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Anna Maria Manferdini

Architectural Engineer, researcher in the Faculty of Architecture of the University of Bologna. She teached at the Design Faculty of the Politecnico of Milan and at the Faculty of Engineering of Bologna. Her interests are focused on representation and on the use of multimedia technologies to communicate architecture and Cultural Heritage.

Elena Manferdini

Architectural Engineer, she has a Mater of Architecture from the UCLA. In the past 7 years she has been teaching architectural design studios at the SCI-Arc Los Angeles. In 2004 she funded Atelier Manferdini, a design office that has been recognized internationally for its ability to create imaginative architecture, fashion and object design.

Synthetic
Synthetic

I materiali sono generalmente associati ad una serie di caratteristiche fisiche che determinano le loro possibilità di utilizzo nel campo della produzione industriale. Recentemente stiamo assistendo ad un interesse crescente verso materiali artificiali concepiti come sistemi in cui geometria, texture, lavorabilità e finitura superficiale sono in grado di stimolare nuove sensazioni.
Questi materiali possono essere descritti come 'sintetici', poiché sono il risultato della sovrapposizione combinata di prestazioni e caratteristiche ottenute secondo processi che possono essere naturali oppure progettati artificialmente.
L'obiettivo di questo contributo è mostrare come l'utilizzo della micro-scala di elementi naturali quale fonte di ispirazione possa ampliare il repertorio di tipologie di materiali da rivestimento destinati all'architettura.

Traditionally materials have been associated with a series of physical properties that can be used as inputs to production and manufacturing. Recently we witnessed an interest in materials considered not only as 'true matter', but also as new breeds where geometry, texture, tooling and finish are able to provoke new sensations when they are applied to a substance.
These artificial materials can be described as 'synthetic' because they are the outcome of various qualities that are not necessarily true to the original matter, but they are the combination of two or more parts, whether by design or by natural processes.
The aim of this paper is to investigate the potential of architectural surfaces to produce affects through the invention of new breeds of artificial matter, using micro-scale details as inspiration derived from Nature.

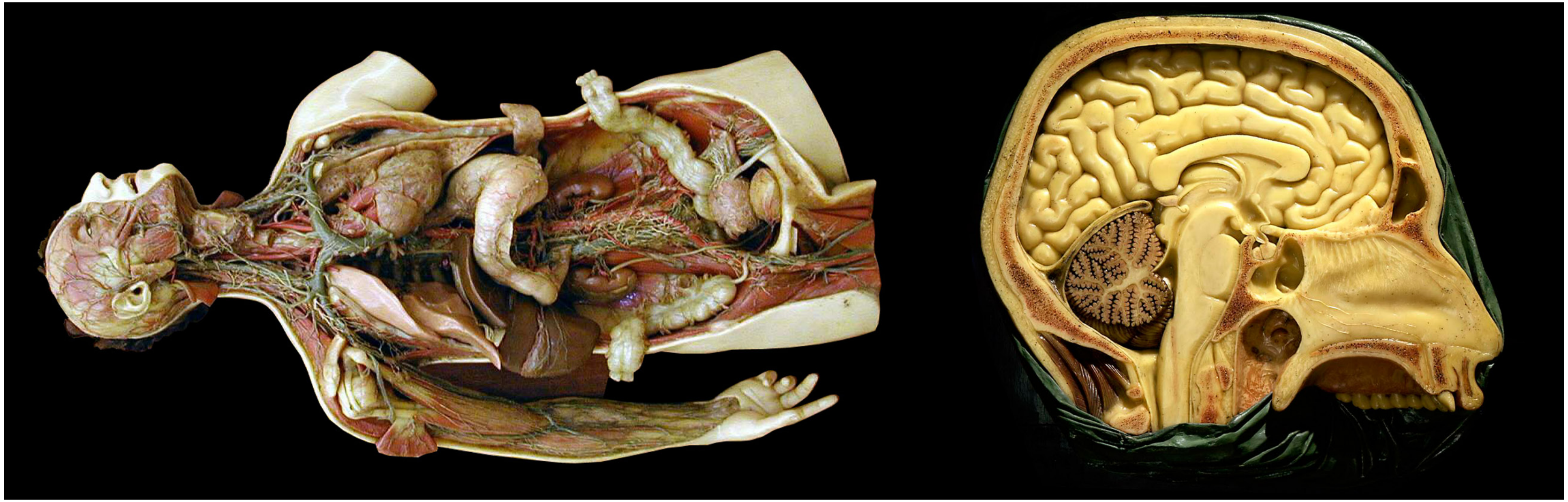

Fig. 1. Examples of wax models collected at the Anatomical Wax Museum "Luigi Cattaneo" of the University of Bologna. Left, wax model by Clemente Michelangelo Susini (1757-1814) representing head, trunk and right limb with demonstration of blood and lymphatic circulation. Right, wax model by Cesare Bettini (1801-1855) representing the magnification of brain and section of the cerebral hemispheres. Cesare Bettini started his career as wax modeler building models larger than real size.

INTRODUCTION

One of the most significant consequences of the introduction of digital technologies in the design and architectural field is the possibility to observe reality from different points of view and at different scales. Digital platforms allow interactions with computer models that can either represent reality or fiction. Therefore digital modelling is instrumental for imaginative and surveying purposes. In the past two decades the relationship between digital technology and creative strategies has been a widely discussed topic and it has been debated in several of its different aspects. Recently, we have witnessed advancements in scientific research and their applications in the digital technology field that have opened interesting new ways to access information and communicate our vision of reality or imagined scenarios.

Historically scientific research has always been supported by the use of tools that enabled observations from inconceivable points of view and different levels of detail. A rich production of illustrations that described and classified reality is the testimony of these advancements.

Starting from the Renaissance, one example of the importance of picture making has been the publishing of the most important treatise of descriptive anatomy (André Vésale, *De humani corporis fabrica*, 1543). In the same period Nicolaus Copernicus discovered that the Earth was no longer the center of the Universe, while Columbus had discovered America fifty years before. All these discoveries were supported by a rich production of illustrations that analyzed, understood and communicated new hypothesis and ideas.

Scientists have always built models, drawn diagrams and illustrations in order to test their intuitions, as well as to communicate the lessons learned during their experiments. Moreover, scientific comprehension has always required multiple scales of representation and various degrees of accuracy.

One of the fields in which scientific research has deeply changed the way of observing and representing reality is Medicine. Descriptive anatomy is the science of observation and discovery of reality and it is based on the practice of dissecting the internal structures of the body in order to understand the relationship between the various organs and their functioning. The dialogue established in the sixteenth century between the anatomist artist and the scientist,

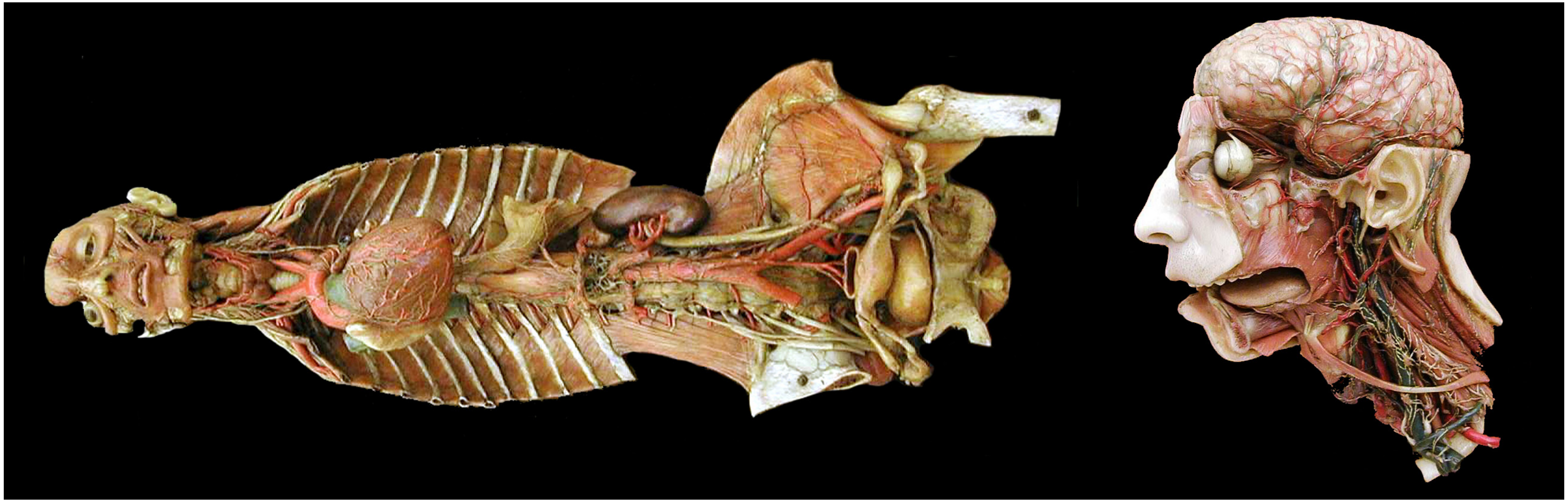

Fig. 2. Wax models by Clemente Michelangelo Susini. Left, representing head, trunk and demonstration of the arterial circulation and sympathetic nervous system. Right, head and neck with demonstration of blood circulation (Anatomical Wax Museum "Luigi Cattaneo" of the University of Bologna).

gave life to an extraordinary production of treatises about the human body [Vésale A., 1543; Del Medico G., 1811; Bourgery J. M. and Jacob N. H., 2008]. For scholars called to represent the three-dimensional shapes and their mutual relationships in space, these illustrations where exercises in understanding, as well as in representing. Their challenge was returning the verisimilitude of volumes, of the colors of matter and of the light that makes them visible.
In the XVI century, the use of more effective instruments as, for example, the optical microscope, revealed the extraordinary complexity of the micro-structure of matter, while in recent days, the discovery of X-rays allowed to see through flash and map the inner parts of the human body.
Furthermore, microscopic observations have been deeply widened since the introduction of the electronic microscope. This instrument doesn't use visible light, but electron beams to produce representations of small details. The combined use of digital instruments and exploitation of physical laws allows to give 2D graphic representations of invisible matter without using light as a mean through which visual experiences take place.
Science reached what is invisible to the naked eyes, looked through matter up to the atomic scale. Through centuries, this extension of the view have often forced the human kind to revisit the established scientific models, shift its moral beliefs and find new cultural perspectives.
Similarly to what happened five centuries ago, today digital technology allows to investigate reality and communicate it in a completely new way.
The lesson learned by Medicine is actually being applied to different fields, such as, cultural heritage, design and architecture.

KNOWLEDGE MODELS

Bi-dimensional representations are one of the most immediate tools to synthesize a problem, compare results and communicate information and achievements to a wider audience. These kinds of pictures display different levels of detail and simplification accordingly to their use and what they want to communicate.
We could recognize and classify a wide range of pictures, ranging from diagrams to detailed illustrations. Scientific diagrams usually have the

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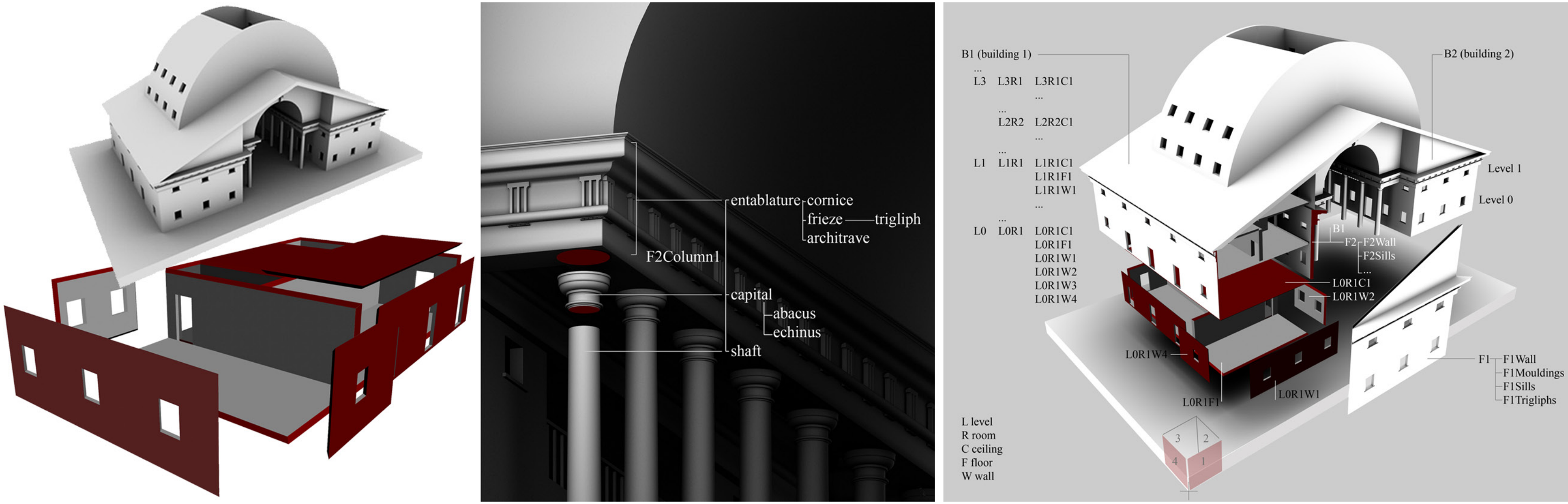

Fig. 3. Semantic segmentation of 3D model of an architecture (the House of the Surveyors of Claude-Nicolas Ledoux). From left to right, whole model, segmentation of the model, detection of sub-components based upon classical orders, naming and organization of the segmented model [Manferdini A. M. and Remondino F., 2010].

power to abstract from reality in order to isolate specific behaviors, laws and ideas. On the other hand, verisimilitude has often been used as a powerful tool to deepen analysis based upon visual observations; botany, biology and anatomy are the main fields in which these kinds of representations have been used as means of knowledge, as well as of communication. Historically, anatomic illustration has always played a leading role for scientific representation. As a matter of fact, in this field, in the XVI century, the shortcoming of bi-dimensional representation has been implemented by 3D wax models which described the full complexity of a reality that had intrinsic three dimensional characteristics and that could be therefore more easily verifiable and transmittable through the *physicality* of third dimension (*Figs. 1, 2*). 3D modelling from real data allows to return the intrinsic three-dimensional characteristics of objects that can be viewed from multiple perspectives and with different purposes, while previous 2d drawings provided a partial and subjective interpretation of reality.

Moreover, as wax modeling allowed to manipulate faithful replicas of the human body without actually acting on it, the possibility to acquire and restore three-dimensional real data in forms of digital faithful copies of it, allows to conduct experimentations and observations without intervening on reality. In addition to the detailed information that it is possible to acquire using digital instruments, which are qualitatively and quantitatively very similar to reality, three-dimensional representations are supported by mathematical models that allow to perform experiments in virtual environments.

Three-dimensional models are therefore cognitive models that allow investigations and prediction of outcomes in fields in which we cannot operate in reality.

Another aspect that characterizes 3D digital models is the possibility to use them in digital environments as graphic interfaces that allow to easily access data bases collecting different kinds of information and therefore increase the possibilities to conduct analysis and researches. The possibility to semantically segment models and visualize them using different degrees of simplification allow to customize the access to knowledge (*Figs. 3, 4*).

In order to increase the effectiveness of analysis

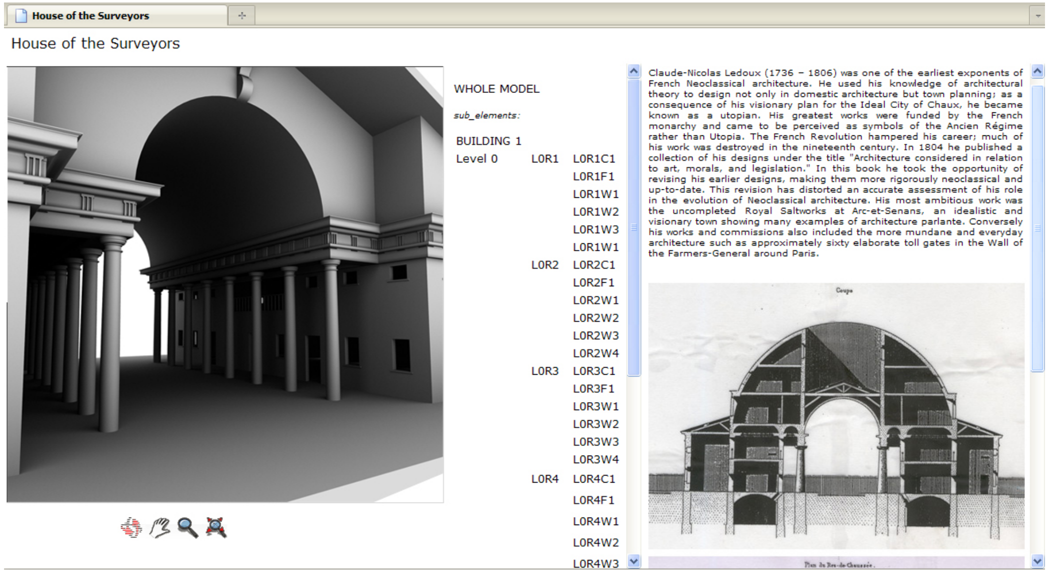

Fig. 4. Visualization of the 3d model in a 3D database. The 3d model is a graphic interface that allows to link different kinds of information [Manferdini A. M. and Remondino F., 2010].

conducted using 3D digital models, scientific research is actually focusing and improving tools and methods to acquire real data in order to build extremely detailed and therefore faithful digital replicas of reality.
This trend towards similarity is primarily due to the belief of the effectiveness of communication using reality based models. In some contexts, reality based models provide a wider range of information because of their detailed representation that often replaces other communication channels, such as, for example, oral or written explanation.
The possibility to investigate a digital model through its micro-scale details allows to observe and understand its structure and aggregative principles that we cannot have a direct experience of.
Moreover, a model that is conceived and built as a replica of reality is assumed to have been built without subjective interpretation by the modeller, so that it can be used by different users and for different purposes that can change through time.
In addition, the opportunity to observe three-dimensional models that restore a deep likelihood extends the possibilities to use them over time, guarantees its transmissibility, interpretation and use by scholars belonging to different cultures and living in different periods of time.
In order to build digital models that hold the characteristics of objectivity and, at the same time, similarity to reality, scientific observation must be conducted according to universality and consistency criteria, in order to represent reality with the least ambiguity.
But the characteristics of objectivity and fidelity to reality of representations using digital models recently started a debate that is still open and that is currently following two different approaches.
On one side the objectivity of representation is achieved when the virtual model is similar to reality in terms of graphic rendering and metric accuracy. In this context, the attention to micro-scale details generally tends to make the model plausible even as a whole.
On the other hand, tools to explore digital models are actually introducing simplification and imperfections in the digital representation in order to re-built reality as we perceive it through the senses (think for example about the limitations of our visual perception of objects in space). In order to both

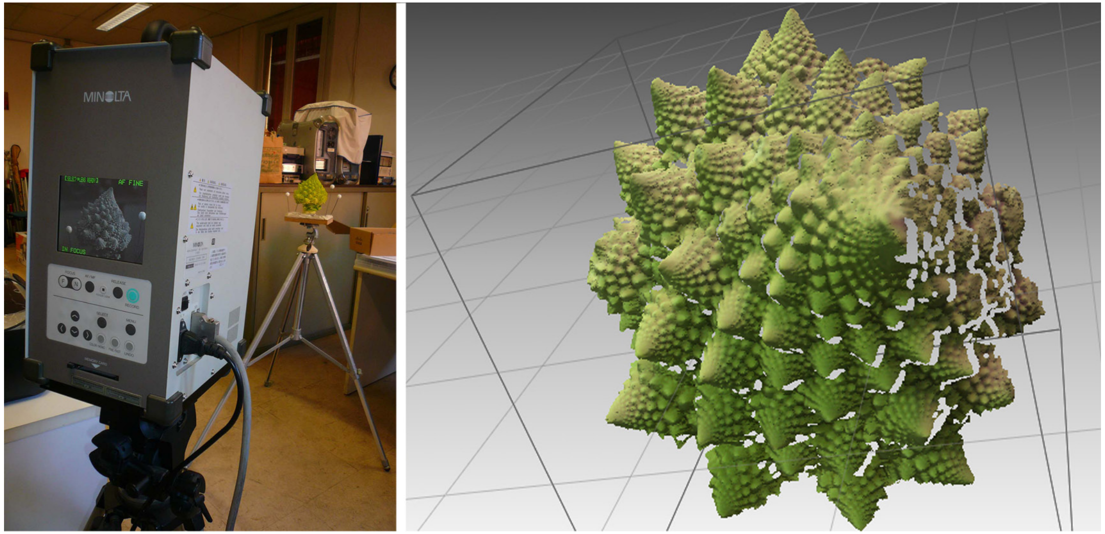

Fig. 5. Acquisition of cabbage using a triangulation laser scanner and derived 3d polygonal model.

preserve the integrity of the reality-based stored data and meanwhile allow users to customize their fruition and perception of information, similarly to what happens using the senses, these simplifications can be introduced during visualization phase.

DIGITAL NATURE

In this paper, the subjects of the observation of reality and of the use of three-dimensional models is applied to the natural datum.

Nature can be considered an interesting field of investigation and experimentation; as a matter of fact, the repertory of images and forms from Nature suggests applications in different fields, such as, for example, design.

The observation of Nature and the acquisition of its micro-scale details was the starting point of a research conducted between the SCI-Arc Southern California Institute of Architecture of Los Angeles and the Department DAPT of Architecture and Urban Planning of the University of Bologna, whose results are visible in some images of this article.

The research, conducted from investigations carried out by Anna Maria Manferdini in the Silab Laboratory of the Dep. DAPT, has been developed by Elena Manferdini and followed by applications within the *Synthetic* seminar held at SCI-Arc during spring 2010.

RESEARCH AIM AND METHODOLOGIES

The aim of this research is to analyze data derived from Nature and observe the micro-scale details of matter acquired in forms of digital three-dimensional models, in order to understand the shapes of micro-structures, their aggregations, thus drawing on a repertoire of new spatial forms.

Through the manipulation of these shapes, the cognitive process allows to experience alterations of reality and, therefore, to understand the rules of connection, working and interaction with the different contexts in which the natural element is located.

The research started from the digital three-dimensional acquisition of case studies drawn from plant and animal kingdom that were chosen as significant in terms of shape complexity and of the levels of detail of their recurrent geometry.

The analysis was conceived as an iterative process of constant handling, testing and checking for understanding reality and experiencing formal

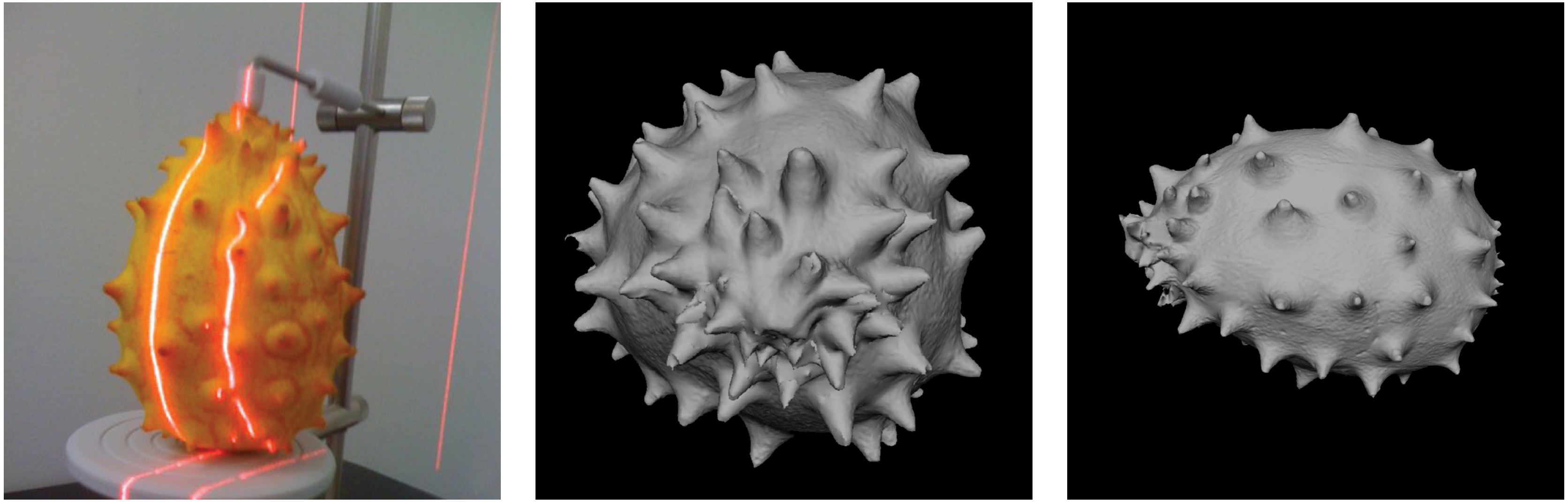

Fig. 6. From left to right, 3d acquisition of kiwano using a triangulation laser scanner and derived 3d model (credits: Kristen George, Jesus Banuelos).

results that were different from those observed in reality.
Through the whole process, both analogical and digital procedures were used as agents of comprehension and design innovation.
The research provided a continuous transition from digital three-dimensional reality, that therefore could be experienced only through the use of two-dimensional outputs (monitor or printer), to the physical one. CNC machines combined with various techniques of tooling, laser etching, casting, vacuum forming, painting, and finishing were employed to fabricate physical model of the digital tree-dimensional acquisition.
Thanks to the use of the third dimension and of matter which are perceivable by touch, as well as vision, physical models are able to produce different sensory effects. Modulation of texture, relief and colours derived by 3D scanned materials were the primary design sources. Drawings have been used as a method for generating detail in artificial matter rather than tools of architectural representation, while scanning acted as a new kind of drawing, as a way of sectioning substances and collecting three-dimensional information.
In addition to these aspects, the possibility to investigate a digital model through its micro-scale details allows us to draw inspirations from a wider range of images that appear new to us because we haven't had a direct sensory experience with them before. Within the design process, these images can suggest interesting applications in different fields, with innovative formal results.
This continuous research of new stimulations and graphic and sensorial effects also involved investigations on matter.
Traditionally materials are associated with a series of physical properties that can be used as inputs to production and manufacturing. These characteristics can be catalogued as the literal behaviours of matter. Recently we witnessed an interest in materials not only as "true matter", but also as a new breed where geometry, texture, coloration, tooling and finish are able to provoke new sensations when they are applied to a substance. These artificial materials can be described as synthetic because they are the outcome of various qualities that are not necessarily true to the original matter, but they are the combination of

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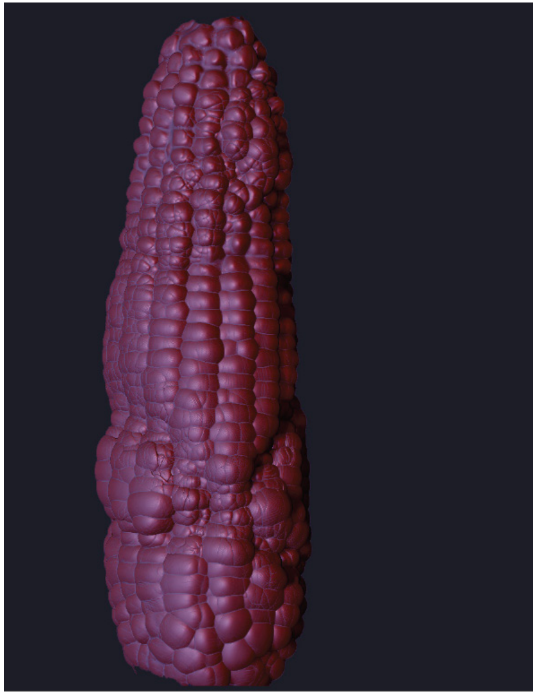

Fig. 7. From left to right: 3D model of corn from laser scanner; deformation of the scanned shape and creation of a different morphology. The right image shows the transition from the original scanned surface to the modified shape (credits: Sona Gevorkyan and Magdalena Zeller).

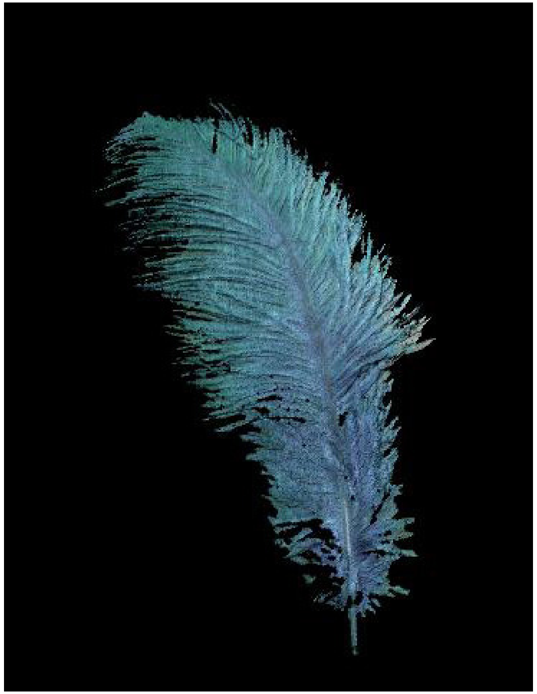

Fig. 8. From left to right: 3D model of feather of ostrich from laser scanner; varied model with augmented relief in order to supply the resolution of laser scanner and add dynamism to the model (credits: Yu-Hsuan Lu, Tiantian Sun).

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Fig. 9. Manipulation of the 3D model of feather of ostrich. The detail of the model has been augmented using Pixologic® ZBrush® tools that allowed to accentuate characteristics of the feather like fineness, fluttering and branching (credits: Yu-Hsuan Lu, Tiantian Sun).

two or more parts, whether by design or by natural processes.

Because of the recent developments in digital technologies and manufacturing nowadays the haptic and visual aspects of materials clearly dominate the architectural discussion, moving away from any prescriptive approach or predetermined outcome, releasing any moral judgment about the right way to use materials. In addition, since digital processes became sophisticated in hiding their procedures, the boundary between real and artificial has become even more blurred.

Within this research, physical 3D models have been built using synthetic materials with the purpose to extend the potential of 3D surfaces, experience new visual and tactile effects and, at the same time, distinguish between manipulated (synthetic matter)

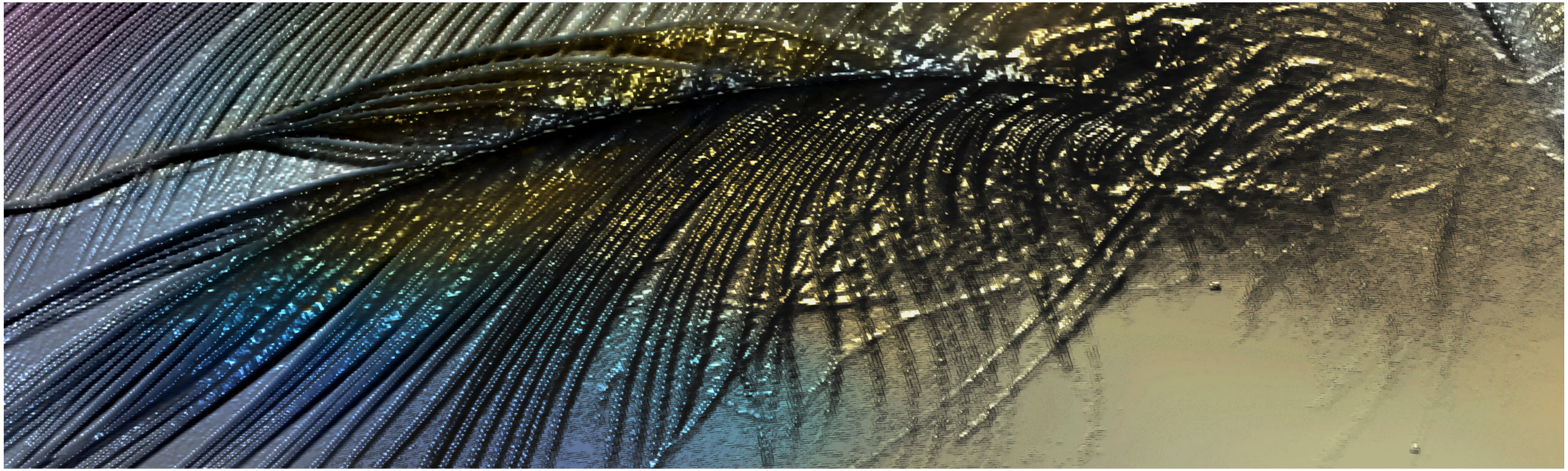

Fig. 10. Digital model of a feather acquired from laser scanner and manipulated using ZBrush®, that allows to add micro-scale details derived from 2d images (credits: Ekaterina Zavyalova, Huan Liu).

and detected data (biological matter). These synthetic materials have been tested, mixed and assembled using production techniques that can be replicated in laboratory.

CHALLENGES

The research highlighted some critical aspects and technical problems that were regarded as challenges and interesting inputs for further investigations.
One of the main challenges of the research was to test the possibilities of enlarging the dimension of micro-scale details, without losing 3d geometric information. During the whole process, the quality of 3d models has constantly been compared to the required level of details provided by magnification of 2d images. Within the acquisition phase, the level of detail of 3d surfaces mainly depends on the definition of 3d scanners and on the geometric characteristics of the detected object. Actually 3d scanners are not able to survey the same level of micro-scale details that it is possible to acquire using optical microscopes. In order to supply this lack of information, reality-based models have been implemented using 3d modeling packages (Pixologic® ZBrush®, Autodesk® Maya®) that allow adding the third dimension to 2d images. This improvement added hyper-realistic effects to the digital models.
But even if on one hand this process has improved the expressivity of 3d models, on the other hand, this addition of 3d information has reduced the possibilities of managing huge data sets in digital environments. As a matter of fact, a crucial problem due to the use of range sensors is the heaviness of files in terms of memory consumption. In addition, the use of high polygon models also affects the building of physical models derived from digital ones. Within this research, many different manufacturing methodologies and procedures have been tested, each one highlighting different characteristics and critical aspects. For example, CNC machines software present difficulties in managing geometries directly derived from 3d scanners, so that decimation and conversions to NURBS surfaces have been required before production process.
Decimation consists in processing algorithms that are able to reduce the number of polygons of surfaces, without losing detail in areas where mesh is required to be more accurate. Some of the most widespread algorithms allow to collapse vertices or edges where the surface is semi-planar. But the preservation of the right level of detail through the recognition

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Fig. 11. Physical panels derived from the 3D model of the feather of an ostrich. (a) the use of translucent matter and the overlay of different manufacture highlights the lightness of the feather through visual depth. (b) the intricacy of its micro-scale details has been re-built using different processes. In particular, MDF has been first milled in order to create main depth. This phase was followed by laser etching of the surface to reproduce the fineness and delicacy of the same geometry at alternate scales (credits: Amber Bartosh and Kristofer Leese). (c) acrylic panel derived from the laser cut of the model (credits: Yu-Hsuan Lu, Tiantian Sun).

of sharp edges and boundaries is not a mature procedure yet. In particular, within this research, we used Decimation Master®, a plug-in for ZBrush®, in order to preserve the required complexity.

Where decimation caused the loss of information, reliefs have been augmented both intervening on geometry and texture.

During the whole research, different technologies have been overlaied in order to create hyper-realism and supply to the lack of definition provided by acquisition and manipulation digital tools. Each step of the process has pushed the boundary of visualization and geometrical description to exceed the original data: relief has been accentuated, texture has been contrasted and colours have been brightened.

CONCLUSIONS

This research has been an interesting occasion to evaluate how to manage digital models derived from 3d scanners and turn them into physical models using manufacturing procedures.

Digital environment was used as a testing ground on which experimenting the magnification of micro-scale details. We faced the problem of the addition of 3d information in order to overcome the lack of precision of range scanners combining reality-based acquisitions and reliefs built using detailed 2d images as inputs.

After those manipulations, from digital environment the models have acquired a real physicality.

The problem of the reduction of complexity of geometries without losing the required level of detail was faced using non isotropic simplification procedures. But in some cases the automatic recognition of singularities using decimation algorithms did not provide the required results.

Although many technologies and methodologies to acquire and manipulate accurate 3d models are actually available and widespread, nowadays the best way to build reality-based 3D models that contain a pre-defined level of detail is still a combination of different modeling techniques. In fact, as a single technique is not yet able to give satisfactory results in all situations, concerning high geometric accuracy, portability, flexibility as well as hyper-realism, image-based and range-based techniques are often combined to fully exploit the intrinsic potentialities of each approach.

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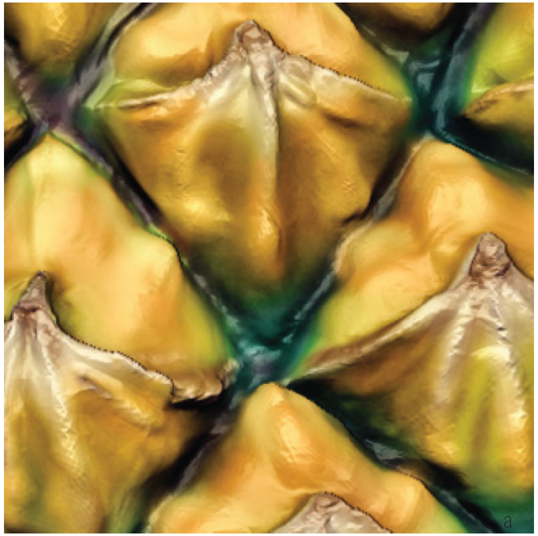

Fig. 12. Manipulation of the 3D model of a pineapple. (a) the original surface forms spirals that grow both clockwise and counter-clockwise. This sequence has been used as an inspiration during its manipulation. (b) process of the production of the physical panel derived from the pineapple. From left to right, milled mold for vacuum forming, vacuum forming, rubber casting and final model (credits: Dong Jun Park, Nanao Shimizu).


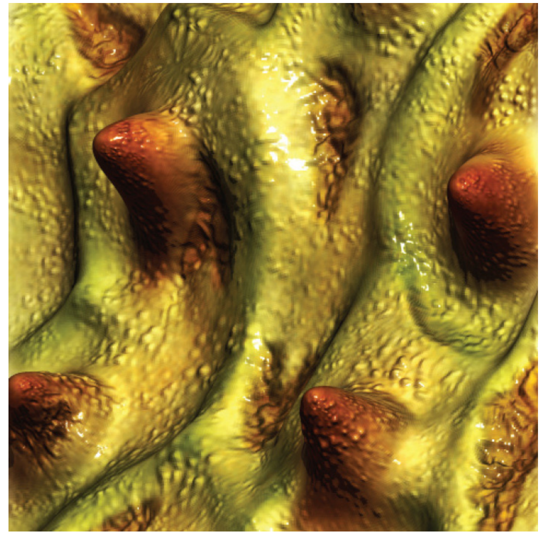

Fig. 13. Digital model derived from cherimoya. Right, pronouncement of the nodules and ridges (credits: Elisabeth Neigert, Anthony Lagunay).

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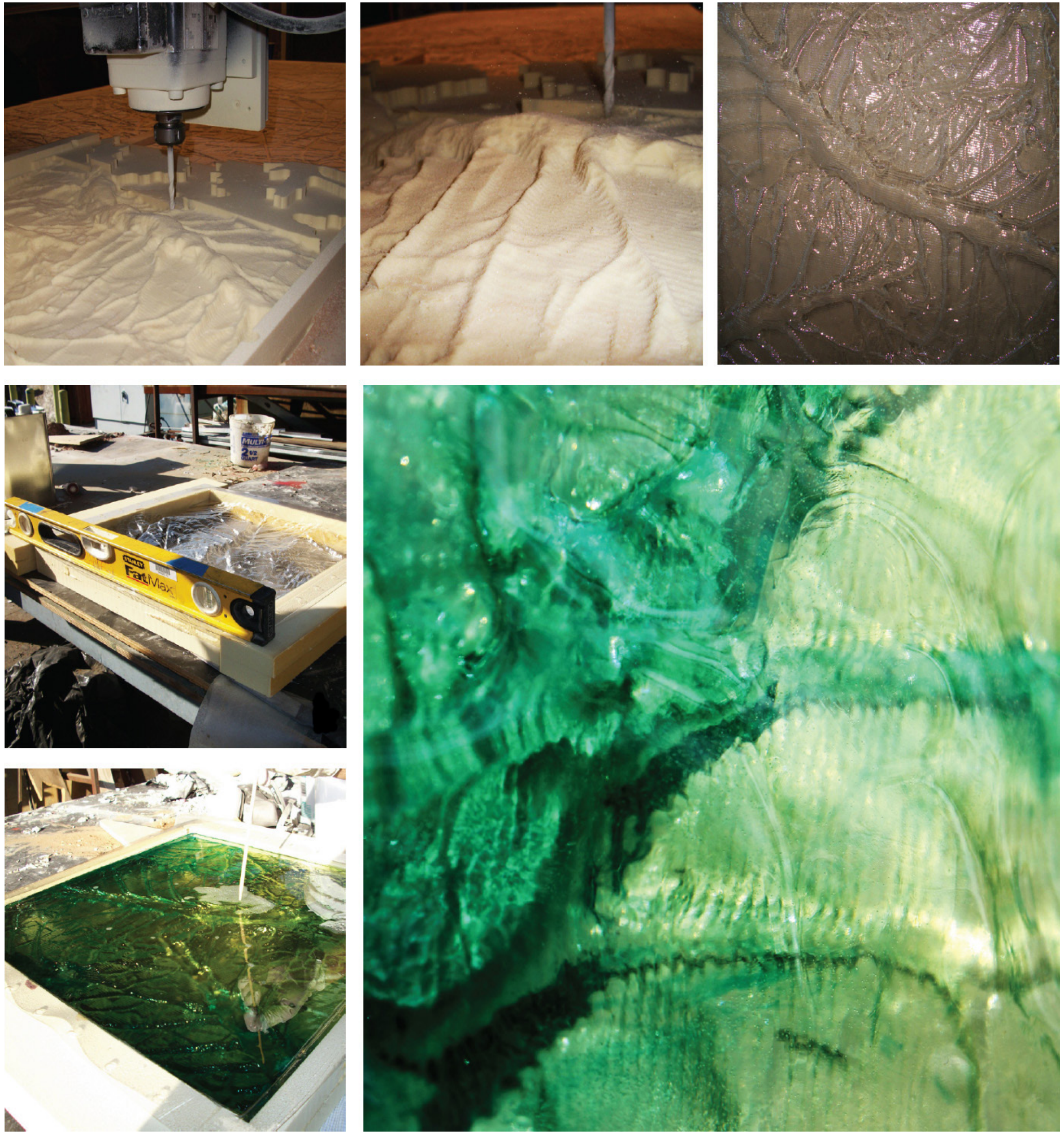
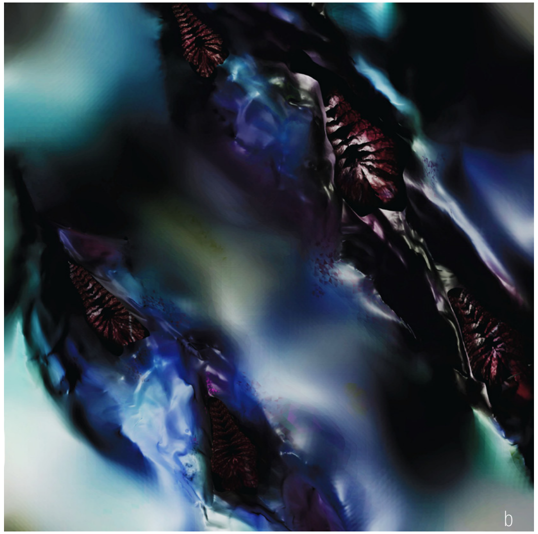


Fig. 14. Process of the production of the physical panel of a brassica oleracea linne. The foam model was created using a CNC milling machine. From top left, rough cuts and finish cut. This panel was then vacuum-formed in order to create the mold that was used to pour the resin for the production of the final panel (bottom right). All these phases usually involve the loss of definition due to physical imperfection and limitations of the adopted tools. In order to supply this loss of information, the digital model had therefore been deeply detailed before its fabrication (credits: Lisa Diaz, Pil Hyun Hwang).

Fig. 15. Manipulation of an oyster shell; (a) photograph; (b), (c) the manipulated model was created pivoting around the contrast between smooth and rough surfaces of shellfish and shell (credits: Christopher Day, Joshua Moratto).

a



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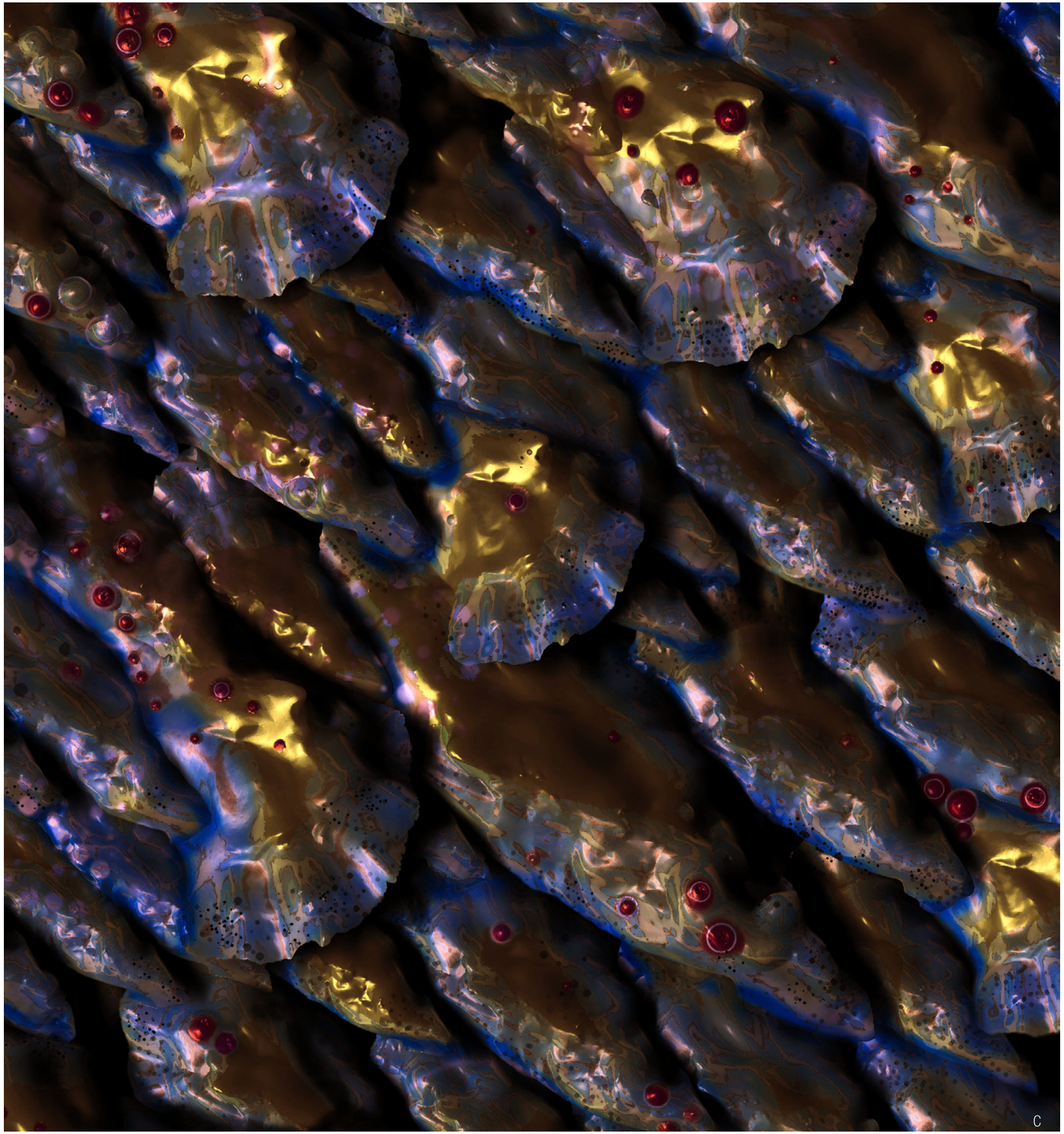

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