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A cloud recycling light

(human) feedback matters

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The paper focuses on the question ``How does our built environment, urban culture and architectural production change through humans feeding back into digital systems of pre-fabrication and systems fostering industry 4.0?'' It discusses some risks and possibilities of digitisation and the city in an era of sustainability, networked design methods, production processes and digital communication tools in the midst of The Internet of Things. Glimpses into the case studies `a cloud recycling light', `dynamic field feedback' and `urban rigid origami switch' discuss the impact of material behaviour, human and machine feedback into digital systems - their behaviour, their ways of communication, the possibility of optimising future design iterations and their form. All of which may result in new architectural and urban typologies, driven by increasingly agile ways of weaving together complex systems.

Keywords: *Industry 4.0, industrial production, Internet of Things, cybernetics, collective intelligence, feedback*

CONTEXT - BEFORE THE FIRST DIGITAL TURN

In 1969, the first message was sent through the APRANET, a network connecting four computers. Three years later the First International Computer Communication Conference took place between 24th - 26th October 1972, in Washington DC. Bob Kahn organised a "computer communication network demonstration (connecting 40 computers) to run in parallel with the sessions." He announced his presentation as follows: "This demonstration will provide attendees with the opportunity to gain first hand experience in the use of a computer network. The theme of the demonstration will be on the value of computer communication networks, emphasising topics such as data base retrieval, combined use of several machines, real-time data access, interactive cooperation, simulation systems, simplified hard copy techniques, and so forth." (Kahn, 1972). Kahn's statement that "The social implications of this field are a matter of widespread interest that reaches society in almost all walks of life; education, medicine, research, business and government" is certainly valid today. A crucial difference, however, may be the rising communication with physical machines as well as increasing complexity and blurring boundaries between observing and learning systems (2nd order Cybernetics) and controlled systems limited to a repetitive input-processing-output linearity disregarding feedback (1st order Cybernetics). Vint Cerf joined

Bob Kahn in 1973 to developed the fundamental structural components "Transmission Control Protocol" (TCP) and "Internet Protocol" (IP) that enabled the flourishing of the Internet as a globally accessibly network for matter-less information transfer. With the advent of its successor the "Internet" - between approximately 1985 and 1995, when, on September 20th, the Federal Network Council (FNC) defined the term "Internet" a new global information system triggered the growth of an inter-connected world (Evans & Hooper, 2017). Since then networked digitisation of communication-, production- and construction-techniques and -technologies have increasingly replaced analogue processes on all levels. As previous industrial revolutions did, the information age is triggering change - through the development of artificial intelligence and "autonomously" acting systems and soon objects of all kinds. Following the industrial age starting around 1760, the machine-age (1880-1940) and electronic-age mainly characterized through its physical geographical fixed location, our contemporary digital network age challenges us humans with a globally, tightly networked and communicating world. A phenomenon that influences the possibilities for personal communication methods, such as hotspots for free usage of the Internet, access to digitally networked objects for e.g., transportation, transformations in industry, research, society, governance, economy and our built environment. The "personal" within the global communication has reached a level where mass-customisation is as possible as direct digital manufacturing in every household. Manufacturing process are hitting batch-size one production lines, which is certainly attractive on a large scale when applied for performance optimisation of modular building components.

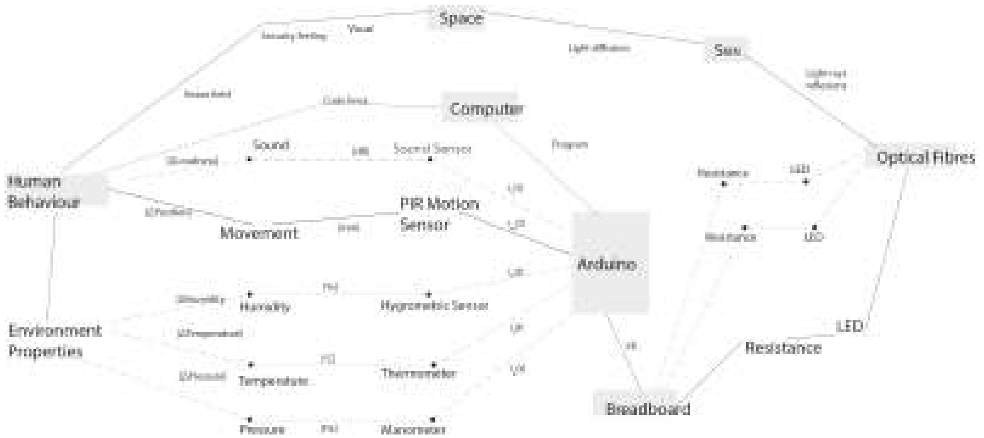
CONTEXT - IN THE SECOND DIGITAL TURN

The following three observations initiated the cross-disciplinary subject: a) The paradigm shift from analogue to digital architecture and development of cities is shaped by the accessibility of digital tools and ubiquitous computing. b) Merging of known top-down and bottom-up design processes (from data-mining to urban design). c) The requirement of re-thinking towards industrial processes in the construction industry - towards individualized pre-fabrication, due to global climatic development and demographic change with rapid population growth.

Figure 1
abstract networked map of Berlin

a) The first observation questions the idea of "the digital" as purely technical interface and encourages the extension of the digital towards, or rather back, to the material world. The query includes the topic of digital-theory (Carpo, 2011) and material making as part of education and research in computer aided architecture and design. The paper, however, introduces technical solutions fostering feedback into architectonic culture, an evolution of the human-machine interface, ubiquitous computing and machine learning, computer sciences, big data, information technology, governance. The technological ecology (L. Werner, Rossi A., PanahiKazemi, L., 2014) circumferences us in a second digital turn. It is offering design tools that can combine self-regulating data generation, systemic thinking, augmented reality, material intelligence, the industrial deployment of industrial robots in the construction industry, and socio-ecological developments. Big data, being implemented in land transformations (LTM) (Pijanowski et al., 2014) urban growth simulations and studies for the future, research in material technology is starting to be implemented in the curricula of architecture

Figure 2
Component and Data Structure Diagram



schools. The global network has - in many cases - succeeded in local communication; it implies ubiquitous computing, augmented reality and material intelligence, but to mention a few. Feedback-based design strategies overwhelm our traditional understanding of the discipline of architecture, encouraging a re-thinking of architecture, the architect's role and responsibility and a general understanding of what the architectural craft is (Kleemann, 2010).b) The second observation, a key topic running throughout the research is the impact of the advent and future perpetuation of intelligent materials, mass-customisation and the use of industrial robots on culture, society, human ecologies and their extension towards a robotic world influenced by artificial intelligence. Present technical changes trigger a reaction within the culture of architecture and urban design, which results in a merging of known top-down design processes and still novel bottom-up design processes. In this circumstance, digital data plays a key role in the learning system 'human-machine-material' - as information carrier and cybernetic feed-back-agents. The existence of interactive digital design laboratories increases continuously (Senseable Lab - MIT, Future Cities Laboratory - ETH Zurich/Singapore, CHORA Conscious City Lab - TU Berlin, Art + Design department - Northeastern University). The potential of digitisation lies in its ability to create and foster social and professional networks. Participation within the urban and local design process is possible. Intelligent pre-fabrication systems allow for the integration and immediate feedback of citizens', future owners' or tenants' desires in the design process in combination with external design requirements such as climate, sustainability, economics or biodiversity.

Figure 3
Sheet of bioplastic membrane

The question this technical development raises is: If industrialised and digitised mass-customisation democratises design and planning? A further question to project is, if this is a desired state and if so, what is the impact globally on a long run. The paper discusses if intelligent digital technologies - merging human and machine feedback - can improve the efficiency and flexibility of production through the customization of production?c) The third observation refers to the topic of human and machine feedback as crucial part for holistic systems integration in order to pre-fabricate, digitally manufacture smart building components for a growing world population in a changing world climate. Firstly, global demographic change (age) with an anticipated rapid population growth from 7,44Mrd. In 2016 to 11,2Mrd. humans in 2100 (source: Deutsche Stiftung Weltbevölkerung, 2016) is a challenge for architects, planners, politicians and the industry. Secondly, our buildings are responsible for more than 40 percent of global energy used, and as much as one third of global greenhouse gas emissions, both in developed and developing countries. This development in conjunction with climate change requires novel design strategies for the realization of human habitats and livingspaces. Hence, this article suggests a shift of the construction industry - following suit the automotive industry -, digital industrial pre-manufacturing and pre-production processes as well as building components with embedded intelligence for performance (internal) and environment (external) data collection - to be used for future decision-making (Chang & Chen, 2017). Modular building components and housing typologies are open to be redesigned innovatively in order to allow for swift construction and resilient sustainability. Projects presented are starting to develop possible models and reinvention of living typologies in a networked 'Conscious City' (Figure 1).

A CLOUD RECYCLING LIGHT RESEARCH CASE STUDIES

Three projects, 'a cloud recycling light', 'dynamic field feedback' and 'urban rigid origami switch' aim at utilizing material behavior in order to developing architectural and urban typologies as well as the development of more flexible and versatile building components with embedded intelligence, resource efficiency and the potential of circular economy.

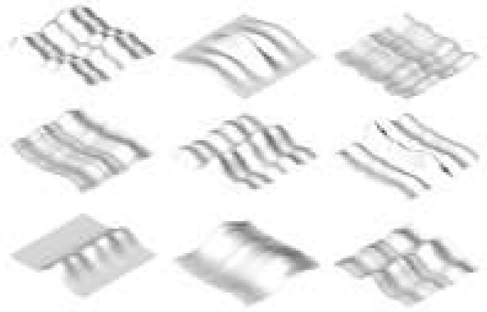


Figure 4
Variety of topography applying Perlin noise.

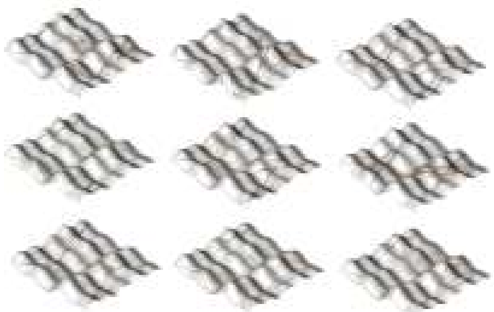


Figure 5
Variety of branch-types.

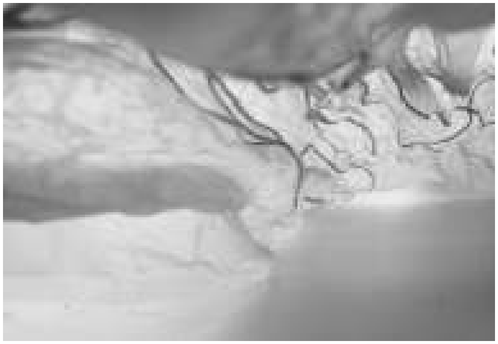


Figure 6
Cloud un-lit

Research is informed by the above thoughts and correlating global debate. 'A cloud recycling light' investigates in a customized component structuring a composite of fibrous bioplastic-material through the integration of structuring fibers (in the prototype made of Sisal) and optical fiber strands. The strands feed on existing light-sources in order to illuminate darker areas in the urban and rural environment. Activation is triggered through movement lighting dark paths for safe trespassing. It is a sustainable low cost material lightening system. This new component of the intervention is mainly made of an organic membrane - potato bio plastic and paper, two low-cost and common materials, and allows for large scale production (Figure 3).

Figure 7
Composite with lit-up optical fibre inside

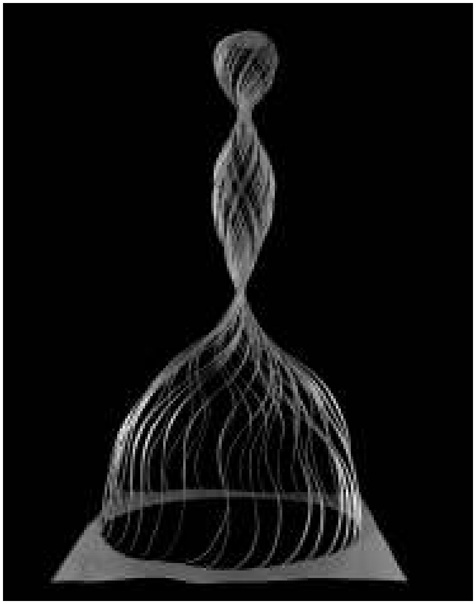


Figure 8
Activated spiral pattern on metallic coated paper

It uses the existing light and leads it through an apparently random network of fiber optics. First hand made, the final prototype aims to be CNC produced while using a pattern recognition process for placing the structuring fibers. Integrating even slight differences on the site leads to an infinite variety of final form. The process enables this element to inhabit the city on an urban scale offering high performance.

The topography of the surfaces is based on pseudo random numbers. Generation through 2-dimensional Perlin noise mappers. The final result of the topography is multiplication of two independent Perlin noise distribution in X and Y direction. The amplitude of Perlin noise (in our case the high of the composite panels) is a value between 0 and 50cm (Figures 4, 5). The original purpose the Perlin noise, developed by Ken Perlin in 1983, was to allow visual artists better represent the complexity of natural phenomena in visual effects. The prototype shows increased interactivity by introducing external parameters as well as a motion sensor.
The 'Component Data Structure Diagram' describes the relationship between visual field, environmental components and computational hard-ware once the component is activated Figure 2). An Arduino Microprocessor is used to measure motion as a variation of distance in millimeters, is transformed into an electrical signal in Amps and finally light (Figure 6, 7).

DYNAMIC FIELD FEEDBACK

'Dynamic field feedback' is a structure developed through the application of processing and grasshopper aiming at an intriguing change of the micro environment based on human, climatic and noise behavior in the city. It suggests a "learning tool for perception".Dynamic Field Feedback is the prototype for a cybernetic kinetic structure. The project's aim was determined Louis Kauffmann's definition of cybernetics as "the study of systems and processes that interact with themselves and produce themselves from themselves" (Kauffmann, 2007 cited in Targowski, 2011). The work is nourished by a rich groundwork, partially provided through Gordon Pask's (Pask, 1969). In 1968, the ICA in London held the "Cybernetic Serendipity", where Pask's "Colloquy of Mobiles" was presented for the first time - an interactive, educatable, computer-based system composed of five mobiles. Representing a social system, the colloquy supported the aesthetic potential environment. By way of light and sound, the rotating elements suspended from the ceiling communicated with each other, independent of external influences. With the help of flashlights and mirrors, the exhibition visitors could assume the roles of the mobiles and influence the learning process (Pask, 1968). Through communication the mobiles learned to optimize their behavior to the point where they could interact with the least possible use of energy.

Pattern and Form. This technique used for the Project was "Kirigami" which literally means (Kiru) cut (Kami) paper and is an actual a Japanese art form. It differentiates with the traditional Origami or Kirie (cut drawing) because of the lack of folding. The project started with simple geometrical forms such as: circle, square, triangle, voronoi cell and hexagon (Figure 8). This limitation enabled us to understand the basic phenomenon before engaging in more diverse and complex designs approaches. Experimentation showed, that the distance between the cut lines affects the flexibility and fragility of the three dimensional form. That lead us to testing the combination of thicker and thinner distances between the cut lines and observed how that affected the form.

The shape illustrated in Figure 10 is generated by applying the pattern on the metallic coated paper. The same pattern was applied on a sheet of 2mm MDF (Figure 9). The thickness between the cut lines and the dimension of the pattern are the same. Due to differences in the material behavior the formal and performative results vary.

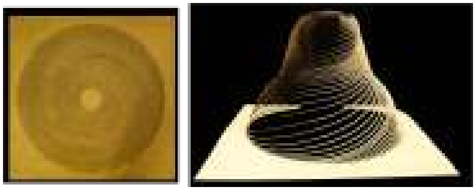


Figure 9
Activated spiral pattern on timber

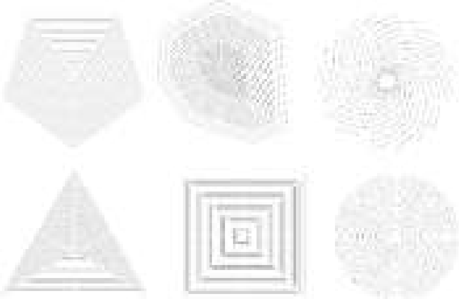


Figure 10
First tested patterns. Respectively rectangular, triangular, hexagonal, voronoi cell, circle, and spiral

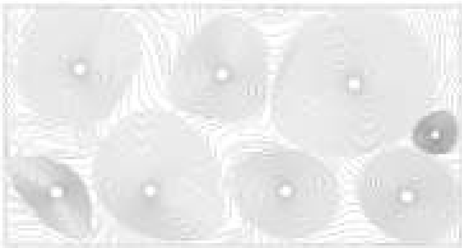


Figure 11
Final complex spiral combination pattern

Figure 12
Cut out pattern

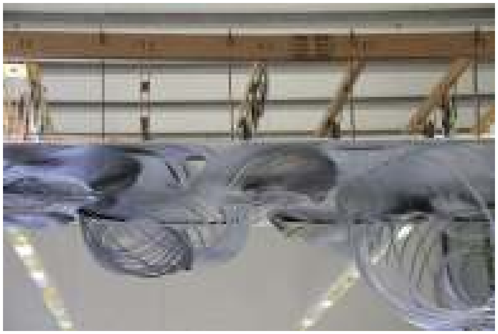


Figure 13
Final prototype

Figure 14
View of the pulley system. A motor activates the first wheel, setting in motion the rest of the system

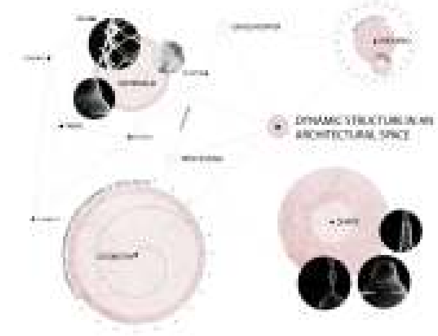


Figure 15
Diagram of Inter dependencies

The form, which emerged on the metallic coated paper was found more aesthetically interesting and hence it was decided to continued working with this material.

Parametric Pattern generation

The mathematical equations of a variety of spiral patterns were tested and simulated using Processing. By changing the parameters of the equation different configurations of the spiral pattern could be generated. This principle was used to create a pattern of multiple interconnected spirals. Apart from that attractor points at the center of each spiral was attracting all the lines. The further the line was from the attractor point the weaker the attraction force was. As a result, a pattern of eight interconnected spiral patterns was decided upon (Figures 11, 12).

Interaction activated motion. While working on a suitable structure able to set in motion our complex spiral pattern, we simultaneously studied a way to activate the mechanical components that would drive the motion. The most efficient way to proceed was to implement a motor device. This is why we decided to work with Arduino: an open-source device using a micro-controllers, and a long list of material that came with the kit we obtained. The communication/coding interface allowed to design the interactive object of desire. We further elaborated a coding file allowing us to control a small DC-type motor. As illustrated in the Figure 16, the DC-motor activates the first wheel of a large pulley system, indirectly setting in motion the complete structure (Figure 13).

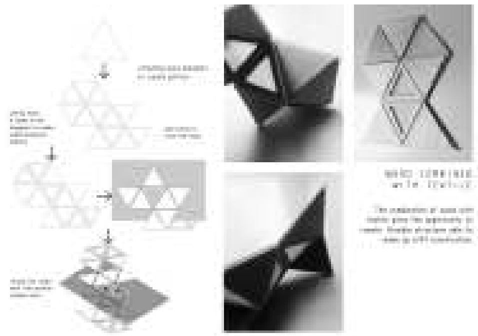


Figure 16
composite panel

As a result, a prototype of a single module of an interactive structure - that if placed in the urban context would create a continuous feedback loop with the passer-by - was built (Figure 14). The user would bring the structure into motion with the touch or movement, while the structure modifies the space, that effects the user. This would be potentially applicable in different scales making use of the same logic.

Figure 17
Triangular Origami pattern

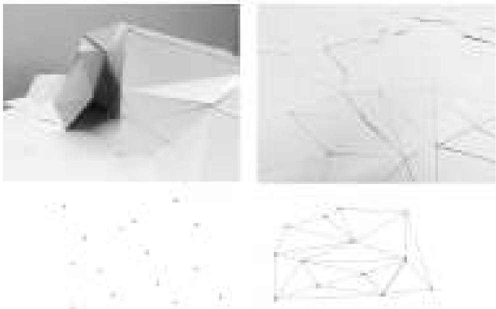


Figure 18
structural folding

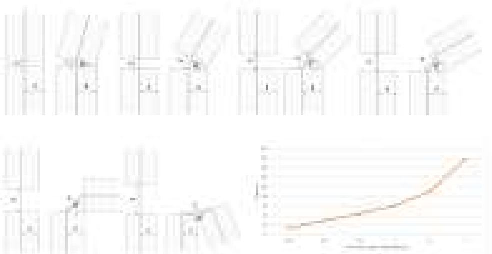


Figure 19
Dependencies between material thickness, panel distance and folding angle

In a building, it could simply act as an interactive ceiling changing in function of certain characteristics for example: noise volume, number of people, the weather also. For a town, it could become some sort of urban telephone where different neighborhoods could connect with each other through the apparition of these structures. It becomes somehow a device that could help a conscious city regulate itself and interact with its inhabitants (Figure 15).

URBAN RIGID ORIGAMI SWITCH'

The project suggests a composite wall based on digital origami development. It investigates modular components for greenery, solar energy collection in conjunction with place-making. A prototype is designed to interact and communicate with its environment. This project describes a prototypical process for a flexible geometrical structure to be applied at an urban scale. The process involved experimenting with common material as paper and wood where the aim is proposing a method to create a composite material able to find application in constructing urban sheltering pavilions, noise and pollution absorbing screens or generally in facade engineering.

The technique of origami folding and rigid Origami was used for its plasticity and facility to create complex movements, forms and shapes using a simple material for example a paper sheet (Figure 19, structural folding - folding lines using a Delaunay pattern on a 2mm thick sheet material) (Tachi, 2009) (Resch, 1960s [1]). The complexity of the membrane increased with the addition of other components. Timber was chosen as the main material for the external panels, with added textile sandwiched it in order to allow greater flexibility in the folding angle. With this a dichotomy between a hard and soft material was achieved.

The contemporary approach to urban and architectural design often does not consider either its impact on future city structure or the rapid climate changes.

Figure 20
Making of rigid origami panel

Current lifestyle and amenities of the 21. Century lead to deteriorating quality of air and water. To maintain the best living conditions while preserving and protecting the quality of life, measures have to be taken. new built architecture should meet the expectations of sustainability and durability.

Figure 21
analogue prototype

Figure 22
elevation of possible ecology origami wall

According to this principle another idea about producing energy came to our minds. In order to cater for sustainability, the folding membrane is designed with bendable joints, that would move according to the sun direction. Combined with a CO2 filter we envisage an efficient membrane for energy collection. Conceptually designed to an urban space it can also be adapted to an interior space according to its conditions. This means that the size of the membrane should be adapted in relation to it - folding and adapting themselves to the environment.

CONCLUSION

The entry question of the article "How does our built environment, urban culture and architectural production change through humans feeding back into digital systems of pre-fabrication and systems fostering industry 4.0?" may have partly been answered with the projects presented. The "wicked problem" (Rittel & Webber, 1973) of designing the built environment is additionally convoluted with the constant definition changes of all components the question entails - may it be "urban", "culture", "digital systems" or "industry" are constantly morphing, establishing novel relationships, levels of relevance and subcategories. The network-age encompasses a technological parametric ecology nourished by noise and perturbations, resulting in a system of increasing complexity and decreasing controllability. The shaping of the built environment is less subject to the above discussed evolution, it is rather a question of political decision-making powers and economic force. Computational Architecture as a field of research integrated in the field of the practical erection of buildings and construction of cities plays an indispensable and vital role in suggesting change, form and content. Thus, the question cannot have one answer, but an answer that evolutes or interacts according and with to the changes of the questions components. What may sound rather philosophical here is, in fact, an example of isomorphism between technology, semantic, action, analysis, optimisation and design. As architects we are designing systems with multi-layered complex relationships rather than discrete objects (L. C. Werner, 2014). The systemic and cybernetic approach described in the introduction and the projects mirrors a "radical constructivist" (von Glasersfeld, 1995) computational approach, which I believe is relevant to handle projects on a rational level of operation. “A cloud recycling light” therefore, acts as starting point, as a step towards solutions and innovation.

Figure 23
urban impression

Acknowledgements

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