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The Assemblage Robotic Plant: A Design Approach

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Abstract This article presents an approach to the design of robotics that values the notion of assemblage. The term assemblage can represent an intermediate state between iterative and design experimentation. Developing robotic integrated systems, such as small network communication between metastable individuals, is costly. As a result, fully integrated automated systems are usually preferred over experimental open methods. That integrated automated process diminishes the potential of establishing assemblage in favours of more arborescent solutions. Here it will present an approach that concentrates on the stability of the microcontroller board and allows the development of the assemblage. At the same time, it opens the exploring potential of differential parts in physical computing.

Keywords Assemblage, Robotics Design, Physical Computing.

La Planta Robótica de Ensemblage: Un Enfoque de Diseño

Resumen *Este artículo presenta una aproximación al diseño de la robótica que valora la noción de ensamblaje. El término ensamblaje puede representar un estado intermedio entre la experimentación iterativa y de diseño. El desarrollo de sistemas robóticos integrados, como la comunicación en red pequeña entre individuos metaestables, es costoso. Como resultado, los sistemas automatizados totalmente integrados suelen preferirse a los métodos abiertos experimentales. Ese proceso automatizado integrado disminuye el potencial de establecer ensamblaje a favor de soluciones más arborescentes. Aquí presentará un enfoque que se concentra en la estabilidad de la placa del microcontrolador y permite el desarrollo del ensamblaje. Al mismo tiempo, abre el potencial de exploración de piezas diferenciales en computación física.*

Palabras clave *Ensamblaje, Diseño Robótico, Computación Física.*

A Planta Robótica de Assemblage: Uma Abordagem de Design

Resumo *Este artigo apresenta uma abordagem do projeto de robótica que valoriza a noção de assemblage. O termo montagem pode representar um estado intermediário entre experimentação iterativa e de design. O desenvolvimento de sistemas robóticos integrados, como pequenas redes de comunicação entre indivíduos metaestáveis, é caro. Como resultado, sistemas automatizados totalmente integrados são geralmente preferidos em relação a métodos abertos experimentais. Esse processo automatizado integrado diminui o potencial de estabelecer assemblage em favor de soluções mais arborescentes. Aqui será apresentada uma abordagem que se concentra na meta-estabilidade da placa microcontroladora e permite o desenvolvimento da montagem. Ao mesmo tempo, abre o potencial de exploração de peças diferenciais na computação física.*

Palavras-chave *Assemblage, Projeto de Robótica, Computação Física.*

Introduction

How should robots be designed? Most specifically, how should robots be designed from the point of view of experimentation? It is known that design solutions come a long way within research practices, user design approaches, creativity and novelty. It is also a way of thinking. While approached from the perspective of conceptual/prototyping solutions it is mainly experimentation that plays a significant role to creativity solutions.

Assembling robots is now a widely publicised process available for different levels of education, such as toys for kids with automatic behaviours. The notion of assembly in those publicised processes, which have its epistemology in English, refers to putting together all parts to produce a functional automatic solution. As such, assembly must be distinguished from the assemblage that we propose in this paper, with roots in French.

The research on the design of robots proposed in this paper is a result of years of the attempt to grasp Gilbert Simondon's thinking from its mother language French and some individual translations of parts to English and Spanish. Lately, the complete philosophy of techniques of Gilbert Simondon was recently translated into Portuguese (Simondon et al. 2020), the mother language of this author. To be able to review the concepts was an enormous motivation to present this paper due to the impact of the ideas of abstract versus concrete object, transduction, technical relaxation, associated milieux, and genesis had played to distinguish the creative act of proposing autonomous robotic solutions open to design experimentation.

In Simondon, an assemblage is a whole, an open system and not an individual. Its existence depends on the collective evolution and relaxation of its parts (elements) within technological individuals. Although the concrete individual is temporary, the movement from the abstract to the concrete allows the perception of an ontology of individuals. This ontological Being will be perceived as a technical object, but it is the assemblage that retains the evolution potential of technicality.

Simondon's philosophy is also a remarkable example of how culture still stigmatises technology. Technologic objects are cultural products as much as a book, a poem or a painting. However, they have a different mode of existence intrinsically related to the condition of transductive processes within technological elements (parts). Those elements are characterised by relaxation, just like any element in visual composition, allowing them to navigate other technical solutions. The creation of technology is a process of experimenting with those relations and their resulting emergent behaviour to understand the possibilities of the design. However, Simondon's philosophy does not talk about robots. They were mostly pure scientific fiction during his time, though computation was becoming more prominent than ever during the end of the 1960s when he presented his thesis.

General culture, with few excuses, still sees robots as semi-cyborg structures. Anything more rhizomatic is conceptualised as a machine or sometimes a system. The notion of Swarm Robots may be the closest thing today as an assemblage within the field of robotics, but each robot is as close to a technological individual as possible.

On the other hand, in research art, the notion of assemblage is adopted as coming from the philosophical works of Gilles Deleuze and Félix Guattari (2013). Through their philosophy, an assemblage functions as a dynamic concept to link the problematic idea of structure with chance and continuous change. There will be an assemblage when it is possible to perceive a coupling made of a set of materials and relations and a specific regime of signs related to them, but not as a dialectic composed of two distinct poles. The assemblage is a fluid entity that moves from one stage to another, from one phase to another. The logic of diversity is based on this central notion of agency that also emphasises Deleuze and Guattari's problematic nature of artistic knowledge and practices. According to Paulo de Assis (de Assis, 2021), assemblage creates a shared understanding of art as a process rather than a product. Art becomes about the plurality of perspectives and voices and avoids the search for the essence of the artwork. This finally shows the explorations of its various constitutive heteroclite parts and flows.

Culturally, the Hacker/Maker movement has its version of rhizomatic existence. Codes, circuits and board designs are created in many different levels of relaxation. Starting a project by hacking an existing one or modifying someone else's solution is widespread. However, most solutions refer to the cultural notion of the product. The tutorials might be led to assembling a part as technological elements. It is challenging to find the development of an intentional assemblage as a plurality of voices presented by Paulo de Assis (2021) to the notion of designing a robot. In this paper, that is the path it intends to demonstrate.

And to demonstrate it, the paper will focus on analysing two different design approaches that produced a robotic plant. The first approach, called the arborescent robotics problem, describes how the results of creating a robotic plant with today's available hardware emphasise the design process from the perspective of creating an individual entity. The second approach will argue how the process that establishes metastability on nodes and valorises assemblage better reflects the concept of plant and plant intelligence.

Mechanisms of intelligence and evolution in plants

Plants are decentralised systems (networks) of cognitive intelligence and, therefore, complex systems. Their intelligence comprises decentralised parts, which use signals and information for self-coordination, learning and evolution in this process.

According to Witzany (apud Baluška et al., 2018), all coordination and organisation processes in organisms result from communicative interactions between cells, tissues and organs. This statement presupposes that there is a direct connection between matter and memory, which according to the author, takes place through epigenetic markings of certain chromosomal sections, targeting memory modes, which are essential for different groups of molecules, as a kind of “frozen image” of the total of an organism’s biocommunication processes in an epigenetically relevant situational context.

Plants are often viewed and studied as machine-like automata of growth, but their coordination is only possible through signals and memory, not pure mechanics. Still, according to Witzany, in plants, there are more than 20 different groups of molecules with communicative functions that have been identified, and up to 100,000 other substances, known as secondary metabolites, which are actively used in the root zone. Another critical issue pointed out by the author is that plants can overwrite the genetic code they inherited from their parents and revert to that of their grandparents or great-grandparents, contradicting the traditional conviction that the DNA of new generations is inherited only from the parents. Thus, plants can replace less appropriate parental code sequences in the current code, replacing these with another from previous generations as a backup copy. But under normal conditions, the operative genetic makeup comes from the parents, which means that plants transfer inheritance and the parental genetic combination, regulatory characteristics of the ancestral genome.

According to Ramsey Affifi (apud Baluška et al., 2018), stimulus and response were not independent events corresponding to the sensory and motor elements of the organism. The author states that something that serves as a stimulus is constituted by the motor activity of the organism and only remains a stimulus because of this continuous motor activity. All directed sensory activity has a motor base, while all directed motor activity is also sensory. Thus, behavioural approaches (Behaviorism) that lead to successful empirical results (read: predictable), maintain a mechanistic interpretation of phenomena and state that this model is unsuitable for contingent decision-making, which contains choice, experimentation, context and purpose. Afifi argues that research with plants needs to avoid repeating this mistake since there is no centralization of the decision-making process in plants, even though there is a root system analogous to a brain. Therefore, there is no passive adaptation to external situations but an active selection relationship and behavioural modification. Therefore, Affifi concluded that “if plants are intelligent organisms, we should not expect to find this by imposing a mechanistic and linear interpretation of stimulus and response to their actions” (Affifi, apud Baluška et al., 2018, p. 23). If so, we should look for evidence that plants engage in unified, intentional sensorimotor coordinates that lead them to modify the meaning of their encounters and alter behaviour accordingly. This discussion is fundamentally essential for this article since it directly interferes with selecting a technological model for constructing complex plant-based systems. Based on this discussion, it is impossible that when dealing with the development of these systems, we start to consider them based on stimulus-response premises. It is necessary to include a structure of intentionality and relevance that lead to an objective, whether evolutionary or growth.

The technological model based on plants

A fundamentally intrinsic concept in human thought is that autonomous machines replicate humanistic or zoological characteristics. For Mancuso (2018), this situation reveals that our perception towards producing new technologies is always related to replicating, expanding and improving human functions. The technological model he proposed is related to research in bio-inspired technology, which looks to nature as a model for solving technical problems. Following this line, technological development inspired by plants should observe how they consume very little energy, make passive movements, are built-in modules, are robust and have distributed intelligence. They are systems of enormous plasticity and adaptation to continuous environmental changes. Their main characteristic is multicellular photosynthesis, with some exceptions. They are constituted by an elevated portion of the subsoil and a root system.

Plants are directly related to the distributed technology construction model, and their bodies are formed of repeating units that constitute their architecture and define their physiology (Mancuso, 2018). Therefore, the architecture of plants is always close to the concept of assemblage, where the basic units of this architecture have a short life, but the colony could live virtually forever. The author also points out that even the definition of an individual is about the animal kingdom and has little relevance in the plant world since not even genetic stability seems relevant to the plant world, considering the famous plant chimaeras.

The arborescent robotic problem

One of the most common platforms to prototype physical computing is Arduino (Arduino, 2021). However, Adafruit is also an excellent example of a platform that delivers semi-ready solutions in physical computing that allows a variety of people to enter the field without a degree in engineering (Adafruit, 2023). Both platforms are examples of online environments where people can buy stable microcontrollers and element boards for prototyping. They are full of tutorials helping to assemble specific parts to specific boards. However, suppose someone looks at the robotic projects presented for both platforms. In that case, they will refer to the notion of product design and individual solutions that will be an arborescent problem.

The idea of hierarchical tendency, like one point that leads to another, that does not consider the many stages that lead to the relation of both points constitutes arborescence.

> If you don't break with the scheme of arborescence, neither the Being nor the Molecular is reached, while a line is referred to two distant points, or is composed of contiguous points. A line of Being is defined neither by the points it connects nor by points that compose it: on the contrary, it passes between the points, it only grows through the middle, and runs in a direction perpendicular to the points we distinguish first, transverse to the localizable relationship between contiguous points or distant (Deleuze and Guatarri, 2013, p. 79).

The concept of rhizome is the opposite notion of arborescence in this philosophy, a very dear concept to art research. The hierarchical way of existence will be left behind on the rhizome, giving space to break the original tendency and create something different.

In experimenting with robotics, this research sought a way to decrease the hierarchical notion of a semi-cyborg entity. Semi-cyborgs are an arborescent problem once all significant decisions are constantly being figured out by the idea of an individual solution, a physical technological/computation thing. By semi-cyborg, it can be considered an individual entity where the entire decision-making process is determined on a central board, with its peripheral sensors and actuators. It is understood as a less experimental design method, which focuses on the individual solution going directly from abstract to physical, without allowing designers to explore the many ways of existence of a robotic Being.

Therefore, the example this paper will demonstrate as an arborescence solution was a design created to explore the idea of a robotic plant. Understanding plants as collective intelligence (Mancuso, 2008) is challenging. Although plants such as trees look like hierarchical structures, they are decentralised in their decision-making solutions to survive in nature. Also, because of their sessile behaviour, they cannot afford to be hierarchical, having to adapt to grow back in many devastating encounters with external events.

Figure 1a is a robotic plant developed in 2020 by the author. The design concept was about making each steam an independent decision-making unit. The problem between designing the abstract concept and prototyping with parts to the final solution bumped into an arborescence problem using Arduino and Adafruit solutions. Although both platforms' stable board solutions can include wi-fi communication interaction, those require establishing a robust environment for use within the boards. They are also very sensible for constantly changing the information transferred from one unit board to another. So, as a result, the design presented in Figure 1a used only one board, a multiplexer (that allows many element boards, in this case, accelerometers and microphones, to be read independently) and a shield (Figure 1b) (specifically designed to receive the connection of many element Adafruit boards into the Arduino microcontroller). A solution like this follows a hierarchical path. The board receives each element board information as an Object-Oriented element. Each element is established and connected on a shield that answers to the Arduino microcontroller board. Finally, each prototyping stem is a sculptural point with decision-making independently but still exchange information through the network of other stems. This solution is arborescence because hierarchy must be followed to create a functional physical solution but existing in the physical world (This paper does not consider this a concrete solution because, in Simondon's time, a concrete object was the one that reached industrialization and, as such, was able to reach the entire environment of culture). So, it means the prototype works, stems individually react to the environment and exchanges information virtually inside the main Arduino code.

For conceptual purposes, Figure 1a was taken without the shield to present the most important idea of a plant with a semi-rhizomatic situation: the stems with its roots as a unit. We would be working with an assemblage robotic solution if roots and stems could be connected to some other points and easily disconnected to be further connected again.

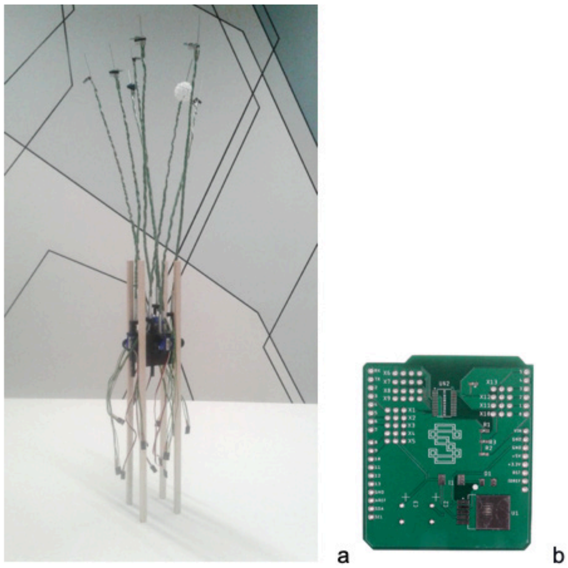

Figure 1: Robotic Plant (a), Arduino Shield develop to be coupled to an Arduino board (b).
Source: the author's archive.

Assemblage Robotics

A fundamental problem in robotic design is balancing the limitations of causal mechanisms of functional parts by including a set of logical statements where reciprocal causality is controllable. This statement summarises the process of incorporating the physicality of technical objects with the production of data and the harvesting of correlations patterns to achieve a specific goal. That is why robotics navigates close to the concept of thinghood or a cyborg, which may be why their argumentation is absent On the Existence of Digital Objects (Yuk Hui, 2016). However, a robot's entire mode of coming to existence should be understood to bring them to the concept of assemblages that navigate both digital and technical *milieux*.

Individuation in Opposite of Individual

Robotic Plants will become something identifiable as a thing, differentiating themselves from a system, a flock or an ambient installation which are seen as networks rather than something limited by a physical structure. A plant is culturally perceived as a being, even in the natural world. Generally, people talk about trees, bushes and pot plants as identifiable entities. An individual entity is, to our perception, limited by its material/form, but it isn't. That is why individuation can help us focus on Being, rather than becoming something. To Simondon et al. (2020. p. 81), the individuation is not uniquely considered from the explanatory perspective of the individualised individual; it will be apprehended, or at least we should say it could be apprehended, before the genesis of the separated individual; the individuation is an event and an operation in the bosom of a reality richer than the resultant individual.

On Being, this paper enters the world of Ontology by Heidegger, where perceived structures are temporary. Metastability on Simondon is a Being that results from the process itself, does not determine the process, or is not determined by formalisation or representation. Individuation will leave a trace of pre-individuation. Here, the text focuses on this trace to employ experimentation in the process of robotic design of plants because it allows future individualisation. Each phase or plateau reaches a metastatic balance and can create new ways or invent new solutions without, necessarily, eliminating the old. Technical objects follow the process of individualisation and reach concretisation while in industrial distribution, where they become natural within the cultural *milieux*. Robots, in the other hand do not usually reach industrial distribution. With rare exceptions like the automaton vacuum cleaners, robots are usually a product of education sold to be assembled or products of advanced research.

A Digital Object is a Being and exists as an industrialised product. Digital Objects, as defined by Yuk Hui (2016), are composed of data and metadata and regulated by structures or schemas. Structures and schemas are essential to highlight in this paper because they can also be incorporated into robotics development once they give semantic and functional meaning to metadata. As a result, the notion of computation could be apprehended as part of robotics. And according to the author, computation is a new type of materiality by itself that disrupts some fundamental philosophical concepts, such as what an object is.

Assemblage instead of Iteraction

The concept of product design relies on iterative methods of the prototype. Designing a product incorporates building something from scratch, testing, analysing, and refining the solution. Refinement is the crucial point in the iteraction method, as it can be apprehended as a repeatable process of improving in relatively short but regular bursts. The idea by itself is beneficial if it reinforces the concept of the absolute beginning of Simondon's work (Simondon et al, 2020). In Simondon, this absolute beginning is a condition of technicity. An example is the phenomenon of electrodes which consists of the transport of electric charges across the vacuum. A triode is not a result of a diode but a different element resulting from this phenomenon.

While thinking about robotic plants, it is desirable that some structures be metastable, like the stem described in the previous section about the arborescent design problem. In that case, a stem design can follow iterative sequences if it incorporates computational decision-making. However, it is not the robot itself. The plant robot should maintain regular communication between those stems and be open enough to connect to a new one or disconnect itself from another. A way of existing following the concept of an assemblage rather than iterative development.

To sum up, the difference between assemblage and iteraction is that the latter leads to an individual vertical development disregarding previously developed solutions on the physical level. At the same time, the former maintains the horizontal expansion. While the assemblage approach to robotics is not an intentional technique to total freedom of experimentation, it is an intermediate possibility within the bases of the understanding of individualisation itself.

The Assemblage Robotic Plant

Finally, here is an assemblage robotic plant with the hopes of inspiring other designers. Its central concept relies on both autonomous agents and cellular automata concepts. Due to the physical connection of the cables to the board, the cellular automata concept seems more appropriate, but this is debatable, especially when discussing plants and autonomous parts to sessile individuations. For this reason, the robotic plant developed here can be better described on the concept of a small-world network of autonomous agents. In this sense, most neighbouring nodes can be reached from every other node with a few hops or steps.

While prototyping with experimentation, the robotic plant had to be open to different sensors in various parts of it. Still, in the design here presented, those parts also needed to have a stable way of communication. The development of a board was required to be a metastability node (Figure 2a). A point where prototyping could be freely done in the same framework of Arduino, using its firmware as the base, but also adding a layer of four direct communication points to the original one of Arduino's boards.

The node board presented in Figure 2a, is treated as a stable unit. This unit is like a cell, with the capacity to sense, act, and make decisions. It also can receive direct information from four other boards physically connected to it (figure 2b). Information may be from another's board directly sensor or encapsulated in a symbolic logic defined by a programmer.

In Figure 2b, the green lines represent communication between the boards. Those are the interconnect ports that ensure data and power-sharing. Its peripheral connection routes were dimensioned to carry higher currents at higher voltages against its internal routes. This feature enables a more significant number of boards per power supply. An energy source connected to a peripheral port will distribute the energy to all others in the network. Each cell makes a local voltage conversion regulated to the internal circuitry.

An exclusive firmware was developed for the board. It has two main classes: <Being> and <SerialSMV1>. The <Being> class defines the attributes of a robotic cell. The <SerialSMV1> class represents the state machine that performs the data capture and interpretation interactions on the contents of the serial input buffer. Each cell defines and instantiates itself and four simulacra, which are representations of its neighbours. Each of these instances is a repository of cell characteristics, states, and their respective sensing data.

```
Being mySelf; //The current cell
Being ngHood[4]; //The four neighbours
SerialSMV1 SSM; //Serial State Machine
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In addition to information about which types of sensors are active, the <Being> class also has an internal structure called <SensingData>. It stores data from sensors according to their kind. Sensor types are enumerated, corresponding to the position of their trigger bit, in a 64-bit map (Activated Sensor BitMap or ASBM). This map is present in the header of communication data packets between cells. Each map bit indicates which sensor types are active in the current cell (<one> for active and <zero> for inactive). As for the sensing and triggering ports, the two diagonal ports have analogue input (ADC) capability at one of its ends. One of them can communicate via the i2C protocol. More two diagonal ports on the opposite end are digital, one of which has two channels capable of outputting pulse-width modulated (PWM). A dedicated PWM port filters capacitors and reduces noise caused when triggering micro-servos.

The board is an industrialised product. It can be directly purchased with a minor additional assembly, and its firmware is available online. It is also an open-source design, allowing it to become the base of other hardware solutions. As such, it can achieve an associate *milieu*, just like other products of Arduino and Adafruit's board can. Concretization is a critical phase in this research because the distribution level confirms the potential of individualization necessary in technical objects according to Simondon's philosophy being argued in this paper.

It is important to note that the connection presented in Figure 2b is not mandatory and that the nodes can be redistributed. In this sense, the solution can work as a cellular automaton with two or four neighbours or as nodes within a small-world network. In the latter option, nodes can reach each other according to a pre-defined logic created by the designer, allowing the system to be understood as an interaction between autonomous agents.

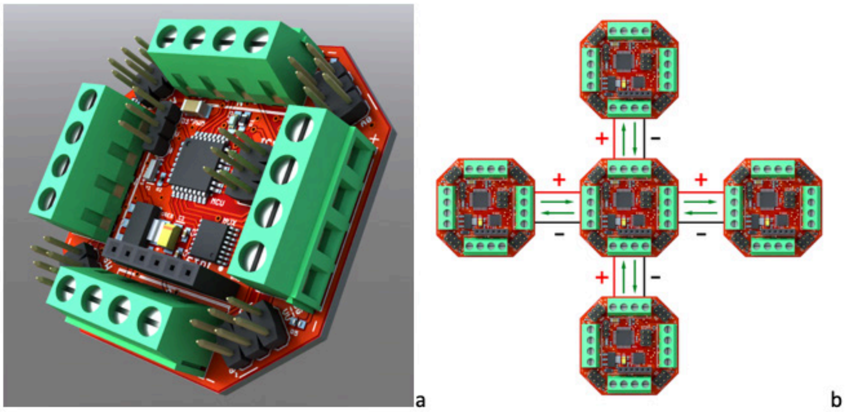

Figure 2: Metastability, created by the development of a board, based on Arduino but with four points of direct communication with other boards with additional firmware.
Source: the author's archive.

Figure 3a shows the artwork resulting from this concept of design experimentation using the solution board described. The entire piece can be considered a prototype as well as an assemblage, as it is not a product nor a stable robotic entity. It is arranged to be seen as a fragile structure due to the art concept desired for the piece. However, it is not only an artwork. It is also an experiment to create a small-world network of five functional nodes, represented in Figure 3a as the three pink flowers on the left and the two blue and white flowers on the right. The small bulbs in the middle are non-functional nodes without a board and work as extensions of two other functional nodes. The entire piece is connected by one power supply of twelve volts, a critical feature mentioned in the developed metastable board. It allows seven nodes to use the same amount of power; if more nodes are needed, another power supply can be included in the network. As such, the presented robotic plant in Figure 3a is one possible network solution, but networks can be created in any format of a mathematical graph.

The network of five nodes and the communication between them can be called the assemblage robotic plant (Figure 3b). In node distribution, N1 and N1' are the first-generation nodes, N2 and N2' second generation, N3 is third generation, and A1 and A1' are the first-generation of appendices. In the conceptual model, the network would evolve from two initial appendices, N1' and N2'. An original node is coupled to another one with the same computational power but with self-sufficient decision-making logic. The couples are N1'/ N1 and N2' /N2. N3 is an independent node, also possible, but without the potential to develop appendices. In growing the network, A1 and A1' would have to adapt to a couple or an independent node. The coupling node can still produce new appendices if it has enough energy. This growing network's entire concept is poetic and does not mimic any plant, although the idea resembles L systems. Also, the concept of generation in this network means both sensor and actuator experimentation, as well as coding in decision-make approaches within the node.

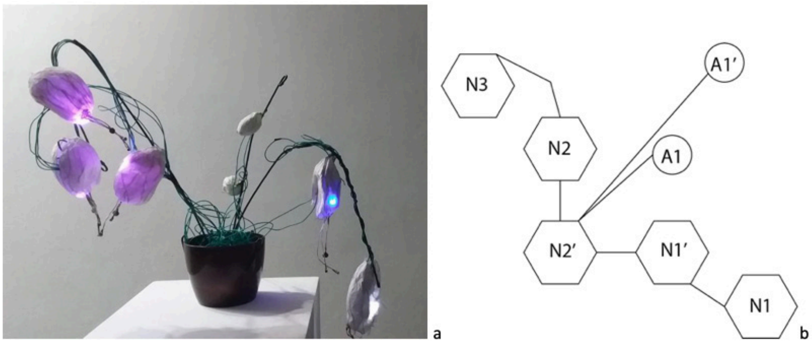

Figure 3: (a) Artwork presented in September 2022, in a collective exhibition in the {removed to blind review}. (b) Network topography, the formation of the assemblage
Source: the author's archive.

Assemblage formation described in Figure 3b represents a possible state of things, combinations of nodes or annunciations of a possible concretization. While the node itself must exist with metastability, sometimes requiring stable parts to be soldered and standard computational decision--making, the nodes can be combined to achieve different plant individualization formats. Moreover, nodes can metaphorically die. The nodes can be removed and reconfigured for new generations without starting the design process from scratch. In this sense, all aspects of the design experimentation, besides the board itself, are open to reconfiguration with each new generation.

The described process focuses on the process of individualization instead of individuation, because the latter depends on the engineering/designer/artist to exist, according to the philosophical work of Simondon used in previous argumentation in this paper. It has yet to be achievable for a robot to develop all this complex structure by itself, although research in robotic swarms can be related to this goal. In the presented case, it relies on human activity to establish both the network itself as well as the node configuration that could be added to it.

Figure 4a represents the prototyping of a node. The conceptual idea is based on a flower called the bleeding heart (Lamprocapnos spectabilis), native to Siberia, northern China, Korea, and Japan. The format of the flower used as inspiration resembles the conventional heart shape, with a droplet beneath. Three light sensors were connected to simulate the metastable node, resembling the droplet part of the flower. They were connected to a small round purple breadboard where a vibrator motor was placed. The small protoboard received all necessary resistors for light sensors and the vibrator motor. The light sensors could detect touch due to blockage of light. A small Adafruit board with an RGB led was used separately to create a sense of colours on the flowers.

Five more nodes were developed to make the small-world network. In each node generation, a different approach to coding was taken. The first-generation sensors only activated reaction within the note itself, allowing the flower to turn white or blue, according to the light available in the environment, and vibrate while touched. However, they signal that interaction is in action with other nodes. The second generation allowed information to change its state. While one node was touched, it only turned blue, but if more than one was touched (including generation one) simultaneously, vibrations would start to work in the generation two nodes, and they would become red. In the red state, generation two would not provide energy for appendices. The third generation was aware of both nodes of generation two, but not generation one, and will behave accordingly to the situation independently of whether being touched or not. In case generation two cannot provide for the appendices, generation three will provide this necessary action for the system.

The entire artwork concept in Figure 3a was to resemble a small network of agents in different stages of their lives. While some had become old enough to get involved in providing for the community, they were still signalling. Others provide for the community, sometimes with more attribution than others.

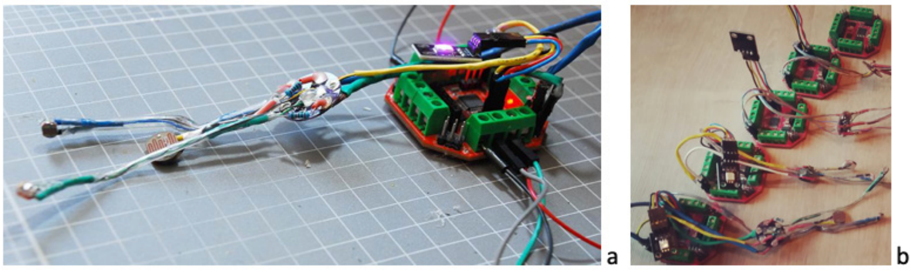

Figure 4: (a) Node prototype, the board was integrated with three light sensors, one vibrator motor and an RGB led. (b) collective of nodes, with some differentiation on soldering and actuators.
Source: the author's archive.

Conclusion

The leading conclusion of this paper is that arborescent structures in robotic design create stabilisation but compromise experimentation. While abstract arrangements, such as diagrams, are commonly thought of as collective assemblages of annunciation and are more flexible. Arborescent structures are too stable in the face of complexity and incapable of dealing with variations in in determination, change and transformation.

Experimentation has ground where there exists the continuous momentum of changing the focus on the structure and focusing on nodes and assemblages. The design approach used to develop the assemblage of this paper wants to extend the time between abstract diagrams and concretization. The board solution presented creates the necessary stability and concretization in the node itself, allowing the proliferation of construction and deconstruction of arrangements. As such, it will enable going one step forward to concretization without giving up the possibility of change. Also, it approximates the concept of robotic arrangements to the notion of assemblage, as the abstract quality of experimentation can be further persuaded during the physical prototyping phase without submitting itself to iterative steps.

The presented design approach also facilitates using electronic components using the same framework available within the existing industry. It also permits reuse, being removed from one assemblage area to another, as well as to different assemblages, also allowing reprogramming them with other computation decision-making. Programming the board itself is also easy due to firmware freely available online, which uses the same coding pattern from Arduino IDE.

The robotic design approach based on the concept of assemblage has resonance in the philosophy of technology and art research. But due to the nature of robotics, the inclusion of object orientation coding (using the developed firmware), and the inclusion of generation approach within nodes, it is also possible to argue that it creates a connection with the notion of digital objects and, as such, can rely on its philosophical discussions for further research.

Finally, developing a robotic individual from scratch is a tumbling project since robots, especially robotic plants, benefit from evolving from coupled metastable systems.

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