The aim of these workshops and conference is to help transfer and spread newly appearing design technologies, educational methods and digital modelling supported by information technology in architecture. By organizing a workshop with a conference, we would like to close the distance between practice and theory.

Architects who keep up with the new designs demanded by the building industry will remain at the forefront of the design process in our information-technology based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get “back to command.”

The other message of our slogan is “Back to command.” In the expanding world of IT applications there is a need for the ready change of preliminary models by using parameters and scripts. These approaches retrieve the feeling of command-oriented systems.

Why CAADence in architecture?

“The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation.”
Editor
Mihály Szoboszlai
Faculty of Architecture
Budapest University of Technology and Economics

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CAADence in Architecture. Back to command
Budapesti Műszaki és Gazdaságtudományi Egyetem

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CAADence in Architecture
Back to command

Proceedings of the International Conference on
Computer Aided Architectural Design

16-17 June 2016
Budapest, Hungary
Faculty of Architecture
Budapest University of Technology and Economics

Edited by
Mihály Szoboszlai
Theme

CAADence in Architecture
Back to command

The aim of these workshops and conference is to help transfer and spread newly appearing design technologies, educational methods and digital modelling supported by information technology in architecture. By organizing a workshop with a conference, we would like to close the distance between practice and theory. Architects who keep up with the new design demanded by the building industry will remain at the forefront of the design process in our IT-based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get “back to command”.

Our slogan “Back to Command” contains another message. In the expanding world of IT applications, one must be able to change preliminary models readily by using different parameters and scripts. These approaches bring back the feeling of command-oriented systems, although with much greater effectiveness.

Why CAADence in architecture?
“The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By definition, a cadence is a solo that precedes a closing formula, in which the soloist plays a series of personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation.”

Nowadays sophisticated CAAD (Computer Aided Architectural Design) applications might operate in the hand of architects like instruments in the hand of musicians. We have used the word association cadence/caadence as a sort of word play to make this event even more memorable.

Mihály Szoboszlai
Chair of the Organizing Committee
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Members of our local organizing team have supported this event with their special contribution – namely, their hard work in preparing and managing this conference.

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Time-based Matter: Suggesting New Formal Variables for Space Design

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Abstract: Presently, digitalisation has moved beyond a desktop paradigm to one of ubiquitous computing; by introducing new possibilities and dynamic materials to various design fields, e.g. product design and architecture, it allows future spaces to be envisioned. Prior to being incorporated in the housing of the future, however, the hybrid character of computational materials raises questions with regard to the development of the appropriate design methods to allow them to be used in the production of space. Thus, merging physical and digital attributes in the material design process and expression not only enables a better understanding of materials through design, but also requires a cross-disciplinary methodology to be articulated in order to allow different perspectives on e.g. material, interaction, and architecture to interweave in the design process. Based on a practice-based research methodology, this paper proposes a cross-disciplinary framework where the notion of temporal scalability – enabled by the character of computation as a design material – is discussed in relation to form and material in architecture. The framework is illustrated by two different design examples, Repetition and Tactile Glow, and the methods behind their creation – merging time, material, and surface aesthetics – are discussed.

Keywords: Temporality, surface design, collaborative methods

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Expressing Architecture Through Materials
An understanding of architectural design as a material practice emphasises the essential role that materials play in the process of designing [1, 2], since material knowledge and experience inform the architect’s choices from the initial phases onwards when constructing artefacts and, at the same time, they enable the formation of a language for expression. Hence, the appearance of and direct experience with materials were taught at Bauhaus as part of an introductory courses in basic design; the study of textures was conducted using experimental methods which enabled students to understand the diverse character of materials through a complex exploration of the visual and tactile properties [3]. Accordingly, materials’ physical properties and expression have influenced the advancement of construction methods in architectural design, adding form expressiveness through material exploration and so facili-
tating the emergence of formal vocabularies in architecture [4].

More recently, rapid material development, driven by technological innovation and the increased digitalisation of fabrication processes, has led to the exploration of new methods of designing [5, 6] and so, at present, the digital has extensively entered into the material world, creating new relations between the material and the virtual and suggesting new hybrid materials and ways to represent artefacts. Subsequently, Manovich’s concept of “augmented space” discusses the idea of non-physical information being superimposed on top of physical space, distorting the perception of the real substance of the built environment. However, he advocates for a change in perspective in architecture, towards the possibilities afforded by the digital, which suggest a new direction for design by, for example, embedding digital information in a built space from an aesthetic perspective – and so enhancing the expression of the substance as a medium with which to expose the digital [7]. Consequently, the digital is opened up as a hybrid space for further explorations that can re-define the character of materials as raw, time-based substances for building and design.

THE POETICS OF AUGMENTED SURFACE: RELATING THE PHYSICAL AND THE DIGITAL IN THE SURFACE DESIGN PROCESS

The increased digitalisation of fabrication processes, along with developments in material chemistry, have redefined the world of raw materials – wood, stones, metal, glass; new materials open up for hybrid processes that combine not only natural and artificial components but also digital and physical characters. Thus, the complexity of the material compositions, methods of fabrication, and design of the present do not simply offer new perspectives for designers with regard to expressing artefacts, but require new methods of understanding them in order to be used in a comprehensible way. In addition, the authenticity of the relationships between material composition, surface expression, and function needs to be re-evaluated in order to enable a qualitative use in design [8, 9]. Hence, Menges considers the role of computational design to be that of a facilitator for both complex exploration and understanding of material properties and design possibilities; his argument is based on the extended landscapes of design opened up for by the digital, which give access to the various layers of information that are embedded in the material, from the level of the substance and rising up to structure and surface definition [10].

The dichotomy between the physical and the digital introduces considerations relating to how the meeting point between the two design spaces is addressed by the design at the micro perspective to the macro level of space. Thus, describing the material context of the present, DeLanda reflects on its complexity with regard to its introducing a new perspective with which to examine the design possibilities and potentials of materials. By making the distinction between properties and capacities, he relates the two notions by connecting the actual – the physical – to the context of use and the possible actions which the material affords. Consequently, DeLanda questions the established perspective on the material, which sees it as a unity; instead, the material becomes a system which incorporates multiple systems of possibilities, each of which is open to different actions/relations that are to be further explored[11]. Accordingly, the dual nature introduced by the digital allows materials multiple states of transformation, as defined by their inherent properties and design, which challenge the designer to question the states of transformation, criteria for selection, and their relations as time-based expressions.

THE TIME-BASED MATTER OF, AND FOR, DESIGN

Time, as part of material and buildings’ expression, brings with it various perspectives. Until recently, the passing of time in architectural design has been organically expressed in the decay of materials – the time frame of change for a building that is naturally affected by daily use and environmental conditions. Yet, the traditional Western architectural aesthetic has been guided by the ideals of permanence. Thus, the criteria
of permanence have been reflected in the selection of materials and their usage, and influenced the development of new materials with regard to durable properties. As a result, the industrialisation of manufacturing processes and further material developments encouraged the architecture of permanence, with a focus on developing high-performance materials by refining the properties of raw materials and principles of construction. Thus, the passing of time, as evidenced by material decay and corrosion, was commonly reversed to emphasise the timelessness of the building’s envelope.

There were opposing views, however, which valued the temporal imprint of buildings – that which signified the passing of time – and interpreted it as part of the building’s aesthetics, in that it framed a past time or slowed or accelerated its passage. Consider, for example, Ruskin’s perspective on time, where memory greatly valued the expression of ruins and the building’s patina, which was formed over an extended period of time [12]. Correspondingly, the passing of time as part of the surface aesthetics was highly valued and accentuated by the choice of materials and nature’s organic growth on the façade in, for example, Alto’s Vila Muratsaalo, or Dixton or Jones’s pre-patinated copper covering the Said Business School in Oxford [c.f. 13].

However, the present emergence of smart materials has imposed a major shift in design thinking, as ‘smartness’ describes a category of materials in which computational capability and physical matter meet [14, 15], adding a new perspective on the temporality of the buildings. In addition, the complexity of the material world today is emphasised by Kennedy, who relates surface temporality to adaptability of use; the ability to change and embed multiple functions in the building envelope is a central element of design, offering a new perspective on design spaces and form [16]. Furthermore, as technology and digitalisation become increasingly present in our daily lives [17, 18], their temporal material expressions need proper design considerations. Thus, Hallnäs and Redström introduce and reflect on the notion of ‘slow technology’, which exists in opposition to the conventional perspective on the digital as an expression of fast change, proposing a speculative design approach which merges technology in a subtle way as a natural aspect of spatial aesthetics, suggesting calmness and reflection [19]. Consequently, the intersection of digital and physical matter implies two radical challenges to the design thinking of architectural practice: the addressing of a novel perspective on temporality of the material during the design process, i.e. guided by the character of the digital, and the ability to design with the physical changeability of the material behaviour and expression in mind, challenging not only the relationship between material and form but also the notion of spatial temporality. Thus, the two criteria cause a transition in the design thinking, in that the material/space becomes a dynamic, rather than static, gestalt [20]. Hence, in this new context, the changeability of material expression is dependent not only on the inherent character of the physical material, but on the programmed behaviour by which its design exhibits the change between different states – projecting the material’s expression into both the past and the future, and alternating these states through intricate expressions [21, 22]. As a programmed material, variations in the artefact’s spatial expression depend on both real and designed time, linking time to material as two fundamental related variables for design.

Time and matter: novel variables for the design

As compared to traditional raw materials such as wood or stone, which are static in their behaviour and have an expression which can be affected over a long period of time, new materials for design are developed based on the idea that they will change over a short period of time, and so present alternate methods to our conventional ways of designing with time – making changes in surface expression directly perceivable through the use of digital computation. So, the temporality of a material’s expression can be expressed in multiple ways: by the inherent transformational properties of the raw material, as well as the ways these changes are programmed to occur [23], either independently or in response to human and/or environmental factors.
i. the temporality of the raw material

Depending on the inherent properties of raw materials, the changes exhibited by them can take the form of one or multiple states of transformation – from a primary State A to a State B, or from State A to B and all the way through to Z [24]. An illustrative example of a material that offers such complexity and design possibilities is leuco dye-based thermochromic ink, which responds to changes in temperature. These inks can be printed on different surfaces or mixed into material solutions to form plastics, and allow for changes in visual expression in terms of colour. When activated at a certain temperature, a Colour A becomes transparent or changes to Colour B; or, when mixed with static colour pigments, one pigment can exhibit multiple Colour states, from A to Z [25] Figure 1.

As compared to other materials that change in response to heat, for example heat-fusible yarns or memory alloys, leuco dye-based thermochromic inks change relatively quickly, depending on the amount of heat applied and the medium used for printing. However, the choice of the basic medium for printing, such as textile or plastic, and the methods used for mixing the plastic solution and surface application, influence the speed of the change in colour. When printed on a light wool, the colour change takes two seconds following the application of heat to the opposing side of the material; by changing the medium for printing from a porous textile to a plastic but maintaining the same parameters otherwise, the colour change takes around 10 seconds Figure 2. Thus, small differences in the way in which the material is designed, for example the medium used for printing or the method for applying the colour, have a great impact on the speed of the change in surface expression, and thus influence the temporal nature of the material and the way the design of the surface is further developed through the process of programming facilitates pattern change and recurrence.

Another important consideration when working with time in relation to surface expression is connected to the properties of the raw material, and its returning to its original state. The way in which the temporality of the pattern is manifested in the material can be reversible – A-B-A – or permanent – A1-A2-A3...An. Light fibres or motors are able to return to their initial expression but, for heat-fusible or thermo-formable yarns, the gradual changes in expression caused by shrinkage or melting finalise the end expression in a permanent way Figure 3.
ii. temporality through sensing and actuation

The transformations in a material’s expression can be programmed to manifest the changes of a surface independently. Without stimuli from humans or the environment, a program controls when to initiate the change in the pattern, how long the change should last, which areas of the surface are to be activated, and how to design the recurrence of the changes so as to create a pattern. The installation designed by Orth exemplifies this way of working with temporality in the surface design, as the textile re-forms the textural pattern of the surface through changes in colour at specific times – allowing the viewer to follow a succession of events and so the passing of time [26]. On a similar example, the temporal design of a surface can be combined with sensing capabilities so as to facilitate surface design that incorporates a relational aspect. Thus, self-actuating behaviour can also be activated by human presence or environmental stimuli, leading to greater complexity with regard to the temporal expression of the surface. Vivisection is dependent on the user’s presence in space; the movement of the surface is planned so as to have two temporal sequences, with one determined by the timing of the changes which re-form the surface and the other dependent on the sensing of presences in space [27]. One of the most complex examples of combined temporal sequences in surface expression is the Aegis Hypersurface, which depends on both human and environmental stimuli. The visual and physical changes exhibited by the surface relate to three time periods; one which controls the surface change, one which is activated by the viewer, and one which is activated by changes in the environment. The ways in which these three time periods are related influence the dynamic behaviour of the surface and, consequently, the temporal design [28].

The time-based material as method

Today, materials are positioned at the intersection of multiple design disciplines, and so require an interdisciplinary approach to their development. Thus, revisiting the synergy between material properties and capacities, and additionally considering the notion of temporality so as to expand this relation, this paper proposes a method for designing. This method is the result of observations attained using practice-based research, as well as a thorough analysis of related examples of research projects.

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>INHERENT</th>
<th>DESIGNED</th>
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<tbody>
<tr>
<td></td>
<td>transformable fabrication</td>
<td>transformable pattern relational pattern</td>
</tr>
<tr>
<td>TIME</td>
<td>speed of change temporal scale</td>
<td>time-based relations</td>
</tr>
</tbody>
</table>

The matrix of material-time relations aims to capture the richness and diversity of the variables that interact in and influence the material design process Figure 4. To better understand the design possibilities of time-based materials and develop proper ways of articulating these conditions in the design process, the proposed matrix starts from the premise that a conventional architectural design process – one which begins with form generation and then selects materials that are suitable to achieving this – is reversed. Here, the time-based material and the field of possibilities opened up for by the material’s temporal inherent character and designed expression are the starting point for this journey.

SPECULATIVE SCENARIOS

Example 1: Repetition

A knitted wall is placed in front of a concrete one. A dancer is asked to execute movements which involve moving away from and back towards the textile wall [29] Figure 5.
Material: The white textile background has a fine striped pattern repeated every 10 centimetres, consisting of interlaced threads of conductive yarn. The knitted arrangement of the conductive yarns generates heat so as to influence changes in the dancer’s dress. The dress is designed to allow certain movements, made of heavy wool, and printed on the right side with thermochromic paste Figure 6. The heavy wool acts as an insulator for the dancer’s body heat but activates when placed on the warm wall; the dark green becomes cyan (from A to B and back to A), reacting to temperatures of above 37 degrees Celsius.

Temporality: By the time the dancer has moved close to the wall, the heat pattern has already been activated as it is self-dependent. It then takes 5 seconds for each line of knit to begin to emit heat and, after 5 more seconds, the lines slowly reach their maximum temperature. The lines are activated in succession, growing one after another, at intervals of 5 seconds. When all of the lines have been activated, the heat output ceases for 20 seconds. When activated, the garment exhibits a change in colour in the foreground; the expression of the translated pattern appears as a visual imprint on the dress, and fades slowly over the course of 30 seconds. There are two heat-generating areas, placed in the mid-upper part of the textile surface due to the fact that it is most probable that these areas will come into contact with the body of the dancer when she moves close to the textile. The dancer executes fast movements when at a distance from the wall and slows down when close to it in a retrograde movement; she stays there for a while for the pattern of heat to be properly transferred from one side of the garment to the other. Having activated the pattern on her dress, the dancer moves away from the wall. When activated, the heat pattern is a clear stripe which slowly fades, allowing the form of the interlaced conductive threads to emerge mirroring the pattern of the wall. An interval of at least 30 seconds is necessary for the garment to retrograde to its initial colour. The programming of the textile wall and the real-time interactions of the dancer combine to form the relational pattern; the two time periods together form a loop, connecting slow and fast movements and mirrored by the changes in the materials’ expressions—wall and garments.

Example 2: Tactile glow

A sculptural form is placed in a space. By touching the surface light patterns start to emerge, which overlap with the geometry of its surface [30] Figure 7.

Material: The surface consists of hard textile modules which form crease patterns, which in turn form tessellations. The textile’s porous character becomes visible when near to the surface Figure 8. The modules’ geometry is designed using a flat knitting machine capable of three-dimensional shaping, performed after each module is heat-set. Alternating mountain and valley folds form each module. The lines to be folded are decided during the knitting process, and so the textile is more transparent in these areas so as to guide the forming of the surface and the placement of...
Linear sources of light, such as electroluminescent wires, are embedded in the mountain folds so that the textile can act as both a sensor and an actuator Figure 9, Figure 10. **Temporality**: Based on the shape of the textile modules, three types of light pattern are formed: a triangle, a square, and a hexagon. Each of the patterns has two possibilities for activation: as foreground, appearing as the outer primary shape, and as background, appearing as the full field of each primary shape. The visual transformation of the surface depends on the bending of the mountain folds – amplifying the near-field interaction. The transformation of the surface texture is random, and dependent on the real-time activation of the surface: a short bending action directly actuates in a fast pace the foreground outer layer of a pattern, which remains visible for 60 seconds. A longer bending action gradually triggers the slow activation of background patterns, starting from the area of interaction and

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>INHERENT</th>
<th>DESIGNED</th>
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<tbody>
<tr>
<td></td>
<td>transformable: light change; self-dependent; dependent fabrication: structural (3D knitting); surface (in-lay techniques for inserting light and sensing)</td>
<td>transformable pattern: growing light pattern; contrast heat pattern</td>
</tr>
<tr>
<td></td>
<td>speed of change: surface activation (slow,fast); pattern emergence (foreground and background) temporal scale: reversible; gradation; real-time</td>
<td>time-based relations: amplified; fragmented; random</td>
</tr>
</tbody>
</table>

**Table:**

<table>
<thead>
<tr>
<th>TIME</th>
<th>MATERIAL</th>
<th>INHERENT</th>
<th>DESIGNED</th>
</tr>
</thead>
<tbody>
<tr>
<td>speed of change: surface activation (slow, fast); pattern emergence (foreground and background) temporal scale: reversible; gradation; real-time</td>
<td>transformable pattern: growing light pattern; contrast heat pattern</td>
<td>time-based relations: amplified; fragmented; random</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 7:** Matrix for time-based material relations for Tactile Glow

**Figure 8:** The textile modules and three basic geometries of light patterns

**Figure 9:** Close-up of the textile modules and near-field tactile interaction
Figure 10: Combination of far-field light patterns resulted from the near-field interactions with the surface gradually filling the field of the primary shapes over the course of approximately 80 seconds in a fragmented time frame. Once completed, the shape of the background pattern lasts 20 seconds longer than the outer shape of the foreground pattern. The background patterns of each of the primary shapes have different times for activation and fading due to the different number of modules that form them; it takes 2 seconds for each module to be activated.

**DISCUSSION**

Reversing the processes so that time-based material capacities inform form, the matrix proposed in this paper illustrates a relational structure for design variables which emphasises methods and attributes that influence design decisions related to expressing time through materials – describing a pattern language [c.f. 31]. Consequently, two basic speculative scenarios: Repetition and Tactile Glow, illustrate how the matrix can be used; these descriptions aim to introduce a vocabulary for temporal variables – for example to describe speed and type of change – and time-based expressions – for example to describe attributes: amplification, mirroring, fragmentation – as a basic framework with which to initiate cross-disciplinary discussions in the design process. Shifting the perspective, from the material/design object as a unity to one which is defined by a field of relations that are related by time [32, 33, 34], the relationship between time and material defined by the matrix can be used to integrate material properties and capacities during the initial stages of a design process – functioning as a relational element between the different practices, for example surface design, form generation, interaction, fabrication, functional analysis, and construction that informs a complex building process. Accordingly, the material from being a pre-defined entity becomes a relational method with which to inform ways of fabricating and expressing spaces, all while maintaining a degree of openness with regard to making aesthetic and functional decisions. Expanding the static view of architecture as expression of permanence, the novel expressions of space through time-based materials can thus be fragmented, amplified, progressive, slowed down, or frozen entirely in time; they depend on the length and relationships between the different time frames of change embedded in the material. Hence, the notion of timing the changes in the building envelope and relating them to aesthetic ways of designing spatial interactions is based on the openness and closeness of these time-based material relations, which affect the different scales of design that participate in the building process. Consequently, the notion of temporal scalability includes not only the real-time exploration of the design object with regard to accessing the details of the material structure, but also the fact that the process uses time as design variable to relate a near-field perspective to the far-field of architectural design opening for the generation of complex time-based spatial experi-
ences. In addition, the relational and responsive behaviours of the new time-based materiality require a space for the development of complementary hybrid methods to relate the physical and the digital, and a space to educate future designers within this frame; this must be performed in order to enable the attaining of complex spatial experiences, based on the exploration of intricate time-based textural perceptions.

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Architects who keep up with the new designs demanded by the building industry will remain at the forefront of the design process in our information-technology based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get “back to command”.

The other message of our slogan is <Back to command>.

In the expanding world of IT applications there is a need for the ready change of preliminary models by using parameters and scripts. These approaches retrieve the feeling of command-oriented systems, although, with much greater effectiveness.

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"The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By definition, a cadence is a solo that precedes a closing formula, in which the soloist plays a series of personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation."