Rabbithole Research (rbt_h0l) : Towards a Hybrid Modeling Technique in Architecture

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What if there were a way to design with digital models similar to the way that we design with models in physical space? As architects we are problem solvers through the making of objects; a highly physical design process similar to sculpting methodology, engaging a rich field of encounters and information seen and unseen – sensed; a process of understanding-through-doing capable of reaching complex levels of comprehension beyond the cognitive. What if we can bring this level of engagement into the digital design environment with all of its power of parametric manipulations?
This research project is designed to examine these questions using the DIY sensors and microprocessors technologies - adding their sensory data capability (pressure, flexion, weight, etc.) into the digital environment, to create a hybrid physical-digital modeling technique. The goal is to achieve workability that approximates haptic methods and associated inherent material understanding, on which architectural practice is founded.
By focusing on modeling, the research specifically targets *architectural design process*, the early stages of design analysis and investigation, seeking maximum impact affecting the way we make/ think about architecture.
The project is motivated by writings of Juhani Pallasmaa and Classical Sculpture, specifically *contrapposto*, in identifying the act of modeling/ sculpting/ designing as one requiring the complex metric of physical systems necessary to examining questions spatially.
This research is also influenced by my 20+ years of architectural practice, one congruous with the shift in architecture from analogue (physical drafting and modeling) to digital; sensitizing me to what has been lost and gained in this shift.

Keywords: Hybrid Modeling, Architectural Design Process, Digital Modeling, Form-making, *contrapposto*

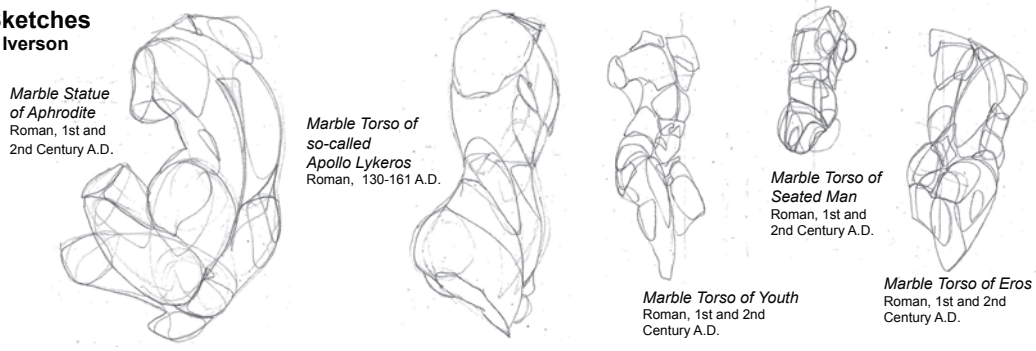
"If the world were clear, art would not exist." (Camus, 1942)

For me this quote suggests that all art, including architecture, functions as hypothesis: proposals for interpreting the world. As end products, (painting, sculpture, music, writing, photography, film, etc.) art embodies universal principles (time, space, nature, God, death, myth, etc.) precisely because it examines them. In this way art (and architecture) is able to resonate broadly irrespective of culture or time period and is therefore, while a product of its age, timelessly relevant.
Thus the first part of the research title, "Rabbit-hole" suggests that any architectural design and research, including the research presented here, functions as a hypothesis and represents only part of an endless exploration that grows, changes direction, and finds new ground – with our technological capabilities and project parameters.

research goal/ end product

The goal of this research is to arrive at a digital method for designing architectural form, one that incorporates aspects of the interaction between physical form and space (such as gravity and weight) as a way to move away from digital design as a primarily visual undertaking.
The present state of my research: developing a hybrid physical and digital modeling technique for designing such architectural form, suggests a dual system modeling technique in which a physical model integrating sensor technology will be linking to a digital model. The physical model will provide the tactile engagement with formal manipulation and transfer this to the digital model.

1. MET Sketches
2008, A. Iverson



between contrapposto and architecture design process

This research project is influenced by two compelling methodologies:

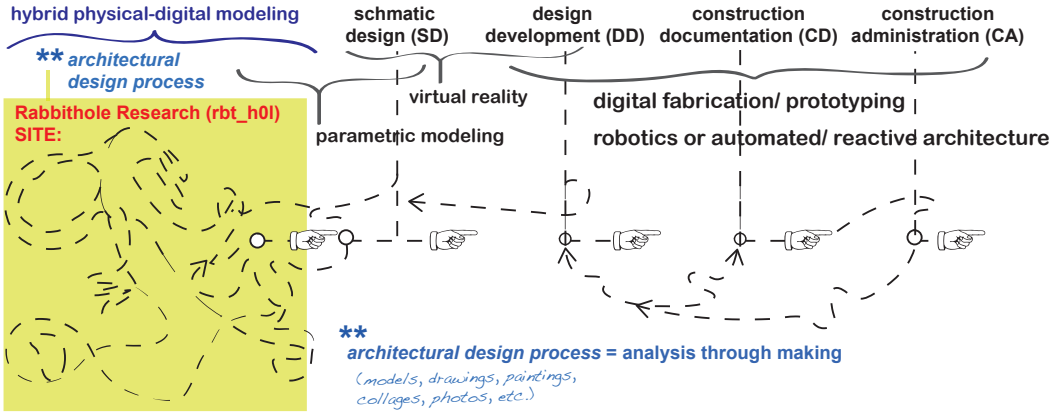
contrapposto in sculpture + design process in architecture

Contrapposto serves as muse and inspiration, while *architectural design process* serves as site or area of intervention.
The technique of *contrapposto* in Classical Sculpture, is one in which the figure is deliberately placed in an off-balance position. This wildly radical act represents a paradigm shift in sculptural practice and, no doubt, in the society witnessing this transformational understanding of figure and space. The technique of *contrapposto* required multiple axial rotations at various scales within the figure in pursuit of balance relative to material weight and gravity, producing an astounding degree of formal and spatial complexity, and an intimacy between form and space in which:

space, the negative partner of form, is calibrated in the reactions recorded in the figure. [image 1]

Architectural design process here refers specifically to the initial stages of architectural design where the form of the design object is being investigated/ discovered. **[image 2]**

2. diagram: architectural practice (phases) + status quo hybrid processes:



In this research *architectural design process* is defined as analysis through making, (drawings, models, etc.) – a uniquely tactile form of analysis in which: thought is action, ideas become spatial objects, and learning is a sensory-integrative experience. *Architectural design process*, as a method of discovery towards the as yet unknown design solution – is the targeted site of this research i.e. where this research seeks to intervene, thus seeking maximum impact affecting the way we make therefore think about architecture.

problem: digital context as spatially reductive

> "Human consciousness, ...is not merely in the brain but is fully embodied, needs an external environment pregnant with meanings and emotions for its self-awareness. It is futile to try to hypothesize what might happen if the environment was simply "smooth" and opposed no resistance ...Despite our present enthusiasm for digital communications ... our consciousness cant actually exist as a brain in a vat, in the absence of dialogue or exchange..." (Pérez-Gómez, 2016)

In contemporary *architectural design process*, that uniquely tactile analysis as form-making, is increasingly located in digital CAD environments which typically prioritize visual-based design, effectively removing the design object from its physical spatial context. In the sense that these CAD design environments typically do not include spatial conditions (gravity, weight, material resistance, etc.) these environments can be understood as reductive.
Therefore if, as suggested by the technique of *contrapposto*: critical manipulation of form requires a relationship between material and spatial conditions, then the problem becomes clear:
architectural design process, the engine of critical architecture, occurs in a spatially reductive environment, one incapable of providing the object/ context dynamic of forces acting through materials in space – or as described by Steven Holl in his forward to Juhanni Pallasmaa's text *The Eyes of the Skin*:

> "While our experience of the world is formulated by a combination of five senses, much architecture is produced under consideration of only one – sight." (Pallasmaa, 1995)

and W.J.T. Mitchell in *Back to the Drawing Board*:

> "... hasn't (architecture) now gone completely virtual, existing as much in speculative, notational and graphic or modular form as it does in actual building. And do not the buildings reflect this virtualization and liquidation, with the seemingly absolute malleability of shapes, materials, surfaces, and spaces." (Mitchell, 1995)

***contrapposto* solution**

Therefore in addressing the problem of locating the uniquely tactile method of analysis (*architectural design process*) within the anti-physical space of digital design, this research proposes the *contrapposto* solution wherein:

Complexity of form requires complexity of context (in which the form is located).

hybrid physical-digital modeling technique

From his text *Attunment*, Pérez-Gómez asks:

> "Are there clues in the tradition of our discipline that point to strategies for embracing modes of understanding, perception, and representation other than the pictorial image? This is indeed the question I wish to pursue." (Pérez-Gómez, 2016)

With this question in mind I looked for clues in my own practice as well as others, toward establishing how best to add complexity – in terms of physicality (gravity, weight, material resistance, etc.) – into the digital context of 3D CAD. Thus the first step (and current stage of this research) involves the development of a new modeling technique – a hybrid of physical-digital modeling capable of translating tactile forces acting on a object in real space into forces acting on an object in digital space,

thereby inclusive of:

"...embodied experience(s) where meaning actually appears ... (un)differentiated among the sensory modalities, and hinging ... upon invisible availabilities present to perception in particular circumstances.." (Pérez-Gómez, 2016)

3. hybrid modeling diagram

Gaudi - example of inventing a new way of modeling

Gaudi, *La Sagrata Familia (*model)

Here also it is worth noting that in focusing specifically on model-making, reinforces the targeted site of this research project: *architectural design process.*

However before we look at this 'Frankenstein's Monster'/ hybrid modeling technique construction and current stage of this research, few important ideas regarding physical model-making as it contributes to the architectural profession, and observations from my own experience in using modeling as a tool in my practice, should be mentioned:

physical model-making

Again quoting from his text *Attunment*, Pérez-Gómez points out that aesthetics or:

"(aas-the-ses) Aisthésis in "the original (ancient Greek) sense ... (referred) not only to visual perception but to apprehension by all the senses, enabling an understanding ...of that which is perceived by embodied consciousness." (Pérez-Gómez, 2016)

From A*bstracting Craft: The Practiced Digital Hand*, Malcolm McCullough states:

"Constraints (in a medium) define specific formal possibilities and guide creativity into specific channels..."

also, "Acute knowledge of a medium's structure comes not by theory but through involvement." (McCullough, 1996)

The above quotes describe the encounter with material properties (in terms of weight, flexibility, strength, etc.) – which provides an external dialogue, capable of "taking us out of our heads" – therefore extending our thought process beyond the limitations of individual knowledge, experience, and preconception.

In manual architectural design process – sketching with pen or pencil, and thinking/ analyzing – feel simultaneous. The same holds true of physical modeling which becomes an immediate and integrative knowledge of hand and mind through the manipulation of materials in space conveying an unequivocal perception of 3D space. Such an embodied engagement forms a vital transfer of knowledge, moving from purely cognitive, theoretical knowledge to one that is practiced, integrated, and experienced.

In my own architectural practice, the act of working with physical model-making, with materials, whether:

a.) wooden sticks glued to form frames **[image 4]**

b.) or flat board scored to form curves **[image 5]**

can be described as a meditation with materials and tools that is not a straight path. During this process of model-making, new aspects of the material, its connections, massing and proportional relationships, etc. are discovered which inform and enrich the initial design intention and, perhaps more importantly, lead to new understandings in the relationship of form and space, such as and referring to the examples above:

a.) hierarchy of frames comes from position in framing system as much as from size of framing members/ distributed loads

b.) strength of flat material can be achieved through geometry with respect to material resistance

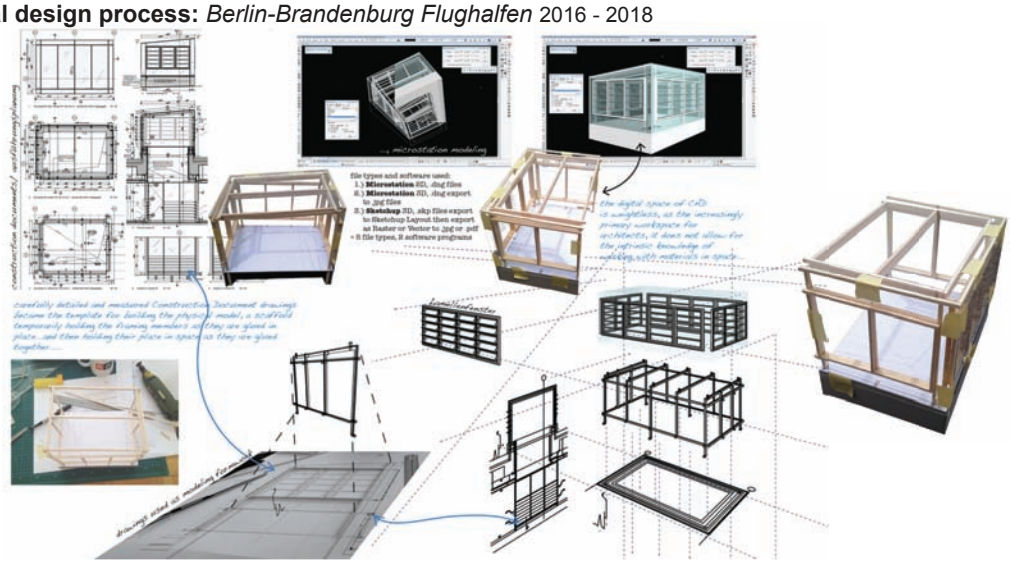
precedent: Gaudí, Otto

This was surely the experience of Antoni Gaudí and Frei Otto – architects who provide precedent for inventing a modeling technique in order to explore a new path for architecture, one in which form-finding involved subjecting physical materials to spatial forces.

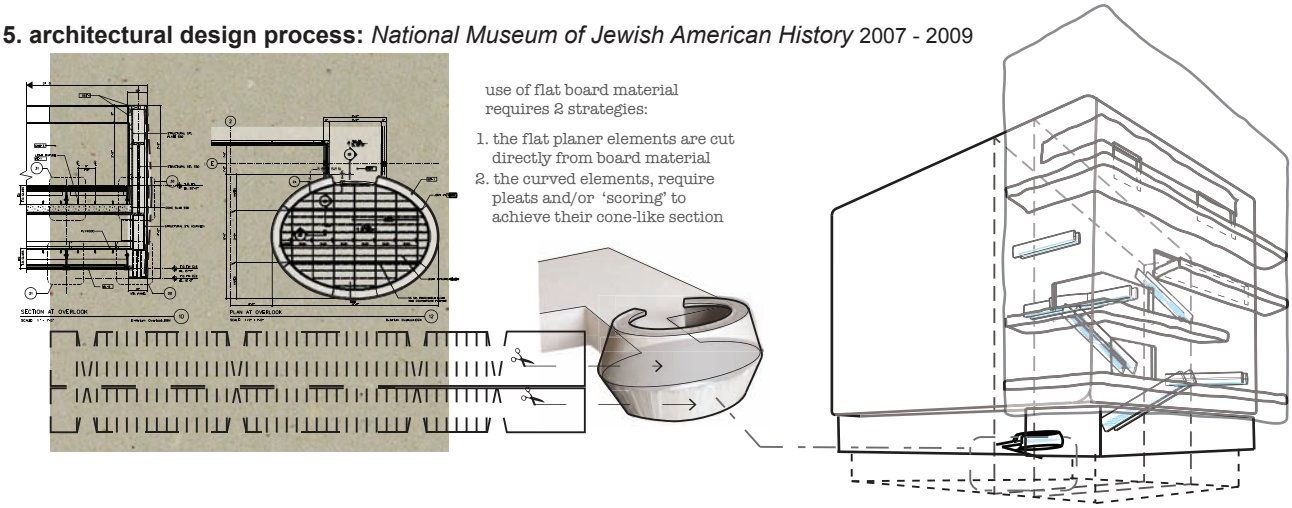
With regard to the technique of *contrapposto* (the act of initiating a figure in an off-balance relationship with gravity) similarities with the modeling process of Gaudí and Otto can be found in that all three strategies:

- shape the figure by subjecting it to a complex context of physical stresses
- recommend working with "simple" physical models (or sculpting) as the best method to examine spatial complexity

4. architectural design process: *Berlin-Brandenburg Flughalfen* 2016 - 2018



5. architectural design process: *National Museum of Jewish American History* 2007 - 2009



Further, through such modeling processes physical forces can be seen not as external to the object but rather as generated by the object, i.e. form-making reveals the dynamic physical forces of space that would remain otherwise undetected:

"... science has realized recently that it is as much about creating the world as discovering it." (Picon, 2008)

Importantly therefore: this doctoral research *purposely* chooses simple (physical) model-making as the means to add spatial variables into the digital environment rather than programming these variables directly into the computer.

historical roots of architecture

Also it should be noted – that this research project, which essentially seeks a tactile relationship with digital form-making, can be seen in-part as returning to the tradition, historically, of architectural practice as a hand-craft founded by masons, sculptors, painters, metal workers, etc.

hybrid digital-physical processes status quo

Locating this research in contemporary hybrid digital-physical practice reveals four main trends or categories:

- Parametric modeling, whereby digital 3D models are parametrically shaped by linking to external physical data such as: sun-path, circulation patterns, etc.
- Digital fabrication or prototyping, whereby a digital 3D model is realized in a physical form through digital 3D printing, laser cutting, or multi-axial routing.
- Robotics or automation, whereby physical components are linked and respond to data collection, for example: adjusting light levels or room temperature based on room occupancy data.
- Virtual Reality, referring to digitally simulated environments experienced via an immersive interface using virtual -reality-goggles and/or gloves, for example: software allowing architects to alter a design as informed by their virtual experience of it.

These practices have been integrating at various stages of architectural projects as corresponds to the level of detail required by each design phase: Virtual Reality technology is typically best suited in the Schematic or Design Development stage where the architectural design is refined whereas Prototyping is generally more suitable to the Construction Document stage where focus is on detailing and evaluating buildability.

rbt_h0l hybrid physical-digital modeling technique

The hybrid physical-digital modeling technique sought in this research project however differs from the above techniques in two ways:

- this research specifically targets the *architectural design process* 'phase', which is a discovery phase concerned with formal exploration and in which the formal design is yet unknown
- this research seeks a hybrid modeling technique whereby physical modeling controls its digital counterpart, thus information flows from physical reality to digital virtual space i.e. a physical-to-digital transfer; which is the reverse of the more common digital-to-physical methods whereby digital objects are transformed into physical objects, as in Digital Prototyping.

Fewer examples of the kind of physical-to-digital process sought in this research exist, however some of those approaching this methodology include:

- Tangible Media Group, MIT Media Lab – led by Professor Hiroshi Ishii in projects such as *Phixels*, physical pixels are constructed which correspond to digital pixels such that when the physical pixels are shaped (pushed or moved) the corresponding action is performed on the digital pixels.
- Surgical simulations using high-speed GPU (graphics processing unit) in which a digital surgical subject (body part or organ) is acted-on by physical elements (scalpel, tweezers, etc.). (T. S. Sørensen and J. Mosegaard, 2006)

rbt_h0l: current research:

The hybrid physical-digital modeling apparatus developed in this research uses: Arduino micro controllers and sensor hardware with Firefly plug-in software for Grasshopper. Combined this system can direct analogue sensor data to control physical objects (hardware), as in DIY robotics, or digital objects (software) such as Rhino digital modeling. The focus of this research is on the latter aspect, thus using analogue (physical) data to manipulate digital models.

Building the hybrid physical-digital modeling apparatus i.e. 'Frankenstein's Monster', is the first step of this research project and the subject of the following text. Subsequent stages of this research will explore the hybrid modeling technique in terms of its relevance to, and affects on, digital *architectural design process*.

rbt_h0l: hybrid modeling explored using architectural design process

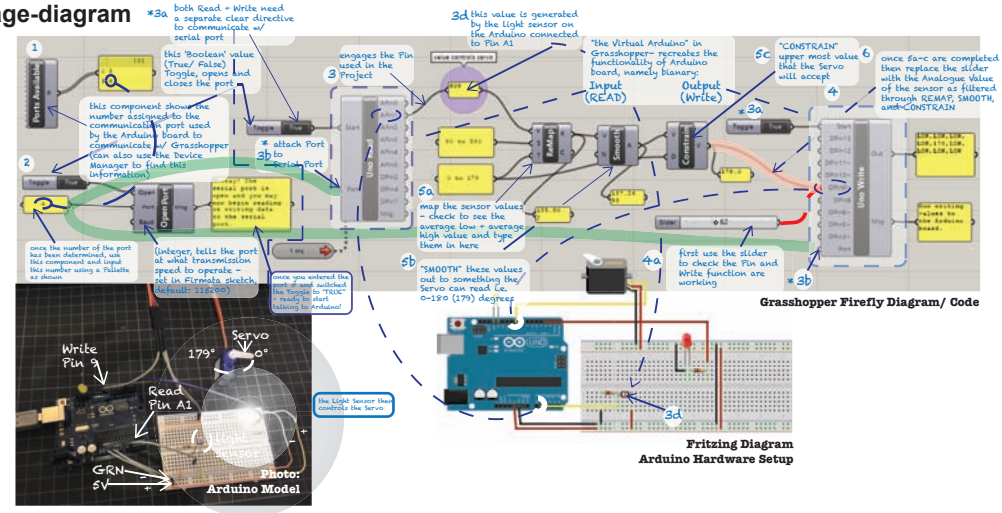
Architectural design process methods were used to explore the component parts of the hybrid technology as well as their physical-digital interactions. This is seen as a kind of doubling-down/ reinforcing of the goal of this research: to strengthen the architectural design process in contemporary digital practice.

Architectural design process produces "analytic makings" (drawings, diagrams, and models) containing inherent spatial relevance and thus lead to unanticipated findings, exposing idiosyncrasies, limitations, and potentials with respect to the hybrid technology and its spatial/ formal significance. These "analytic makings" include:

- Hardware models (simple micro controller and sensors models) were wired and programmed to test the ability for the physical/ analogue information collected by the sensors (distance, flexion, pressure, light levels, etc.) to affect hardware (LEDs, LCD screens, Servomotors) and software (Rhino model elements)
- Hardware collage-diagrams examining parametric graphic notation linked to Arduino hardware enabling analogue sensor data to be read and directed to control hardware (Servomotor) and software (Rhino).

[image 6]

6. hardware collage-diagram



- Digital Models and collage-diagrams describing 3D digital elements (mesh plane) linked first to parametric physics simulation software (Kangaroo) then replacing this with physical analogue hardware sensor data – to examine the process of adding forces (gravity, point load, etc.) to digital objects. Notably: this required 'mapping' the analogue sensor data to a more controlled set of numbers i.e. more regular input values.

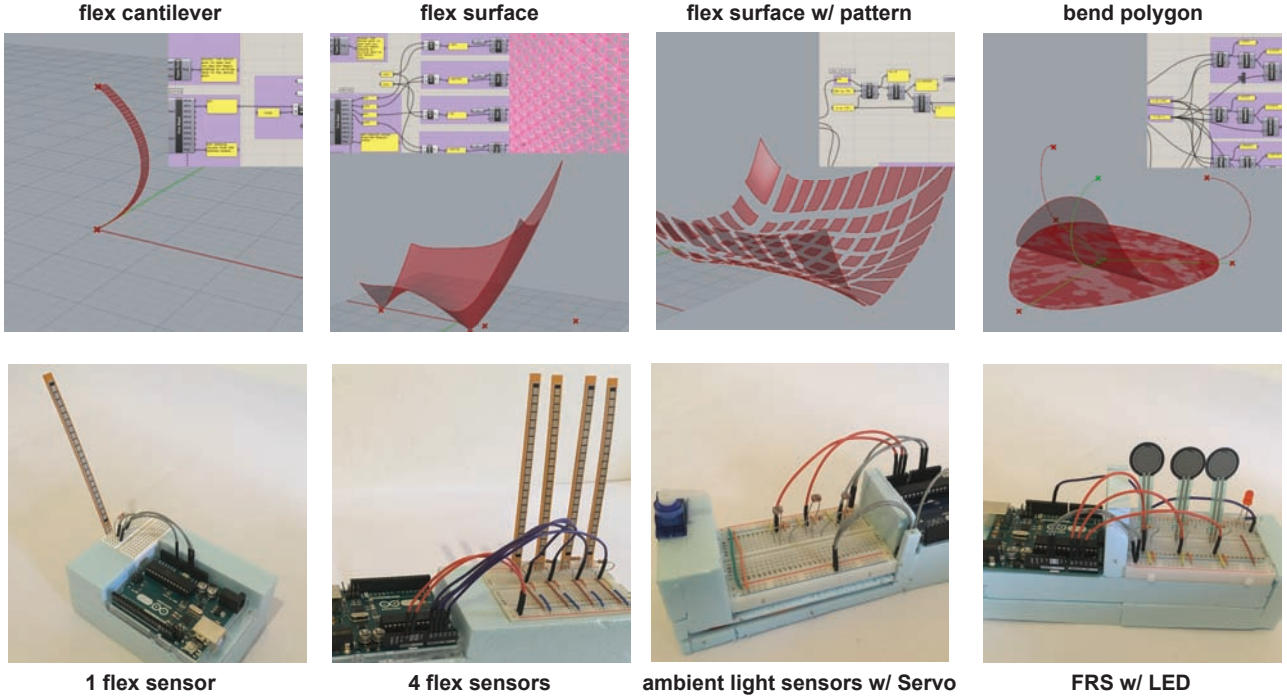
rbt_h0l: Hybrid-Minis

Informed by the above initial examination of physical-digital components and interface – the next step towards developing a hybrid physical-digital modeling technique, consists of a series of smaller experiments, referred to as Hybrid-Modeling Minis or Hybrid-Minis.

Four Hybrid-Mini experiments were tested, focusing on the ability of sensor data (physical) to affect the a digital object **[image 7]**:

- Flex Cantilever – uses a single flex sensor to generate a cantilevered form between 2 points located in Rhino
- Flex Surface – a digital plane is manipulated by a physical flexible plane with 4 built-in Flex Sensors
- Flex Surface with Pattern – this is similar to the previous experiment except the surface is a pattern – manipulated here by 3 light sensors. Also, a Servomotor is controlled by one of the light sensors– as a bit of fun.
- Bend Polygon – a polygon is bent using 3 Force Resistance Sensors (FRS). Also, a LED light is controlled by one of the sensors – as a bit of fun.

7. rbt_h0l_hybrid-minis - small initial experiments into hybrid physical-digital modeling technique



These Hybrid-Mini experiments are simple micro processor sensor models linked to basic 3D digital elements (mesh planes, surfaces, points, etc.) which test the ability for the physical/ analogue information collected by the sensors (flexion, pressure, light levels) to acting on, influence, articulate, and create digital objects. Thus these Hybrid-Minis begin to build a hybrid modeling technique whereby 'tactile' information can be translated into digital actions!

rbt_h0l: Hybrid-Mini - spatially significant findings

As *architectural design process* (analysis through making), the Hybrid-Minis revealed 3 findings with potential architectural and spatial relevance:

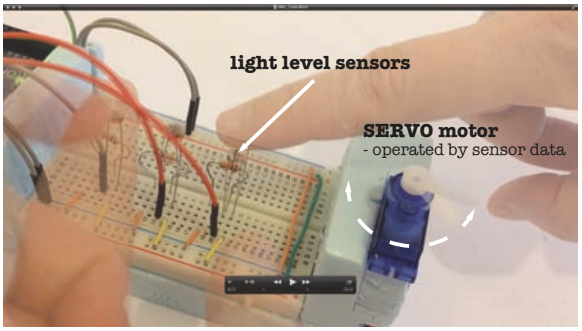
1. "seeding digital space"

All four Hybrid-Mini experiments use simple 3D digital elements (points, curves, surfaces, etc.) and link these to analogue sensor data through digital code describing what actions this data would take on the digital objects. Together, the simple 3D CAD elements (digital) and the data stream directed toward it (physical input), determines the digital figure/ form that is made. Therefore, and perhaps obviously, this hybrid technique is a combination of elements that exist half-in and half-out of digital space. Metaphorically, this technique can be seen as "seeding" a digital field (with digital elements), which are then acted on by forces (data streams) over time to 'grow' the resulting design object.

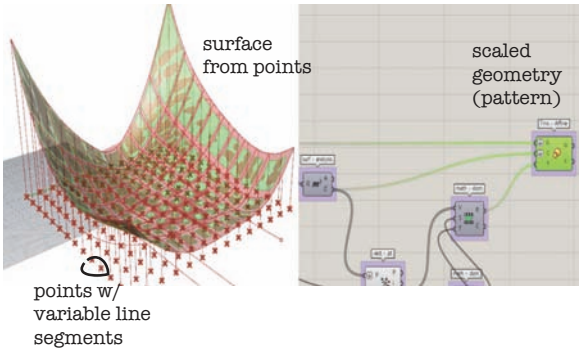
spatially/ architecturally this suggests: this presents a redefinition of object from independent, finite singularity to a spatial composition of rudimentary digital elements responding to designed data.

8. rbt_h0l_hybrid-minis *'force choreography'*

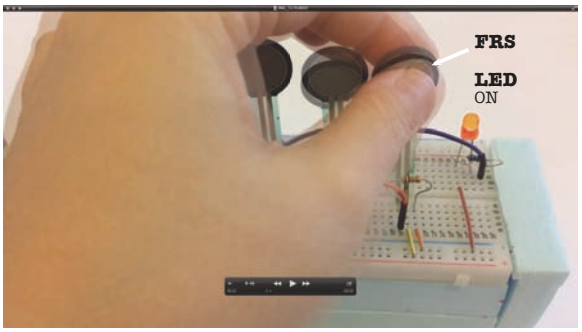
A1. light level sensors - data corresponding to **light** levels **shapes model**

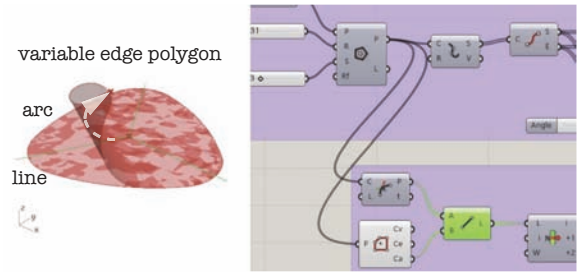


B. Rhino model - transformed by data run through code



A2. force resistance sensors (FRS) - data corresponding to **pressure** applied to sensor **shapes model**





2. "data mapping"
Analogue data collected by the sensors is in a 'raw' form; this meaning the sensor data from: light, distance, pressure, etc. come in as numeric values with many decimals and wide fluxuations. This 'raw' data requires mapping towards the desired affect on the digital figure, for example: a.) FRS sensors (force resistance sensors) responding to pressure send numeric values that are successively 'mapped' (made more regular) to be useful to the desired result: curving the edges of the polygon. b.) Flex sensors are bent, sending numeric values, which are then acted on by a divide component, translates the data into smaller decimal values, which determine the length of the line segment guiding the shape of the bent surface.
spatially/ architecturally this suggests: data mapping, or data design, is a significant "third" part of the hybrid architectural modeling technique, linking hardware and software.
3. "force choreography" **[image 8]**
The Arduino with integrated sensors explored in this research reads does not distinguish between force sources, meaning that sensor data from: light levels, distance, flexion, pressure, etc. is translated to numeric value and therefore the original source of the force (type of sensor) is interchangeable. This leads to the curious condition in which, for example, both light levels and FRS sensors (reading pressure) are able to bend/ or shape digital objects.
spatially/ architecturally this suggests: hybrid modeling does not recreate the one-to-one relationship experienced in physical model building, in which I cut and bend a surface. Instead in hybrid modeling light, distance, time etc. can be sensed together with tactile manipulations – to apply pressure or tension i.e. to manipulate digital form. Therefore man-made and naturally occurring forces with respect to architectural modeling can be choreographed to work together to design architectural form.

summary + future
The Hybrid-Mini experiments, as initial steps towards developing a broader hybrid physical-digital modeling technique, establish that some tactile control of digital objects is possible. Additionally, these experiments reveal data design to be a significant part of the hybrid modeling technique, such that between digital and physical methods there exists room to manipulate, design, and direct data; such findings potentially broaden the field of architecture in contemporary practice (to include data design) as well as begins to rethink basic assumptions (such as the definition of object).

It is these types of critical, innovative discoveries that underline the importance of *architectural design process* as a unique form of analysis through making (objects). As objects such analysis re-contextualizes the subject studied into a spatial and therefore architectural relevance – one capable of examining the scope of architectural practice and form-making while shedding new light into the relationship of digital era processes on contemporary architectural design.

While the focus of this research up to now has been on building a hybrid physical-digital technique/ apparatus/ Frankenstein's Monster, the next step will be the use of this technique in design while building on the lessons of this

such as:

- contrapposto applied to digital design – shaping the digital figure in (virtual) gravity
- shaping the digital figure through tactile/ manual engagement (through data sensors)
- and Hybrid-Mini observations: seeding digital space, data mapping, and force choreography

The objective then will be to examine how close this hybrid technique comes to forming a tactile relationship with digital design, thereby examining the effects of this hybrid technique on digital architectural design process (analysis as digital making) and thereforeour ability as architects to think critically through (digital) making.
If this research can be understood as searching for a technique that reconnects to working intuitively digitally – and, quoting Frei Otto who worked with both physical models and computer models:

> "... in computers you only find what you are looking for, but with free experimentation you can find what you have not sought." (Vrachliotis, 2016)

– it is the hope of this research, concerning the development of a hybrid modeling technique, to insert free experimentation into digital design.

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