A process where performance drives the physical design

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Abstract

This paper investigates the consequences of information flowing from the material of architecture towards the virtual models of architecture. The consequential feedback-loop, results in processes with similarities to form finding experiments made during 1960ies where form was derived using the principle of entropy between material and natural forces in interaction. In contrast to known form finding experiments, this paper will discuss how embedded computational systems might guide a novel form and performance finding process, utilizing sensory devices capable of measuring architectural parameters. This paper will investigate the distinction between ‘embedded sensors’ and ‘external sensors’ and outline some intrinsic differences between the two strategies. The paper will also describe unconventional sensor strategies, utilized by the computational systems, needed in order to navigate the emanating environment where pre-calibration is not possible.

1 Introduction and precedence

Architecture has over the past decade been heavily influenced by both new industrial materials and development for the information technology and technology in general. The confluence of these two areas has enabled architects to investigate complex material compositions within architectural designs. *Material systems* often actualized through intricate flows of information from the computational models towards the physical material (Menges, A. and Hensel).

The paper will deal with the consequences of information flowing from material compositions (materialized architecture) towards the virtual computational models. The research described deals with experimentation reviving the praxis of physical *form finding* analogous of the research of Frei Otto, but where Frei Otto and others utilize natural forces, this research attempts to utilize sensors and computational techniques to guide form and performance. (Otto, F and Rasch, B 1995).

Computers and digital technology can be used for system analysis and simulation of material behaviors, properties which Deleuze, calls intensive (Deleuze and Guattari, 1980). By applying algorithms to all the specificities of the system, they are able to simulate the entire behavior of aggregates. (Reiser, 2006) The paper will question how this information becomes relevant to the productive approach of architecture, and the research deals with sensors as mediator for this. Experiments with design using real world data in a feedback system has been made by Salim and Jaworski in the Smartgeometry 2011. They explore physical feedback design loop, where additional real world information and simulation results are projected onto the physical design in real time. The user of the system is then able to base further design iterations on an increased variety of real-world information. (Salim and Jaworski 2011)

Conventionally, sensors are used as units installed into known environments, calibrated to give data concerning specific fluctuations. If the environment and the fluctuation is of complex sort, *sensor fusion* is utilized, “*The idea is that if you combine the data from a variety of different sensors, you will be able to measure parameters for which no single sensor exists*”(Laughlin 2002) The strategy can be used to exclude or include certain phenomena and occurances. (Toko 2000). This research will embrace this idea of *sensor fusion*, and utilize it as a driver for design, hoping that sensors of different kinds are able to attain quality of various design variables simultaneously.

“Today, online sensing of material properties, combined with real-time control, is making the goal of self-directed, intelligent processing a reality.” (Eror, 1995) He concludes that sensors are to be placed in particular places of concern or embedded as components in structural elements and that material technologies facilitate the development of new

sensor materials with specifically designated properties, and invention of new composition matter. He argues that a novel approach to sensing is needed, such as sensor fusion responsive to physical phenomena.

2 Proposition

This paper propose to utilize sensors in the design and development of performing aspects in architecture.

Sensors and embedded computational systems is suggested as design tools for developing and modifying performing aspects. It is also proposed that the sensors and computation might support and assist the prototype development in certain design tasks. Two cases investigate the difference between embedded and external sensors. The cases are designed for simplicity in order to gain insight to their intrinsic differences.

After identifying that many processes of creation entails a feedback from the emanating, take for example the approach of sketching, where an idea of form or sense is emerging from the precedent unfinished lines. A process of sense making is occurring in this feedback process. On the other hand, when considering architectural realization processes, this type of feedback from the building under construction, is not considered productive to the design process, on the contrary, regarded as ‘a bump on the way’. It is prudent to investigate how this reverse information of unforeseen consequences might prove useful in both design and realization of architecture. In order to test this hypothesis, the prevailing idea of planning and preconception, is eliminated. The test should be a physical analogy to the emergence of a drawing on blank paper, done without any initial scene to depict or projective form. The test must be able to evaluate various aspects of performance, and when initiating a design and building process, the embedded computational system must record changes and reacts according to the various changes in performance.

2.1 Chain Sensing

In order to maneuver in an emanating environment, various sensors are used in a manner I define as ‘Chain sensing’. This strategy is relying on changes in the environment, and on the aspect that multiple of the same type sensor is present in different locations. By comparing the relative change of each value (chaining), no pre-calibration is needed to see relative alterations in the environment. In this way emanating environments can be constantly investigated.

2.3 Outline

This paper will in detail describe the procedure and results of two physically embedded computational systems. The systems consist of a one-type building block system. In system 3.1 the building blocks themselves are sensors (embedded sensors), the other system 3.2 has exteriorized sensors. The sensors will in both 3.1 and 3.2 inform the status of performance through a computational negotiation, then, guide the next step of design for the block system.

2.4 Questions

Could sensors be operational within a complete changing environment, and what strategies might be utilized or developed to manage non-calibrated sensor data?

How does sensors identify and evaluate what is emanating and what does it entail for sensors to detect themselves as part of an emanating environment?

What does a productive feedback loop entail? What minimum information is necessary/redundant to loop, and what are the differences in information regarding embedded vs. external sensors?

In which part of the loop are conflicting criteria dealt with?

3 Methodology and setup

In order to discuss these productive setups and gain strategic knowledge on the sensing methodology, I consider two strategies for sensing. *External and embedded*. They will both work with Chain Sensing, as they operate within emanating environments.

The sensors will focus on various architecturally relevant performance aspects of the artifact, and a rule-based computational system will utilize the captured data to steer and conduct the construction. In the specific examples the actual assembly is done by hand according to the instructions from the system. The instructions are either given via a monitor or through a projector mounted over the top of the system.

3.1 Embedded Sensors: Sensor active building blocks as self-informed body.

In this setup, wooden sticks are made actively sensing by applying a semi-conductive layer to the surface. The sticks are only able to detect their connection to other sticks. Any stick in a conglomerate will have some connection to any other. The sum of connectivity is then calculated for each stick. The only information in focus is the two sticks with the lowest connectivity to the conglomerate. Fig. 1 shows two conglomerates. Stick 1 is its own conglomerate without connection to the larger conglomerate formed as a straight pile of sticks. In that pile, the stick in the top and the stick in the bottom has the least connectivity within the conglomerate. Fig. 2 shows another conglomerate; here stick 10 has most connectivity, while 2 and 12 has least measured connectivity, although in theory all sticks except 10 should have same connectivity, as they are all only connected to stick 10. The rule for the experiment is simple; the next stick must be placed in such way it connects the two stick with least connectivity.

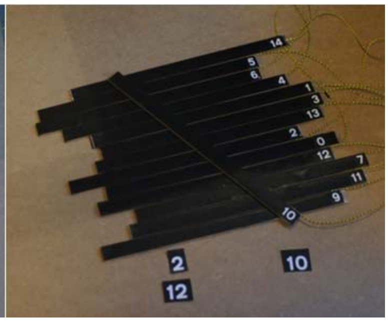

Fig.1 Fig.2

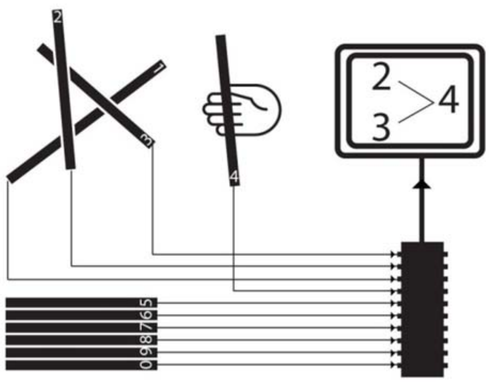

Fig.3 Diagrammatic illustration of the stream of information and material. The monitor informs that 2 and 3 has least connection to the conglomerate, so 4 must connect to those two.

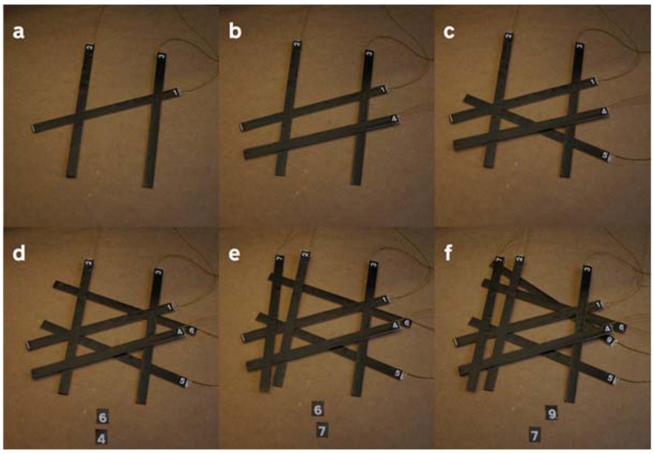

Fig.4

Fig 4 A buildup where two blocks are placed across one other. (a) Logically block 2 and 3 in the top has the least connectivity. (b)Then block 4 is added to connect them. (c) Now they should have equal connectivity, but the system says stick 3 and 1 has least, so stick 5 is placed. (d) 3 and 2 are connected by stick 6, and now stick 4 in top and stick 6 in bottom are least connected. (e) now 6 in the bottom and the new top is least connected.(f) stick 9 is added in the bottom and after this it is hard to add a stick to connect 7 and 9. This buildup demonstrate a conglomerate that does not stretch out, but rather tries to bind together.

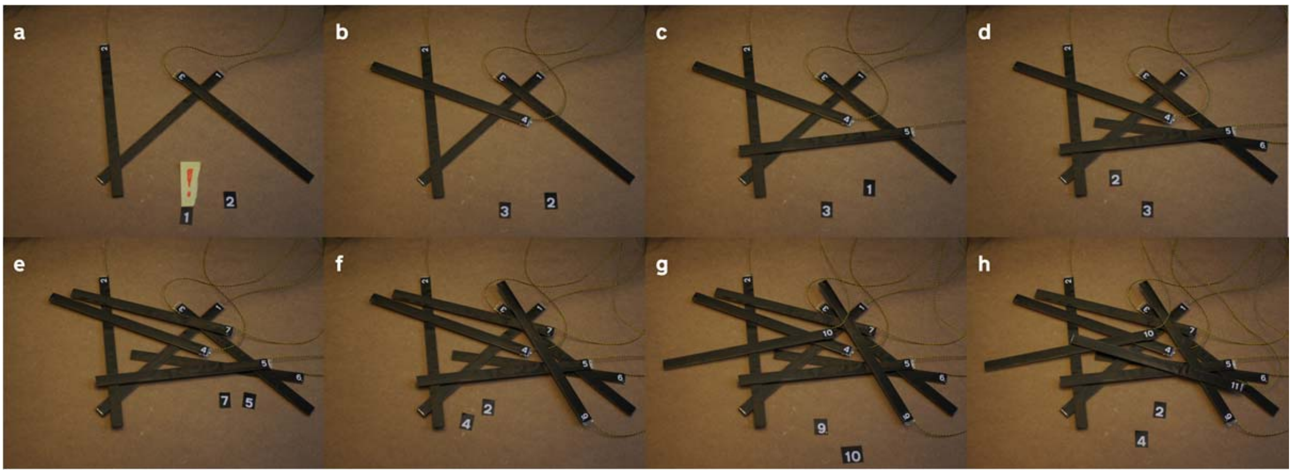

Fig. 5

Fig 5; A buildup where an exception starts the initial condition by connecting the least and the most connected (a-b). By looking at the development (c through h) it is clear that there is no branching out, rather a tendency to bind together again.

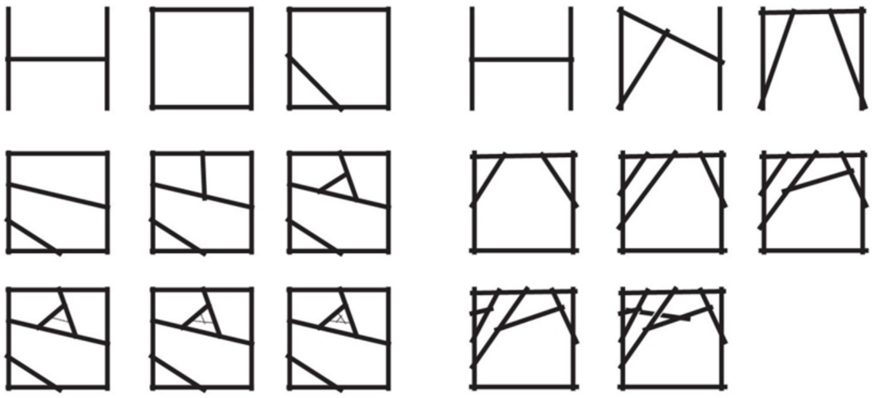

Fig. 6

Fig. 6; Two build-up session as diagrams. Many of the additions is in coherence with the rule of connectivity, some are in a 50/50 percent choice between two equally possible and then some are not in coherence at all. The thin dotted lines are predictions based on the occurring pattern.

3.2 (B) Simulation and sensor fusion directing emergence of the artifact. –existence external to.

In this setup sensors are placed around the building block system. The single building block consists of three rhombic plates that are connected by three shared edges to constitute a ridged part. These building blocks can be connected to the conglomerate by gluing any of the tree sides to any side in the conglomerate. This way the conglomerate can grow in many directions and create strings, plates or solids. Sensors placed under the initial elements direct the balance of each conglomerate, while light sensors regulate the shade and reflection and air flow sensors regulate airflow.

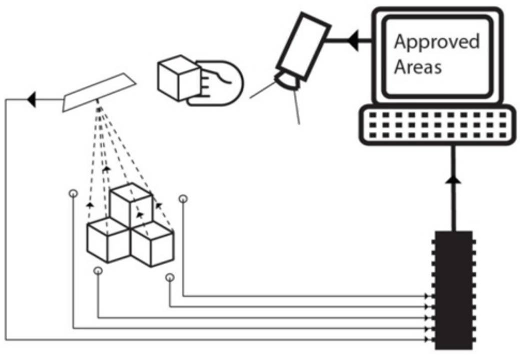

Fig. 7; Diagrammatic illustration of the stream of information and building blocks.

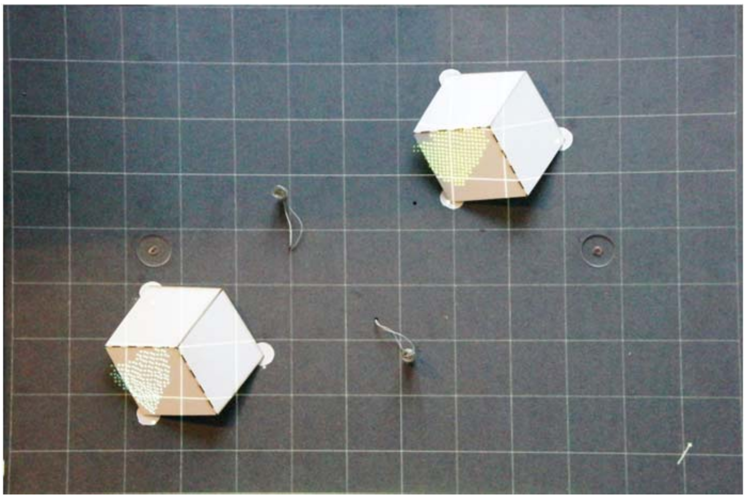

Fig. 8; Pressure sensors are placed in the baseplate under each footing of the start blocks. Two light sensors are placed next to each start point and two air flow sensors are placed between the start blocks. The conglomerates are monitored from the top by a Kinect Xbox 360 3d sensor, and a projector is placed right behind it to project on the building blocks where to add further blocks.

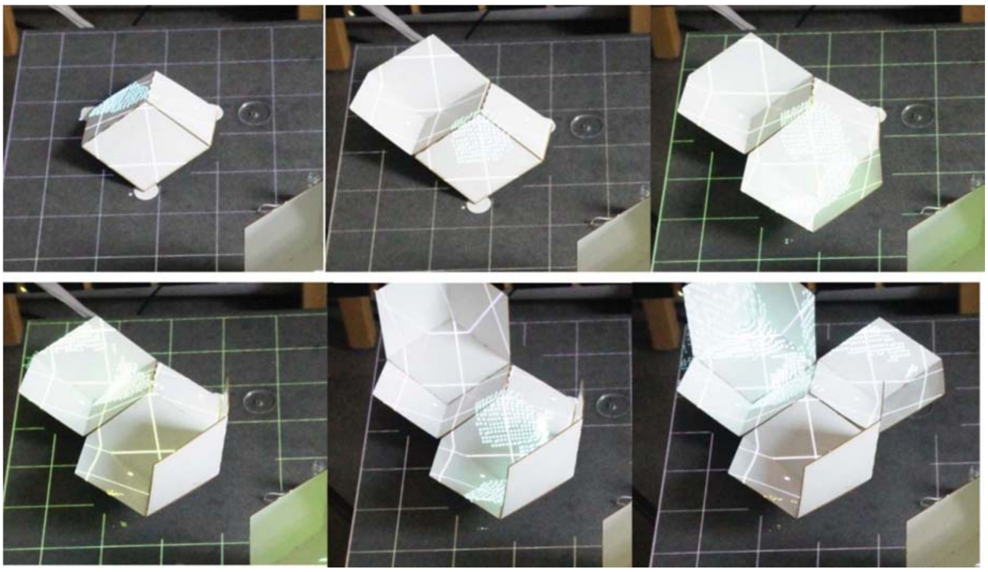

Fig. 9 shows a focus on the buildup of one of the elements, when only balance is regarded.

The ruleset is as simple as possible; the light sensors are comparing values, and as the conglomerates grow, they grow avoiding shade on the sensor with least light and promoting shade on the one with most light. The sensors for airflow balance in a similar manner.

The computational system is built using processing (Java) and mainly consists of conditional settings for the 3d point cloud. Wind and light directions are given and according to the balance between each pair of sensors, certain 3 dimentional volumes are ‘recommended’ to build within. However as the conglomerate might not exist within these areas, only the recommended areas where the conglomerate exists can be projected upon and build upon.

The hierarchy between these multiple sensor readings and physical criteria is essential. For the conglomerate to build shade over and area, it must maintain balance to reach out to cover that area, and whilst creating counterweight, it cannot interrupt the balance in the airflow.

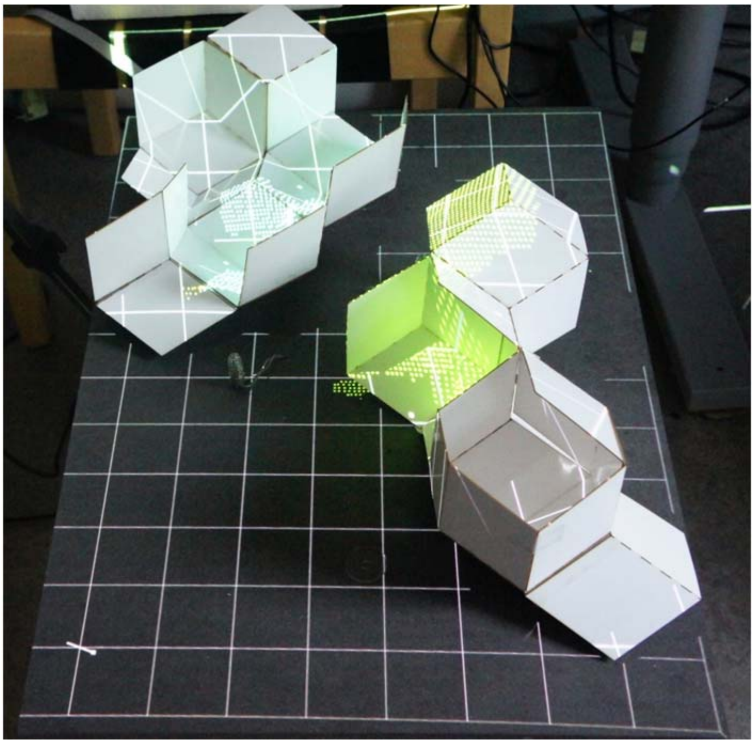

Fig. 10 shows the result of a small buildup. The two conglomerates are in balance over the single initial building block. They each attempt to create shade and reflect light onto the respective areas where the light sensors are placed.

4 Observations and Evaluation

4.1 Generally **t**he setup with embedded sensors in sticks presented in 3.1 shows that having the sensor being the actual building block, non-evident information becomes accessible. The structure can be understood on a holistic level, and information about internal events, relations and structures might be traced.

This particular setup shows a structure with a rule set and logic that contradicts the physical qualities of its parts. When the nature of the conglomerate wants to connect to its outer less connected parts, the building blocks responds with bad performance due to their shape as straight sticks. They are too ridged and unbendable for the conglomerate to really start attaining an all-round good connectivity. A more flexible material might perform better in this task of all-round connectivity. Models for good connectivity are sponges where voids interconnect and branch or hairballs, where long fibers are crossing many other fibers. The intrinsic nature of these straight sticks connected in a flat manner responds badly to this rule of connectivity.

It also becomes evident how the system does not regard other than connectivity. It has no up or down; just outer and inner, connected or less connected. Locating the sensors was expected to be problematic; however when the information was solely relative to the existing elements, it was easy to relate position to information in the physical model without complicated location techniques.

When the buildup session plays out, the user makes important choices that will affect the continuation of the buildup. If deliberate mistakes are made as in fig. 5, branches can occur, strings or chunks that grow parallel to each other. However this is only for a short while, either they reconnect because the ends of each branch are being connected, or there is a connection, impossible to make, and the session ends.

4.2 The setup with externalized sensors proves complicated to process and calculate. Opposite the embedded sensors, the externalized sensors must have a location in the virtual model. So not only a virtual model tracing the structure, but also a ready defined virtual model positioning the sensors and aligning them to the traced model. In short the models must align in a common coordinate system across virtual and physical world. The externalized sensors in this system are dependent on knowing their own position relative to the conglomerates, and even then they must be enforced by the coding of the system. There is still more to develop on this system to see the full potential. But a part like balance proves effective. There is a long consideration regarding contradicting criteria; should these be solved in coding or can they be left to smart sensor placement and simple rules?

Conclusion

Intrinsic and extrinsic are other two words to describe the type of information overview gained with the two different strategies. The embedded sensors seems to help our sensation and perception of the intrinsic *behaviors* of the conglomerate, whereas the external sensors helps our perception of how the conglomerate *perform* according to those particular sensors in the near environment. Distinguishing between behavior and performance for the two systems is important. The embedded sensor system understands mainly what affects itself, whereas the externalized considers its relation to the surroundings.

If these strategies are to be projected onto real architectural prototypes or even building, it seems that a rule-of-thumb when designing sensor system could be considerations whether behavior or performance is to be traced. That does not mean a project should choose between one or the other, a building system can easily contain multiple sensory strategies.

Drawing the line between the embedded and externalized is not exactly straight forward in that unlike these examples building systems most often consists of different overlaid parts and materials, so if one part is embedded with sensors in order to traces behavior, that entire building part would simultaneously act as external sensor to the other parts of the building system.

It seems externalized sensors must have more elaborate control systems whereas embedded sensors seems more autonomous. Both systems are highly dependent of the building system morphology. The interplay between system logic and morphology seems to be an area to pursuit.

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