SOONGSIL UNIVERSITY STUDENT UNION / ZVE FRAUNHOFER INSTITUTE / EXAMINING THE NEW SEOUL CITY HALL ARCHITECTURE THROUGH THE CULTURAL MACHINE
디지털 물성은 건축적 표현의 새로운 변화를 말한다. 물성은 디지털의 특성이 더욱 빠르게 임주하고, 이는 실질적으로 건축의 피사체(physia) 본성이, 본질, 자연에 영향을 줄다. 디지털 물성은 설계과정에서 디지털화와 물체의 간의 상호작용을 통해 진화한다. 확인할 뿐이 보이는 디지털 세계의 물질 세계의 합성은 새로운 다양한 현실을 생성한다. 정보, 물질, 프로그래밍, 사물이 갖는 것이다. 이런 합성은 디지털 제작(digital fabrication) 기술에 의해 충진되며, 건축가가 디자인 정보를 통해 제조 과정을 통제할 수 있도록 해준다. 물체 정보를 받아 동적변환. 미래에는 건축가가 디자인뿐 아니라 제작 과정 전반을 다루게 될 것이다. 이 새로운 상황은 건축가의 가능성을 척탄적 범위에 변화를 준다.

디지털 물성은 디자인 과정에서 구축과 프로그래밍이 동화되어 생동한다. 우리는 건물 구성 요소의 생산과 컴퓨터 프로그래밍이 간단히 구현된 후에야 보이기 시작한다. 현재 7개의 개인 컴퓨터로, 17개의 서사와 현재로서는 서사로 통치하게 만든다. 그 과정에서 서사가 물체로 통보할 수 있다고 한다. 그 결과 디지털 물성은 인간 인식의 다양한 단계를 드러낸다. 디지털 물성은 다양한 정보화의 개념으로 보인다. 정보는 인식의 변화를 통해 제작 과정을 통제한 결과, 디지털 물성과 물리적 변화에 근거해진다. 정보는 전자기의 정역학적 특성을 통해 제작 과정의 변화를 설명하고 있다. 디지털 물성은 정보의 완성에 따라 변화하는 것이며, 디지털 물성은 정보의 변화를 통해 제작 과정을 통제하고 있다.

구축의 프로그래밍

디지털 물성은 디자인 과정에서 구축과 프로그래밍이 동화되어 생동한다. 우리는 건물 구성 요소의 생산과 컴퓨터 프로그래밍이 간단히 구현된 후에야 보이기 시작한다. 현재 7개의 개인 컴퓨터로, 17개의 서사와 현재로서는 서사로 통치하게 만든다. 그 과정에서 서사가 물체로 통보할 수 있다고 한다. 그 결과 디지털 물성은 인간 인식의 다양한 단계를 드러낸다. 디지털 물성은 다양한 정보화의 개념으로 보인다. 정보는 인식의 변화를 통해 제작 과정을 통제한 결과, 디지털 물성과 물리적 변화에 근거해진다. 정보는 전자기의 정역학적 특성을 통해 제작 과정의 변화를 설명하고 있다. 디지털 물성은 정보의 완성에 따라 변화하는 것이며, 디지털 물성은 정보의 변화를 통해 제작 과정을 통제하고 있다.

로봇을 사용한 구축

로봇은 컴퓨터의 디지털 현실과 건축의 물리적 현실을 연계한다. 디지털 제작은 건축을 요소와 재료의 결합으로 간주할 때 발전할 수 있다.
Gramazio & Kohler, Procedural Landscapes, ETH Zurich, 2011

Geometric precision of the digitally designed landscape produced by robotic machinery.

Concrete element / A prototypical concrete element
이미지 1

이 이미지 1의 주요 내용은 다음과 같습니다.

**분산(>variation)과 다각성**

분산은 디지털 물체를 통해 동물학적 다각성이 된다. 이는 물체의 형태와 구조가 서로 다른 특성을 가질 수 있으며, 이는 디지털 물체의 특성을 통해 다양한 구조와 형태를 형성할 수 있다. 디지털 물체는 시간과 공간의 변화를 통해 다양한 구조를 형성할 수 있으며, 이를 통해 다양한 구조를 형성할 수 있다.

**디지털 과정**

디지털 과정은 디지털 물체의 구조를 통해 시간과 공간을 통해 다양한 구조를 형성한다. 이러한 구조는 시간과 공간의 변화를 통해 다양한 구조를 형성할 수 있으며, 이를 통해 다양한 구조를 형성할 수 있다.
## 건축의 새로운 피시스

디지털 기술을 이용한 디자인이야 이상과 예상 가능한 현실을 구현한다. 건축 디자인은 최적화된 결과물을 성취하는 것으로 축소할 수 없는 디지털 문화적 산물이다. 디지털 물리적이고 공극적인 인간적 규모와 문화적 생활의 질이 어려움이 드러난다. 컴퓨터 그래픽과 산업 로봇을 사용한 제조 등은 극단적인 합리성을 기반으로 한다. 이때에서 건축가는 감각기관을 통해 연상적·다각적·실제적으로 건축을 사고하고 구축하고 경험한다.

이상에 기반한 디자인과 체적 방식은 건축과 핵심의 확률을 높인다. 사람들은 시각적 표현이 건물로 전환되는 형식과 다른 디자인 방식을 납득하게 생각한다. 건축적 표현은 디자인과 물질과 과정에서만 생산되며 그 특성은 서서히 형성된다. 이로써 디지털 물성은 건축의 피시스와 개수할로, 나아가 건축에 대한 사회적 이미지를 변화시킨다. 자료제공: 피바오 드라마피오, 미디어스 플러어

출처: 피바오 드라마피오, 미디어스 플러어, 건축에서의 디지털 물성, 라스 헬러, 2008

Gramazio & Kohler, ETH Zurich, 2006
가상적 제작 방식 / Additive robotic fabrication at 1:1 scale

Gramazio & Kohler, Room-acoustical information, ETH Zurich, 2008
로봇 마이크로 사용해 음향적 특성을 가진 형태를 제작할 수 있다.
A prototype with specific acoustic quality produced with the milling robot

Gramazio & Kohler, Curved Folding, ETH Zurich, 2011
재료 정보를 조작으로 여러 로봇의 협업이 가능하다.
Curved folding with three independent robotic arms with custom-made fabrication data

Gramazio & Kohler, Spatial Aggregations, ETH Zurich, 2012
다수의 충돌적 요소를 복잡하고 구조적으로 조립할 수 있다.
Performing complex structural assembly of a large number of generic building elements
We use the term *digital materiality* to describe an emergent transformation in the expression of architecture. Materiality is increasingly being enriched by digital characteristics, which substantially affect architecture’s physis. *Digital materiality* evolves through the interplay between digital and material processes in design and construction. The synthesis of two seemingly distinct worlds—the digital and the material—generates new, self-evident realities. Data and material, programming and construction, are interwoven. This synthesis is facilitated by the techniques of digital fabrication, which allow the architect to control the manufacturing process through design data. Material is thus enriched by information; material becomes “informed”. In the future, architects’ ideas will permeate the fabrication process in its entirety. This new situation transforms the possibilities and thus the professional scope of the architect.

### Sensuality of Digital Order

*Digital materiality* leads to a new expression and—surprisingly enough, given the technical associations of the term “digital”—to a new sensuality in architecture. Digital and material orders enter into a dialogue, in the course of which each is enhanced by the other. *Digital materiality* is thereby able to address different levels in our perception. It is characterised by an unusually large number of precisely arranged elements, a sophisticated level of detail, and the simultaneous presence of different scales of formation. Despite its intrinsic complexity, we experience and understand it intuitively. *Digital materiality* addresses our ability to recognise naturally grown organisational forms and to interpret their internal order. Its expression is novel, but not alien. *Digital materiality* is not rooted solely in the material world and its physical laws such as gravity, or in material properties. It is also augmented by the rules of the immaterial world of digital logics, such as in its procedural nature or calculatory precision. Digital orders intensify the particularities of materials. Materials do not appear primarily as a texture or as a surface, but are exposed and experienced in their whole depth and plasticity. Even familiar materials—such as bricks, which have been known for over 9000 years—appear in new ways.

For the observer, a tension spans the intuitively perceptible behaviour of a material and the design logic, which may not be immediately obvious. The logic can be sensed, but not necessarily explained. This obscurity seduces our senses, sending them on a voyage of discovery and inviting us to linger and reflect.

### Programming Constructions

*Digital materiality* is generated through the integration of construction and programming in the design process. We use...
the conceptional affinity of the production in building components and computer programming. Today there are 700 million personal computers in use, in addition to 1.7 billion mobile phones, the latest generation of which are essentially mobile computers, plus countless other microchips built into various electronic devices. There is much that a computer cannot do, but certain things that it can do very well. It cannot be the substitute for the architect in the creation of designs, but is an invaluable design tool. A computer programme describes the processing of data as a sequence of individual calculation steps. Similarly, the manufacturing of a building component takes place as a temporal sequence of individual steps in fabrication.

The sequence of construction steps – which step is first, which step follows – is usually not arbitrary, since they build upon one another and thus determine successive steps. This sequencing is most the radical analogy between construction, the knowledge and art of putting individual building components together as a built spatial ensemble, and computer programming. By mapping the savoir-faire of construction onto a programmed process, we gain immediate control over digital fabrication. From now on, we are no longer designing the form that will ultimately be produced, but the production process itself. Design and execution are no longer

phases in a temporal sequence – design sketches do not need to be converted into execution drawings anymore. The design incorporates the idea and knowledge of its production is already at its moment of conception. In turn, the understanding of construction as an integral part of architectural design takes on greater significance. Digital craftsmanship thus continues the tradition of construction in architecture.

Does it make sense to formalise designs completely or partially in computer programmes, to write down architectural logics instead of drawing or modelling architectural forms? As architects we have had little experience of the unfamiliar “language” of programming. Many architects find it constricting, because it requires precise settings from the outset. To allow oneself to be limited by this precision would however be as pointless as capitulating before a freshly sharpened pencil. Because in reality, it is precisely programming that provides the necessary instrumental basis for liberating oneself from prevailing images of digital architecture production.

The practical, “hands-on” experience of programming demystifies digital technologies and fosters a liberated, autonomous approach to the computer. Through these practical skills we emancipate ourselves from existing CAAD tools and the passive application of their built-in paradigms and menu functions, which are mostly programmed simulations of traditional drawing processes. Instead, it is necessary to develop programming languages suitable for architecture that account for the fact that when designing, the exception is often just as important as the rule; or that hierarchical dependencies can change throughout the design process. Like spoken languages, programming languages and their paradigms are also subject to continuous change. Architects can intervene in this evolution by developing their own dialects that take up the subjects of construction, materials and space.

II Building with Robots

The robot connects the digital reality of the computer with the material reality of built architecture. The simple insight that architecture is largely built through the addition of parts, or the aggregation of materials, allows us to advance digital fabrication. As we accumulate materials precisely at the point where they are needed, we can weave form and function directly into building components, never limited to the design of their surfaces. The industrial robot enables us to implement this additive principle on an architectural scale.

Worldwide, there are currently more than a million
multifunctional robots in use, predominantly so-called articulated-arm robots; the number in use has risen steadily since the 1980s. The industrial robot has become the standard in automation precisely because, like the personal computer, it has not been optimised for one single task but is suitable for a wide spectrum of applications. Rather than being forced to operate within the predefined parameters of a specialised machine, we are able to design the actual “manual skills” of the generic robot ourselves. We do not just steer it to a particular point in space, but also determine its capacities for physical manipulation and processing. By defining the robot’s hand — also called the “end effector” — and determining its movements, we teach the robot a desired type of construction. We teach it to register its surroundings through sensors, and to affect the environment via the robot hand. The robot thus connects the world of immaterial logic with that of material construction in the most direct possible way.

One might ask whether, and why, architects should use industrial robots or even computer programming, tools that can appear architecturally irrelevant. In our opinion it is crucial that architects, now and in the future, choose their means consciously and master their tools. Accessing these tools enables architects to create their individual design instruments and thus generates diverse forms of expression. They will thereby be in a position to answer contemporary demands with contemporary means and concepts. The fact that no new conventions have arisen in the design and building world in recent decades, shows that built architecture has so far benefited only marginally from digital technologies. Through its link to the tradition of construction, digital materiality changes the culture of architecture, both in its expression and in its productive capacity. Architects are predisposed to forge links between technology and the built environment.

II Variation and Multiplicity

Through digital materiality, architecture becomes increasingly rich and diversified. This diversification affects different scales, from materials and building components to spatial sequences and load-bearing structures, to houses and urban development zoning. Variation emerges as it becomes possible to design large numbers of elements in differentiated ways using digital means. Such designs would have made very little sense before the availability of computers and digital fabrication, but their realisation has now become a matter of course. The potential of digital design and production processes can best be exploited where a very large number of parts must be combined. Here they extend the architect’s human capabilities; they improve his or her overview and multiply the possibilities for control of the design. In order to design a facade with hundreds of windows, for example, or a large building volume with mixed forms of housing, the architect has until now had to turn to the classical manual aids such as the grid, or to develop repeatable types. Repetition makes it possible to manually organise variation, to control and construct it with simple procedures. With the rise of digital materiality, the frontier between system and variation is renegotiated. As a consequence, architectures develop that place diverse, complementary logics in relation to one another.

In the digital age, our concept of serial repetition, which was the product of industrialisation, is being transformed much in the same way as the opposing romantic conception of the “natural” uniqueness of craftsmanship. A language of diversity is emerging that gains its identity through the design of processes, rather than final forms. In these processes, different elements combine adaptively into a coherent, harmonious whole. The multilayered, sometimes complex arrangements that constitute the aesthetics and expression of digital materiality may be reminiscent of the organic structures of the animal or plant world. This comparison, however, though appealing, falls short: it masks the fact that digital systems do not arise out of biological conditions, and are not rooted in them either. The digital is an independent cultural achievement, resulting from centuries of human engagement with logic. Precisely for this reason the computer is a fascinating instrument, one that motivates a designer to exploit the human potential for associative thinking in order to discover new organising principles, and establish new relations to the built environment. The multiplicity that attends the design of digital processes seems novel, but not entirely strange, since it refers to familiar experiences of perception. The forms in all their variety appeal to the senses while continuing to assert their distinctly inorganic derivation.

II Designing Processes

Digital materiality leads us from the design of static forms to the design of material processes. In doing so we give up geometry, whether drawn or modelled, as architecture’s actual building plan and its primary basis for design decisions. Instead, we design the relationships and sequences that inhabit architecture and that emerge as its physical manifestation. But once we begin to invent such material processes, a new way of thinking about architecture reveals itself. It is a conceptual way of designing, with architectural parameters, conditions, relationships and degrees of freedom. We ask ourselves: which parameters determine the design, and which do not, but still have an effect on its form and function? Using digital logics we define relationships and intentions in the form of rules. We weigh the influences that the design-generating factors have on each other. Through the medium of programming we can model complex decision processes, checking and refining them iteratively. Architectural expression thus takes on a different character, because new conventions emerge in the medium of programming.

In this way of conceiving architecture, processes are not mere metaphors for a process-oriented approach to design, but are concrete sequences of operations, procedures that have to be designed. These procedures are determined, they have a beginning and an end. They produce directly tangible results, the qualities of which can be tested intuitively and analytically, as we can with sketching or building models. We exploit the advantages of programming by integrating them into our traditional methods of design. When architecture becomes the design of material processes, we no longer have a static plan in front of us, but a dynamic set of rules. We design a behaviour. A set of rules like this has the advantage that even very fundamental interventions can still be implemented even late in the process, as long as they are anticipated as an open parameter in the design. We can work in a determined manner, but with open conditions that will be set only at an advanced design stage. This even offers the possibility of intentionally ceding partial control over selected design parameters to customers or partners. We thus design architecture itself as an open system, with different active participants. This type of design, detached from a drive towards form, does justice both to the ever more complex conditions of our profession, and to the material substance of architecture, including its sensual qualities. Designing architecture as a sequence of processes thus strengthens the central role of the architect as proactive author.

II The Changed Physics of Architecture

Design using digital technologies interests us because it
delineates the boundaries of rationality and of predictable reality. In our opinion, designing architecture is not an activity that can be reduced to performance optimisation – it is multifaceted cultural production. It is precisely digital materiality that shows us quite plainly the essentially human dimension and the quality of its production. Under the conditions of an apparently extreme rationality, ranging from computer programming to fabrication using the industrial robot, we discover associative, manifold and tangible ways to think, build and experience architecture, using all of our senses. We realise that the probability of encountering discoveries and innovations is increased, not limited, by using rational means of design and fabrication. Our senses are taken by surprise, as we cease designing by means of visual representation, intended to be converted into buildings. Architectural expression is instead produced only in the course of the design and materialisation process, and takes on its character little by little. Digital materiality changes the physis of architecture, altering the Gestalt, and ultimately shifts the image that society has of architecture.

Material provided by Fabio Gramazio + Matthias Kohler

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Gramazio & Kohler, Vertical Village, Zurich, 2011
5면 개의 주거 공간이 형성될 수 있다.
The layers of the structure providing living space for over 30,000 inhabitants

Matthias Kohler and Fabio Gramazio are joint partners in the architects' office Gramazio & Kohler in Zurich where numerous award-winning designs have been realised, integrating novel architectural design into a contemporary building culture. Founding also the world’s first architectural robotic laboratory at the Swiss Federal Institute of Technology ETH Zurich, their academic research concentrates on a multi-disciplinary practice between computational design, robotic fabrication and material innovation. This ranges from 1:1 prototypical installations to the design of robotic high-rise buildings. Gramazio & Kohler were awarded the Swiss Art Awards, the Global Holcim Innovation Prize and the Acadia Award for Emerging Digital Practice. Their work has been published in a large number of academic journals, further contributing to numerous exhibitions around the world such as the Architecture Biennale in Venice (2008), the Storefront Gallery for Art and Architecture (2009) New York or Flight Assembled Architecture at the Frac Centre Orleans (2011).