Virtual Pace
Digital-Material Hybrids and their Designed Temporalities
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The architectural craft has always traded on the poetic boundaries between idea and materiality, bridged by inventive media, representational devices, projective construction, built dreams, immersive experiences. The term virtual reality however is misleading in multiple ways. It is commonly associated with dark caves surrounded by projection screens, clumsy helmets containing nauseating head-on displays, computer gaming and generally with the establishment of escapist alternative realities a la Second Life or The Matrix. When used to describe such digitally created immersive worlds, virtual is used in a merely metaphorical sense. It dilutes the concept of the virtual itself, in regard to any of its original theoretical conceptions. It does establish a binary opposition of virtual and real, while it can be argued that the virtual reality is not unreal, as all the electrons and photons and algorithms encoded in digital states of circuitry are unarguably real, as is our experience of the virtual worlds. It is as real as the reflection of trees in a pond, which belongs to the characteristics of the constituents of the natural environment and is a part of the natural phenomena we perceive and by which we understand the natural world.

As can easily be derived, virtual reality is never detached from reality, but always embedded in it, in the most profane case by a mouse, a keyboard, a computer screen and speakers as mediating material devices. Yet even the distinction between these devices amongst each other, our bodies, and to what else is connected from other locations, becomes dissolved in the immersive experience not only as we navigate the rendered foggy hallways of computer games but in our daily lives as well. The boundaries become blurred, the transitions between digital and material constituents of reality are multiple and ubiquitous, placing the architectural trade at everyman’s hands yet requiring skills even architects have not yet become accustomed to.

In this article, research and developments in these digital-material hybrid situations, which always involve ‘virtual reality’ as understood in the commonplace sense, will be discussed. At the hand of projects developed at Hyperbody, the various kinds of boundary conditions and transgressions will pass by, in the form of immersive environment, interactive building constructs, designs for hybrid environments, fabrication experiments.

While always superimposed upon each other, as are our own bodies and minds, material and digital reality do follow each their own contingent laws and rules, and so do the various forms of hybridization. For this reason, the laws of digital environments will be approached, from the perspective of design tooling, realizing interactive architectures, and fabricating. An aspect of the design of virtual reality which is often dismissed or circumvented is temporality. This may as a matter of fact be a malaise of the modality of academic exchange; an article and neither illustrations do possess temporal dimension, so they are only fit for philosophical reflection or laborious description of what actually is happening over time. It is similar to in sport or computer games, a description of players, rules and spaces is not sufficient to constitute for the experience of playing or even watching. And furthermore, while a such a description does not easily lead to comprehension of the character of a game, actual participation in the game itself will result in intuitive and immediate hands-on knowledge. Still the topic of temporality has to be approached, as a characteristic of digital environments which is definitively setting them apart from other media that may possess a part of the temporal complexity, fluidity or associativity but never the full set of possibilities digital environments offer.
1 Digital-Material Hybrids

1.1 Hyperbody

The still common notion of virtual reality as separate worlds detached from the inhabitable material world does not hold. Virtual mediation is not opposed to the material world but rather a way of inhabiting the built environment, resulting in a digital-material hybrids. These hybrids are no substitute for the material world but do revise it, changing our notions of space, time and perception in radical ways. Marcos Novak’s explorations of transArchitecture, which stem from his earlier investigations of liquid architecture, are original forerunners to this research. According to Novak, ‘transArchitecture attempts to mend the rupture between knowledge and architectonic exploration. It brings knowledge that has been put on standing-reserve back into the realm of poietic experience. transArchitecture […] has a twofold character: within cyberspace is exists as liquid architecture that is transmitted across the global information networks; within physical space it exists as an invisible electronic double superimposed on our material world.’ (1995)

The projects presented in this article are developed by the author and colleagues working under direction of Kas Oosterhuis at Hyperbody, a unit at the Faculty of Architecture at Delft University of Technology. Kas Oosterhuis (2002, p. 38-52) defines ‘A Hyperbody is a programmable building body that changes its shape and content in real-time’. In design and realizations of such constructs, Hyperbody follows the agenda of Swarm architecture. In Swarm Architecture as brought forward by Kas Oosterhuis, ‘the essential components of every building construct, is a swarm of reference points, which are in the process of building relations with each other. … I do consider the development of any building construct – from furniture to the city – as an informed swarm of relatively stupid reference points behaving in real time’ (2006, p. 14-28). A building is thus seen as an assembly made of interconnected, communicating and dynamic components, a swarm interacting with context, environment and inhabitants. It is important to notice that this swarm paradigm can actually be realized in material constructs with the application of building-embedded ubiquitous computing, sensors, actuators and media. Hyperbody has realized a series of projects merging digital and material environments.

1.2 Virtual Reality Operation Room

The Virtual Reality Operation Room (VROR) (Oosterhuis, 2003) was developed by Hyperbody for an exhibition of the Delft Museum of Technology. It is a transfer of the principles of collaborative interactive design environments towards a futuristic environment for surgeons to operate in. It consists of four virtual worlds, the first representing the VROR itself, and three immersive presentations of organs of the human body for use by different medical specialists. The behavior of the organs is modeled according to the principles found in natural organ growth and function. Medical specialists are immersed virtual representations the body of the patient, directly influencing the operation and fighting causes of disease. Travel between the organ-worlds takes place via the connective VROR itself, which is modeled the swarm architecture paradigm as virtual-real hybrid. As a projection of current developments in medical technology, the VROR exhibit is a merely representational experience, a visualization of a medical vision. Yet is finally intended to be merging the immersive augmented experience of the surgeon with the action of advanced organ scanning and non-intrusive operating techniques on micro- and nano-scale.

1 Hyperbody, Faculty of Architecture, Delft University of Technology. http://www.hyperbody.nl
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 environmental influences, applying a set of several simple rules. Out of the interrelated behaviors 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 evolutionary development of an ideal form in successive generations; the swarm evolves and adapts to changing influences in real-time, continuously adapting its goals and attractors.

Figure 1. VROR swarming membrane, immersive innerspace, growing brain tissue (Christian Friedrich, Michael Bitterman, Sven Blokker)

The self-organizing characteristics of the swarm are of great value to the efficient transmission of forces, energy and information, but the swarm also is an unpredictable, uncontrollable being. Out of it continually new structures emerge, 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.
1.3 ProtoSpace

Initiated by Kas Oosterhuis and realized by Hyperbody and ONL, ProtoSpace (Oosterhuis et al., 2008, p. 37-46) is a collaborative design environment supported by virtual reality projections, multimodal ambient interfaces. In this dynamic space the team of designers uses handheld devices, which allow them to move freely in space and interact with each other in an unobstructed, haptic manner.

In this setting, the design team assembles for rapid design sessions. They have the possibility to connect the specialist models present in their professional software packages with each other in real-time. Also, they can apply custom-made design tools to explore design solutions in early design phases.

Architectural design processes are ruled by conceptual design decisions. They require freedom to jump between and explore alternatives not only in content but also in method at any given time. Even more so than in collaborative engineering, architectural design thus requires for a highly flexible environment, since the design process itself might be subject to change and will have to be permanently adapted. ProtoSpace, in the first place, is a mode of operation not bound to a specific place, which allows for such adaptations.

The ProtoSpace approach is technically and spatially facilitated by the physical ProtoSpace environment (Oosterhuis et al., 2007, p. 1-10), which has been installed and tested in the iWeb at TU Delft in spring 2007. The physical ProtoSpace environment is a spatially open environment not obstructed by office desks and desktop computers, providing a space suitable for teamwork. PC workstations are hidden behind the scenes and the only visible system components are the interface devices. The main displays of ProtoSpace are five large projection screens and a multi-channel audio system surrounding the work area. A range of wireless devices is available as input devices, with varying characteristics to fulfil specific tasks, complemented by a range of sensors monitoring the activity and environmental factors inside the space. In ProtoSpace large screens replace small computer displays and the workspace remains open giving its users an optimal freedom of movement. Wireless controllers and motion tracking technologies replace desktop input devices like the keyboard and mouse. These custom interfaces aim at giving the users the most natural and unconstrained controls over the system.
1.4 Muscle Projects

Behavioral digital design tools provide malleable, fluid worlds for developing and evolving models in a flow of dynamic interactions. These dynamic interactions however often seize to exist as soon as the fluid digital models are to be built. In Interactive architecture they are continued in real-time in the realized buildings. Such buildings are designed as a holistic interactive population forming a performative architectural environment which can adapt over time. While such constructs at first glance may seem futuristic and in need of not yet invented materials, it does not take much knowledge or very advanced materials to realize such building constructs, as Hyperbody has proven repeatedly in the 10-weeks bachelor course. In this series of projects, pneumatic industrial actuators developed by FESTO are integrated in the building structure as dynamic tension elements. Their behavior comes forth from internal rules of the structure and is informed by visitors, which trigger by their presence, location and movements proximity sensors, motion-tracking cameras and touch sensors.

![Figure 3. Hyperbody BCs6 Muscle Projects (Hyperbody)](image)

Here behavioral design environments prove to be of additional value, as they can be used to not only design but also to control and form the behavior of the dynamic construct. Coupled with the material construct, fed by parameters received from sensors and giving output in the kinetic and media behavior of the construct, they become part of a digital-material hybrid in which the design action continues in the perpetual adaptations taking place in use of the building.

1.5 Digital Pavilion

In 2006, architectural office ONL of Kas Oosterhuis and Ilona Lenard was invited to propose an interior design for a Digital Pavilion at the core of the Digital City, near Seoul, Korea (Oosterhuis et al., 2007, p. 1-10). The proposal of ONL came forth as an ambitious and groundbreaking initiative to mix in unprecedented ways real-life, augmented reality and online experience in a state-of-the art architectural design. The scenario is extrapolated from technology employed by ONL and developed by its research partner, Hyperbody at Delft University of Technology. The Digital Pavilion, a building as living installation, is designed to provide a great opportunity for the South-Korean high-tech industry to present its global significance.

Digital pavilion goes beyond the common conception of “intelligent environments”, which often merely consist of distributed of artifacts with intelligent behavior. In Digital Pavilion project, these artifacts are bound by unifying principles and converge towards a new kind of architecture which contains integrated intelligent technologies in its conception, construction, maintenance and interactive engagement with its occupants.
Digital Pavilion’s geometry is based on the same, unifying principles on each level, principles which support the immediate generation of structure and relationships from point-clouds informed by the stakeholders and users. This feature is used in the collaborative investigation for a coherent design on the exhibition level, with the spatial structure acting as mediator between the various exhibitors and their individual demands, and on the interactive levels as means of assigning dynamic relationships in a topologically adaptive space.

Digital Pavilion is conceived as complex adaptive robotic system of interacting installations. Visitors are individually identified using RFID tracking and build up their unique profiles as they navigate through the floors of the pavilion. Each visit will be a unique experience, since the installation will never repeat its exact shape and content, which is continually adapted in real-time in coordination with the movements of the visitors and the streaming content. Visitors interact with the installations using a handheld device.

For achieving this behavior, several techniques which have proven their value in previous ONL and Hyperbody projects are applied. The structure achieves its kinetic behavior with the use of industrial actuation technology, as commonly found in industrial automation. These linear actuators are to be embedded in the edges of the spatial cell structure.

Digital Pavilion showcases with architectural means the impact of digital technologies on our lives. This theme is elaborated specifically for each level of the pavilion, fit for the various usage demands given by the consortium: on the Level Zero as a Hub and portal to other worlds, on Level One as exhibition area which supported by digital technologies can be reconfigured with the use of rapidly prototyped structural components according to the demands of its stakeholders, on Level two as an augmented interaction zone where material and physical environment are superimposed on one another.
2 Virtual Pace

Prior discussions on temporality in architecture mostly refer either short-lived buildings, or the experience and appropriation of static built structures by users. Temporality is also factually considered when sustainability is addressed and the lifetime and lifecycles of building materials, components and building uses are taken into account (Leupen, 2005). Real-time interactive architecture however enables buildings to act dynamically and brings the speed of change in buildings down to split-seconds. Adaptations become an essential part of user experience, and the building a pro-active environment persuading users into interaction. As Novak explains, transarchitectures ‘lead to the re-problematization of time as an active element of architecture at the scale of the cognitive and the musical, not just the historic, political or economic event’ (1996).

Complex architectural time is to be understood as the time taken by a time-based architectural system, as its space is the space which it takes. This kind of organization provides the architectural time and space with definitive specific properties. Space in architecture is organized as the filling of a certain volume with as system walls, stairs, doors, aisles etc. These introduced elements create a system of separation and connections, enclosures and exclusions, turning the real shortest way between two points from a straight line into a broken one or, in general case, into a fractal or a curve. As spatial organization is thus a system of barriers, similarly temporal organization has constraints or hard barriers (Mikhailovsky, 1995). Temporal barriers in interactive architecture are given by the characteristics of both material and digital artefacts, the speed and frequency with which they can adapt, whether their operations are reversible, and whether they can act simultaneously or have to share space and time as limited resources in a concurrent manner.

Architects have to consider in their temporal design the organization of manifold interlinked processes which are unfolding over time and at different timescales. Interactive media developers have applied a series of chrono-tools which could aid in this process. The timeline, derived from video editing, acts as absolute measure for placing events in temporal duration. Flowcharts on the other hand define the order of sequences of events, without any notion of duration. In computational music, tools for handling ongoing real-time streams by means of filtering are applied. Advanced game authoring tools allow for sketching as well as for applying behavior in temporal extension and sequence, as they are made for creation of immersive experiences. Yet, it is up to architects to develop and apply their own methods and tools which are suited to elaborate complex time scenarios in architecture.

2.1 Design tools

Virtual space is often thought to be spaces where everything is possible, yet they are bound to laws of their own. Certain actions which tend to be very laborious in the material world, for example copying an object millions of times, may be realized effortless in virtual space. Many operations however are however very difficult to achieve, especially to mimic the material world, as the budget of any Hollywood movie employing digital effects does show. For the realization of digital-material hybrids, modes of operation have to be found to operate between both sets of laws, which not only organize digital models and material construction in space but also determine how they can unfold over time.
Developments in architectural design media have challenged architects to revisit the design process, towards an increasingly non-linear, networked, algorithmic endeavor, eventually incorporating real-time, collaborative design interactions. The earliest kind of design media are absorbent media, for example pen and paper or clay. They absorb the manipulations of the designer who can read back the effect and development of the design action. These media have each their own material logic which sets the mode of design exploration. For example, in sketching the design act is constrained by the need to recognize the lines as representation of a three-dimensional object of certain proportions, hence only forms which can be comprehended from a fixed point of view can be effectively sketched. Clay modeling is constrained and guided by granularity and cohesion. Absorbent media act purely as reflective devices; all input is absorbed by the medium by cannot be actively transferred by it, in a sense all input is lost and has to be read back by means of copying, scanning, re-sketching, in order to serve as guide for reformulation on another level. Next to the material logic of each absorbent medium, which can act as design guidance, absorbent media are very direct to work with, showing up immediately the applied changes. They allow the designer to enter a state of flow, similar to playing a musical instrument, in which the design intention can be tested against possibilities of formulation. This kind of exploration may help the designer to become more aware of the task in a reflective manner and to explore design possibilities within the material logics of the chosen medium.

Early digital design media often mimic material absorbent media as reflective one-way input devices, but generally lack the immediacy of input as they force the designer to follow a restrictive mode of input modalities and operations. Applications as AutoCAD are mimicking the drawing table, and the drawing entities defined by the designer are originally meant to end up in a printed plan, even though the tools allows to digitally exchange the information, quickly create different versions and make multiple prints with little effort.

Algorithmic tools offer a very different mode of design exploration. They are script-based and have a clear distinction between script editing and run-time, where the first allow the designer to formulate pre-conceived rules of design formulation and the second in the classic case no interaction until the script has run completely.

The possibility of running the algorithm again with different parameters at demand makes it a reactive medium, entering the realm of parametric design tools. Parametric design tools generally only update the design model in reaction to user input, completely regenerating the model based on the new parameters. In this way, they work as algorithmic tools which compute fast enough to give a split-second update and provide an interface for applying multiple interconnected operations in a visual manner. Recent examples favored by architects are the Grasshopper plug-in for Rhino3D and Generative Components which runs on Microstation. With parametric design tools we enter the realm of interactive media, which include a feedback loop fast enough to let the user experience the relation between input and outcome and to establish an interaction which allows for flow-states to occur.
A further evolutional step of digital design tools leads to behavioral media, as developed by Hyperbody on the basis of the game authoring platform Virtools. These are continuously, iteratively computing the effect of design rules applied to the model, in an ongoing stride to optimize according to the set of rules formulated and used by the designer. These tools offer the most direct mode of interaction, and let the designer interfere even during the optimization process. The result is a tool which lets the designer develop a haptic sense for the behavior of design models, which can be seen as computer-generated equivalent of material logics. The possibility for formulation of these logics together with the immediate feedback do enhance the designer’s facilities to develop design awareness. This can even be furthered by the possibility of digital tools to accurately handle spatial computation and giving specific visualizations of the ongoing process and spatial setup.

There is another aspect to the way in which behavioral design tools challenge prior digital media. Each behavior is running as distinct continuous process, fed by both the user and the other running processes. It is up to the designer to define when or under which circumstances the processes run, whether they are working sequentially or simultaneously. One solution preferred by Hyperbody are swarm design applications, and related techniques as particle spring systems. These allow to freely experimenting with spatial layouts, while the given constraints are met by the application and unforeseen design alternatives may emerge. An example of a generic system for expressing design concepts as behavioural networks objects are scripted BehaviourLinks (Friedrich, 2003), a design tool where objects with typifiable properties can be linked. A BehaviourLink is a piece of programming code that is executed in real-time and defines interactions between conceptual entities, by manipulating data contained in one entity based on data contained in another entity. The nature of these manipulations is dependent on the type of link chosen by the user. The conceptual entities can represent architectural concepts but also digital interfaces to sensors, users and exchange data.

By defining conceptual nodes and laying BehaviourLinks (Friedrich, 2003), users can grow a parametric diagram of the urban plan. Its shape, structure and visualization originate from the behavioral design rules and decisions made by the users as well as the feedback negotiation between interacting nodes. The interactive diagram lets a group of stakeholders make fast and well-informed urban design decisions.

In BehaviourLinks :: Urban Mode, all data is subject to real-time interactive, iterative adaptation by the behavioral links the user laid between entities. Functional extensions of BehaviourLinks consist of node typifications, which can be affected by additional link types. For BehaviourLinks :: Urban Mode, extensions have been implemented that let the users simultaneously explore how the program of demands, volumetric plan, traffic models, parametric spatial relationships, shadow volumes, facade styles, plan boundaries and urban data affect each other, with direct visual feedback and embedded media of the actual site.
Examples for behavioral design tools are SmartVolumes (Friedrich, 2007, p. 132-142) and SpaceGraphs. These tools maintain an awareness of spatial depth, which means they do actively create a topological map spatial relations between objects as points, lines and surfaces, and the spatial partitions and volumes they establish, and provide them as basis for refining form and structure of a design. Based on point cloud formations, from the real-time updated complete topological mapping of the space layout, subsets can be filtered to function as reference for the construction of building geometry. All these operations, from the behavioral shaping of point clouds, to the mapping of topologies, the filtering of topology subsets and to the construction of geometry, can be applied in real-time, simultaneously or partially constrained. The result is a tool set which allows for multi-directional design exploration of actual deep space, instead of modeling with and on boundary surfaces only. The possibility for interaction with real-time feedback, intentional application of temporal constraints, and concurrent operations let the designer engage in a design process of high temporal density and complexity. Spacegraphs and SmartVolumes maintain descriptions of spatial relationships of generated, actuated or sensed sets of elements, which facilitate generation of aware informational or material structures. As such they are a generic tool for architectural design exploration and to inform the behavior of interactive environments.

2.2 Immediate Architecture

‘Immediate Architectures’ takes the temporal convergence of design, fabrication and usage phases a step further: is an exploratory investigation into possibilities of immediate constructive interaction with the built environment supported by digital technologies. Aim is to realize interactive reconfigurable architectural objects that support their informational and material reconfiguration in real-time. The outcome is intended to become a synergetic amalgam of interactive architecture, parametric design environment, automated component fabrication and assembly. These are to be supported by computational and material strategies that are developed approach the state of immediate architecture and applied in real-world prototypes.

Multi-linearity in architectural design processes and in the encounters with interactive environments is a major theme of the contemporary discourse on digital architecture. The next step and include production and reconfiguration, to reach a process where the building is not just informed by emergent processes but in its entirety is undergoing an open-ended emergent process. Immediate Architecture is, by virtue of collapsing the phased timeline of the architectural process into a singularity in time, a radical challenge to conventional notions of architecture.
Figure 6. Examples for behavioral design tools are SmartVolumes (Friedrich, 2007, p. 132-142) and SpaceGraphs. These tools maintain an awareness of spatial depth, which means they do actively create a topological map of spatial relations between objects as points, lines, and surfaces, and the spatial partitions and volumes they establish, and provide them as a basis for refining the form and structure of a design. Based on point cloud formations, from the real-time updated complete topological mapping of the space layout, subsets can be filtered to function as a reference for the construction of building geometry. All these operations, from the behavioral shaping of point clouds, to the mapping of topologies, the filtering of topology subsets and to the construction of geometry, can be applied in real-time, simultaneously or partially constrained. The result is a tool set which allows for multi-directional design exploration of actual deep space, instead of modeling with and on boundary surfaces only. The possibility for interaction with real-time feedback, intentional application of temporal constraints, and concurrent operations let the designer engage in a design process of high temporal density and complexity. Spacegraphs and SmartVolumes maintain descriptions of spatial relationships of generated, actuated, or sensed sets of elements, which facilitate the generation of aware informational or material structures. As such they are a generic tool for architectural design exploration and to inform the behavior of interactive environments.

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Figure 7. Developed as a design and fabrication toolbox, the Streaming Fabrication technique acts as a device for linking spatial experience immediately to action, design and to production.

The digital design and fabrication toolbox then is used as device for linking spatial experience immediately to action to design to production. Digital design environments and fabrication devices then are applied for orchestrating in real-time concurrent, simultaneous operations of usage, design, planning, fabrication, construction. In this combination of interactive architectures and digital design environments with computer-controlled production techniques, the designer’s dialogue with the built environment may reach an unprecedented state of immediacy. To this goal, a series of techniques are developed providing a tool framework for handling real-time architecture throughout the mentioned fields. The techniques do not divide the design and construction process in phases, are orchestrating a state of now, which can be directed by designers as well as users.
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References


