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IN[FORM]ATION SMART LIVING ARCHITECTURE

A B S T R A C T

As Information Era Technologies and their impacts on architecture change, their relationship calls for new or adapted concepts, where Buildings and Cities seamlessly intertwine with digital content and where the language of electronic connections tie in with the language of physical connections.
Architecture cannot be just inhabited and rigid, but users and the environment should integrate with it.
If computers were once the size of buildings, buildings are now becoming computers capable of performing on I/O Communication protocols or being programmed at molecular-material – nanoscale, or even operating on self-learning genetic algorithms.
If the public space we inhabit today was basically constructed at the start of the Industrial Revolution, the Information Society is now bringing to bear new principles and technologies with which to rethink the functioning and structure of the streets, avenues, squares and infrastructure of the City.

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FAB LAB

Architecture and ICT open up a series of possibilities and new projects in different architectural scales (from the nanoscale of matter, to buildings and cities), from bits to geography. At IAAC, together with a strong team of researchers, we develop new design ideas and bottom-up processes where importance is not the final aesthetics but rather than data and information that prepare the ground for the birth of efficient, responsive and in-formed architecture of cities and buildings.

Buildings

In the early 20th century, the concept of 'dwelling' was defined as a 'machine for living', a reference to a new way of understanding the construction of inhabitable spaces that characterized the Machine Age. Today, a century later, we face the challenge of constructing intelligent and sustainable prototypes; living organisms that interact and interchange resources with their environment, following the principles of ecology or biology rather than those of mere construction and which function as entirely self-sufficient and responsive nodes with the potential to use and produce resources.

Additionally, the extended use of smart materials such as shape-memory materials, piezoelectric, thermoelectric or bio-materials able to adjust their properties in different environmental conditions allow for programming buildings at a nanoscale and open up a series of applications in the architecture of building skins and structures. The latter in combination with Artificial and Computational Intelligence, sensors, actuators, as well as with bio-mimetic innovations provide revolutionary ideas on growth, adaptability, repair, sensitivity, replication and energy savings in architecture.

Can buildings think?

Should we keep on constructing rigid structures?

How can we design and construct buildings as living organisms able to grow, adapt and act as trees in a field?

IAAC agenda on Smart and Self Sufficient Buildings include outcomes such as the 1:1 scale construction of the Fab Lab House or the Endesa Pavilion, parametrically designed houses whose form follows the data of the solar path of the area to be implemented. Fab Lab House has been entirely digitally fabricated by a group of researchers and students and is able to generate twice as much the energy that it needs to consume, through flexible solar cells adjusted to the optimum form of the building.

Other projects include anti-gravity 3D printing manufacturing processes through robotic arms and polymer mixes for new automatized data-based construction systems or dynamic prototypes of foldable reactive skin modular systems that can be rearranged by the users, adapt to the structural movements, and by inflating pockets of air or gas insulate and provide transparency or translucency, as desired.

This type of projects, as pilot projects, help to understand how material, artificial and computational intelligence allow for new and efficient design and manufacturing processes of intelligent buildings constructions.

The advances in the building design and construction cannot leave the urban scale unaffected. In this way, each action on the territory implies a manipulation of multiple environmental forces, connected to numerous informational flows and networks such as energy, transport, logistics and information, generating new inhabitable and responsive nodes with the potential to use and produce resources. Territorial and urban strategies and building operations must therefore be coordinated processes that extend architectural knowledge to new forms of management and planning, in which a multiscalar thinking also entails an understanding of shifting dynamics, energy and information transmission and continuous adaptation.

Cities

Urban Environments have always stood in close relationship with the technologies of production, transport and communications. By introducing Information and Communication Technologies (ICT) in spatial planning, these can be conceptualized as a new type of infrastructure for the transport of data or information that allow cities to perform as organisms and become behavioral.

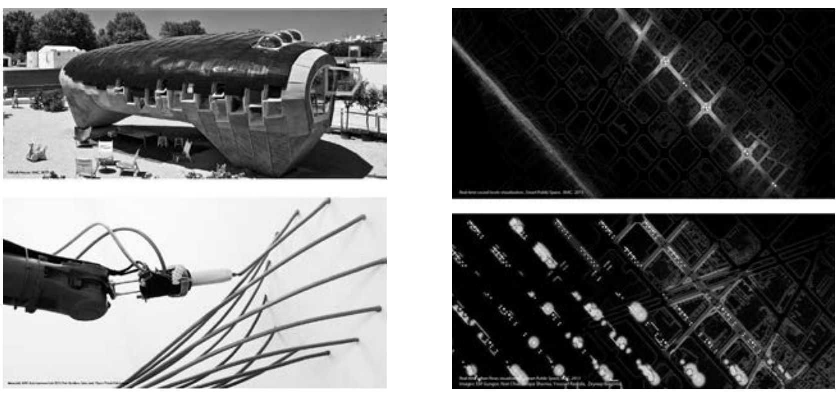


Figure 01. In[form]ation: Buildings, Cities and Manufacturing Processes

Projects such as “City Protocol”, “Smart Citizen” or “Networked City” are research agendas initiated by IAAC in the effort of understanding the ICT implementation in urban environments, how cities could be responsive to environmental or social data and users needs and how citizens can participate in the collection and sharing of data of their neighborhood.

How do people interact with the public space?

What happens when the Internet of the things becomes the Internet of the cities?

The projects focus on monitoring technologies through sensor devices that collect data, process them, using applications and visualization tools creating communities able to define actions based on efficiency. Cities are able to filter water (kidney system), to manage ventilation and air quality (lung system), to locate and balance traffic levels (visual system), to process waste in order to produce biofuel (digestive system), to create real-time data urban farming irrigation systems, to blur the lines of the current highways and pavements with responsive tile systems.

Citizens, on the other hand, are able to visualize their neighborhood data, to participate in public space distribution, to access urban interfaces and open data platforms, to calculate the shortest routes to their destination, to be aware of their energy consumption impact in their urban block and finally be part of an urban evolution based on self-organization rules related to local parameters, social or emotional factors of the citizens when occupying space.

We are moving, thus, towards a different [form] of “habitats”, where we do not just inhabit our architecture but we integrate, interact and evolve with it. Internet of Cities, Buildings of which form and matter follow data and Materials responding to environmental conditions and digital content are part of an architecture that is not just mimicking the living but is roaring into life.

It is necessary to generate complex knowledge with a multi-layered reading of realities that have traditionally been thought of as separate, such as energy manipulation, nature, urban mobility, dwelling, systems of production and fabrication, the development of software and information networks. This opens up the possibility of generating new architectural prototypes, based on principles of different disciplines and capable of engaging with complex and adaptive environments.

And no doubt, if ever there was a time to go deeper into the architectural metabolism through new multidiciplinary and technological models applied in our “habitats”, this certainly is.

SOLAR PROTOTYPES AND DIGITAL MEANS OF PRODUCTION

Sun and architecture were primary undetached forces. But fastness and a badly understood industrialization made us forget it. Now energy and material efficiency come back as critical bullets on innovation agendas. Mass customization, digital means and new fabrication techniques are challenging traditional standardization patterns. Information technologies changed the way we work, the way we interact, the way we produce and distribute goods... But still, they did not change our cities, yet.

The Endesa Pavilion is a self-sufficient solar prototype installed at the Barcelona Olympic Port within the framework of the BCN Smart City Expo World Congress (SCEWC 2012). Over a period of one year it will be used as a control room for monitoring and testing several projects related to intelligent power management.

The Pavilion is the first 1:1 prototype of a wooden solar-tracking façade system applicable to different scales and latitudes. An adaptive modular system based on parametric modeling and digital fabrication. An algorithm coded to optimize geometries depending on local conditions. A constructive system that tries to integrate passive strategies with active ones, traditional knowledge with cutting-edge technology, local conditions with global logics… The Endesa Pavilion is just a skin that reads and makes readable the energetic conditions that surrounds it.

It is a result of a long combined research in self-sufficiency and information technologies, aiming at working on mechanisms to merge natural processes with digital ones. (Fig. 02)

Form Follows Energy

Like a tree, the pavilion takes the energy from the sun, and it’s geometry describes that of the seasonal sun paths. From the famous 20th-century mantra of “form follows function” to its 21stI century version: “form follows energy”.

Ancestral recipes regarding energy and acclimatization are updated with mathematical precision due to the contemporary digital modeling capabilities. Like a tree leaf, each building component is producing energy and generating

Figure 02. Endesa Pavilion. Southwest façade and electric bike.

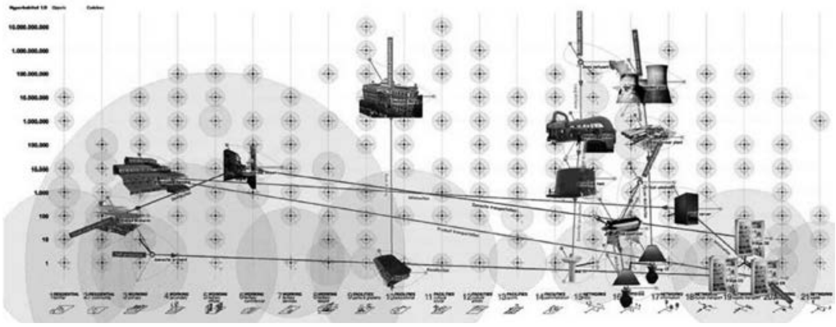


Figure 03. Hyperhabitat. Venice Biennale, Multi-scalar diagram.

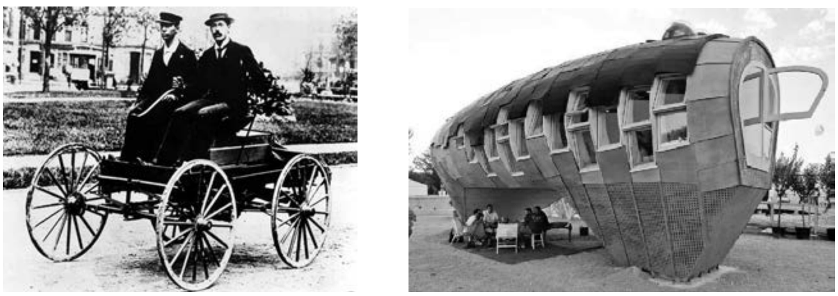


Figure 04 a, b. New technologies integration, (a) Charles B. King, Detroit 1896; (b) Fab Lab House, IAAC, Madrid 2010.

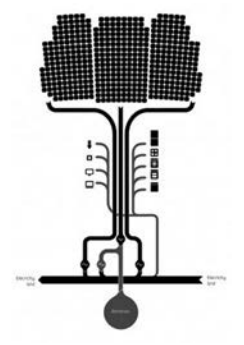


Figure 05. Metabolics and integration; Fotovoltaic tree diagram, IAAC, 2010.

Figure 06. Natural logics of integration; Fotovoltaic tree diagram, IAAC, 2010.

protection at the same time. And each one of these components, each "leaf", is precisely calculated to optimize its performance. The building is thought of as the result of the simple aggregation of these intelligent components, in the same way we could understand a tree as a result of the aggregation of leaves.

Mass customization

As a prototype, the pavilion is a research on the possibilities of combining traditional industry with the latest digital fabrication techniques. Each façade module is calculated and generated using parametric design tools, is fabricated using CNC milling on microlaminated wood panels, pre-assembled, transported and "plugged-in" the structure, all in a process of five weeks. Conventional industries, used to mass production processes, and new technologies, adapted to mass customization requirements, are inter-weaved in a single continuous workflow.

The pavilion is not a closed item but a construction system. It is not intended as a definitive and finished icon but an open and multi-scalar proposal. It is a façade system based on a set of mathematical rules and logics ready to export and to be adapted to any location or material, ready to be integrated into the local conditions and thought to be locally fabricated.

Matter

And in this case, wood.

When Salvador Rueda (Spanish urban ecologist) was asked about the materiality he stated: "a solar building should be made out of a solar material". Wood is a renewable material. It grows with the sun. The same energy that now powers the photovoltaic panels of the pavilion made grow its wooden structure.

Self-sufficiency is a matter of scale of thought. When we open a tap, we are consuming resources from distant infrastructures, affecting landscapes located kilometers away. When we fabricate in wood, instead of opening new quarries, we are activating forests, we are generating productive landscapes. Understanding the whole production chain, along all scales, is basic to reprogram the process, to achieve real and productive self-sufficiency. Architecture should integrate and try to give transparency to these logics. (Fig. 03)

Endesa Pavilion wooden systems are exposed to the user: microlaminate fir for structure (kertoQ 45mm), FJI joists, laminate fir as exterior finishing (kertoQ 27mm), 9mm laminate birch for interior finishing, OSB as flooring, vegetal fiber insulation, all joints and construction layers are exposed.

The warm, welcoming and domestic perception of wooden structures has a deeper meaning. Wood is an understandable technology, easy to trace and intervene. Technology here is not a black box. We tried to apply this same principle to each one of the layers of the design process. This transparency is the first step in generating environmental awareness.

Material Organization

The first automobiles were horse carts with engines attached to them. The first car designers were not able to realize that when a new technology appeared, it forced fundamental changes transforming all logics of design. It took at least two decades for cars to start looking like cars. At times, the relation between innovation, industry and society is that slow. (Fig. 04)

And architecture is not any faster. Today, we are witnessing a similar shift in paradigm. Climate change and resource scarcity are in the focuses of new economies and geopolitics. But architecture stays the same.

Sustainability and self-sufficiency are triggering innovation, but too many examples and attempts of integrating these new technologies end up in mechanical additions and plug-ins, “old strategies” plus “new technologies”. A solar house is not a house with solar panels on it. As in the case of the automobile, new technologies demand from us to generate new design logics.

In nature geometry is the coherent result of integrating physiology and physionomy. In nature metabolism and form are different expressions of a same system. Form follows energy, thermodynamics, chemical processes, changes, growth... The material organization of a tree is making its metabolic processes transparent. In front of that we could say that the Sullivan’s statement – “form follows function” is somehow limited by not taking time and energy management into consideration. (Fig. 05)

The Endesa Pavilion research represents the effort of integrating the logics, technologies and processes demanded by this new paradigm into a single constructive system. A constructive system based on adaptation and not on repetition. A code that is able to read the context conditions and respond to them. (Fig. 06)

Data Management

It is through the new information technologies that we are able to encode this responsiveness. Data management, together with the new digital tools, bring us closer to the real dynamics. Architecture, traditionally closer to the idea of permanence, is now able to integrate the logics of change.

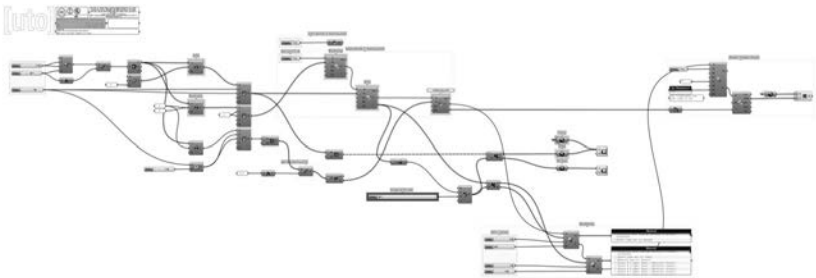


Figure 07. Grasshopper environmental analysis through Geco, IAAC, 2011.

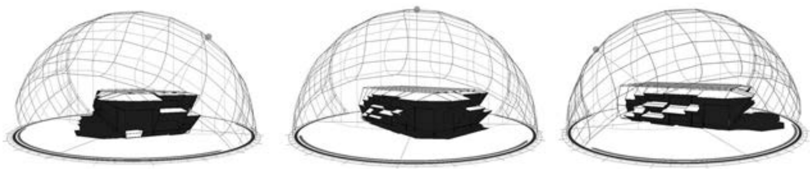


Figure 08. Ecotect summer modeling. IAAC, 2011.

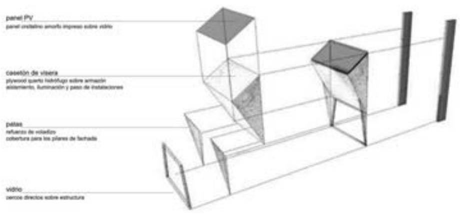


Figure 09. Endesa Pavilion component elements. IAAC, 2011.

Figure 10. Endesa Pavilion component assembly. IAAC, 2011.

Figure 12. Endesa Pavilion electrical ecosystem. IAAC, 2011.

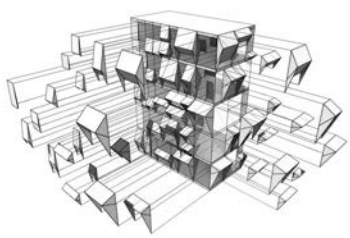


Figure 11. Multiscalar plug-in system. IAAC, 2011.

Figure 13. Endesa Pavilion coast-line view. IAAC, 2011.

Parametric design has been applied in other disciplines and industries for some time, but it was only recently imported into architectural design. And the jump from analogue to digital is not just that one of a simple switch of tool.

First. Digital data management allow us to model complex dynamics, that is, introducing time as a base parmeter. We can calculate shadow casting effects along the whole year, predicting the exact point where the shadow will arrive some specific day at some specific hour. We can model thermal behaviors, wind blows or solar radiation with incredible accuracy. Today, dynamic and immaterial processes can be described and managed with the same precision than in the past when we were dealing with statics and materials.

Second. Parametric design opens the logics of design. Geometries are (they can be now) the precise result of a set of transparent and unveiled mathematical and physical calculations. There are no random gestures, just evolutionary laws being displayed. And this mathematical logic can be clearly exposed, highlighted and exported. A design today is not (should not be) the definition of a static object but the description of the set of rules that make it work.

Third. The openness of the logics of design make the whole process exportable. The same code of the Barcelona Pavilion could be run with Helsinki weather data. The logics would be the same, but the code would give a different geometrical output. We export logics instead of exporting materials or plans. (Fig. 07)

The Endesa Pavilion is just the Barcelona version of an adaptative code able to be applied (grafted) in different situations with different demands. A simple logic drives the whole design. The relative position of each façade component with the different seasonal sun-paths defines its geometry (openness, deepness and paneling inclinations). (Fig. 08)

Each component is defined globally but resolved locally, calculated individually (module by module) following the same shared rules (topological relations). Each component generates its own energy, controls its own sun radiation, natural light and artificial interior and exterior illumination, storage, insulation… Each component contains and resolves locally all architectural requirements following a single shared logic.

Each module is different because it is responding to slightly different conditions. And this level of organic responsiveness was something unthinkable with traditional modeling systems and conventional means of fabrication. (Fig. 09)

DIGITAL fabrication

Digital fabrication will mean to the physical world what internet meant to digital one.[1] Massive customization patterns are changing the rules of economy, market and industry.

The second industrial revolution, following Fordism principles, was strongly based on imposing types and repetition. Same hotel rooms in distant cities of the world, same façade systems applied interchangeably in Helsinki or Barcelona... But in the success of this “economy of scale” lays the reason for its failure. The loss of identity is also a lack of adaptation. A façade of Helsinki should never be the same as one in Barcelona.

The so called third industrial revolution[2] is already producing the shift from centralized means of production to have distributed ones. Digital revolution became physical and today CNC fabrication permits to differentiate and give identity to each constructive system, to each façade module, to each wooden skateboard (not being just a naïve example). Architecture can now respond to the specificities of the user, context and environment locally, freeing from the indistinct impositions of old industrial models.

Endesa pavilion is a laboratory that challenges the alliance between mass customization and mass production techniques. It is a hybrid, made possible thanks to the use of digital fabrication technologies, between industrial scale and craft adaptability. (Fig. 10)

A code was scripted (designed) and sent to the factory in the nearby Catalan mountains in two months, the wood was mechanized in two weeks and preassembled in one. The structure was assembled during one week and the façade modules were plugged-in during another week. In total, on-site operations took only three weeks (photovoltaic fields and electric cars charged).

The integration design-to-production was fast and resilient. Flexibility, during this 21st century, might be more related to responsive adaptability and not anymore to the flat and indistinct.

Scale and time

And flexibility is a time-based concept. We update our operating system each year, our laptops every 3 years, our car every ten years... The speed of innovation that characterizes new technologies demands a time-based design. But buildings and cities are still being designed in a fictional timeless space.

Structures can perform perfectly fine seventy years, interior distributions thirty, façades maybe fifteen, photovoltaic cells become more and more efficient each year… We should start thinking in temporal dimensions too.

And to do so, to speed up architecture discipline, to get closer to other technology-based industries, we have to work with open and transparent logics. Construction systems should be easy to understand, to manipulate, to adapt and to update. Anybody can understand and intervene on his bike, actualizing it to their changing necessities, but architecture of last decades is each time more like a black box for their users.

After some decades of non-stop construction, the market today is in the renovation of the already constructed: recycling, updating and optimizing our cities for a better management of energies. And that is why the prototype was thought of as an abstract open-coded plug-in system. (Fig. 11)

The combination of big industrial processes (modularity, prefabrication, standardization…) with adaptive design techniques (parametric design, open code, latitude-responsive…) allows for a flexible "scalabitity". In this case, the system outcome is a pavilion in Barcelona, but the same system can be applied to some office hi-rise buildings in Boston, industrial warehouse in Basel or some huts-resort in New Delhi. Open digital code makes it ubiquitous and CNC fabrication makes it local.

Self-Sufficiency

Finally, self-sufficiency is a matter of scale. It is a matter of integrating in itself the cyclical processes that were left outt. It is a matter of thinking about open networks instead of closed objects.

The Endesa pavilion is now a totally self-sufficient building, working exclusively with sun energy. But smart cities are not made just out of smart buildings. It generates 140% of the energy it consumes, uses electric cars as batteries and charges a set of electrical bikes. The surplus of production of Endesa Pavilion could feed the consumption of a conventional (consumer) house. (Fig. 12)

The prototype was used to perform experimental research of the digital management of energy grids. By being able to control digitally the flows of energy, we could cross real-time data with decision making. The internet of energy[3] brings the flexibility of a Cloud to the physical world.

Networking, collaborating and interchanging are essential means to make a cohesive resilient system. That is why new informational technologies, with their inherent open participatory character, are crucial tools. It is in our hands to use it in the right way.

As internet did in the digital sphere, self-sufficiency is blurring the distinctions between producer and consumer. Traditional hierarchical centralized structures of power (energy and goods) will slowly be counterbalanced by distributed networks of producers-consumers. Self-production opens up the way to a new horizontal set of relationships.

The fundamental shift in paradigm here is in understanding cities (and architecture) not as efficiently designed machines, but as dynamic ever-changing ecosystems. (Fig. 13)

ANTI-GRAVITY ADDITIVE MANUFACTURING

The current paper[4] describes a new method of additive manufacturing using a robotic arm. The research project presented is based on a technique that allows the creation of 3D objects on any given working surface independently of its inclination and smoothness, and without a need of additional support structures. By using rapidly hardening thermo-set resins in combination with innovative extrusion technology it is possible to 3D print double curved lines of varying diameter without the need of support structure.

Over the past several decades, the transition from analog to digital has revolutionized many fields; most notably the distribution of information, computing and social media. The digital era not only changed the way we communicate, socialize, organize people around ideas, or even disseminate critical information across national and political lines provoking political changes, it is now also starting to define an evolution in the way we finance, manufacture, distribute, sell and also recycle products in the physical world.[5]

In its turn, the digitalization of production not only allowed automatization of existing manufacturing techniques but also brought in life new manufacturing processes such as the additive manufacturing process, well known as 3d printing.

While all traditional manufacturing techniques (computer driven, or not) mostly rely on the subtraction of material, additive fabrication is a process of producing a three-dimensional object layer-by-layer, particle-by-particle. The process of adding successive layers of particular material allows unprecedented freedom in the design of the form and in its complexity.

There are many known methods of additive manufacturing that are used to form three-dimensional objects and many more different devices that use these methods. Some of the most known methods are Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Stereolithography (SLA) and Powerbed and inkjet head 3D printing. These methods of forming three-dimensional objects have a lot of differences, though they have one very important similarity: they all produce three-dimensional objects from computer data by creating a cross-sectional (two-dimensional cross-sections) pattern of the object and then forming it by laying in an additive manner plurality of formed and adhered laminae.[6]

Limitations

Above mentioned methods share similar limitations, the most important of which are: the necessity of a support structure under hanging laminae, a required working surface for additive manufacturing to take place and the need of mutual adherence of laminae.

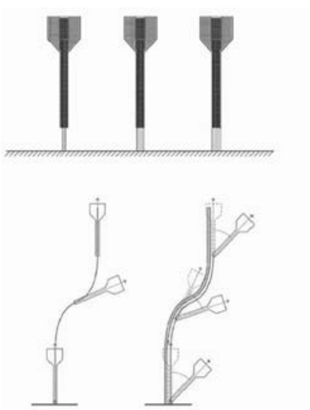
In the cases of SLS, Powerbed and inkjet head 3D printing this problem is usually solved by the presence of preceding layers of material that are used to create previous lamina. In the cases of FDM or SLA methods, this problem is usually solved by laying support lamina usually calculated by software. This results in additional structures connected to the final object, which require post processing that can sometimes result in the object's damage.

Most of these methods usually require a special horizontal working surface for the forming of objects. With most common 3d printers objects can not be formed on working surfaces with irregular height, and can not be formed on vertical working surfaces due to the force of gravity, resulting in the disability of forming objects on such surfaces like walls, ceilings and unsmooth surfaces.

Although, 3d printing tests in microgravity has already happening especially for exploring how additive manufacturing could be used on the International Space Station[7], those tests are limited in small scale printing objects or food and always inside hermetic closed microgravity boxes.

While the previous mentioned methods are efficient for forming high resolution objects inside of designated machines, they are not adequate for forming

Figure 14.



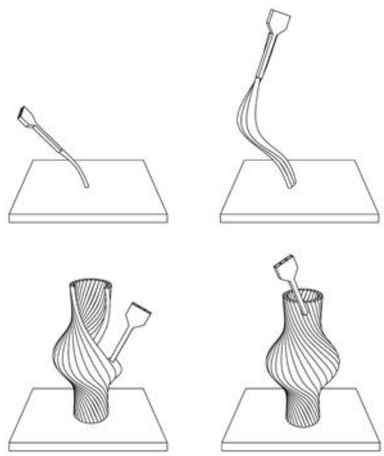


Figure 15.

Figure 17.

objects outside of the machines on unprepared settings and forming objects that don't have support underneath them.

It was apparent to the research team that the need exists for a method whereby on one hand the objects could be formed on any given working surface independently of its inclination and smoothness, without a need of support structures or limited sized machines. On the other hand the team focused on generating a method that would allow creating three-dimensional curves instead of working with two-dimensional geometries as it happens in conventional additive manufacturing methods (Figure 14).

Material prototyping

Precise material-state manipulation was essential for the process, as late solidification would result in low strength of formed curve and early solidification of material would result in a clog.

After conducting a large number of material experiments with different polymers, the use of very rapidly hardening two-component thermosetting polymer was selected as the more appropriate mix of materials and first prototypes of the extruder were created. A static mixer-nozzle and a two-barrel constant-rate plunger extruder are used to mix the source material components. (Figure 15). Both source material components are pushed through the mixer with such speed that solidification takes place precisely 1 mm away from the nozzle aperture (Figure 16).

Initially, some acrylic tubes were used as barrels, but due to the high viscosity of the material they failed to withstand the pressure, which resulted to cracks. Finally, the acrylic tubes were replaced with aluminum equivalents and the first printing experiments were held using a CNC machine to position the nozzle. The experiments proved that the prototype worked and a spiral line of 50 cm long connected to a vertical surface was printed. Though the results were successful, there were important issues of low printing speed.

Additive manufacturing speed is always limited by the chemical properties of the materials used since those can only be extruded so fast, and at such a rate before you start to destroy the properties of the part.[8]

After exhaustive tests of the material properties of the mixed thermosetting polymers in different heating and deposition speeds the most optimized scenario was followed and as a consequence two heaters were connected to the nozzle for speeding the curing process of the mixed material (Figures 16 and 20). The optimized scenario achieved allows a final speed of one meter printed height per five minutes.

Robotic prototyping

Next research steps focused on the digital fabrication techniques and protocols and an ABB 2400L robotic arm at Joris Laarman Lab premises was used for fabrication tests and fine-tuning the material prototypes. The S4 controller controls the robotic arm while the reach of the arm is 1800 mm.

Since there was no existing software to control both robotic movement and extrusion speed, a customized plug-in for Rhinoceros software was developed by the research team and scripted with Python language. The software was used to control the robotic arm movement as well as material extrusion speed, since the synchronization of these two factors is a vital factor for the project development. The customized plug-in gives the ability not only to control the robot for printing complex structures but also control thicknesses of the printed curves by changing the extrusion speed. For example, if the extrusion speed is halved – the diameter of the printed curve is halved accordingly (Figure 17). Therefore one curve, for instance, can have a thickness of 5mm in one part and 15 mm in the other, while the flexural strength of the curve is 160 mPa.

Avoiding collision of the robotic arm with previously formed curves is a significant and complex problematic which cannot be solved just with software control. After numerous experiments it was discovered that the nozzle could incline from the vector of the printed curve in order to avoid precedent curves without affecting the quality of the result (Figure 15, 16 and 18). This inclination control significantly simplified the collision avoidance solution.

Additionally, a coloring feature was developed in an effort of offering different color possibilities of the final printed object. Color dye is mixed in programmed proportion and injected in the static mixer. This feature allows user to preprogram the color of the printed object increasing the aesthetical capabilities of the presented technology (Figure 20).

Architectural Application

Introduction of additive manufacturing to architecture and construction industry is being researched in a number of institutions and considered to bring a lot of possibilities in these fields[9]. From Enrico Dini and DShape large

Figure 16.

Figure 18.

Figure 20.

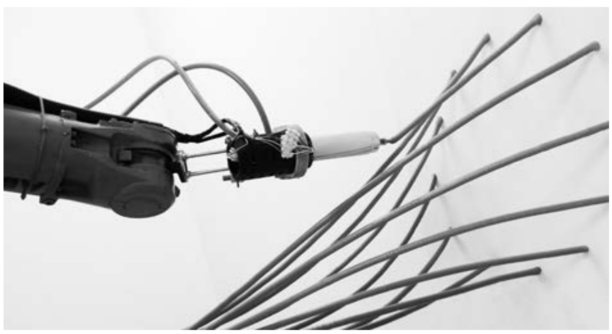


Figure 19.

scale 3d printing-stone machine to the concrete contour crafting of Behrokh Khoshnevis or the "Freeform Construction Project" from the University of Loughborough, additive manufacturing is becoming a significant revolutionary technique for the future construction.

Until it could be fully applied in real construction multiple limitations need to be solved; one of such problem is the requirement of support material during the printing process.

The present method presented in this paper is considered as a big and important step in the direction of solving this limitation. Based on this method, series of different devices may appear in the following years, from desktop 3d printers to building construction and restoration robots. The proposed technology can considerably influence architecture and design industries as it provides possibilities to control form in a much more elaborate way than before. Furthermore, it brings closer the concept of on-site digital fabrication of architectural buildings.

SMART CITIZEN _ OPEN DATA, KNOWLEDGE AND PRODUCTION PLATFORMS IN CITIES

The relationship between technology and humans has continuously been changing in time. Since early ages the humans created technologies in order to obtain resources, improve the living conditions or adapt to changes in the environment. The first computers and CNC machines were invented in the mid 20th century, personal computers became commercial products in the 1970's, the Internet became a civilian tool in the 1980's, smartphones are becoming a massive product today; all these tools produced an evolution in how and for what we are using extended capabilities to relate ourselves to our environment and other humans. New tools are part of our everyday activities, giving us a vast access to the production (and consumption) of knowledge as never before and at the same time providing us with the opportunity to share that knowledge (information) from/to anywhere, at anytime and by/for anyone. As we became information producers in the last decades, we will turn back into physical objects producers, turning bits into atoms through accessible and democratized means. The provision of tools for citizens could change the dependency on technology, in order to develop a closer relationship between humans and machines, working together for a common purpose, both in the physical and the digital world, if its separation is not obsolete yet[10].

How can cities create tools for the citizens to participate in the "production" of it? How can we understand a new urban ecosystem in which the cycle of the matter is part of the inner city fabric? Are we at the beginning of thesecond renaissance or a high tech medieval age?

Technology and Humans

From the early civilizations, technology has provided to humans an extension of their capabilities. From the first tools to acquire food (energy), produce fire, construct shelters, to the Greek Athenaeums, the first steam engine or the Sputnik, technology has exponentially extended our capabilities to study and understand our surrounding environment at different scales, from the microscope to the Hubble telescope. Nevertheless, humankind is becoming the biggest agent of change on the planet; acquiring capabilities to modify ecosystems as never before.Internet, ubiquitous computing and fabrication technologies advances are building up new ecosystems in the urban environment. Computers started to be transformational when they became personal and accessible to common people (at late 1970's and early 1980's). We certainly embedded personal computation in our lives by the use of devices, which have small computers to develop tasks in order to make our systems work. Internet was invented during the cold war for military and security reasons, which it was never used for; it became the most important invention during the last decades when it became accessible and available to be used by anyone. PCs with Internet connectivity constructed the digital and informational era we are living in today[11]. The formula does not work when all these tools are just used for entertainment, advertising or to conquer other countries, porn industry helped to make the major improvements in live streaming and changed the online video industry, many other innovations were based on our basic instincts as humans like sex, food or war and most of them ensuing from the development of the military industry[12].

Open source hardware and software are opening up innovative processes in cities, driven by citizens that become main actors in it by using real-time connected computation devices, and a new set of tools for invention and local production. Citizen self-empowerment through technology plays a key role on the development of future cities and communities. The do it yourself (DIY) movement, collaborative invention (DIWO, do it with others), open hardware and open software are bringing a fascinating set of tools for everyone with a computer and connectivity. In this sense, the tools that have been used to go in and out of the digital world are now the main channels to act in the physical world, by connecting computers with machines that are able to transform bits into atoms in short periods of time. Distributed manufacturing is accelerating the process of industrial production from weeks to hours and minutes, but still at a lower scale as regards the quantity. Low cost and easy to use minicomputers with sensors and actuators equipped with connectivity capabilities, which are sending real-time data of our environment and making it available to others; 1.5k USD 3D printers connected to our computers making objects in our living room; online open APIs for anyone to connect different online platforms in a single solution for specific needs are just examples of how we are in front of the most fascinating times for creation and innovation coming from ordinary people and not from NASA, DARPA or MIT engineers, or the military industry, as it happened in the past.

SMART CITIZEN. A Person and a Microcontroller Doing Things Together

We are in the times of Smart Cities, or at least this is what IBM, CISCO, ERICSSON or city councils are telling us at any large fair, congress or expo. Driverless cars, intelligent stoplights, expensive sensor networks, or buildings that talk to other buildings are just very few examples of the whole new market and business places that are being promoted in any major city in wealthy countries. The Smart City model is aiming at the creation of new services and products to be delivered to the citizen, in closed packages that just need to be unwrapped to be used. The new Smart Cities industry is opening big business for big companies and governments, by the addition of new infrastructures, intelligent equipment and high-tech solutions for cities' needs. The question comes when we stop for a second thinking about the role of any citizen in a Smart City:

- Should citizens be consumers of a new set of products and services?
- Will citizens be able of understanding Smart Cities' technologies when taking them from companies and governments as services?
- Can citizens participate in a productive way in cities, by the use of ICT?

Those questions came out within the Fab Lab Barcelona and IAAC, and have been the inspirational causes for the development of the Smart Citizen project. Smart Citizen is a platform for citizen's participation in the production of cities based on open source tools for data capturing and sharing, distributed production systems based on 3D printing and recycling and sharing obsolete products between citizens. The Smart Citizen project was launched in July 2012 on a crowd-funding campaign by Fab Lab Barcelona, the Institute for Advanced Architecture of Catalonia, Hangar Art Production Center, and Goteo crowd-funding platform, and has been successfully funded to be deployed in Barcelona in April 2013.

The Smart Citizen project begins with the assumption that intelligent cities ("Smart Cities") have to be produced by intelligent citizens ("Smart Citizens"). The reason to fund collectively this project was basically to justify its own goal; if the project would not have any reception from the citizens then it would not be possible to develop it. The project achieved the development of the Smart Citizen Kit (SCK): an electronic board and shield based on Arduino (Open Hardware) that can capture environmental data and broadcast it to an online platform using Internet. It consists of a set of sensors, battery and WiFi antenna, and can be used by any citizen with no experience in electronics to understand the performance of its environment and share it with other citizens. At the same time, the kit has been designed to allow advanced users to add features and capabilities, depending on their needs, since it is adaptable and customizable according to each situation. Additional shields could be designed by any user and attached to the main board.

For its first release, the SCK was designed with a set of environmental sensors embedded in a shield. The separation of the board from the shield allows other collaborators to design new sets of shields which can have additional sensors, not considered in this iteration. The sensors available on the Smart Citizen Kit are:

- Humidity
- Temperature
- Nitrogen Dioxide
- Carbon Monoxide
- Sound pollution
- Solar radiation (Solar Panel as a sensor)
- Wavelength exposure (WiFi antenna as a sensor)
- Battery charge level.

Considerations on platform's implementation include the ownership of the data. At the moment the data architecture of Smart Citizen resides in COSM (former Pachube), which allows for the free use of the API for the generation of optimized backend processes for data visualization and sharing. The ownership considerations include the distribution of the data in the city, by having a distributed version control system of that data in people's houses, and not in centralized data rooms. These features will be included in future versions of Smart Citizen, now under development.(Fig. 21)

Locality: making the cloud to rain in my backyard. There are several projects related to personal data collection and sharing, or the Internet of Things,

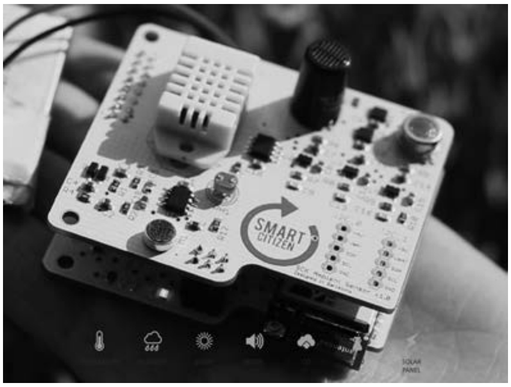


Figure 21. Smart Citizen Kit

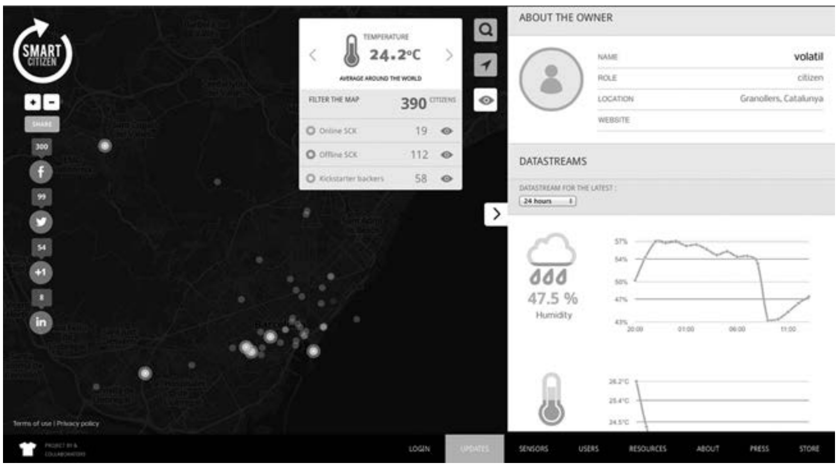


Figure 22. Smart Citizen Digital Platform

which can be found through the Internet and ordered from almost everywhere in the world. Some examples are: Twine, Ninja Blocks, Air Quality Egg or Sensor Drone; all these projects are brilliant examples of the possibilities of technology today, and how we can develop advanced tools that are not only coming from the industry but from the scientists enthusiasts, who take their extra hours to develop technology and then make it economically available through different crowd-funding campaigns, disrupting into the traditional innovation processes and industries. All these projects are available online, they are in the cloud, but one single criticism we can make of them is the lack of community and localization, in a metaphor: the cloud does not make it rain on my backyard, or my front door. The geo-localization and community sense of the Smart Citizen project aims to locate users within a few kilometers radius, which can exchange and meet in the city and compare their data or devices in order to improve the project at a larger scale. 200 backers supported the project in Barcelona through the crowd-funding campaign, finished in September 2012; additional kits will be distributed during 2013, and the aim is to make them permanently available through different open source hardware distribution platforms. (Fig. 22)

The project was directed to Barcelona active citizenship (in the first phase), people with interests in the use of open source hardware and software, people with ideas to change the productive and management models which operate in the city and institutions whichwould like to investigate about new models of city dynamics. The goal is to extend the project beyond Barcelona city and make it available to other cities in Spain and the world. In 2013, the project will be implemented in Santiago de Chile, Malaga, Lima, Caracas and other cities in the world.

Smart Citizen will be extended to applications involving distributed 3D printing and manufacturing, and will add options to register resources like Fab Labs, Maker Spaces, Hacker Spaces, MakerBot 3d printers (www.makerbot.com/) or RepRap (reprap.org/wiki/-RepRa/es), among others, and make them available as a service to manufacture in the city, understanding the city as a distributed production facility.

Cities and Crisis: The Fab City

Future development of cities should not rely only on the Smart City concept. The application of ICT in cities for its optimization has to be closely related to the citizen participation, at different scales. The appropriation of technology in people's everyday life is a reality today; all our communications are based on mobile information through the use of smartphones. If in 20 years we look back, we will find out that the erruption of ubiquitous communication have created a new set of relations between people in the cities. Today a phone is not only a phone, it is also a word processor, a blog publication tool, a video and photo camera, a journalism tool, or a geo-location tool, among many other applications. If we can use these tools to create an impact around us, then the results will be unpredictable. Air quality awareness, sound pollution, fixtures on the streets and public services, efficiency in mobility, etc, all crowdsourced by the development of tools which can be embedded in our existing ones, without having to make major investment in infrastructures, expensive devices and unknown experts. The cities' strategies should be focused on the delivery of platforms for active citizen participation, by the use of existing technology, and not high-tech fairy tales.

The 20th century industry development created a clear separation between production and consumption, producer and consumer, designer and user[13]. Nowadays we are hybridizing more and more all these concepts, by the introduction of production tools in our everyday lives[14]. Today, every major city has a Fab Lab, a MakerSpace, a TechShop or a HackerSpace within its borders. All these organizations are basically places, machines and people available for everyone to make whatever they want, on an individual basis or at community scale. Fab Labs have been developed and curated by MIT and a worldwide network of institutions in all continents (there are around 150 Fab Labs in 35 countries in the world, doubling next year); Fab Labs have a curated inventory with digital fabrication machines and tools which allow everyone to share anything within the network, they are equipped with similar equipment and a set of components which allow for the exchange files in bits format which actually represent atoms; the network is developing its own university through the Fab Academy, and is designing its own mechanisms of regional organization.

Fab Labs are organized through communities, institutions and other organizations. Hacker Spaces and Maker Spaces are more free organization than the Fab Labs; they are more community based, and have not content curation, they serve as platforms for hackers and makers around the world to organize events, workshops and activities. Tech Shops are fabrication facilities, which work in gym format, in which members pay a monthly fee to have access to equipment and knowledge to develop design and fabrication projects. All these platforms are providing anyone with the means to make anything anywhere and are growing in an exponential way in different countries of the world; these phenomena are similar to the appearance of personal computers, now named personal fabrication machines, which can lead to the change of a productive model, from a centralized one to a distributed one[15]. If we consider the existing crisis in job creation, and the elimination of many traditional entities, which make the world exist as we know it, about to collapse, then we can say that Jeremy Rifkin in The end of work was right[16]. Rifkin explained in 1995 how the massive unemployment by replacing the work of the man by the machine, is going to create the conditions for the reconstruction of society by community based self-organizations. According to Rifkin this will create the third sector, which is going to be able to provide new jobs based on services associated with the improvement of our everyday life.

The combination of an existing crisis situation in the western world with the appearance of this new movement of DIY and DIWO, is creating an ecosystem for the active participation of citizens in the production of their cities, using technology as means for the production of wealth. If we are able to produce our own tools to improve our lives, then we can be the Smart Citizens.

NOTES

1 Neil Gershenfeld. *FAB* (New York: Basic Books, 2005).

2 Jeremy Rifkin. *The Third Industrial Revolution* (New York: Palgrave MacMillan, 2011).

3 Ovidiu Vermesan. *Internet of Energy* (Helsinki: SINTEF, 2011).

4 The research project was carried out in collaboration with Joris Laarman Lab advised by Joris Laarman. It was conducted during IAAC Open Thesis Fabrication Program (OTF 2012) directed by Areti Markopoulou and advised by Luis E.Fraguada, Fabian Scheurer and Mette Ramsgard Thomsen.

5 Areti Markopoulou. *Towards the Democratization of production, Additive and Personal Manufacturing in Fab Labs* (Re-public, 2012).

6 I. Gibson, Rosen, D. and Stucker, B. *Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing* (New York: Springer Science+Business Media, LLC, 2010).

7 NASA, Made in Space, 2013. 3D Printing in zero gravity, http://www.nasa.gov.

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9 P. Yuan and Lynch, N. *Fabricating the Future* (Shanghai: Tongji University Press, 2012).

10 William J. Mitchell, *Me++: the cyborg self and the networked city* (Cambridge, Mass.: MIT Press, 2003).

11 Neil A. Gershenfeld, *Fab: the coming revolution on your desktop--from personal computers to personal fabrication* (New York: Basic Books, 2005).

12 Peter Nowak, *Sex, bombs and burgers: how war, porn and fast food created technology as we know it* (Toronto: Viking Canada, 2010).

13 Jeremy Rifkin, *The end of work: the decline of the global labor force and the dawn of the postmarket era* (New York: G.P. Putnam's Sons, 1995).

14 Neil A. Gershenfeld, *Fab: the coming revolution on your desktop--from personal computers to personal fabrication* (New York: Basic Books, 2005).

15 Vicente Guallart, *La Ciudad Autosuficiente: Habitar En La Sociedad De La Información* (Barcelona: RBA Libros, 2012).

16 JeremyRifkin, *The end of work: the decline of the global labor force and the dawn of the postmarket era* (New York: G.P. Putnam's Sons, 1995).

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