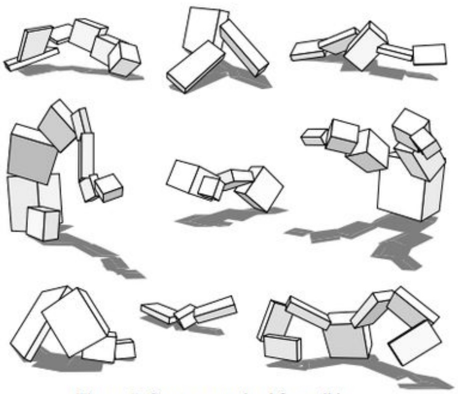


Figure 7: Creatures evolved for walking.

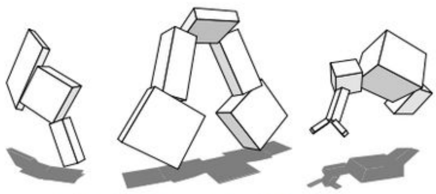


Figure 8: Creatures evolved for jumping.

http://www.karlsims.com/evolved-virtual-creatures.html
(Simulating Darwinian evolutions of virtual block creatures. Each creature is tested for their ability to perform a given task, such the ability to swim in a simulated environment.)

3.3 Necessity:

So, we can clearly conclude that there is a growing trend among the population to know more about their DNA and health, we can also conclude that people like personalized products. And with the advancement in computing power, it is now possible to simulate far better the natural phenomena on a personal computer.

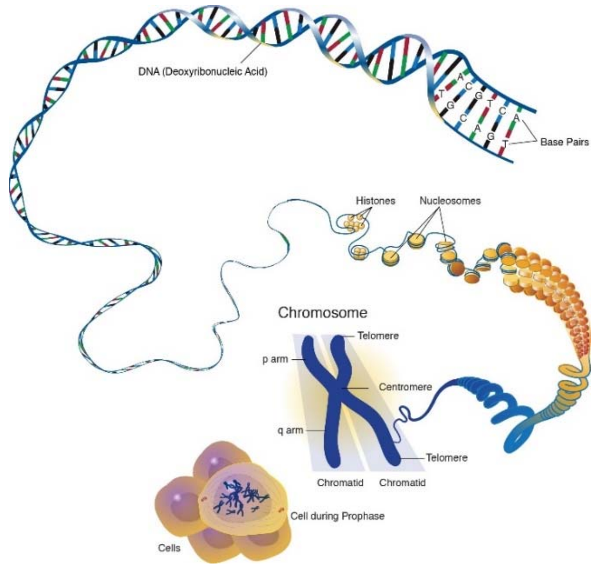
The **challenge** will be relating global trends (DNA analysis), necessity (Personalization) and personal interests (Artificial Life Forms) so that can fit in the domain of industrial designing.

4. FINDINGS

4.1 General view

Human DNA strand has 23 chromosome pairs (46 in total), around 25,000 genes. Genes are composed of DNA, and it is predicted that there are over **3 billion** base pairs in the human genome.

No two humans are genetically identical. Even monozygotic twins (who develop from one zygote) have infrequent genetic differences due to mutations occurring during development and gene copy-number variation. As of 2017, there are a total of 324 million known variants from sequenced human genomes. As of 2015, the typical difference between the genomes of two individuals was estimated at **20 million base pairs** (or 0.6% of the total of 3.2 billion base pairs).



(DNA information hierarchy)

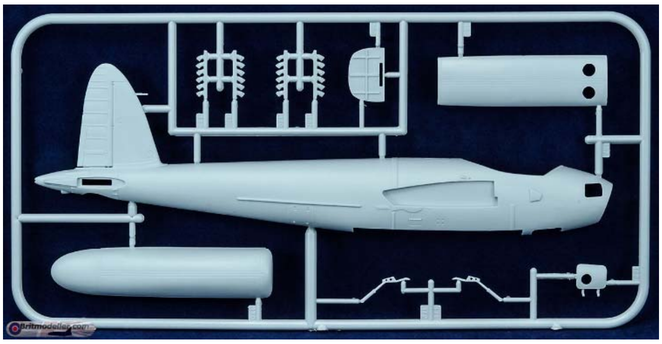
Genes are almost like a blueprint to any organism. We can find a lot of interesting information about the organism just by reading it´s DNA. For example, the risk of various diseases, height weight, heredity etc.

Also, DNA are unique to us. There is nothing more tailored to / personalized than the genes.

4.2 Case studies

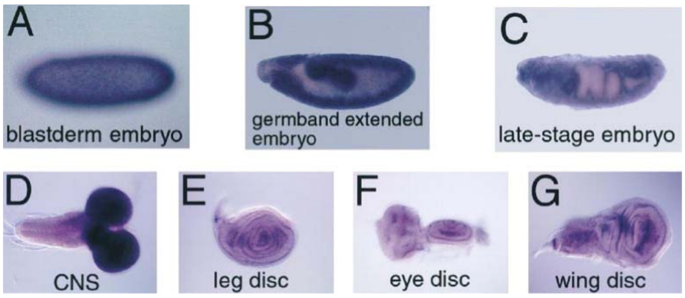
4.2.1 Construction Method

Most man-made objects are assembled from components. In nature the key difference is that the instruction list only specific task that a cell can carry on.



https://www.cybermodeler.com/hobby/kits/tam/kit_tam_61062.shtml
(Airfix kits de havilland mosquito)

Growing structure from homogenous material (like polymer, clay, silicone etc) for the starting phases of development of Artificial life forms eases the complexity related to computation.



(Embry development of a common fruit fly)

4.2.2 Langston´s Ant

Langton's ant is a two-dimensional universal Turing machine with a very simple set of rules but complex emergent behaviour. It was invented by Chris Langton in 1986 and runs on a square lattice of black and white cells.

The ant just follows two rules,

-At a white square, turn 90° right, flip the colour of the square, move forward one unit
-At a black square, turn 90° left, flip the colour of the square, move forward one unit

The by-product of such system is a complex behaviour but with basically two simple rules.

4.2.3 Biomorph

Biomorphs are virtual entities that were devised by Richard Dawkins in his book The Blind Watchmaker to visualize the power of evolution.

The vector, line length, angle represents the genes of these virtual creatures. By manually selecting the desired biomorph, we can guide the process of evolution. These processes can also be automated by putting a fitness function as an objective.

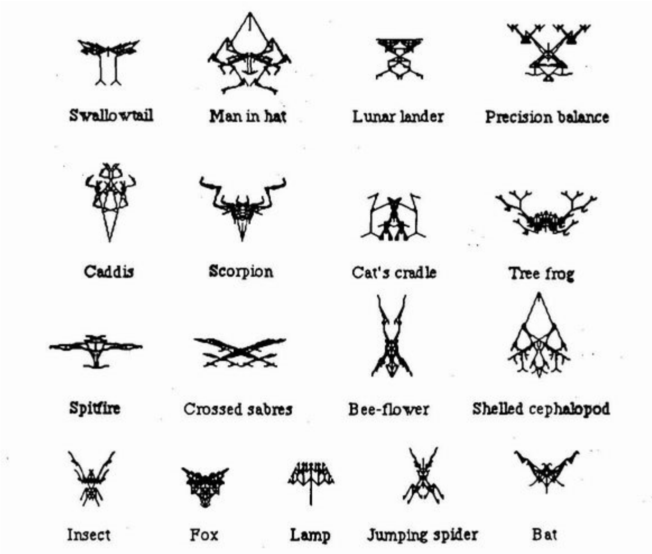


Figure 5

(BioMorphs, the Blind Watchmaker, Richard Dawkins)

5. METHODOLOGY

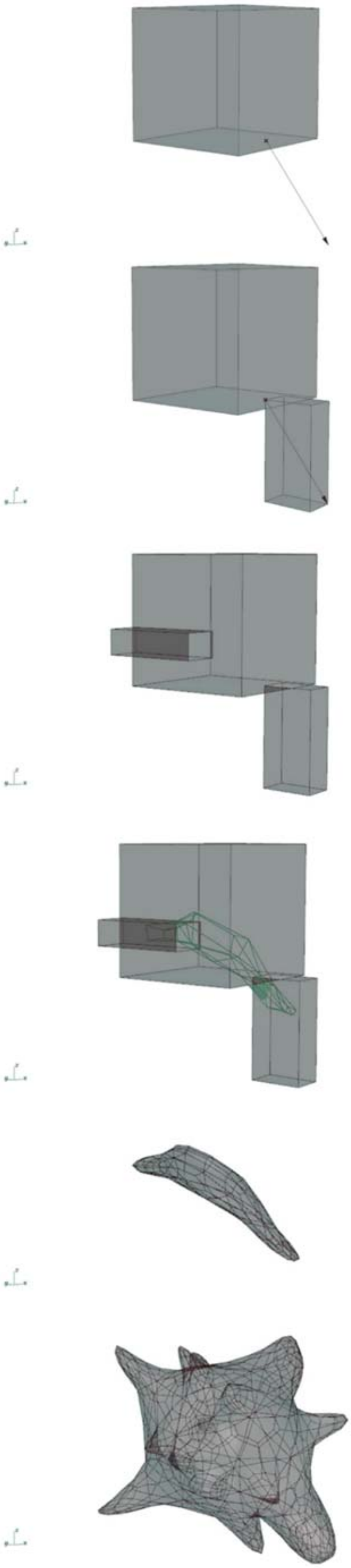
To gain insight about various Artificial life systems, a few experiments were made.

Reverse Engineering

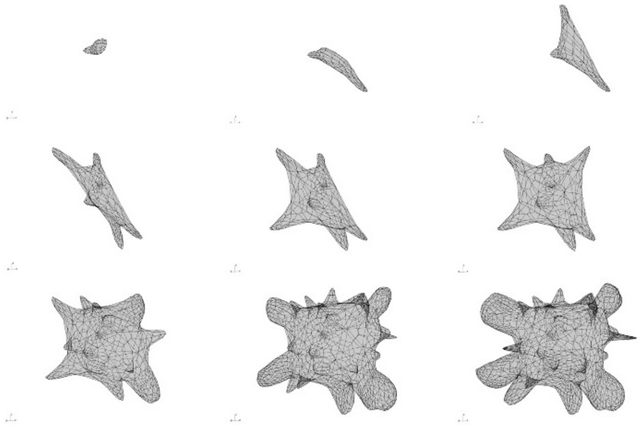
We can study nature to find solutions to design problems. That's where inspiration comes from, so we pick a solution already spotted somewhere in the organic world, that closely resembles our design problem, and use it in a constructive way. First, examining it, disassembling, sorting out conclusions and ideas discovered, then performing an act of 'reverse engineering' and putting it all together again, in a way that suits our design needs. Very simple ideas copied from nature can produce complexity and exhibit self-organization capabilities when applied in bigger scale and number. Computer algorithms of simulated artificial life help us to capture them, understand well and use where needed.

5.1 Petri dish:

Petri dish is a fun experiment to get used to the idea of iteration and loop with simple set of rules. The goal of the experiment was to simulate the first week of the IVF (In Vitro Fertilization stage.



(Creating an outgrowing cell by using random vector and mesh relaxation.)

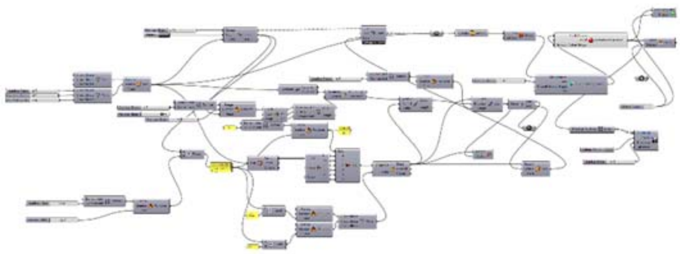


The embryology of an organism in digital Petri Dish.

(a)

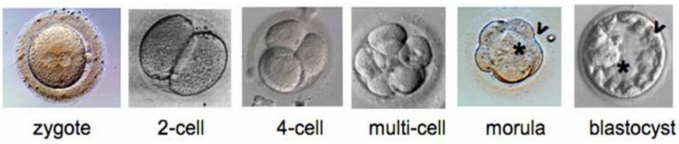
(b)

(a) and (b) rendered image of possible organism forms.



Grasshopper defination. Rhinoceros.

Another variation of the petri dish experiment was to grow cells based upon distance between each cell of a guiding nerve.

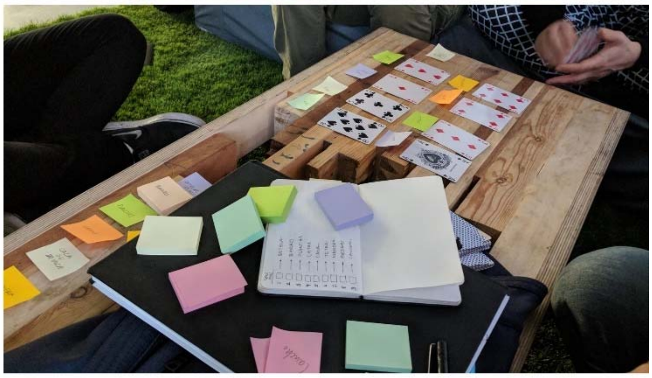


This also helped to get insights about the developmental process. For example, the algorithm had random mutation in the growth process, and each time the simulation was run, earlier mutations resulted in forms extremely different than their parents.

(Growth, Iterations and form, simulated on Grasshopper, Rhinoceros)

5.2 Genemulator:

In the framework of product design, it is important for designers to develop a wide variety of creative solutions to problems. Many product design processes suggest that the creative process has a period of broad idea generation followed by a period of selecting concepts. This is nothing more than divergent thinking followed by convergent thinking. However, simply suggesting that divergence must follow convergence ignores the reality of the way that people think. Humans do not simply turn on and off their creativity. People are creative at different times for different reasons.



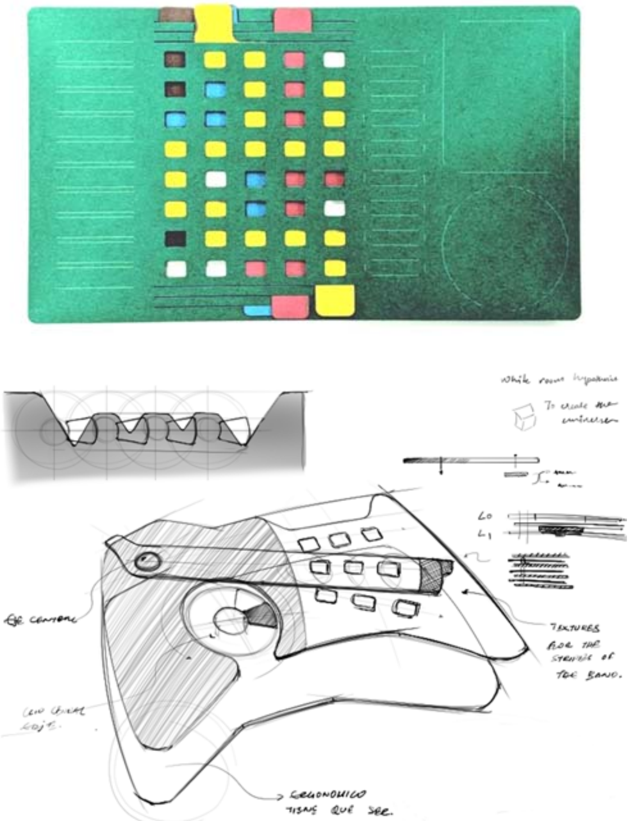
Idea A

Idea B

Idea A +B → **New Idea C**

MUTATION

It is a Creativity Enhancement Tools based upon the principals of genetic algorithm simulated on a non-digital platform. It resolves the problem of linear thinking and puts a barrier on emerging thinking pattern, hence enhancing the creativity of a designer. By simulating random combination, crossover, non-random selection and mutation on a non digital platform. It can be really useful for designers, creative thinkers.



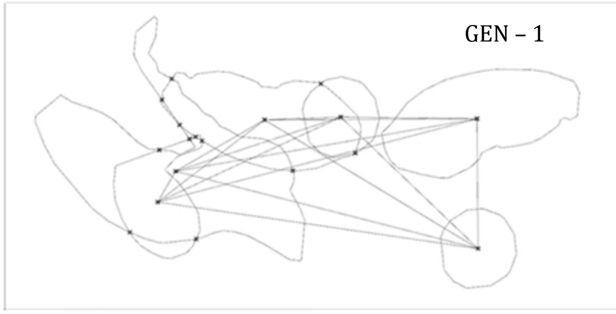
(Genemulator, a tool to simulate evolutionary algorithm on a non-digital platform to increase creativity of a designer)

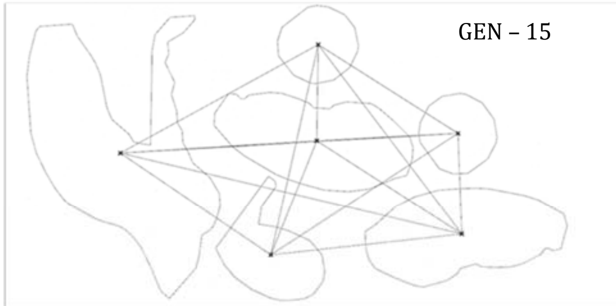
5.3 2D sheet optimization:

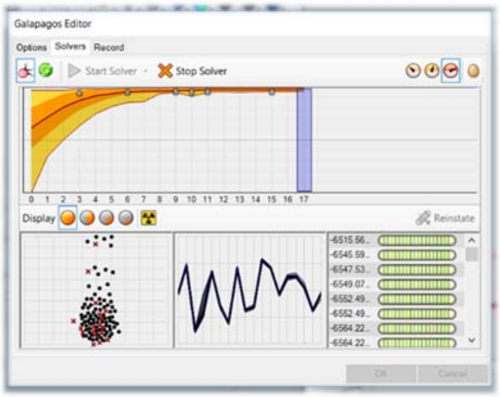
This experiment used genetic algorithm for 2D optimization of a flat CNC/Laser cutting surface. The goal was to develop an open source optimization definition for Grasshopper, so that students at **FabLAB** around the globe can reduce the underutilization and wastage of materials.

(Mind Map used for the creation of the 2d optimization Genetic Algorithm.)

The ideation of this experiment required to think this 2D world as a real, spatial world with physical laws & constants, life, food, resources etc. The organism which saved the most amount of surface area was considered the alpha of the generation and could pass its capabilities to its children with slight random variation.



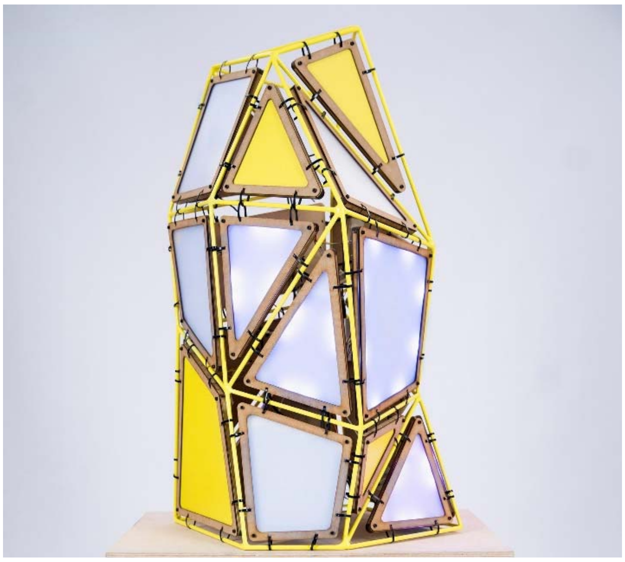




The conclusion of the Rhino Nest experiment was kind of interesting. Although the algorithm need a lot of work to be done, and it was not able to reach its desired efficiency, the algorithm surely gave creative ways to optimize the 2D sheet, which with help of human assistance, could generate overall positive results.

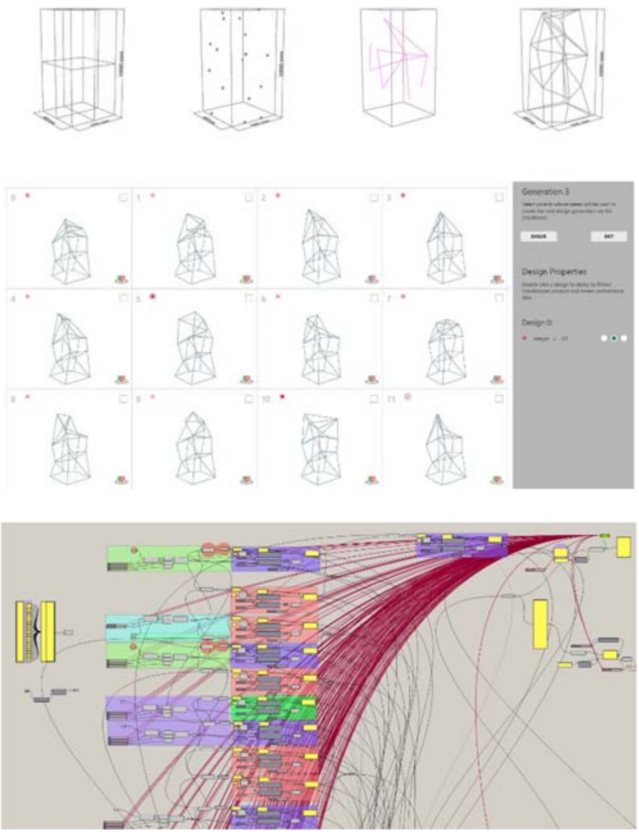
5.4 Chromastone:

Chroma Stone is a retro arcade game, for one or more players, Open Source, scalable in size and created by generative design.



(Chromastone, Mecedorama, 2018 IED Madrid.)

(Chromastone, Mecedorama, 2018 IED Madrid.)



(Chromastone, Mecedorama, 2018 IED Madrid.)

Using the Grasshopper tool, Galapagos and its optimizer, we created a definition that allows us to match the error with the initial 3d model vs the welded physical model. Using an evolutionary algorithm, the error was fixed by comparing the 3d model and actual model.

6. FOCUS AND IDEAS

The data about the dropping rates for DNA sequencing and rising demand for personalized goods, points us to an opportunity to make industrial products made from the DNA information of individuals.

Also, there are around 20 million different base pairs from one person to another. Thus, we have around 20 million data points that cannot be repeated between one person to another. Specific genes can point to specific need of a person.

Few ideas can be

- Using DNA information to design an abstract art.
- Growing sculptures by reading DNA sequence.
- Making products that satisfy a function based upon the DNA information.

From the above experiments (Refer to Index No.5) we can use distinct aspects of various Artificial Life forms to formulate an Idea. There are around 20 million distinct DNA nucleotides between individuals. In this era of digital fabrication, there is a huge market for hyper personalized products.

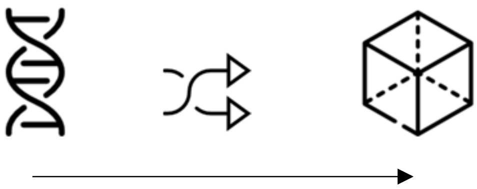
The focus will be making products that satisfy a function based upon the DNA information.

7. SOLUTION

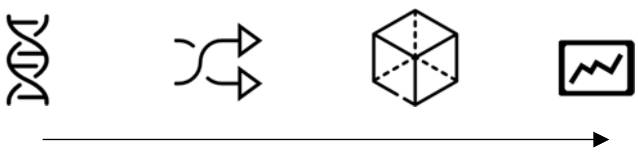
The human genome contains more than **20 million base pairs** (or 0.6% of the total of 3.2 billion base pairs). The solution is to use these base pairs to create unique personalized items.

What is it? : a design methodology to use human DNA information to give rise to Artificial life forms.

What does it do? : It transcript and translate human DNA nucleotides to digital proteins, which later interact with other digital proteins to make the shapes and forms.



What does it solve? : This methodology of design bridges the two upcoming trends about DNA testing and product personalization.



For whom? : Potential clients can be designers who work in the sector of personalized products. Although being self-sufficient, it can be used by the end users directly.

8. CONCEPT

Our 46 chromosomes are made from 3 Billion DNA molecules. These are constructed out of four building blocks, os base; adenine (A), guanine (G), cytosine (C), and thymine (T). The DNA molecules are arranged in chains of bases (such as ACAATGC), forming long strings. Each base pair stores the equivalent of 2 binary digits of information.

The Double helix can be read as a chain of continuous information. For example, 3 base pair of ATCG can be organized 64 different ways (AAA, AAC, AAG……. GGG). Each combination give rise to unique digital protein, which later interacting with other digital proteins give rise to the structure of the product.

This way of interpreting DNA data opens a whole new way of DNA data visualization (Materialization of DNA information)

Viability – DNA sequencing price has been cut from 100 million in 2001 to mere 200 hundred bucks in 2018. It is far easier and convenient and safe to have DNA data sequenced now than it was a decade ago.

Sustainability – Being a system of Artificial life, sustainability goals can be hard coded into the systems to make the most of resources.

Use – The sequence information can be used to make personalized reused to make new personalized products ranging from health to

Aspect – The genes give one and only unique aspect to the design, there cannot be another one, as the DNA information is directly linked to the morphology. This is what one can call true individual made from the same information that makes an individual.

Start Vs End – When I started investigating about artificial life, the idea to create designs using evolutionary algorithm was fascinating, and seemed so obvious and easy.

But after investigating in this field, I became familiar with the shortcomings and difficulties regarding these techniques. Although, there is no difference in my enthusiasm and passion about this field of research.

~~DESIGNER = SOLUTION~~

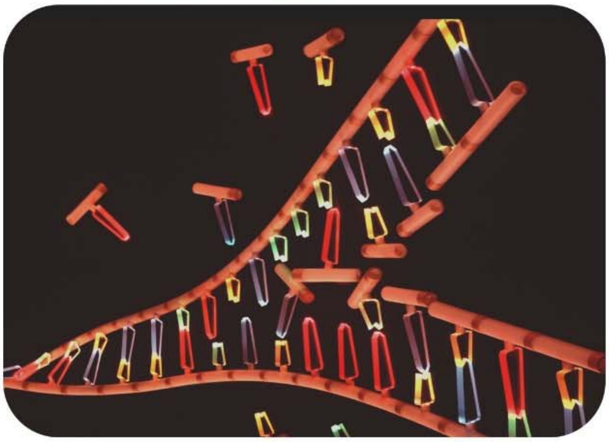
DESIGNER = SYSTEM = SOLUTION

The traditional way of designing has been that the designers create solutions.

But I am proposing that we create systems, where the solutions, creatures, designs, emerge into existence!

9. MOODBOARD

EMBRYOLOGY DNA ACTG
GROWTH FORM COMPUTERS FOOD
MORPHOGENESIS EVOLUTION



10. DESIGN STRATEGIES

For the proper functioning of the algorithm, the new design should fulfil the following criteria.

10.1 Primary Function – The primary function creating personalized products based upon the user DNA data.

10.2 Secondary Function – The secondary function is making sense of useful information in the DNA. And possibly creating artificial life forms.

10.3 Technical requirement – Flexible and dynamic to adapt to variety of products. Also, the algorithm should be able to run on a regular PC.

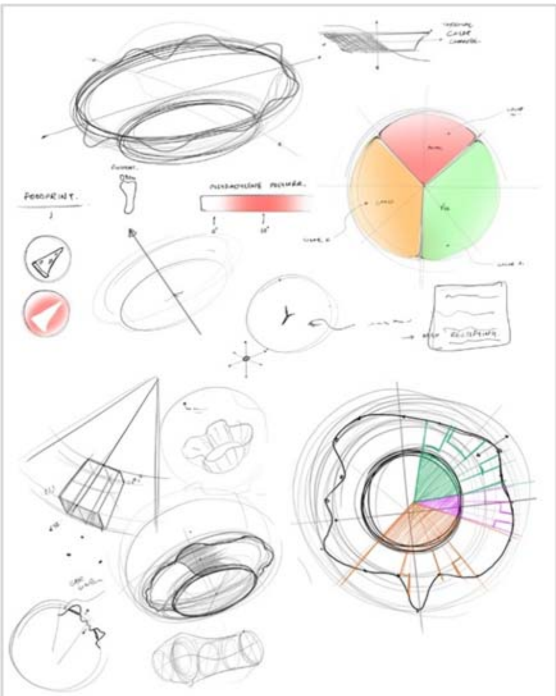
10.4 Types of users – Any individual with basic and intermediate knowledge about genetic algorithms and familiar with basic Evolutionary Biology and genetics.

10.5 Context – Increase in general trend about DNA testing and personalization.

10.6 Sustainability – There should be some constraints applied in the formation of the algorithm that favours sustainable solutions and rejects otherwise.

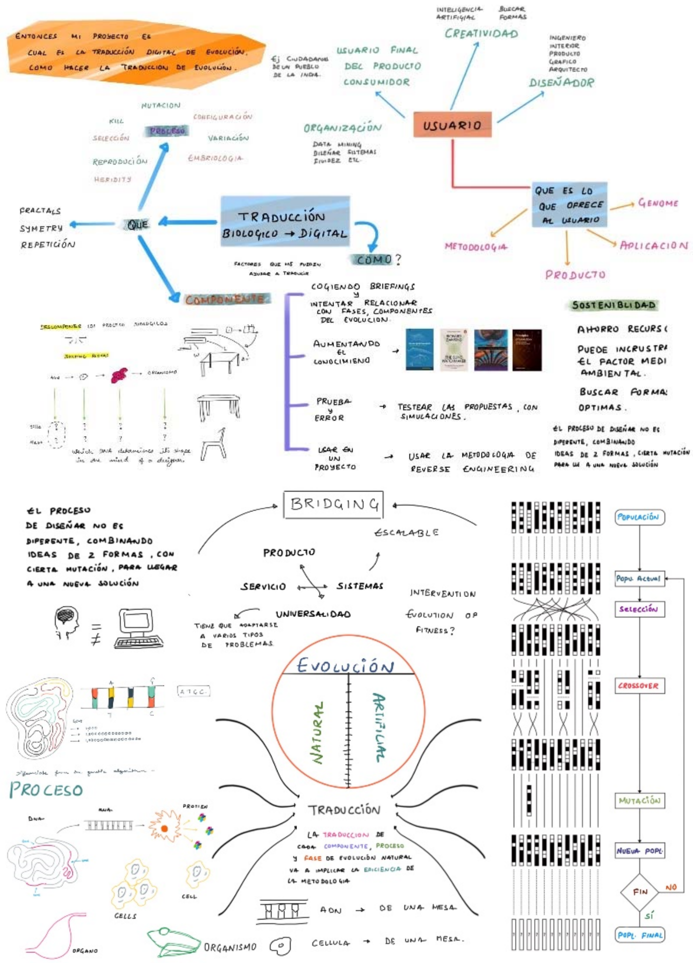
11. CREATIVE PROCESS

11.1 Sketches



(Initial Sketches)

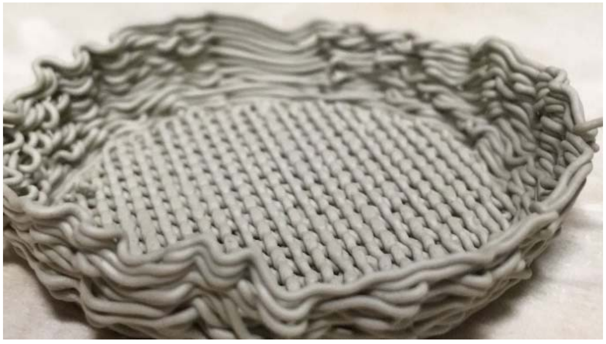
11.2 Brainstorm



Key words – Translation, Component, Growth process, Artificial DNA, Embryogenesis, 23&Me.

11.3 Experimentations

(3D printing Vector Fail)



(Process : 3D printing with Delta Wasp 3D ceramic printer)

11.4 Design Strategies

The principal strategy of this technique is to approximate as much as possible to the natural processes of Growth. Here are the main strategies needed to be incorporated with the system.

Regulating Genes

The transcription of a gene begins when the right kind of chemical sticks (or binds) to the beginning of the gene on the DNA molecule." other words, genes are expressed only when a chemical trigger their expression. There is a very good reason why this is required. Imagine if there were no triggers. If all genes were always transcribed all the time, then every cell would pump out the full repertoire of proteins all the time. And since cell contains an identical copy of our DNA, they would all be the same. Produce the same proteins, and you become the same cell.

Growing through a stage

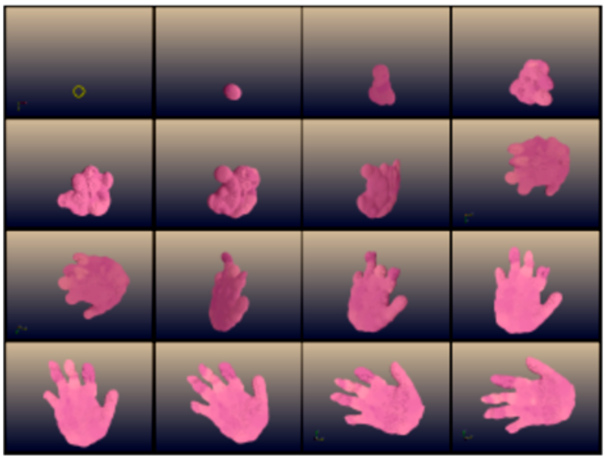
There are four main processes in development: the first is the spatial organization or **pattern formation**. That is how different parts of the embryo acquire different identities. Then you have **cell differentiation**. Because cells are in different positions, they acquire different characters and ultimately end up muscle and cartilage and that sort of thing. Then you have **morphogenesis** or change of form. And that's about the forces that mould the shape of the embryo. If pattern formation is like painting, morphogenesis is like sculpture. And then you have **growth**."

Cellular Pattern Formation

A plant needs to make sure stems go up and roots go down. an animal needs to have mouth end and an anus at the other. For amphibians, the point at which sperm enter the egg during fertilization helps to define the head-tail orientation, gravity helps to tell cells which way is up, as they float on top of the yolk in their eggs. But for mammals such as the mouse, all directions are thought to be defined by cell interactions: protein messages sent between the cells.

Differentiation

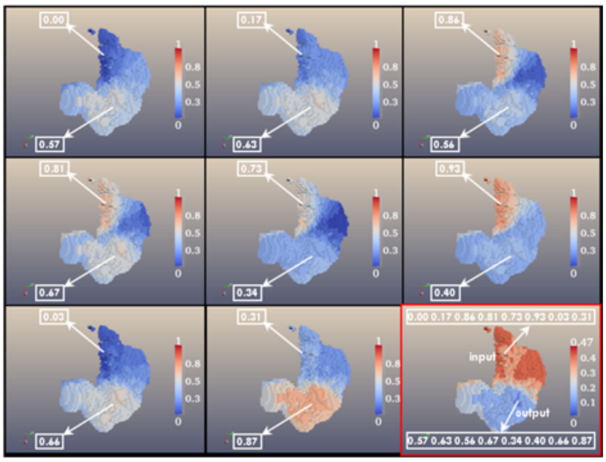
When cells with certain combinations of active genes divide, their children are subtly different. Aided by the protein messages from the cells in their environment, the children have a slightly different pattern of gene expression. So, when they divide, their children subtly different from them, and their children different again. Over many generations, cells become more and more specialized for different tasks. It's like a handyman having a son who becomes a carpenter, who has a son who becomes a cabinetmaker, who has a son who is an expert on marquetry for cabinet doors. Each child is more Suz So as we specialized than the previous one.



Evolution and development of complex computational systems using the paradigm of metabolic computing in Epigenetic Tracking Alessandro Fontana, Borys Wrobel. Evolving Systems Laboratory, faculty of Biology, Adam Mickiewicz University

Morphogenesis

No single cell knows anything about the whole organism. It has no idea whether it is destined to help shape a foot, a heart, or a brain. Cells just produce proteins according to their genes, which affect other cells in their immediate neighbourhood. And yet when a developing embryo is studied, we see astonishing changes of form. Large sheets of cells fold themselves inward to form internal hollows and tubes. Corrugations form, vast groups of cells elongate, twist, and move. Structures seem to turn themselves inside out. Our genes take the art of origami to a new level as they help to build us. And it's all done with proteins.



Metabolic computation using a 3D multicellular structure. The first 8 panels (with black frames) show the concentration maps of each substance on the best individual evolved for 4 examples, using one of the examples.

Growth

Embryos grow larger throughout their development. It's a process that is needed to help push and mould organs into the right forms. But most of growth happens when embryonic development is largely complete. And growth happens using three mechanisms cell proliferation, cell enlargement, and accretion.

11.5 Genotype to Phenotype

Our 46 chromosomes are made from 3 Billion DNA molecules. These are constructed out of four building blocks, os base; adenine (A), guanine (G), cytosine (C), and thymine (T). The DNA molecules are arranged in chains of bases (such as ACAATGC), forming long strings. Each base pair stores the equivalent of 2 binary digits of information.

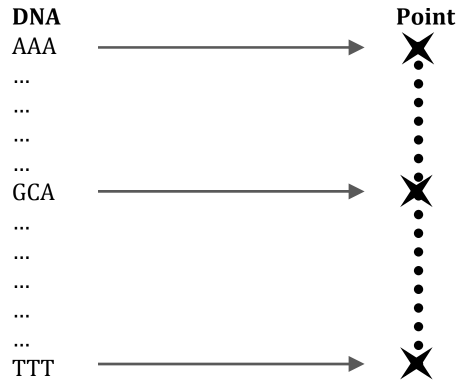
ACAACTGAATACTGC……………………………

So, to get bits of information, we can break chunks of 3 nucleotides. A chain of 3 DNA base can be arranged in sixty-four different types.

ACAACTGAATACTGC……………………………

<u>ACA</u> <u>ACT</u> <u>GAA</u> <u>TAC</u> <u>TGA</u>……………………………

We can give arbitrary value to these chunks, for example, AAA = 0 and GGG = 64; Or CGT is the mid-point in the curve etc.

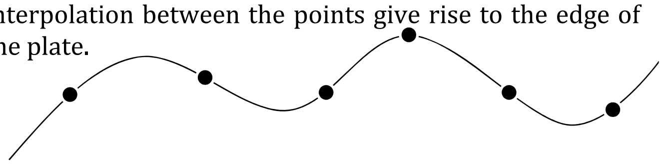


We draw a circle with an offset. And divide n times. A line is drawn between the inner and the outer dividing points of the two circles. These lines are the domains where we are going to draw points on the curve based upon what the DNA information says.

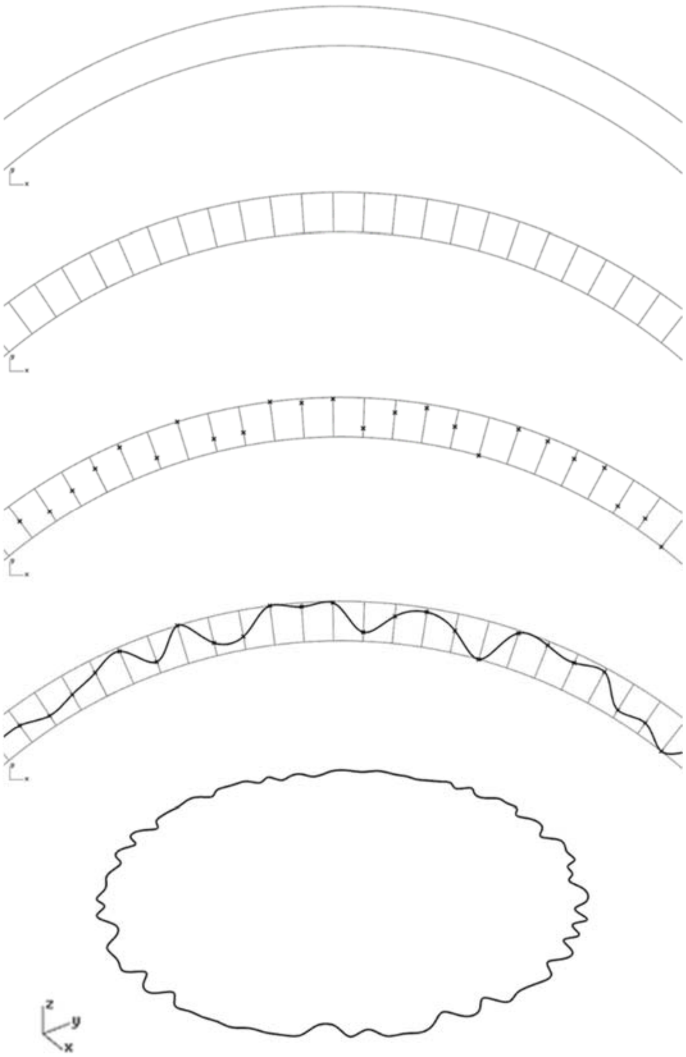
*n = number of chunks of information.

Once we have all the points, we are going to interpolate to fill the difference in between. In this simple set of instruction, the complexity of the geometry increases as the more we read the DNA information.

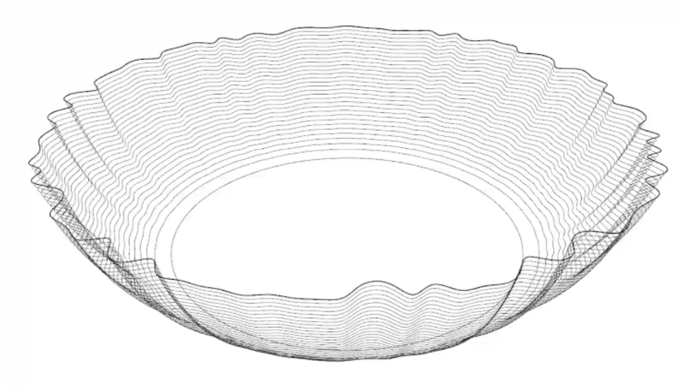
Once the point has been marked in each line, an interpolation between the points give rise to the edge of the plate.



The curve is closed to form the upper edge of the plate. The upper edge and the base disc are joint by the loft option.



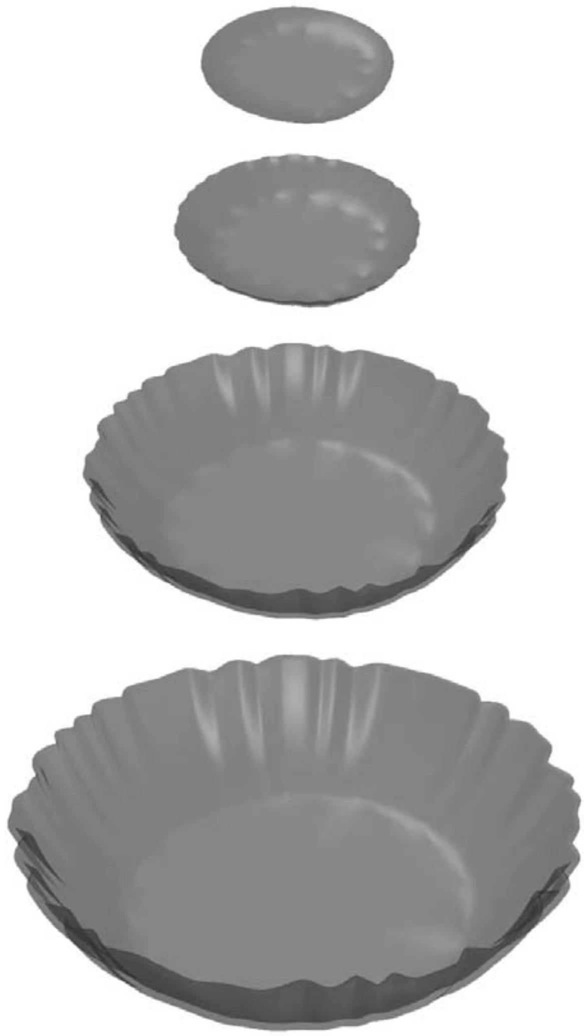
(The translation phase of the artificial life plate)



(The final possible structure)

Once the structure of the DNA is defined, the process of growth can take over. It starts with a disc and slowly starts to grow from extremes to upwards.

The growth process follows around 1500 iterations. Each iteration is repetition of the same instruction but with the information of the previous iteration as input, just like a loop, but building upon the previous data.

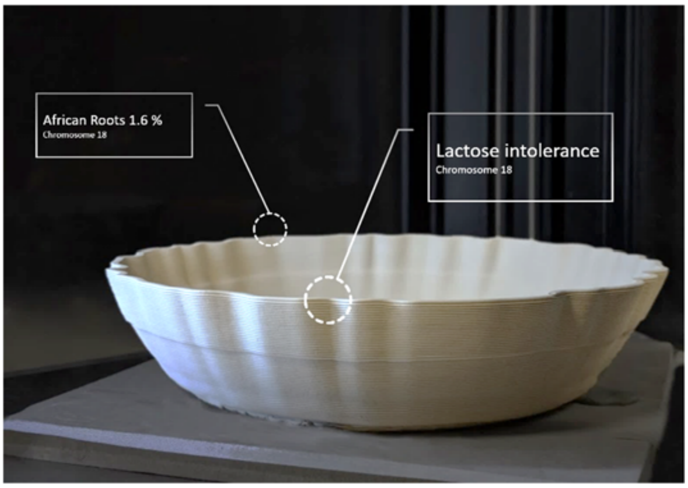


(The **transcription** phase of the artificial life plate)

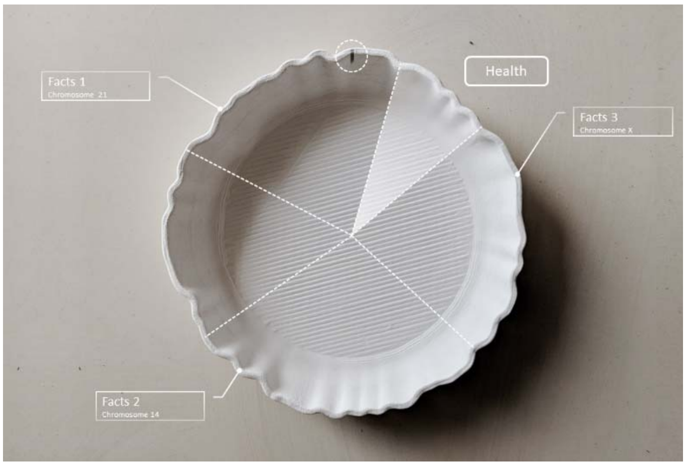
12. DESIGN INFO

12.1 Primary Image

12.2 Positions

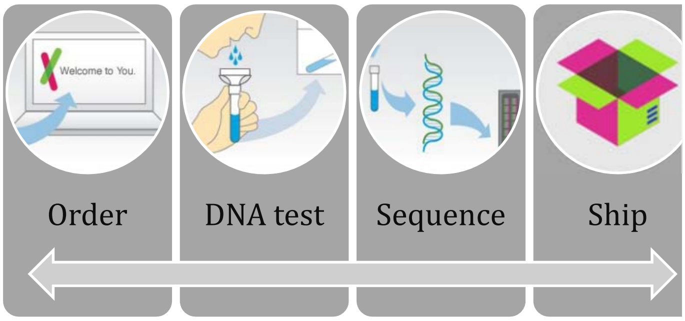


DNA data visualization through mountains and valleys on the edge of an artificial life form plate.



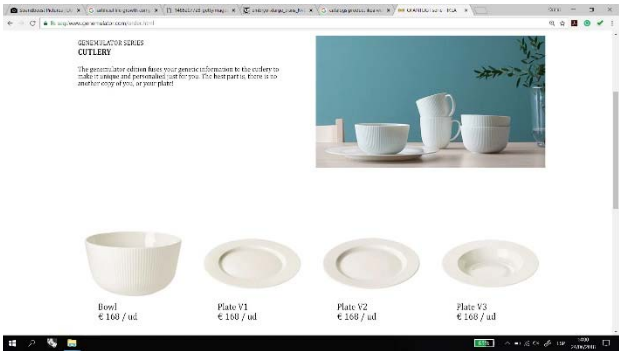
The plate can show information about intolerance, genetics, heredity, physique, or any aspect that can be decoded from the Genes.

12.3 User journey



Phase 1: Order

The user can navigate the products available for personalization. When the desired product/s are selected, the user can proceed to the checkout.

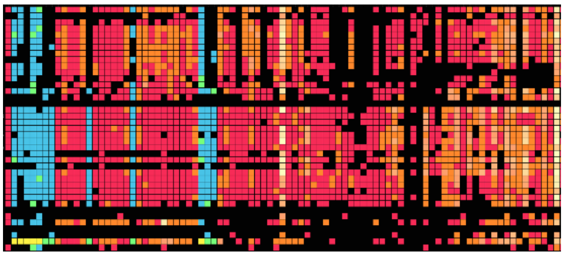


Phase 2 : DNA test
The user will receive a DNA test kit after the order has been realized. They have to fill the tube with saliva and send it to the company.

23&Me Saliva sample collection kit. The kit comes with a saliva buffer to increase the life of the DNA info in the saliva in harsh conditions. The kit also includes a biohazardous plastic bag.

Phase 3 : Sequence

The DNA data will be analysed and sequenced. According to the DNA info, the product will take different morphology.



Phase 4 : Receive

Once the product is ready, it will arrive as soon as possible. Ready to be deciphered!

12.4 Context

(A)

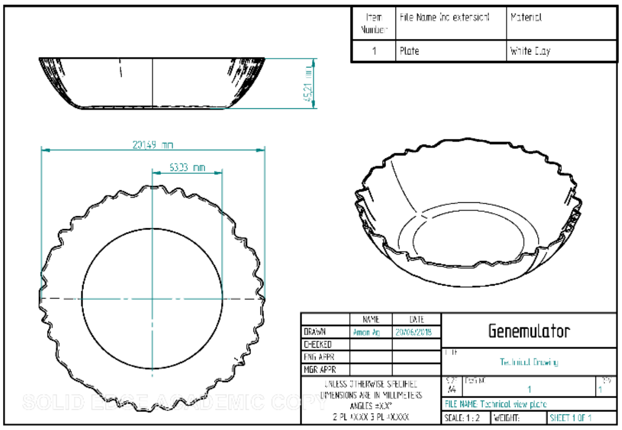
(B)

(C)

(A) (B) (C) Photos in context of a plate and a cup designed by artificial life system.

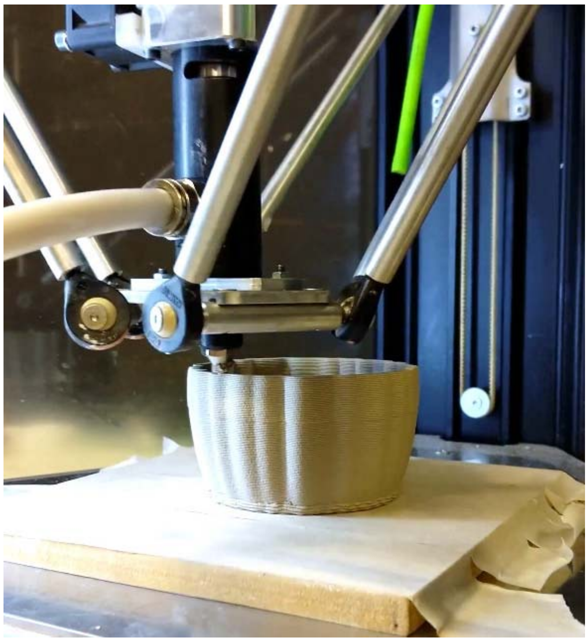
13. TECHNICAL INFO

13.1 Technical Drawing



13.2 **Sustainability strategies**: 3D printing was chosen as the fabrication process for the custom DNA plates because it is the most sustainable way of fabricating personalized products. Especially if the product must be made from zero. By adding the valleys and mountains in the vertical direction, the pate gains resistance, hence making it last longer

13.2.1 **Fabrication and Materials** – The plates were 3D printed with the Delta Wasps 3D printers. With the extruder diameter of 2 mm. The material used to print the cup is Grey Paper Fibre PCLI Paper-Clay. The plates are printed with white clay.



(Wasp 3D ceramic printer)

The plates were baked at 800ºC for a day. Later they were enamelled with white enamel. Finally baked at 1000ºC for 24 hours.

(Pre- baking at 800ºC. Later heating at 1000ºC for 24 hours)

Material – The principal material used in this test is white clay, and paper clay. The selection of material is mainly so because of the ease of working and manipulating it with 3D printing. Also, it has a lot more sustainable advantages as compared to the polymer counterparts.

13.4 **Finishing and Colour** – The 3d printed plates were cleaned from artefacts after the first baking at 800ºC. 2 coats of white matte enamel was applied before baking the plates for another 24 hours at 1000ºC.

13.5 **Budget** – *Per article (Approximate)

Article	**Budget**
DNA sequencing+ data protection	80 €
Paper clay white	13.5 €
Enamel	4.5 €
3D printing service @weceramics Spain + Furnace rent	48 €
Transportation + Insurance	12 €
Total	**158 €**

13.6 **Ergonomics** – The plates are designed in such a way that they don´t change their function and usability because of their new form.

The cup couldn´t be made with the waves at the top, as it wouldn´t be a comfortable experience to drink anything with it. Hence the new design incorporated the waves at the lower half of the cup.

(Lateral view of the 3D printed cup)

14. CONCLUSION

SUGGESTIONS FOR FURTHER RESEARCH

There are few researches going on in this field of Artificial Life systems and they show promising results. I have applied this methodology to some of my projects and I have seen the benefits. To be clear, my goal is not to design plates, but to test the methodology and if it is viable.

I can see myself investigating in the field of Artificial Life and its implications on the realm of industrial design.

We can already see that specially personalized dietary plans, medication and health reports are being made based on DNA information. In future, the same methodology can be applied to design specific products that can have a function and not just aesthetics.

Being grown up in a religious family, I was deprived from the marvels of evolution as a young kid. Another by-product of this research, which to me seem equally important as the primary use of this paper, can be used to teach young minds how evolution works, not like the textbooks, from Homo Habibis to Homo Erastus to homo sapiens, but the process of Growth and Evolution in its interactive form. And inspire them to come up with new ways to apply Artificial Life systems to real life problems.

Acknowledgments

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