Swarm Tectonics

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In *Matter and Memory* Henri Bergson wrote:

> *if we suppose an extended continuum, and, in this continuum, the center of real action which is represented by our body...Everything will happen as if we allowed to filter through us that action of external things which is real, in order to arrest and retain that which is virtual: this virtual action of things upon our body and of our body upon things is our perception itself.*

In other words, there is no distinction between the real and the virtual for Bergson they form a continuum in which our actions on real objects and our perception are linked through our nervous system. This insight -based on recent scientific discoveries of the time, studying the relationship between the physical state of the nervous system and its purely abstract processing of information. It allowed him to go beyond the traditional metaphysical opposition between realism and idealism in which either only the physical world or only the world of our imagination was real –the other being but an illusion.

A similar deep-seated dichotomy has existed in architecture in recent years where the idealism of modernist formalism has been opposed by the relativism of post-modern formlessness. The Modernist ideology of “Form follows Function” was replaced by the post-modern where form no longer represents function but rather becomes a representation of “complexity and contradiction.” Both of”these positions are based on the same assumption, however, that material (form) and its abstract contents (function) are related only by representation.

Modernist architectural production was based on the creation of an ideal image formed by apparent causal necessity. The architect represented this ideal in built form. The increasingly apparent complexity of our world made this self-assuredness of the Modernist architect appear more and more suspect leading eventually to a crisis in architectural production.

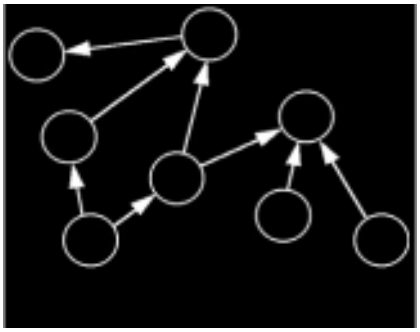
This resulted in Post-Modernist practice which repositioned the architect as a critic and observer rather than producer. This new position resulted in a necessary and effective critique of the Modern project and it attempted to accommodate greater complexity than Modernism had acknowledged. But it has also led to severe limitations on the capability of architects to advance their field through the production of new ideas which can accommodate the increasingly rapid technological and social developments currently taking place.

In recent years, new methods of design and modes of production have begun to necessitate an increasingly instrumental role for architects. As techniques advance rapidly architects risk becoming marginalized and irrelevant if they do not engage those techniques. By reaffirming their productive nature, without ignoring the complexity of our

world, architects are no longer either autocratic, all-seeing God figures or immersed reactive critics but rather can become a kind of demiurgic nano-machine responding to ever-changing conditions in a consistent but varied manner.

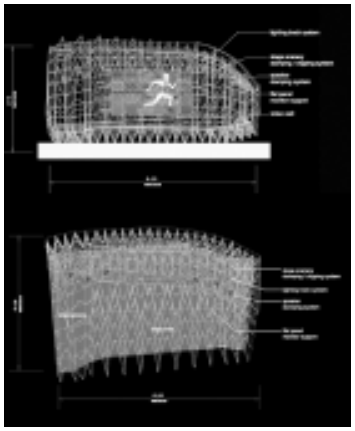
Deleuze and Guattari In their work “A Thousand Plateaux” distinguish between two distinct “machinic phylums” or underlying thought mechanisms. These they describe in various terms as the Statist vs. the Nomadic or the Striated vs. the Smooth. They note the traditional favoring of the Statist, Striated model in Western philosophy and set out to counter that with their studies of the Nomadic, Smooth model. In their rare references to architecture they describe what they term a “Romanesque” and a “Gothic” tradition. The Romanesque corresponds to what they call the striated or Statist tradition. Architects would recognize it as primarily the “Classical” tradition which emphasizes the appearance of buildings over their performance.

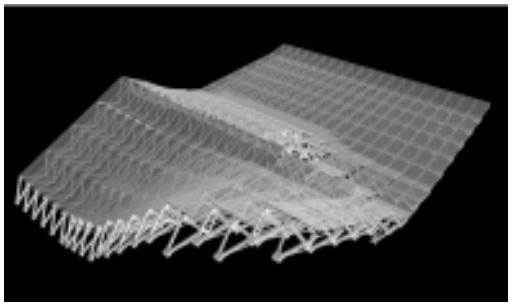
To this Classical tradition Deleuze & Guattari contrast what they term the “Gothic” - a primarily performative method. In this”*method*, form emerges from technique as opposed to what happens with a *style* where form is imposed from outside. The Gothic is a performative method rather than a formal system, the performance of individual elements of the tectonic and their combinations determine the visual appearance of the building. Both Modernism and Post-modernism, are *styles* based on the “Romanesque” tradition where the appearance of the building is more important than its performance. Today, however, with increasing programmatic social and structural complexity the performative aspect of architecture is more important than ever.



In an increasingly complex and media-saturated world, Environmental factors, Economics, social relations, property values and regulations are all information structures which have real material impact on architectural bodies. With increasing densities of information on all these levels the response of buildings to perturbations in design and use becomes more important than their formal representation of an ideology or the lack of one. During the Gothic age the successive technical developments in stone-work over many generations gradually led to more and more efficient structures. This process advanced gradually, through experimentation rather than through stylistic or representational innovations. This is an example of a bottom-up process of advancement.

The first project we want to show was an Entry for a Nationwide Design Competition which called for new ideas to activate the south wall of the building of the Dept of Energy in Washington DC. This project was awarded as Honorable Mention by the Jury. The Site is just off the Mall in DC, in pretty stagnant and rather lifeless surroundings. It is the huge, blank, concrete wall facing south.



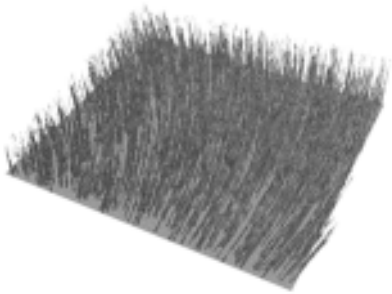


We started by analyzing the path of the sun relative to the site at different times of the year. The dynamic phenomena of weather and climate are the raw materials of this project.

We wanted to make an installation which interacted with its environment so that the weather itself becomes an active part of the design. We took inspiration from the phenomenon of flowers turning during the day to follow the sun, in order to maximize their solar gain. The fascinating performance of the field of sun flowers happens over several hours with rather slow motion. We were also interested in more dynamic movements such as a field of grass billowing in the wind.

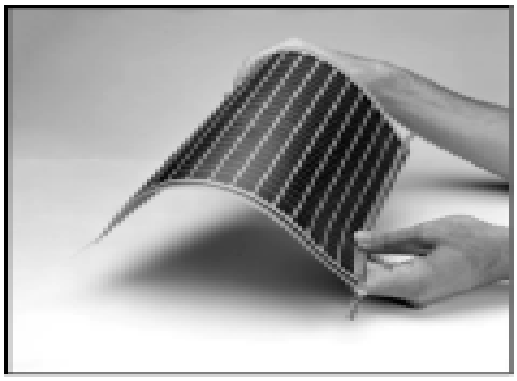
A computer simulation model was set up to study the relationship between the overall form and interconnectivity between individual blades of grass and their response to wind. As we looked into the performative aspect of this system we saw it as taking in data from the atmosphere and outputting it as visual material.

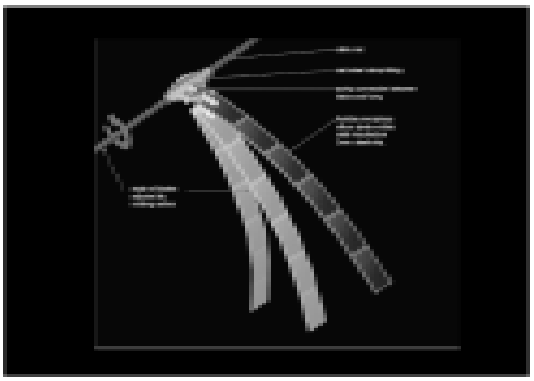
We also did extensive research into the newest photovoltaic technologies. One recent development is the flexible PV: This type of PV is mounted on very thin, flexible sheets of steel or aluminum which allows it to bend while retaining its power-generation capabilities. By pushing the possibilities of this new material further and taking our series of tectonic studies of the grass field as a model we developed a prototype, which we called a "solar-blade""–it's like a blade of grass but mounted vertically and capable of generating electricity.

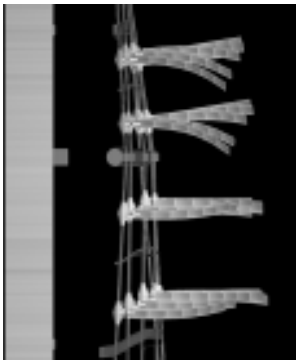


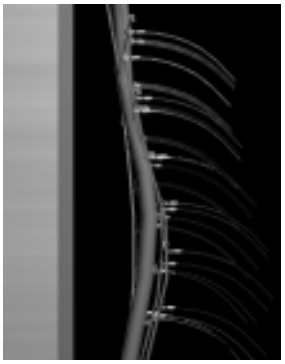
To develop the system further we started from the small scale of these blades and worked up towards the assembly of an overall system. A dynamic net was set up to support the blades, which is similar to the root systems of grass and which would be arrayed in a field over the entire extent of the site.

The effect of this vertical field of grass is a combination of the bending of the blades in the wind, their rotation towards the sun and the flexibility of the net. It is producing an ever-changing visual impact and transforming the space according to the local weather. The architecture makes the microclimate of this small forgotten area of the city visible to all who pass by and at the same time harvest it's own energy.



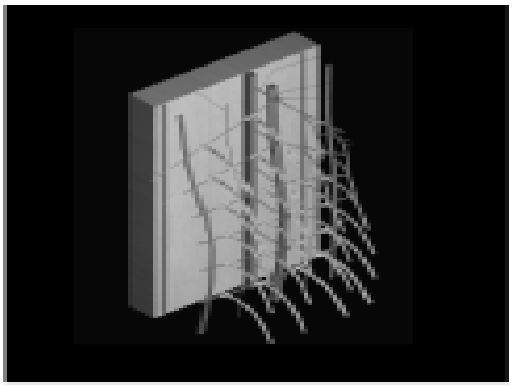


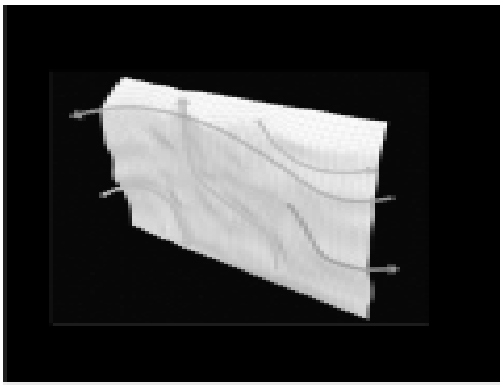


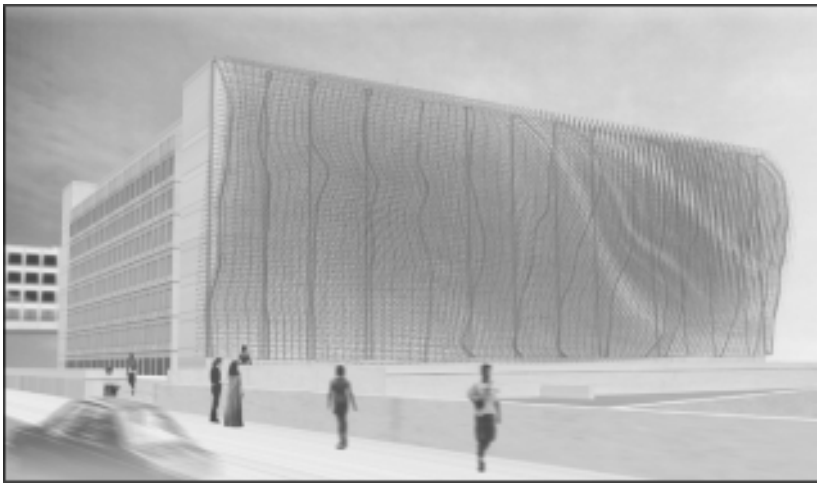


We started by studying climate-data for the site to try to identify patterns on a yearly basis. We were also interested in the potential power-producing and morphological effects of the extreme local tides.

The building becomes a body immersed in its unique environment acting as a filter between exterior climate and more controlled interior conditions. A large atrium at the shoreline collects on- and off-shore breezes to passively cool the space in the summer time while collecting sunshine in the winter. A permeable mat based on the pier structures of southern England projects into the water, moving up and down with the tides and creating an artificial beach and sun-terraces facing south. Along this new landscape a series of bedroom-wings are arrayed, their skin responding to changing weather and user-requirements.



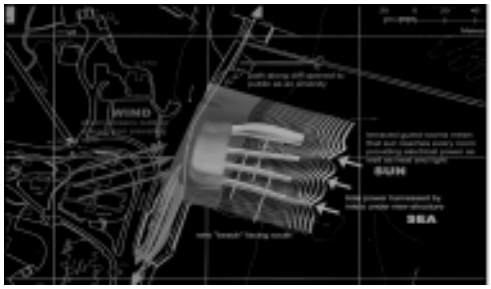


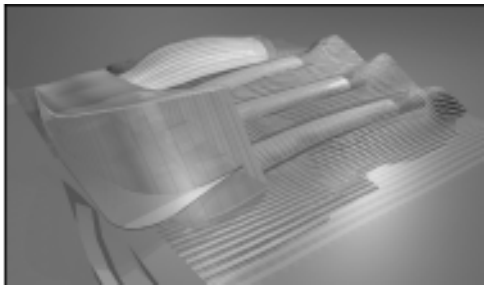


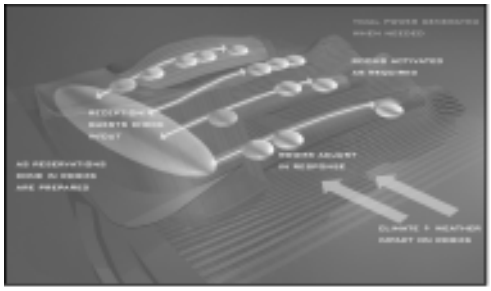
The next project is a proposal for a “Holistic Hotel” on the seafront in Wales. This site is characterized by the largest Tidal in variation in Europe –up to 6M (20 ft.) at certain times of the year.

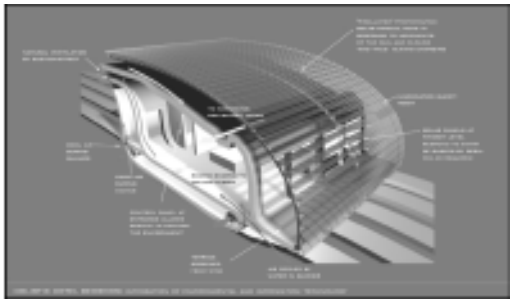
We took the idea of Holism to implicate every aspect of the building from construction through use. In a seasonally occupied building such as this, climate affects not only the energy usage of the building but also its programmatic content which varies over the year with the type and number of guests.

But the Building is also an information-structure consisting of both hotel-management and building-management databases: We studied the po-



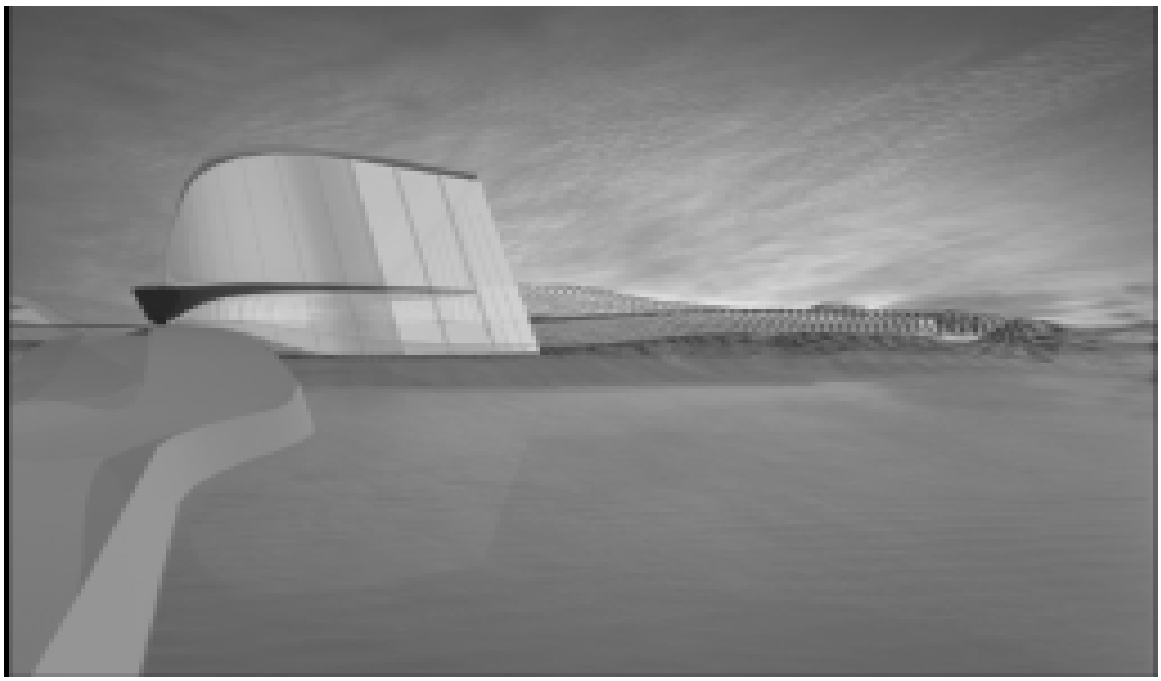






tentials for beneficial connections between these two systems –resulting in a fully Computer Integrated Building. The Hotel as a typology is seasonal, at some times of the year, the building will be almost empty in which case energy consumption should be kept to a minimum. Our project divides the program into different parts some of which, the reception, conference and recreation areas for instance, are in use year round and others, specifically the bedrooms and sun decks are only used periodically. After guests have made reservations their rooms are prepared for their arrival by being “aired”, letting in fresh air and gradually heated to acceptable levels.

When the Guests actually arrive their bedroom would open up, its pixellated skin reformatting to let in light and views. Like a large animal slumbering on the shore, the building adjusts itself to the changing weather, and to the variations in its interior. Its skin flickers and twitches as waves gently lap around it.

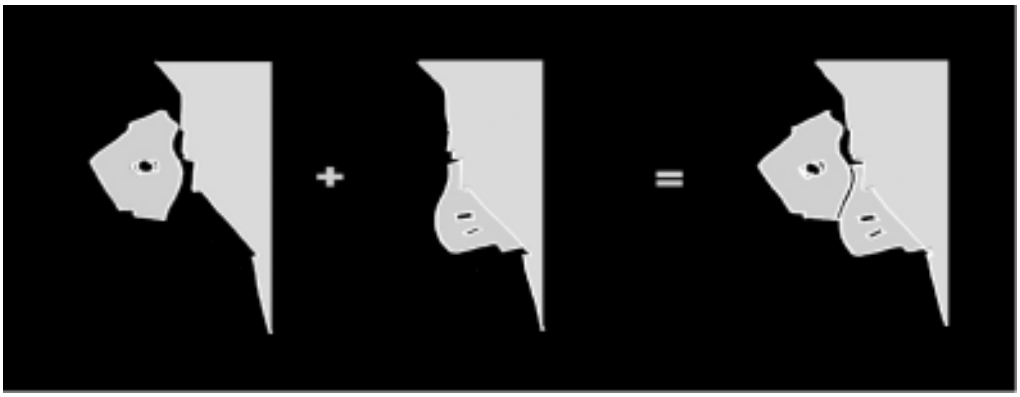


The next Project we will show is for a New Concert Hall for the City of Stavanger in Norway Learning from our earlier projects where material and information interact in real time we began to see information as instrumental in the material organization of buildings at all scales. The Program called for a Classical-Music Concert Hall and a smaller Multipurpose Theater along with rehearsal rooms, offices, public areas and parking etc. with a total area of 120,000 sf. The site is on the waterfront occupying a former harbor area facing the old town of Stavanger.

We started by gathering and analyzing information about circulation routes through and around the site. There is an Existing Park and Music Hall adjacent to the site but these are cut off from seafront promenade which connects the site to the old town.

mine the optimal layout -a database of solar information is used to determine the position of physical objects in space. The Final layout leaves an un-shadowed area at the south-east corner of the site, along the promenade and facing the old town of Stavanger. This area becomes the nexus of public circulation through the site, crossed by paths which do or do not intersect with the building.

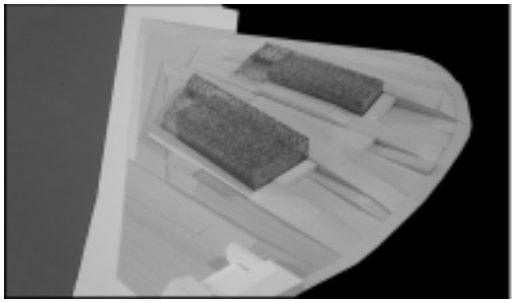
Taking the keys of a piano as a model landscape subject to manipulations based on a specific set of instructions - a manipulable datum which can be tilted to various angles and heights- the park is divided into a series of strips which are tilted into a landscape of openings, rising and falling in tune with the changing programmatic requirements within. The park would expand, contract and split open to accommodate the various programs be-

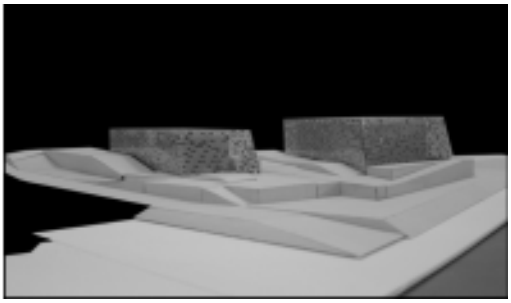


To make an architecture which can accommodate both transient and static populations we integrated the existing park, the new concert halls and the seafront promenade into a continuous landscape. Given the extreme northern latitude of Stavanger the disposition of the large new concert halls could produce undesirable shadows in the low winter sun, so a series of analyses were carried out to deter-

low adjusting its topography to their requirements for light, ventilation and acoustic isolation. In this way programmatic information shapes the material of both building and landscape.

The result is a fissured, programmed terrain from which two minimalist boxes emerge. The landscape tilts and adjusts to accommodate these variations

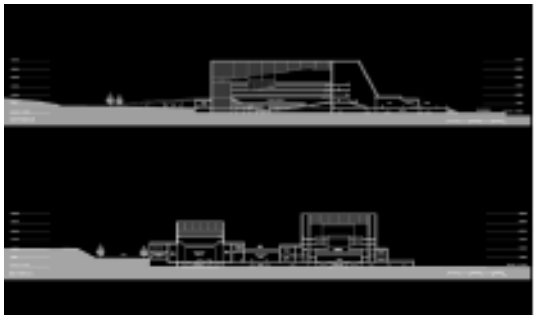


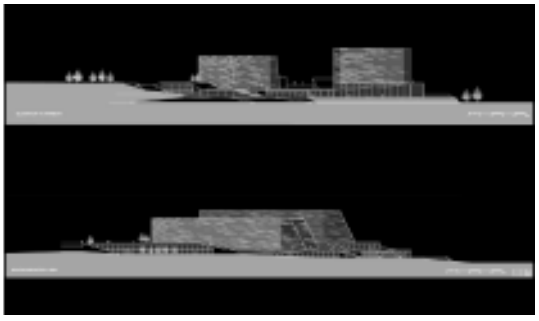


in a consistent manner. At the upper levels the plans show two boxes sitting in the landscape, as you move down landscape and program begin to interweave in more complex ways showing the apparently autonomous boxes to be part of a larger system. Rather than being contained in buildings within the park the subsidiary program is integrated with the new landscape, leading to a merging of building and park at the lower levels.

distribution of light and heat within. The concrete box absorbs heat during the day releasing it into the halls at night –thus reducing the heating load on the building.

The Main lobby and the outdoor public plazas weave together as a series of ramping planes, each inflecting the other as their program requires them to move up and down. Access to the building is

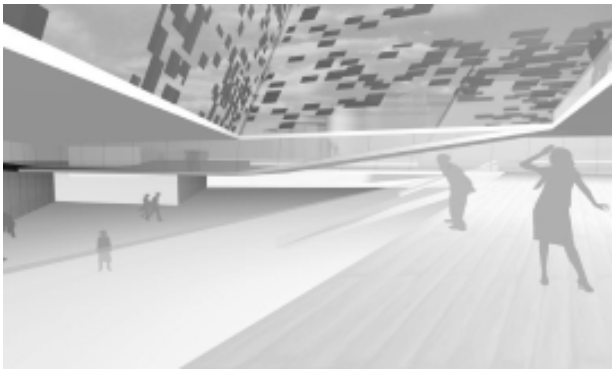


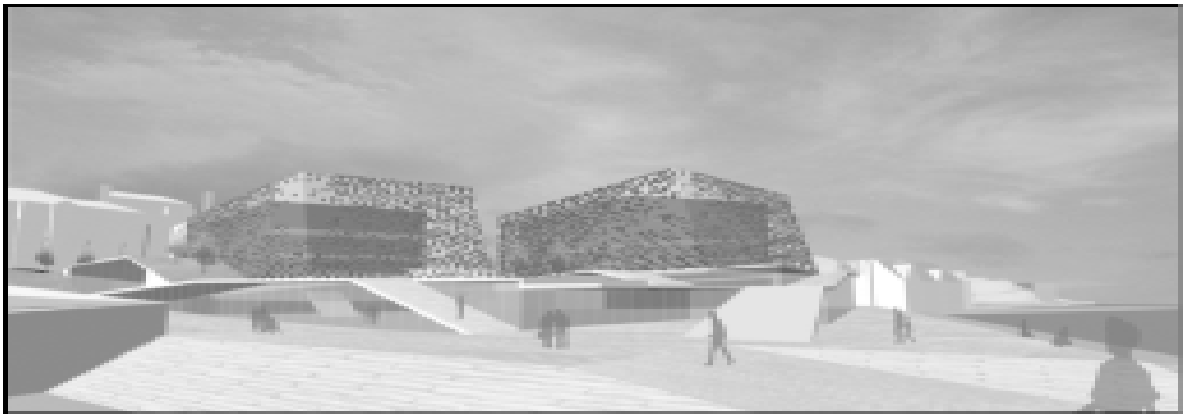


The apparently simple boxes containing the two halls actually incorporate a complex interaction with their environment, acting as filters between the extreme outdoor climate and the strictly regulated concert hall interiors. Three layers of materials mediate between the hall interiors and the outside climate. The innermost layer is a solid reinforced-concrete box; This is wrapped by a skin of glass which encloses circulation spaces. The outermost layer is a pixellated field of ceramic panels, the density of which is locally adjusted to maintain even

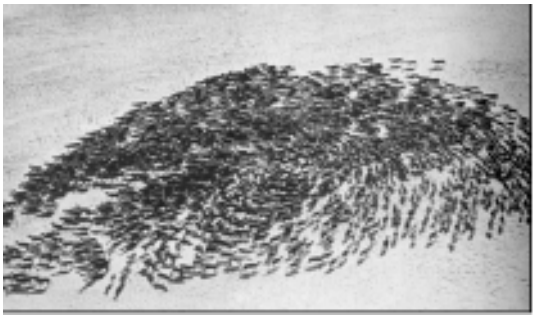
possible on 3 different levels, each connected to a different part of the park. This allows different combinations of classical and pop performances to take place at the same time. The Interior of the Classical-Music Concert Hall reflects the color of the outer façade animated in this case by the audience and the performers.

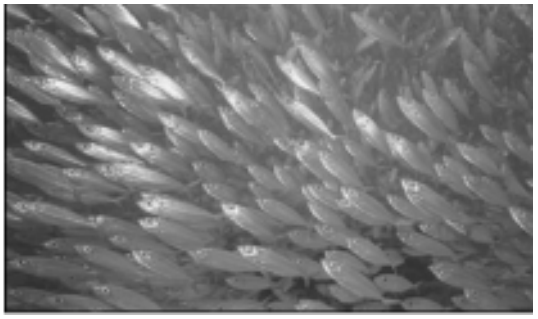
In his project we wanted to achieve a seamless continuity between analysis and production. Rather than a representation of inner functions, it is a





spatialization of activities and information in a localized strategy of responses to specific requirements. As a work method, the building material is deployed on the site, its performance as an instrument to organize program is assessed and it is then adjusted in order to determine the final form. Landscape, circulation and program work together to shape its material reality.

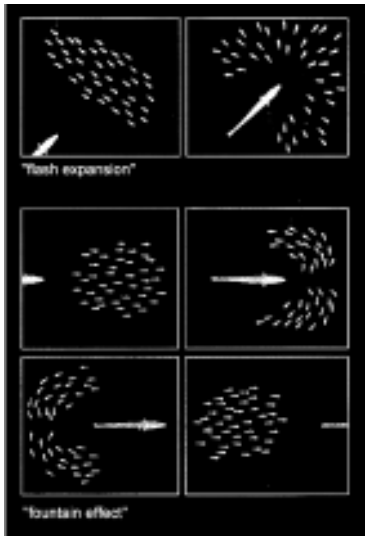


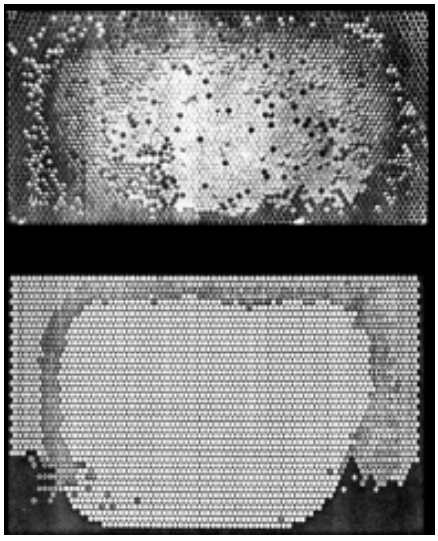


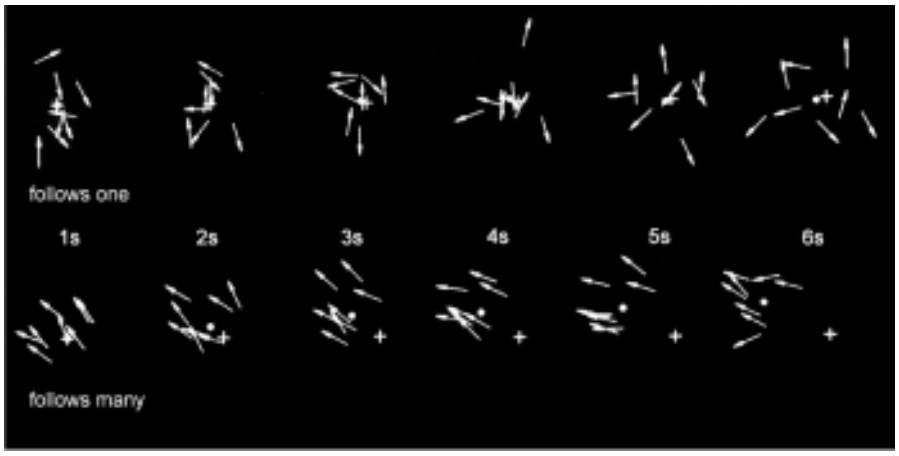
SELF –ORGANIZING SYSTEMS:

One of nature's most inspiring phenomena is the sight of hundreds, thousands, or even millions'of animals moving together as a coordinated unit. They seem to suggest an intelligence that far transcends the abilities of each group member. A system of living cells or organisms builds a pattern and succeeds in doing so with no external directing influence, such as a template in the environment or directions from a leader. Instead, the system's components interact to produce the pattern, and these interactions are based on local information. In a school of **fish**, each individual bases its behavior on its perception of the position and velocity of its nearest neighbors, rather than knowledge of the global behavior of the whole school. A school of fish maneuvers gracefully, with all its members moving in parallel in the same direction. When a school suddenly changes direction, all its members rapidly respond, moving cohesively, almost in unison, as perfect as if they were parts of a single organism.

To capture prey efficiently or avoid a predator effectively, these collective motions require that individuals coordinate their movements with other members of the group. During these maneuvers, individuals seldom collide with their neighbors even in the frenzy of an attack.





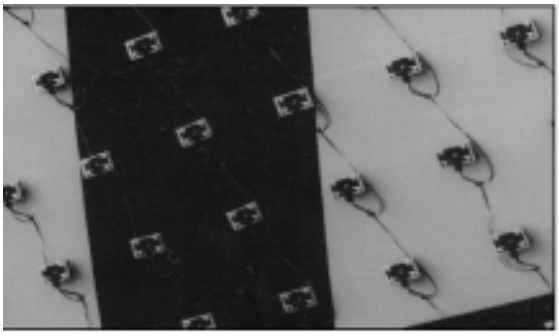


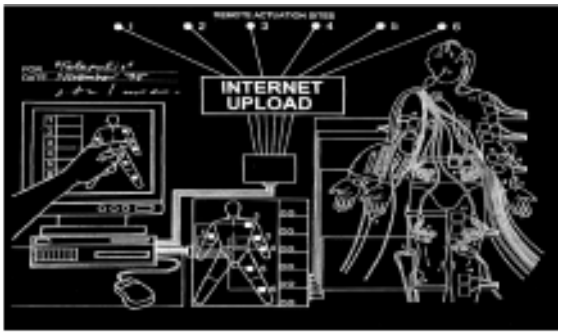
This image shows a series of computer simulations studying two different decision-making models. The top diagram shows how each fish moves according to ***one*** of it's neighbors resulting in collision and stasis. The bottom diagram shows each fish adjusting its velocity based on the average influence of its four nearest neighbors. In this model the group moves in an organized way, almost as one, and progresses away from its starting position.

The comb patterns in honey bee colonies are another example of self-organization. A colony pattern emerges from interactions among individuals at the lower level of the system. The brood area is surrounded by a band of pollen and a peripheral region of honey, with empty cells scattered across the comb. The pattern indicates the preferential emptying of honey and pollen from cells nearby the brood even though each cell is built individually and without a master-plan. In the building of these large biological superstructures, it is hard to imagine that any individual in the group possesses a detailed blueprint or plan for the structure it is building. The structures are orders of magnitude larger than a single individual and the construction may span many individual lifetimes.

A series of small intelligent members can influence the configuration of larger areas of a structure. Increasingly these small elements are being incorporated in the design of structures, driving the performance of the overall organization. Architectural Bodies are being infiltrated by information. They are becoming part of the global network; becoming continuous with their exteriors, connected to databases that update themselves in real-time.

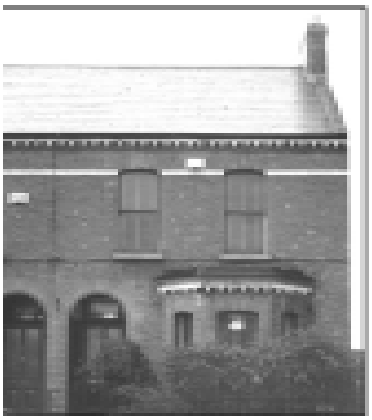
To see the body not as a perfect form but rather as a self-organizing viral system of decentralized decision-making, the architectural body is produced





as a bottom-up organization of parallel decisions, accumulating into overall emergent patterns. The architect becomes a shepherd of many various processes rather than a creator of ideal objects. Architecture is no longer a static final image, its visible form is becoming as unpredictable as the weather. New relationships between the form of an object and its information contents are already beginning to emerge.

The next project was a house addition for two engineers with 2 children in Dublin, Ireland which is quite dense city. The Site was so confined that it is necessary to overlap functions within the space of the new addition.

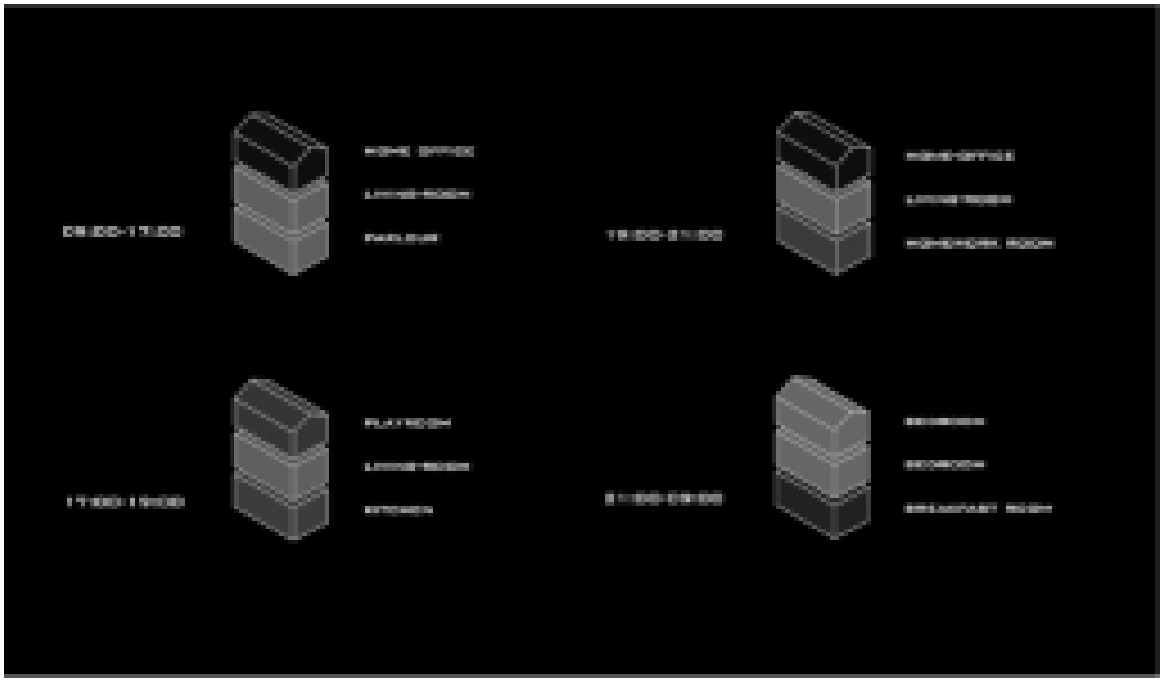


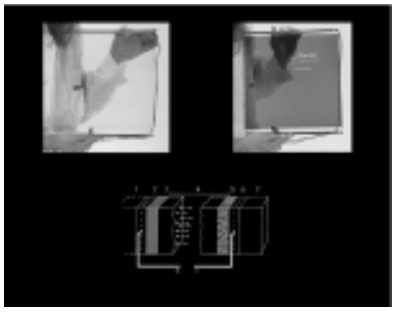
This led to the development of a time-based program where functions can vary over time. For instance, home office, living room, playroom can be programmed for the same space but in different time frames with different lighting and spatial quality required for each. We take this programmatic information as a force to develop a material solution that incorporates a new technology.

New technologies allow a single material such as glass to incorporate many different states. The material becomes active, being able to change property over time. The incorporation of different interlayers allow the glass to become opaque, reflect or absorb light, light up itself or even change color.

These changing qualities are achieved by varying a current through the material and can be easily controlled by simple algorithms. This allows us to vary the spatial conditions of the space without the use of moving parts. We realized however that a façade which incorporated this technology could actually do much more than just change over time to suit changing programs.

The possibilities for dynamic variation in the openness and density of a purely 2-dimensional simple pixellated grid is endless: By pixellating the interlayer and allowing each pixel to be independently switched “on” or “off” and by combining two layers of two different colors we are able to achieve widely varying effects. Through a combination of adjustments by user interface, pre-programmed schedules and auto-responses to the changing weather the wall can be either completely under the control of the occupants or completely automatic. For instance as clouds roll overhead -as they so often do in Ireland- the turbulence of the atmosphere becomes apparent in the façade as it ad-



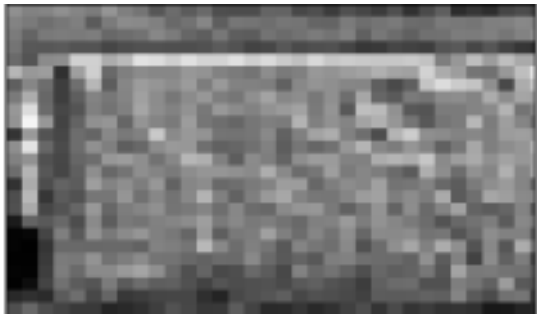


justs its transparency to compensate for changing outside light-levels. It was also part of the intension that through the incorporation of touch sensors users could interact directly with the wall, for instance “drawing” a window where they need light or a view.

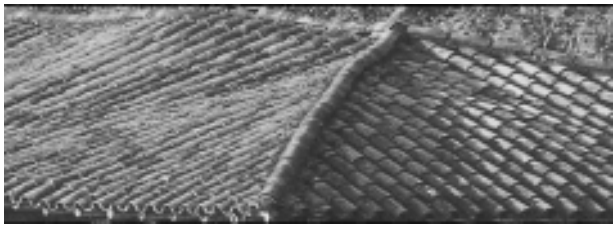
This chameleon-like construction adjusts its skin in response to changes in the weather or the moods of its users.

The façade becomes more than just a screen between indoors and out –it becomes an active member of the household, a pet almost, which occupants can train it to do their bidding and which also displays its responses to the street.

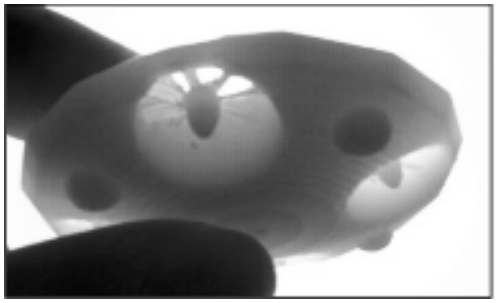
While buildings are infiltrated by networks, becoming more and more interactive their material organizations need to adjust to accommodate this. There are however, inherent in traditional practices, the germs of new tectonics which will make this possible. When we look at a brick wall information technology is not usually the first thing that jumps into our mind. But there are surprising links be-

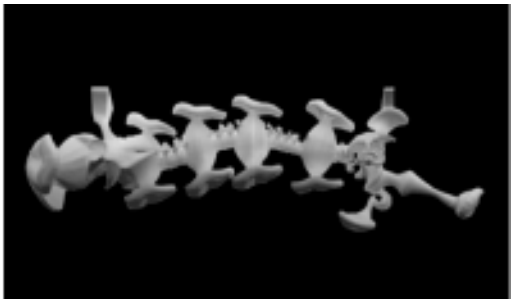


tween traditional construction and digital techniques. Contrary to what Amazon.com might have us believe “bricks and mortar” and”“pixels and bits” are not completely foreign to each-other. They are, in fact, based on the principle of difference through repetition -very similar techniques of accretion of small simple elements into overall complex patterns. But even today traditional construction materials are almost always used in very regimented regular organizations resulting in the familiar rectilinear forms we see around us every day. In response to the greater complexity of design possible with the computer, however, architects are increasingly forced to search for new material techniques to achieve that kind of complexity in the real world. Roof Tiles are an example of traditional techniques but sometimes, just sometimes, like in this image you can begin to see the potential morphological complexity of these traditional systems based on simple, completely regular elements repeated but slightly differentiated.



In marked contrast to traditional construction the small uniform elements of the digital ***are*** being used to create infinitely variable overall patterns. 3-D printing is an example where layers of material are laid down until they accumulate into overall shapes which can be incredibly complex.

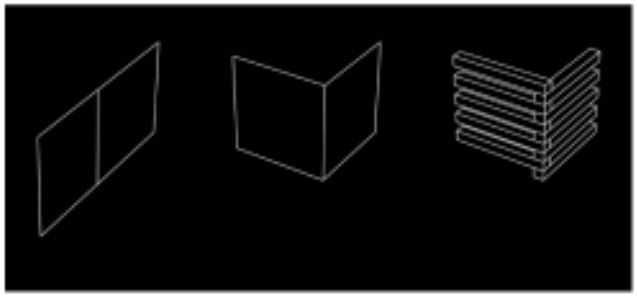




The next project we are going to show, which was prepared for the city of Tallinn in Estonia, explores these issues in a radical updating of a traditional building technique. Tallinn is a city of many distinct districts—from a historic medieval core to soviet-style industrial suburbs. The city wanted a proposal for street furniture for the entire city which would be flexible but aesthetically unified. Our approach was to develop what we call a “digital tectonic”, learning from traditional construction and digital technologies, to produce consistency within the required variations of both program and location.

Working on this basic insight but breaking free from the traditional rigidity of this form of construction we developed a folding-surface module which gains its structural stability from its shape. Starting with a generic wall and roof surface required to provide shelter, we folded it first like a concertina to gain rigidity, We then manipulated the resulting profile to allocate material-resources where stresses were greatest. Finally we folded the center edge of each module to produce lateral stability.

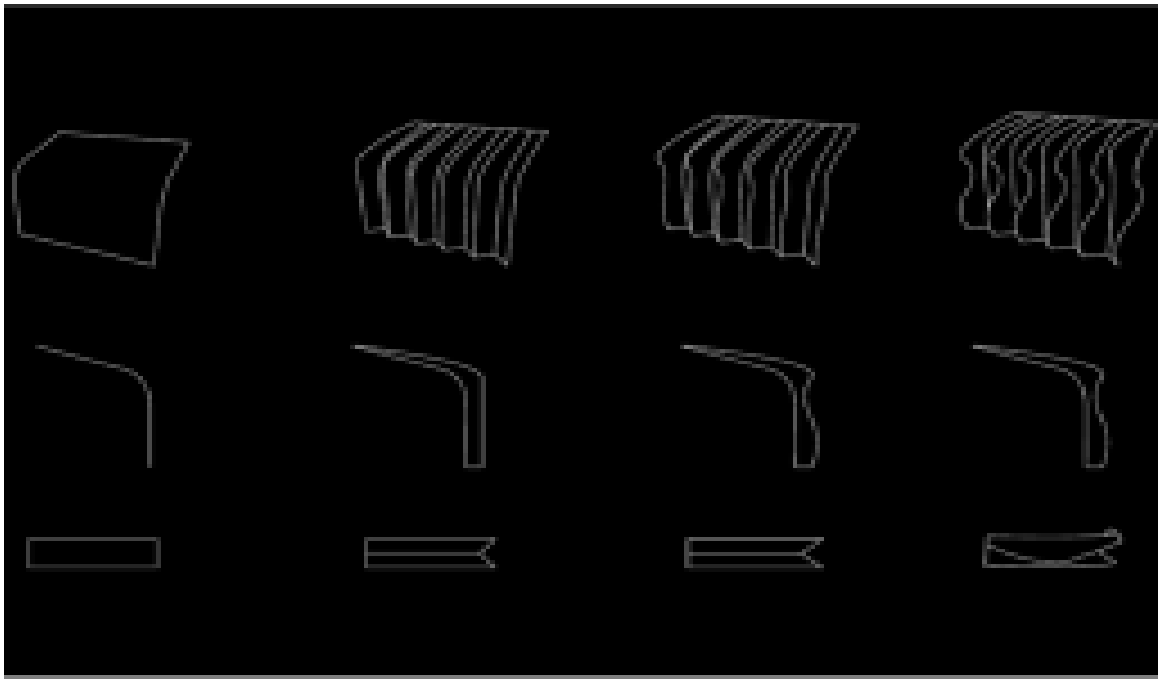
The resulting module can be varied to accommo-

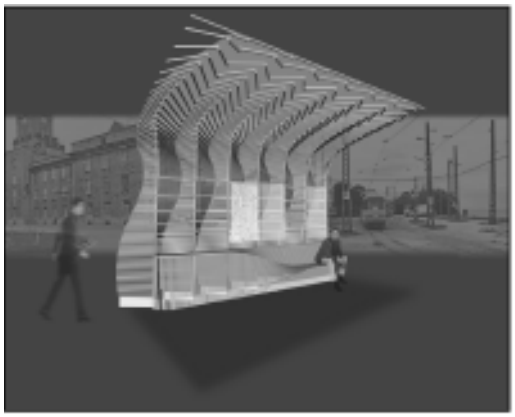


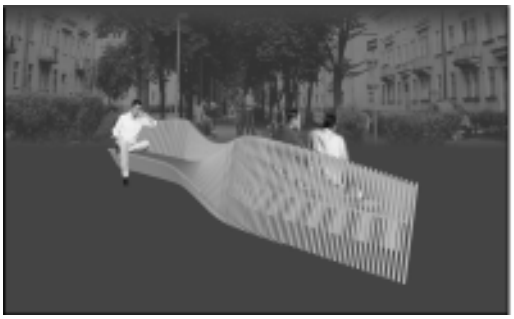
Estonia is in fact the home of Log Buildings which were developed there over 3000 years ago. We saw The Log building as based on a similar tectonic to 3-D printing where walls are laid down in layers, accumulating into an overall form. Studying log construction, we saw that The building gains its stability from the corners which act as interlocking folds –like the fingers of two hands.

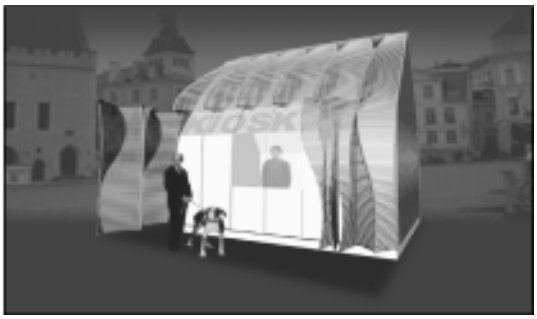
date different uses and combined in different ways. For instance: A Bus stop, Kiosks, Benches, Lamp-posts, trash bins etc. Having received a Special Prize in this competition we have been asked to develop the project further by the city of Tallinn.

The next project began as an entry for the International Competition for Ephemeral Structures for

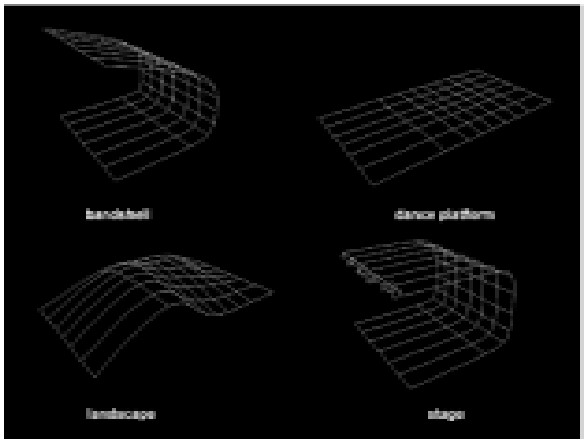




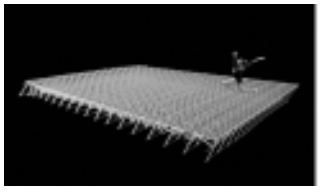


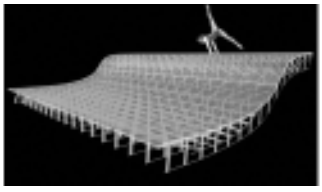


the Olympics in Athens, in which we won First Prize. The theme of the Ephemeral was our initial inspiration: In a world of networked bodies, architecture is ready to practice the ephemeral by being able to sensitively respond to the environment and react to users not only by using the devices of an updated technology but also by incorporating that technology into its very conception, design and occupation.



The Program was for an Events Platform a multi-function platform to stage various cultural events –each of which would have different requirements. These variable requirements led to the idea of an interactive surface which could adjust its morphology assuming different positions in response to different programmatic requirements. To achieve this we developed a new structural tectonic –what we call the Network Structure. This is an intelligent structure which incorporates new materials and information technologies within its very fabric, where program, information–and material form a continuum.

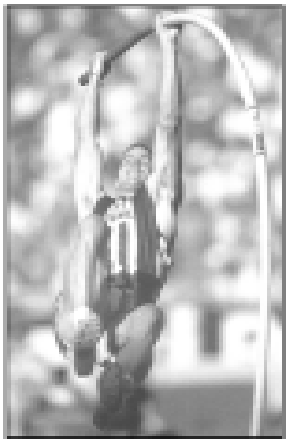




This Surface would be able to literally pull itself into position. Like our own skeleton the structure responds to increases in stress by adjusting its position. The combination of active muscles and a lightweight skeletal frame reduces material resources to a minimum. We explored this idea in an intensive series of physical and computer models.

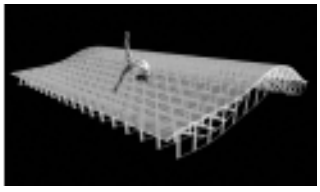
The result was a decentralized network of node points linked by rigid and semi-rigid structural members but also linked by information flows.

The Network Structure can alter its morphology by altering the strength of its links: Each semi-rigid link contains a “Muscle” which pushes and pulls according to the information it receives. The structure can also compact itself into the smallest

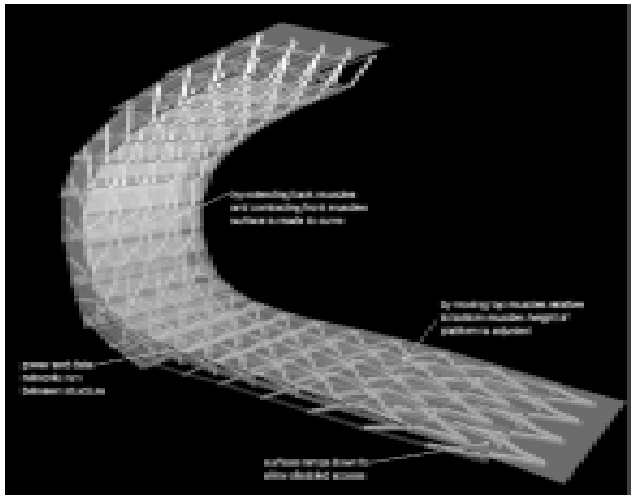


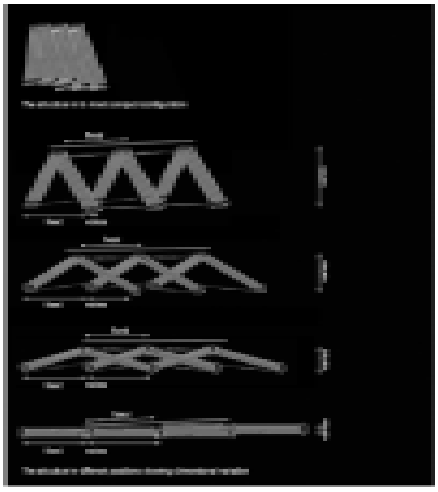
volume for transportation and storage. Like the biceps and triceps of Olympic athletes the muscles flex to move the rigid structure, unlike athletes however, the muscles are arrayed in a field, a field of muscular tissue defining a non-oriented surface.

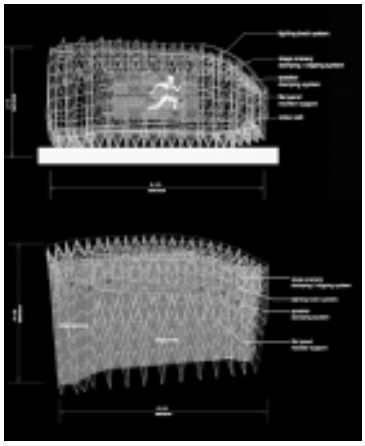
This structure is able to exchange with the surrounding environment by taking in different modes of use and outputting different topologies, providing various different shelter conditions and creating a surrounding environment with a changing relationship to the landscape. The Network structure is actually an integral part of the global net-

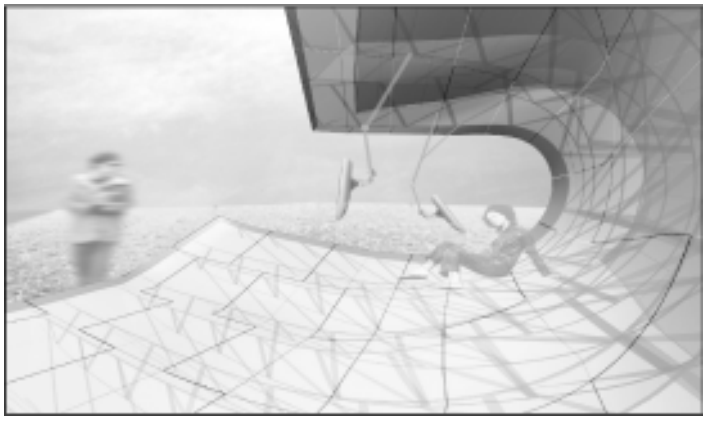


work. Its body is infiltrated by information. When not in use as an event platform, the structure becomes an information hub–taking-in and giving-out information while also being shaped by it. The already-networked structure means that every node is wired and can be tapped-into at any time. This system is perfectly fulfilling the needs of the









Olympic event which is, itself, ephemeral and site-specific. With the pack-and-go ability, this network structure can appear locally in Athens or globally in any other city.

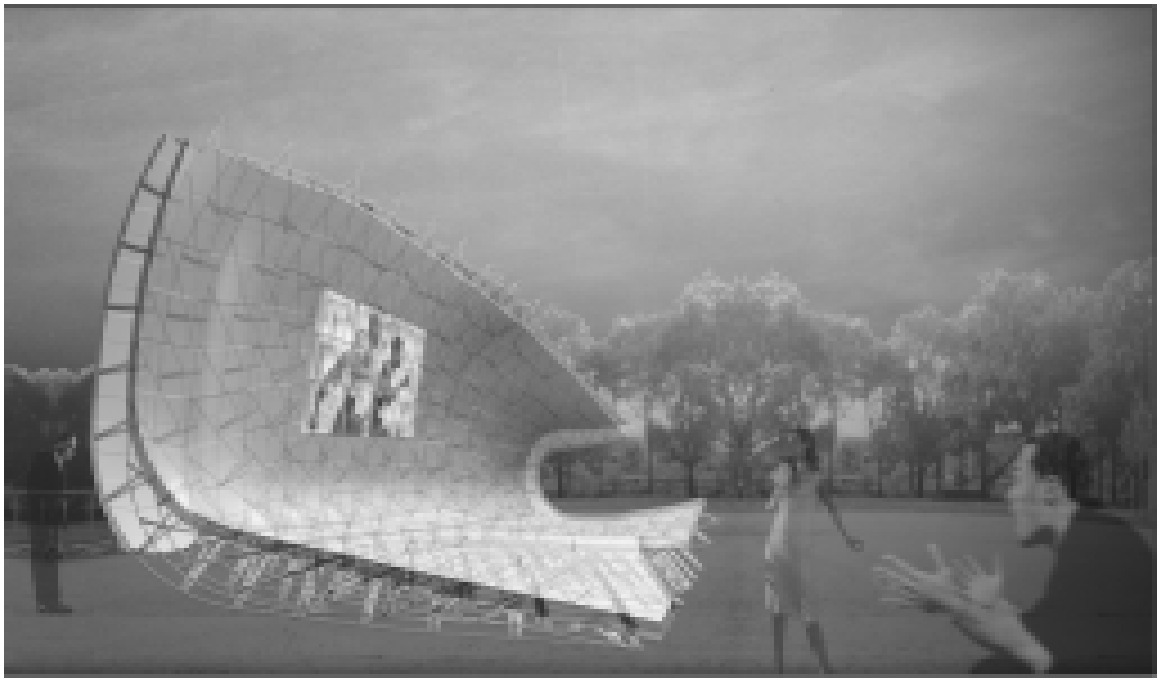
After the competition we were asked to develop the design further. A series of experiments and studies on the performance of different material and network configurations were carried out.

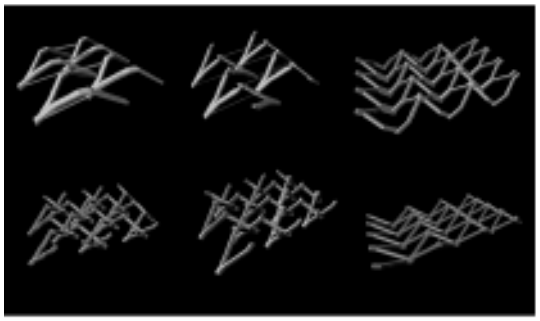
Collaborating with Ove Arup & Partners in London & New York, we began by studying the structural configuration -examining its performance in both simulations and physical tests. Many variations, investigating different levels of connectivity, densities of structural members and degrees of freedom of movement etc. were examined.

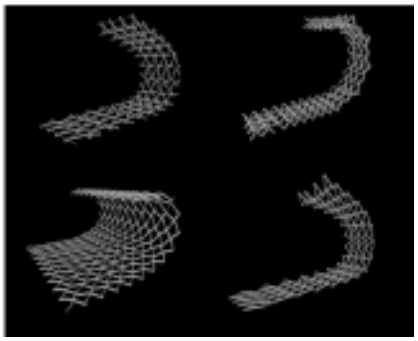
Physical models were used to understand how the building actually fabric performs. We eventually settled on a structural system based on rotation in one plane which could be controlled by linear expansion and contraction of the muscles.

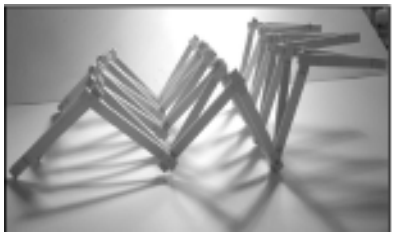
In this phase we also conducted extensive materials Research–looking at both old and new, dumb and smart materials. Electro-Active Polymer researchers at the Jet Propulsion Laboratory have developed materials which have enough strength and durability and are ideal for this kind of application. They also have distinct advantages over conventional hydraulic or pneumatic devices in that they have no mechanical moving parts and act as their own sensors–moving and adjusting automatically.

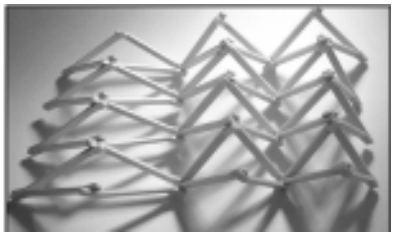
Material considerations were very important for us in this project, as we wished the structure to be warm and approachable–a piece of urban furniture- and to avoid the cold technical feel of many hi-tech buildings. Following this concept of the project we used wood with aluminum nodes, for the structure. This yields a lightweight flexible





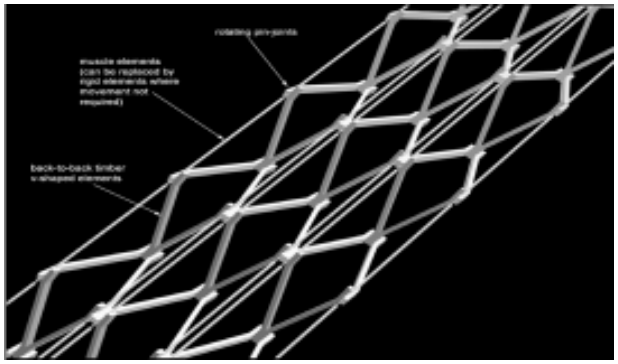


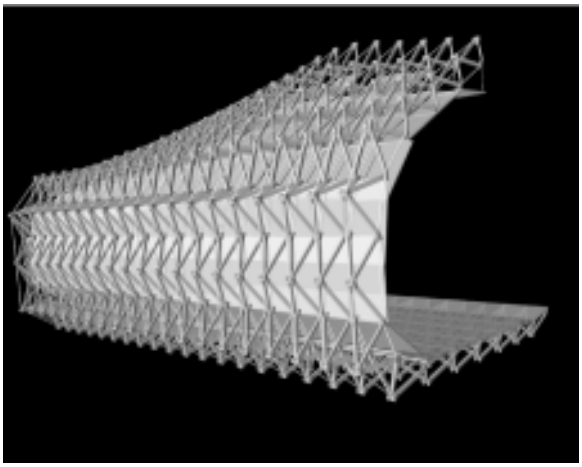


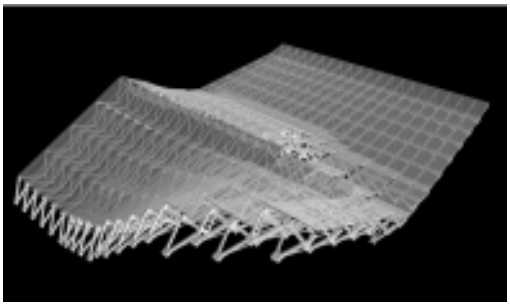


structure with hard-wearing joints which would be covered by a translucent skin of fiberglass composite panels. [images show the Design Development & Details of how the structure will be fabricated. The working drawings of the actual parts. etc.] The final design is a synthesis of the virtual and the real. It is quite close to the original conceptual studies in the computer program, Maya, achieving the same performability with real materials.

Architecture today lives a life contingent on many different factors interacting with each other, locally or globally, in space or time. By studying Matter and Memory Henri Bergson went beyond the established distinction between the Real and the Ideal to discover the inherent continuity of bodies and their milieu. By thinking not in terms of Form and Function but rather of Material and Information, we can develop an architecture which incorporates







the digital as one of its materials –a material which is active from the initial design right through the completion and even the occupation of the building. By thinking of the increasingly blurred boundaries between materials and information technology we begin to see form and function as elements of a continuous system. The virtual and the real are interwoven. This results in a new situation for architecture: Where material becomes programmable, function can vary like the weather –form and function become a continuum in constant flux.

The incorporation of information technology into the very fabric of buildings demands new material solutions. The fact that buildings contain decision-making systems along with inert matter demands new ways of thinking: The simultaneous activation of two directional thinking patterns: both Bottom-up and Top-down- achieves a delicate balance and reveals the dynamic potential of architectural bodies. The ability of bottom-up systems to self-organize into coherent and productive patterns, combined with the top-down management of those systems by the architect leads to new emergent patterns of architectural behavior. These new potentials for architecture, along with the material solutions developed to facilitate them, constitute what we call a “Digital Tectonics.”