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two systems find a new equilibrium: number of people, goods, light, temperature, and data. The door processes by counting what passes through the opening.

In iA we do exactly that -- our iA software counts every change that occurs in the position and configuration of any IPO object. Each object that is defined in Protospace software (developed during the past few years by the Centre for Interactive Architecture), behaves in time and keeps track of changes. Each object is a kind of IPO machine, an agent communicating with other agents. An example of this type of communication is a bird communicating with other birds in a swarm. Birds are complex adaptive IPO systems. They receive signals, they process these signals and they send signals. They respond bi-directionally in real time. Birds follow some simple flocking rules. Complex behaviour is the result of the execution of a simple set of rules. Swarm behaviour forms the basis of iA / Protospace software.

iA is not possible without an understanding and adoption of the new rules of non-standard architecture [NSA] in the design process. NSA means that all constituting components of a built construct are principally unique. They all have a unique number, position and shape. If two components are the same then it is pure coincidence and NOT a simplification of the structure. In the design process and in the mass-customized file-to-factory production process, all components are addressed individually. Repetition is no longer the basis for production and therefore, no longer the basis for design. Repetition is no longer beautiful. In NSA, the unique characteristics of the components are perceived as natural, logical and beautiful.

What is the relation between non-standard architecture (as we know it from the past few decades) and iA? What does iA exactly have to add to the masterpieces of NSA? Despite all the achievements of NSA in the dynamic design
process, the built product is still static, just like the repetitive modernist buildings based on mass-production. Our example door is, in static architecture, operated and set in motion by a human. But watch it: the operation of doors and locks is undergoing significant changes. Doors have become automated and locks pro-active. Soon doors will lock and unlock, open and close as they wish. But don’t worry: they will also open when you wish them to open. What will be added to the passive behavior is that the doors will become aware of changing circumstances themselves, and they will act accordingly without instruction from a single human or a single sensor. Doors will become active building components, and so will each of the thousands of individual components which assemble the built construct. Once electronics sneak into the building components, the next inevitable step is that the doors will be programmed to respond selectively, based on a complex evaluation of many impulses. As a logical next phase in the evolution of doors, they will become pro-active. They will propose changes themselves. Again, this is nothing to be worried about -- humans will co-evolve just like they co-evolved with dogs and other domesticated life forms. In fact, people will like it.

While iA is NOT just responsive and adaptive, it IS pro-active. iA, in fact, proposes actions. It proposes new configurations in real time, all the time. Sometimes these propositions are unnoticeably slow, sometimes faster than you can see. In iA software, active behavior is built into the scripted code of the design. Each component is calculating in real time its new input and is producing its new output / behavior, continuously changing the state it is in. This ever-changing state acts as a new input into the IPO system of other components and so on. The functionally related group of components together display swarm behavior. The consistent set of thousands of active components is the complex adaptive system [CAS] of the building. Interactive architecture is the art of conceptualizing the CAS and the art of imposing style on the active building materials, being aware of the fact that many of the constituting components are programmable actuators.

In iA, the architect becomes an information architect. The information architect is sculpting data; he designs the flow of information and constructs IPO components selectively -- transmitting, absorbing, transforming or simply bouncing back the information flow.

My question will always be: can iA be beautiful? It is certainly necessary and functional, but can it compete with historic architecture and be appreciated as good, relevant and beautiful? I believe that it can. Objects in [slow] motion get more attention then static objects — iA objects are constantly in motion. Humans relate more naturally to dynamic structures rather than to static ones.

It simply is more fun to watch live action than to watch the paint dry.

The iA bookzine series will consist of twelve issues bi-annually published over a period of six years. Each issue will have at least one scientific paper on a particular aspect of iA, one iA-driven MSc project, one iA-inspired case study from practice, one interview with a renowned researcher / practitioner, and one blog by Kas Oosterhuis. The blogs will be regularly published on the iA website www.hyperbody.bk.tudelft.nl

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Form-Finding Process: Styling
The ONL form-finding process is hybrid. It relies on diverse concepts and techniques. It incorporates digital and non-digital media. Splines and hand-drawn curves, 3D computer models and physical models are complementary and are used in the creative process. Digital design and reverse engineering constitute integral parts of the process as well. While digital design refers to computer-generated design, reverse engineering is the inverse of this process. It implies a process of translation from physical to digital. The 3D scanning of the physical model is followed by a software conversion process, which allows for regeneration of the scanned model as a digital 3D model.

The complementary use of these techniques is reflected, for instance, in the design process of the project WEB of North Holland. This process starts with a free-form digital model. Its concomitant CNC milling allows for further formal experimentation, such as adjustment of the shape by means of conventional techniques. The subsequent translation of the physical model into a digital model (by means of reverse engineering) enables digital manipulation. In the digital manipulation process, an icosahedron is mapped on the NURBS surface, in order to define a generic structure. After being twisted and deformed according to spatial and formal requirements, the warped icosahedron represents an initial structural model. It establishes a spatial matrix for further generation of CNC data for digital fabrication.

File to Factory
File to Factory refers to the seamless merging of the design process into fabrication. It involves the direct transfer of data from 3D modelling software to a CNC machine. It employs digital design and fabrication strategies based on computational concepts.

Digital Design
ONL projects rely mainly on four computational concepts. The first concept implies the geometry of continuous curves and surfaces mathematically described as NURBS: Non-Uniform Rational BSplines. The second is based on parametric design, the third implies scripting and programming and the fourth computational concept relies on motion kinematics and dynamics.

Freehand drawn curves resemble BSplines because of their free-formed complex shape. The ability to effortlessly control their shape by manipulating control points allows for formal experimentation. For instance, BSplines establish the geometry of the building in the project Acoustic Barrier. They follow the trajectory of the highway, defining a bulge within the sequence of a relative smooth curve, that is, the Cockpit.

The Cockpit as integral part of the Acoustic Barrier is generated according to a rule-based design. This is achieved by expanding the virtual volume between the lines in such a way that the length of the Cockpit is 10 times bigger than the width. In this way, it appears smooth when passed by at a speed of 120 km/h. In addition to NURBS-geometry, Acoustic Barrier and Cockpit also imply...
parametric design and scripting as computational concepts. [Figure 1. Acoustic Barrier: NURBS Model (2004)] Parametric Design refers to parametric definitions such as \( 1 = x^2/a^2 + y^2/b^2 \) to describe a 2D curve. Each time a parameter changes, the model regenerates to reflect the new value. The parametric model is a metadesign that can be reconfigured. In order to establish a parametric model, the NURBS surface of the Acoustic Barrier, for instance, is intersected with a generic structural model generating a point-cloud [Figure 2. Acoustic Barrier: Point Clouds (2004)]. The point-cloud represents a parametric setup: it describes the volume by points and establishes spatial relationships between them. Between these points, structure and skin are generated via scripting.

Scripting and programming refer to the process of writing a simple program in a utility language to orchestrate behavior. It consists of a set of coded instructions that enables the computer to perform a desired sequence of operations. In the case of Acoustic Barrier, the geometry is based on several MAXScript routines. The first script loads the (DWG) files containing the point clouds. It builds the axis of steel profiles that form the structure and it projects the planar surfaces generated between the points, defining the shape and position of the glass panels. The second script generates a detailed 3D model of the steel-glass structure [Figure 3. Acoustic Barrier: Steel-Glass Structure (2004)]. The third script is in development. It will verify the 3D model resulting from the previous two scripts, apply constraints such as maximum tolerance and effectively replace deficient parts. Finally, the data generated by scripting is directly transferred to the steel and to the glass manufacturer for further digital processing, such as laser cutting.

Digital Fabrication

Digital Fabrication is a CNC technology that transfers data from a 3D modelling program to a CNC machine. It controls fabrication by means of formative, subtractive and additive techniques. These processes allow production of small-scale models and full-scale building components directly from 3D digital models.

In order to produce small-scale models, ONL uses additive and subtractive techniques such as 3D printing and CNC milling respectively. Subtractive techniques refer to material removal processes, like multi-axis milling, where the machine is exclusively computer-controlled. Additive techniques involve processes of layer-by-layer addition of material. 3D Printing, which is an additive technique, uses ceramic powder and glue. The final physical model is generated in a process of selective additions of glue layers. At the end, the loose powder is separated from the model. Beyond generating small-scale models by means of Rapid Prototyping techniques, ONL projects, as mentioned before, make use of CNC technologies such as laser cutting.

ONL establishes direct communication and data-transfer with manufacturers, by using a common Internet-accessible database. It also allows digital data from the 3D model to control the CNC machine. Digital fabrication allows for variable, non-repetitive design. It implies the concept of mass-customization, which in turn enables the development of non-standardized building systems through digitally controlled variation and serial differentiation (Kolarevic, 2003). The concept of mass-customization is reflected in the project Variomatic, which is a web-based housing project [Figure 4. Variomatic: Web Page (2004)]. Within certain limits, Variomatic proposes individual designs, where volume, shape, material and openings are variable. The website www.variomatic.nl offers an interactive interface for its clients. While changes in the geometry take place in real time, the customers become an active part of the design process. The final design is converted into data for industrial production. The participants in the collaborative production process access data from a common database on the Internet. While digital fabrication allows for serial production based on local...
variation and differentiation, collaborative design and collaborative construction via the Internet enable participants to communicate and collaborate to develop individual designs and to produce customized buildings. The process of collaborative design and collaborative construction is effective because of the direct link established between customer (client), architect and manufacturer. It skips several unnecessary iterations such as the generation of 2D drawings (construction documents) for industrial production. (Bier, 2004). Also, generation of designs according to the client’s need is replaced by interactive software on the Internet.

ONL creates a platform for collaborative design and collaborative production processes. In the design process, it not only makes use of NURBS-geometry and parametric design but it also introduces scripting and programming in the design process of complex shapes such as double curved surfaces. This allows not only for automated 3D modelling of building components according to the script but it also allows for automated generation of quantitative and qualitative data to control the CNC fabrication of the components.

Construction Strategies

In response to the requirements of double curved surfaces, ONL employs specific construction strategies and concepts such as Structural Skin, Polygonal Tessellation, Generic Detail and Composite Material. As a construction concept, Structural Skin, proposes skin geometries, such as double curved surfaces, that are structural, therefore capable of self-support. The constructive concept of structural skin opposes the modernist concept of the separation of skin and structure. It refers to the transformation of the surface from curved to faceted, enabling a subsequent extraction of 2D, planar surfaces from double curved surfaces. Generally, the transformation of a NURBS surface into a faceted surface refers to automated tessellation processes based on surface subdivision algorithms that provide several computer-generated tessellation alternatives.

ONL develops a different strategy to transform NURBS surfaces into polygonal structures. In the first step, it intersects the NURBS surface with a generic structure in order to create point clouds. These points result from the intersection between equidistant lines - defining a pattern of identical triangles - and the NURBS surface establishes a spatial matrix. From these points, the structure and the envelope are developed by means of scripting, where the point clouds establish general conditions for the development of a generic detail.

The constructive concept of the Generic Detail is based on the premise that there is no separation between building components such as vertical and horizontal elements, like walls and floors. Such a separation is one of the hallmarks of traditional architecture. From the generic detail developed according to the requirements of the whole, specialized details are developed according to local rules. For instance, the triangulation of the skin of the WEB (of North Holland) corresponds to the concept of generic detail, implying that every single panel, although triangular, has an individual size and shape. Even though the elements are the same, since they are all (generic) triangles, they are all different and therefore specialized. “One building - one detail” as stated by Oosterhuis (2003) refers to the principle of the development of specialized building components from generic components. [Figure 5. Web: Structure and Skin (2002)]

The composite displays properties of the different components since it is produced by combining different constituent materials, which improves performance. For instance, the two mm thick hylite aluminium panels employed in the project WEB of North Holland are composed of a polypropylene core between two ultra thin layers of aluminium. By fastening the triangle at the midpoints of three sides and subsequently fastening the edges of the triangle with omega shaped fasteners, the panels are able to follow the geometry of the curved surface.

NURBS rely on non-Euclidean geometries, which are based on axioms different from Euclid’s. In Euclidian geometry, everything takes place on a flat plane or in space. Non-Euclidean geometries study the properties of lines and points on a concave or a convex curved surface, whereas Euclidean planar surfaces expose a special condition of zero curvature. New spatial concepts are challenging the traditional concept of “ability, symmetry and formal hierarchy” (Kolarevic, 2003) in architecture based on Cartesian principles. Even more, the paradigm change from mechanical to digital challenges the concept of repetitive, modular systems of organization of modern architecture: It introduces the concept of nonrepetitive -- variable designs developed, designed and constructed by means of digital technologies.

ONL implements new spatial concepts based on non-Euclidean geometries by means of digital design and fabrication, while it develops its own (design) tools appropriating computer programs designed for the movie, automotive or airplane industry. Since these computer programs are not specifically designed
for architects, they are modified to suit.

ONL develops its own tools. It customizes its design tools by programming them with the objective of developing a computer model containing all qualitative and quantitative data necessary for the design and production of a building. While the single source of information is the digital model, ONL establishes a platform of collaborative production with numerous parties in the building process via Internet. ONL also develops prototypes for programmable interactive architecture by engaging in future-oriented research with the Hyperbody Research Group at the University of Technology in Delft.

**Real Time Behavior**

Real time computing implies applications and systems, which operate to an input-output latency of seconds, enabling response to stimuli within milli- or microseconds. Trans-ports, for instance, is a programmable building. It changes shape and content in real time according to data-input from the Trans-ports website. Hydraulic computer controlled cylinders are connected to spherical joints and form an active (space) frame. The movements of the frame are controlled by a computer program that calculates in real time the changes in form and sends the corresponding instructions to pneumatic cylinders.

Basically, interactive architecture is based on the concept of hyper-architecture. Like hypertext (html), hyper-architecture establishes connections in real time. While hypertext connects users all over the world via the Internet, hyper-architecture establishes connections between the building and its user. It responds to specific requests to reconfigure itself in real time. It is based on the premise that interaction can take place only between two active parts, where one active part is the user and the other is the building. The building is not only active but it is also proactive, anticipating developments and acting in advance. The building is connected to the world through the Internet and to the users through the user’s interface. Hyper-architecture continuously processes information, reconfiguring itself in real time. Hyper-architecture exhibits Real Time Behavior.

**Computational Concepts**

Real Time Behavior implies an (additional) computational concept: motion kinematics and dynamics. These are motion-based modelling techniques such as forward and inverse kinematics and dynamics. Basically, kinematics studies motion without a consideration of mass or external forces, whereas dynamics takes into consideration physical properties such as mass, elasticity and physical forces such as gravity and inertia. Generating design in such environments offers the possibility, for instance, to simulate the movement of people in order to develop architectural devices responding to this movement. Interactive spatial reorganization and re-configuration are typical features of responsive architectures. [Figure 6. Trans-ports: Motion Kinematics (2001)]

**Computational Processes**

Protospace (PS), developed within the Hyperbody Research Group at the University of Technology in Delft, is a web-based multi-user environment relying on computational processes that are based on: 1) Virtual Reality 2) Collaborative Systems (Group Decision Systems) and 3) 3D Game Programming.

VR describes an environment that is simulated by a computer. VR environments are primarily visual experiences, displayed either on a computer screen or projected onto surfaces in space. Users can interactively manipulate a VR environment, either through standard input devices like a keyboard, or through specially designed devices such as interactive interfaces. The simulated environment can be similar to the real world - for example, in simulations for pilot training - or it can differ significantly from reality, as in VR games.

PS is an immersive system: It employs sensor and effector technologies based on multimodal and multisensory devices incorporating human-machine interfaces. These interfaces process human input by accepting gesture, speech recognition, gaze, and head tracking. In turn, they generate visual, audio and haptic feedback.

Collaborative Systems rely on the concept of shared virtual space, wherein collaborating participants work synchronously or asynchronously on the same project. Intelligent engines, which reside in this shared space, support the activities of the participants by providing automated services, such as detecting design changes and automatically notifying the participants of changes. Underlying the shared space is a series of databases, which contain information related to the project. Databases include 1) 3D models of the evolving building; 2) a document management system containing and managing correspondence, contracts and lists; 3) a discussion platform and; 4) a shared software database that provides software applications to the parties.

PS operates as a research facility providing not only a means of design representation (such as walkthrough, flythrough) but also a means of design development (such as 3D modelling, performance analysis and simulation). PS
Research is a spatial medium enabling Computer-Supported Cooperative Work (CSCW). In this medium, Group Decision Systems (GDS) intervene only when a coordinated decision-making effort between the communicating individuals who possess specialized (and unspecialized) knowledge takes place. PS proposes four specialists - designer, engineer, ecologist and economist - each of their views are accepted as reflecting particular aspects of the same project.

3D Game Programming: The programming is based on Virtools, which is a platform for creating interactive 3D applications. It is employed for creating multi-user applications, establishing database connectivity, and ensuring accessibility of custom components. Virtools generates behaviors that obey the fundamental laws of physics while employing the digital concept of motion kinematics and dynamics. This allows for precise definition and programming of complex behaviors. VOR (Virtual Operation Room), as a subproject, within PS explores ways to develop an adaptive system, which responds to commands from outside (weather) and from inside (user) the system, and acts as a space for transaction and negotiation between participants. [Figure 7. VOR: Responsive Geometry (2001)] [Figure 8. VOR: Initiation World (2002)] In order to develop its own dynamic and to reorganize itself in real time, VOR relies on the self-organizing principles of swarms. In analogy to swarm behavior, elements of the structure interact with each other in response to environmental changes. “Swarm architecture is based on the idea that all building elements operate like intelligent agents” (Oosterhuis, 2003) where the self-organizing aspect of a swarm is of special interest. This idea is derivative of Reynolds’s (1986) studies regarding swarm behavior. He created a computer program that simulated the flocking behavior of birds. The birds abide by simple rules of movement: maintain a minimum distance to vicinity, match velocity with neighbours and move towards the center of the swarm. These rules are local, establishing the behavior of one member in relation to the next member in its vicinity. While hierarchically the formation of flocks is from the bottom up, organizationally flocks tend toward similar configurations (Allen, 1999).

Similar to Reynolds’s flocking rules, VOR establishes rules regarding the movement of its vertices. The initiation world of VOR has a WEB-like internal structure, namely, the structure of an icosahedron. The movements of its vertices are controlled by the following rules: 1) Try to be at a certain distance from your neighbours (vertices); move there faster if you are further away. 2) Try to be at a certain distance from your neighbours’ neighbours; move there faster if you are further away. These rules aim to establish a desired state of equilibrium implying that VOR aims to organize itself as an icosahedron. Under exterior influences, VOR executes geometrical-spatial transformations according to the rule 3. [Figure 9. VOR: Purification System (2002)] 3) Try to maintain a certain distance to the avatar, where the avatar is an embodiment (icon) representing a user in a multi-user virtual reality. VOR, as a multi-user virtual reality, is a computer simulation of an imaginary system (game) that enables users to perform operations on the simulated system. It shows the effects of those operations in real time. VOR, for instance, features a responsive geometry. The geometry responds in real time to the actions of the players of the game, where avatars embody the players. Basically, VOR consists of three bodily systems: a lymphatic system, a purification (kidney) system and a brain. In each of these responsive systems, the player interacts by pointing, shooting and killing cells while the input device, a joystick, allows for intuitive navigation. The score reflects the total number of points made by each player based on the ability of the player to catch bacteria, for instance, while navigating through the lymphatic system. In the end, successful players are congratulated for having healed themselves.

The changes in geometry (in the Brain) rely on GAs (Genetic Algorithms), which...
are, in fact, search tools. They have been used for problem solving in science and engineering. Once the objective is encoded in a structure called a genome, the genetic algorithm creates a population of genomes. These genomes apply crossover and mutation to the individuals in the population to generate new individuals. These techniques are applied in this case to develop multiple designs according to rules such as “adjust amount and size of structural parts according to its future use.” (Oosterhuis, 2003). [Figure 10. VOR: Brain World (2002)] [Figure 11. VOR: Lymphatic System (2002)]

Beyond changes in geometry, VOR exposes interactive behavior patterns developed in 3D game software. Basically, VOR employs a self-diagnosis and self-treatment game concept: its goal is to heal the patient embodied in the avatar. The game begins with information regarding the patient’s state of health based on 3D computer tomography, for instance. In accordance with the diagnosis - in this case cancer - the treatment involves the destruction of the cancerous growth, the ultimate goal being complete healing.

3D Game Programming involving Virtools is employed not only in VOR but also in the project the MUSCLE, which is a built prototype for a programmable structure. It changes shape in real time, driven by Virtools software connected to 72 programmable muscles wrapped around an inflated volume. The pressure inside the inflatable volume and the tension in the (pressurized) tensile muscles changes accordingly to the programmed behaviour. This describes three degrees of activity: 1) bored (low activity), 2) happy (high activity), and 3) nervous (hyper-activity). The degree of activity the Muscle exhibits is correlated to the input coming from people in its next proximity. [Figure 12. MUSCLE: ]
In regard to the technology and components, the pneumatic muscles are composed of contractile hoses. By means of air pressure, these hoses are able to generate tractive forces up to 6 KN corresponding to 600 kg. The air pressure is controlled by programmable switches, where singular or multiple strings of muscles can be activated. Working together, muscle groups perform complex movements such as twisting, hopping, and crawling. The MUSCLE’s movements are, in fact, responses to external inputs coming from people moving around and interacting with the MUSCLE. Infrared motion and proximity sensors detect people movements in the surrounding area, prompting the MUSCLE to react slightly, while touch sensors induce a stronger reaction.

ONL develops software (like VOR) and physical-prototypes (like MUSCLE) for programmable interactive architectures. ONL’s ultimate goal is to develop a highly sensitive architecture that responds directly to the requests of its users on a massive scale. This architecture already possesses the ability to reconfigure itself in real time, connected to the world through the Internet and to the users through a user’s interface. It not only responds to the requests of its users but also proactively engages in the communication and reconfiguration process.

References

Acknowledgments
This paper is based on research and project oriented work of ONL and the Hyperbody Research Group at the University of Technology in Delft. List of projects and the corresponding project teams:
Envisioning the responsive milieu

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An investigation into aspects of ambient intelligence, human machine symbiosis and ubiquitous computing for developing a generic real time spatial prototype.

The Hyperbody Research Group (HRG) at Delft University of Technology is a research body driven by contemporary Information communication technologies. It focuses on issues of collaborative design in a media-augmented (digital and electronic) spatial environment. The HRG conceives a real time interactive environment by building a generic connectivity with virtual prototypes. These prototypes are representative of existent spatial scenarios articulated with parametric relations and embedded sensing technologies. Emergent spatial behaviours can be simulated through real time data exchange, connectivity and a networked architectural grammar that constitutes the corresponding physical prototypes.

The HRG has worked consistently with ONL, a multidisciplinary design office. This collaboration has given architects, visual artists, web designers and programmers an opportunity to work together and join forces, fusing art, architecture and technique on a digital platform. Together, we developed an interactive spatial prototype.

The prototype that HRG and ONL developed is essentially a re-configured version of an interactive installation called the MUSCLE, also developed by HRG and ONL for the Non-standard Architecture Exhibition at Centre Pompidou Paris in 2004 [Figure 1. The MUSCLE and the Muscle Re-configured transformation]. The MUSCLE is a completely programmable building, endowed with the capacity to change shape by contracting and relaxing industrial muscles. The contractions are the result of rigorously programmed direct response to sensed contextual data, such as proximity or movement of people. The apparatus consists of a pressurized soft volume wrapped in a mesh of tensile Festo muscles. These muscles change length in accordance with air...
pressure variations. The MUSCLE project illustrated how sensing technologies and corresponding tactile responses can be fused together to develop an architectural body akin to an alive, organic entity. When utilitarian space is transformed into a living organism, augmenting itself through time to cater to its inhabitants, the user is placed in the foreground. This scenario completely reverses conventional ICT-based projects where the user has to adapt to the IT enhanced object. The prototype is an experiment to observe the result of inculcating ambient intelligence with an engrained human-centric computing component. Its behaviour is carefully programmed in accordance with its core conception, human centric design. Multiple usability of space is intensified and fostered while reacting to and interacting with its contextual dynamics. The prototype reacts to contextual changes by means of tactile variations of physical entities/system components. This allows for maintenance of optimal surface variations for relaxation, food consumption and related leisure activities. Ambient intelligence plays a vital role in formulating the core conception of the space. It imparts both the physical and psychological notion of control over the behavioural aspects of the spatial loop. An environment that is aware (by means of sensing devices) of the activities occurring within itself and that is imbued with the ability to act appropriately, aids in reducing the cognitive load on the users of that space. Therefore, it can improve the efficiency and performance of both the architectural space and its users. An intuitive interaction, opinionated towards seamless information exchange between the otherwise closed systemic framework of the architectural world, is hence initiated through the research experiment.

Ubiquitous computing is seen as the backbone of such a construct. The prototype is seen as a network of nodes, which are linked in space in a highly interdependent manner, constantly exchanging information and behaving as a collective whole to attain spatial re-configurations. Simple ‘If-Then’ Rule-based control algorithms are developed, to coherently knit together these internal and external nodes of the system. These algorithms enable programmed behaviours to materialize. Ideas inherent in swarm-based behaviour, information exchange, self organisation and biotic processes are used to develop a continual information flow between these components. This flow enables a dramatic response that transforms the hard-edged articulated nature of the strip (in its neutral mode) into soft, luxuriant but meaningful progressions. A typological hybrid, the prototype is conceived as a multi-disciplinary construct, focusing on a synergetic merger of science, technology, art and architecture.

The Muscle Re-configured

The Muscle Re-configured prototype has been developed as an evolved version of the aforementioned MUSCLE project. The core conception, of utilizing Pneumatic actuations as a medium of producing tactile variations, persists. The re-configured prototype uses the same set of actuating components, which are Pneumatic Fluidic Festo muscles. However, instead of the soft volumetric alterations of the external form (as in the first MUSCLE project) this new prototype embodied an approach emphasizing internal spatial response. The soft inflatable skin of the first MUSCLE project was exchanged for a new aesthetic with the innovation of ‘Hylite’ panels. These ‘Hylite’ panel were used to construct the new prototype’s spatial envelope. By using the shear compression power of the pneumatic muscles to bend and warp the hard-edged Hylite compositions into soft, luxuriant and meaningful variations, the Muscle Re-configured installation achieved its goal.

The root of the research was to create an intuitive responsive reaction in the occupants of the spatial loop. As a result, the HRG-ONL collaboration formulated a multi-disciplinary construct. The prototype is formulated as a strategic alliance between the fields of ambient intelligence, control systems, ubiquitous computing, architectural design, pneumatic systems and computation (real time game design techniques). It is instrumental in mapping the inherent linkages prevailing between these fields. This synergistic approach substantiates a generic systems (open-systems) view for conceptualising architectural space. Hence, the central issue of fostering multiple usability of space via spatial augmentation attains the dimension of constructing an adaptive system that is continually engaged in activities of data-exchange and optimal augmentation of itself. A systematised exploration into the above-mentioned research fields led the team to the careful extrapolation of specific threads of interest. This extrapolation was instrumental in binding the material and the digital components of the prototype into the following areas:

- parametric design - via real time information exchange between software and hardware components;
- control systems - embedded sensing and actuation technologies;
- ambient intelligence - focusing upon human-computer symbiosis;
- pneumatic systems – identifying actuation possibilities;
- computing – utilising graphical scripting techniques (specifically using Virtools, our interactive game design software);
- and finally, ubiquitous computing - interdependent nodal networks.

Such technological inclinations and a bottom-up systems approach allowed the team to simulate emergent spatial behaviours through the resulting real time data exchange between the prototype and its contextual settings. 
The prototype is visualized as a three-dimensional section in space, which is cohesively programmed to respond to human occupants through its sensing, processing, and actuating enhancements [Figure 3. Spatial loop (soft) animated simulations]. This three-dimensional strip/loop-like conception in space, akin to a genotype, embodies behavioural logistics. It further hints at the possibility of developing an ever-expanding programmable spatiality by means of attaching similar spatial strips (each delivering specific performance criteria) in succession. The experiment was seen as a platform to encourage meaningful spatial mutations, which would result in the production of a networked bio-system of intelligent archetypes. The prototype, as it stands now, is a scenario-driven, singular loop developed for testing purposes. The prototype was envisioned as a collective whole, by conceiving of the whole through the successive agglomeration of individual components in a systematized manner. Implicitly, an inherent communicative connectivity was also developed. A strategic extraction of system components, actively communicating with each other, was woven together to become a singular entity.

An exhaustive methodological dissection has been charted out, in order to materialize a complex adaptive system. This dissection is made possible by incorporating a bottom-up design perspective. The entirety of the system is seen as a product of a generic interaction between the soft (virtual/digital) models, representative of constructed scenarios, and the hard edged world of architectural reality. The so-called architectural reality is the hardware/system components constituting the system architecture. A detailed list of the system components, further segregating them in accordance with their generic usage, led to the identification of the following typologies:

**Pneumatic entities**

Fluidic Muscle Type MAS. A flexible tube with reinforcing fibres in the form of a lattice structure. These allow up to 10x higher initial force than a cylinder of identical diameter. The muscles tend to contract 20 percent of their initial length with the induction of air pressure. In this way, they act as an actuating device that alters the node positions of the prototype. Application: Actuating devices connect Hylite plates to a singular networked whole. [Figure 4. Festo based pneumatic muscle]

**The Black Box**

A hard-edged box housing the switching mechanisms, which are I/O boards connected to the 72 valves controlling the air pressure lock of the Fluidic muscles. The box has provisions to attach the compressed air intake pipes through distribution channels; it also houses the CPU and power back-up mechanisms. Application: Used as a secure container, it houses the brain of the installation. From here, the Fluidic Muscles are instructed to one of two modes: contract or relax. [Figure 5. The black box]

**Flexible skin**

Hylite panels. Hylite is a sandwich sheet of two thin aluminium layers with a plastic core in between. It was developed for car body parts. It integrates high flexural stiffness and extreme lightness. Compared to steel sheet with the same flexural stiffness (0.74 mm) and aluminium (1.0 mm), Hylite is 65% and approximately 30% lighter respectively. These results have been obtained by combining the best properties of aluminium and plastic in a single material. The Hylite panels were specifically selected for the skin of the prototype due to its flexibility criterion and the ease involved in its handling. Application: Spatial envelope, interactive furniture surface, projection surface. [Figure 6. Actuated flexible skin]

**Control system**

Sensing devices. These devices are used to enrich the activity recognition criterion of the prototype. The selection of the sensors, involved two basic sensory distinctions: the global and the local. The global deals with proximity of users in respect to the prototype. The local level deals with finer adjustments
made to the prototype by means of individual-user inputs. These adjustments occur through the pressure sensors, hence providing partial control by the user.

**Proximity sensors**
These are for sensing the distance of the occupant from the installation (they are specifically attached to the furniture elements).

**Touch sensors**
These are for sensing the amount of pressure exerted upon a surface (specifically attached to the seating surfaces).

**MIDI and PCI cards**
MIDI. These Digital to Analogue (and vice versa) converters connect the sensor input channels to the CPU. MIDI was chosen as a middleware for transferring data sensed through the sensors. Both proximity and pressure sensor readings are converted from analogue to a digital format through the MIDI interface, using Virtools-designed data processing script. Application: Used for converting and inputting sensed (analogue) contextual data to the CPU (digital).

PCI cards are used to handle the output processed via the processing scripts. The cards are described as ‘Smart lab controllers’ developed at ONL and HRG. They are specifically programmed to receive the output signal (a long numeric string) and communicate it with the In/Out board mentioned earlier (black box), hence controlling the sequential opening and closing of airlock valves. Application: the PCI cards deal with system output and help attain appropriate spatial variation of the prototype through actuators (fluidic muscles).

**Game-design software**
Software. Virtools Dev 3.0, a software used for interactive game design, is used for scripting the behaviour profiles of the prototype. Virtools revolutionary technology allows the user to create interactive applications by graphically assembling ‘behaviours’ in Virtools’s intuitive interface. Application: The graphical scripts are systematically composed to communicate dynamic data. The data is related to the proximity of users (through sensors, via the MIDI) to a set of arrays (the interface between the real and the virtual worlds) built into the software file. These arrays are constantly updated via the ‘sensor reading script’ developed at the HRG, which primarily uses the MIDI inputs for this purpose. Apart from this script, there is a parallel operation that concerns the ‘Status’ of each system unit. One Hylite panel attached to two Pneumatic Muscles is tracked constantly by updating the corresponding valve status linked to the muscles. These two operations formulate the so-called first level operations of the script, which are aimed at capturing the context within which the prototype is embedded.

The second level involves the ‘data processing script’ to check in accompaniment.
with the previously acquired information, the ‘Status’ and ‘sensor reading scripts.’ This level abstracts the change in context by means of reading the updated array and the current position status of each system unit. This information is gathered by means of compiling it in the form of genotypic numeric strings, which are forwarded to the ‘Smart lab’ PCI cards. The PCI cards, as mentioned earlier, further relate these numeric strings in correspondence with airlock valve status and run re-checks for any updated arrays in parallel to create a phenotype string. This phenotype string involves a long numeric string equivalent to the number of pneumatic muscles in the prototype; it represents the new on/off status commands by means of numeric 1 and 2 codes. This processed data directly communicates with the airlock valves and results in the opening/closing of valves corresponding with the numeric data delivered to the black box. In this way, specific sets of pneumatic muscles are actuated to produce an appropriate system response.

The graphical scripting environment of Virtools made it possible to assemble these scripts in such a manner that each individual system unit would act locally while communicating the change in its state to its immediate neighbour. This environment made it possible to create a flock-like behaviour, which gives rise to meaningful spatial variations.

System performance

The system architecture conceived to bind the above mentioned components (0.3) successfully transmits contextual data by means of the systems sensing capabilities. This data is sent to the behaviour enriched graphical scripts developed in Virtools, where rule-based computations generate optimal solutions producing real time spatial augmentation. The prototype, at a higher scale than the subsystem, is further typified into three units: Relaxing furniture units (relaxation chairs and table), Responsive ceiling units, and Responsive wall units. Each of these typologies are held together by a network of Fluidic muscles with differing configurations that create the desired effects from the overall construct. A carefully scripted rule-based operation scenario responds intelligently to create coordinated augmentation between the three units, hence supporting the holistic appropriation of the spatial loop.

Responsive ceiling units

The ceiling is materialized as a network of connected Hylite panels. These panels are placed in position by creating rigid connections between them with the fluidic muscles. The orientation of the panels is directly related with the manner in which the ceiling units have to operate/bend (Figure 12. Responsive ceiling units (controlled behavior producing soothing augmentations)). The operation results in the creation of projection surfaces, the generation of smooth, soothing curvilinear forms for relaxation purposes, and the creation of openings in the ceiling surface that allow light to pass through. These operations are visualized with one connecting property of the fluidic muscles: the compression forces that it can generate and the ease with which they can be linked together to create one long string of compression elements.

The ceiling units have been programmed to operate in two modes: the local level, and an automated behaviour setting (pre-programmed). The local level, two stages by means of two sets of sensing devices: firstly, the data concerned with the proximity of people near the units is captured by means of proximity sensors, embedded at the facing edges of the furniture units. This sensed data, captured as analogue signals is transmitted through the MIDI interface to the CPU, where the data is processed through Virtools scripts to return actuation commands which are re-routed through the PCI cards interface and sent back to the Black box to trigger the Muscle contractions. This first stage creates an initial curvature in the furniture surfaces, enough to allow people to sit on it. The second stage involves a much more direct interaction of the people sitting on the furniture surface. The surface has two touch sensors attached to it, which trigger adjustments in height and curvature of the furniture units [Figure 11. Responsive furniture units (testing the weight capacity and tactile variations)]. The data communication, this time concerning the amount of pressure exerted on the touch sensors, follows the same sequence as mentioned for the first stage and creates appropriate curvature variations in accordance with the choice of the user.

Responsive ceiling units

The ceiling is materialized as a network of connected Hylite panels. These panels are placed in position by creating rigid connections between them with the fluidic muscles. The orientation of the panels is directly related with the manner in which the ceiling units have to operate/bend (Figure 12. Responsive ceiling units (controlled behavior producing soothing augmentations)). The operation results in the creation of projection surfaces, the generation of smooth, soothing curvilinear forms for relaxation purposes, and the creation of openings in the ceiling surface that allow light to pass through. These operations are visualized with one connecting property of the fluidic muscles: the compression forces that it can generate and the ease with which they can be linked together to create one long string of compression elements.

The ceiling units have been programmed to operate in two modes: the local level, and an automated behaviour setting (pre-programmed). The local level,
as mentioned earlier, specifically deals with the users’ input: touch sensor readings obtained from the seating units. The ceiling units directly above the seating units are bound together, hence acting in co-ordination with each other. Pressure exerted on the touch sensors also creates a subsequent change in configuration of the ceiling units, creating a harmonious spatial augmentation. The automated mode is put into action if the prototype doesn’t encounter any activity in its immediate context. It uses any tactile response as a manner of attracting potential users. This automated performance is pre-programmed in Virtools, and is attained by simply instructing the air lock valves corresponding with the Pneumatic muscles (connected to the ceiling Hylite panels) to induce air pressure if no sensor data is received (which results in null updating of arrays) within a set period of time.

The responsive wall units

The wall elements constitute the same generic Hylite panels, which are woven together to create a continuous surface with the ceiling elements. The same principle of compression strengths goes into materializing the wall, which, when actuated, bends to create projection surfaces and seating surfaces [Figure 13. Responsive wall units (context aware manipulation of states)]. The actuation of the wall and ceiling elements are also intrinsically linked up with the furniture element actuations, hence weaving the entire construct into a cumulative whole. However, there are also provisions in which, for experimental reasons, one can individually trigger these entities.

Conclusions

The installation performs in real time, transforming from a hard-edged rectangular sectional strip to a much softer, humane envelope [Figure 14. System components working in cohesion as an intelligent being]. This shift, from the traditional view of perceiving space as a closed container object, to a more subtle responsive body is intimidating and perplexing at the same time. An intuitive interaction, directed toward seamless information exchange, is initiated through the research experiment. It transforms everyday utilitarian space into an interactivating (and interacting) responsive organism. The prototype convincingly fuels the idea of developing pro-active spaces that communicate and reconfigure in real time, while being sensitive to their context. The successful accomplishment of the project is also suggestive of the benefits yielded by the collaborative effort of various fields of expertise. Such a collaboration promises further emotive architectural beings that understand and respond to their occupants.

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Virtual Reality Operation Room

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The Hyperbody group of the Faculty of Architecture at Delft University of Technology aims its research at interactive architecture. Just like cars, websites and other media, buildings should become increasingly sensitive. The Hyperbody group believes that they should be intelligent and that they should have the ability to act and react. In order to study and develop this phenomenon, we build interactive games in Virtools. Virtools is a virtual reality development software program designed by a Paris based company of the same name. Some recent architectural ideas, like freeform architecture, swarm behaviour and genetic algorithms have been addressed and combined in a game for the Technology Museum in Delft called ‘Virtual Reality Operation Room.’ In this article, we will explain and demonstrate the game.

Interactive architecture can become so complex that collaborative design among different specialists is necessary. Collaborative design and concurrent engineering implies cooperation of design partners right from the start of a project. One of the main conditions for this cooperation is a good workplace (HAR 00). We believe that real-time projection of the design in 3D on the surrounding walls and surround sound will help the design partners to evaluate the design of interactive architecture. We want to make a ProtoSpace with those qualities in a pavilion designed by Kas Oosterhuis and which was bought for this purpose by Delft University of Technology.

Besides a projection and sound system, we feel that there are other requirements for successful collaborative design. Data exchange, for example, between the partners in a design team is crucial. Because of the many software applications that are in use, standardization of the product model data is needed. (Haas, 2000). A database system must take care of the actual exchange with version management. Such a database system has many requirements (Carnduff, 2000). Parametric design might help to speed up the generation of alternatives. An introduction to ICAD at the faculty of Aerospace Engineering at Delft University of Technology taught us that translating the different relating components of a building into LISP code would take years. And that, of course, would not even include the generation of new interactive architecture. In fact ICAD is more than parametric CAD, it is knowledge-based engineering software. ICAD allows for not only the geometric relationships between parts but also the complete design rules. Finally, the process of cooperation is to be considered. Project management and decision support systems are a research field all their own (Gunsteren 2001). This paper concentrates on Virtual Reality.

VR is not only animation in real-time. First, the behaviour of objects must be calculated in the behaviour engine; after that, a render engine does its work. The position and other attributes of objects are calculated, or, if objects collide or due to gravity are falling, these actions are also taken into account. We can also simulate the use of sensors. If an object has a collision detection script and the distance of a character to an object becomes smaller than a certain value, this object will send a pulse and can start any other process. It will be of no surprise that if all those behaviours become too many and too complex, the frame rate slows down. If any frame rate below 15 images per second occurs, then the feeling of immersion is lost.

The program that we use in our design work is Virtools. [Figure 1. Virtools] Virtools is a virtual reality development software program designed by a Paris-based company of the same name. It won the IST Grand Prize of the European Commission’s Information Society Technologies research programme in 2002. It can be used for e-marketing, e-learning and gaming, as well as other applications. We use it for the simulation of interactive architecture. We selected it because of the user friendly interface and the extended functionality. There is a free, downloadable player on the Internet at www.virtools.com.
The interface allows the user/designer to have a 3D view of the game. The designer has the ability to add cameras, lights, to move around objects, to zoom, and to orbit. At the same time, the user/designer can work in other windows to develop the script. A script is the code of the game. It doesn’t show as code, but more as a flow diagram. The rectangles are called Behaviour Building Blocks (BBs). You simply pick one from a list and drop it in your script. Connect the BBs, adjust the input parameters and your game is ready. The ease of use makes it suitable for architects and students who have no experience with programming. There is also a Software Development Kit, but you must be able to work in C++ to use it. The newest version has a scripting language. The white rectangles with text are comment boxes, which explain the ideas to future developers.

Recently, we purchased the Virtools Multi-user and behaviour server, which makes the development of multi-player games possible, with Internet messaging and distributed objects. Now, we can really get into collaborative design. Before VR, CAD was very influential upon architecture. VR and CAD together have created a new way to see the design stages of architecture. We know an architect who changed an important aspect of his design when he noticed, in a simple walkthrough animation, that someone in a wheelchair would not have a nice view from within the building. With new technology, the architect had the ability to see things from the wheelchair user’s vantage. It is without any doubt that the use of CAD-systems lead also to a new kind of architecture, the so-called freeform or Blob architecture. It is easier to define double-curved surfaces with CAD. And the data exchange with the production company’s machines, the so-called file-to-factory process, makes it affordable. It is no problem any more if every part of the construction is different, since the cutting and welding machines in the factory can produce them almost automatically. A code on every piece makes assembly on the building site efficient. For those who would say that double-curved surfaces were constructed long before CAD, we could agree on one level. However, the recent use of them was limited to rather simple structures (like roofs above station entrances) because the labour in western countries became so expensive.

Now VR adds the influence of interactivity to architecture. Our VROR project (Virtual Reality Operation Room) shows some interesting examples. One of the levels shows a way to grow architecture using genetic algorithms. Another level shows the organic qualities of freeform architecture. The game begins with the entrance to a space where every point of a mesh is positioning itself using flock behaviour.

Genetic algorithms are the mechanisms that nature uses to give form to its organisms. This might be an interesting subject to investigate, if we are searching for ways to create architectural forms. The principle is based on a certain way of reproducing itself, on different levels of the hierarchy. Each level is at the same time the output and the input of the same calculation. This principle is called fractal growth. In programming terms, it is created by constantly going over another level of the hierarchy with the same calculation (Flake 1998). The beauty of this system is in its simplicity. Complex shapes can be created out of a single object by doing nothing more than determining the principle upon which it must be copied. Instead of shaping the environment by hand, we set the conditions and the way the object reacts to these conditions. The shapes that are easily grown with this program are difficult to create when you design them yourself. Even if one succeeded in doing so without the program, the result would be far less interesting. Because this shape would always be the same, while the environment changes, it wouldn’t match nature’s standards. By investigating the principles upon which a tree grows, we get a higher understanding of what really happens when a plant is growing. Instead of copying the end result of this growth, we try to copy and understand the principles of its design. In this way, we can use a natural example to further explore alternative design methods.

In the VROR project, the 3D experience is completely determined by one box-shaped object. This object is copied, translated, scaled and rotated according to this genetic algorithm. It creates on its own a new form each time you start the program. In this algorithm, certain external factors are taken into account, which make the object react to its surroundings. For instance, when a player comes close, the organism will try to bend towards the player. There are, however, other objects in the game that influence the organism the other way around. The organism has limitations as to the length of the tentacles, angle toward its previous body part, to its speed and to the amount of new growing parts. In figure 3, the input shape is shown, a box. It has a texture applied to it. The rest is all done by the script.
From this box, the complete organism is grown. In this script, one of the most important aspects is its ability to account for fuzziness when growing. [Figure 4. Fuzziness]

There is a little randomness in every factor used. Even in the exact same environmental conditions, there will be slight differences to the grown objects. Leaving this fuzziness out, the models will become boring and predictable. Maybe in real nature this, what appears to us as fuzziness, is actually a result of even smaller processes, which have a kind of similar principle. Going deeper in to this matter doesn’t have enough relevance to our research because of the small impact it has on the end result. Taking these calculations into account would slow down our program dramatically because the amount of calculations has an exponential factor towards the current smallest level. In the end, it would lead us to the understanding that in this smaller calculation, we come up with the same problem. It has again a certain fuzziness, which can be explained by another calculation in a lower level. Therefore we stop at the size of this box, and take this shape as an input for our program.

When we let the program run for a while, it creates on its own a complete, new environment. If we look at the shapes, we experience a world that can hardly be made by the human hand. [Figure 5. Not made by the human hand] And, in fact it isn’t made by human hands, because all the shaping is accomplished by the program. This kind of program could be used for the design of nature-like shapes. While playing with controllable parameters, for instance, such as the position of the avatar, you can see the environment react. This is how the environment is custom made for each situation. The world becomes interesting when you see the difference between the worlds created by different players. Going further, one could even imagine an application, which adapts to building technology conditions, by combining various calculation techniques. It could, for instance, adjust the amount and size of the structural parts according to its future use, giving the genetic algorithm, as well as advantages to the visual designing part, a technical use.

VROR, immersion in ‘free form’ spaces

This paragraph describes generative and immersive aspects of continuous ‘free form’ surfaces.

Super smooth blobs are hip. Or at least they were hip. (We hope that this statement doesn’t defy the development of a sufficiently ‘scientific’ text. However, the use of complex terms like ‘hip’ may actually be more scientific…) How come? (Blobs are/were hip) It seems to appeal to several more or less archetypal (human) interests:

1. The blob, or so-called ‘free form’ space, is seemingly new, relative to modern formal language, and to the spatial experience of line or surface-defined space. Also, it is new relative to composite (added-up (stacked, combined etc.) intersected, added, subtracted) space. To explain the attribute ‘seemingly’ that I combined with ‘new,’ I would like to briefly point toward the spirit of
Mannerism and Baroque. This spirit has an interest in, beyond generating (versus transforming) complex geometries – it is the synaesthesia of different media (space, time, image, sound) for the sake of experience.

We lived in caves a few thousand years ago and every human being grows inside a free-form-space called the uterus. Beyond these examples, we have dreams and stories and movies, all with the ability to create highly immersive, multidimensional, continuous and spatial experiences. These are all probably as old as the technology of nervous systems. New, on the other hand, is interesting, sells and thus can become hip.

2. It seems that the long dreamt dream of flying, of immersion, of body extension and of dissolving the boundaries of the human body resonates with the fascination for the motion. Specifically, motion through a relatively complex geometry. In this geometry, the understanding of one’s position and orientation and objective is not simply two dimensional. It is not as simple as relating one’s eye position to the converging lines of perpendicular architecture; it must make use of dimensions such as light, colour, sound, force, air and temperature flows. It must make use of other relatively autonomous information beings, like other avatars or files, beings that are moving relative to the immersed self. The absence of certain habitualized referential systems will activate the integrative use of other present systems in the human body.

The identity of the self is modified in a space where elements that are used to being relatively static, start to change relative to the self and to other elements.

Examples in the VROR

1. The blob-effect: the hyperskin reveals fully what is in your proximity and partially what is structurally more distant. However, there is less of a nodal connection. Doors for example, unless opened, form separate elements revealing nothing of what is behind. They reveal much more the sense of outlet or throughput. There is a seamless and levelless progression between containing spaces and connective spaces. So there is a seamless possibility to model privacy and (literal) openness. To model sameness and difference, see point 5 on how to make it.

2. Behavioral liquification: you move and are being moved at the same time. Your position and motional vector are affected by the flow of a virtual liquid. You are modelled by acceleration fields (like magnetic attractors). Consequently, the immersed ‘self’ feels free to merge with the vectorial volume of the space. Just like a butterfly in the wind or a seahorse in water. The rotational effect is calculated, basically, by simulating real world swirling in liquids. [Figure 6 Immersion in the Interactive Blob]

3. Immersion: more than just existing - existing within. A pleasant immersive condition has to balance on the edge of being rationally identifiable (thus stimulating thinking and the idea of relative control) and being relatively complex (therefore activating intuition/stimulating the body and the idea of being relatively controlled).

‘Non-scientifically’ speaking, it is somewhere between confusion and clear understanding. (Flake 1998). The immersion is truly affected by the modulating identification of the self, a self that can, at certain moments, incorporate properties of the ‘space’ of other selves.

4. Beauty or relationship of multidimensional entropies. (Entropy describes the level of randomness within a chaotic system).

The human capacity to rationalize, that is, to represent information with relatively stably and identifiable quantum of information and to relate those quanta to each other in a ‘logical’ fashion, is not just reserved for thinking. Or better, feelings are rational. There is an intrinsic logic to how we feel. It is not random. There is a constant feedback condition between what we perceive and how we evaluate that and how we will react/act towards this. But perception is larger than what we could consider mere sensing (using the digital information coming in through our body senses eyes, ears, skin.) The interaction between the different sensitive systems, happening more or less conscious to the human self, generates a higher level perception.
However, beauty in this definition is neither reserved for the mere audiovisual realm nor for the structural realm but it is substantially present as behavioural beauty.

5. How do you make a hyperskin? - Generation vs. Transformation

In the case of the VROR, a metaball system is used to describe the skin of the hyperbody. A metaball system is an interpolated space. A set of spheres which ‘seek for connections’. The connections interpolate between these spheres in a NURB (non uniform rational b-splines)-like fashion. [Figure 7 Generated Metaballskin]

Another strategy, yet different: one can smoothly (in a NURB-like fashion) pump up volumes in certain areas of the connective structure, like, in the VROR case, a tubular network. Ideally however, one would GENERATE the hyperbody’s skin. The hyperskin would be a special ‘rendering’ of a point-cloud. Every information quantum (skin vertex in space) would negotiate, in a swarmlike fashion and in real time, its position relative to its neighbor’s in the skin and to the oppositional skin. To speak of free-form is, in this case, not referring to the freedom of the sculptor’s neural and emotional network. It is not referring to animation-based techniques connected in a relatively long-term-’real time’ process to a human neural net. It is referring to the relative freedom of the skin components themselves, within their real time interactive verification process. Forming a highly interconnected, relatively autonomous, and finally intelligent device within the distributed being, formed of all components affecting this process, it would be better described as a swarm-form.

The VROR is a working example of a spatially self-organizing built structure. It follows the paradigms of flocking. The elements of the structure react to each other and to environmental influences, applying a set of several simple rules. Out of the interrelated behaviours of the swarm-members, the hive-mind emerges. Through it, the swarm as a whole reacts to the environment as a higher intelligence, trying to achieve a state in which all swarming elements reach happiness – in their relation to each other, persistently improving the structure’s integrity and strength within the changing environment. In this it is different from the evolutionary development of an ideal form in successive generations; the swarm evolves and adapts to changing influences in real-time. [Figure 8. Flocking]

The self-organizing characteristics of the swarm are of great value to the efficient transmission of forces, energy and information, but the swarm is also an unpredictable, uncontrollable being. New structures continually emerge out of it, out of its complexity bringing forth beauty, to our surprise and inspiration. Swarming architectures manifest themselves in the physical world, if building elements can sense, think and react, or rather receive, process and transmit information. And they already do, not only in the form of people, images, smells, gas, current, air and light, but also as pure data in hardwired and wireless networks, and as physical expressions driven by actuators, and steered by multiple controllers.

In the VROR game, the vertices (points in 3D space that constitute a surface) of a surface are the swarm-members, the surface is the swarm. The rules working on the vertices are simple:

1. Try to be a certain distance away from your neighbors. Move to that certain distance faster if you are farther away.
   This rule creates elasticity, since the surface can now be stretched only by ‘force’.
2. Try to be a certain distance away from your neighbors’ neighbors. Move to that certain distance faster if you are farther away.
   In combination with the first rule, this rule creates a certain ‘stiffness’ of the surface. As the distance of the second rule becomes larger than twice the distance in the first rule, the surface will become stiffer; as it becomes smaller.
The first two rules constitute the behaviour within the swarm, which wants to create a surface of uniform density with as little folding as possible. As the surface used in the VROR is a genus-zero surface, constituted by the topology of the connections (which make the points neighbors), by following only these two rules, it will organize itself in a spherical shape.

Several exterior influences are moving around the sphere, the avatar is one of them. These influences affect the swarm with a similar rule:

3 If it is within a certain range, try to be a certain distance away from it. Move to that certain distance faster if you are farther away.

The combination of these rules results in a complex behaviour of the VROR. It can ripple, crease and unfold in never-repeating complex patterns. We cannot predict those patterns, but we intuitively understand them, since our daily environment behaves in similar ways. The VROR invites us play, to touch and to see what happens – to become one with the swarm. [Figure 9. VROR start screen]

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Designing a hyper-body of a train station design lab

Tomasz Jaskiewicz

In the second semester of 2003, a group of ten Master of Science Architecture students started their research semester in the E-Motive Architecture studio, an educational program of the Hyperbody Research Group. The design assignment they were given was a relatively common one – to design a train station. The path that they were required to follow to accomplish that task, however, was highly innovative.

The aim of the Hyperbody Research Group is to study interactivity in architecture and to develop its practical applications. Some of these practical applications include programmable buildings that illustrate the paradigm shift from animation to real-time behaviour. ‘Hyperbodies’ are intended to be proactive building bodies that act in a changing environment. Thus, the assignment for the students was not just to design a building for the Central Station in Rotterdam; it was to design the body of that building as a ‘hyperbody.’

To build a structure that will manifest its own behaviour, quite apart from designing the technical properties of that structure, one must also design the behaviour. A common approach would be to study all the possible factors that may affect potential actions of such a body and to construct a model that describes how specific events are linked to the execution of actions of such a structure. Students in our group were new to this subject. On one hand, they were strongly inspired by the recent developments of IT and the new theories originating from them. On the other hand, they leant on their background in traditional architectural design practice, which is rarely concerned with non-static design solutions. Therefore, the work of students went on in two parallel streams. One was to research and study various ways of programming behaviours, both on a practical and on a theoretical level. The other stream focused on applying that knowledge to a specific design assignment.

Initially, most students began by defining a variable factor that they found integral to the interactivity of the building and the design -- a relation between that factor and the building body. To support students in their work, classes in Virtools Dev, a 3d software development platform, were given within the studio framework. Using this toolkit, students were able to script their own behaviour models for forms that they had designed in 3d modelling packages (like Maya or 3d Studio Max).

In this way, some of them managed to design and script behaviours of interactive structures, like an interactive roof that covered the designed space, the volume of which could be linked to the number of people present in the building, or, a shape that would optimize itself to make the most optimal use of the solar energy. [Figure 1. Gianni Albertoe – Structure reshaping itself according to the position of the sun] [Figure 2. Tomasz Jaskiewicz – A roof that can react to the movement of people under it]
Even though this approach resulted in interesting outcomes, we concluded during our inspiring group discussions that such a top-down attitude toward designing behaviours has substantial limitations. Structures designed in this way may respond well to situations that can be fully anticipated by their designers, but when unexpected events occur, the whole system crashes. To give an example: Gianni Albertoe used his script to link the shape of a building to the movement of sun. Clearly, this idea has a safe foundation, since it is possible to precisely anticipate the relational position of the building to the sun. On the other hand, using, for instance, human behaviour or some other dynamic factor related to it to control a building’s actions, is highly problematic. People tend to act beyond simple patterns; hence a generic interpretation of their actions and expectations in constantly changing social conditions becomes utterly complex and practically impossible with a top-down design approach.

Not many factors, other than the number of people present in the building, can be unequivocally extracted from the building environment. Human activities and behaviours are highly subjective and difficult to categorize or evaluate in any way. Therefore, even though we may potentially use various technologies capable of tracking human behaviour in space, the most difficult part lies in defining how this behaviour should be linked to the behaviour of the building body.

As the 3rd Master of Science semester is predominantly focused on research, the students continued their design assignment by applying the theoretical knowledge they obtained from their “Literature and Media” and “Research and Design” courses -- courses that were held conjointly with the design studio. The main emphasis of their work focused on how decentralized computation logics could be used to overcome problems encountered in the interactive behaviour design process and its application.

Research interest has been especially drawn to the notion of swarm intelligence. Swarm intelligence is an artificial intelligence technique based on the study of collective behaviour in a decentralized, self-organized system. An application to interactive architecture could emerge if each component of the building, having a predefined range of movement, had at the same time the properties of an independent agent. That is, if it were able to interact locally with other agents and their environments. Although there is normally no centralized control over such structures that would dictate how individual agents should behave, local interactions between them often lead to the emergence of global behaviour.

A first attempt to achieve this was a project called Flockject, created by one of the MSc3 students, Christian Friedrich, who was working as a research group’s student assistant. In Flockject, each vertex of a spherical, triangulated mesh had a separate script attached to it, which would be responsible for keeping a node at a certain distance from its target, such as a person approaching an element of a building. As a result, a global emerging behaviour was to reshape the structure according to the user’s movement in a way which would not be possible to achieve by more traditional top-down behaviour definitions. [Figure 3. Christian Friedrich – Flockject project]

Yet, although a self-organizing concept may seem relatively simple in the case of the Flockject project, it becomes much more problematic when we start dealing with larger and more complex structures, especially those operating in environments hosting intricate processes of various kinds. The further work of students focused mostly on analyzing the behaviour of people, pedestrians or humans using different modes of transportation. Issues related to structural limitations, economy, ecology, contextuality of the urban setting, or society and culture were deliberately excluded from the projects, although the potential of taking into account other types of environment-related factors has always remained a core idea of their concepts.

A direct implementation of a Swarm Intelligence-inspired solution was achieved in the project of the design group of Max Cohen de Lara, Anastassios Kanellos and Rolf Kuck. Yet, swarming entities were not, like in the Flockject project, parts of the building structure. They acted as an intermediate way of translating the activity of people into the activity of the building. Consequently, in their design, a purely virtual flock of objects would be influenced by the activity of pedestrians -- that flock’s behaviour would trigger a certain readjustment of the building form. In that way, an intelligent core of the building stayed more independent from its form, yet still it used the same decentralized system principle as the aforementioned Flockject project. [Figure 4. Max Cohen de Lara, Anastassios Kanellos and Rolf Kuck– Rotterdam Central Station project]

The design group of Cheng Hui Chua, Dominik Otto, Zhi Xiang Siow and Tomasz Jaskiewicz used a different independent system to control the behaviour of their form. In their case, it was a network of urban paths and nodes inspired by...
the theories of Kevin Lynch. These network paths were the basic elements of the swarming system; they changed their length and height according to the potential intensity of the use of spaces that they were corresponding to. On top of that structure, a soft shape of a kinetic roof was constructed and would in real-time readjust to varying parameters of the network. [Figure 5. Dominik Otto – Self-organizing system] [Figure 6. Cheng Hui Chua, Dominik Otto, Zhi xiang Siow and Thomas Jaskiewicz – Rotterdam Central Station project]

The third student project, by Christian Friedrich, Dee Dee Lim and Gianni Albertoe took a different, more universal approach. The resulting product was more of a design tool than a specific project for a central station. The distributed logics of a swarm intelligence was addressed in such a way that designers using that tool would be able to insert different objects into a virtual 3d space, such as components of the building, or other site-specific objects like trains, cars and pedestrians. Those objects could then be connected by specific behaviours. In that way, a structure would emerge that would be a complex system, potentially exhibiting intelligent behaviour properties. This behaviour could be eventually further enriched by inserting more complex interactions, such as the relation of the whole structure to the sun. To simulate an application of such a system to a real situation, in the project development phase, a pedestrian and a traffic simulation could also be embedded. [Figure 7. Christian Friedrich, Dee Dee Lim and Gianni Albertoe – Rotterdam Central Station project]

The results of the students’ work evolved into products that can not be compared to traditional outcomes of a usual design practice. Their design focus moved from the common aesthetics-driven form-designing to designing behaviours of large-scale interactive structures. All student groups eventually addressed the potential use of swarm intelligence in their projects, yet each group took a very different approach to achieve their goal. Each of these unique approaches promise wonderful potential for new applications to real life projects.
Emo-tive

Emotive office & bubble education

Dominik Otto

Effective office

for the first time architecture is playing an active role inside the office with the idea of interactive interfaces that affect employees’ workplace. The use of materials influences the appearance of their office.
expressing emotions indirectly without any consequences
education

arousal

pleasure
> education

every employee has 1 hour a day to use ->
every department is in charge of its activities [figurehead of a department]
features are changing
calling for interaction of employees
can either be directly chosen or be proposed according to emotional state
employee S, female, 24 years

after 5 hours of data-entry S is very bored and tired

she clicks:

her emotion gets part of the surrounding

her emotional state is detected

S. needs a break, and some inspiration...

she decides to watch a few video clips

S. feels prepared for another 2h of data-entry
On February 25, 2005, Leonel Moura, a Portuguese artist, gave a workshop at Delft University of Technology about “robot driven swarm paintings.” It was a workshop for the master students of the Hyperbody Research Group of the Faculty of Architecture, to inspire them to use software programs to generate architecture.
It happened exactly as Leonel Moura had described. In the beginning, the robots leave random traces. Their movement is straight without many changes of direction. Some times they hit the carton border and sometimes each other (they are, however, equipped with proximity sensors). Colourful lights blink under the robots exactly where the colour sensor is located.

The canvas size was approximately 1 x 0.7 m. The artist stated that he has tried making his art with larger canvases (5m long), but that he must use a proportionally greater number of robots, as many as 10. After 45 minutes, the robots’ behaviour was obviously different. They detected the colours on the canvas and they were oriented accordingly, reinforcing the traces with the same shade. They also began to make curves and circles, adding complexity to the whole painting. Figure 8a, 8b, 8c, 8d, 8e, 8f

The robots were working hard for two hours before we all decided to stop the process. A large part of the canvas was now coloured. It was interesting to see that in some places the traces were denser, with lines overlaid upon previous lines. On the other hand, in some parts, the density of the colour was not apparent. This justifies what the artist told us before. The “pheromone” detection was working perfectly.

At the end, a strange painting was ready to be placed on the wall. Made by “artists” who were made by an artist, this painting tells the story of its creation. It also speaks about the collaboration of humans and machines in producing art. As Leonel Moura states on his web site: “The art object is the product of a non-human entity, indifferent to concerns about representation, essence or purpose. In fact, we are dealing with unmanned painting-vehicles driven by randomness and stigmergy. The artists/robots are not concerned with individuality or identity; they function collectively and perceive the world as a common ground shaped by indirect communication through the environment.”

Protospace was gifted a fresh, brand new painting to be hung on its walls. Figure 9 It is important not only because of the painting’s high price, but because it represents the human-robot collaboration in art. It is a strong example of a new kind of art; the art of robotics and artificial life.

**Symbiotic Art Manifesto**

[Making the Artists that make the Art]
1. Machines can make art
2. Man and machines can make symbiotic art
3. Symbiotic art is a new paradigm that opens an entire unexploited field in art
4. Object manufacturing and the reign of the hand in art can be abandoned
5. Personal expression and/or human/artist centrality can be abandoned
6. Any moralistic or spiritual pretension and any representation purposes can be abandoned
KO: I would like to find out if we can find common ground. Are we working on
the same sort of issues here? The word [quantum] can be interpreted in many
ways. You can work with it as pure natural physics, you can work with it as
a metaphor, like you state in your book, Quantum City, or you can make the
quantum world view work—that is, you can make it have an activity.
In the beginning of your book you say that the first important thing is the metaphor.
Can you explain why you would be satisfied with using it as a metaphor?

AA: Because very simply, as I speak to people who have thought about
the quantum concept before or who generally think about any concept that
relates to natural physics, as they try to apply it to other disciplines, including
architecture, there is a risk. There is always a risk when you bring things literally
from one discipline into the other. As an architect, I would never know exactly
what quantum physics is. I would have to study the theory as a scientist. As a
quantum scientist, I would never know what architecture is to the same degree
as the architect.

KO: Did you talk with any quantum scientists? Could you understand what they
were talking about?

AA: I have a scientific background. At high school I did a course, which was
directed towards biology, physics and mathematics, so I had a good basis to
start with, and it is a subject that I enjoy. Quantum physics is a very interesting
subject. Quantum physics was described in terms of molecular and subatomic
physics. But it was never thought of (at least not when I was in school) from
the point of view of metaphysical or philosophical paradigm shifts. Quantum
physics is the physics of the subatomic world. At some point in the early 1920s,
scientists had to deal with tools that would allow them to look into the subatomic
quanta. They found that it is not simply made up of a nucleus and electronics
spinning around it. This model turned out to be an overly simplified and abstract
version of what is actually out there. It is not like a planetary system, instead
it is something that is impossible to fix as a physical object. And it is more a
cloud of potential positions that these electrons could be in. The problem
was (and is) that every time they tried to select where exactly this electron
was, they lost a whole set of data about the electron. They could tell
where it was, but it was impossible to
tell where it was going and what the
speed was. Conversely, they could
measure at any point what was the
speed of any electron, or, they could

the first
important
thing is the
metaphor
KO: That was to a large extent due to the instruments that they were using. The way that you observe determines what you get out of it. We look through our eyes, data comes to us through our eyes, and we depend completely on the architecture of our eyes to receive it. We see many things, but we do not see radiation, for example. This room is filled with information and radiation. We don’t see it and yet it is there. Information is lost because the monitoring and measuring is achieved through our eyes. Why were they talking in metaphors to communicate the quantum concept, what sort of metaphors were they using exactly?

AA: Because of the impossibility to understand both the position and speed of any subatomic particle, they had to develop a concept, which they called the uncertainty principle. It is like if you have 100% accuracy on one part of information, you have 0% accuracy on other parts of the information. In other words, it’s impossible to understand and to have full information about any system in a particular moment and time. This is a total break with classical science, which started with the scientific evolution in the early 18th century and was highlighted mostly by Newton and his laws of physics. In classical science, the world is predictable.

If you would start at point A, you would know exactly where this object is going to be at point B and how it is getting there. What quantum physics tells us is that we cannot even know where point A is exactly, so how can we know where it’s going to be? To be able to deal with this kind of information, we would need to measure both aspects. If we use a tool to measure the position of a particle, then the particle will act as if it was a physical particle with coordinates at a particular point in time. But if we measure it by trying to understand where it’s going, then we have to use tools that measure the interferences and waves. The particle will give us information about itself that is something like a wave, a thing that transcends the space, because it has no exact boundaries but instead, possesses qualities. One of the first metaphors that came out of the development of the uncertainty principle, is that everything has both particle and wave aspects.

KO: What I exercised mentally was to think of matter that does not exist in our human experience. I may look right through this table. My exercise tells me that I only feel this as a table, because I am built in the way I am built. I feel this as a surface. If you look at it on the microscopic scale, it is all empty space. And inside my fingers is also empty space. What happens here? It will happen exactly on that particle wave level. You can construct an ephemeral concept that you can look right through, while somewhere on the subatomic level, there must be an interaction. Otherwise I could not be informed. Somewhere it must happen between the skin of my finger and the skin of the table. If we would have been built in another way, then my finger would not feel this but would slice right through.
through the table, like our bodies are cutting through air, which has a molecular structure just as well as the table.

AA: A new form of matter has been developed recently. I think it is called the Hypersolid. It's a new space of matter, where actual solids can go through each other; it was recently done in a lab for the first time ever.

KO: I was thinking of it as a mental construct.

AA: What is interesting in this physics is that there are possibilities that can either be taken to a practical level, or be taken to a theoretical level. I am interested in going back to basics. I looked at how cities were designed over the ages. And I found there is always a direct link between how we build our cities and how we understand the universe.

KO: The worldview.

AA: These world views direct everything we do—all our culture, interactions, everything. It comes from the source of knowledge. We started to invent mythology and religion, which told us how the world functions and we acted by designing our cities around temples and churches. At some point in the history of the city and in the history of science, the source of knowledge has shifted from religion to science. It happened in the early 18th Century. I call it the objective scientific revolution, because it showed a shift in focus from an organic to an objective view on the universe. As the objective observer I would understand the whole thing, and be able to separate myself from it.

This concept has affected how we build our cities. It has been transformed into a purely mechanical worldview because we are so sure of our science, we are so sure of how predictable our theory is and how our formulas work. We thought we could have a deterministic society, a deterministic economy, deterministic politics and of course deterministic architecture and urbanism. And we started imagining that if we could build the perfect city, we would have the perfect society. There is always a lag of a couple of generations between these ideas and the time when they start affecting cities on a larger scale. Ideas are changing. In the case of the mechanical worldview, this view has been recreated almost literally by the modernist movement. This movement says that the world is a big machine, and therefore man is a machine. We are living in the machine, our buildings are machines, and our cities are machines. It all works perfectly because we know all the rules of the game. Meanwhile, science has found new things.

Einstein came up in 1905 with the relativity theory which says that we always have to take into consideration the observer. The whole field of space time is one big measurable source of energy and it is affected by who I am, where I am and what I am doing. Therefore, you cannot continue thinking of the universe as one absolute linear entity. Seventy years later, relativity started to be misinterpreted as relativism. The first movement of post modernism and the reaction to the movement of modernism appeared and with that, the notion that if relativity means relativism, then we can do anything and anything will work.

KO: Is that your tragic view of architecture?

AA: No, because science itself is probably a misinterpretation or an approximation of the universe. In general, this is why I am interested in the metaphor, because when you go to the metaphor, it’s probably less dangerous. Whenever one tried to take these things literally, it has caused social problems. But if you work with it as a metaphor, it can still have space to manoeuvre. What is interesting about the metaphor and the quantum metaphor in particular is that the quantum worldview by definition says that we need to have complementary notions of working. It cannot be black or white, it cannot be either-or. In that sense it can take notions from modernism, from classicalism, from post-modernism—that is not the problem. What is important however is how to produce a workable city or a workable society.

KO: We have to see our profession as a process and we have to jump into the process and work inside the
process, to be able to make something more actual. We have computing power now. We can run a complex environment and build the interactions between all players in that environment. Players can be anything. The player can be a cup, the player can be a book, a word, a person, or a building component. We have to build the rules for the design game, we are as much architects when we construct a rule that is a running process that interacts with that running environment. That is basically what we are trying to do in the Hyperbody Research Group and in the Protospace Lab, because we think that is the way to go using today’s computation-based tools. That is a paradigm shift. Think of an environment where the data and information is processed in that very instant. This resonates very much with what you write in your *Quantum City* book. Cities seen as a process, as a set of dynamic relationships. We then interact with the processes by developing new design proposals for the city.

AA: You are totally right. This is the message of the book. And I do like to put things in historical context.

KO: The theory of the Dutch Stijl Group around the early twenties was very much connected to physics, mathematics, and the universe. They were quite close to the actual development in science. In their worldview, everything existed in a continuum. They translated that notion into a concept of fluid architectural space. Walls could move, the living rooms could be changed into different configurations; the reality of built constructs was seen as building variations in the density of the universe.

AA: Things can start immediately after an idea comes out. The seventy years I mentioned is the time for this idea to be generally accepted, when it becomes mainstream, not just a group of independent thinking people doing it. *Quantum City* was written in 2001 and published in 2002, and it started with a research project in 1997. Your research group here did not exist yet in 1997. Now I am seeing different groups which are doing similar things, they are not using the word quantum, it is not important. There are many people interested in this different worldview of flows and bottom-up processes. Quantum physics allowed all the technologies that we are using to exist. By having new tools we see new worlds, and by seeing the new worlds we can have new ways of understanding things and therefore of designing things. Quantum physics is the major discovery that opened up the computer age. The Internet is based on the paradigm that everything is connected, allowing immediate access to any knowledge and access to open source software. I call this the quantum worldview—it includes complexity theory, emergence theory and systems theory. It is not only quantum physics, which is very particular branch of physics.

KO: I was looking at the subatomic world, which unfolds between 10–16 and 10-22. The bandwidth of all the interacting particles is 106. If you look at a small architectural detail at one side of the bandwidth and the cities at the other side, the bandwidth is roughly 106 to 108. If you now look at our world, which is quite complex, would this subatomic world be just as complex?

AA: Just as complex? Could that be?

KO: I would expect it to be just as complex as our world. I refuse to see our world as the zero point of the universe. If we could position our senses at 10-20 in the universe and live there, we would see completely different things. Eventually, I think, we would be able to walk through the table. I think it is relevant to consider, because if you choose a point of view, then you will build your construct from there. In the Platonic world, we would have a fixed object with a single fixed position. In running swarm systems, you would have billions of possible valid positions. It is my hunch that since we humans and our cities are very complex and based on the complex interaction of interacting swarm systems, the subatomic world is most likely at least as complex.

AA: Don’t you believe that we are more than sum of our parts?

KO: I believe that we are part of many sums. My brain has no relevance at all as an insolated brain. My brain only has relevance because it is related to all other brains. My personal existence has no meaning at all if you do not take into account my connections to the other six billion people.

AA: And the six billion people have no meaning without the rest of the organisms that live in them, on them...
and after them. The organism is made up of six billion bodies and minds. It is more than each individual by herself and it is more than six billion people, is something emerging. In the same way that you are more than the sum of the atoms that make you up, your mind is as well, unless you believe that the mind is purely a physical thing. Because only by having a certain configuration of particles plus something—I don’t know what it is—we shift into something called consciousness. The layer I want to add is the culture and the languages that we use to build the relationships between the six billion people.

KO: The complex relationships themselves are what you call consciousness and culture; it is inherent in the swarm system.

AA: Exactly. Quantum theory is incomplete, because quantum theory describes a world at the subatomic level. Then you have relativity theory, Einstein’s theory that describes the world at the super-macro level, and these two theories do not like each other at all. Physics is always trying to find a unifying theory that brings them together. One of the theories that seems to have most luck in unifying them is called the super string theory. The super string theory states that the world is not made of quarks but strings, tiny vibrating strings. Each mode of vibration corresponds to a quark and an electron. So if you imagine that everything in this universe is based on the same element, which is the tiny streaming vibration and it vibrates in any direction with any frequency, these vibrations do not happen only in the dimensions of space and time, but they can unfold in 21 different dimensions. These dimensions that we are not aware of are so small that we can never perceive them, but they are there as a mental construct. It’s difficult for us to understand what the 4th, 5th or 6th dimension could be, because we don’t experience them. That is our limitation. The problem with string theory is that actually there are supposedly 21 dimensions. I think we must take what quantum theory is giving us on a mental level; in other words, we must work with the quantum metaphor. This gives us the inspiration to apply localized models for each project we do. Take it back to the small interaction level, model it, and then learn from the metaphor.

LF: How do you translate your theory into your profession as an architect, as an urban designer? The two of you are both trained as architects dealing with urban spaces and architecture, you both are inspired by natural physics. How do you apply these theories in your practice?

KO: I am only interested in things that work. I am not interested in a theory that describes one thing, and then you do something else. We build tools to see the world in a certain way, and then we work with it, we test it, which is a scientific approach in itself. I tell my students that they may propose anything as long as it works. We work with Virtools, building graphs and writing scripts. If it doesn’t work, you only have the story. The important thing to me is to connect to the world around you and have influence on that world. To me the act of designing is related to tools. The tool can be a pen, a computer, a hammer. I am always amazed by the fact that if I have to do even the smallest practical task, I will use a vast number of tools. I need a table full of tools to do something very simple. Where would I be without these tools? I would be simply thrown back in the Stone Age.

LF: Can I understand architecture as a tool as well?

KO: My favorite position is that there is nothing that can be truthfully framed by the word “architecture.” It’s hard to make a good definition of architecture, much like it’s difficult to create a definition of art. It is more relevant how the construct works for you. We construct interaction between the nodes of the construction. These nodes have a behavior. They have a relation to other nodes. Scripting and real time behavior resonates very much with the quantum worldview.

KO: When you think wave, you see the wave. When you think particles, you see particles. It is extremely important what graphical representation you use to explain your ideas.

AA: Charles Jencks wrote a book in the 1980s called Architecture of the Jumping Universe. His simplified answer to the quantum world is that if we design anything which looks like a wave, it is OK, which is totally opposite of what we are discussing here. To go back to your concept of tools and to answer Lukas’s question of how to relate the theory to the practice, I relate to my profession as an architect and I
If you want to collaborate with someone and share ideas you need to have a common language to be able to exchange views. My Dutch is terrible, my German even worse, and I am sure that your Arabic is not better than my Dutch. We wouldn’t have this conversation if we were not talking in the same common language which is called English. At the same time, our knowledge of English is limited, there are notions you can think of in Dutch, there are notions I can think of in Arabic, that I will never be able to express properly in English. We are talking in terms of nationalities and cultures. But also in terms of architects, urban designers and sociologists. All these are separate disciplines and have separate cultures. Therefore I want to go one level up and create a unifying quantum language.

The question is, can we bring together two ways of thinking, complementary relationships and particular relationships, and develop this relational quantum based thinking? We are in a time in history where potentially the worldview is going to shift away from the western world and is going to move toward a more oriental setting in the next hundred years. I do not want to try to save the western world, because some worldviews will eventually die and other worldviews will naturally take over. What I would like to do is take the best elements of the western culture, and go and meet people from other cultures, and together develop the new world view.

One of the reasons for the success of the Roman Empire was that instead of imposing its system blindly, it was also taking culture in from the environment. And if you go further forward in time, the Islamic empire that lasted from the 7th until the 12th century, settling in places such as Spain, you see that it changed along with the local culture. Scientific research was carried out by the Arabs. Historians seem to forget this bridge between the ancient Greeks and the current western world.

KO: This is what the Chinese and Arabs do today. They come to study in the USA and in Europe, and then they bring back the knowledge to China and the Gulf region and build a strong new culture. China and the Emirates feed on the world.

LF: How do you apply it to your profession, not as an architect who is interested in science, but as a practicing architect and urban designer?

AA: When I went to Oxford to do my master’s degree in a center of education, where most people like me come from other cultures, I realized that there is almost nothing that I had been taught that I could apply where I came from, because so much of what I learned at Oxford centered on a local view of what the city is. And I found out that this local view is not exportable.
Protospace supports design reducing the overall timeframe to increase the quality of design while and performance. Protospace aims the process to a new level of complexity and to bring the entire design different experts in a project team the professional dialogue between experts. The primary of Protospace is to intensify the architectural design into China with a global perspective. The idea is to provide a valuable reference for professional architecture design practice and education development in China and to furnish Chinese architecture students and professionals with rich information on the world’s new architecture culture experience. From France to Italy, from U.S to Spain, Netherlands, Germany, Finland, all the architects are carefully selected with extensive consulting from experts in both U.S. and Chinese architectural education institutes and have gone through rigorous examinations of our advisors. Hyperbody Logic gives an extensive overview of the recent works of Kas Oosterhuis and Ilona Lénárd of ONL with a special emphasis on interactive projects. English and Chinese published AADCU, 2006, 254 pages, Hardcover, ISBN10 7-5434-6164-1, ISBN 13 978-7-5434-6164-2. Visit www.aadcu.org/project2006a/index.htm to find out more.

Protospace, an initiative of Prof. Ir. Kas Oosterhuis, is a development of Hyperbody Research Group at the Delft University of Technology. It is a revolutionary design environment for architecture, urban planning and other disciplines. In 2007, Protospace will become part of the iWeb pavilion, currently being constructed in front of the Faculty of Architecture at the campus of TU Delft. The primary aim of Protospace is to intensify the professional dialogue between different experts in a project team and to bring the entire design process to a new level of complexity and performance. Protospace aims to increase the quality of design while reducing the overall timeframe. Protospace supports design processes by digital means. The system allows experts to use professional software tools while sharing common project data with other design team members. This environment allows all of the experts to work on the group’s design concurrently, each using their own tools. As a result, each of member has a specific view of the project data, related to his/her role. By sharing the project data amongst each other, changes by one expert are immediately visible in all the other experts’ views, thus allowing for the professional dialogue to take place in real-time on the design tool level. This networked system architecture is complemented by an advanced user interface aimed at allowing full freedom of movement and high flexibility.

Protospace is a spatially open environment not obstructed by traditional screens and keyboards. Computers are hidden behind the scenes and the only visible system components are the interface devices. The main displays of Protospace are five large screens and a multi-channel audio system surrounding the work area. A range of wireless devices are available as input devices, with varying characteristics to fulfil specific tasks. Additionally, Protospace is to be equipped with a range of sensors monitoring the activity and environmental factors inside the space. Visit www.protospace bk.tudelft.nl to find out more.

iWEB The spaceship WEB of North-Holland, as designed by Professor Ir. Kas Oosterhuis of design studio ONL [Oosterhuis_Lénárd] in Rotterdam, entered the world stage at the Floriade World Exhibition in 2002. The WEB of North-Holland has been disassembled and renamed the iWEB and has made a soft landing at the Mekelweg in front of the Faculty of Architecture. The iWEB is designed to become a transfaculty server to host Protospace, the augmented design studio for Collaborative Design and Engineering in Real Time. The faculties of Civil Engineering [CiTG], Aerospace [L&R], Management [TBM], Electrical Engineering [ITS] and Industrial Design [IO] have been approached to collaborate with the iWEB_Protospace initiative of the Faculty of Architecture. The CUR, TNO-Bouw, Telematica Institute and parties from the Dutch Building Industry are informed and are open for further collaboration. Visit www.iweb bk.tudelft.nl for more information.

Books ONL Hyperbody Logic. The book series A Global Survey on Digital/ Multi-media/Net Based Arch Design is designated to introducing c ontemporary digital, multi-media and Internet information-based architecture design into China with a global perspective. The idea is to provide a valuable reference for professional architecture design practice and education development in China and to furnish Chinese architecture students and professionals with rich information on the world’s new architecture culture experience. From France to Italy, from U.S to Spain, Netherlands, Germany, Finland, all the architects are carefully selected with extensive consulting from experts in both U.S. and Chinese architectural education institutes and have gone through rigorous examinations of our advisors. Hyperbody Logic gives an extensive overview of the recent works of Kas Oosterhuis and Ilona Lénárd of ONL with a special emphasis on interactive projects. English and Chinese published AADCU, 2006, 254 pages, Hardcover, ISBN10 7-5434-6164-1, ISBN 13 978-7-5434-6164-2. Visit www.aadcu.org/project2006a/index.htm to find out more.

GameSetandMatch II. On Computer Games, Advanced Geometries and Digital Technologies. With the new technical possibilities of worldwide electronic networking and the ubiquitous employment of new media and digital technology in various fields of research and practice, conventional disciplines are gradually dissolving as new transdisciplines develop. Contemporary architecture too resides in a state of transgression that gives rise to new architectural conceptions benefiting from a multitude of influences. This publication brings together the manifold, international and
interdisciplinary contributions to the ‘GameSetandMatch II Conference - The Architecture Co-Laboratory,’ directed by Kas Oosterhuis, Professor at the Faculty of Architecture of the Delft University of Technology, the Netherlands. It addresses contemporary and future changes within and across the boundaries of digitally-driven architectural and design practices. The notion of architecture as a co-laboratory accentuates this strong devotion to experimentation and collaboration. In so doing, this co-laboratory approach offers a kaleidoscopic view of, rather than a defined perspective of current developments in the digital design domain. The authors of the essays and papers included in this book come from diverse backgrounds ranging from architecture and design to technology and engineering as well as computer sciences and humanities. An interlaced series of three thematic areas - ‘Play’, ‘Geometry ++’ and ‘Open Source’ - will relate diverse sources of knowledge and enable the reader to cross reference, question, re-contextualize, and even create new connections among the content presented. This collection of writings serves the generally interested reader as well as the scientific reader and provides a source of discussion to draw inspiration and motivation from.

GameSetandMatch II includes contributions from Robert Aish, Ole Bouman, Raoul Bunschoten, Bernard Cache, Jan Edler and Tim Edler, Georg Flachbart, John Frazer, Mark Goulthorpe, Branko Kolarevic, Anne Nigten, Marcos Novak, Kas Oosterhuis, Antonino Saggio, Katie Salen, Norbert Streitz, Tom Verebes, Peter Weibel and many more. By questioning current and future changes within and across the boundaries of digitally-driven architectural and design practices, the conference brought more than 150 researchers, practitioners and students together from diverse academic and professional backgrounds. The conference’s intense program included 67 lectures and presentations by architects, engineers, artists, designers, game developers, physicists, mathematicians, programmers, IT experts, philosophers and historians coming from 19 countries. Open panel discussions with keynote speakers at the Netherlands Architecture Institute in the evenings offered a forum for the further discussion. Overall, the GameSetandMatch II conference was a great success. It conceptually challenged new possibilities of digitally-enhanced design and architecture and professionally provided a remarkable forum for people involved and interested in this field of research to exchange knowledge. GameSetandMatch II socially established lasting personal relationships amongst the participants. Organizational, the conference was effectively and providently conducted. Visit www.gamesetandmatch.bk.tudelft.nl to find out more.

AWARDS
ONL wins Dutch Design Award 2006 for Hessing Cockpit and Acoustic Barrier. The Hessing Cockpit and Acoustic Barrier project by ONL has been announced the winner of the Dutch Design Awards 2006 in the category ‘Ontwerp Openbare ruimte’ [Public Space]. Visit www.nldp.edc.nl/nederlandsedesignprijzen/winners/?cat=19 to find out more.

ONL wins National Steel Prize 2006 for the Cockpit and Acoustic Barrier. ONL [Oosterhuis_Lénárd] has been awarded the National Steel Prize 2006 in the category ‘Utiliteitsbouw’ for the Cockpit and Acoustic Barrier project. Visit www.bouwenmetstaal.nl/pdf/categorie_A_06.pdf to find out more.

CONFERENCES & EXHIBITIONS
GameSetandMatch II Conference 2006. The international and interdisciplinary GameSetandMatch II conference, directed by Professor Ir. Kas Oosterhuis, organized by the Hyperbody Research Group at the Faculty of Architecture of the Delft University of Technology and the Netherlands Architecture Institute, Rotterdam, from 29th of March until 1st of April 2006.

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ONL / Hyperbody exhibition in Suzhou Creek Warehouse, organized by FAR gallery, Shanghai. From 17th to 25th of June 2006, ONL and the Hyperbody Research Group held an architecture exhibition at the Suzhou Creek Warehouse in Shanghai, organized by FAR Architecture Center Shanghai. This exhibition

DIAF Festival Beijing, May 2006. The Dashanzi International Art Festival [hereafter referred to as DIAF] is a large-scale event held in the Dashanzi Art District and a combined effort of the DIAF organizing committee and the various artistic initiatives around the district. Every year in spring, the DIAF stages a lively dialogue between citizens and contemporary culture through a wide range of events, all taking place in the Dashanzi Art District during one month. The festival integrates sound and visual, movement and stativity of both image and body by using multiple forms of contemporary art: visual art, live music, dance, theater, and performance art along with design presentations and film projections. To serve this objective, DIAF invites artists with different backgrounds and nationalities. Visit www.diaf.org to find out more.

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Emotive City course were challenged to build an interactive installation especially for the GSM II conference. The students came up with an impressive spacious installation using pneumatic Festo muscles, bamboo sticks and motion tracking systems that visitors could enter. Visit www.bambooster.com to view the installation.
configuration, not being specifically propose pro-actively changes in their than that, architectural constructs and load bearing surfaces. But more than that, architectural constructs propose pro-actively changes in their configuration, not being specifically triggered to do so by the designer or the user. The built construct develops an identity of its own, an identity that both the designer and later the user will interact with. Interaction requires two active parties. One party is the designer/user, the other party is the constructed environment itself. Hyperbody invites their BSc and MSc students to look at the world from the point of view of NSA and subsequently from the point of view of RTB. Visit www.bk.tudelft.nl to view examples.

**Excursions**

Excursion China June 2006: Nanjing, Shanghai, Beijing. From the 11th to the 21st of June 2006, Hyperbody organized a trip for 8 students to three cities in China. Prof. Kas Oosterhuis guided the group, with coordinator Hans Hubers and assistant Xin Xia. We visited 5 stars hotels for the “Hotel Design” studio, universities for further cooperation, famous architecture construction sites for the inside view. During this trip, HRG was selected to present in Architectural Biennial Beijing 2006, and a long term cooperation with Southeast University and Tsinghua University started.

Excursion Beijing September 2006. At the end of September 2006 a group of students from the Hyperbody Research Group was packed up and ready to go on an intense journey to Beijing. We left the Netherlands to visit our design project site which was located in the “Art district 798” in Beijing. We went to the Beijing Planning Exhibition Hall (www.bjghzl.com.cn) for an overview of Beijing. This showed the organisation and orientation of the city and how big it really is. Beijing is situated on the meridian going from north, which means Bei (Beijing), to South, which means Nan (Nanjing is an important historical city in the south of China). The main reason for our trip to Beijing, beside visiting the location of our project, was to meet the professor and the students of SouthEast University of Nanjing and Tsinghua University of Beijing. They are also working on the project, but on another part in the area. We went to Tshinghua University to watch a presentation of their design. The following day, we went to the location. We were all very surprised by its difference from the rest of Beijing. We found out that it is a symbolic place for revolutionary thinking and movement. The district was a former factory and has been transformed into a culture haven. We spent a part of the day there to watch architecture and art. Since our experience on the site of 798 was so good, we moved our project to the 751 area, which was next to the 798, but less developed and still in a not liveable state. This way it was more realistic for our project and design, although it will not be realised. For all of us, China was a great experience. Some were shocked, some were disgusted, some were impressed, and some were really sad to leave. For several of us, this might have been the first, last and only travel to China and for others, it became clear that this was the first of many trips. We learned about the culture, the politics, the history, the new developments, the food, the traffic, the fake markets, and so much more. It is easier to understand this nation, after having seen what living there is like or at least what visiting there is like. [Excerpts from a report Nora Schüler and Marije van der Laag]
Cas Aalbers (The Netherlands)
Cas Aalbers graduated from the Rotterdam Academy of Architecture and Urban Design as an architect, and he worked at ONL in Rotterdam.

Ayssar Arida (Lebanon)
Ayssar Arida is an urban designer (MA with Distinction, JCUD Oxford Brookes), architect (BArch., American University of Beirut), writer and entrepreneur. Since 2002, he has been the director of the award winning cross-disciplinary consultancy Q-DAR (www.q-dar.com). Based in London, he consults and lectures internationally. His first book, Quantum City (Architectural Press, 2002), addresses the chaotic urbanity that is currently influencing urban design, education and practice worldwide. A follow-up to Quantum City titled Quantum Environments: Architecture in the New Paradigm is currently in production. Two co-authored books are forthcoming: New Urbanism and Beyond (Rizzoli, Tigran Hasic ed., 2008) and The Design Dictionary (Birkhauser, Tim Marshall and Michael Erlhoff eds., 2007). Ayssar’s research focuses on developing relational languages informed by the new sciences (quantum theory, emergence and self-regulation, complexity and fuzzy logic), to analyze and design the urban realm. He has taught at the American University of Beirut, lectured and published internationally on the subject of organic and postwar urbanism and the relationship between science, worldviews and the city. He is the co-founder of the Centre for the Spatial Realm, which aims to raise public awareness of urban space through science and art. Ayssar Arida is available for talks or project commissions, or any discussion, and can be contacted by email at ayssar@quantumcity.com, or through the websites quantumcity.com and q-dar.com.

Henriette Bier (Germany)
After graduating in architecture (1998) from the University of Karlsruhe in Germany, Henriette Bier has worked with Morphosis (1999-2001) on internationally relevant projects in the US and Europe. She has taught computer-based architectural design (2002-2003) at universities in Austria, Germany and the Netherlands. Recently, she began doctoral research at TU Delft (2004). Her research focuses not only on analysis and critical assessment of digital technologies in architecture, but also reflects evaluation and classification of digitally-driven architectures through procedural and object-oriented studies. It defines methodologies of digital design, which incorporate (Intelligent) Computer Based Systems proposing development of prototypical tools to support the design process. Results of her research have been published in books, journals and conference proceedings. She regularly leads workshops at universities in Germany, Italy and Belgium, and teaches at design studios within the Hyperbody Research Group and SpaceLab at TU Delft. Currently, she is project coordinator of the workshop and lecture series on Digital Design and Fabrication within DSD (Delft School for Design).

Nimish Biloria (India)
Nimish Biloria is an architect/designer from India. After completing his undergraduate education (BArch. with honours) at The Centre for Environmental Planning and Technology (CEPT) in Ahmedabad, India, he completed his graduate education (M Arch) at the Architectural Association, London, where he specialized in the field of Emergent Technologies and Design. He is currently working on a PhD at the TU Delft, Netherlands, with a focus on developing real time responsive/adaptive corporate office environments. He has also been associated with the Hyperbody Research Group (HRG) at TU Delft as a design tutor for the past three years. His research deals with attaining a synergistic merger of the fields of control systems, electronic media, computational design, kinetics and architectural design. Nimish Biloria continues his experiments that deal with the idea of interconnections and interdependence that formulate a relational network for the generation of performative morphologies.

Michael Bittermann (Germany)
Michael Bittermann graduated cum laude from TU Delft as an architect. He studied architecture at the University of Applied Sciences Stuttgart, École d’Architecture Bordeaux and Delft University of Technology. During the course of his studies, he worked on virtual reality applications for architectural design at the Hyperbody Research Group at Delft University of Technology. His master’s thesis dealt with information visualization in virtual reality. During his studies he was employed as an intern in the architecture firms 1100 Architects in New York and ONL in Rotterdam. Currently, he is PhD student at Delft University of Technology in the chair of Design Informatics at the Building Technology department. His PhD research deals with advanced computational methods applied to architectural design for design enhancement. In particular, he is interested in modeling visual perception, knowledge-based design assessment, and solution identification in problems that involve multiple and conflicting criteria. The methods he applies to accomplish these tasks belong to the domain of computational intelligence.

Sven Blokker (The Netherlands)
Sven Blokker has been working as student tutor in the Bsc. course of the Hyperbody Research Group (HRG), TU Delft, Netherlands. Earlier, he worked as an intern for ONL under Kas Oosterhuis and Ilona Lénárd, where he mainly focused on the MUSCLE project. For ONL, he also worked on the Virtual...
Operation Room (VOR), exploring the spatial qualities of L-growth algorithms in the format of a computer game. VOR was on display at the Techniek Museum in Delft. He is currently in the process of finishing his graduate education (M Arch.) at the Department of Interiors, Faculty of Architecture, TU Delft.

Sander Boer (The Netherlands)
An architect/designer born in the Netherlands, attained his graduate education (M Sc) at the Eindhoven University of Technology, where he specialized in the field of Design. He is currently involved as an architect at Mecanoo architects in Delft, Netherlands. He has also worked for ONL architects in Rotterdam, Netherlands, where he was involved in the development of the file to factory process that was used for the erection of both the Web of North Holland pavilion and the Hessing Cockpit.

Lukas Feireiss (Germany)
Lukas Feireiss is a philosopher, cultural scientist and curator born in Germany. He completed his graduate education in Religious Studies, Ethnology and Philosophy at the Free University in Berlin, Germany and at the University of Rome ‘La Sapienza’, Italy. He specialized in the dynamic relationship between architecture and other fields of knowledge, specifically theoretical linguistics and religious philosophy. He is currently working on his PhD at the FU Berlin, Germany, with a focus on the historical context, philosophical origins and architectural legacy of performative concepts in the contemporary debate. He has been working with the Hyperbody Research Group (HRG), at TU Delft in the Netherlands, as project manager of the GameSetandMatch II Conference (2006) and as Literature & Media tutor. He is currently teaching in a postgraduate Masters of Arts and Architecture program at the Academy of Arts in Nuremburg, Germany. As project manager for international projects such as the German Pavilion, 10, the International Architecture Biennial Venice 2006 and an upcoming exhibition of Coop Himmelb(l)au, Museum for Applied Arts (MAK), Vienna, Austria, Lukas Feireiss is deeply involved in the interdisciplinary discussion and mediation of architecture on an academic as well as a professional level.

Christian Friedrich (Germany)
Christian Friedrich was born in Germany. After studying Physics and Philosophy in Berlin and completing an architectural engineering degree at Hanzehogeschool Groningen, he finished his graduate education (MSc) in architecture at Delft University of Technology, Netherlands. He is the co-founder of the media artist collective Eztheses. He has been associated with the Hyperbody Research Group for four years, as student assistant, master student and researcher. His work with the HRG includes teaching Virtools courses, conference lectures and developing the ProtoSpace group design environment. During the last four years, he was involved in several projects of the architectural office of Kas Oosterhuis and Ilona Lenard, ONL. He is currently developing his PhD research project in which he intends to describe and actualize the architectural singularity: a point at which the architectural process loop is executed in real-time and shifts from a phased process into a behavioral network, in effect reshaping architectural praxis.

Hans Hubers (The Netherlands)
Hans Hubers is an assistant professor, building engineer and coordinator of the Hyperbody Research Group of Delft University of Technology. He specializes in CAD and multimedia. Prior to joining the HRG, Hans was managing director at Hubers Multimedia Delft and before that, he was managing the Union of Computer Using Architects with 200 of the largest architectural offices in the Netherlands. For the past two years, Hans has been working on his PhD Collaborative Architectural Design in Virtual Reality. He has become a specialist in programming real-time 3D design environments with database connections over the Internet.

Hyperbody Research Group (The Netherlands)
Directed by Prof. Kas Oosterhuis, the HRG aims its research at excellent design of e-motive and interactive non-standard architecture. (‘Non-standard’ architecture as opposed to the standard mass production architecture.) It is based on the mass-customisation concept achieved through advanced ICT driven design methods and file to factory production. Kas Oosterhuis, who contributed much to this paradigm shift in architecture, adds to this shift a second one, e-motive and interactive architecture in the form of hyperbodies. Hyperbodies are pro-active buildings acting in a changing environment. It is a complex paradigm, involving research in the fields of kinetic structures, human-machine interfaces, parametric design and free form architecture. This goal, and the work, are too much knowledge for one person to handle. This is a reason for collaborative design and one of the reasons to start the iWEB/Protospace project. The realization of the hyperbody concept is studied in the HRG’s MUSCLE projects. HRG has twenty collaborators (12 fte), five of whom are PhD students.

Tomasz Jaskiewicz (Poland)
Tomas Jaskiewicz is an architect and urban designer from Poland. He graduated as an architect, with a specialisation in urbanism, at the Technical University of Gdansk. He obtained his master’s of science degree in architecture at the Delft University of Technology. His working experience includes projects with bAR architects and Prof. Jacek Krenz design studio. Since 2001, he has been in close cooperation with diaade, and ar+di, a dialogic design research lab in Gdansk. In 2003, he joined the Hyperbody Research Group at TU Delft, first as a student assistant, and eventually as an associate researcher. In January 2007, he started a PhD thesis, which he has titled ‘Complex Systems in Interactive Architecture’. Since 2005, he has been working as an architect and project manager with ONL [Oosterhuis_Lénárd].
Kas Oosterhuis (The Netherlands)

Born in 1951 in Amersfoort, Kas Oosterhuis studied architecture at the Delft University of Technology. Afterwards, he taught as unit master at the AA in London. From there, he worked and lived one year in the former studio of Theo van Doesburg in Paris, together with visual artist Ilona Lénárd. In 1989, he founded Kas Oosterhuis Architekten in Rotterdam (renamed into ONL [Oosterhuis_Lénárd] in 2004). Since 2000, Oosterhuis has been professor of digital design methods at the Delft University of Technology and is a Member of the Board of Museum Witte De With in Rotterdam. Award winning building designs include the Saltwaterpavilion at Neeltje Jans (Gold Award 1997 for innovative recreational projects, Zeeuwse Architectuurprijs 1998), the Garbagetransferstation Elhorst/Vloedbelt in Zenderen (Business Week / Architectural Record Award 1998, OCE-BNA Award for Industrial Architecture 1996, Aluminium Design Award 1997) and the Hessing Cockpit in Acoustic Barrier in Utrecht (National Steel Award 2006, Glass Award 2006, Dutch Design Award for Public Space 2006).

Dominik Otto (Germany)

Born in Leipzig, Germany, Dominik Otto began his study of architecture at the TU Dresden in 1997. In 2000, he moved to the Netherlands to continue his studies at the TU Delft.

In his master’s thesis at the emotive architecture lab, chaired by Prof. Kas Oosterhuis, he investigated the possible interactions of a built environment with the surrounding and human emotions within it. That resulted in the set up of an office complex, in which the employees’ emotions were measured, processed and finally visualized to influence and alter the appearance of their workplace. When living for one year in Barcelona, he came across the concept of ‘Papabubble’. In 2005, he opened a branch of this candy store in Amsterdam, which was at the same time his first ‘architecture project’ to be realized.

Dimitris Theocharoudis (Greece)

Dimitris Theocharoudis is a student at the School of Technology, Faculty of Architecture of Aristotle University of Thessaloniki. He is participating in the Erasmus/Socrates exchange program at the Faculty of Architecture of Delft University of Technology. In the course of this exchange program, he came in contact with advanced information technologies used for architectural design. He attended there the master’s course in Emotive Architecture under the supervision of Prof. Kas Oosterhuis. He is currently working on his research essay and diploma thesis focused on interactive design and representation of architecture using digital means.

Xin Xia (China)

Xin Xia is from Nanjing, China. She studied at the Nanjing Arts Institute for Decorative Art Design. In 2000, she moved to the Netherlands for postgraduate studies, where she completed master’s degrees at both the Dutch Art Institute (Visual Art) and Amsterdam University (Film and Television Studies). Her practice was mainly in painting and installation. Her research was focused on Cognitive Film Theory and Contemporary Video Art Installations. She is currently working as a researcher in Hyperbody Research Group, and as a Director Assistant at ONL [Oosterhuis_Lénárd]. She is also working on conference and excursion organizing, book editing and publicity.