



Synthetic

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Abstract

Purpose:

The aim of this paper is to show the results of a research whose aim is to investigate the potential of architectural surfaces to produce hyper-realistic effects through the invention of new breeds of artificial matter, using Nature and the observation of its micro-scale details as a field of investigation which is instrumental in analyzing and understanding its structure and behaviour.

Method:

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 geometry. Physical 3D models have been built using artificial materials with the purpose to extend the potential of digital surfaces and experience new visual and tactile effects. Modulation of texture, relief and colours derived from 3D scanned materials were the primary design sources. 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 3d acquisitions. The research provided a continuous transition from digital reality to the physical one: through the whole process, both analogical and digital procedures were used as agents of comprehension and design innovation.

Result:

One of the challenges of this research was to test the possibilities of enlarging the dimensions of micro-scale details acquired using 3d laser scanners, without losing geometric detail. During the digital manipulation process, the quality of 3d models has constantly been compared to the required level of details provided by magnification of 2d images. In order to supply the lack of information due to laser scanner accuracy and resolution, reality-based models have been implemented using 3d modelling packages that allow adding the third dimension to 2d images. This improvement added hyper-realistic effects to digital models, with evident drawback upon the possibility of managing huge data sets, so that decimation procedures became necessary to overcome this aspect. In order to create new visual and tactile repertoire of synthetic materials, many different manufacturing methodologies and procedures have been tested, each one highlighting different characteristics and critical aspects.

Discussion & Conclusion:

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, so that image-based and range-based techniques are generally combined to fully exploit the intrinsic potentialities of each approach.

1 Introduction

Architects have been taught that materials have a “true nature” and they should be used accordingly to these physical properties [1].

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. These artificial materials can be described as “synthetic” because they are the outcome of various qualities that are not necessarily true to the physical property of a specific matter, but they are the combination of multiple stratification, 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 [2, 3, 4, 5], 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.

2 Purposes

The aim of this paper is to show the results of a research held in order to investigate the potential of architectural surfaces to produce hyper-realistic effects through the invention of new breeds of artificial matter, using microscopic details derived from Nature as point of departure.

Nature has been chosen as an interesting field of investigation because of some peculiar characteristics. In particular, the observation of its micro-scale details is instrumental in analyzing reality, understanding its behaviour and let us access to new repertoires of images and 3d shapes.

Historically Nature has often provided case studies upon which scientific research has conducted investigations supported by the use of tools that enabled observations from inconceivable points of view and different scales. A rich production of illustrations that described and classified reality is the testimony of these researches and advancements.

Scientists have always used representation codes as knowledge mean, as well as for communication aims; they 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. In the XVI century, for example, the use of more effective instruments such as, for example, the optical microscope, revealed the extraordinary complexity of the micro-structure of matter, while in recent days, science reached what is invisible to the naked eyes, looked through matter up to the atomic scale.

Similarly to what happened five centuries ago, today digital technology allows to investigate reality and communicate it in a completely new way. Recently, the use of tools and procedures to acquire reality in forms of 3d digital models allows managing information that reproduce spatial characteristics of 3d shapes and hold different levels of complexities.

In this context, the present paper aims at showing the results of investigations on the potential of digital technologies in acquiring real data derived from Nature, manipulate them in a digital environment and create new visual and tactile repertoire of synthetic materials.

3 Research methodology

The research started from the digital 3-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 geometry.

Our purpose was to use digital technologies to enlarge micro-scale details and therefore allow to directly experience these magnifications through the senses, without losing detail. In addition, these case studies have offered us the possibility to test the performances of digital technologies in acquiring small scale 3d shapes and physically reproduce them using digital procedures.

In order to directly derive accurate and detailed 3d information from reality, two different triangulation laser scanners were tested and the derived data have been analyzed in order to compare them with the original ones and with our pre-defined communication aims.

In particular, we used Konica Minolta Vivid 900 and NextEngine Desktop 3D scanners, whose main characteristics are:

Minolta Vivid 900, tele lens (f=25 mm), distance 60 cm, fine mode:

accuracy: $x=\pm 0.22$ mm; $y=\pm 0.16$ mm; $z=\pm 0.10$ mm
resolution: $x=y=0.174$ mm; $z=0.052$ mm

NextEngine Desktop 3D scanner, macro mode:

accuracy: 0.127 mm
resolution: 400 dpi

When survey technologies didn't allow to acquire the pre-defined level of detail, information have been implemented using different tools and methodologies. For example, in case studies that have very small details and volatile characteristics, such as feathers, the enlargement purposes haven't been fulfilled using only laser scanners because their performances were lower than minimum dimensions of micro-scale details in terms of accuracy and resolution.

Figs 1, 2 and 3 show the meshes derived from some vegetables and feathers and the limitations of laser scanners in acquiring the pre-defined level of detail.

In those cases the surveyed 3d models have been implemented using high definition 2d images and 3d modelling packages such as Autodesk® Maya® [6] and Pixologic® ZBrush® [7]. Through those software, the scanned three-dimensional surfaces have been enriched through micro-irregularities generated by the software that used 2d magnification photos as inputs and translated radiometric information into 3d geometry. Within this process, micro-geometry has been rebuilt assuming lighting and colour as parameters to define reliefs and convexities, integrating the digital reconstruction where laser scanner failed.

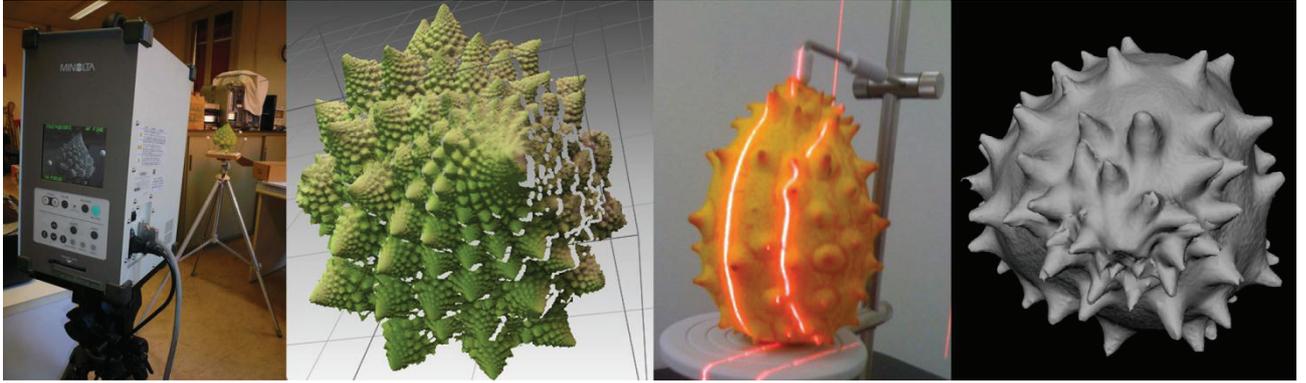


Fig. 1 Images of the acquisition phase. Left, survey of the geometry of a cabbage using the Konica Minolta Vivid 900 triangulation laser scanner; right, acquisition of a kiwano using the NextEngine Desktop 3D scanner. In both cases, the acquired geometry has been supplied with micro-scale details derived from high definition 2d images.

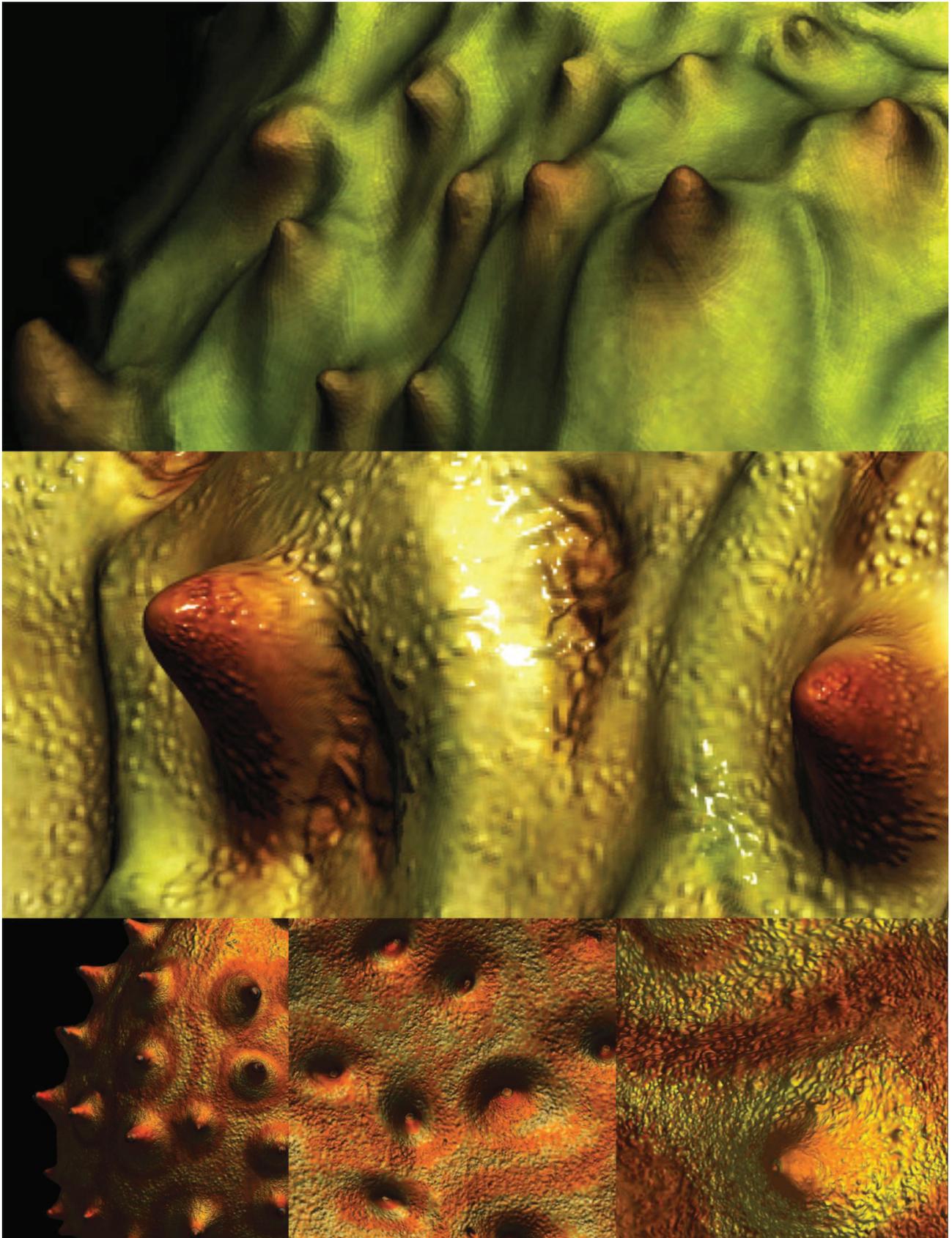


Fig. 2 Top, polygonal model of a kiwano derived from laser scanner. Center and bottom, the 3d model has been enriched through micro-irregularities generated by the software through the use of high definition 2d photos in order to add hyper-realistic details to geometry (credits: Jesus Banuelos, Kristen George, Anthony Lagunay, Elisabeth Neigert).

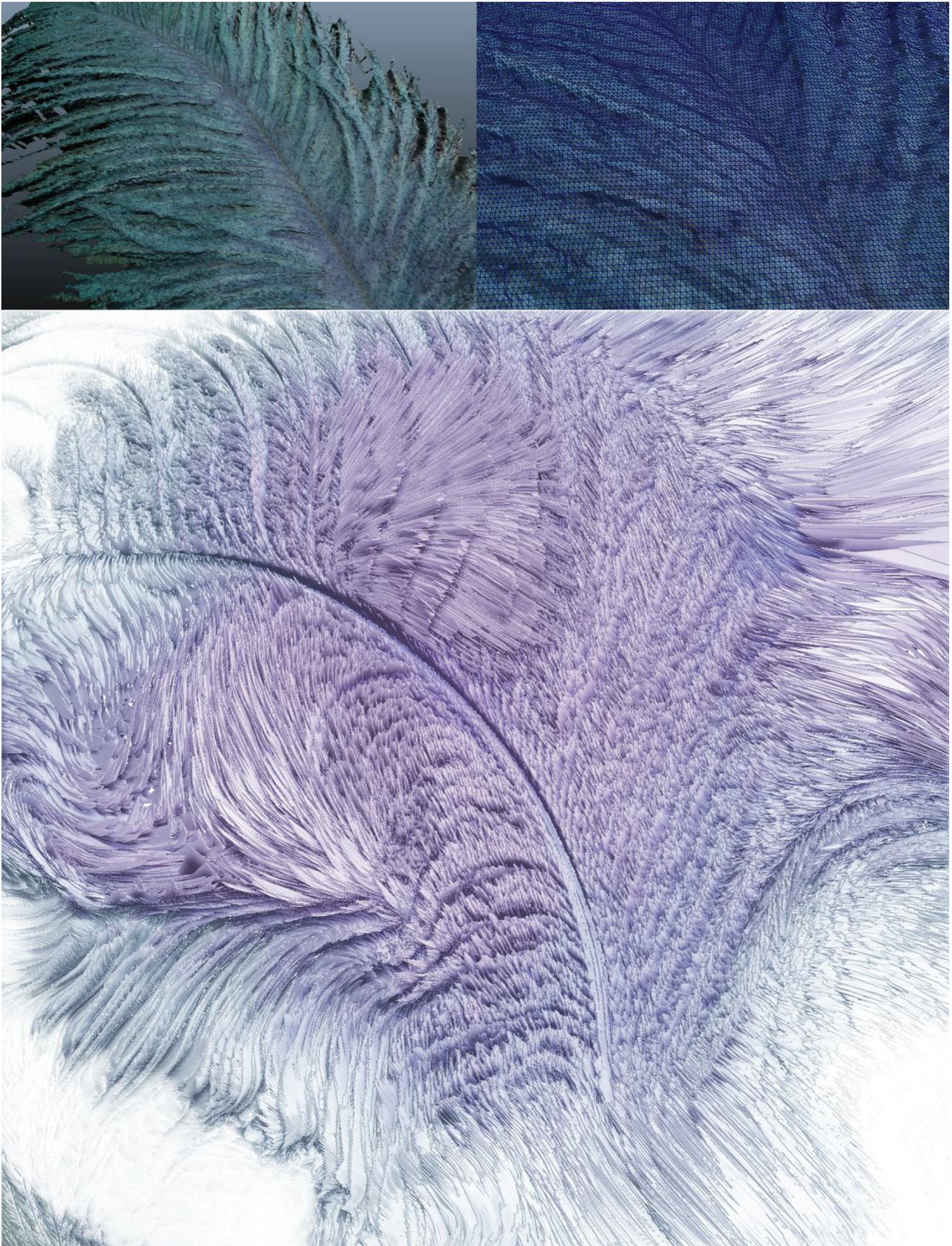


Fig. 3 Top, polygonal model of a feather derived from laser scanner. Left, the volatile elements near the border of the feather haven't been detected by laser scanner; right, tessellation of the mesh is not adequate to the pre-defined level of detail.

Bottom, the same 3d model has been enriched through micro-irregularities generated by the software that used 2d magnification photos as inputs and translated radiometric information into 3d geometry. The varied model with augmented relief supplies the resolution of laser scanner and adds dynamism to the model (credits: Yu-Hsuan Lu, Tiantian Sun).

Assuming that observation can be considered as a multisensory approach to reality, the research has investigated the possibility to sensory experience mutations developed in a digital environment using both sight and touch. The research provided a continuous transition from digital three-dimensional reality to the physical one in order to analyze data and compare them with the pre-defined purposes.

Through the whole process, both analogical and digital procedures were used as agents of comprehension as well as design innovation.

Within the transition from physical reality to a digitally manipulated one, multisensory checks represented an

essential experience towards knowledge purposes. Physical 3D models have therefore been built using synthetic matter and procedures in order to extend the potential of 3D surfaces and experience new visual and tactile effects.

Figs 4 and 5 show some phases of the fabrication process.

Modulation of texture, relief and colours derived from 3D scanned materials were the primary design sources. CNC machines combined with various techniques of tooling, laser etching, casting, vacuum forming, painting and finishing were employed to fabricate physical models of digital 3-dimensional acquisitions.

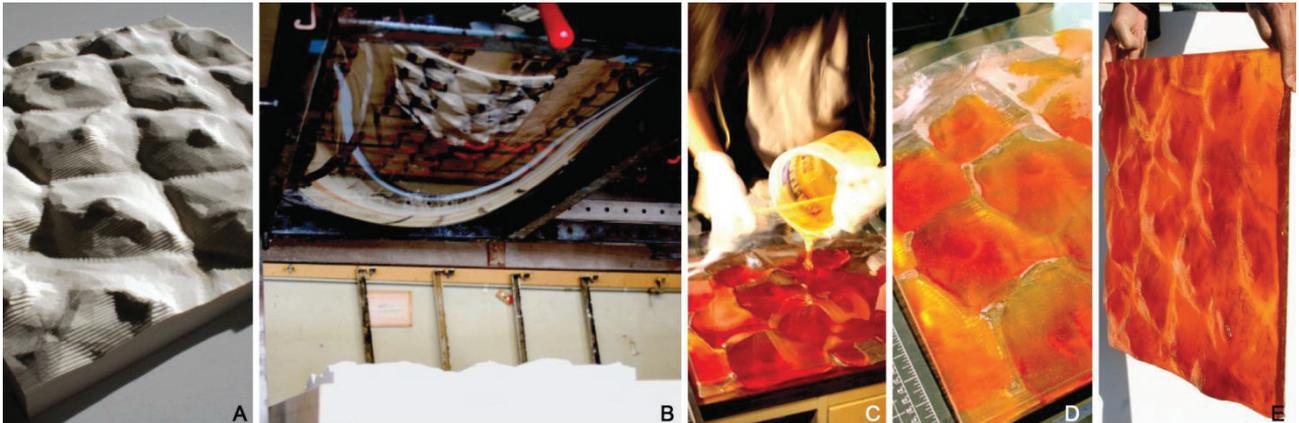


Fig. 4 Fabrication of the physical panel derived from a pineapple. A, milled mold for vacuum forming; B, vacuum forming; C, D rubber casting; E, final model (credits: Dong Jun Park, Nanao Shimizu).

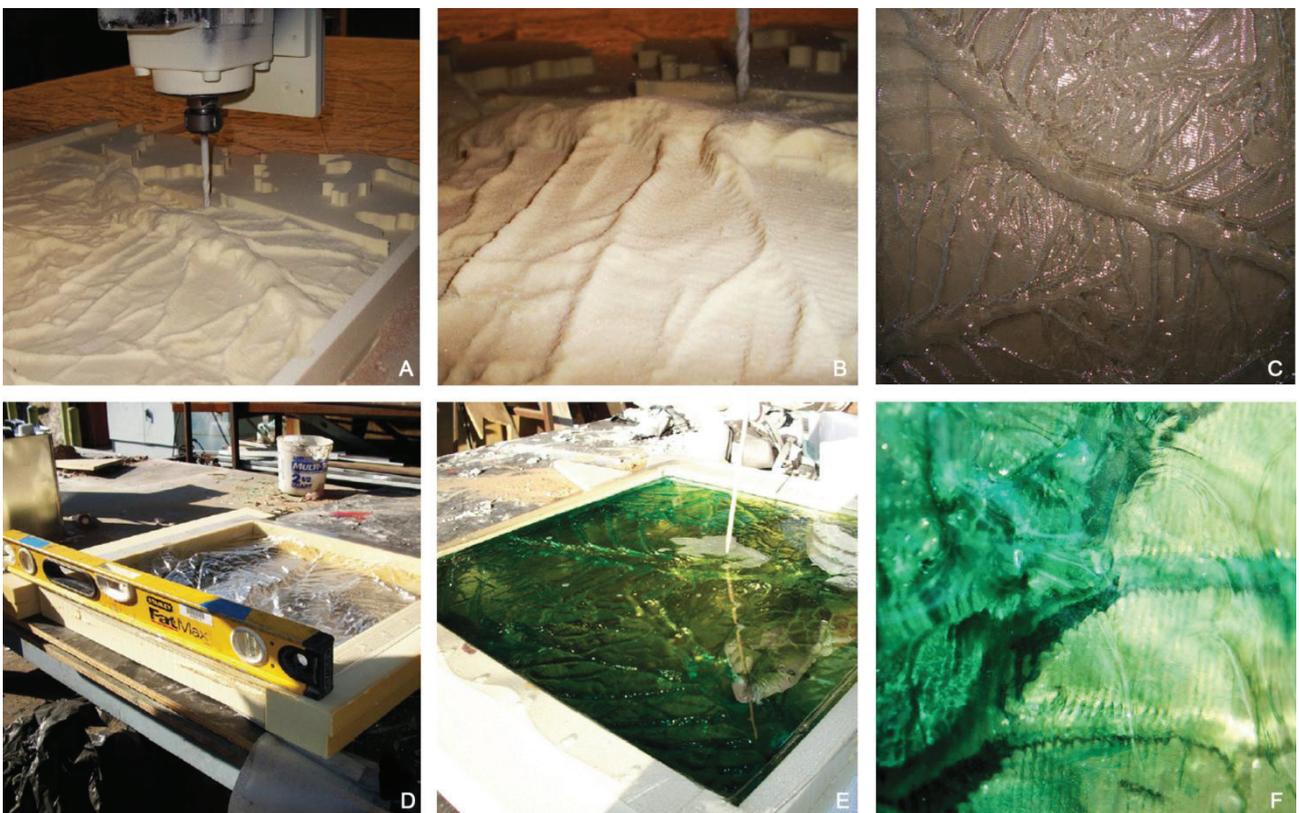


Fig. 5 Fabrication of the physical panel of a brassica oleracea linne. The foam model was created using a CNC milling machine. A, rough cuts; B, finish cut. This panel was then vacuum-formed in order to create the mold (C, D) that was used to pour the resin (E) for the production of the final panel (F). 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. 6 shows the pipeline of our methodology. The workflow was organized into different phases, each one scheduling continuous checks of the correspondence between the quality of the acquired information and the pre-defined level of detail.

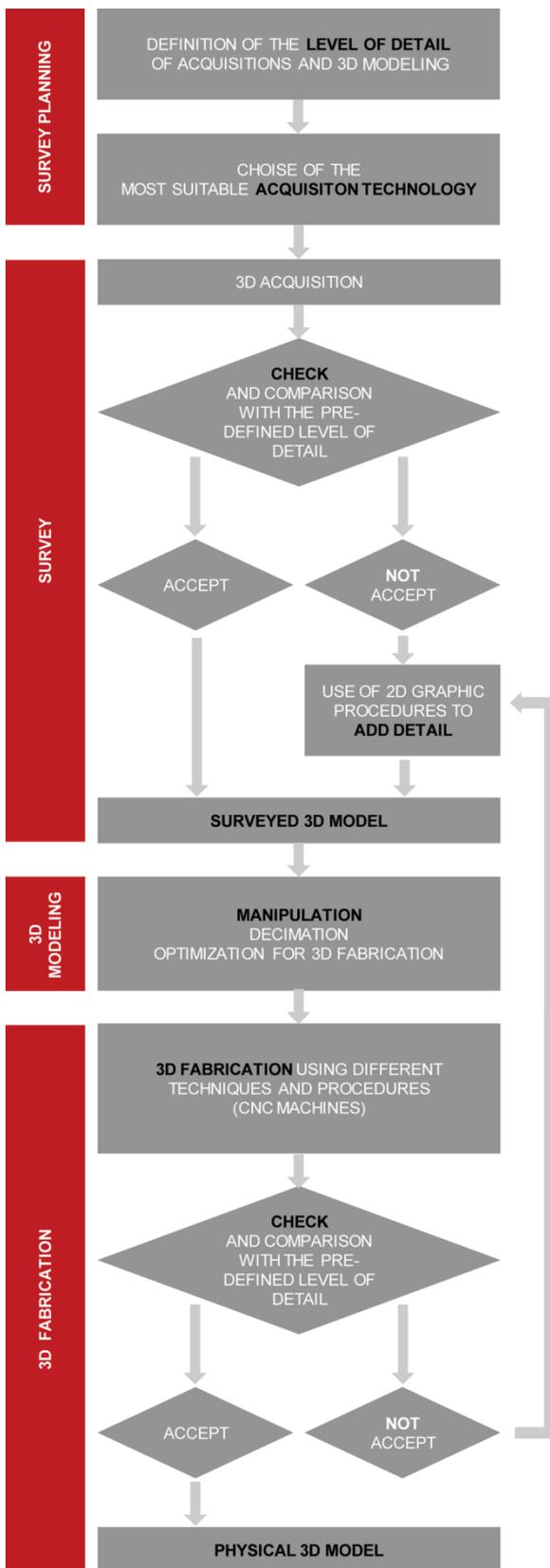


Fig. 6 The pipeline of our methodology.

During the entire process, the surveyed 3d data required its implementation through the use of 2d graphic procedures each time that range sensors showed lacks of precision and density and when the translation and optimization of 3d surfaces for CNC fabrication highlighted loss of details (i.e. during the translation of polygonal surfaces into NURBS).

Evident drawbacks of these implementations were the increasing of information and the consequent limitation in the management of huge amount of data. In order to overcome these restrictions and face the problem of the reduction of complexity of geometry without losing the required level of detail, different decimation procedures and algorithms have been tested.

During last 40 years, scientific research has developed different algorithms aimed at reducing redundant data and meanwhile preserve significant information within 3d models [8].

Actually, the algorithms that have been integrated in some of the most widespread modeling packages reduce the complexity of models accordingly to the visual importance of objects and to the location of the point of view.

Within the present research, in order to reduce redundancy of data in semi-planar surfaces and meanwhile preserve sharp edges and 3d irregularities, non isotropic decimation procedures have been investigated. In particular, we used the Edge Collapse Decimation algorithm that is available in MeshLab [9] and the Decimation Master® [10] plug-in that is integrated within Pixologic® ZBrush®.

In some cases, the automatic recognition of singularities using decimation algorithms didn't provide the required results, so that surface irregularities and hyper-realistic effects have been emphasized in order not to lose information during the decimation process.

4 Innovation and conclusion

This research has been an interesting occasion to evaluate the potential of digital technologies to acquire small scale details of complex 3d shapes, manage the derived 3d surfaces and turn them into physical models using manufacturing procedures.

Our methodology was organized into different phases, within which planned evaluations of the quality of the acquired information were constantly compared to our pre-defined purposes.

Within the entire process, the addition of 3d information in order to overcome the lack of precision and density of information surveyed using range scanners was not a secondary challenge, that we faced by combining reality-based acquisitions and reliefs built using high definition 2d images as inputs.

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 modelling 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, so that image-based and range-based techniques are generally combined to fully exploit the intrinsic potentialities of each approach.

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Fig. 7 Left, 3D model of corn from triangulation laser scanner. Right, deformation of the scanned shape and creation of a different morphology. The image shows the transition from the original scanned surface - bottom right corner - to the modified shape - top left corner (credits: Sona Gevorkyan, Magdalena Zeller).



Fig. 8 Manipulation of the 3D model of a 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).



Fig. 9 Physical panel derived from the 3D model of the feather of an ostrich. 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, Kristofer Leese).



Fig. 10 Physical panel derived from the 3D model of the feather of an ostrich. The use of translucent matter and the overlay of different manufacture (CNC milling and laser etching) highlights the lightness of the feather through visual depth (credits: Amber Bartosh, Kristofer Leese).



Fig. 11. Digital model derived from an octopus. A, photograph of a detail; B, mesh acquired using laser scanner. The original surface has different and varying rigidities and textures. In C, the manipulation of the original surface had the goal to highlight these different qualities (credits: Nina Handelman, Louis Polidori).

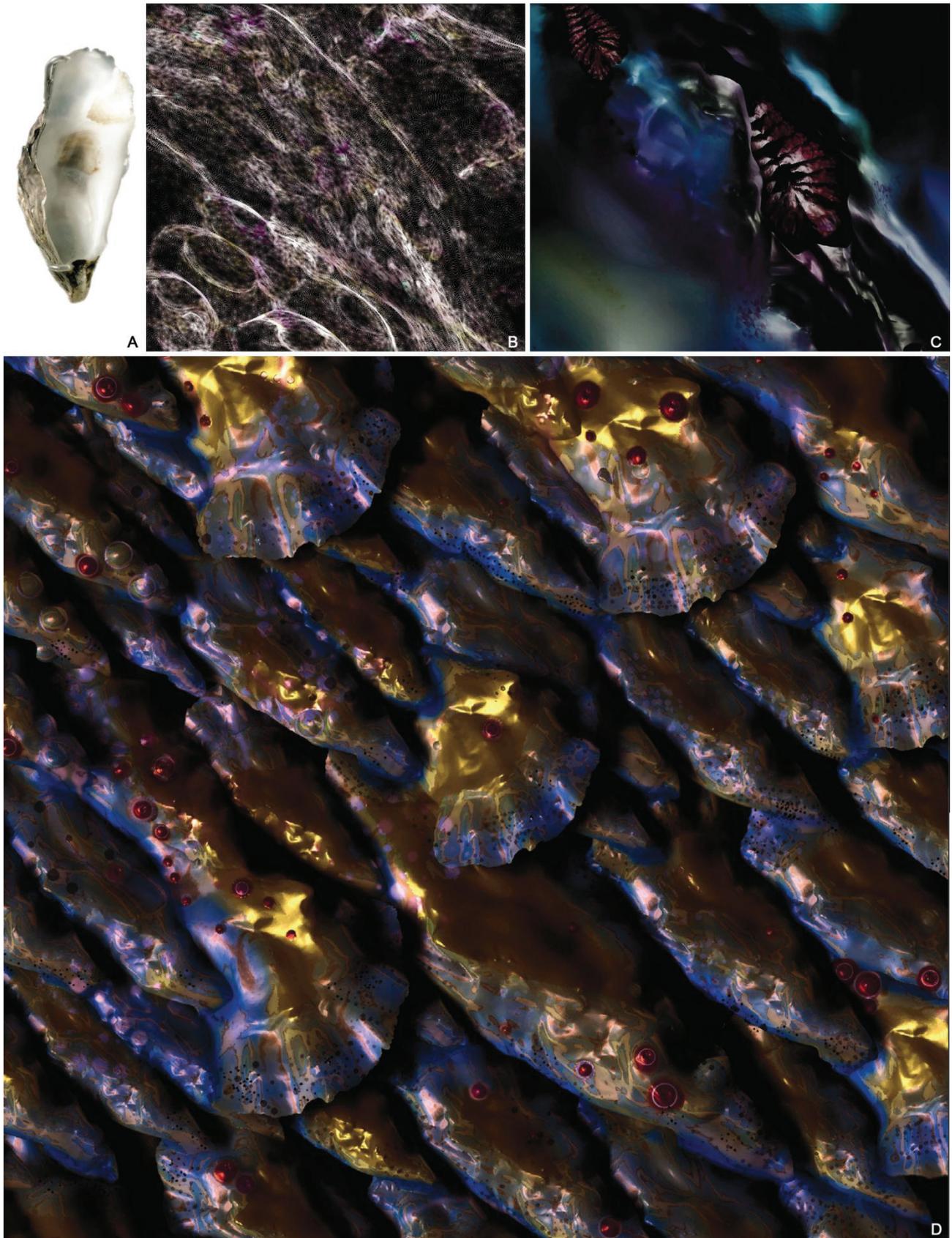


Fig. 12. Digital model of an oyster shell. A, photograph; B, ZBrush model. C, D, the manipulated model was created pivoting around the contrast between smooth and rough surfaces of shellfish and shell. C, detail of the manipulated model (credits: Christopher Day, Joshua Moratto).