JIDA'20

VIII JORNADAS SOBRE INNOVACIÓN DOCENTE EN ARQUITECTURA

WORKSHOP ON EDUCATIONAL INNOVATION IN ARCHITECTURE JIDA'20

JORNADES SOBRE INNOVACIÓ DOCENT EN ARQUITECTURA JIDA'20

ESCUELA TÉCNICA SUPERIOR DE ARQUITECTURA DE MÁLAGA
12 Y 13 DE NOVIEMBRE DE 2020

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

umaeditorial

GILDA
GRUP PER A LA INNOVACIÓ I LA LOGÍSTICA DOCENT EN ARQUITECTURA

GILDA GRUPO PARA LA INNOVACIÓN Y LA LOGÍSTICA DOCENTE EN ARQUITECTURA

Organiza e impulsa **GILDA** (Grupo para la Innovación y Logística Docente en la Arquitectura), en el marco del proyecto RIMA (Investigación e Innovación en Metodologías de Aprendizaje), de la Universitat Politècnica de Catalunya · BarcelonaTech (UPC) y el Institut de Ciències de l'Educació (ICE). http://revistes.upc.edu/ojs/index.php/JIDA

Editores
Berta Bardí i Milà, Daniel García-Escudero

Revisión de textos
Alba Arboix, Jordi Franquesa, Joan Moreno, Judit Taberna

Edita
Iniciativa Digital Politècnica Oficina de Publicacions Acadèmiques Digitals de la UPC
Publicaciones y Divulgación Científica, Universidad de Málaga

ISBN 978-84-9880-858-2 (IDP-UPC)
978-84-1335-032-5 (UMA EDITORIAL)
eISSN 2462-571X

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***JIDA'20**. VIII Jornadas sobre Innovación Docente en Arquitectura*
Málaga, eAM'-UMA, 12-13 noviembre 2020
DOI: 10.5821/jida.2020.9312

Formaciones Feedback. Tres proyectos con materiales granulares manipulados robóticamente

Feedback Formation. Three teaching projects on robotically manipulated granular materials

Medina-Ibáñez, Jesús[a]; Jenny, David[b]; Gramazio, Fabio[c]; Kohler, Matthias[d]
[a] Chair of Architecture and Digital Fabrication, Gramazio Kohler Research. ETH Zurich, Switzerland, medina@arch.ethz.ch; [b] Chair of Architecture and Digital Fabrication, Gramazio Kohler Research. ETH Zurich, Switzerland, david-jenny@arch.ethz.ch; [c] Chair of Architecture and Digital Fabrication, Gramazio Kohler Research. ETH Zurich, Switzerland, gramazio@arch.ethz.ch; [d] Chair of Architecture and Digital Fabrication, Gramazio Kohler Research. ETH Zurich, Switzerland, kohler@arch.ethz.ch

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Abstract

This chapter presents three different case studies on robotic fabrication as dynamic design processes, exploring the relationship between computational design, digital fabrication, and complex material systems in different teaching formats at the Department of Architecture at ETH Zurich. All projects explore the control of material formations through digital tools, creating an educational environment that allows the designer to directly interact with and develop an intuitive understanding of the material processes at hand, and suggesting a novel approach linking digital control with reversible construction techniques.

***Keywords:** construction, robotic, fabrication, design.*

***Thematic areas:** technology, digital fabrication/active methodologies/self-regulating learning methodologies, experimental pedagogy.*

Resumen

En esta sección se presentan tres diferentes propuestas sobre fabricación robótica como procesos de diseño dinámico, estudiando la relación entre diseño computacional, fabricación digital y sistemas de materiales complejos en diferentes formatos de enseñanza dentro del departamento de arquitectura de la ETH de Zúrich. Todos estos proyectos exploran el control en la formación de material a través de herramientas digitales, generando un entorno educativo que permite al diseñador interactuar de forma directa y desarrollar un entendimiento intuitivo de los procesos matéricos en cuestión, sugiriendo un enfoque novedoso que vincula el control digital con técnicas de construcción reversibles.

***Palabras clave:** construcción, robótica, fabricación, diseño.*

***Bloque temático:** tecnología, fabricación digital/metodologías activas (MA)/metodologías de autorregulación del aprendizaje (MAA), pedagogía experimental.*

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Fig. 1 Robotic Landscapes III Design Studio, Fall Semester 2019, ETHZ (Chair of Landscape Architecture, Prof. Christophe Girot + Chair of Architecture and Digital Fabrication, Prof. Fabio Gramazio and Prof. Matthias Kohler). Students: Leon Beck, David Brückmann, Tobias Etter, Mevion Famos, Claudia Fleischmann, Nicola Graf, Leo Graf, Luana Günthardt, Mathias Häcki, Hannah Kilian, Severin Kurt, Vanessa Magloire, Yuki Minami, Sakiko Noda, Joelle Schmied, Zehra Ter, Wei Wei Toh, Caspar Trueb, Lorin Wiedemeier, Yueye Xu, Matteo Zwyssig. Tutors: Ilmar Hurkxkens, Fujan Fahmi, Benedikt Kowalewski (Chair of Landscape Architecture), Jesús Medina Ibáñez (Chair of Architecture and Digital Fabrication)

Introduction

Technological innovation can reform our understanding of materials and their manipulation. Processes like robotic fabrication, 3D printing and sensing have introduced new methods for creative engagement and herald the discovery of new geometries and aesthetics. Here, we see academic teaching formats as a unique opportunity to explore new digital workflows at the intersection of scientific rigour and playfulness.

All three projects presented use granular material of different particle size from coarse sand to gravel. These are natural, inexpensive, accessible and reusable materials, and thus a perfect medium for iterative conceptual explorations in robotic material processes. Rather than using it as “un-informed” bulk material, the robotic manipulation can adapt to and control the behavior of particles, which is closer to that of a liquid than a solid-state material. Parameters defining time, speed, and acceleration of the robotic arm underline the dynamic nature of the design methods, while the design of end-effectors and spatial robot trajectories can be considered the starting-point of design. During the process, the design is repeatedly “handed over” to its inherent forces and behavior, a play between friction and gravity of material, between control by the machine and control by nature. Loose and therefore fully re-usable, the ephemeral beauty of granular material formations combines the creative production with a circular design strategy. (Fig.1)

Teaching Methodology

Utilizing digital technology within a curriculum means that relevant skills need to be taught in a rigorous way, yet creative freedom and explorations need to be encouraged. For the courses presented here, students are first introduced to different digital tools such as Rhino, Grasshopper and Python as a programming language. These computational skills are complemented with a basic understanding in robotic control to operate the robotic set-up. The small six-axis collaborative robots (Fig. 2) allow for a direct interaction with the machine and students quickly learn how to 3D print tools as end-effectors for the robotic arm. With this set-up, "The Digital" is presented as a process that facilitates new and creative connections between robotic and material processes through computation. Innovative approaches and computational competence are combined with unique robotic methods to foster an intuition for new models of production. The fabrication part enhance the world of ideas and concepts while working with technical knowledge, dynamic processes, material behavior and environmental conditions. Encouraged by the workings of digital tools, students are brought in contact with the characteristics of a multidisciplinary, integrative design method at the intersection of technology, science and creative learning and invited to critically reflect on their own design practice.

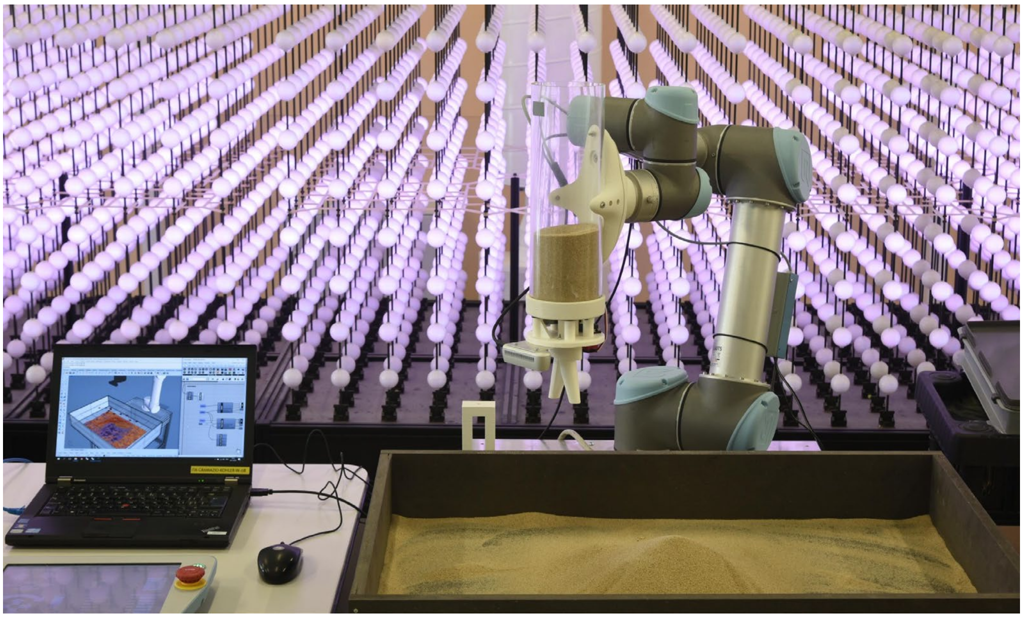

Fig. 2 Robotic Setup. The Digital in Architecture II. Fall Semester 2019. Chair of Architecture and Digital Fabrication
Prof. Fabio Gramazio and Prof. Matthias Kohler

Evaluating computational processes in relation to material behavior give processes primacy over products, while highlighting the intrinsic relation between process and product. What is computational efficiency when we work with self-organizing materials? Can we inform algorithms by sensing the context with 3D scanning and augmented reality tools? There is a broad effort in research to describe and integrate real-world processes in order to feed actual conditions as input in the digital process to inform design and online fabrication (Fig. 3 a & b).

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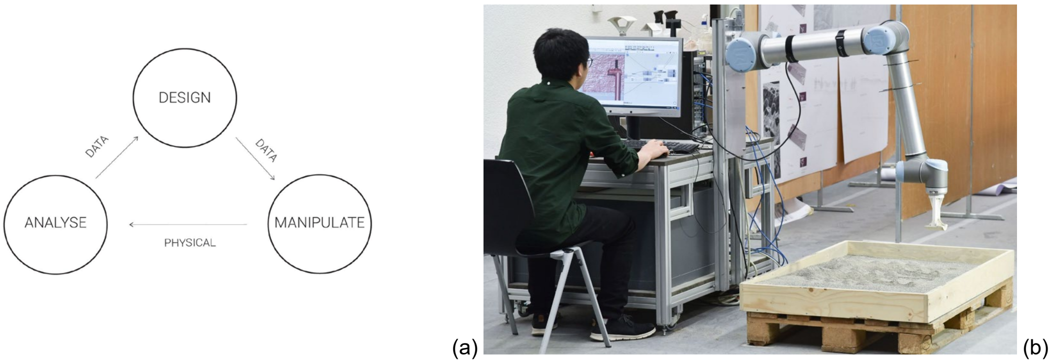

Fig.3 (a) Feedback loop diagram. Computational workflow for Designing-Manipulating-Sensing. Fig. 3 (b) Robotic Setup (UR10) for Material manipulation. Robotic Landscapes III, Fall Semester 2019. Chair of Landscape Architecture, Prof. Christophe Girot + Chair of Architecture and Digital Fabrication, Prof. Fabio Gramazio and Prof. Matthias Kohler

How can this translate into teaching formats where new forms of creativity, and novel material explorations are developed? In the following, three different teaching formats exemplify possible strategies. The different Case Studies operate at very different scales, from small scale abstract exercises (*The Digital in Architecture II*), to models which oscillate between sculpture and representational model (*Mini-Jammed*), to the modelling of landscaping scenarios for large swaths of land (*Robotic Landscapes III*).

1. The Digital in Architecture II

During the Fall Semester 2019, the Elective Course *The Digital in Architecture II* embraced the complexity of particle deposition (Fig. 4 a). In a series of weekly exercises, students expanded their skills in programming and robotic control, building upon the basic knowledge they previously acquired in the Spring Semester course *The Digital in Architecture I*. Along the course, students learned how to develop a simple fabrication and material-aware digital design process linked to a robotic fabrication procedure. The fabrication setup was pre-developed for the course and consisted of a small six-axis robotic arm with a custom-designed sand extruder (end-effector) built from 3D printed components and a plexiglas tube filled with sand. Students adapted the constant sand flow with parameters such as speed and acceleration of the robotic tool in addition to the geometrical description of the robotic path. While the CAD-drawing of an architect and designer has the inherent goal of precisely defining the physical product, here, the geometrical description of robotic paths remain indicative. The dynamic fabrication and material self-formation ultimately define the result. Within this teaching context, material behavior was not digitally simulated upfront, but understood in its performance by careful, iterative observations of the physical process. Students engaged in a dynamic learning process mastering parametric and algorithmic modelling in Rhino, Grasshopper and the Python programming language, thereby improving, optimizing and expanding, not only their design intention but also the code itself which can be reused, adapted and shared in other projects.

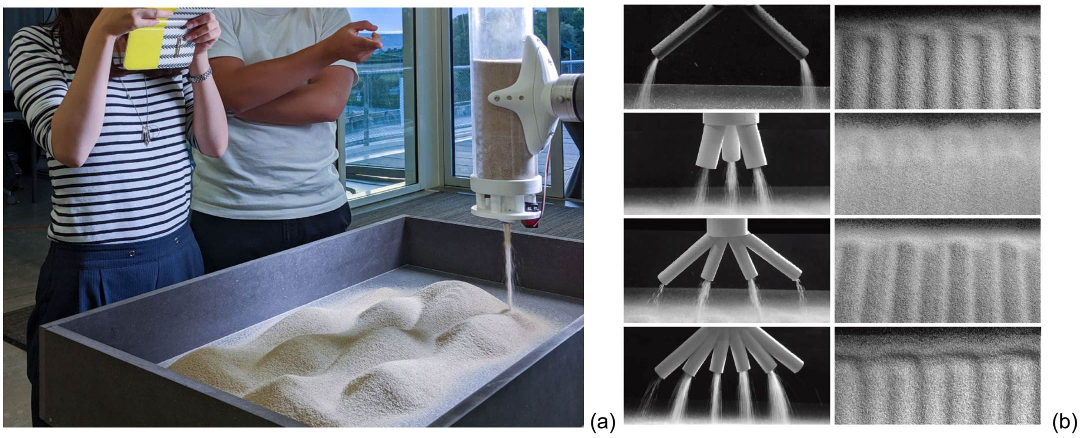
(a) (b)

Fig. 4 (a) Robotic sand deposition process (Students: Ruiqi Zhang, Ziou Gao (Tiger), Noa Nagane), ITA Elective Course The Digital in Architecture II, Fall Semester 2019. Chair of Architecture and Digital Fabrication, Prof. Fabio Gramazio and Prof. Matthias Kohler, ETHZ*. Fig. 4 (b) Custom 3D Printed Nozzle for Sand extrusion explorations* (Students: Hager Al Laham, Gordan Kucan, Laura Martin, Kaushik Ravi)

The projects carried out by four different groups approached robotic processes in different ways. Responding to the taught input on Rhino, Grasshopper, Python, robotic control, basic math operations, 3D scanning and material aware processes, students were able to execute simple robot commands, gradually building up complexity. They designed a custom-made 3D printed nozzle (Fig.4 b), which was attached to the end-effector for a tool driven manipulation where parameters such as sand flow had a direct influence on the extruded sand models. By doing so, the range of possibilities opened up to new ways of articulating robotic processes and sand deposition. One example was the creation of a series of multi-nozzle extruder, which led to very versatile tool in combination with the robot’s ability to tilt and rotate the tool.

The First project was developed as an exploration of different mathematical functions, where the robotic path was always changing in height and speed directly depending on the height value of the TCP (Tool Center Point) at each location. This procedure was executed along different iterations together with 3D scanning operations from where new variables were extracted from the point cloud as new feedback values. At the same time, a custom made 3D printed nozzle was attached to the end-effector being able to manipulate the sand flow while extruding, generating diverse design variations informed by previously scanned material layers.

The second project attempted to control material deposition by simply alternating the sand flow with “bi-nozzle” sand extruders. This operation was accomplished by computationally assigning determined plane rotations along straight robotic paths, leading to limit the robot maximum rotation angles where a constant sand flow still could be ensured. This opened up different possibilities in novel geometrical approached for 3D printed sand deposition nozzles.

The third project was presented as a procedural catalog of diverse calligraphic gestures, defined by a smart simple approach for different robotic configurations. Here, the need of a brush-like effect in a 3D Printed nozzle took different iterations until an appropiated diameter of the pipe could allow a constant flow of sand grains. This project demonstrated that sand deposition can yield to a large range of variations into an open ended design system where robotic speed and accelerations can turn into driver parameters referring to deposition and material self-formation.

The fourth project of the course took speed values as a main input parameters to control locally peaks of material accumulated along intersecting robotic paths. The final goal was to achieve a homogeneous distribution of sand by 3D scanning every iteration and compensating sand

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deposition in all this area where the material appeared in a lower height. In doing so, the students were able to activate a Feedback Loop that consisted of using re-mapped height values from a 3D scanned mesh in new speed parameters.

Understanding the complexity of this large and diverse range of parameters made students present their projects as procedural matrix catalogs (Fig.5 a), were information could be understood and easily explained during regular presentations with professors or external guests. This is an example of how students approached data management. Students learned how to integrate, transform, govern and present their data. They furthermore, integrated various outside sources such as 3D scanning. (Fig. 5 b)

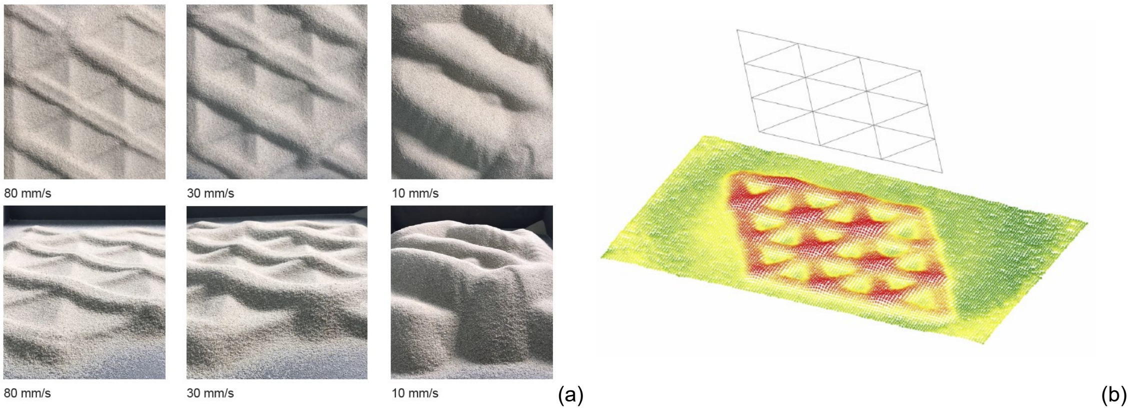

Fig. 5 (a) Variation of Speed while sand extrusion (Students: Jil Kugler, Ömer Acar, Philipp Henestrosa, Michaela Ulmann), The Digital in Architecture II, Fall Semester 2019, Chair of Architecture and Digital Fabrication, Prof. Fabio Gramazio and Prof. Matthias Kohler, ETHZ*. Fig. 5 (b) Point Cloud analysis for real time interaction (Sand height as speed parameter)*

2. Robotic Landscapes III

The Robotic Landscapes III Design Studio was the third iteration of a collaboration between the Chair of Landscape Architecture, Prof. Christophe Girot and the Chair of Architecture and Digital Fabrication, Prof. Fabio Gramazio and Prof. Matthias Kohler, during Fall Semester 2019. The studio sought proposals for large-scale robotic terrain modelling methods to make the Gürbe river and valley course, between the Bernese Alps and Midlands of Switzerland (Fig. 6 a), more resilient to flooding and mudflows. In response to the challenges of future natural hazards, students had to develop innovative topographic strategies to ensure a long-term equilibrium of the river in this dynamic, hence, constantly changing landscape.

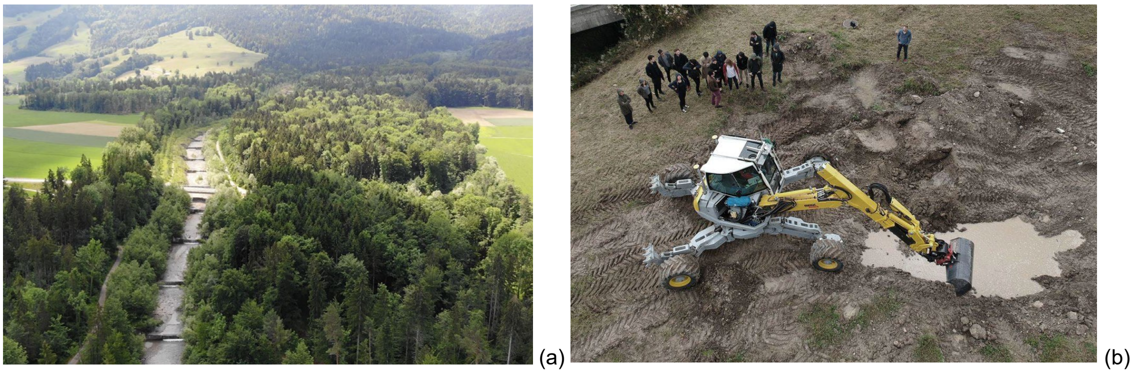

Fig. 6 (a) Drone view of Gürbe River and valley, Switzerland (Chair of Landscape Architecture, Prof. Christophe Girot)
Fig. 6 (b) Menzi Muck (Robotically Controlled Excavator) Robotic Systems Lab, ETHZ

The studio operated at two scales: First, the unifying vision for the project was the development of different computational design scenarios for the landscaping which were to be executed on-site by an autonomous excavator, an upgraded Menzi Muck excavator developed by the Robotic Systems Lab at ETH Zurich [JUD, D. 2017] (Fig. 6 b). Guided by digital data, this Menzi Muck is able to autonomously manipulate large amounts of soil and rock in difficult terrains.

Second, scale-models in the form of a sand-box were to be "aggregated" and manipulated with a small collaborative six-axis robotic arm to test and represent the suggested landscaping processes. The fabrication method was similar to the one used for the first course presented in this article. However, the design process was now informed by "real" parameters such as flood dynamics in relation to terrain, topography, vegetation, and settlements.

The Sand box is where both the physical (material) and digital layers (robotic paths) meet. The Sand box introduces a different way of understanding the landscape where explorations and mistakes lead to discovery. It can be understood as a piece of land that serves as a sketch box for materially informed computational design decisions. By robotically manipulating and shaping the coarse sand and fine gravel, both the material and the design are in continuous transformation. The studio methodology combined analogue design processes with digital design tools and fabrication. Different workshops on soil textures, robotic fabrication, and physical landscape modeling further guided the students in form-finding methods. (Fig. 7)

Along the Design Studio, the different student groups developed strategies responding to the diverse phases of natural events and debris flows in the valley. This analysis helped students to develop first concepts for their robotic manipulations in the sandboxes. For this, different digital and computational tools like Rhino, Grasshopper, Python programming language and *Docoffosor* plugin for Grasshopper [HURKXKENS, I. 2019], among others, were used in order to validate the design assumptions. Moreover, the material behavior of coarse sand required a feedback loop capable to inform the digital design for further iterations. For this, an Intel RealSense was attached to the robotic arm able to 3D scan the manipulated topographies. The goal of this method was to put the design focus on generating open processes instead of final geometries, reflecting the ever changing landscape as a natural process. From the 3D scan, students extracted other types of data such as maximum and minimum relative heights, paths along the surfaces, insertion points for material manipulation (pick and placing), operations between different iteration phases, etc... At the end, all this procedures were used to inform the intended 1:1 landscape intervention where the Menzi Muck excavator would act as the on-site machinery capable to manipulate boulders and material accumulations along the valley.

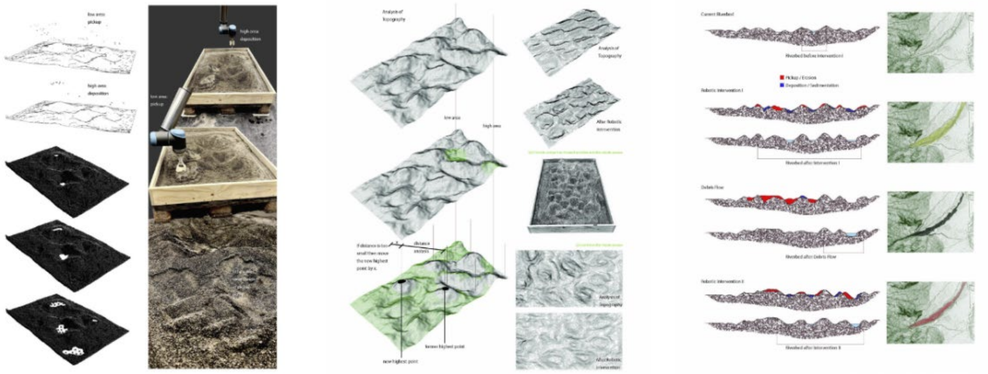

Fig. 7

Robotic strategy for material manipulation, Robotic Landscapes III, Fall Semester 2019. Chair of Landscape Architecture, Prof. Christophe Girot + Chair of Architecture and Digital Fabrication, Prof. Fabio Gramazio and Prof. Matthias Kohler, ETHZ

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Digital processes in landscape interventions are active when it comes to information processing systems, focusing at first level on natural hazards, natural material behavior, material formation and erosion, turning these parameters into fundamental ingredients for the development of each student project. That way, alternative strategies for understanding and intervening in unstable terrains can be developed where conventional protective measures such as debris flow structures and barriers common to the alpine regions are difficult to be executed or maintained.

3. Mini-Jammed

Mini-jammed was a three weeks design project during the MAS in Architecture and Digital Fabrication 2017/18 based on the *Jammed Architectural Structures* research (JAS) [AEJMELAEUS-LINDSTRÖM, P. *et al,* 2020]. JAS is based on a principle called "jamming", which refers to the aggregation of granular materials – such as gravel – that are crammed together in a way that they hold their form and shape like a solid under compression. JAS explores how the robotic placement of loose gravel can be combined with robotically placed layered string patterns to build fully reversible structures at architectural scale. For Mini-Jammed, the principle was explored at small-scale and students were encouraged to test the geometric and structural limits of jammed structures, investigating overhangs, voids, vertical textile reinforcements and post-tensioning, complex interwoven geometries, and equilibrium of multiple elements. (Fig. 8)

The project immersed the students in a computational and robotic fabrication strategy, digitally generating the string tool path and the sequence of gravel deposition. As the process is fully reversible, meaning the structures can be separated into a heap of fine gravel and a roll of string again, students could engage in physical prototyping and material testing using the same material repeatedly. Material was only temporally bound to a use while the digital and robotic processes were constantly optimized and design explorations became increasingly daring.

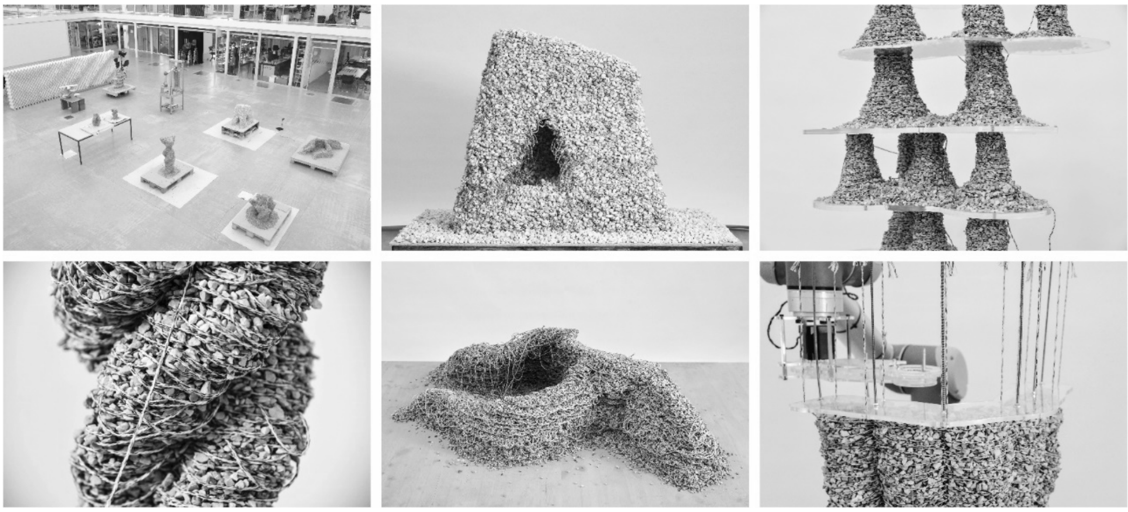

Fig. 8 Mini-Jammed project final designs. MAS in Architecture and Digital Fabrication. Chair of Architecture and Digital Fabrication, Prof. Fabio Gramazio and Prof. Matthias Kohler, ETHZ. Students: Rafael Pastrana, Jun Su, Frank Lin, Angela Yoo, Fernando Cena, Georgia Chousou, Yao Wang, Zong-Ru Wu. Tutors: David Jenny, Petrus Aejmelaeus-Lindström, Gergana Rusenova, Jesús Medina Ibáñez

Throughout the course, students expanded the boundaries by translating their personal motivations into computational logics informed by their understanding of the material. For instance, one group of students developed highly slender twisted columns reaching maximum overhangs, another project introduced a post-tensioning system activating structures under its jamming principle. At the same time, other approaches included the idea of exploring massive conglomerates of string and gravel of which voids could be extracted to form cavernous spaces in loose material. One group explored the combination of architectural elements such as wooden floor slabs to build multi-story structures and to have cantilevering parts. As such, the different explorations of all groups are understood as a collaborative design research exploration into a complex material and fabrication system.

The first project was developed as a proof of structural stability by introducing maximum overhangs. This operation was applied along its vertical axis by making use of a temporary perimetral scafold contained with sand and built inside a removable bricklane wall. This temporary support held the overhangs until the whole extra material was removed. The idea here was to locally define extreme symmetrical moments where the structure could keep its vertical balance in order to counteract the cantilevering moments. The implication of this strategy is far reaching, as it suggest the possibility of a vertical growth combined with extreme self-balancing overhangs systems generating a whole static system.

The second project introduced a post-tensioning system under compression forces activating its “jamming” principle by creating pre-fabricated elements. This operation certainly starts by engineering an end-effector, capable to interweave horizontally the string with pre-tensed vertical cords, generating inner pockets where gravel could be placed manually. This process breaks the notion of an on-site system oppening this technique to prefab jammed components.

The third project stayed within the purely exploration of voids inside jammed structures. The difficulty to generate negative spaces inside such as structures generated the starting point to define a smart and simple strategy that could contain computational challenges in combination with inner material removal. In its conventional fabrication approach, openings can only appear in a branching system that grows vertically by decreasing the section transitioning from wall to column typology, keeping the center of mass under its base. This project proved that simple vaulted openings not only is an extra design value to introduce in jammed structures, but also a feasible constructive solution that provides the basis for future developments in larger structures by aligerating weight after material removal bringing a potential of its use in architecture.

The fourth project sought the possibility of finding new typological potentials in high rise construction. This operation was presented as an opportunity to explore with jammed structures in height, towards new series of typological hybrids that combines gravel columns with wooden floors. This successful approach opened the discussion by introducing structural concerns as monolithism, structural continuity, load paths and horizontal bracing inside jammed structures, being the designer who stablishes the criteria. Finally, the team presented diverse solutions with different performances, in order to enlarge the range of possible solutions by operating at different scales and different context conditions.

Because of their complexity, none of the mentioned projects could have been simulated in a virtual environment. For that reason, what became meaningful in terms of learning was the human capacity to integrate learnt criteria in combination with the acquired computational and robotic fabrication skills. While the framework is computational, the result is a collaboration of man and machine, an intuitive exploration of material behavior and developed robotic processes.

4. Conclusion

The presented research and student projects formulate examples of how standard digital workflows can be rethought to integrate dimensions such as material reusability, sustainable

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design processes and waste reduction. While the large-scale projects envision a profound transformation of building methods, the same logic is applied at teaching level. What is conceived to be re-usable building material is also a re-usable model making material. Material processes can be scaled, yet retain their inherent logic. Consequently, students themselves can tangibly explore "the nature" of digital materiality, how material is informed through computational design and robotic fabrication processes and experience how such strategies can be employed at different scales, from a small abstract exercise to the shaping of landscapes. Although the implementation of research towards construction is not always directly applicable, it presents students important insights into a field of rapid developments and prepares them with skills to situate themselves as architects in the digital era. This includes developing an understanding of sustainability and sensibility for ecology, where material resources and process optimization are brought together into a more integrative architectural design process.

Along the different case studies explained above, students benefited from a variety of encounters with researchers and specialists of different domains. While students learned faster due to the expert input and became aware of underlying complexities and challenges, the researchers benefitted equally from these collaborative teaching projects. The creative power of a large group of students presented a wealth of solutions and different paths to how a certain technique can be employed. Committed to try and error, the solutions were often surprising and exceeded what had been believed to be the limits.

The common challenge in all projects presented is the material behavior during the process of manipulation and construction. Usually, digital processes are associated with efficiency and precision. However, to date, the precise modelling and simulation of the exact behavior of each particle is computationally too expensive and hence, not efficient. Thus, the projects rely on the controlled self-formation of the material, exploring different strategies from human observation and feedback (learning) to sensing and computational feedback loops. These processes explore the ephemeral beauty of a managed self-organization approach that balances natural forces with computational control procedures. These investigations are not limited to researchers but provide a rich ground for teaching explorations and experimental digital design in the field of human-machine collaboration.

5. Bibliography

AEJMELAEUS-LINDSTRÖM, P., RUSENOVA, G., MIRJAN, A., MEDINA, J., GRAMAZIO F., & KOHLER, M. (2020), Rock Print Pavilion: Robotically fabricating architecture from rock and string. Constr Robot 4, 97–113 < https://doi.org/10.1007/s41693-020-00027-8>

GRAMAZIO KOHLER RESEARCH. *Vimeo* <https://vimeo.com/user14316338> [Consult: August 4th 2020]

HURKXKENS, I., BERNHARD, M. (2019). Computational Terrain Modeling with Distance Functions for Large Scale Landscape Design. In: Buhmann, E., Ervin, S., Helh-Lange, S., Palmer, J. (Eds.), Journal of Digital Landscape Architecture, 4-2019, Wichmann Verlag, Berlin. <https://gispoint.de/fileadmin/user_upload/paper_gis_open/DLA_2019/537663024.pdf>

ITA ELECTIVE COURSE - THE DIGITAL IN ARCHITECTURE II. Gramazio Kohler Research, ETHZ. <https://gramaziokohler.arch.ethz.ch/web/e/lehre/401.html> [Consult: August 6th 2020]

JUD, D., HOTTIGER, G., LEEMANN, P. & HUTTER, M. (2017), Planning and control for Autonomous Excavation. IEEE Robotics and Automation Letters, 4 (2), 2151-2158. <https://www.research-collection.ethz.ch/handle/20.500.11850/172404>

THE DIGITAL IN ARCHITECTURE. Online platform for course teaching materials (ITA Elective). <https://gramaziokohler.github.io/teaching_materials/> [Consult: August 4th 2020]

ROBOTIC LANDSCAPES III - DESIGN STUDIO HS2019. Chair of Landscape Architecture, ETHZ. <https://girot.arch.ethz.ch/courses/design-studios/design-studio-hs2019-robotic-landscapes-iii-2> [Consult: August 6th 2020]

ROBOTIC LANDSCAPES III (Simulation). Chair of Landscape Architecture. *Vimeo* < https://vimeo.com/387934699> [Consult: August 4th 2020]

ROBOTIC LANDSCAPES III (Student work). Chair of Landscape Architecture. *Vimeo* < https://vimeo.com/387930860> [Consult: August 4th 2020]

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