Information-matter hybrids

Prototypes engaging immediacy as architectural quality

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Abstract

'Immediate Architecture' is an exploratory investigation into possibilities of immediate interactive and 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. To this end, computational and material strategies are developed to approach the condition of immediate architecture and applied in real-world prototypes. A series of developed techniques are presented, ranging from real-time volumetric modeling, behavioral programming and meta-application protocol to streaming fabrication and dynamic components for interactive architecture.

1. Introduction

The mass transition from analogue to digital media, the digital revolution, took place a decade ago. In contemporary architectural praxis, as in everyday life, digital technology has become ubiquitous; we participate in the ongoing evolution of the digital tools and devices which are now part of our environment.

Digital media radically changed the relation between information and the material carriers used for its communication and storage, in effect changing how we situate both informational and material artifacts. The multimodal interfaces between the informational and the material domain provided by digital technologies do introduce more flexible superpositions of one onto the other, in adaptive, addressable manners. Information can be wirelessly communicated around the globe in an instance, stored in various media, processed in ubiquitous devices be affected by and written back as streams of light , sound, energy or into the material environment. Users can route how sensory data gathered from the environment shall be interpreted, processed, communicated and controlling fabrication tools which mold and forge materials by heat, laser beam, drills, band-saws and printers.

Since architecture is all about informing the material formation of our built environment, applications of computational techniques already have radically affected architectural practice. In the design phase, successive generations of parametric design applications, intelligent computing techniques, and scripting environments make tools for handling design complexity more accessible to the architectural profession. Collaborative environments facilitate exchange of information between partners in the building process. Non-standard production techniques allow file-to-factory production of mass-customized building elements. Interactive, kinetic architectures preserve a part of the fluidity of the parametric model, the adaptation of which becomes an open-ended conversation between users and acting buildings.

Digital technologies put higher performance at the hand of designers. They offer an extensible, shared medium for creating and realizing higher complexity designs with higher precision at higher speeds in economically feasible manners. Digital technologies start to integrate the design process and the built environment. Digital media can sense the built environment, be involved in the material construction, compute and propagate, be interfaced towards the bodies of users and designers. It is remarkable how little the design processes of digital architects are yet influenced by live-mapped sensory data of the project's environmental context, and how little the stakeholders are integrated into design and decision making. How few buildings are after their realization still affected in their

material configuration by the computational processes that were involved in their design and construction.

2. Immediate Architectures

'Immediate Architectures' 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 is to close the big loop 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.

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.

In order to approach this state of immediacy, unifying principles of digital architecture have to be found and applied as basis for the realization of prototypes. These principles should allow for handling the informational domain, modeling information, executing code and having a spatial representation which goes beyond description of surfaces. They should also offer ways for binding the informational structure to actuating and sensory material elements of the material structure as well as into the fabrication and assembly process of new elements.

3. Executable Topologies

Non-standard reconfigurable, interactive structures are an inherently topological challenge: in the geometric descriptions of smallest parts, in the conception of the parametric elements with variable amount of parts and connections, in the structure of assemblies of elements, in the behavioral code running in each computing core, in the behavioral relations between cores and between elements and the users, and in the topological changes of the built structure by interactive kinetics or reconfiguration.

Executable topologies are the project's code. They can be generated, computed, produced, assembled; they define the production network and are the basic description of interactions which are foundations for emergent behavior. This topological continuum of structures and relationships can be encoded as Graph, interactions as BehaviorGraphs, spatial relationships as SpaceGraphs. With executable topologies, *The Building is the Information Model.*

3.1. Spatial representation: SpaceGraphs

For the prototypes, representations of space are developed for the state of immediacy. In contrast to conventional architectural geometry, where demands are fit into a chosen structure, with these representations the structure is an outcome of an abstract description

of demands. In real-time exploration, it becomes possible to model topology and geometry of the prototype at the same time.
Smartvolumes is a method for deriving structural topologies immediately from the spatial constellation of point-clouds. Modeling the behavior of the pointcloud nodes is combined with volumetric design exploration based on three-dimensional (additively weighted) Voronoi power diagrams. The method combines fast calculation of three-dimensional weighted Voronoi Power Diagrams with a volume-dependent feedback loop, resulting in a real-time interactive modeling tool. This tool, named SmartVolumes, has been integrated into the modeling environment BehaviourLinks, where the interaction between parametric volumes and other entities can be further elaborated through behavioral linkages. Applications of SmartVolumes in urban design and architectural design are described, implications of the use of Voronoi diagrams for architectural modeling and environments are discussed and directions of consecutive developments are indicated.

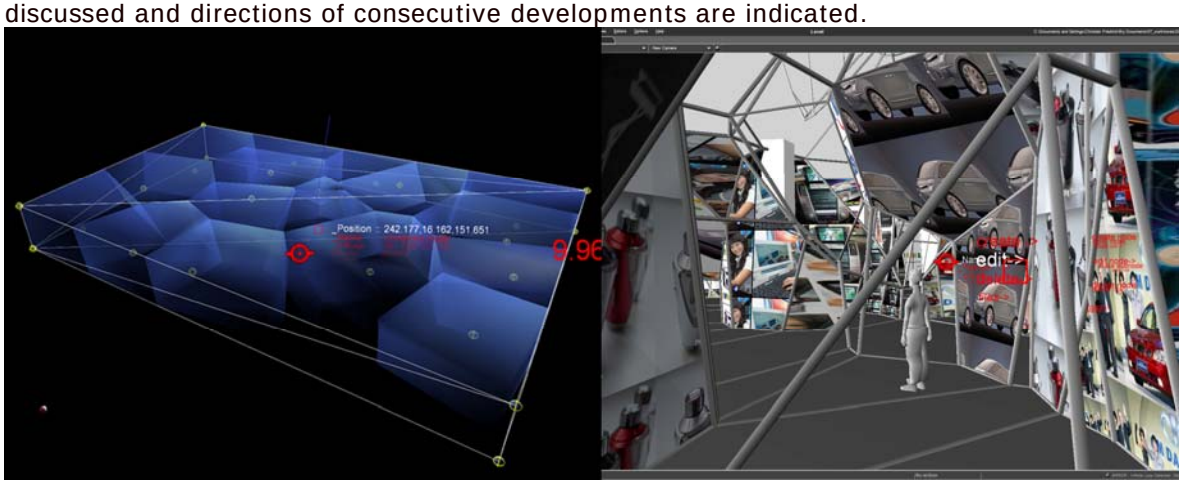

Figure 4. In-game screenshots of SmartVolumes modeler

SmartVolumes is a tool for finding structures and generating geometries based on volumetric and behavioral demands. It supports designers in the exploration of the complexity of geometries based on Voronoi diagrams: In a three-dimensional Voronoi diagram the location of points, the volumes of cells, the faces of cell surfaces, the edges of these facets and the endpoints of these edges are all implicitly related to each other. Each change to the generative point cloud simultaneously affects structure, building physics, details, aesthetics and other performances of the design. These complex interrelations demand for a tool to efficiently explore possible solution spaces. SmartVolumes is intended to meet these demands.
Spacegraphs represent design space as network of its partitioning into generic elements nodes, edges, facets and cells. Spacegraphs are a description 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. Smartvolumes is a first exploration into Spacegraphs, to be used for real-time conceptual design exploration.

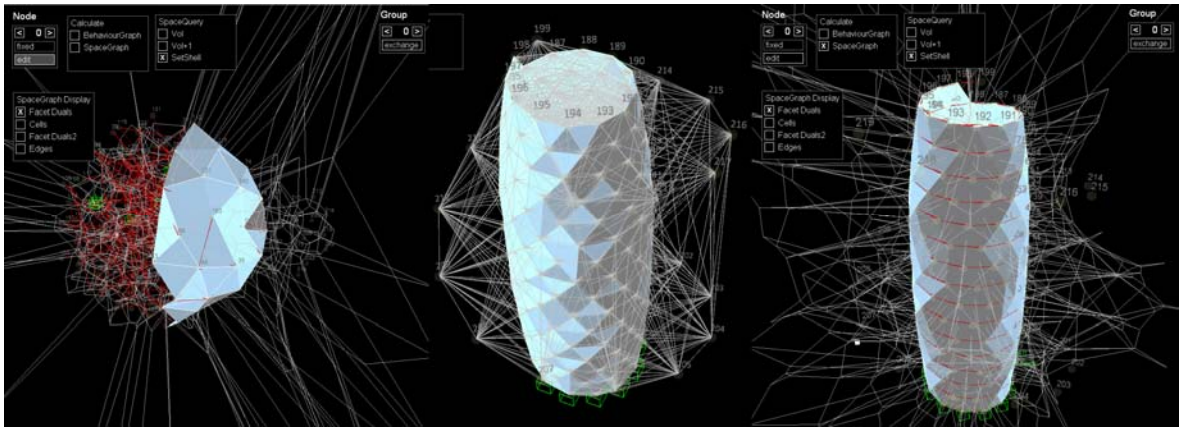

Figure 3. Pointclouds modeled with BehaviourLinks, their SpaceGraphs and surfaces resulting queries of the SpaceGraph network

Figure 3 shows the outcome of a Spacegraph query, which traverses the network according to types of relations and specified types of nodes in the neighborhood. The query returns design features, in this case a set of facets that form a surface.

3.2. Processing: BehaviourLinks

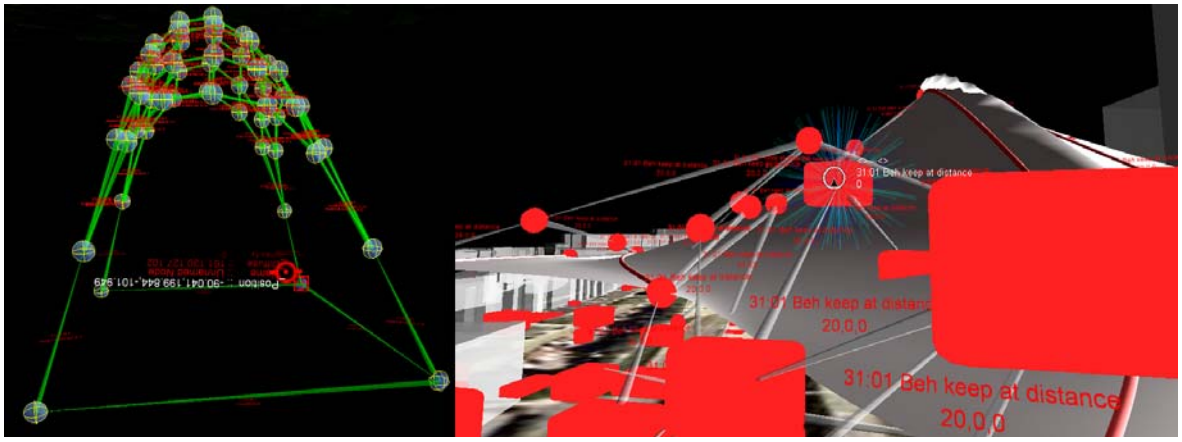

Figure 2. BehaviourLinks examples: particle-spring system, parametric surface

BehaviourLinks is at the intersection between parametric design environments and programming. It defines interactions between conceptual entities. These entities can represent architectural concepts but also digital interfaces to sensors, users and exchange data. By defining conceptual nodes and laying behavioral links, users can grow a parametric diagram of the design. Its shape, structure and visualization originate from the behavioral design rules and decisions made by the user as well as the feedback negotiation between swarming nodes.

3.3. Information Modeling: XiGraph

The information model chosen allows for real-time changes and is based on the semantic network paradigm, structuring design data by defining connections and building networks. This generic kind of data structure can be meaningfully organized and mapped by users. For this end, XiGraph library provides a generic basis.

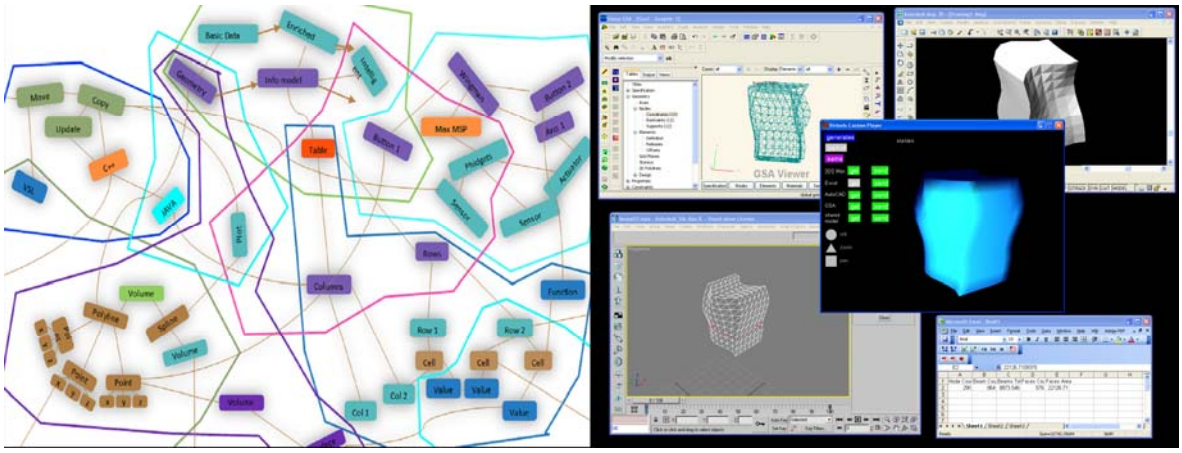

Figure 1. XiGraph: principle and real-time exchange

XiGraph is a meta-application protocol, which allows for concurrent modeling and exchange of information structures via a semantic network. In this network, the data structures present in various data sources, including professional design software and custom-made tools, can be represented, related and updated in real-time. The modeling of connections and transformations between various data structures in design computing, previously the domain of experts, with protocols like this can be handled by novices and within the design process. XiGraph is a basis for the implementation of BehaviourLinks and a way of connecting it to existing off-the-shelf software.

4. Material topologies

Interaction with material architecture takes place on two strata. The first is construction and constructive reconfiguration, which currently is a long-term interaction but is becoming faster, more accessible, more integrated and increasingly non-linear. The second is dynamic interaction with kinetic and medial structures, which can already take place in real-time but always has limited, pre-defined degrees of freedom of expression. As the state of immediacy is approached these two strata can be expected to eventually converge.

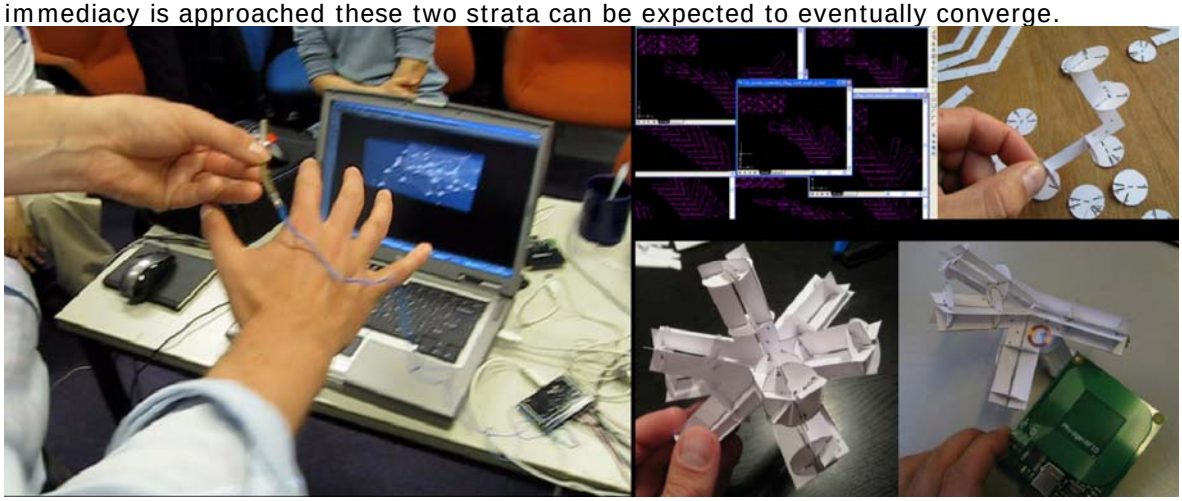

Figure 6. Streaming fabrication experiment

Networked Performative Modules are prototypes for interactive assemblies that are actively involved in the continuation of their design process. They are to be put together from

modular cells, which can differ in form, structure, material and affordances. A module can be merely structural, or actuating, contain sensors, sound equipment, processors. It could act as projector, interface or screen.
Non-standard production modes, combined with just-in-time concurrent production of architectural elements, bind the digital design models directly into ongoing fabrication processes. In this continuum of concurrent design and production, file-to-factory [F2F] production evolves towards an open-ended streaming fabrication.

5. Information-Matter Hybrids

Immediate architecture is architecture coming together in real-time. Users can explore the design space, and encounter, entwined in the physical structure, behavior which emerges from the hybridization of material elements and streams of information. Architecture becomes an activity, becomes immediate to the building-body whose configuration became open-ended. Architectural praxis is no longer focused on obtaining the building-object. The building-object is fiction, a fleeting asymptote towards which the open-ended process is steered. The building is no more a series-of-one, but becomes the event of ongoing material and informational reconfiguration driven by our bodily experience and feedback of the material structure.

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