Research Book

Fabricating Society

13th International Fab Lab Conference and Symposium
Santiago, Chile | August 2017

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Fabricating Society

Andrés Briceño & Tomás Vivanco

After a year and a half of working and generating a proper platform to host an intense and diverse event such as the International Conference and Symposium of FabLab Network, we are pleased to receive and welcome professionals, academics and fabers from all around the world to Santiago, Chile.
It was an extraordinary challenge to organize Fab13, and we were finally able to make it happen thanks to the Chilean Government, amazing sponsors and an incredible team that worked really hard to offer the best experience to our guests.
Chile is an insular and curious country; with more than four thousand kilometres in length and an average of a hundred eighty in width, it generates an intense territory with many different cultures crossed by all kind of climates and natural ecosystems. Among the driest desert in the world, the longest mountain range, Valdivian jungle and a feeling of an infinite Pacific Ocean in front of us, our culture and society is marked by this intense territory.
This insular context, has isolated us for many years from the rest of the world, and therefore it has allowed us to watch all types of worldwide events occur from a far distance, including wars, social revolutions and cutting edge discussions.
Sometimes this particular situation was positive or negative, but the final feeling of our people was a sense of silence and disconnection, building a gap among our natural Latin American scarcity.
Today, thanks to technology, our chilean culture and society is becoming more and more integrated to the rest of the world, generating a sort of understanding to other alternative ways to grow as a country, society and community.
This represents a natural trend that is proof of the idea of potentially being all connected, questioning the current model, opening a novel window to something else.
The 13th International Fab Lab meeting will offer all of us an chance to understand the implications embedded within these ideas and question the systemic approach that fablabs insinuate. Welcome to Fab13, and welcome to how to fabricate societies!

ARTÍCLES

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Distributed Design Towards a holistic and political design process

Andrés Briceño Gutiérrez
Architect, MAA IAAC-UPC
Co-Director & Co-Founder FabLab Santiago, Distributed Design Foundation.

"It could almost be said that theories are revolutionaries and its applications are always reactionaries. We are within such a mystery, that we are not moving forward almost anything: we are thinking through a thinking language and nowhere space that we do not know, we are using our intelligence but we do not see how is it"
Roberto Matta

We are currently living a globally high unstable period, but from which it comes off a common key circumstance that allows us to evolve as society: a particular sense of freedom that generate a lack of understanding from *status quo*.
Among history, we could identify several moments where people spontaneously use novel inventions outside conventions, working between everything known and a sense of potential freedom coming from the accessibility gifted by this new invention. As in times of printing, where communities were gradually empowered by a brand new communicational platform that offered the chance to have a sort of social expression autonomy, Internet is again gradually empowering people, providing autonomy from conventions and potentially transforming our society.
This sense of freedom organizes several sociocultural activities created over the base of self-organisation, thus, apparently all the parameters to think and to do our build environment is changing because of it.
This temporary liberty allows advanced groups to generate potential new models and holistic approaches using the novel tools, moving forward within the existing body of knowledge pushing it, increasing it and eventually transforming it into something that will prove another way *to be* in society. No matter how difficult is our present times, autonomy is given us a theoretical flexibility to

operate within this complexity and after decades of a sustained process of depoliticization generated by the intense presence of the market in our life, people is using this emancipation energy to generate sociocultural transformation with potential economic consequences. Hypothetically, this independence phase creates a novel and creative scenario, building a transition era.

Theoretically, this journey will extend until conventional and new *status quo* take control of this transformations, monetize the particular process and taking possession of the flow of this new system. Nowadays, is the common sense to observe the consequences that novel communication, fabrication, interaction, education among others structural sociocultural items have immersed within an uncertainty process where from a systemic point of view is still starting.

Distributed Design

Mies Van der Rohe, one of the key architect of our contemporary times, define architecture using a colloquial expression, "*architecture is to put together two bricks, carefully". Architecture define a body of knowledge related if what does it means to design, and, if we start the idea of creation of something from two pieces (bricks), the main idea of design, according to Francesco Dal Co, is at the end to do it but carefully (Dal Co, 2003).*

To design is an inherent human being act; we originally design from the scarcity that survival demands and considering the amount of collected information generation by generation we are in a position where survival was crossed by desire. Step by step, to design became a strategical process where matter was organized by information, *carefully* defining our built environment, our habitat and existential space. In things we build the sure path that allows us to cope with the everyday and in them (things) a timeless value is concentrated that is inherited generation after generation: the information that defines it.

The idea of design emerges through a synthetic codification of matter, aligned, balanced and carefully equalized to bring beauty and function at the same time, configuring an accepted meaning for people. Then, to design is a strategic tool to create sociocultural value, organizing matter and communicating their effects through a specific function that transform

our build environment. To design is always a political action, but obviously it depends of the designer will. "*More and more, design has moved away from the idea of "intelligent problem solving" (James Dyson) and drawn nearer to the ephemeral, fashionable and quickly obsolete, to formal aesthetic play, to the "boutiquization" of the universe of products for everyday life. For this reason, design today often is identified with expensive, exquisite, not particularly practical, funny, and formally pushed, colourful objects*." (Bonsiepe, 2006)
Nowadays, design has potentially more chances to be close to generated positives transformation within our society by several novel digital fabrication technologies and Internet holistic capabilities to generate more possibilities of social cohesion, expanding the inherent objects capacities to instances that construct systems from themselves. As a consequence, we could start using the idea of a systemic approach through design, using the potential abstraction that technology allows us to think our built environment, opening he capabilities of objects to propagate its multiples effects to society.
A systemic approach of design, gather the possibility of create an emergent social organisation, expanding the horizon of objects to networks that open citizen participation, potential interaction and eventually a social cohesion process. Considering the amount of distance between people after several decades of depoliticization from status quo and eventually each other, the idea of an integrated society is still crossed by an underestimate utopian feeling, congregating this to advanced groups that operates occasionally as outsiders and counterculture dynamics.
If the depoliticization of society has been one of the structural axis of western culture social equation and one of the most silent but relevant facts to keep people away from the information that people in power do manage, technology and freedom that continue to be suggested by Internet define the realms in which we may once again think of the possibility of improving language, stave off bureaucracy and once again attempt to break through the spheres that establish boundaries through the designs and the creativity of human beings. The question that this leads us to, then, is this: what kind of society do we believe is possible if we can all potentially be connected? That is the utopian vision of our age.

Thus, hypothetically the operational process of design is influenced by cybernetics and theoretical computer science now, transferring it language and potentiality to several distributed applications that are arising from people and not necessary from corporation, ergo, avoiding conventional market and economic vision. Apparently, it is a transgression process coming from regular and diverse people, sometimes coming from counterculture spaces.
"In such a universalizing theory (cybernetics), shared conceptual models would force a reconsideration of disciplinary perspectives, ad Gordon Pask argued, when cybernetics 'considers economy not as an economist, biology not as a biologist engine not as an engineer. In each case its theme remains the same, namely, how systems regulate themselves, reproduce themselves, evolve and learn'. Taking an interdisciplinary view, Pask argues that cybernetics high spot is the question of how they (systems) organise themselves" (Dubberly, Pangaro, 2015)
Distribution is still an abstract concept that potentially has novel holistic possibilities to combine the sense of freedom plus autonomy as maximum levels of parameters to create self-organization, self-interaction, self-regulation, or using Stafford Beer's theoretical premise: a viable system model.
If we want to distribute bikes for instance today, we have two considerable path: first, to design a technology focused into the particular objet (bike) and distributing its value using the conventional economic flow (supply & demands) limiting its access who gather requirements to be a subject to loan, or on the other hand, to design a bike system that build a self-organisation framed by defined parameters that guarantee accessibility to a wider range of people, reducing the overall cost of all. To design in these terms, compromise a potential dispersion of the strategical role of it, but consequently, it demands connection with several disciplines that just a few years ago start a real conversation each other such as computer science, biology or physics, opening a way to a design process with greater rigor and precision, touching sciences perspectives but without losing balance of the capability to generate meaning.
"*The sciences approach reality from the perspective of cognition, of what can be known, while the design disciplines approach reality from the perspective of "projectability," of what can be designed. These*

are different perspectives, and it is hoped that, in the future, they will transmute into complementary perspectives. So far, design has tried to build bridges to the domain of the sciences, but not vice versa. We can speculate that, in the future, design may become a basic discipline for all scientific areas. Relating design activities to the sciences should not be misinterpreted as a claim of a scientific design, or as an attempt to transform design into a science. It would be foolish to "design" an ashtray using scientific knowledge. But it would not be foolish—and even mandatory—to tap scientific knowledge when designing a milk package with a minimal ecological footprint. It is no longer feasible to limit the notion of design to design disciplines such as architecture, industrial design, or communication design because scientists also are designing. When a group of agricultural scientists develops a new candy from the carob bean that contains important vitamins for school children, we have a clear example of a design activity" (Bonsiepe, 2006)

An Integration Defiance

"Revolutions, violent or not, do blow societies apart - because they deliberately take the inherited system outside its physiological limits. Then the system has to be redefined, and the new definition must again adhere to the cybernetic criteria of viability. Then it is useless for whoever has lost his privileges to complain about his bad luck so long as he uses a language appropriate to the system that has been replaced. He must talk the new language or get out" (Beer, 1973)
The more technology evolves, the more conditions to design are changing, nevertheless, economic model has generated environmental conditions that hinder the particular potentiality of all these phenomena. The conventional economic model starts over the premise of justify status quo, meaning, in order "*to justify the acquisition of wealth and power, arise the new economy discipline (the ancient chrematistics). According to this, poverty was supposed to be determined by the natural law and through such reasoning –with an obvious logical gap- it was assumed that when powerful amass wealth all the world benefits*" (Max-Neef, Smith, 2014). This particular approach evidence the very essence of our conventional model, which push competition, operative-efficient environment and but above all,

gradually abolish the natural emphatic condition of human being, or in other words, supress our political and collective approach for an individual one, because it is the best condition to control the indissoluble conflict: the relationship between the common man and the powerful.
We are potentially all connected through novel technologies, but it is a fact that our currently cultural condition pushes us to be isolated, to focus our effort within a particular ambition, we can have lived all concentrated in cities, but we barely know our neighbour, we can easily use several Apps to generate a sense of participation, but still we are not see each other with honesty, transparency and literally real time. We are living a transition time where in comparison with decades ago we have more possibilities to transform our system matrix, and apparently one of the biggest chances to do it will come from counterculture another time again. As Goethe said centuries ago, if we cross our great civilisation and collective knowledge with faculties such sense, imagination and intuition, perhaps we can generate a collective bifurcation that will make a fairer system, at least, we can recover the utopia relevance for now and works to be close and destroy it.

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Distributed design: Speculative prototypes for emergent scenarios

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Towards a distributed topology.

The two major socio-technological revolutions have been structured in network topologies in which they support the unleashing of territorial, commercial, communicational, social, and productive relations over time. The first Industrial Revolution based on a centralized network topology, shaped a unidirectional system between the peripheral and central nodes. When a connection is lost, a node is immediately isolated, staying out of any participation within the system. The second Revolution was constituted on a decentralized topology structured in groups of peripheral nodes connected to the same node and connected to a central node. This topology involved the change from a unidirectional to bidirectional system, from an oligarchic to a hierarchical system, reducing its possibility of failure. From the production and information, both topologies defined in their bases a logic supported on objects as principle of transfer, industrially produced under Fordism and Taylorist principles.

The development of communication new media allows the multidirectional interconnection of nodes generating a distributed network structure, with low probability of failure, heterarchical, without previously conceived organizations. This produces a dispersion of time, distancing itself from physical objects as elements of transfer, focusing on information. Distribution requires that the materialization of the information can be modified and adapted to conditions without corrupting the original script

implicit in the objects, being able to change the formal qualities according to the specific requirements of the environment. From this perspective, objects become to dematerialize themselves to be understood from the relationship of their original configuration and environment.
The great socio-technological revolutions have not only shaped the way in which we produce objects and goods, but also have triggered the great migratory processes from the countryside towards cities, transforming an economy based on agriculture by one based on industrialization, mass production and consumption. Linking the modern city with individuality among people, it is through the process of constitution of the modern city that individuals are no longer governed by tradition but through constant change and flow, being the growth of consumer culture the integral element to create these conditions (Jane, 2006).
The appearance of the new rich (Veblen) at the end of the nineteenth century, who in an act of imitation to those who had shaped their wealth in the first industrial revolution, began an intense process of consumption of goods and services to demonstrate their success and well-being. Producing an elongation of consumption to reach who had elitist status who extended the upper margin causing continuous growth.
Centralized object manufacturing with highly optimized Taylor processes under the Ford model is the direct response to the market's need to produce high-speed consumer goods by contributing to engineering processes, standardizing components, manufacturing processes and, finally, products. The speed and efficiency of these tasks requires that errors must be minimized, forcing workers to perform only one task in a repetitive way, optimizing their productivity and production.
This results in a mismatch between the world economy and the territorial economy, generating a delay in the action-reaction relationship, where the demands of the dynamic market are not able to stop at the socio-territorial complexity, without reacting. The own times of a territory supported in both social and natural resources, do not allow the regeneration of the them, breaking the local ecologies and forcing the market to look for new territories, increasing considerably the entropic invoice (Rifkin, 2011), breaking the basic

support structure for our society development.
The construction of a world society has led us to the homogenization of, among other things, culture, identities, production and economy. The capitalist economy, supported in the globalized model, has been from its origin the economy of this world society, where specific solutions become massive without always matching local needs. Disabling people from any possibility of creating or redesign local objects surround us.
The linearity of systematic and prolonged use of some technological advances damages certain industries, increasing the decadence dynamics of cities (Kotler, Haider, Rein, 1994) in a recursive process, affecting directly the creativity and its capacities to create new goods, from the scale of the dynamic creative economies to great passive monopoly companies to assimilate new developments. In this scenario, the process of change of the capitalist machine as creative destruction (Schumpeter, 1942), destruction to those who do not respond dynamism of new innovations and creative for its ability to start a new process where new options arise. This results in the creation of new cycles or economic gaps.
The new information technologies allow us to modify the time lag, reconnecting demand and supply from local questions and needs, reformulating the productive model that conventional capitalism proposes, consolidating a people-centered ecosystem supported by an ecological and social floor.

From user centered design to an scenario centered design.

As described above, the characteristics of objects in our environment have been strongly influenced, in other things, by their manufacturing processes and commercial viability, conditioning the experiences of interactions between users and objects. Such a point that designing within an object-dependent topology network requires the optimization of resources in the creative process to achieve commercial success.
Building archetypes to define costumers and users are in a conventional industrialized mass production logic, without allowing the needed opening to design in a distributed way. Caricatured users and costumers bias to understand other possible options or results from the design process. In a way, user centered design is in crisis.

Locate an object in a defined environment, there are two main situations happening at the same time. From one hand, the same intervened environment changes, so we should not consider it as the same context were the original observations and design variables where taken. On the other hand, the object is exposed, becoming public. Now, not only the direct users interact, but a complete ecosystem that involves much more complex social dynamics.
The unfolding capacities of objects (Dominguez, 2015) define the most extended uses of design building a new environmental, political and social dynamic in a constant process of reconfiguration, questioning the actual condition of objects, transforming them in an evolutionary and unpredictable prototype, sensitives to social interactions.

From Object Oriented Design (OOD) to Non-Object Oriented Design (NOOD).

A common way of describing objects is from their explicit information, that is, of how we interact with them, defining their edges, formal properties, materials and technology. This way of understanding objects is detached from the original script, individualizing it. This causes an object-dependence by narrowing the relationship between people and things towards a temporal desirability.
By contrast, understanding objects from their broader relationship with the environment and human interactions allows us to move towards a link that extends over its edges or formal boundaries, valuing the direct interaction between the internal code of each object and the environment where it performs. In this way, objects are deprivatized to become public, open and common. From this perspective, in a distributed topology network, design must move from an object-oriented logic (OOD) to a non-object oriented design (NOOD).
Operationally, the constitution of open objects requires the definition of clear rules and edges that allow them to be crystallized, communicated and socialized. In the distance between idea and conception where the force of displacement prevails supported by the collective consensus responsible for measuring if the solution can satisfy a specific need. The differential of distance is the ability to convert a utopian idea into a realizable utopia.
Non-object-oriented design takes distance from

the object-oriented design, which depends on an interaction of non-extensive needs based mainly on commercialized design and production logics. For this, rules must be established so that formal speculation can be validated within a current scenario, such as that it should not be commercial, fiction should be used as a communication mechanism and should be developed under a prototype based methodology (Auger, 2013).

La construcción de escenarios Futuros y utopías sociales.

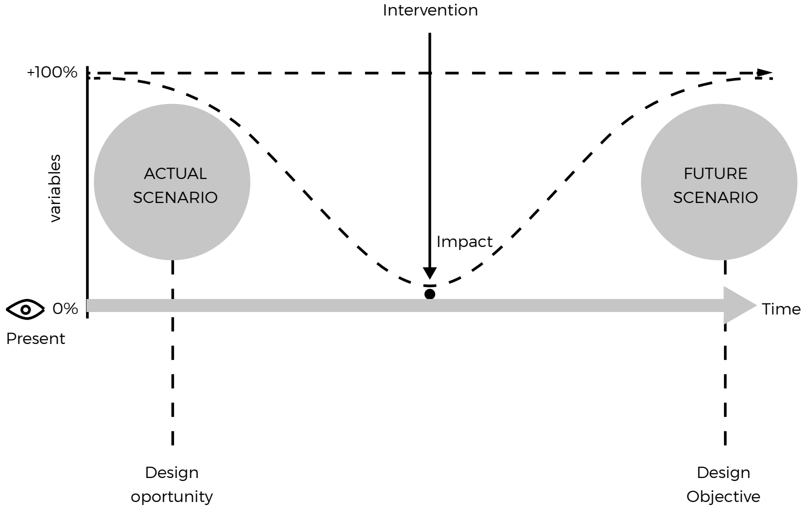
More than 50 years of the law established by Gordon Moore where he projected that the number of transistors per surface of integrated circuits would double every 18 months, designing an exponential curve that allows to determine the expiration of technological objects. Understanding this law and the conventional production systems, the future visualization of the impact or transcendence of the objects produced today is hard to detect. Designing in three dimensions is a daily practice of both academic and professional practice, however, the relationship between professional and academic practice distances itself when within the creative process the fourth dimension is considered.

During the exercise of designing towards the future, it is necessary to involve in detail how the variables, both positive and negative, could shape things (Fry, 2009). For this, the original observation must be understood from a broad perspective, ecological and social from the combination of quantitative and qualitative information on different phenomena or materials that must be studied accurately for projection over time.

The fear of approaching the unknown in design often leads us to forget about the future fusing on the present, either because of the uncertainty of visualizing a future dystopia or because of the simple human condition of well-being and temporal satisfaction.

If we cannot determine the necessary technological media to support the construction of future scenarios, these could become possible utopias lacking any sense of reality. Depending on the collected, projected and amplified data towards the future without considering possible measures of external agents into the design process, such as the establishment of public policies, there is a risk of visualizing and constructing dystopic scenarios which do not allow scope for action.

If we project the information that we handled in the present (image 1) to the future and we drew a line inside and two axles graphic where the horizontal is time and the vertical axle the data variables, the trajectory of the information vector will be the one that will allow us to understand the impact of the designed intervention, which will modify the curve by constructing a new scenario, conquering new design objectives.



By opening the creative utopia, proper of the construction of a fictitious scenario for the initiation of a design process embedded in the designer, towards society allows the design iteration, validating it as a medium to satisfy a public pain or collective dissatisfaction. Therefore, the opening of the creative utopia towards society is necessary, transforming it in a social utopia.
A realizable utopia is constituted from three basic principles for the identification of opportunities, definition of means and socialization (Friedman, 1971). The first principle is, based on the understanding of our environment from a human perspective, to detect a collective pain or dissatisfaction. The second is to define a valid medium to rectify the previously detected dissatisfaction. Finally, the defined medium must be socially iterated to establish a collective consensus which will determine if it is valid to correct the pain or not.
The interesting thing about this process based on

realizable utopias is that it is very probable that the object or intervention projected will never be able to constitute itself as a finished product, always acquiring the role of mediator that channels to a new scenario, always changing the current conditions. Therefore, the design object is constituted as a purely speculative and open prototype validating itself from its capacity of questioning, implicit script, performance of its deployment and not from its formal resolution.

Speculative prototypes: Foresight emerging scenarios

During the Studio class "Speculative Design for Social Development” developed between 2016 and 2017 in the School of Design of the Pontifical Catholic University of Chile, students observed social, environmental, political and cultural issues for the extraction of relevant information that would allow the construction of future scenarios. From these scenarios, the students had to design interventions that allowed the creation of awareness, enable a change of habit or build a social relationship from the design of a new product. Four projects developed in this studio class will be described below.

Na-Nai.

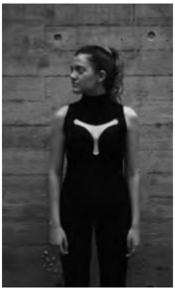
Students: Florencia Aguirre y María Jesús Álvarez.

This project build a scenario where many parents who work far from their family completely lose physical contact with their children, who are in full affective development. The physical affection of their parents is essential for their good development. The proposal is a first layer garment that allows the physical connection between parents and children who are separated, through the affection simulation.

(Image 2, from the project authors)
Both the father or mother as the son use a device, which is activated when the other person makes a hug gesture. The receiving device contracts and presses the person's chest.

Affective objects.
Students: Anath Hojman y Soffia Pizarro.

By the year 2050, human contact will have disappeared and machines will be intermediaries of the totality of our interpersonal relations, understanding that machines, permanently interconnected, will be all the objects that surround us. In this scenario, the physical relationship between people will be purely from their digital social interactions and the expression of their feelings will be clearly dependent on the association between machine and humans.



(image 3. From the project authors)
This wearable is permanently connected to the social networks of those who use it, reacting in real time according to their digital interactivity. Receiving notifications activates vibrations in the chest, not receiving them illuminates the spine of the back to alert your environment that you are not being stimulated to be petted by others.

Incuba.
Students: Florencia Toro, María Jesús Sotoluque, Bernardita Contreras.
In a 80 years projected scenario, the oxygen levels will decrease considerably and the plants will begin to disappear. Cultivation as a daily activity will become an essential activity people's life. The scarcity of urban land along with all the extensions of rural land would be under private ownership, making land access impossible for people and cultivation. This proposal establishes a new dependent relationship between the human body, perhaps the only private property of people, and plants through physical stimuli.

(image 4, from the project authors).
The dependence is achieved by a series of sensors and actuators that allow real time monitoring and stimulation of the body and the plant for the mutual leveling of oxygen, carbon dioxide, temperature and humidity.

DICO: collaborative device.
Students: Mónica Kattan, Mario Vergara.
Towards a not so distant future, the scarcity of resources and time has become a problem that affects all households, leaving time as a single resource for the collaboration between people of the same community has become fundamental in people's lives.
DICO is a system that encourages and organizes the collaboration of daily tasks through the valuation of time as a resource for the exchange of activities among people belonging to bounded communities. This allows organizing and maximizing personal capabilities, making these a contribution to the community, and fostering and impregnating collaboration as a social channeler.

magen 3: Cada dispositivo pertenece a una persona, el cual cambia su color dependiendo de las necesidades de otro miembro de la comunidad.
Cuando un miembro ofrece su servicio ambos dispositivos se sincronizan, una vez cerrad el trato, las dos personas se encuentran y conectan físicamente ambos dispositivos para recargar puntos.

Conclusions

From the role of design, global trends can be seen from two general perspectives, from one side we can have a continues practice that integrates global "consensus" established by the laws of a market based on the productive nodes and urban areas; Or we can build a new flow by the contribution from a critical, speculative perspective already open to the construction of new not so distant scenarios from the present time in the search to modify patterns of behavior patterns for the establishment of a new social relation.
Designing within emerging future scenarios based on quantitative and qualitative data gives a creative, open, direct and distributed freedom between

infrastructures, technologies and people for defining design as prototyped social interventions instead of objects as understood as products.

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The mass distribution everything

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Introduction:

We already have the capacity to produce energy using solar technologies plugged to home batteries, or grow food at domestic and local scale using synthetic biology to cultivate our own meat, or we could produce anything we need with endless recycling materials using digital fabricationtechnologies in neighbourhoods. Our current economic, political, legal and social structures are struggling to control everything, to keep population more dependent of external agents, and justify their existence. The current "operating system" running the world is not ready to support the democratisation of productivity, and the mass distribution of everything. We have an unique opportunity to make technology more accesible to everyone in order to increase the resilience of communities and individuals. If we boot a new "productive operating system", it would mean that millions of intermediaries controlling the distribution of wealth will loose their advantages: we might see bankers applying to get the universal basic income, as dystopian as it might sound. The extended global economic crisis is making evident that money is loosing its value thanks to the emergence of fluid infrastructures for fluid economies, based in trustable and transparent assets. Blockchain technologies are disrupting the creation of “money” by allowing anyone to be their own bank, or build new digital institutional infrastructure. In few years we will be able to have the computer power and data storage of a google or Facebook server farm in the size of a home appliance thanks to quantum computers, being able to store the Internet (or parts of it) locally. In this context, we need an optimistic view of the rather challenging transition we are living today, and make it operative to build the future we want. The synchronicity that is making possible the convergence of technologies like fab labs, blockchains, open AI, VR, accesible solar panels, synthetic biology, robotics, open source electronics, and even new approaches to politics, could be comparable to the beginning of the XXth century, when we started to build our current economy based on oil, computation and telecommunications control. We developed an economy that has denigrated democracy to the level of having criminal states administrating resources with only one objective: make more money. In the context of a global mafia trying to control access to resources, it is imperative to build new models, and focus in proposals and actions, rather than protests and destruction. I am proposing some options in this article, based on our work done for more than a decade in Fab Labs around the world, and specially in Barcelona.

From agriculture to mining

Thousands of years ago human agriculture made possible the excess of production, which lead to accumulation of goods, the concentration of population in towns (which would become cities), and the end of the hunter-gatherer. In order to handle and trade with the production surplus, we invented a system to organise the exchange of services and products in an abstract level: money. Today's economy is based on the flow of real and fictional money that simplifies the value of assets, skills, people, resources, and almost every single element of our built and non-physical world. Money has become a mean and an end itself. If agriculture transformed dramatically the way humans inhabited this planet, money monoculture is threatening life itself. In order to grow money, economies should grow in a limitless planet, according to the wisdom of many of our democratically elected representatives, and the technical knowledge of our great corporations that satisfy our needs with products. Our current economy has been simplified to look after one objective, no matter what: we need to cultivate money. Money monoculture is possible thanks to the control over the access to information (the Internet is being sequestered in case you did not know), and concentration of the means for production: energy, agriculture and objects/tools, which allow humans to survive and better interact with their habitat. The management (sequester) of physical assets and natural resources is being done by other abstractions we have invented recently: nations and corporations. By democratising and opening the access to the means of production, and the ownership of information, we are challenging fundamental and very old values of the established power. Economy, politics, and social structures are being challenged as never before, even if your Facebook feed keeps talking about nationalism and totalitarian regimes guaranteeing natural resources for the cultivation of money, to satisfy larger interests predicating GROWTH. But things are fundamentally changing, and we have entered into a transition that has no return.

The polarisation of politics responds to the nature of our current transition period, which might last years, decades or an entire century. This transition will produce winners and losers, as it happened a 100 years ago, and more than 500 years ago. Although it looks like we are repeating history and be condemned to it, it is only up to us not to do it, and build on top of it by taking the best from it. William Gibson used to say that the future is here, but it is not evenly distributed: The challenges of our times are not about developing the next big futuristic technology, instead, we have to find out how we will give technology a different purpose beyond sustaining a model that only seeks mono-cultivation. Check Silicon Valley VC fever to make useless technology extracting money from voluntarily uninformed population. As in every transition, we live surrounded by paradoxes and contradictions, in which the old and the new overlap with each other. Our values and ethics are challenged everyday, ideology dissolves fast, or tries to survive, no matter what. We claim to be saving the planet while we are mining it until exhaustion using coltan from Congo, Aluminum from Australia, meat from Brazil, sneakers from Vietnam, mobile phones from China; while moving materials and products thousands of miles until they get to our hands, used and disposed; while burning million of years petrified dinosaurs to have a warm bedrooms and living rooms, or to move our cars and planes. We live in a beautiful world with many good things too, we invented it, we can re-invent it and make it even better, anytime we want.

We are sitting on top of gold, and we trading it for mirrors

Purpose and ownership are two key words to keep in mind when talking about the future. The conversation is not really about VR, AI, AR, ML, Robots, Quamtum Computers, Automation or Synthetic Biology. Instead, we need to ask ourselves: what and who are these technologies serving for? who decides what to do with them? and how much I really know about them? For more than ten years we have been wondering about the role of technology in society in the Fab Lab network. These questions motivate individuals, communities and organisations to collaboratively propose and build new ways to own and use technology, to put it to the service of humans and the planet, not only to survive, but to transcend in harmony with our living systems. At least that is the aspiration, we do want to invent the future, not only to predict it (as Lincoln would say), but to make it more accessible, and respond to the biggest challenges of our times, which are mainly social and environmental.

The first Fab Lab outside MIT was created by Mel King (social and political leader) in Boston's South End Technology Center in collaboration with MIT's Center for Bits Atoms more than a decade ago, and its purpose was not about technology itself. Instead, Mel's vision was to use the technology that the lab could offer to recover the livelihood of a neighbourhood that was being victim of racial segregation and economic depravation during decades, thanks to an extractive real state market . Jane Jacobs alerted about the negative consequences of mass urban development that followed pure economic principles in New York some decades before, when she stood against Robert Moses in one of the most recognised confrontations in the history of urbanism, activism and sociology. Jacobs defended the idea that cities should be produced by its citizens, and by prioritising the tyranny of the car by building highways, and removing the identity built for generations in an area, the market and progress was killing the city DNA itself. The market (and segregation) was choking the future of kids in South End in Boston, but the local community and Mel decided to take action to avoid it: to make technology accessible in order to build the future of kids left behind because they did not fit into the “normal” educational system, and to find alternatives to the usual jobs that one black or latino kid would expect. SETC has been operating for around 15 years now, enabling Bostonian kids to be able to get free workshops and advice to develop their creativity. Mel's lab has inspired hundreds of Labs in the world, bringing the social dimension to technology as one of the main purposes of what is done in these workshops. We usually hear that Fab Labs are elitist, or too MIT-centric, or even just a place for nerds; the world should know more about Mel King, who for the last 50 years have been organising brunch at his house every Sunday, where people sing, discuss and debate issues of the community, or just get together to read poetry.

But could a Fab Lab help to rebuild communities and bring new economic opportunities in neighbourhoods?

Fab Lab Barcelona opened 10 years agoas the first Fab Lab in the European Union located at Poblenou: a post-industrial neighbourhood with a strong history of manufacturing and union movements in Barcelona. Known as the Catalan Manchester, the local community has been suffering the consequences of the deindustrialization process that hit almost every city during the last quarter of the XXth century, facing an economic crisis that would put in doubt the 22@ urban renovation plan (developed by the city council to reinsert investment in real state at the area). The 2008 crisis reduced dramatically the options for capital investment to land in Barcelona, and the real state market did not bloom at Poblenou as expected. However, some Universities did, alongside with few large corporations that could resist the economic breakdown. Instead, the neighbourhood started to be occupied by new creative industries, such as design studios, small schools of design and architecture, digital fabrication businesses, which together with galleries and collectively occupied buildings started to create a new identity of the neighbourhood, comparable to Brooklyn, Wynwood, or Mitte, including the gentrification issues they share. Poblenou is now becoming an ecosystem of different initiatives that are giving it a different identity, which was not planned, and that emerged thanks to the economic crisis, but also thanks to the obsolescence of traditional planning itself. The neighbourhood has now an association created as a private initiative (Poblenou Urban District) that brings most of this creative industries together, keeps the communication among its members,

organises events and outreach to the city and the world about the potential of the area. It is in Poblenou where Fab Lab Barcelona and Fab City found the perfect context to build a case about the future of technology, and its potential impact in society.
At Poblenou, the recently launched Maker District (as part of the Barcelona Digital Plan) is looking to add a new layer to the existing dynamics of the *barrio*. The Maker District is framed as a collaborative and co-created process that aims to build together with the local community and a global network the vision of the Fab City project, and create an experimentation playground to design, make, test and iterate new forms of governance, trade and production at the neighbourhood scale, using advanced technologies to accelerate the process of making cities more resilient and inclusive. At the city scale, Fab Lab Barcelona lead the development of the public network of Fab Labs together by assessing the city council to build the first infrastructure layer for the Fab City, which vision could be read in the project's whitepaper. The newly named Ateneus de Fabricació (as a *Catalanisation* of terms according to the council), would have then to decide between two operations models advised: they could be bureaucratised by the City Council *machine*, or they could be the avant-garde force to innovate in public policy. This question is yet still to be answered. Beyond the public intervention in the innovation ecosystem in Barcelona, the private initiatives have been flourishing and finding their way to create a business opportunity on top of the *maker movement* in both Barcelona and Catalonia. Spaces such as Makers of Barcelona, TEB (a very similar model like SETC in Boston), Tinkerers Lab, Beach Lab, Green Fab Lab, to name a few from dozens, have combined different models of making technology accesible to people by connecting it with existing co-working activities, social action initiatives or educational programs. An interesting model to explore, and that we have proposed to different Barcelona administrations, is the public-private partnerships in the creation of new labs: instead of the city council to try to concentrate innovation and spend millions of euros in new buildings, less than 30% of that same investment could be directed to private initiatives happening in the city, in exchange these initiatives would offer open and free hours to citizens through school programs and educational workshops to address unemployment by building new skills.

The public and private investment in new digital fabrication technologies in Barcelona is acquiring a larger dimension with he emergence of the Industry 4.0, which aims to digitalise the manufacturing processes at large scale. Industry 4.0 has been wrongly simplified to Internet of Things and 3D printing, which are some of the emergent technologies that will complement manufacturing processes. A new industrialisation of cities should look beyond the techno-centrist view and bet for a social model to make technology closer to people. At the same time, industries will have to withdraw the traditional economic approach that puts them as “takers” under an extractive model, and become “enablers” to keep being relevant in a context of distributed production. In the other hand, the public sector might want to experiment with models in which less control allow to nurture new forms of businesses, employment and innovation without having to spend millions of Euros in infrastructure that replaces or competes with private initiatives. In this sense, the Catalan government is also launching the CatLabs initiative, as a way to create the mechanisms to enable the creation of a larger ecosystem in the territory, and understanding the idea of the “lab” as a permanent way of living. I our constant changing world, innovation is not an option, it is almost a need in order to keep improving and to play a role in the fluid economics.
Barcelona has a unique ecosystem that could be used to prototype new forms of production in cities, that is also happening in Paris, Santiago, Amsterdam, Shenzhen or Detroit, or countries like Bhutan and Georgia. With the emergence of new forms of politics in the called liquid democracy we might be in an interesting turning point of traditional governance in a city that is used to have a strong public presence in almost every sector, only challenged by central governments or large corporation logics, but that still needs to be seen. In a new form of democracy, participation will not be only about giving an opinion or translating power to representatives, but will be about co-creation and co-production of neighbourhoods and cities. The risk is that at high level power struggles (city, region, country, corporations), the remaining actors (citizens, communities, small businesses) are condemned to navigate in uncertainty and ever changing rules of the game, and through the personalisation of power. Without institutional

infrastructure to enable a new productive model of cities we are risking to repeat the same mistakes of the existing extractive and market driven economy. We have the opportunity to test new forms of governance between these players, in a fair and transparent way, using new technologies that can enable the transition to a new economy, to the mass distribution of everything.

Notes for future research on the impact of the Fab Lab network

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Abstract

Throughout the years, research initiatives related to the global Fab Lab network emerged by addressing several issues with scientific articles and popular books, among the many publications. However, there are still many issues in the Fab Lab network that should be addressed by future research, specially regarding the impact of Fab Labs on society. This short contribution aims at proposing a set of research questions and methods for the Fab Lab network, that should be considered more as notes shared among members of the community than as a structured research proposal. The notes presented in this article reflect upon this topic and emerged from working in a Horizon 2020 research and innovation project of the European Union, MAKE-IT, that is specifically oriented at understanding and improving the social impact of Makers and therefore also of Fab Labs. Understanding the impact of the Fab Lab network on society is one of the most strategic directions for improving the network and its role in society. This short contribution proposes a framework, a list of research questions for moving forward in this direction, in order to start a discussion, research initiatives and potential collaborations in them.

Introduction

In the past few years , research initiatives related to the global Fab Lab network emerged by addressing more issues, from digital fabrication technologies (Hawkes et al., 2010; Knight & Stiny, 2015; Liu, Boyles, Genzer, & Dickey, 2012) to the everyday practice in labs (Wolf, Troxler, Kocher, Harboe, & Gaudenz, 2014); from exploring specific labs or contexts (Ronald N. Beyers, Blignaut, & Mophuti, 2012; Fonda & Canessa, 2015; Kohtala & Bosqué, 2014) to exploring the global social ecosystem (Menichinelli, 2016b); from exploring business models of labs (Troxler, 2013; Troxler & Wolf, 2010) to exploring the work dimension at a national scale (Menichinelli, Bianchini, Carosi, & Maffei, 2017); from exploring educational activities in workshops (Ronald Noel Beyers, 2010) to exploring them at a national scale (Menichinelli, Bianchini, Carosi, & Maffei, 2015); and finally towards addressing sustainability (Kohtala, 2013, 2016b, 2016a). Furthermore, the Fab Lab network has been explored in several books as well, starting from the first book that contributed to launching the movement (Gershenfeld, 2005) to a more recent wave of publications (Bosqué, Noor, & Ricard, 2014; Eychenne, 2012; Menichinelli, 2015, 2016a, 2017; Walter-Herrmann, 2013). However, there are still many issues in the Fab Lab network that are largely unexplored and therefore should be addressed by future research, expanding existing investigations, opening new frontiers and testing and adopting new research methods. This short contribution aims at proposing a first set of research questions for the Fab Lab network, that should be considered more as notes shared among members of the community than as a structured research proposal.

"*Fabricating Society*" is the central topic of the 2017 edition of the International Fab Lab Meeting, the 13th edition, focused on how to address the "*many gaps in strategic dimensions that make the process of constructing a developed society challenging*"[1] by presenting and discussing successful projects that create high social impact. The notes presented in this article reflect upon this topic and emerged from working in a Horizon 2020 research and innovation project of the European Union, MAKE-IT[2], that is specifically oriented at understanding and improving the social impact of Makers and therefore also of Fab Labs.

The MAKE-IT research and framework

The growing interest on online platforms is arguably one of the consequences of the success of companies like Amazon, Apple, Facebook, and Google, that have based their business models less on competition and more on collaboration with providers and users by

[1] http://fab13.fabevent.org/

[2] http://make-it.io/

building ecosystems, partnerships and communities (Simon, 2011). Their ability to leverage the long-tail of markets and communities and scale is one of their most admired features (Anderson, 2008), together with the ability to offer a place for multiple individuals or groups to get together in order to exchange goods and services (multisided platforms) (Evans & Schmalensee, 2016). The general interest that is emerging from such platforms is mainly due to their economic performances, but there are several other platforms that are also interesting for different reasons: not for conquering markets and creating profits, but for supporting democratic practices that are environmentally aware, participatory and based on sharing and collaboration. These platforms are called by Fabrizio Sestini Collective Awareness Platforms: (CAPS) (Sestini, 2012): and beside MAKE-IT several other Horizon 2020 projects[3] are working in this context along these directions: Open Democracy, Open Policy Making, Collaborative Economy, Collaborative Making, Collaborative Consumption, Environmental action, New Collaborative approaches[4]. CAPS are therefore not limited to only one sector, but more generally "*are defined as ICT systems leveraging the network effect (or the "collective intelligence") for gathering and making use of open data, by combining social media, distributed knowledge creation, and IoT. They are expected to support environmentally aware, grassroots processes and practices to share knowledge; to achieve changes in lifestyle [...], production and consumption patterns; and to set up more participatory democratic processes. The ultimate goal is to foster a more sustainable future based on a low-carbon, beyond GDP economy, and a resilient, cooperative democratic community.*" (Sestini, 2012, p. 58). Rather than just focusing on technology, the goal of such platforms is "*to move beyond purely technology-driven solutions to enable new organizational, social, and governance models. These are needed to face the current societal challenges and achieve sustainability and well-being*" (Sestini, 2012, p. 54).

MAKE-IT is a Horizon 2020 European research project focused on how the role of CAPS enables the growth and governance of the Maker movement, particularly in relation to Information Technology, using and creating social innovations and achieving sustainability. The results of this research will help to understand the uses and impacts of CAPS in different

[3] https://capssi.eu/

[4] https://ec.europa.eu/digital-single-market/en/collective-awareness

contexts, as well as of the Maker movement itself. The mainresearch questions of the project are:

- How can Maker communities achieve sustainability and organize themselves?
- What do Maker participants do, and how do they behave?
- What value do they create, and how does this benefit society?
- How can we help their governance, their impact and sustainability?

MAKE-IT started in January 2016 and it is now finalizing research activities and outputs that we are already sharing on thewebsite make-it.io and that we hope can be useful for the Maker movement and for all its stakeholders in research, policy making and business activities. One of the most important elements of MAKE-IT, specially for future research, is its main analytical framework (Millard et al., 2016)that can be adopted for understanding the impact and social dimension of Maker initiatives and not just on platforms. The role of the framework is to foresee and monitor the development of the Maker movement in the context of the CAPs approach, as a flexible conceptual and analytical tool for MAKE-IT during the project and as a final output for all the researchers interested in it. The focus of MAKE-IT and its analytical pillars (Figure 1) is on the role of CAPs in:

1. how Maker communities are organised and governed;
2. what Maker participants do and how they behave;
3. the various ways this impacts on and adds value to society.

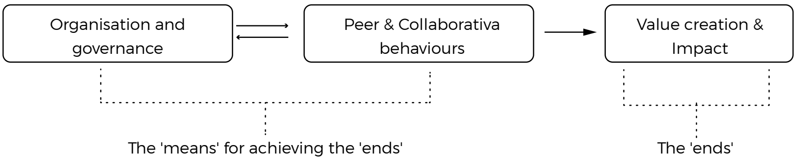

Figure 1: The analytical pillars of the MAKE IT framework (Millard et al., 2016)

This simple framework could be very useful for informing several researches for the Fab Lab network, especially the ones dedicated to understanding the impact of the network and of its labs and participants on society. The role of digital platforms is important, and often crucial in connecting people, labs and researchers, but the framework can be used also outside digital platforms, more generally for understanding the social impact of Maker initiatives. The importance of this framework is of exposing the social interactions and processes that enable the impact of Maker initiatives, giving therefore more depth to understanding what could improve them. I suggest to consider the investigation of the impact of the Fab Lab network as a very strategic move, it is a sign of maturity for the network and for its researchers, at least for these reasons:

1. if we understand our impact, we can reorient our activities in order to strengthen it wherever and whenever necessary;
2. if we understand our impact, we can further communicate it and improve it (and this, hopefully, would bring to a larger impact by getting more stakeholders involved);
3. if we manage to measure our impact and find interesting results, then we are becoming a more self-aware community and more experienced researchers, and ultimately we can provide evidence of our role in shaping society.

The history of Maker movement and of the Fab Lab network is the history of like-minded people finding each other all over the world, in spite of differences and distances. If we manage to understand the impact of the Fab Lab network we can also then apply the knowledge and expertise acquired in order to understand the impact of other ecosystems made of distributed and autonomous agents.

Notes for future research questions

Research in/with/for the Fab Lab network should aim at both understanding the present conditions and also at proposing potential future developments. Here is a first list of potential research questions that might be helpful to understandthe impact of the Fab Lab network and that would be strategic to address in the future:

1. Social dimension and its sustainability

1.1 What are the sizes of the local communities of each Fab Lab and what is the size of the global network? Given the distributed nature of the network, how can we measure them?

1.2 And beside just the number of people participating

in the community, what are their demographic characteristics? Are there any gender gap or other gaps, and how could we reduce them?
1.3 How can we understand the social structure of the local communities and of the global network? What are the interactions and processes taking place among members of the communities? How can we improve collaboration and social structure in the communities?
1.4 Is there only one culture in the network, or do we have several cultures? What are the cultures of the local communities of each Fab Lab and, as a whole, of the size of the global network? How can we research and understand this dimension?
2. Economic dimension and its sustainability
2.1 What are the existing business models of labs, what are the most recurring patterns? Could these business models be improved, changed or developed? How could we measure the impact of existing and new business models on the activities of users and labs and of the network as a whole?
2.2 What are the existing business models of projects developed in labs, what are the most occurring patterns? Could these business models be improved, changed or new ones adopted? And how could we measure the impact of existing and new business models on the activities of users and labs and of the network as a whole? How could we improve the design, acceleration or incubation, sharing, commercialization and distribution/deployment of such projects?
2.3 What are the existing work conditions of users accessing the labs or people working in the labs? How could we understand them and improve them?
2.4 How are the business and work dimensions of labs, projects and people interconnected? How can we balance them and understand how this activity influences them?
3. Environmental dimension and its sustainability
3.1 Have Fab Labs measured their supply chains and the life cycle of materials, components and projects? How could we help Fab Labs and the network in this task, and improve their sustainability?
3.2 Have Fab Labs measured their usage of energy and carbon footprint in labs and in the network as a whole? How could we help Fab Labs and the network in this task, and improve their sustainability?
4. Impact
4.1 Do Fab Labs have an impact on society, economy

and the environment? How can measure it for single labs and for the network as a whole?
4.2 What is the influence of labs and their projects on local systems, even beside manufacturing? For example: does a Fab Lab influence the local production of food or educational activities or unemployment? And how could this be measured (and best practices scaled) at network level?
4.3 More specifically, what is the impact of labs and their projects on city, regional and national resilience?
4.4 How can we take into account the differences among Fab Labs and their local contexts in order to have a balanced understanding of their impact between local impact and global impact and knowledge transfer with other labs?
5. Role of platforms
5.1 What could be the business models for the Maker and Fab Lab platforms?
5.2 How could we design the Maker and Fab Lab platforms taking into considerations the needs of a worldwide community of users and labs and by balancing all these different needs with the complexity of a platform?
5.3 How could we improve the participation of users and labs in the design/development and managing of such platforms?
5.4 How can we measure and understand the impact of a platform over the activities and sustainability of users, labs and of the network as a whole?
All of these research questions are important on their own, but they would become strategically relevant when integrated in a coherent model that can be used for estimating the impact of Fab Labs on society, the environment and the economy, if any. A model, although it is a simplified map of a very complex reality, could be also used to communicate quickly the impact of a Fab Lab, a sort of Fab Lab Impact Index, for example like OECD measures and visualizes well-being at national[5] and regional level[6]. The MAKE-IT framework can be applied to this in order to understand the role of organisation, governance, processes and interactions on the creation of value: in order to understand the immaterial elements of social interactions and processes that most of the time go unnoticed.
Research in/with/for the Fab Lab network is not an activity that takes place without the participation of makers and of the Fab Lab community, and it should

[5] http://www.oecdbetterlifeindex.org/

[6] https://www.oecdregionalwellbeing.org/

learn from the continuous creative activities done. For this reason, I suggest to adopt also a design approach, following the definition of design elaborated by Nelson and Stolterman which establishes design as a method of inquiry separated from the scientific and the artistic ones, which is not a mix or intermediate approach between the two but a culture of its own: *"Design is a tertium quid— a third way — distinct from the arts and sciences. In support of this argument we make a case for the reconstitution of sophia— the integration of thought and action through design. We make a case for design as its own tradition, one that reintegrates sophia rather than following the historical Western split between science and craft or, more recently, between science and the humanities."* (Nelson & Stolterman, 2012, p. 11).
The important point of the design approach is that it points to future development rather than to an analysis of existing conditions. In this direction, I suggest to especially experiment with a *research through design* approach where the design practice generates insights with its own original methods, tools and skills. The artifact is not the goal of research through design; knowledge and understanding is and artifacts are a side effect: *"researchers make prototypes, products, and models to codify their own understanding of a particular situation and to provide a concrete framing of the problem and a description of a proposed, preferred state [...] By practicing research through design, design researchers can explore new materials and actively participate in intentionally constructing the future, in the form of disciplined imagination, instead of limiting their research to an analysis of the present and the past".* (Zimmerman & Forlizzi, 2008, p. 42).

Conclusions

Several researches have been done in order to better understand the Fab Lab network, and understanding its impact on society is one of the most strategic directions for improving the network and its role in society. This short contribution proposes a framework and a list of research questions for moving forward in this direction, in order to propose potential collaborations in new research initiatives.

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From material scarcity to artificial abundance: the case of FabLabs and 3D printing technologies

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Abstract
Digital media allowed for the emergence of new artistic practices and innovative modes of production. In particular, the advent of Internet and digital technologies drastically enhanced the ability for multiple authors to collaborate towards the creation of large-scale collaborative works, which stand in contrast to the traditional understanding that artistic production is essentially an individual activity. The significance of these practices in the physical world is illustrated by the recent deployment of FabLabs: Fabrication Laboratories that employ innovative technologies – such as, most notably, 3D printing, which is recently gaining the most interest – to encourage the development of new methods of artistic production based on participation and interaction between peers. By promoting a Do It Yourself (DIY) approach, Fablabs constitute an attempt to transpose the open source mode of production from the domain of software into the field of art and design. Yet, as opposed to the information realm (where scarcity has been added artificially – by legal means – to inherently abundant resources like software and creative expression), artistic and design production in the physical world is riddled by the problem of material scarcity: physical resources are inherently limited and cannot be reproduced without using, converting or otherwise disposing of others kinds of resources. Over time, open source practices have managed to “hack” these provisions by means of contractual instruments designed to eliminate artificial scarcity

so as re-instate the original state of abundance in the information realm. One has to wonder whether similar instruments could be conceived to eliminate – or,at least, reduce – material scarcity in the physical world. The underlying question that will be addressed throughout the paper is, therefore, "how could we hack the law to turn technical material scarcity into artificial material abundance?"

Introduction

The advent of Internet and digital technologies drastically enhanced the ability for multiple authors to collaborate towards the creation of large-scale collaborative works. While most of this happens in the digital world, these practices also exist in the physical world, as illustrated by the recent deployment of FabLabs: Fabrication Laboratories that employ innovative technologies – such as 3D printing– to encourage the development of new methods of artistic production based on participation and interaction between peers. By promoting a Do It Yourself (DIY) approach, Fablabs constitute an attempt to transpose the open source mode of production from the domain of software into the field of art and design. Yet, as opposed to the information realm (where scarcity has been added artificially – by legal means – to inherently abundant resources like software and creative expression), artistic and design production in the physical world is riddled by the problem of material scarcity: physical resources are inherently limited and cannot be reproduced without using, converting or otherwise disposing of others kinds of resources. *Artificial scarcity* denote a situation whereby a resource that is technically non-rival (*i.e.* its consumption by one person does not prevent its consumption by another person) is turned into a scarce resource by legal or technical means. In the realm of information, this is achieved by means of intellectual properties laws (such as copyright, trademarks, or patent law) aimed at reducing the availability of resources to allow for monopoly pricing. This generally results into a deadweight loss for society, to the extent that some people can no longer afford to consume information. Over time, open source practices have managed to "hack" these provisions by means of contractual instruments designed to eliminate artificial scarcity so as re-instate the original state of abundance in the information realm. One has to wonder whether similar instruments could be conceived to eliminate – or, at least, reduce – material scarcity in the physical world. The underlying question that will be addressed throughout the paper is, therefore, "*how could we hack the law to turn technical material scarcity into artificial material abundance?*" [1]

1. The Information Realm

1.1. The Copyright Regime: Introducing Artificial Scarcity to a Non-Rival Resource

The main purpose of copyright law is to turn information – an inherently non-rival resource – into a commodity that can be traded on a market for information goods. This is done through the establishment of a series of exclusive rights over the content of information that allows authors to control the reproduction, distribution and exploitation of such content. The underlying argument for copyright law is that authors need to be rewarded for their intellectual endeavours. Indeed, given the ease at which information can be reproduced, it is often argued that others can easily free ride on what has been previously expended in the initial production of a work. Authors are thus granted a temporary monopoly right over the exploitation of their works so as to acquire an incentive to produce more works. Information is thereby turned into a commodity, which – albeit non-rival in consumption – nonetheless features the properties of a private good in terms of artificial scarcity and excludability.

The problem is, however, that – by virtue of artificial scarcity – the copyright regime ultimately reduces the opportunities for society to benefit from global and unconditional access to a large variety of cultural works; a "market failure" or "externality" that the (neo-classical) market is unable to account for.

1.2. The Copyleft Regime: Removing Scarcity from an Artificially Scarce Resource

It is in response to this problem that the concept of *copyleft* (as opposed to *copyright*) has been elaborated by Richard Stallman (an American software freedom activist and computer programmer) as an attempt to limit the negative impact that copyright law had on the ability for people to freely use and modify software. In the context of software licensing, the copyleft clause – first introduced in the context the GNU General Public License (GPL)– is a contractual provision stipulating that anyone has the right to access and

[1] By analogy with artificial scarcity, we rely on the concept of ***artificial abundance*** to denote a situation whereby resources that are naturally scarce are made more abundant (or less scarce) by legal or technical means.

modify the source code of a particular piece of software, but only provided that the modified software is made available to the public under the exact same conditions as the original software. This clause (also known as the "share-alike" clause) has become, over time, a central tenet of many Free/Libre Open Source Software (FLOSS) licenses.

The concept has been later transposed into the realm of the arts with the emergence of the Open Content movement and its corresponding licensing schemes. On that regard, Creative Commons developed a set of licenses specifically designed to encourage the dissemination and facilitate the reuse of original works of authorship protected by copyright, while nonetheless allowing authors to maintain a certain degree of control over the exploitation of their works (a move from "*all rights reserved*" to "*some rights reserved*").

The Open Content movement defends the idea that cultural production is always based on a more or less substantial reuse of prior works, which constitute – either directly or indirectly – the basis on which authors can build upon to produce new original works of authorship. Hence, it is often claimed that, in order for cultural production to flourish, it is important that information be freely available for use and reuse by everyone.[2] The legal excludability introduced by copyright law is, as such, seen as a threat rather than a support to creativity.

While the copyleft regime does not actually eliminate the artificial scarcity introduced by copyright law (*i.e.* it does not go counter the exclusive rights granted to authors under the law), it does, however, constitute an attempt at bringing back the properties of non-rivalry and non-excludability into information. The goal is not to turn information back into a public good, but rather to provide the legal means to turn information into a *commons*[3] – or, more precisely, into an *information commons*:[4] a resource belonging to the common cultural heritage, that is not owned by any single moral or legal entity but is, rather, held in common by all members of society (and can thus be freely accessed, consumed and reused by all).

2. The Digital Realm, Spreading the "Meme" of Collaboration and Sharing in the Physical World

Sharing digital works and contributing to the

[2] Lessig 2004

[3] The term commons refers to all resources accessible to all members of a society, including natural resources (such as air, water, etc) and cultural resources (such as information). Although they might qualify as either public or private goods, the particularity of these resources is that they are not owned privately, they are held in common by the members of a particular community (Bollier, 2002).

[4] Information commons have been defined as as "information and knowledge resources that are collectively created and owned or shared between or among a community and that tend to be non-excludible, that is, be (generally freely) available to third parties" (Fuster Morell, 2010).

production of large collaborative works has become an increasingly popular practice, leading to the free availability of content that can be reproduced, distributed and built upon without restrictions. In recent years, many dedicated online communities have emerged, whose goal is to promote collaboration amongst a large number of individual users (see e.g. Sourceforge, Wikipedia) or to enable people to contribute to an online platform with user generated content (e.g. Flickr, Vimeo and Youtube). These practices encourage novel forms of artistic expression that – due to the material, spatial and temporal restrictions of the physical world – were hardly ever practiced before.
With the advent of modern, computer-controlled manufacturing tools (e.g. 3D printing technologies or CNC machines), the open source model of production is being progressively transposed to the physical realm, where it can be employed for the production of physical works. Software programs for digital design represent the tool-chain that creators use to gradually turn an idea into its material manifestation. Computer-controlled production machinery – laser cutters, mills, 3D printers – are subsequently employed to generate physical objects. The past decade has seen an exponential growth in the availability of such machinery. Professional service bureaus offer materialisation of digitally designed artefacts in almost any size, material, and quality. Publicly accessible shared machine shops such as FabLabs are spreading, offering the use of computer-controlled production machinery to everyone at affordable cost.
By providing a common platform for tools, materials, and technical training, FabLabs and public machine shops provide all physical means for experimenting with new models of production based on cooperation among peers. Indeed, if the model of peer-production can be easily employed for the production of digital content (which can be easily replicated and modified without affecting the original), it fits equally well with the digital tool chain and computer-controlled machines for the production of physical products. Several communities and platforms have sprung up to encourage collaboration and promote the sharing of (at least) the interim results of production (e.g. Instructables, Thingiverse, Wevolve). These platforms are not yet as common as those in the purely digital environment, since novel forms of artistic dialogue

have yet to develop. However, we can already observe emerging movements around concepts such as "Open Design" and "Open Hardware" which aim to replicate the principles of copyleft in the physical world.
Yet, while the values of collaboration can easily be transposed into the physical world, the principle of sharing does not properly fit with one major constraint of the material world: the scarcity and limited malleability of (material) resources.

3. The Physical Realm

In contrast to the digital world – which is inherently intangible – the physical world is characterized by technical excludability and material scarcity. Hence, by virtue of their materiality, all resources in the physical world are both rival and excludable.
We distinguish three different types of resources, which each play a different role in the production chain. The first comprises raw materials (such as steel, wood, plastic, gas or electricity) that are used up in production and are thus no longer available afterwards. The second refers to all production facilities or infrastructures that are used in the process of production, but which remain available for further use and reuse (even though they might, eventually, deteriorate). The third is the output of production: resources produced after raw materials have been assembled at one or more production facilities.
It is worth noticing that, while all three of these resources are naturally scarce, the current system of production based on capitalist principles introduces an additional layer of scarcity over certain types of products (mainly of the third type) by concentrating most of the knowledge and means of production into the hands of a few large corporations.
In the information realm, while copyright introduced artificial scarcity and excludability over a non-rival good like information, specific legal tools (such as Creative Commons licenses) were able to eliminate such scarcity by contractual means. Could a similar effect be achieved in the physical world? Can we turn a naturally scarce resource into an artificially non-rival resource, by either legal or technical means?
Referring back to the three types of resources identified above (raw materials, production tools or facilities, and resulting end-products), we will investigate whether it is possible (and useful) to reduce the level of scarcity and/or excludability that they are

naturally associated with, looking at how we could: (1) reduce material scarcity for raw materials; (2) decrease the degree of excludability for production tools and facilities; (3) provide free access to all the knowledge necessary to operate these tools and to produce the expected end-products.

3.1. Reducing Scarcity of Raw Materials

Various mechanisms can be employed to turn raw materials into a more abundant or less excludable resource. Abolishing property (or introducing temporary property rights) is a potential solution aimed at eliminating the *legal* possibility for the owner of a non-used resource to exclude others from benefiting from it. This solution does not, however, encroach on the attributes of physical resources, which remain inherently rival. It does not, as such, resolve the problem of natural scarcity, nor does it eliminate the possibility for people to exclude others from accessing a resource by technical or physical means.

Alternatively, to decrease the scarcity of raw materials, one could imagine a situation whereby people could freely take certain types of materials from a common pool of resources whose ownership is shared amongst all members of a community, but only provided that they commit to giving back a similar amount of the same kind of materials in a given period of time (give-back provision).[5] This approach would make it possible to provide free raw materials to a certain community, while nonetheless preventing the common pool of resources from being depleted over time.

[5] For instance, a pot-maker could take as much clay as allowed by community rules, but - after a determined amount of time (e.g. from 1 to months) - he would have to put back one kilogram of clay into the common pool for every kilogram of clay that has been taken from it.

Another way to reduce material scarcity of raw materials is to adopt material saving techniques. Additive manufacturing processes – commonly known as 3D printing – offer great prospects here as they allow to build structures that consist of the minimal amount of material in exactly those places where a structure would need it to respond to mechanical stress.

Finally, material scarcity could also be reduced through extensive recycling or upcycling, *i.e.* by turning old neglected resources into raw materials, so as to produce a whole new set of resources without consuming any more raw materials.

3.2. Shared Tools and Production Facilities

In the case of technical facilities, tools or infrastructures which persists over time, the focus is not so much on reducing scarcity, but, rather, on eliminating (or reducing) excludability – so that a maximum number of people can benefit from their use.

One possibility is to establish public FabLabs to provide public access to tools and facilities that people might need, in the same way as we have public libraries providing public access to information. The goal is to maximise the access to and usage of specific resources by providing a platform encouraging people to share or lend the resources they own to others needing them.[6] This is the concept behind the emerging concept of “collaborative consumption”[7] – according to which people are increasingly consuming goods in a collaborative rather than individual manner, so that access to a resource is gradually becoming as important – if not more important – than property.[8] Indeed, most people only seldom need a laser-cutter or a 3D printer – and, given the costs of these tools, they are unlikely to purchase them. Yet, in a few occasions, these tools could actually help people achieve a specific task.

FabLabs can be provided either by the state (which already provides public libraries as part of its mission) or specific communities that believe in the idea that everyone from the community should have access to certain tools or facilities. Thus far, FabLabs are experimenting with novel approaches, using traditional co-op or more innovative mutual strategies, covering expenses through membership contributions and bench fees, employing various types of voluntary contributions, establishing barter systems, or a mix of the above.

3.3. Free Access to Knowledge and Skills

Of course, public access to production facilities, even if combined with a large amount of raw materials, is only useful to the extent that people have the necessary knowledge and skills to use the production infrastructure. This is what inspired initiatives such as Makezine.com, Hackaday.com or Instructables.com, where people can upload precise instructions to a variety of DIY projects.

Yet, intellectual property laws, such as copyright or design rights, are restraining the exploitation of original works of art, including their models or designs. This is where the Open Design / Open Hardware movement comes in, as a way to ensure that – after it has been conceived and designed for the first time – a product can easily be reproduced by anyone else by simply feeding the digital manufacturing machines with the proper instructions.

This can be regarded as a way to bring the values of

[6] Sundararajan 2013

[7] The term "collaborative consumption" was first coined by Felson and Spaeth 1978 in a paper dealing with the practice of car-sharing as a means for car owners who make only occasional use of their vehicle to benefit from the lending of their car to people who only need occasional access to a vehicle. It was subsequently popularized by Botsman and Rogers 2010 in their book “What’s mine is yours”

[8] Gansky, 2010

the Open Source / Open Content movements into the physical world, encouraging people to collaborate towards the production of a design, which can then be reproduced indefinitely – by either reproducing the design, or “printing” the product in the physical world, without any quality loss and at cost that – as technology develops – becomes closer and closer to the marginal costs of production.

FabLabs thus encourage artists to share their knowledge and to ensure that their artistic productions are and remain available for the community to build upon them. Many require that artists release their works into the “commons” (*i.e.* the common pool of resources that can be freely used and reused by the community) by means of specific licenses (such as the Creative Commons licenses) designed to reduce the default level of protection granted by default under the law. These licenses are meant to maximize the dissemination of works, while promoting the further development of cultural artefacts through the process of incremental innovation.

Finally, if one wants to get rid of the additional layer of scarcity that has been established as part of the capitalist system of production (*i.e.* depriving people from having access to the means of production), it is important that citizens are able to produce their own infrastructure of production. This is the concept underlying various initiatives, such as, most notably, the RepRap: a 3D printer that has been designed with the objective of reproducing itself. Again, this means that all plans and designs for such machines should be made freely available to the public, in a way that does not only allow for people to reproduce the piece, but also to create derivative versions thereof, so as to either add new functionalities or improve currently available ones, as well as to build upon it in order to create alternative version of the machine which are more tuned to one or another specific application.

Conclusion

We are observing today the emergence of new social practices (mostly derived from the meme of collaboration and sharing that established itself in the digital world) aimed at encouraging collaborative consumption and the sharing of physical resources, which – despite being inherently rival in consumption – are increasingly held in common and shared amongst the member of a particular community[9] according to specific governance rules or social norms which prioritise *access rights* over *property rights* as an alternative system for managing common property resources.[10]

The objective of this paper was to identify ways to hack the law so as to turn technical or material scarcity into artificial abundance. We do not pretend to have found any ideal answer to that question, yet we believe that this objective can be achieved if three important conditions are met: (1) raw materials have to be readily available; (2) production facilities and tools must be and remain freely accessible to all; and (3) all knowledge concerning the making and use of products or machines has to be open and free for anyone to build upon.

Although we are only at the early days of these technological developments, the advent of 3D printing and other self-fabrication technologies constitutes a paradigm shift in society that is likely to have a considerable impact on the way people perceive and consume most of the everyday products.

If these technologies were to achieve widespread adoption, anyone needing a particular product – such as a table, a chair, or a lamp to give a few examples – would only have to find or select a particular design for that object within the common pool of available designs, eventually adjust it to specific preferences or needs, and subsequently travel to a public workshop or FabLab in order to actually build that object with the tools and machines that have been made accessible to every community member. Thus, assuming that a sufficient number of FabLabs are deployed in every city or community, one could imagine that – sooner or later – products will only be as scarce as the raw material needed for their construction.

[9] Betts 2010
[10] Weitzman 1974

Systems of Resilience: A Dialogue on Makers, Making and their Principles of Conduct

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FabLabs make available to citizens digital fabrication technologies, the low-cost equivalent of industrial prototyping equipment, and enable 'making' and 'fabbing' activities where hobbyists, professionals, inventors and the curious can experiment with and realise their own ideas. There are many different types of makers and maker communities today, each drawn together by different motivations, missions and even manifestos.
This dialogue departs from where Jane Jacobs left off in Systems of Survival *and* The Nature of Economies, *bringing the various maker characters to the same table to discuss the present and future of making. It first appeared as a chapter in* Agents of Alternatives *and is reprinted here with permission.*

www.agentsofalternatives.com

Raissa's Summons

As Raissa had extended the invitation, she made sure she was first to arrive in the kitchen at the co-working space. She was setting out coffee mugs when Grosvenor arrived, with Harriet in his wake. Hugh entered with a broad smile, tipping his hat at the others; Fernanda came in at that moment and imitating Hugh's gesture, causing them all to laugh. They all shook hands smiling and then sat down at the table, looking at Raissa expectantly.
When all the coffees had been poured, Raissa started:

“I know you’re wondering why I called you here today; there is something I want to discuss with you all.” She picked up the envelope that was on the table and drew out four sheets of paper. “Armbruster sent this to me last week. He said it was an assignment from Jane.” Hugh’s eyebrows went up; Fernanda looked puzzled. Raissa set one of the sheets on the table and the group bent over to examine it.
“So the questions Armbruster wanted us to discuss are about systems of organisation and sanctioned behaviour. We decided together that you four represented the right range of viewpoints.” She consulted her notebook. “In other words, what precepts govern our behaviours and what do we reward? What are your definitions of success? Why do you pursue what you do, and why do you devalue other actions? That would mean your various communities – you and your hackerspace, Hugh, for instance.”
On the sheet of paper was a chart:

The Commerce Moral Syndrome	**The Guardian Moral Syndrome**
* Shun force	* Shun trading
* Come to voluntary agreements	* Exert prowess
* Be honest	* Be loyal
* Collaborate easily with strangers and aliens	* Be exclusive
* Compete	* Take vengeance
* Respect contracts	* Respect hierarchy

“What does the word ‘syndrome’ mean here?” asked Harriet. “Jane says it means ‘things that run together’. So these are like symptoms that characterise a condition. And these two syndromes are the way we operate as humanity: we either trade things, as in commerce, or we take them and then need to protect them, as guardians,” explained Raissa.
“Well, I think hackers are more traders than takers, but I’m a bit allergic to the word ‘commerce’,” Hugh began. “Still – we collaborate more than we respect any hierarchy.” “But you still have some kind of hierarchy in hacking – it’s just based on competence or experience or time put in rather than on any traditional roles or ideas of status,” Fernanda offered. “At least that’s how it is in my makerspace.” “And you certainly don’t shun trading in your space!” Harriet exclaimed. Fernanda looked at her quickly. “What do you mean?” “I thought makerspaces were supposed to be free and open and

there to provide access to technologies to everyone. Yet you make good business from selling services and holding workshops, so everyone learns how to use a laser cutter and is no longer interested in actually doing anything with their hands," Harriet said, rather defensively. She straightened her shoulders and continued: "And then everyone prints out plastic Yodas and MDF press-fit boxes and all the waste and off-cuts just go straight to landfill – along with those Yodas and boxes that no one actually needs. And as soon as the next version of the technology comes along, you ditch it and replace it with the newest and shiniest..."
"You have a point, Harriet," Hugh intercepted her flow of words with his hand, "but don't forget that learning how to use the equipment is a valuable learning experience in and of itself. It can teach us not only about how mass-produced products are made, but also how to repair them. And a 3D printer in a hackerspace, ok, it is of limited use, but it's really useful to know how to make one." "But how many makerspaces in future will actually stick to those DIY self-assembly machines? The more they evolve, the more complicated they become, but they also become easier and easier to use. They become just like the closed boxes personal computers are today – easy to use but impossible to control. And then there is no more learning of any kind, not to mention any kind of traditional making," Harriet countered.
Fernanda raised her hand in protest: "I'm all for learning craft skills, and we certainly have enough hand tools and workshops on craft in our makerspace, but some of that is just becoming less relevant in the 21st century. Why should I hand-make a plywood box with bad-fitting joints when I can print out a press-fit one that doesn't even need any glue? And especially, why should we protect occupations that are clearly obsolete? You know, we used to have people whose only job was to go out to the lakes and cut ice and bring it into the cities and sell it. We don't have those jobs anymore. Should we preserve ice-cutting just for the sake of tradition?"
Harriet shook her head. "Maybe we should think a lot more about what *is* worth preserving and what traditions are worth sustaining.Maybe people need to think a little longer about what they're fabricating before they just press the button. I've been thinking a lot about 3D printers, because they've been so much in the news lately. And it's quite interesting how this idea

of the 3D printer has been sold to us." She took a sip of coffee. Grosvenor took advantage of the break in the conversation: "What do you mean?"

"It's like we're being sold the idea that we weren't able to do *anything* before 3D printers came along. Their slogan should be, 3D printers: MAKING MAKERS." Harriet gestured in the air as if a big banner was hanging there in the air over their heads. "And people have such cultural amnesia, thinking that this is such a revolution and we've never seen this kind of transition before. Back in the 50s, for example, electric power tools were only sold to industry or to workshops and craftsmen. They were high quality and durable, perfect for the professionals, but they were *only* sold to these people. So the tool brands started to think about how they could sell more. They started to develop multi-functional tools, additional power units, components and widgets, and all those new tools were meant for ordinary people because they were quite cheap. The other ones were quite expensive because they had longevity. But to sell to ordinary people the companies had to sell the *idea* of you being a craftsman even if you weren't. You could be equal to professional craftspeople by having this tool. And this is the same idea that is being sold to us now: you can be a maker by having this 3D printer." Harriet grabbed the paper. "So at least in terms of ethical behaviour and responsible consumption and preserving valuable skills, I'd definitely promote 'Respect hierarchy' and reject 'Compete'. 'Be exclusive' if it means we can preserve endangered skills. What's going to happen when we see the next energy crisis? All those fabrication tools are going to be silent and no one will remember how to use a hammer." She sat back in her chair.

"Hmm," Fernanda said quietly, "I don't really know about that. Some stuff coming out of the maker movement is undeniably crappy, but we are also seeing some excellent ideas that just couldn't have emerged earlier because of hierarchies – the silos separating engineer and scientist and craftsman."

Grosvenor snorted: "Oh, yes, excellent stuff like DIY-pharmacology. That's really safe. I would also go for hierarchy and being exclusive if it also means preserving natural resources, to add to what Harriet was saying."

"I'm surprised, Grosvenor," said Hugh, after a somewhat awkward pause. "I'd have thought that you guerrilla

gardeners and open source ecology crowd would rather promote contracts and agreements rather than capitulating to forms of hierarchy that are, let's be frank, completely obsolete in this day and age. I mean, aren't you actually breaking city rules rather than being loyal to them? Shouldn't we have globally binding carbon cap agreements rather than some flimsy reliance on ideas of honour and loyalty?"
Before Grosvenor could answer, Raissa raised her hand. "I think this could be a good point at which to introduce the next set of precepts." She put another sheet of paper on top of the first. This time the chart was expanded:

The Commerce Moral Syndrome	**The Guardian Moral Syndrome**
* Shun force	* Shun trading
* Come to voluntary agreements	* Exert prowess
* Be honest	* Be loyal
* Collaborate easily with strangers and aliens	* Be exclusive
* Compete	* Take vengeance
* Respect contracts	* Respect hierarchy
* Use initiative and enterprise	* Deceive for the sake of the task
* Be open to inventiveness and novelty	* Be obedient and disciplined
* Be efficient	* Treasure honour
* Promote comfort and convenience	* Show fortitude
* Dissent for the sake of the task	* Adhere to tradition

"Well, this gets more interesting," said Hugh, leaning forward and putting his finger on the left side of the chart. "I'd definitely agree that fabbing and hacking is all about inventiveness and novelty…" "Not to mention initiative and enterprise," Fernanda interrupted. "…But being efficient? That's the last thing that's on a maker's mind. Promote comfort and convenience?" Hugh laughed. "Have you actually *visited* my hackerspace or tried to use any of my inventions lately?" he said dramatically.
Grosvenor smiled, and then asked Raissa, "What does dissenting for the sake of the task mean here?" "Jane was referring to how commercial life can improve things or develop completely new things: dissenting from the way things were previously done, whether this is in production or distribution or whatever," she explained. "And deceive?" pursued Harriet. "Well, it helps, for one, to exert prowess: to both have power and use it effectively." Raissa checked her notebook.

"It comes down to us from our previous existence as hunters – the need to deceive in order to secure the prey; the cheese in the mousetrap. For survival, hunters need to understand the end goal and commit to achieving it, so does the military, and that's why tradition, obedience and hierarchy are so important to guardians."

Grosvenor frowned. "I'm not sure my network of growers fits in either of these categories. I mean, I was talking earlier about the importance of guardians and the need to protect natural resources and the public commons, but these precepts don't fit what we're actually doing." "Go on," Raissa nodded. "Well, as you know, we work a lot with developing urban agriculture and gaining a better understanding of our relationships with the natural ecosystems. Fernanda's fab lab is a perfect place to play with prototypes of stuff we need that we just can't find in the normal marketplace. And it's been great for learning stuff, as Hugh said. But it took a long time before we even knew what we were doing and could actually achieve things. Once we recognised the pattern, how we could best work together, we could identify the barriers and opportunities of working as a self-organised group. And we knew our skills, what each person was good at."

"So not actually a hierarchy," Hugh suggested.

"That's right. In fact, because there is no hierarchy, if something doesn't get done there is no one to blame," answered Grosvenor. "'Get done' in terms of what? What goals do you have and how do you decide on them?" asked Fernanda. "We tend to pick an idea from society that we would like to learn about," Grosvenor spoke slowly, examining the chart as he spoke. "We do research, but because we are not trained in those particular fields, for example, biology, then we go through sometimes a long research process to learn what we need to learn. Or we might need to learn how to weld. Or even act! So then – for example, with beekeeping – we come to understand what we already know and what we need to learn; we know our network, so we know what skills we already have. Then you can pick out the jobs that you can do or want to do, and, as I said, if something is left out there is no one to blame."

Fernanda appeared sceptical: "I know exactly what you mean, but it's a really hard way to work and it can actually end up being really exclusive because there is such a high threshold." "What do you mean?" asked Raissa. "I mean, people from 'normal' life are so used to company hierarchies and meetings and how decisions are made – you stick them in that kind of Bar Camp or Unconference style meeting, and they're totally lost. It is meant to be open and accessible and democratic, but it actually scares some people away. Even in the fab lab: because it isn't a normal print shop where you walk in and pay for a service, people just don't get that you're supposed to do your stuff yourself, that's the whole idea. If they want to learn something, they want to be given their role and the instructions. They don't want to self select, not to mention continuously self organise. Hence the high thresholds," Fernanda concluded.

"Yeah, there are a lot of growing pains," Grosvenor admitted. "We did that energy harvesting from waste project a couple of months ago; afterwards half the participants said it was a nice week, but the way we got there was total chaos. Some participants said, 'Please don't do it again'. The other half of the group said, on the contrary, 'Look at what we achieved. We managed to get everything we wanted'. So I think we're getting better at chaos." Hugh nodded: "It's a critical time – we're moving from an industrial era to a peer-to-peer era. We need to learn how to operate together." "Especially in an environmentally responsible way, not just socially conscious," Grosvenor added. "Everyone is so focused on the information commons – they totally neglect the public commons." Raissa looked around the group to see if anyone had anything further to say. She pulled out the third paper from the envelope. "This is now the whole chart," she said.

The Commerce Moral Syndrome
* Shun force
* Come to voluntary agreements
* Be honest
* Collaborate easily with strangers and aliens
* Compete
* Respect contracts
* Use initiative and enterprise
* Be open to inventiveness and novelty
* Be efficient
* Promote comfort and convenience
* Dissent for the sake of the task
* Invest for productive purposes
* Be industrious
* Be thrifty
* Be optimistic

The Guardian Moral Syndrome
* Shun trading
* Exert prowess
* Be loyal
* Be exclusive
* Take vengeance
* Respect hierarchy
* Deceive for the sake of the task
* Be obedient and disciplined
* Treasure honour
* Show fortitude
* Adhere to tradition
* Dispense largesse
* Make rich use of leisure
* Be ostentatious
* Be fatalistic

"Now I'm confused again," Hugh said. "As a society I don't think we should operate according to what looks like clear consumerist, profit-led capitalism," pointing to the left, "but neither am I attracted to what looks like Versailles on the right." Raissa nodded: "Yes, remember that Jane meant these as the characteristics associated with the system of commercial life on the one hand, to support daily needs, and the system set up around territorial responsibilities, on the other, to combat corruption and enemies. What is a virtue on one side becomes a vice on the other, so if you're operating in a particular syndrome some consistency is warranted – and rewarded. A mix can result in a confused morality, what she calls 'monstrous hybrids', such as organised crime or when governments try to operate like private corporations."

Fernanda interrupted her: "I have to disagree a little with Hugh. Being industrious and thrifty and inventive – and profit-minded – is the only way makerspaces are going to survive. You can have your lofty ideals, but ideals don't pay the rent. I don't see the problem people have with making money in the maker movement – what is so wrong with commercialising it? Why shouldn't we brand it and commoditise it so that it *really* can be open access – get rid of those high thresholds I was talking about earlier? Make the equipment easier to use so that – really – *anybody* can use it, even my granny? So what if the equipment producer is a big multinational. Wouldn't distributed production be a better economic model than mass production? More empowering, and maybe even more environmentally beneficial, Grosvenor?" she challenged.

Grosvenor looked like he was trying to control an outburst. "Distributing and democratising is not the same thing as sheer profiteering! I thought fab labs were all about open source. The more the maker movement is exploited by those big corporations, the more proprietary the equipment is going to be – and we're going to end up in the same mess we are now with mass production supply chains!" He took a breath, and then looked at Raissa. "Surely there are other ways. Aren't there other hybrids that are not monstrous?"

"Well, there are examples of commercial-guardian symbiosis that can escape mutual corruption, cooperative lending systems, for one, but Armbruster and I agree that we just don't understand them well enough yet, and there are so few examples existing to learn from," Raissa conceded. "But because this is a good point in the discussion, and also because we are running out of time, I'd like you to have the final discussion based on this." She pulled the final sheet from the envelope:

MARKET	**HIERARCHY**	**NETWORK**
* Shun force	* Shun trading	
* Come to voluntary agreements	* Exert prowess	
* Be honest	* Be loyal	
* Collaborate easily with strangers and aliens	* Be exclusive	
* Compete	* Take vengeance	
* Respect contracts	* Respect hierarchy	
* Use initiative and enterprise	* Deceive for the sake of the task	
* Be open to inventiveness and novelty	* Be obedient and disciplined	
* Be efficient	* Treasure honour	
* Promote comfort and convenience	* Show fortitude	
* Dissent for the sake of the task	* Adhere to tradition	
* Invest for productive purposes	* Dispense largesse	
* Be industrious	* Make rich use of leisure	
* Be thrifty	* Be ostentatious	
* Be optimistic	* Be fatalistic	

Fernanda sat forward and then hesitated, but the others nodded: "For one thing, the speed of markets is much better for today's society than the pondering, excruciatingly slow pace of government decision-making. If something happens, you need to react and it's better to react fast. Networks are much more resilient and agile." "What about trust?" asked Harriet, who had been strangely quiet. "Don't you need trust in both syndromes?" Grosvenor pointed out. "Or in all three types of organisation?"

"What is virtuous behaviour when you are operating in a network?" Raissa prodded. "I think in networks you are shunning self-interest," Harriet offered. The others nodded. "You want to share and collaborate, not compete," she continued.

"So you don't esteem the worth of contracts, you work to build your reputation instead," Hugh added. "You work in an open source project and you try to earn respect and polish your reputation in that network by contributing high quality work. Property rights are not important, and sanctions are normative, not legal, so contracts are rather irrelevant." Harriet wrinkled her brow: "So you mean quality is ensured through reputation maintenance? For artisans, that is also true, but it's more through discipline, and honour, satisfying the idea of what a guild would judge as quality. If everyone can be a designer, or maker, or artisan, like in a maker network, then I still think quality goes out the window."

"But it's as much about the means as well as the end, in sustainability networks, anyway," countered Grosvenor. "If you're working in open source ecology projects, the end goal is always moving and you always have to be in learning mode. Quality of the solution is how well it fits your resources at that moment and how well it actually accomplishes what you were hoping for." "That's why efficiency isn't a relevant value for a network," Fernanda pointed out. Hugh jumped in: "Maybe it should read, 'Be experimental' instead of 'Be efficient'." "Or 'Be reliable'?" Harriet said. Grosvenor smiled. "Invest in strengthening ties," he said. "Trade know-how," Fernanda offered. "Donate for the sake of the task," Hugh grinned.

Raissa closed her notebook and the group rose to their feet, taking their cups to the sink. "If you are so inclined, we could continue these discussions on this topic," she said, as Hugh reached for her cup and washed it. Everyone nodded, then looked at each other, embraced and parted ways until the next meeting.

The characters in this fictional dialogue, Fernanda, Hugh, Harriet and Grosvenor, represent various perspectives in today's Maker Movement, from Fabbers – enthusiasts of digital fabrication and especially its technical, commercial and entrepreneurial opportunities – to Hackers and Fixers, promoting a better understanding of mass-produced products as well as sheer invention; to Handicraft, craftspeople and artisans; to the Growers who seek to exploit digital fabrication but in more ecologically oriented urban practices. Several passages are actual quotes spoken by real makers in the European (mostly Helsinki) maker scene. Raissa is the Researcher who brought them together, and on her behalf I thank all the makers, my research subjects, for allowing me to observe and participate in this fascinating post-industrial transition.

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Citizenship and democratic production

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Citizens of Barcelona assemble a Smart Citizen Kit to produce open data. Photo: Gui Seiz, All Rights Reserved.

Abstract

The democratisation of all areas does not exclude production. The citizen-producer, on the one hand, takes advantage of the opportunity to harness networked knowledge and, on the other hand, benefits from new production spaces such as Fab Labs and maker and hacker spaces. New skills and know-how are required, however, for the inclusion of all social sectors. The appropriation of shared knowledge and infrastructure is fundamental to the promotion of a democratic and open productive citizenship.

In the last decades we have seen how the concept of innovation has changed, as not only the ecosystem of innovation-producing agents, but also the ways in which innovation is produced have expanded. The

concept of *producer-innovation*, for example, where companies innovate on the basis of self-generated ideas, has been superseded by the concept of *user-innovation*, where innovation originates from the observation of the consumers' needs, and then by the concept of *consumer-innovation*, where consumers enhanced by the new technologies are themselves able to create their own products (Von Hippel, 2005). Innovation-related business models have changed too. We now talk about not only patent-protected innovation, but also *open innovation* and even *free innovation*, where open knowledge sharing plays a key role (Von Hippel, 2017).
A similar evolution has taken place in the field of the smart city. While the first smart city models prioritized technology left in the hands of experts as a key factor for solving urban problems, more recent initiatives such as Sharing City (Seoul), Co-city (Bologna), or Fab City (Barcelona) focus on citizen participation, open data economics and collaborative-distributed processes as catalysts for innovative solutions to urban challenges (Cañigueral, 2016). These initiatives could prompt a new wave in the design of more inclusive and sustainable cities by challenging existing power structures, amplifying the range of solutions to urban problems and, possibly, creating value on a larger scale (Balestrini, 2017).
In a context of economic austerity and massive urbanization, public administrations are acknowledging the need to seek innovative alternatives to increasing urban demands (Saunders & Baeck, 2015). Meanwhile, citizens, harnessing the potential of technologies - many of them accessible through open licenses – are putting their creative capacity into practice and contributing to a wave of innovation that could reinvent even the most established sectors.

Contributive production

The virtuous combination of citizen participation and abilities, digital technologies, and open and collaborative strategies is catalyzing innovation in all areas. Citizen innovation encompasses everything, from work and housing to food and health. The scope of work, for example, is potentially affected by the new processes of manufacturing and production on an individual scale: citizens can now produce small and large objects (new capacity), thanks to easy access to new technologies such as 3D printers (new element); they can also take advantage of new intellectual property licenses by adapting innovations from others and freely sharing their own (new rule) in response to a wide range of needs.

Along these lines, between 2015 and 2016, the city of Bristol launched a citizen innovation program aimed at solving problems related to the state of rented homes, which produced solutions through citizen participation and the use of sensors and open data. Citizens designed and produced themselves temperature and humidity sensors - using open hardware (Raspberry Pi), 3D printers and laser cutters - to combat problems related to home damp. These sensors, placed in the homes, allowed to map the scale of the problem, to differentiate between condensation and humidity, and thus to understand if the problem was due to structural failures of the buildings or to bad habits of the tenants. Through the inclusion of affected citizens, the community felt empowered to contribute ideas towards solutions to its problems, together with the landlords and the City Council (Balestrini et al., 2017).

A similar process is currently being undertaken in Amsterdam, Barcelona and Pristina under the umbrella of the Making Sense Project (http://making-sense.eu). In this case, citizens affected by environmental issues are producing their own sensors and urban devices to collect open data about the city and organizing collective action and awareness interventions.

The FrogBox, a temperature and humidity sensor created by citizens of Bristol.
Photo: KWMC, all rights reserved.

Citizen-led work

In the last decade we have witnessed the emergence of new forms of micro-production through the expansion of the so-called citizen production laboratories – i.e., workshops for individual digital production -, equipped with a series of computer-controlled tools and materials which can produce "almost anything" (Gershenfeld, 2008). Fab Labs, maker and hacker spaces have emerged in most cities, and have established themselves as co-creation spaces for digital social innovation, for learning 21st century skills, and for citizen entrepreneurship.

A number of innovations have emerged from these laboratories, such as the free code 3D Ultimaker printer, or a startup that creates toys and electronic devices from waste in Togo. In many cases, these innovations are co-financed by citizens through micro-sponsoring platforms like Kickstarter (for instance, the Smart Citizen environmental sensor), or are being commercialized through p2p platforms such as Etsy. In this way, citizens contribute to their city's productive fabric, while learning new skills and creating job opportunities for themselves and others.

In addition, these design and production spaces enable the acquisition of digital production knowhow, creativity and collaboration, all of which have been highlighted as necessary skills for work performance in the future (World Economic Forum, 2016).

Citizen-led health

Digital social innovation is disrupting the field of health too. There are different manifestations of these processes. First, platforms such as DataDonors or PatientsLikeMe show that there is an increasing citizen participation in biomedical research through the donation of their own health data.

Second, creations such as the open-source artificial pancreas, resulting from the collaboration between scientists and amateurs (O´Kane et al., 2016), or projects such as the Open Hand project, which uses 3D printers to create prosthetic arms for low-income people, show that the combination of new technologies, the free code and citizen skills can improve the citizens' quality of life at a cost and scale previously unimaginable.

Finally, projects such as OpenCare in Milan and mobile applications like Good Sam show how citizens can organize themselves to provide medical services that otherwise would be very costly or at a scale and granularity that the public sector could hardly afford.

Citizen-led food

Eating/feeding is one of the most important and widespread human activities. However, industrial food production has a proven negative impact on the environment (FAO, 1996) and, from time to time, on public health (OMS, 2003). A growing number of

digital social innovation initiatives in this field are promoting the emergence of a food system that can improve people's lives and contribute to environmental sustainability, as well as to the creation of new production ecosystems in the cities.
Several existing manifestations of these processes allow us to view how networked citizen innovation can have an impact on the way in which we produce and consume food. On the one hand, initiatives such as the 900-strong Europe-wide Food Assembly, a local consumer platform that uses digital technologies to connect consumers and local producers, show that there is a willingness on the part of citizens to promote local production and consumption, and that this can be done at a very low cost, connecting already existing elements within the ecosystem.
On the other hand, projects such as Aquapioneers or Spirulina Lab show how customized digital production and open source tools allow citizens to produce their own food so as to achieve food self-sufficiency and reduce the negative impacts on the environment.
Finally, urban garden initiatives and projects such as Connected Seeds or the Grow observatory show how neighbourhood communities are organizing to re-appropriate existing spaces, using sensors to monitor environmental factors and digital platforms to share knowledge in order to produce food collaboratively at local level but on a larger scale.

Implications

The production processes of these products and services force us to think about their political implications and the role of public institutions, as they question the cities' existing participation and contribution rules. In times of sociopolitical turbulence and austerity plans such as these, there is a need to design and test new approaches to civic participation, production and management which can strengthen democracy, add value and take into account the aspirations, emotional intelligence and agency of both individuals and communities.
In order for the new wave of citizen production to generate social capital, inclusive innovation and well-being, it is necessary to ensure that all citizens, particularly those from less-represented communities, are empowered to contribute and participate in the design of cities-for-all. It is therefore essential to develop programs to increase citizen access to the new

technologies and the acquisition of the knowhow and skills needed to use and transform them.
It is also necessary to establish the collaboration principles between the city and its citizens, so that the right of citizens to contribute to the co-design of the physical and digital environment of the city is not only acknowledged, but also appropriately valued (through incentives and rewards), and their contribution motivated and not exploited for other purposes. To this end, it is essential to establish an ethical code and a set of engagement rules as the backbone of open citizen innovation and of a new contributory model for cities.

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Fabricating the City Itself

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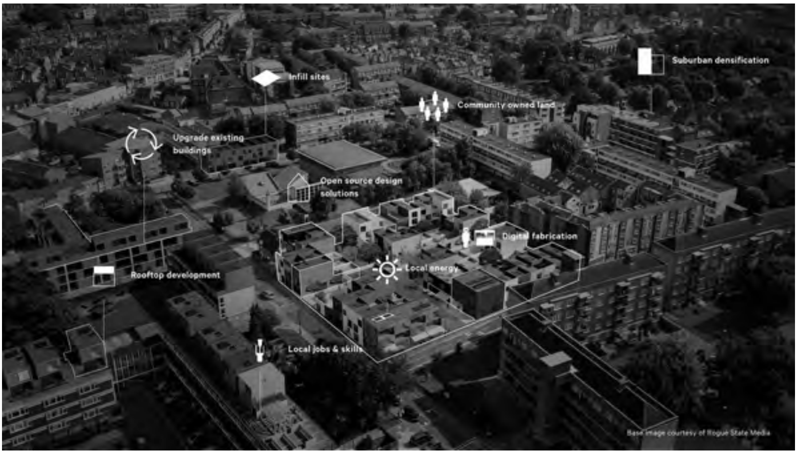

Since the industrial revolution, the production of buildings and neighbourhoods has been something done-*to*, not done-*by* local economies. The assumption has been that the only viable model for urban development at speed and scale was through centralised models of capital investment, labour and large scale mass-housing development, building whole neighbourhoods at once: rows and rows of small, one-size-fits-all homes to be rented or sold.

So when it came to housing, the defining political argument of the 20th century was not for or against this centralised model of urban development, but rather who should do it: the state, or the private real estate market.

What we overlooked is that the two models had more similarities than differences. Both require unsustainable levels of debt and risk, and both gradually become less and less affordable. Both see low-energy homes and circular components primarily as costs, not investments. Both design for an imaginary 'average' human. Both are hugely energy-intensive and wasteful. Both are based on linear material economies. Both treat people essentially not as active citizens and resilient communities, but as isolated consumers, dependent on external services, and therefore on jobs or welfare.

The problem is, these models simply won't serve us in the 21st century. By 2050, we have to support a global population of around 9.7 billion. Factoring in urbanisation, it is the equivalent of building a city the size of New York every 5 weeks for the next 33 years. There is no company, no government, no organisation that can do this using the old model alone.

So what are the alternatives? There were very real, practical reasons why we had to stick exclusively to the centralised model, where a small number of large developers build cities for us. Put simply, the cost, risk and difficulty of designing and building homes was so high, that the 'long tail' – the many small citizens and local businesses building homes for themselves – was not seen as a scalable, regulatable or investable economy. It was just seen as 'informal housing'. More problem than opportunity.

Digitisation is giving us the opportunity to change that. Just as the web has transformed our information and services economy by moving from centralised to distributed models (think Wikipedia and AirBnB), so the web and digital fabrication are bringing about a similar revolution in the production of physical things. This of course, is the core of the Fab concept, and it applies to many domains, from energy, to clothing, to food to electronics, to tools. But of all these, we believe the production of the built environment itself – our homes, workspaces and community buildings – is most ripe for transformation, and one where a change is most desperately needed.

It's not hard to see a better production model for cities. One where local communities and economies have access to the open knowledge and tools to design and digitally fabricate buildings for themselves. Where sustainable design solutions are common knowledge, and are easy to customise, fabricate and assemble. And of course the city is never finished: it is a continuous process of maintaining, upgrading buildings, and then re-using the parts. If part of your building needs repairing, you should be able to do so yourself, or in a fab lab down the road.

But to make that common vision a reality, we need to start working quickly. Six years ago, we started the WikiHouse project as an experiment, and were almost shocked by how well it worked, and how enthusiastically it was taken on. It turned out we weren't the only ones who could see this future, and saw the opportunity to apply the lessons of open source software to the built environment.

The first WikiHouse technologies are now being used commercially in pilots in various places around the world, but there are still only a small handful of technologies, primarily based on WikiHouse WREN, which uses plywood and CNC routers to fabricate a flatpack-style kit. But most of the digitally fabricated construction methods haven't been invented yet.

We need a wave of innovation, developing locally-appropriate, digital, modular, fabrication machines and construction solutions that can deal with all kinds of densities, climates and cultures and use all kinds of materials as a feedstock, from wood to recycled plastics, concrete to composites and bio-materials. Methods will range from cutting, to milling, to 3D printing to extruding to growing. Teams need to be ruthlessly practical in testing their innovations in terms of simplicity, cost, scalability, factory cost, meeting regulatory standards and addressing cultural barriers adoption (in other words, the buildings have to be beautiful). They also need to be courageous enough to open source their technologies, allowing others to improve them, so no problem needs to be solved twice. We've shared the basic design principles we use https://wikihouse.cc/about.

The second thing we need to do is invest to build the common digital infrastructures: to connect up this distributed network to form open, distributed supply chains. That's what WikiHouse Foundation is working on next, using web-based automation to try to make it as simple as possible for small players to design and deliver projects. Along the way, we're working with partners to explore fascinating new domains, from new land ownership and investment models to digitising regulation, open standards and smart contracts.

The final step is to bring the two layers together: locally-appropriate fabrication methods, running on shared supply chains. That allows local teams with one-off prototypes to replicate them across neighbourhood and city-wide pilots.

For example, we are working with local housing associations to unlock the thousands of small sites and rooftops in their cities; which have always been neglected by the centralised development model. The central message is this: We *can* take on the big, wicked challenges of building sustainable, equitable, circular and resilient buildings and neighbourhoods. And we *can* do it at the scale and speed we need to. But we won't do it just by sticking to the same old centralised models, building houses *for* people. Rather, the only way to do it is to put the tools and knowledge directly into the hands of local economies to build *for themselves*. In other words, as paradoxical as it may seem, if you want to solve a housing crisis, *don't build homes*; build the capacity of local citizens and businesses, and the homes will take of themselves. For us, that is the amazing potential of the Fab City vision, and when it comes to the production of our built environment it's a very serious proposition. If we can work together, within a decade we could be living in an economy where it is considered quite normal to locally fabricate low-cost, high-performance buildings. It is a practical, achievable and necessary aim.

Making as Social Fabrication: Towards a new Fab Commons?

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After cautiously appearing with the new millennium and making its official start some ten years ago, *Making* has become a term attached to a phenomenon that will persist for a while. Its various incarnations—maker movement, Fab Labs, maker spaces—have become the subject of political agendas, socio-economic and academic inquiry. *Making* is a pastime, an educational innovation, a new renaissance, reuniting the liberal arts with science and engineering and constituting a new industrial revolution which claims to empower people through technology. *Making* has a geeky flavour to it, consciously or unconsciously as an ingredient of the branding of some maker initiatives. Yet *Making* has certainly become more than just the occupation of a few consenting nerds.

Making is starting to have an economic impact as boutique manufacturers integrate principles of *Making*—such as prototyping, digital tools, open source and communities—in their business models. There is potential for self-employed and micro-enterprises to build a network and grow laterally instead of only gaining more mass individually or being swallowed by some large multinational. In that context, it is interesting that businesses are also starting to prototype their business models as they grow.

Even incumbent industry is starting to develop an interest in these principles and is looking into new ways of innovating and manufacturing. Whether the reason for this is open innovation, more effective use of internal talent or simply employee retention that motivates companies, *Making* is becoming a ‘tool’ in the hands of business. Yet incumbent industry could also benefit from the networked, lateral approach that is often at the core of collaboration between *Making* initiatives.

Leaving traditional GDP-oriented markets and economics, *Making* also develops a strong social meaning. Aizu and Kumon (2013) coined the term Social Fabrication and understand it as part of a first information revolution that is happening in parallel to the third industrial revolution (in the sense of Rifkin (2011)). They foresee a further development in which robotics and new social institutions will form. *Making,* in that context, is not just an activity of producing goods, rather it is a social activity—deep play (Rifkin 2004), conviviality (Illitch & Lang, 1973), and building a commons.

Making has a significant link to education. There is a strong call for more STEM education, which is not undisputed but resonates with the skills demanded by a high-tech world. There is an equally strong drive to equip students with 21st century skills which, some argue, could be achieved by including *Making* in the curriculum—as a very concrete, hands-on implementation of constructionist learning.

However, adding, for instance, a Fab Lab to a school or university also requires a profound revision of educational practice, including planning activities and assessing performance and outcomes. Simply offering something different for a change is not good enough, and revising education also needs to address the question in whose name education is offered, why to provide maker education and not only how and what.

Making and urban (re)development are also connected. On the one hand, there is a new and changing manufacturing industry, from boutique to established, that is looking to accommodate its activities, ideally in places that reflect the spirit of *Making.* On the other hand, there are many places in which post-industrial urban (re)development is desired or already happening, for which *Making* is an attractive ingredient—much akin to the argument of the creative class.

However, the spirit of *Making* is not just redoing urban development with a new ingredient. Rather, the social and empowerment character of *Making* is supportive of new ways of urban development—urban development as a collective process of change (Peek, 2015), Fab City as a data-in-data-out system replacing

the traditional product-in-trash-out paradigm (Diez, 2016), and fair gentrification (Godsil, 2013).
Finally, there is also a deeper link between *Making* and contemporary urban (re)development which relates to the issue of prototyping. Prototyping is one salient ingredient of *Making*—both with respect to the products of services and with respect to the way a *Making* business is established. Prototyping—or rather an incremental development path—is becoming a key characteristic of urban (re)development. The latter is evolving into a much more co-created practice that leaves room for experiments and creates multi-dimensional value—social, economic and physical.

The Future is Lateral

There is a common thread which connects the three areas discussed, namely *Making*, education, and urban (re)development—a different way or organising, grouping, aligning and governing activities in these fields. This way of organising is resounding a theme that has been discussed in economics, social science and to a certain extent in organisation theory for a while: the theme of the network (Barnes, 1954), of self-organisation (Trist & Bamforth, 1951), of peer-production (Benkler, 2006), of the Commons (Ostrom, 1990) and of lateral governance (Rifkin, 2011).
If considered to be more than just an assembly of individual maker heroes, ***Making*** is fundamentally cooperative when it eschews the lure of venture-capital fuelled individualism with its grim exit perspectives. The future of *Making* lies in cooperation: the key to Fab Labs and the maker movement is not personal fabrication, but social fabrication. The grassroots proponents of the maker movement basically carry the power of lateral governance.
There is maybe a threat of corporate takeover in *Making* if multinationals start to sponsor *Making* activities and begin to incorporate pockets of *Making* into their own structures and operations. There is a threat to groups within *Making* to become overly self-contained through aggressive branding, wanting to become world-leaders in *Making*, establishing standards that exclude rather than include the out-group. The answer to these threats is to return to lateral governance and to nourish the network, even if there is no easy ready solution and even if one has to abandon the craving to achieve the position of ‘the first’, ‘the biggest’ or ‘the leading’ enterprise and adopt a lateral attitude.

Such an attitude must come from **people** who have learnt to think, learn and act in laterally governed settings. The most prominent setting to learn such an attitude is certainly education. Being able to interact laterally is learnt similarly to 21st century capacities. Both essentially require personality development gained through being exposed to situations that require these capacities, rather than memorising facts and behavioural action scripts.

Creating situations of lateral governance in education means fundamentally discarding instructors and educators as hierarchically superior. In a constructionist educational setting, teachers must act rather as facilitators, curators, navigators of a field or discipline, approaching teaching from a lateral attitude themselves.

The **places** where *Making* will happen also need to be developed, maintained and governed in a lateral way. Many development initiatives —however naïve, idiosyncratic and non-cooperative they sometimes might be— already aim to co-create urban spaces and places. City councils and regional and national governments are increasingly waking up to the call and are eager to include grassroots initiatives and to create an environment for lateral development—albeit coming from a traditionally hierarchical position. There is still a lot of room to create and animate cooperation, to provide education about the commons, and to develop lateral business and governance models in urban development. The right criteria to evaluate initiatives need to be found, inclusiveness has to be addressed and a possible bias towards corporate solutions has to be investigated. Grassroots initiatives often also have to stop themselves being competitive and develop a relationship of 'coopetition'.

Beyond Consenting Nerds

For Making to move beyond the circles of consenting nerds it needs to contribute to the bigger challenges of society—becoming economically, socially and ecologically sustainability, developing the network, achieving equality, defying technocracy, and elaborating on the notion of lateral governance.

Sustainability

Notwithstanding its limitations, *Making* can have a substantial impact on sustainability—economically, socially and ecologically. For *Making* to contribute to economic sustainability there needs to be a development away from depending on public subsidies and towards developing value propositions that allow makers to become economically self-sufficient. Experience shows that this requires new approaches to creating value that are based on network approaches and involve multiple, interdependent parties. Such business models are not taught at business schools and do not emerge from the practices of general business consultants. Rather they require conscious co-creation by the parties involved and, as examples have shown, 'uniting profitability with a 2.0 and open rationale, thus solving the "puzzle" of the open business model' (Delbosc, 2014, p. 59).

For *Making* to contribute to social sustainability it needs to pursue its path of individual empowerment. However, it is important not to leave social innovation and empowerment to chance: social innovation must be pursued actively and in conjunction with attaining economic sustainability. Many enterprises in the 'sharing economy' have promoted individual empowerment as social innovation, but eventually only recreated an old-style 'renting economy' in which those entities which profit economically from a 'sharing' business do so by exploiting resources they do not even own and augmenting inequality. By creating networks of value creation, *Making* will be able to contribute to positive social transitions that broadly contribute to diversity, equality and inclusion.

Ecological sustainability is an equally challenging call for *Making*. Energy and material consumption and waste generation are serious issues at present. Taking 3D printing as an example, the materials used are either ABS (acrylonitrile butadiene styrene, a common plastic polymer) made from oil or PLA (polylactic acid, a bio-based polymer) which is often made from genetically modified corn. While oil is not a sustainable source of raw materials, the issue with corn is the competition between food, material and biofuel manufacturing for farm land. Both materials, ABS and PLA, do not degrade naturally in landfills. There are currently no easy recycling routes for these materials that would guarantee the material safety that is required in their application. Research on sustainability in Fab Labs has only just started (see, for example, Kohtala, 2013; Kohtala, 2016). So far, the conclusion is that it remains to be seen if Fab Labs are able to transform themselves into a platform for participatory ecological innovation.

Network

Despite its prominent place the term network has, for instance, in the Fab Charter—it stars with the sentence 'Fab Labs are a global network of local labs' (CBA, 2012)—and the important functions the network is supposed to provide—'operational, educational, technical, financial, and logistical assistance'—the Fab Lab network has still to develop. Other initiatives in *Making* are even more disconnected and thrive, for example, mainly on the marketing efforts of Makermedia.

There are a few services the network offers to the Fab Labs, mainly a couple of yellow pages listing the Fab Labs globally. There are also a number of websites offering guidance for setting up Fab Labs and a plethora of other sites aiming to promote exchange, to create business opportunities and to attract funding. It has been acknowledged early on in the Fab Lab network that it requires multiple forms of alignment—lateral, bottom-up and layered instead of top-down—and that the network needs distributed leadership that is based on influence, not authority (Cutcher-Gershenfeld, 2007). Yet many of the initiatives to strengthen the network are in actual fact authoritative approaches as they are try to become the single central resource for a certain purpose or to define what a Fab Lab is once and for all.

Equality

The annual ritual in which the Fab Lab network gathers for an international fab forum and symposium (or 'conference and festival' as it was called in Barcelona in 2014) is one established structure for promoting connections within the Fab Lab network. Local and regional Maker Faires have a similar function. The growing attendance to these events, however, conceals that they risk losing out on broad, inclusive participation from the whole network. The cost of attending is high if it involves international travel to far away countries—and for a large section of the *Making* population any destination is by definition far away. Spending several days away is a substantial demand on the time budget of many a maker. Remote participation is virtually impossible, and while selected content might be available as a video stream, bandwidth at the receiving end might not be sufficient. It is a huge challenge for the whole maker movement to become and remain inclusive and not to create a divide between the ordinary members of the maker movement and a Making elite. However, developing the sharing capabilities of the network is a burden borne mainly by the wealthy participants in the network. There is a potential issue of colonisation, of the Western white male ideology (or role model) dominating the discourse. A telling example is the promotional video 'A Fab-ulous Future: What Is a Fab Lab?' by the Manufacturing Institute (2012) where a plane is seen circling the earth and parachuting replicas of the Manchester Fab Lab onto remote parts of the planet.

Technocracy

Another challenge which *Making* faces is its position in relation to social and political questions, as was mentioned above. The louder voices in the maker movement appear to side with the ideals of liberal individualism, projecting makers as a new breed of Randian heroes. Is this image of the creative individualist, who perseveres against all odds in the pursuit of his goals—even when his ability and independence lead to conflicts with others—really the ideal *Making* aspires to? As *Making* empowers people through technology, they have to acknowledge that technology is a site of power. Consequently, the question needs to be asked 'In whose name is this done?' If the maker movement is indeed the final phase of winning the digital revolution (Gershenfeld, 2006), the earlier developments in this digital revolution should be a warning: the first decade of the Internet revolution (approx. 1995 to 2005) brought horizontality, cooperation and decentralisation, and a vaguely anarchistic outlook. The second decade of Web 2.0 with its focus on data placed central control in the hands of unregulated corporations, 'politically speaking … a counter revolution' (Stalder, 2013).

What is required is developing a critical discourse around a few implicit assumptions—technology is not neutral but 'society made durable' (Latour, 1990), technology and people are 'entities that do things' (Latour, 1994), and technology comes with built-in societal, cultural and political assumptions. Participation will not just work, out-of-the-box as it were, but is influenced by local cultural and social variables, such as heterogeneity and the role of elites. Downward accountability and upward commitment are key to making participation work (Mansuri & Rao, 2004). As *Making* is at the forefront of technical innovation in and for society, in moral controversies it is expected to provide leadership and not to adopt a ‘neutral’ hands-off attitude. Overall, in Morozov's analysis, ‘there’s more politicking—and politics—to be done here than enthusiasts … are willing to acknowledge’ (Morozov, 2014). A particularly difficult case in point is the issue of funding of Fab Labs and their activities by large business corporations.

Lateral

While still growing at an exponential pace, the maker movement, Fab Labs, maker spaces and makers in general have to develop their practices of interaction and exchange. They have to keep abandoning top-down, centre-out as the one single possible imaginable approach for organising and experimenting with polycentric, bottom-up and lateral schemes. This in fact means that actors need to engage in constructing their practice and becoming institutions in ‘a dialectic synthesis of what is going on in a society and what people are doing’ (Sztompka, 1991, p. 96). They will need to avoid the potential enticement of the corporate privatisation of *Making* and the cajolement of fab-washing. While being earnest—as an infrastructure for learning skills, developing inventions, creating businesses and producing personalised products, and as a movement that is building its identity in a complex socio-technical and politico-economic environment—Fab Labs should not forget that play is a crucial ingredient, as is their non-utilitarian social role as third places, distinct from the first and second places of home and work (Oldenburg, 1989), providing for civil society, democracy and civic engagement.

In the long term, *Making* has to prepare for a time when the concept has lost its novelty, when fabbing is not fabulous anymore. Depending on the decisions players like Fab Labs make about their purposes now and the routes they take in the near future, this could mean retiring to the position of consumer-oriented, commodity-producing facilities for consenting nerds, or being part of a much broader development of the cultural, scientific and political (re)configuration of society.

A Fab Commons

Eventually, for *Making* to contribute to a more equitable society within the means of the planet (Raworth, 2015) lies the necessity to abandon the market/state duopoly of the first and second industrial revolution, the market economy that is based on the assumption of unlimited growth and the fair functioning of the free market. The principle of the commons has been proposed as a generative paradigm to step outside of the dominant discourse of the market economy. A commons is a social system for the long-term stewardship of resources that preserve shared values and community identity (Bollier, 2014, p. 175). *Making* as social fabrication requires developing such stewardship for people and planet.

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PAPERS

Thinking social housing through robotic technology: DESIGNING AN ARCH-ROBOTIC HOUSING SYSTEM

Adriana Lima
Eduardo Lopes

Abstract

The paper focuses on the possibility of thinking social housing production through robotic technology in architecture.
Initially naming this theoretical-projectual initiative as ´arch-robotic housing system`, the paper explores some ideas that have been generative of the proposed approach to social housing.
A number of conceptual variables have been considered, as the potential of customized production instead of mass production; and the increasing multiplicity of benefits that these concepts enable for thinking such gaps in architectural theoretical-projectual explorations. Also, considers the increasing use of technology in architecture for the purpose of making possible the construction of complex articulations of form, structure, program, and context for the corporate industry. Digital technology that could be used also for a low-cost project and to improve areas of social importance as the construction of social housing.

Keywords: robotic architecture; parametric design; housing problem

Introduction: A paradigm shift

As has been theorized by many architects, historians, and theoreticians in the field of architecture; one of the most important characteristics of the use of digital technology in architecture is the possibility of dealing with complex, and networked problems. From the concept of complex forms, as the curvilinear turn

and topological variations of space, to the network of information systems that give to any specific location in the globe the potential to interact with others.
The paradigm shift explored in this paper relates to the turning point of the endless variation of a topological series, where the object can be materialized considering its temporal ´duration` as an additional parameter of the differential series.
The paper explores the effects of this paradigm shift in the production of social housing. The possibility of thinking architecture as not based on a mass industrialized system, but on a customized system approach. Departing from the design of typological housing units to a design based on a performative set of variations pre-established in its hybrid and mutational component.
´the Design of Robotic Fabricated High Rises design research studio at the Future Cities Laboratory illustrates a pioneering attempt to place digital fabrication in the context of architectural production, and to explore the potential of robotic construction processes in the context of large-scale residential tower developments. In order to overcome the prevailing paradigm of repetition and mono-functionality in such urban developments`, (Fabio Gramazio, Matthias Kobler and Jan Willmann, 2014)

DCP (Digital Construction Platform)

The arch-robotic housing system is thought as a ´loosely bound aggregate field` (Stan Allen, 1999) of generative components. It is composed of three parts that articulate different functions in the overall system. The arch-robotic technology is thought as a generative component of the housing system. After generating the housing components, assembling and connecting them, part of the arch-robotic generative components become embedded in the constructed house unity as its structural system.
The sequence of functions follows the common construction logic: structural foundations, anchoring platform (fig. 1), structural frame (fig. 4), and the mini-not, named in this paper as ´bot-shell habitat` (fig. 6). The structural frame functions also as a guiding device for extrusion. The structural frame when used as guides for the ´in situ` fabrication, has a similar function as a DCP (Digital Construction Platform) (Keating, Steven J.; Leland, Julian C.; Cai, Levi; Oxman, Neri, Mediated Matter Group, MIT Media Lab, ´Toward site-specific

and self-sufficient robotic fabrication on architectural scales`, 2017).

The basic assumption for the development of the arch-robotic housing system is the increasing importance that this technology has acquired in architecture.

´Over the past decade, robotic fabrication in architecture has succeeded where early digital architecture failed: in the synthesis of the immaterial logic of computers and the material reality of architecture where the direct reciprocity of digital designs and full-scale architectural production is enabled. With robots it is now possible to radically enrich the physical nature of architecture, to ´inform` material processes and to amalgamate computational design and constructive realization as a hallmark feature of architecture in the digital age, leading to the emergence of a phenomenon we described a few years ago as ´digital materiality`. (Fabio Gramazio, Matthias Kobler and Jan Willmann, 2014)

Architectural Expanded Technological Field

The main objective of the paper is to find new design solutions for the housing problem that is pervasive in the logic of space-production in contemporary society. Combining two main vectors in the architectural expanded field (Anthony Vidler, 2013) of research; the low cost that a high technology development is achieving – the use of robotic technology - with the necessity of attending a customized production of housing for a diverse group of people, in different societal configurations, specific urban contexts and natural conditions, as topography and climate variations.

The architectonic-robotic house is primarily thought as a programmable robotic platform that auto-generate the house components. The structural system is composed of articulated parts of the proper platform that unfold in space. Other components, as interior walls, or interior-exterior interface components are extruded and connected by the mini-bot shell habitat. The house generates itself as a living organism, following the pre-established programmable variations digitally configured on the robotic platform.

The paper concept exploration follows Marco Vanucci`s open system approach in the ´new generation of parametric design systems`:

´The instrumentation of parametric setups into architectural practice is starting to shift the role of the architect in the design processes: from the design of specific shapes to the determination of those geometrical/algorithmic relationships describing the project and its components. ` (Marco Vanucci, 2008).

The architectonic-robotic housing system generates a new tectonic logic through its building process. Building process that amalgamates the different phases of architectural production. Architecture free itself from the rigid linear sequence of thought from the first sketches to the site of construction. A concept can be thought at any stage and progress in any direction.

´robots are now connecting technology and knowhow, as well as imagination and materialization, like never before, and have the potential to reveal a radically new way of thinking about and materializing architecture.`, (Fabio Gramazio, Matthias Kobler and Jan Willmann, 2014).

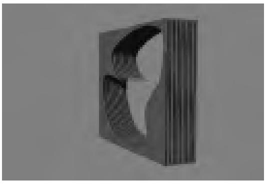

Fig. 1. Conceptual modeling: structural frame of the DCP (Digital Computer Platform)

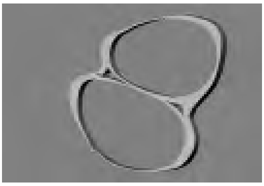

Fig. 2. Conceptual modeling: prototyping the shell-habitat

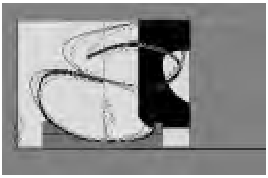

Fig. 3. Sketching the shell-habitat

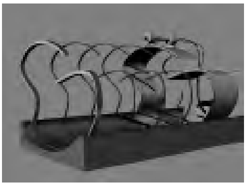

Fig. 4. Conceptual modeling: structural frame of the DCP (Digital Computer Platform)

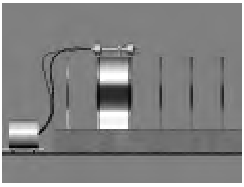

Fig. 5. Conceptual modeling: structural frame of the DCP (Digital Computer Platform)

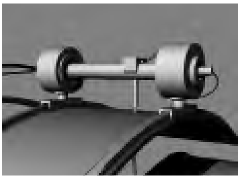

Fig. 6. Conceptual modeling: mini-bot shell-habitat

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FabLab in Nigeria's Innovation Space: A Report from GreenLab Microfactory's DIWO Event

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Abstract

The present overall impact of the FabLab initiative is tremendous, with records of its significance been recorded across different economic sectors, from the agriculture, energy, education, and to the health sector. However, with recorded advantages, Nigeria a country of approximately 200 million people does not have one. In lieu of this, on the 20th of April 2017, GreenLab Microfactory, the first registered FabLab on Nigerian soil, kicked off with a Do-It-With-Others (DIWO) workshop, appropriately named AJUMOSE meaning collaboration or cooperation in the Yoruba language. The goal of the workshop was to promote the FabLab concept in Nigeria, to the participants, through displaying the significance of collaboration and openness in solving social issues currently existing in the Nigerian community.

This article gives an account of the event and its goals, detailing the results and findings from the workshop as well as benefits, lessons learnt which could be applied to future projects, and limitations of the event realised. The report also includes the analysis of feedback collected from the events participants.

1. Introduction

For a positive and sustained change to occur Chavis, Florin and Felix (1993) indicated the need for co-production of services by citizens and community institutions. For this particular reason was FabLab, a digital fabrication laboratory established. From numerous articles FabLab has been identified as a facility that creates a self-learning community (Morel and Le Roux 2016; Schelhowe, 2013), as a major facilitator of decentralized production system (Sylvester & Doring, 2014), as a hub supporting local embedded economies (Sylvester & Doring, 2014), as a potential facilitator of reverse migration from urban to rural areas for employment (Kulkarni, 2013), as a promoter of STEM, and as a social hub that encourages unhindered transmission of knowledge from the source to different destinations (Dyvik 2013).

FabLab was quoted as transcending the do-it-yourself (DIY) culture which on its own produces a unique breed of individuals that promotes a sustainable economy. Drawing from the benefits highlighted by Sylvester and Doring 2014, FabLab encourages a Do-It-With-Others (DIWO) which is also known as Do-It-Together (DIT) culture. Kohtala (2016) further illustrated other benefits accrued to the FabLab movement as an avenue for disruptive technologies where new practices around open design and open innovation compliments the effective and efficient usage of raw materials and energy as a sustainable alternative to bypass the negative ecological impacts of mass production, aligned with empowerment and peer learning for creative making and invention.

Drawing from these acclaimed benefits, the GreenLab microfactory was introduced in the Nigerian community to further provide adequate studies of the FabLab concept in a third world country, to measure its significant contribution to the global competitiveness and innovativeness of a country as depicted in the global competitiveness report and global innovation index (Osunyomi & Redlich, 2015).

In this research paper, section 2 takes a look at the growth of FabLab through the aid of a comparison study of the growth of FabLab highlighted by Osunyomi et al (2016) to the present growth rate as of May 2017. Section 3 provides a detailed analysis of the GreenLab microfactory, the first registered FabLab in Nigeria, detailing its objectives, and the report of its first open source event. Section 4 presents a synopsis of the participant feedback survey conducted on the participants of the event. Lastly, section 5 presents a conclusion and remarks on further study on the FabLab ecosystem.

2. Growth of FabLab

A prior research study was conducted on the FabLab ecosystem in 2015 (Osunyomi et al 2016), and during the study the global density of the FabLab ecosystem was 490 from over 50 countries. Zijlstra (2013) & Gershenfeld (2009) in their articles hypothesized that the numbers of FabLab doubles every 18 months. According to the initial research studies conducted on the FabLab ecosystem, we discovered that on a global presence this hypothesis is indeed valid, as the number of FabLabs in the world is almost triple two years after the conduction of the previous research. To further test this hypothesis we conducted a continental breakdown of the FabLabs which was compared to the initial breakdown down in 2015 (see table 2 and 3 below). From this we discovered that this hypothesis is valid in 5 out of the 6 continents, with Australia and Oceania still 3 FabLabs short, while Africa just slightly prove the validity of the hypothesis.

Table 2: Continental breakdown of the FabLab Network
(as of April 2015)

Continents	Numbers of FabLab Network
Africa	22
Asia	50
Australia and Oceania	6
Europe	273
North America	98
South America	41
Total	490

Table 3: Continental breakdown of the FabLab Network
(as of May2017)

Continents	Numbers of FabLab Network
Africa	45
Asia	165
Australia and Oceania	9
Europe	636
North America	196
South America	88
Total	1139

There are various evidences that proves that FabLabs are feasible, however, the sustainability aspect of the movement is left to the individual perceptions and abilities of the respective labs. Though sustainability of a subsidiary organization is organization-specific and solely dependent on the strategies embedded with the organization. Could the lack of sustainability be linked to the lack of collaboration between the FabLabs as highlighted in existing literatures (Osunyomi et al, 2016)?

3. GreenLab Microfactory

The aim of GreenLab is to encourage small-scale development of valuable artefacts, by providing access to digital fabrication tools and technologies that encourages learning, rapid prototyping, ideation, innovation, and small scale development of artefacts. Furthermore, GreenLab aim to encourage the utilization of dormant, recycled and abundant eco-friendly materials and resources in rural areas to encourage innovation and sustainable development. From prior research studies, and in the recent published world's innovation index, human capital was identified as the most important resources on which the sustainability and growth of an economy is dependent. Without doubt, we purport that investment in human capitals and capabilities should be the stringent focus of third world countries in order to transcend beyond its poignant developing stage status. From a recent research survey conducted, Osunyomi et al (2016) discovered that a well implemented social digital fabrication initiative not only enhances human capital, but it also provides various empowerment opportunities for the populace irrespective of their social status. Therefore, the envisaged benefits of GreenLab microfactory in the community and country are very enormous, some of which are given below:

· Aid the development of endogenous technologies through communal learning, sharing, rapid prototyping, frequent oriental workshop conduction, and active engagement of the community

·Development of localized innovative strategies

·Enhance the country's educational system by fortifying and reorienting a STEM focus (science, technology, engineering, and mathematics) by initiating the integration of digital fabrication (DF) techniques in school curriculums. This has been identified by the innovation index as the major contributor to the innovativeness and competitiveness of a country.

·Adequate development of the human capital by increasing and encouraging more entrepreneurial flair and opportunities.

·Scalability: - The GreenLab micro-factory will use a scalable model, by localizing and reusing materials, such as using shipping containers rather than building real workshop, which means nodes can be added to the micro-factory without disrupting the productivity and quality of work done within the factory. Which also save quite some time and money.

·Replicability, Flexibility, Applicability, and Feasibility: - Due to the usage of localized resources, open sourced tools and technologies, and other eco-friendly / sustainable equipment. GreenLab microfactory can be easily replicated in other locations, and with a raction of the developmental costs incurred by existing human capital developmental initiatives.

GreenLab microfactory was launched in Ibadan, Nigeria on the 20th of April 2017. The initiative started with an open source DIWO event tagged Ajumose which spanned from the 20th to the 22nd of April.

The following section gives a detailed explanation of the event.

3.1. About Ajumose

The word ‘Ajumose’ is paramount to the indigenes of Oyo state, and according to the Yoruba language Ajumose could mean collaboration, teamwork, co-working, or cooperation, etc. The major agenda of Ajumose was to promote collaboration, openness, communal learning environment, and development.

It also aimed to show people the magnitude of what could be accomplished if they collaboratively focus on providing solutions to social problems by localizing the resources used for production.

Initially, the set objectives of Ajumose were to build a solar panel from scratch, and assemble 2 RepRap 3D printers. Of the 2 3D printers, one was a hangprinter, a low-cost open source 3D printer that could accomplish an enormous 3D printing, developed by a Swedish/ Norwegian confidant named Torbjorn. The second 3D printer to be assembled was an off the shelf RepRap 3D printer produced by Geeetech.

The numbers of participants were a little close to 80 with professional backgrounds ranging between, pupils (+ or - 40), high school students (+ or – 20), tertiary students (7), traders (5), teachers (4), artisans (car mechanic and photographer) (2), engineers (3), and Financial managers or accountants (3).The youngest participant was aged 4, while the oldest was 69 years of age.

The workshop started with a brief explanation of the objective of the workshop, explanation of FabLab, its concepts, its technologies, and its benefits. In addition, a brief explanation of the equipment to be developed was given, followed by acknowledging the sponsors, after which the participants were split into three groups. Group 1 comprised of participants below the age of 13, they were given in-depth lessons on the FabLab concept, a basic Arduino lesson covering chapter 1 and 2 of the Arduino project book, as well as a basic lesson on how to use a CAD software. Group 2 comprised of participants above 13 years of age but assigned with the task of assembling the 3D printer. Lastly, group 3 also comprised of participants above 13 years of age and they were equally assigned with the task of developing and assembling the solar panels. The following section entails the lessons learnt from the workshop, the benefits, and limitations of the workshop.

3.2. Lessons, Benefits, and Limitations

3.2.1. Lessons

Using a unique innovative strategy - HIDES which represents Hearten, Ideate, Develop, Explore, and Share. GreenLab microfactory attempted to reverse engineer the learning process by introducing the participants to the 3D printing technologies and solar panel development by charging them with the task of assembling one themselves. Drawing from the observation of the participants, this innovative approach proved to be much more effective because all the participants prior to the event had no knowledge about the existence of the 3D printing technology. However, a day after the commencement of the workshop majority of them were able to use the technical terms of the 3D printing technologies. This was mostly apparent when the component of the low cost 3D printer purchased for the workshop started giving unexpected challenges due to missing components, differences between the components listed in the manual and the packaged components, as well as some differences between the smooth linear rods of the 3D printer. Which inadvertently hindered the successful assembly of the 3D printer. However, the event participants had already acquired an ample knowledge about how 3D technology works, also they were able to state most of the technical components used in the open source 3D printing platform. From this event, two vital lessons were learnt, these are listed below:

1. As a community it is possible to achieve a lot if given a conducive environment. Despite all the setbacks experienced, the successful execution of a DIWO workshop is majorly reliant of the complementarities, accumulation, and utilization of diverse knowledge and experiences.

2. The second lesson learnt, is that the bottom-up approach is not only applicable in small-scale manufacturing. From the event, we discovered that bottom-up concept could be applied in the learning environment with the potential of shortening the learning curve to empower people in rural communities hence bridging the knowledge-divide. The efficacy of the bottom-up learning approach is evident in the genuine approach used to teach the participants about 3D printing. By providing a do-it-yourself 3D printer kit, and not an already assembled 3D printer, the assembly team were able to gain major knowledge about the technical components of a 3D printer, as well as the functionalities of the technology. Which proved to be a breakthrough experience even when the 3D printer could not function as planned.

3.2.2. Benefits of Ajumose

The most humbling benefit of the workshop occurred on the second day of Ajumose. On this particular day, a group of final year students from a nearby high school attended the workshop to participate right after their national examination. In order to explain the FabLab concept, open source, GreenLab, and other topics, I decided to reverse engineer the teaching process by quizzing the participants in group 1 about all the concepts, and to my greatest surprise the children displayed an impeccable level of gathered knowledge by confidently answering all questions asked correctly, therefore imparting knowledge to the high school participants that were on average 7 years their senior.

Other benefits include:

1. Provision of new knowledge, information, and technology
2. Social and community togetherness where Ajumose noticeably brought joy and opportunity to a community of individuals that otherwise may not have had such an opportunity
3. Empowered participants and the community to think about and be drivers for change in their innovation space therefore enabling the solving of social issues, especially in the region of electricity generation, through the development of a solar panel system.
4. Introduced opportunities for participants to develop both technical and intellectual skills in the form of soldering, equipment construction and critical thinking
5. Recycling and reusability of resources otherwise

rendered useless in the form of the salvaged wood used for the frame of the solar panel.

6. Tinkering: This became obvious when the 3D development team noticed some differences in the rods of the y-axis and z-axis of the RepRap 3D printer being assembled. They collaboratively solved the problem with the y-axis, but the z-axis was unable to be fixed.

3.2.3. Limitations of Ajumose

No matter the yardsticks used to measure the success of Ajumose, it would have been seamless without the following limitations:

1. Inadequate access to Internet services: In this day and age, the Internet has been the fastest, convenient, and one of the most reliable source of information. Which made it impossible to gain access to the assembling /building video of the 3D printer. Fortunately, with regards to the development of the solar panel system, videos on how to build a DIY solar panel system were already downloaded. This proved very useful when the information were needed.

2. Epileptic power supply: Though the GreenLab microfactory was conceived to be self-sustaining and to a large extent independent on external resources that are not ecology-friendly. Right from day 1, due to the inconsistent power supply we were humbled to resolve into using electricity generators to power the tools used during the development process. Most importantly during the development of the solar panel that needed a constant electricity due to the soldering and connection of the solar cells.

3. Inconsistent Group Leadership: This had both positive and negative effects on the success of the project. The negative being that there was a huge waste of time due to the lateness or nonappearance of the leader of Groups 2 and 3 (3D assembling and Solar panel) on the following day's activities. However, the inconsistencies gave opportunities to some individuals to assume the role of leaders, fix the problems at hand, and decipher a way forward with regards to the specified objectives of the workshop.

4. Unparalleled assignment of roles and responsibilities: this limitation builds on the previous limitations of inconsistency with the group leadership. This would have been adequately handled if roles and responsibilities were assigned to the members of groups 2 and 3, but due to the novelty of the organization, event and the community. Vital lessons

were learnt that would be built on for future events
5. Cumbersome workload of the workshop on the organizer: At some point during the workshop, the organizer was literally being summoned by all the groups. Which hampered the progress of the groups.
6. Inadequate tools and equipment: During the workshop, we had to improvise for some tools. Most of the equipment used for the workshop were brought from Germany. Due to inadequate infrastructural development and technology advancements, some tools and basic resources needed were impossible to get. Which was profound when the 3D printed objects for the second 3D printer (Hang printer) got damaged during the long flight to Nigeria, which after two attempts to fix it led to the cancellation of the development of the hang printer. It also crippled the progress of the event.
7. Insufficient funds: A majority of things done during the workshop would have been easily accomplished if there was sufficient fund. As indicated earlier, Ajumose was solely sponsored by LaFT, who basically covered the acquisition of the technologies used for the workshop. Due to the size of some vital equipment, we resolved into trying to see if we would be able to find those technologies in Nigeria which proved abortive.
8. Non-functioning 3D printer machine: Due to the unexpected issues with the linear rods supplied with the 3D printer, having a functional 3D printer became a mirage.

4. Participants’ feedback survey Analysis

At the end of the event, we conducted a participant feedback survey to know how the participants learnt about Ajumose, their general interest, their level of innovativeness, lessons learnt, and suggestions on how to improve the Green vision of the GreenLab microfactory. The questionnaires were distributed to the participants above the ages of 13 which comprised of the development and assembly groups (group 2 and 3). The survey was conducted on a population 30 of the participants, out of which we collected 15 responses, which equates to 50% response rate. This section presents analysis of the participants’ feedback survey based on the gender distribution of the participants, profession, qualification, awareness of the DIWO event, knowledge of digital fabrication initiatives, factors inhibiting their innovativeness, and suggestions for the GreenLab microfactory.

4.1. Gender of Respondents

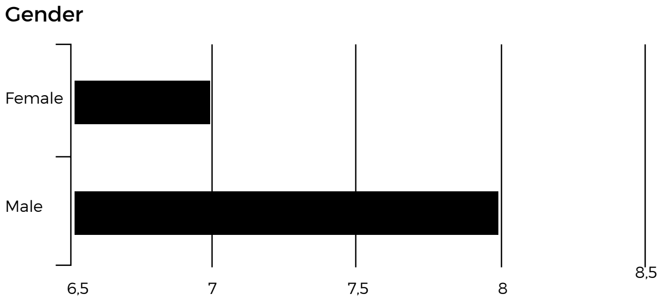

Fig. 1: Gender specification of the respondents (n = 15) x

From the figure above, 53% (8) of the respondents are male while 47% (7) are female. However, the gender of the participants had no significant effect on the tasks of the event. As all the participants took equal turns in soldering at least one solar cell, had their opinions voiced most importantly when faced with some technical limitations, as well as fulfilling a role or task as assigned by their local leadership authority. This typifies the egalitarian structure portrayed by the FabLab ecosystem.

4.2. Profession

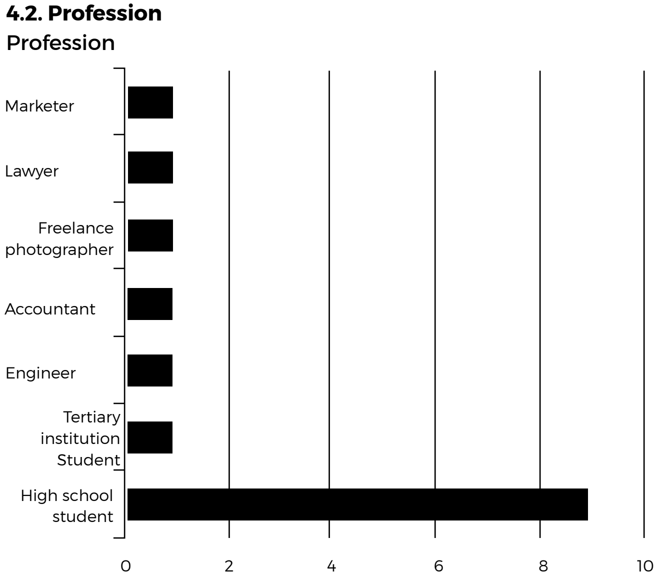

Fig. 2: Profession of the participants (n = 15)

The highest concentration of the respondents 9 (60%) are high school students, while the remaining respondents which ranges from engineers, accountants, lawyer, marketer, tertiary institution students, and freelance photographer constitute 7% of the responses. This typifies the sole purpose of the event which is to give equal learning opportunities to everyone irrespective skills or experiences.

4.3. Qualification

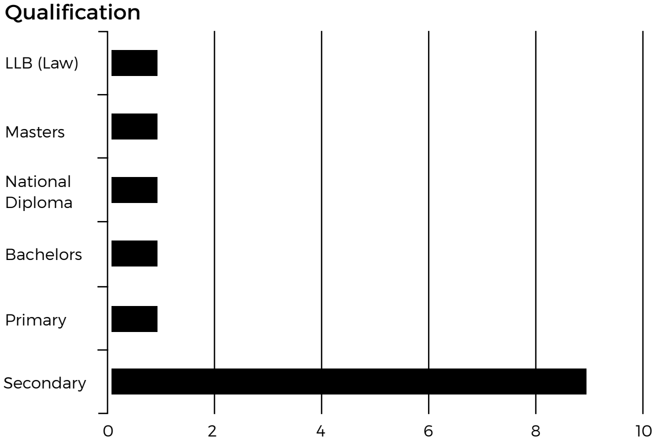

Fig. 3: Qualification of participants (n = 15)

As indicated in the figure 3 above, majority (64%) of the respondents have a secondary school certificate, while the rest which ranges between a LLB degree, MSc degree, primary school education, BSc degree, and an ordinary national diploma constitute 7% of the responses.

4.4. Awareness

Awareness of Ajumose

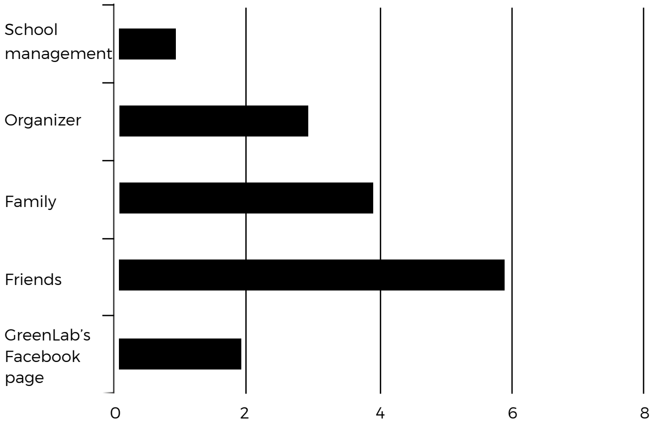

Fig. 4: Awareness of Ajumose (n = 15)

The respondents were asked how they learnt about the workshop, 38% indicated that they learnt from their friends, 25% indicated they learnt from their family members, 19% indicated that they learnt from the event organizers, 13% indicated that they learnt from GreenLab's Facebook page, while 7% indicated that they learnt from their school's management. This shows the effect lack of technological infrastructure has on socially oriented initiatives, therefore in the case of Ajumose word of mouth or personal referrals works better in a rural setting. However, in order to cover a huge area, social media plays a significant role.

4.5. Awareness of Digital Fabrication Initiatives

Knowledge of Digital Fabrication Initiatives

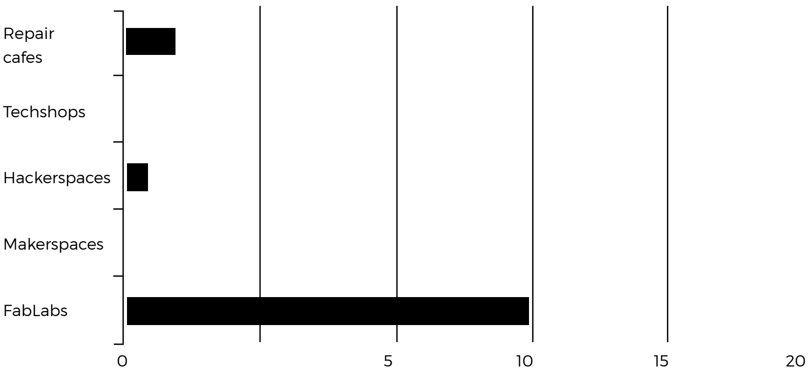

Fig. 5: Knowledge of Digital Fabrication (n = 15)

All the respondents (83%) indicated their vivid knowledge of the FabLab ecosystem, 11% indicated knowledge of the repair cafes, while 6% indicated knowledge of hackerspace. It is worth noting the contribution of Ajumose towards the dominant number of the knowledge of FabLab, because prior to the event, majority of the participants were left in the dark about FabLab and its concept.
While the remaining 80% were asked on the reason behind their lack of inventiveness, and majority (20%) indicated lack of knowledge, 13% indicated lack of technological resources as the reason behind their lack of inventiveness, 6% indicated lack of opportunities, while the remaining 60% did not give any reasons.

4.6. Factors Inhibiting Innovation

Factors limiting innovation

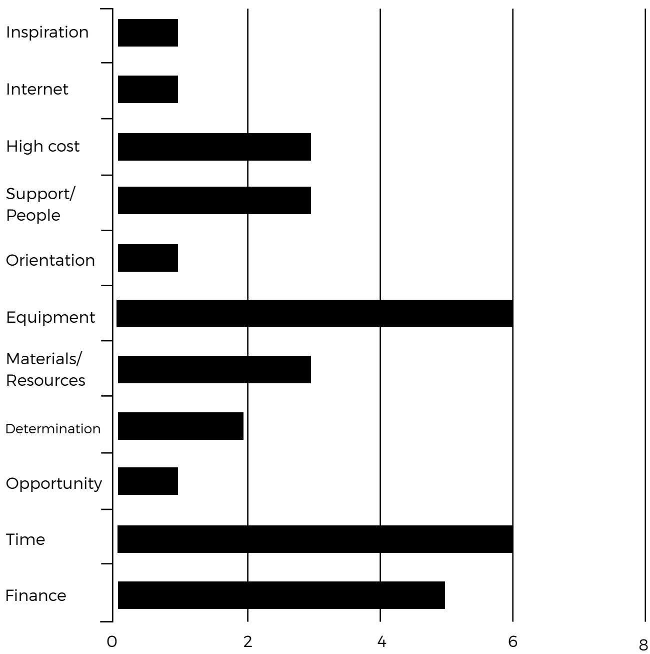

Fig. 6: Factors limiting innovation (n = 15)

When asked to indicate the factors that inhibits the innovativeness of individuals in the country, majority (19%) indicated lack of time and inadequate equipment, 16% indicated inadequate funds, 9% indicated high cost of innovation, lack of support and inadequate material resources, 6% indicated lack of determination, while the remaining 3% indicated lack of orientation, weak internet connection, lack of opportunity and lack of inspirations.

4.7. Suggestions for GreenLab Microfactory

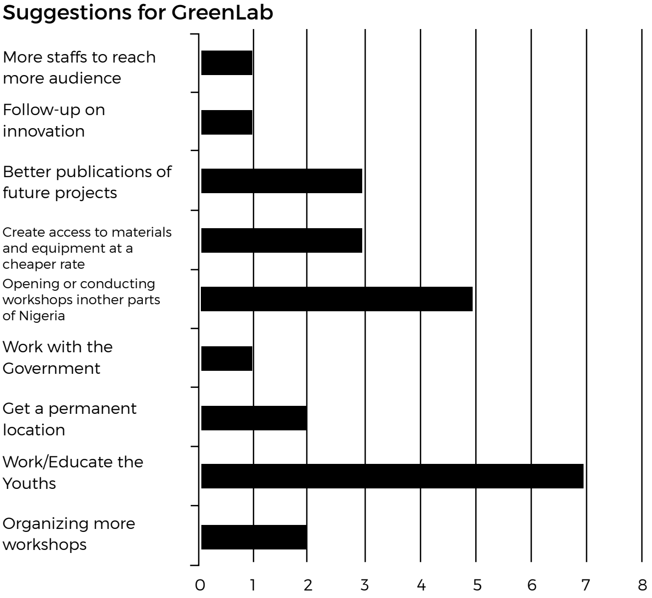

Fig. 7: Suggestions for GreenLab (n = 15)

According to the figure above, 7 (28%) of the respondents suggested that the GreenLab should establish and consider working more on empowering the youths irrespective of their location, 5 (20%) suggested opening and conducting more developmental workshops in other part of Nigeria,12% suggested that the GreenLab should endeavour to create access to cheaper and more affordable materials and resources, another 12% suggested that GreenLab should employ other methods to publicize future events/workshops, 8% suggested to organize more open source workshops, another 8% recommended to get a permanent physical location, while 4% suggested to conduct a good follow-up on innovation, get more staffs so as to reach more audience, and also to consider working with the government on future projects.

5. Conclusions and Remarks

Even though most emerging economies are still playing catch-up in the innovation and development space, which could be attributed to inadequate investment and involvement in developmental activities such as R&D, human capacity development etc. From the outline of this research paper, it can be concluded that initiatives such as FabLab that encourages user participations and grassroots/social innovations and development, are the most feasible means to jump the developmental chasm presently in existence within the continent at large. Hence, leading to the development and deployment of policies through which the continent can effectively beneficiate from its unique resources.

From the DIWO workshop, an adaptive strategy was developed that could be used by the third world countries to efficiently roll-out FabLabs to cater for the demands of their citizens, as well as to boost their innovative and entrepreneurial flair while leveraging the localization of resources used within the facilities. In addition, the event also revealed vital lessons which could strengthen the sustainability issue presently existent in the FabLab ecosystem. Despite the minor setbacks experienced during the DIWO event, the complementarities, accumulation, and utilization of diverse knowledge and experiences proved to be a significant trait of an average FabLab. Another vital lesson learnt, is that the bottom-up approach could also be applied in the learning environment with the potential of shortening the learning curve to empower people in rural communities hence bridging the knowledge-divide.

Lastly, from the feedback survey analysis, it was discovered that if the benefits of DFIs are to be effectuated or maximized in any community, the factors inhibiting their innovativeness should first be minimized. As discovered in the feedback analysis there is a need for frequent events or workshops that strengthens both the innovation prowess and entrepreneurial flairs of the populace to be conducted, the development or acquisition of more DFI equipment is paramount, collaboration with governmental parastatals as suggested by some of the respondents should be established, and mostly the community should be adequately informed about future open-source events.

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MyOrthotics: Digital Manufacturing in the Development of a DIY Interactive Rehabilitation Orthosis

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Abstract

Digital manufacturing and additive processes have become more prevalent in recent years due to the increased accessibility of tools and the individualization in the processes of prototyping. In comparison to the past, the process was individualized, taking months and requiring detailed research and development made by physical therapists and small manufacturers. Until now, this process is still done in the same long and expensive process. MyOrthotics is an orthosis development using Digital Manufacturing (Reversing Engineering, 3D Printing, electronics) to produce an individual and low cost solution for hand and arm disabilities, allowing patients, therapists, and practitioners to develop this assistive device in collaborative maker spaces.

Keywords

Assistive technologies for persons with disabilities; Orthotics, human factors, DIY; digital manufacturing; embodiment devices.

Figure 1: Development from the sketch to the final prototype using traditional and digital prototyping technique to produce MyOrthotics.

Introduction

Digital manufacturing (3D Printing, Laser Cutting, Electronics Design, Embedded Programming, etc) have become increasingly popular in almost any field of interest such as computer science, design, automobile industry, textiles, architecture among many others. In recent years, mostly private non-commercial users took over these techniques and make extensively use of them. FabLab's maker Spaces and other Groups of interest arose. The Fab Labs[1] ("Fab Foundation," ,2016)support the development of digital fabrication, contribute in the creation and production of prototypes and allow the global community to take up a challenge and solve it. As a consequence, there is a shift from experts only usage to almost everyone and this applies to almost any domain

A special domain is the medical field i.e. orthopaedics, Every person's body is unique and in case some loses capabilities such as being able to move her arm, hand, etc., prosthetic and orthotic limbs might help for a solution, furthermore the manufacturing of this process demands the development of a bespoke products with expertise and dedication for creating such detailed devices. (Hofmann et al., 2016)("The Raptor Hand – Enabling The Future," n.d.).

This is why custom manufacturing (Rovelo, n.d.), and producing products with orthopaedic technologies for individual patients is such a challenging process (P. Rovelo 2016).

The cooperation of Fab Labs in the development of individual devices and how this process can contribute to help of disabled people by using Open Source software and hardware to support the assistive technology development (Schull, 2015) are primary factors that can reduce the costs and provide solutions in cases that are not available in the market.

This paper presents an initial work of a 3D printed orthosis for a real case of customizing the design of an interactive orthosis for a patient with a paralysis of the left hand and forearm. The use of digital manufacturing, 3D printing and electronics production offer the possibility to produce an affordable solution.

RELATED WORKS

The development of the 3D printed prosthetics through the E-Nable community[2] has increased in the last years ("Enabling The Future," 2016.). This community spreads this concept of collaborative

[1] *Fab Lab* is the educational outreach component of MIT's Center for Bits and Atoms (CBA), an extension of its research into digital fabrication and computation. A Fab Lab is a technical prototyping platform for innovation and invention, providing stimulus for local entrepreneurship. A Fab Lab is also a platform for learning and innovation: a place to play, to create, to learn, to mentor, to invent. To be a Fab Lab means connecting to a global community of learners, educators, technologists, researchers, makers and innovators- -a knowledge sharing network that spans 30 countries and 24 time zones. Because all Fab Labs share common tools and processes, the program is building a global network, a distributed laboratory for research and invention *(FabLab foundation, 2016)*

[2] The *e-NABLE Community* is made up of teachers, students, engineers, scientists, medical professionals, tinkerers, designers, parents, children, scout troops, artists, philanthropists, dreamers, coders, makers and everyday people who just want to make a difference and help to "Give The World A Helping Hand."

technologies and share knowledge that has been incredibly useful for people that have some background in this area. The construction of DIY orthoses and prostheses have similarities, for example the Raptor hand[3] (Wege and Hommel, 2005) which is one of the first models of a 3D Printed prosthesis helps in the development and understanding of the DIY orthosis construction. Nevertheless, the development of an orthosis has different requirements, such as, the weight of the body and the strength of the fingers that are completely different.

Other studies focus on wearable robotic arms (Kang et al., 2016) in the area of orthotics and get insights in movement and interaction. Conventionally, these robots were designed in three ways: a link-based rigid exoskeleton (Wilton, 2013), a polymer-based soft exoskeleton using pneumatic actuation (Lee et al., 2014) and a fabric- based or soft silicone exoskeleton using a tendon drive (Polygerinos et al., 2015). All these different applications in robotic arms are incredible works and encourage the development of a precise system using sophisticated actuators, nevertheless the systems are not designed as DIY. This is also the case of the Polymer-Based Tendon-Driven Wearable Robotic Hand (Kang et al., 2016), which has advantages and disadvantages regarding to the actuation method. The implementation of a pneumatic actuator makes the devices harder to carry and the stabilization of the movement of the wrist is not considered. As a DIY system, the appropriation and customization of the system must be considered in terms of complexity of this system.

Other types of orthoses with a rigid exoskeleton structure are considered in the works of ZMorph and Elisa Wobel, in the *3D Printed Rehabilitation Orthosis* ("The Making of a 3D Printed Rehabilitation Orthosis," 2016)This implementation works in linear movements, permitting the structure and synchronization of these movements. In fact, the development of the MyOrthotics design is based on this kind of construction, nevertheless without an interactive system, the construction is not able to offer to the patient the flexion and extension movements. MyOrthotics system uses Myoelectrical signals ("MyoWare Muscle Sensor," n.d.) and electromechanical actuation, (it will be explained in the interaction part). It includes a splint in the forearm and back of the hand in order to immobilize the wrist. The mechanism to

It supports an international network of passionate volunteers using 3D printing technology and education to develop and deploy hyper-affordable prosthetic devices to children and other underserved populations around the world in a safe, sustainable manner. (Schull, 2015),(Hofmann et al., 2016).

[3] *The Raptor Hand* is designed with ease of printing and assembly in mind. Features include 3D printed snap pins, a modular tensioning system, and compatibility with both Velcro and leather palm enclosures. ("The Raptor Hand – Enabling The Future," n.d.)

mobilize the fingers make use of three servo motors: one for the thumb, one for the index finger and one for the middle finger. These are attached with the ring and little finger and the connection to this mechanism cause the flexion and extension. These motors respond to the impulse of two Myo sensors located in the tricep and bicep muscles of the patient.

CASE

The development of MyOrthotics is based on a patient around 60 years old. He has a semi paralysis in the left part of his body, a condition that he suffered after brain tumour removal. The goal is to develop an individualized orthosis that permits the recovery of the movement of the hand in order to be independent in different daily activities like grasping a coffee mug, opening an envelope, and using the mouse and keyboard. He lives in the most industrial region of Germany, nevertheless there isn't any kind of orthosis that can help with his symptoms. Furthermore, the treatment therapies and infrastructure, in his situation, implicate a huge cost. It is expected that he will recover a little bit of the movement of the hand in the long run.

Nerve disorder: There are more than 100 kind of peripheral nerve disorders ("Peripheral Nerve Injury," 2015) that can affect one or several nerves causing spasticity[4]. There's still a lot of untapped potential for helping the patients with cases of mild and partial paresis, who need lighter and more comfortable 3D printed rehabilitation orthosis.

PROCEDURE

MyOrthotics is the solution to this case. Using digital manufacturing techniques to actuate in an individual case, such as 3D scanning, different 3D Printing techniques, and electronics production a, to create a proper solution in an efficient procedure for the patient.

The objectives in prototyping MyOrthotics are the following:

- To customize and produce an orthosis for a patient using reverse engineering, instead of the traditional processes of moulding and casting, to accelerate the production.
- To simplify the fabrication, assembly and the repair of the orthosis, which the patient can do himself.
- To provide the parametric design of the models and design reference for future innovations.

[4] Spasticity is a condition in which certain muscles are continuously contracted. This contraction causes stiffness or tightness of the muscles and can interfere with normal movement, speech, and gait. it is usually caused by damage to the portion of the brain that controls voluntary movement. ("AANS | American Association of Neurological Surgeons," 2006.)

- To propose the accessible materials for every patient.
- To simplify the electronic design based on an open source board, affordable and possible to make in each Fab Lab.
- To familiarize the patient and therapist with the process of production of the orthosis, enabling the understanding of the benefits and constraints of the prototyping and learning through this process.

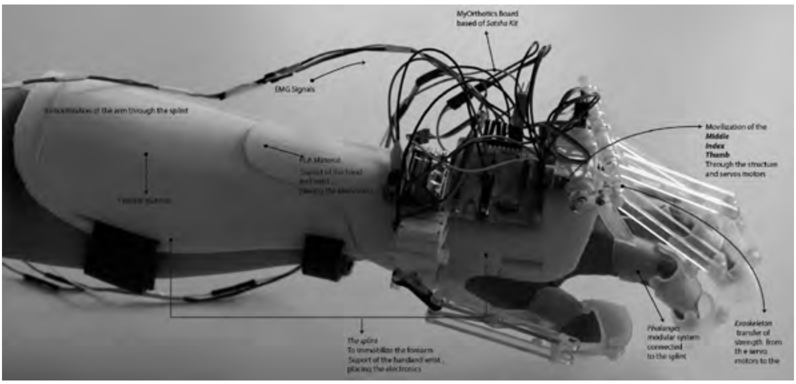

Figure 1: Development from the sketch to the final prototype using traditional and digital prototyping technique to produce MyOrthotics.

Design Criteria:

- The model has a semi parametric design. The arm must be scanned in order to modify the 3D scan model and to produce a parametric 3D model.
- The *phalanges* were modelled in a parametric design, in order to make them adequate for each finger and also for in the future to adjust this model for different patients. Each phalange is connected to the splint and each finger to the corresponding servomotor.
- The *splint* is designed to perform the following tasks: to immobilize the forearm, and place the hand and wrist in an adequate position.
- The first part covers the back of the hand and the wrist, stabilizing the position of the hand. In order to attach and stabilize the whole function of movement in the fingers, the external surface at the same time supports the electronics, the micro controller board, and servo motors.
- The assembly of the joints and the structure is responsible for distributing the force in the fingers.
- The *exoskeleton* enables the transfer of strength to the fingers through the phalanges and is connected with the servomotors. The servomotors are connected

to the Myo sensors in the tricep and bicep muscles, in order to generate analog values and send the impulses to the microcontroller board. More details will be presented below, in the Interaction section.

ANALYSIS AND DESIGN

Reverse engineering and modelling:
In the first trial only the forearm and the palm of the hand was scanned, due to the spasticity in the patient's fingers, in order to generate the first model of the splint. The Sense 3D scanner was used for this model, because the condition of the patient prevented holding and extension of the fingers for a long periods of time. The scanner provided good results in a short period of time.

Figure 3. 3DScan of the patient

The model was edited in Fusion 360, a complete computer aided design (CAD) software for a variety of applications. This program especially supports the parametric tools and analytic mesh tools that are well-suited to the challenges faced in designing DIY prosthetics and orthotics.

Figure 4. Free Form in 360 function from Fusion 360 software allowing the creation of mesh nodes in X and Y direction which are attached in the original 3D Scan.

The model of the fingers is based on the index finger with three phalanges, permitting the customization of the other fingers and also the customization of the model for other patients. The joint mechanism permits the printing of the pieces and joining of the phalanges, for having the whole movement of 90 degrees, as you can see in the in the following picture.
The exoskeleton is independent from the 3D printing

process, to accelerate the process; it was prototyped with the laser cutter and following the linear function of transferring the strength between the motors and the phalanges.

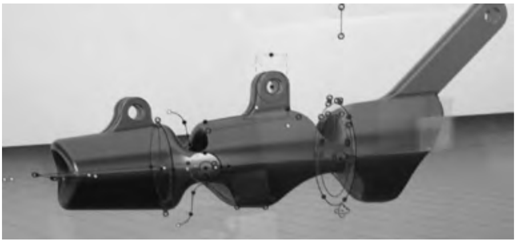

Figure 5. Parametric model of the phalanges and joints between them

The exoskeleton is independent from the 3D printing process, to accelerate the process; it was prototyped with the laser cutter and following the linear function of transferring the strength between the motors and the phalanges.

The Interaction:

MyOrthotics has a system based in the mechanical movement of the three principal fingers: the index, thumb and middle finger.

This system allows the following functions:

- Measuring the MYO signals of the bicep and tricep muscles, in order to provide sufficient information to the micro-controller.
- Sending the information through the microcontroller to the actuator.
- Development of a microcontroller board for programming and controlling the flow of information.
- *MYO (electromyography) and MYO ware* (“MyoWare Muscle Sensor,” n.d.)

This is a sensor that permits the measurement of muscle activity. Measuring muscle activation via electric potential, referred to as electromyography (EMG), has traditionally been used for medical research and diagnosis of neuromuscular disorders. However, with the advent of shrinking, and yet more powerful microcontrollers and integrated circuits, EMG circuits and sensors have found their way into prosthetics, robotics, and other control systems (Kamiski, 2016). The use of this sensor permits the mapping of the ROW values from a very sensitive lecture until the very strong movements depending of the calibration.

Mechanical actuator and motor

The actuator should follow and support the forces

and mechanical resistance due to the spasticity of the muscles. As is showed in the following pictures:
The goal of the actuator and the exoskeleton is to recover the traction and extension of the phalanges, distributing the strength in the proximal and distal phalanges, through the skeleton.

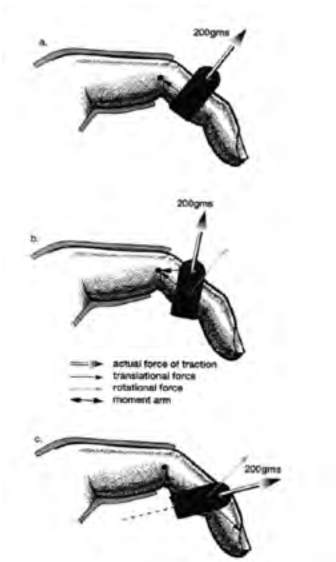

Figure 7. Mechanical Resistance of the spasticity considering forces and angles of the fingers movements. (Illustration. J, Wilton, 2014) [19].

In the first trial, I considered using Smart Nitinol Wire (SMA) in order to embed it in the splint.
Advantages: The use of Nitinol produces a natural movement making it ideal for body devices. Due to its flexibility, the actuators can be integrated in the shape of the orthotic.
Disadvantages: Less force: depending of the diameter of the wire, the force is directly proportional to the needed current (force).
Retraction: for the simulation of the muscles, the capacity of reaction should be within milliseconds, that the commercial SMA cannot achieve (time/speed) (gravity can improve the results of retraction). The current needed for all the functions of the hand, could impose a risk in this area that has a lot of contact with different surfaces and materials.
The consideration of an accessible motor enables the easy and understandable process, combining the rotation of the motors in this case around 60 degrees

with the function of the exoskeleton. The servomotor offers more strength in the mobilization of the fingers, and at the same time, a motor which is light and simple to use, wearable and provides enough torque to move at least three fingers (900 grams) plus the weight of the material (15 grams).
For more information about this trial you can see ta video of the torque of the motor and the movement trough the skeleton in the following https://youtu.be/GWtmCX_sRwc
For index and thumb fingers there is a servomotor for each one that is responsible for the flexion and extension as is illustrated in the Figures 8 and 9.
The index is the most important finger in which I based the implementation of the phalanges design.
The thumb has two phalanges. Instead of creating a circumduction movement (circular movement of the finger), it makes a linear movement that is synchronized with the index finger for grasping objects. The motor of the middle finger is attached to the two others finger to achieve the whole movement of the hand.

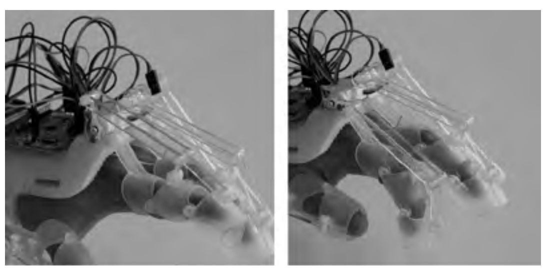

Figure 8 . Extension of the finger through the Exoskeleton and the motors torque (90 degrees). Figure 9. Flexion of the finger through the Exoskeleton and the motors torque (90 degrees)

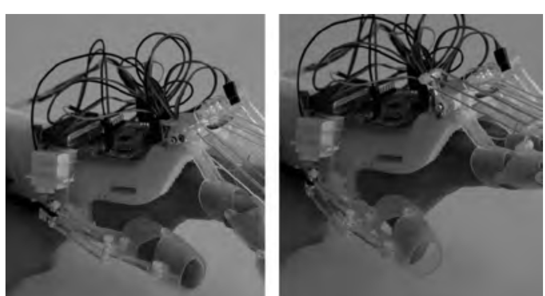

Figure 8, 9. Flexion and extension of the Thumb finger.

Microcontroller board and programming

In the MyOrthotics case, the board is made to generate enough connection for the devices. This board was made in the Fab Lab using the Milling Machine MDX40a Roland model and the open source software Fab Modules, reducing the costs and customizing a special board for MyOrthotics project. For more information, visit the Github page.

The board is programmed in Arduino IDE software, following the function of:

- Mapping the threshold sensor and defining two statuses: one impulse for closing and one for opening.
- The Myosensor in the bicep controls the movement of the index finger, and the sensor in the tricep controls the movement of the thumb and the middle finger.
- The mapping and calibration of the Myosensors and the motors and servomotors enable the customization of the interaction of this orthosis in case of improvements or degenerative diagnostic of the patient.

TESTING AND RESULTS

General patient Feedback: In the first meeting (1.jun 2016) the patient had an abstract idea of the implementation of this process, with the visualization of the 3D Scan provided clear idea of the orthosis procedure. However, the patient had at that time only had an abstract idea of the orthosis Figure 11.

In the second meeting trough the visualization of the first model, the 3D printed finger structure of the fingers enables a small test with the little finger, testing the joints, explaining about the materials and the functions of the structure of the phalanges. The patient could get a better idea increasing the interest for the development of the process.

Figure 11. 3D Scanning Process forearm and back of the hand. https://youtu.be/7QCgrAymrlM

The model and the 3D printed phalanges were tested with three different kind of materials, and also, these tests illustrate the constraints of the materials.
The first trial with PLA generated a very rough surface due to the supports.
The second trial with flexible material (Innoflex 45% elasticity) was successful. Nevertheless, the interior part came out a little bit rough, which means that the interior parts of the pieces should be sanded.

Figure 12. Printed Process whit PLA material, 13. Innoflex Flexible material, 14. Clear resin 3D printed material.

The printed parts were made in the final test with clear resin, printed in a 3D SLA printing process (Formlabs), providing a flat and fine surface that allows a smooth and comfortable hygienic contact with the skin.

Figure 15. 3D Printed Thumb phalanges testing the accuracy and calculating the size of the exoskeleton connections.

In the next meeting was tested the first 3D printing model of the splint, In this trial the whole splint with PLA in the Big Rep 3D Printer, the splint fitted perfectly to the patient, however this model provided evidence that the design of the orthosis required the use of a flexible material for the forearm arm, and rigid material for the wrist and the back of the hand.
Also, the patient was surprised of the colour and was sceptics of the use of this device.

In this meeting, the test of the first prototype of the orthosis was made by the patient, as is showed in the Figure 16.
The sensor was calibrated with the refined signal using the Interface in a manner that The patient could see the interaction of the arm and the values.

Figure 16. Testing the part and the interaction of the Myoware connection of the Myoware to the SatshaKit and assembling the Satshakit + Myoware + Motor + Orthotics Prototype. https://youtu.be/_kyQ4P8TT0I

The second prototype consist in the development of the back part of the hand printed with Polylactic Acid (PLA), as it supports more strength and also for the support of the electronics rigid materials as the PLA are recommended.

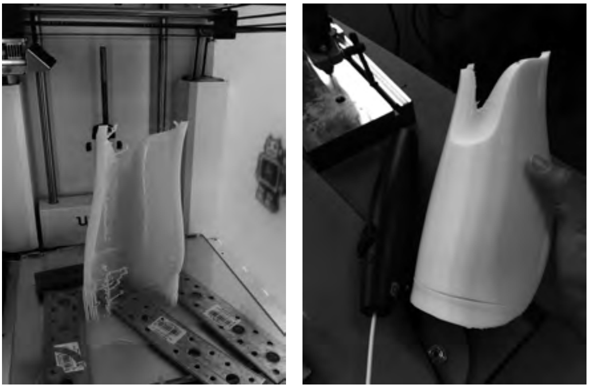

Figure 17. 3D Printing Process of the flexible part of the splint.

The second part of the splint using Innoflex 45% natural white, the assembling of the electronic and in this day I tested the function of the orthosis, looking for the movement function and at the same time the constrains of the material with the following performance:

PERFORMANCE AND AFFORDANCE OF THE SYSTEM

With this orthosis the patient was able to produce the flexion and expansion of the index, middle, and thumb in a correct posture, showing improvements in a short time of the prototype. The whole development process lasted around one month, including research and design.

With the initial prototype, the movement of the index finger, enabled, for example, the use of the mouse of a computer could be achieved.

The patient provided positive feedback and was impressed with the new result. In addition, he confirmed that the use of the design would be beneficial in his daily activities by allowing fine adjustments of fingers and providing him the ability to grasp his walker, thereby allowing him more personal independence.

The cost of the MyOrthotics initial prototype for all the material is around 170 euros . This includes the different 3D printed materials (PLA, flexible materials, clear resin), Electronics (Servo Motors, Sensors, DIY microcontroller board), laser cutter materials, accessories, Velcro band, and joints. The construction of the orthosis with the easily accessible materials allows production of this in any part of the world.

Figure 18. Testing of the second prototype of the Orthosis in the Fab Lab Kamp-lintfort, during the presentation project of the FabAcademy 2016 https://youtu.be/rnSr5HDS5wQ

EVALUATION AND FUTURE WORKS

MyOrthotics would not have been possible to realize without the interest and case of the patient, Frank Miller. The purpose of development of the orthosis was in order to help Frank with his disability. It explores how digital fabrication can contribute to

the improvement of treatment for this disability in combination with traditional techniques, for better results.
With the visualization of the 3D Scanning, model and prototype of his orthotic, the patient could participate in and understand the whole process.
Making the first prototype of the orthotic for my own hand put me in the shoes of the patient, having only one hand for adjusting the things as the other one was occupied with the prototype, simulated the disability.
Bringing the Patient to the Lab and the explaining how the process was done, experimenting from a very abstract to a functional prototype in this case the orthosis, was a huge surprise for the patient, and it also brought hope and expectations for his new orthotic.
Future works:
There are many possibilities for improvements in this work. During this process, different experiments were made in taking measurement of each finger. I tried to do the 3D scan of each finger, nevertheless it didn't work very well. In the end, I still wasn't able to find the right adjustments for the patient fingers. Due to the complex case of deformity and spasticity of the hand, the moulding and casting method is still the more traditional, and for this purpose, it is the next step for development of better accuracy of measurement for the finger phalanges. After the casting of the mould, one can then proceed to do the 3D scan of the fingers.
About the splint: I have to do some adjustments and also consider that if Frank recovers a little bit of the movement of the wrist, I could use this data as a measurement for another sensor. In the splint will be consider the case of the electronics.
My idea is to implement a new board, using the Satsha Micro, in order to reduce the size of the board, making it more wearable. MyOrthotics Sku, based on the Satsha Micro, is the customization of the size and it adapted the I/O entrances of the MyOrthotics

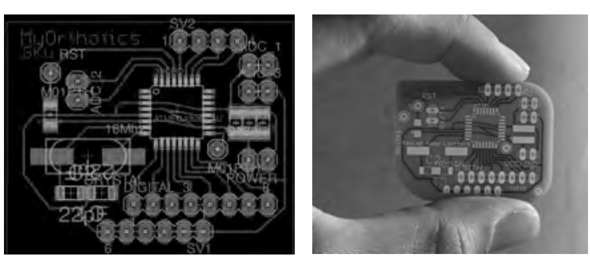

Figure 19. Schematic and proto board of the MyOrthotics Sku board

In the future, it could be evaluated to implement or develop the MyO sensor not only reducing the cost of the processes, and making this accessible for other people but also adapting it better for daily use.
The system is designed to be replicated and individualized for other patients with similar disabilities, and, also I hope that the project grows in the open source community supporting assistive devices.

SUMMARY AND OUTLOOK

This work presents the development of a DIY orthosis using Digital Manufacturing, evaluating the case of a patient with spasticity in his left hand. MyOrthotics was made possible with the collaboration of the patient and with the advisement of the physical therapist. This project (“A,Cabrera,” 2016)was developed during the Fab Academy 2016 Course, supporting different areas of prototyping. Personally, I assumed the challenge of the individualization of a prototype using digital manufacturing, however I consider that the background of the traditional techniques contributes and support the development of this bespoke work, and the transfer of knowledge between the therapist and my colleges was fundamental to archive the results of MyOrthotics. This model is 100% made in the FabLab Kamp-Lintfort(“FabLab Kamp-Lintfort | FabLabs,”2017.). This factor highlights the importance of materials and tools related to prototyping, that encourage user engagement in design, thus demonstrating that the assistive technologies can be developed in collaborative and transdisciplinary environments.
From this workflow derived recommendations for advances that would enhance the prototype assistive devices.
This work also argues the benefits of the open source of the parametric design and the contribution for future works, encouraging patient’s families and practitioners in the collaborative spaces to learn and share this knowledge.

Acknowledgments
Through the whole process I had the support of the therapist Mr. Carsten Rubel, from the company VitalCentrum HODEY AG Germany, who contributed greatly with his medical expertise.
Thank you so much for your support. I would also like to thank Mr Frank Miller As patient of the MyOrthotics

Project. For his patience and making this project possible, very thanks Frank.
Also Daniele Ingrassia, my classmates from the Fab Lab Kamp-Lintfort, and Support of the Faculty of Communication and Environment of the University of applied Science Rhine-Waal during the realization of the Fab Academy 2016, and the 3D-Kompetenzzentrum Niederrhein for the support, and the countless individuals who shared their knowledge, expertise and generous assistance, making this experience an unforgettable and amazing journey. To all of you, I extend my deepest appreciation

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ABSTRACTS

BioLabs and Blanket Forts: creating the bridge between Fab Lab and DIYBio cultures

Wendy Neale, Alison M, Stringer, Craig Hobern
Keywords: DIYBio, Open science, sustainable practices, resilience, bio-materials

Similarly to the Fab ethos, DIYBio aims to make the tools and techniques of research available at low cost, in an open way that enables innovative solutions to developed. How does a Fab Lab engage with the Do it Yourself (DIYBio also known as biohacking) culture without embedded scientific knowledge? What are the steps we can take to adopt DIYBio culture and incorporate it into the Fab Lab culture? What are the legal issues involved and how do we build knowledge and expertise in a sustainable way? How do we temper naive enthusiasm with science , yet retain a sense of adventure and exploration?
This paper discusses the trials and tribulations, the successes and deep learning that have accompanied Fab Lab Wgtn's journey into yet another unknown space. The space of science and the natural world. Three years ago, Fab Lab Wgtn had already established its Resilience Project, an outcome of a Fab Academy group project. We presented a paper on this project at Fab10. We had been creating compost from our clean wood waste, creating circular systems with many of our materials, and the Project had come to represent an overarching value that we wished to integrate into our systems.
As a result of this, we had become increasingly interested in DIYbio and citizen science, and curious as to how we might synthesise this into our existing programmes. Visiting the Green Lab at Valldoura during the Fab10 conference was particularly inspirational. How could we become an even greener lab, based in a city, on a university campus? We looked at the new programme BioHack Academy, and started talking more people locally.
While at Fab 11, participating in a session about the new Bio Academy, this reaching out paid off. A tweet, a response, and a meeting upon returning to New Zealand has led to the development of our beautiful DIYBio Lab (Blanket Fort), some great reciprocal relationships, DIYBio workflows, and some pretty great documentation. We have worked with edible

fungi, growing them as a food source as well as experimenting with them to create new materials from our clean wood waste.
This paper discusses the process and the outcomes to date, and postulates a future that no longer feels so distant. Taking a shared ethos of curiosity, decentralisation, open science, open data, open tools, this is the story of how an independent scientist and two designers worked together to create a new way of understanding our world. We all wanted to understand the potential of new materials and processes, and how they would impact on our everyday design|make|scientific practice.

Design and Construction of Electro-Mechanic Transtibial Prosthetics for Both Lower Limbs

John Hernández Martin, Luis Alberto Parra Piñeros, German Antonio Mendieta Mendieta.
Keywords: Foot. Transtibial, joint, Prosthesis, Ankle.

All human beings possess a natural characteristic, intrinsic to our bodies, locomotion. However, in some cases, this natural attribute is lost, due to different circumstances. The most frequent factors are directly associated to situations such as violence, a high accident ratio and medical factors directly involving the person. For the specific case of violence, we delve into the issue of landmines use in the armed conflict; this matter is a global problem for public policies in society. According to the Red Cross International Committee (RCIC)[1], the most affected countries are Cambodia, Angola, Bosnia-Herzegovina, Afghanistan, El Salvador, Nicaragua and Colombia, with a high number of active landmines, due to armed conflict. For the specific case of Colombia, some distressing statistics have been retrieved; according to the Observatorio De Minas Antipersonas de la Presidencia de la Republica (Landmine observatory from the President's office), by 2011, around 1080 people have died due to landmines. On the other hand, in most cases the patient does not die, but loses one or both lower limbs, thus rendering landmines as one of the main causes for disability. Unofficial figures from the medic Thomas Küchenmeister[2] indicate that, by 2011, the armed conflict in Colombia has left 20.000 victims

[1] C. I. D. L. C. ROJA, "Minas terrestres: legado de la guerra," 2016.

[2] C. Reyes Rodríguez, "La amenaza de las armas pequeñas, ligeras y explosivos ALP-ME," *Borradores de Investigación: Serie documentos Ciencia Política y Gobierno y de Relaciones Internacionales, ISSN 2027-615X, No. 1 (Enero de 2011)*, 2011.

counting deceased and disabled.
As one of the most affected countries for this situation,[3] Colombia has a high percentage of disabled population, making these people require medical and psychological service[4] on a daily basis.
For Colombia, it becomes necessary generating around 4000 new prosthetics a year to cover the needs produced by the armed conflict[5] and amputations due to diabetes and accident tolls. Therefore, it is necessary to implement a bank of medical prosthetics which covers said need. Likewise, it is also important to consider if existing prosthetics meet economic and functional needs of each patient. It is important to be aware that this type of elements represent a high investment and must be imported from other countries, since there is no local production.
In the same line of thought, it is possible to say that Colombia does not have many entities which design and implement elements to assemble prosthetics. For this reason and the fact that over the last five years the Metrology Design Center has been working on the design and adaptation of orthotics and prosthetics with imported components, this research was based on the design and implementation of a transtibial electro-mechanic prosthetic, using medical and technological resources available within the country and thus, developing a 100% local, self-manufacturing system. This system is expected to comply with all functional and ergonomic characteristics for patients with this disability. Currently, there is an undergoing manufacturing process from a design, result of hard work with patients and prosthetics from the training facility.

[3] C. G. de la Nación, "Primer informe de seguimiento y monitoreo de los entes de control a la ley 1448 de 2011 de víctimas y resttución de tierras," ed: Bogotá, 2012.

[4] R. J. Álvarez Márquez and N. J. Ospina Grajales, "Reparacion integral a las víctimas de MAP, MUSE, AEI," 2013.

[5] A. a. Victimas, "Direccion Contra Minas, Ministerio De Postconflicto Derechos Humanos Y Seguridad," 2016.

Digital Badges and Skills Recognition in Fab Labs

Geoffroi Garon

Keywords: Skills, learning, Recognition, Digital badge, Living Lab, Fab Lab

The use of digital badges and microcertification is an emerging practice in assessing and valuing skills acquired in formal and non-formal contexts of co-design and improvement of digital literacy and collaborative intelligence, with researchers, practitioners and citizens. This communication will present a research-intervention project of development and recognition of competences via a system of digital badges and will discuss its issues for collaboration and social learning. The latter is used in echoFab, a Montreal-based Fab Lab (Fabrication Laboratory) in Canada, managed by Communautique, a hub for open innovation Living Lab, dedicated to learning, collaboration, research, and experimentation in social and technological innovation. The project is part of the UQAM Laboratory of Applied Community (LCA), which uses the methodology of Community informatics design (Harvey, 2014) as a new field of applied communication to analyze and design digital social systems such as digital badges system. We will present the problem, the theoretical framework and the methodology that we used to carry out this research. We will present the results of several aspects: 1. The analysis of the types of competences (digital, cognitive, social) that are integrated in the concept of 21st century skills, 2. A description of the characteristics of the digital badges (motivation, recognition, certification), valorization strategies and usage contexts in a Fab Lab environment, and 3. Exploring technologies for implementing a digital badge system (Assertion, metadata, functional architecture), the Mozilla Openbadges standard, and available platforms and systems (Open Source, SaaS, LMS). We will conclude on future research from a perspective of formal and informal learning throughout lifelong learning of the Fab Labs movement.

Digital craft for mud monolithic shells as a housing solution

Maite Bravo, Stephanie Chaltiel

Keywords: Monolithic Shells, Digital Fabrication, Human Interaction, Additive Manufacturing, Digital Craft Housing

Earth construction for monolithic shells can be found in ancient traditions, and could be described as the placement in layers of paste like materials that are arranged along a curved surface under compression to achieve a self supporting condition. Some examples include the Nubian vaults (Sudan), the Harran Beehive houses (Turkey), and the Musgum mud huts (Cameroon), among others. These modest but relevant referents were simply constructed by placing lumps of sticky clay that are thrown by hand following immaterial trajectories of simple and repeated motions. The recent emergence of digital fabrication tools is exploring the use of earth construction, but has encountered some problems related to the feasibility of its immersion in the construction industry due to the scale of the equipment available, the incipient development of suitable materials, and the limited construction techniques implemented. This paper proposes a framework for the implementation of digital fabrication strategies of mud monolithic shells by combining traditional craft techniques, digital design methods, and robotic spray fabrication protocols.

The implementation includes traditional material practices by using branches that form self-standing peripheral and internal bending arches, from which an elastic membrane (Lycra) is stretched by hand to create a tense surface. A clay mix is sprayed on top of this fabric and manually mixed with fibers that merge creating an assembly of interlocked materials, and the temporary formwork is removed once the clay surface is dry and self standing.

Computational design techniques implement parametric logics for the design and optimization of possible solutions (Rhino 3dm, Grasshopper plug-in), as well as providing the opportunity to make adjustments during the process of digital fabrication by using scans (Agisoft) together with optimization softwares (Karamba) that are able to correct the robotic trajectories (Kuka PRC interface) during the fabrication process.

Additive manufacturing protocols features a spray technique that deposits material through a nozzle under pressure that is able to 3d print with a robotic arm piped to a paste of cement or clay, that is simultaneous drying while printing in the air. This novel method presents some opportunities for the automatization of its placement, to replicate the geometrical guides found in traditional techniques, adding the intelligence and creativity that novel fabrication protocols of additive manufacturing can offer.

These protocols have been tested in several instances, and are still being continuously improved and enhanced, and hope to be implemented at full scale in the near future. Two case studies are presented in this paper featuring a complete strategy for the construction of mud shells from the initial form finding

stage to the completion of self-standing structures reaching up to 2.0m in height.
This workflow provides a solid foundation to explore the design and construction of simple mud shells or vaults, that can be combined in systems as temporary or permanent housing solutions for zones where local materials are abundant (such as in arid climates). This new production model will allow the immersion of innovative and collaborative construction techniques, integrating traditional crafts with technological advancement, while supporting sustainable communities.

Fab labs as catalysts for sharing economies in Latin America

Emilio Velis, Isaac Robles

Keywords: Fab Lab, sharing economy, cooperativism

Sharing economic models have been the center of much attention and criticism in recent years. Their cooptation by the so-called “death star platforms” have put the concept under fire and have raised the question of whether these so-called “collaborative” models can live up to the expectations in terms of creating sustainable models that can create impact in their contexts. The present paper explores the concepts of sharing economy and platform-based cooperation and how can these concepts applied to the Fab Lab Network can become a catalyst for social-based innovation leveraging on such concepts. By asking whether a sharing economy can still become a game-changer for society, and how sharing initiatives, such as fab labs, aid to this goal, will help us to better understand how a fab lab can create new dynamics in the community is inserted in, from a social and economic standpoint. Observational data from Fab Labs from the FABLAT (Fab Lab Latin American Network) will be used for illustration purposes to outline some of the biggest collaborative initiatives in the region ins terms of funding and impact.

Halasuru Traverses: Retelling history using digital fabrication

Anupama Gowda, Pavan Kumar

Keywords: history, local stories, community, digital fabrication, education, puppetry, CNC Laser

Retelling past using mythology, folklore, living tradition and local histories never looked better given the production value of imageries has grown with time. In fact, various genres in visual medium is seeing a surge, yet the retelling of living traditions and local histories through traditional forms remains an enduring passion for many story-tellers across the globe.
Halasuru Traverses has been one such arts education intervention project with the local community children of Halasuru to explore the artistry and history of their neighborhood. With accessibility to Bangalore FabLab- Workbench Projects, children for the first time were exposed to technology in ways unimagined. The outcome of this eight month-long project resulted in a public performance of the students' production of a digitally fabricated leather puppet show.
With hands-on immersive experience to design, contemporize and make characters of present times children exercised new ways of retelling their neighborhood stories. Playing the role of traditional puppeteers touched by the wonders of digital fabrication, children immersed through an artistic process from beginning to end; from story telling, scripting, story ritual, character building, music, lighting and final staging where they unfolded the magic crossovers of a traditional form with high cutting edge technology. The project worked with the archetypes, which heightened the leather puppet movements and gestures with meaning and puppet manipulation to go through the stories, narratives and iconographies that signified the importance of Halasuru.
Collective resources of teachers, parents, local urban architects, artists, historians, fab-facilitators and the local authorities, the project presented a gripping storyline with a good balance of historical data and the students popular taste in presenting the production.
This paper presents the journey and the processes that made the exceptional use of Bangalore FabLab and its resources in empowering the first generation young learners in its vicinity to open out to the million possibilities that the children now are exposed to.

Open Jails to Education: How can Fab-Labs contribute to democratize the knowledge?

David Chaupis-Meza

Information is power. Of course, but how the power is distributed in our society?
In fact, this distribution of information (the public knowledge) is not equal for all, conventionally called inequality of educational opportunity (IEO). Currently, we are living the impact of globalization phenomenon “which encompasses a great variety of tendencies and trends in the economic, social and cultural spheres” (Bertucci & Alberti, 2001), being four major factors considered as the driving forces of worldwide interdependence: entrepreneurship, liberalization of trade and investment, technological innovation, and global social networks. Nevertheless, the open access to equal opportunities in worldwide education remains the gap of globalization that is not closed yet. Then we shall ask does globalization provide the same benefits for all members of the global community? Clearly not, because the global crisis is the most important capitalist crisis since World War II (de Berris, 1988) and Latin America (LA) was also affected. So, how may an economic crisis affect inequality of educational opportunity? “As in the industrialized world, equalization appears to be driven by expansion in the context of universal access by the upper class” (Torche, 2010), therefore, the power of information should be based on an inclusive education (the democratization of knowledge).
To talk about an inclusive education we need to construct an open society to our children, especially focus on those that who are often discriminated, because of disability, race, language, gender, religion, poverty and even many of them will not have a timely education just for being inmates son. In such society with IEO these children are restricted to repeat the same mistakes as their parents did and, for such reason; we need to change that vision. But how we can change that vision in our current society?
For such transformation we need to open jails to education! That is to say, an open education. According to UNICEF (2013) around of 240 000 children and adolescents are deprived liberty and grow behind bars with their parents in a jail, they are called the invisibles children, in countries such as Argentina, Brazil or

Chile where exist the highest ratios of convicts.
Our challenge is to create an inclusive education system for those children based on strategies of the popularization of science and technology.
This paper is a proposal to contribute for democratizes the knowledge from to Fab-Labs in LA, really, the most import labour to develop to favour of open access, by creating laboratories without barriers such for example: the PUQUNA project.
The PUQUNA project is an initiative in inclusive education, created in Peru, to use the Fab-Labs format (as biomaterials, digital design and 3Dprinting) within a workshops-program (during 3 months) to schoolboys, finally, these boys can motive to their peer which don't have the same opportunity to attend a formal school; for this reason, PUQUNA means fertile or mature (in quechua) and it refers about to close the gap: by creating (a critical mass), sharing (opportunities for all) and re-educating (our real inclusive society). This is our moment!

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