Resurrected spire at Notre Dame:

Designing with digital tools as a design companion.

Siri Pålsson

Chalmers School of Architecture
Department of Architecture and Civil Engineering
Gothenburg, Sweden

Architecture and Urban Design
Material Turn Studio
Supervisor: Jonas Lundberg
Examiner: Kengo Skorick

Resurrected spire at Notre Dame de Paris:

Designing with digital tools as a design companion.

CHALMERS

Master Thesis Spring 2020

<u>Siri Pålsson</u>

Chalmers School of Architecture
Department of Architecture and Civil
Engineering Gothenburg, Sweden

Architecture and Urban Design
Material Turn Studio
Supervisor: Jonas Lundberg
Examiner: Kengo Skorick

ABSTRACT

The way we design and represent architecture is in a constant state of change. This thesis is an investigation of how to implement 3D tools in an architectural design process and how they can contribute in the development of a design proposal.

How can the capacities of 3D scanning and 3D modeling be used to develop a design proposal of a 3D printed spire at Notre Dame de Paris?

To seek an answer to this question texts have been discussed and field trips have been conducted to visit the site and reference projects relevant in the topic. A digital model of the spire using 3D scanning has been designed through an iterative process and a physical model of Notre Dame including a new spire have been made using 3D scanning and 3D printing.

The result being a design proposal where scanned details from Notre Dame available online have been used to introduce a new spire through a method that strived towards a partly uncontrolled process.

The possibilities of digital tools and their impact on the design result is important for the architect to understand in order to achieve a desired result. We can let the tool become a design companion when a partly uncontrolled process and sometimes unexpected result is welcomed.

Keywords: Digital tools, 3D scanning, 3D modeling, 3D printing, Digital design, Notre Dame, Design companion,

STUDENT BACKGROUND

Siri Pålsson

"The details are everything as well as nothing. What makes a whole bringing them together is important to the expression, no one is irreplaceable but we still need them all."

New techniques and trends in modern and future construction and the idea of how it could co-exist with traditional ways of building inspires me. I have in previous courses chosen to write about the digitalization of the industry and how it clashes with the traditional work of architects. What happens when computers become involved in making and creating buildings? Is it possible to combine historical buildings with modern technology? These are questions that I want to further develop.

TABLE OF CONTENTS

01: INTRODUCTION

BACKGROUND

Purpose & Aim

BACKGROUND:

Society and technology are both developing rapidly as well as the way we design and represent architecture. Digital 3D tools enables many new opportunities and possibilities when designing. It is necessary to understand their abilities in order to use the tools in a context where it can contribute to the development of architecture. By increasing the knowledge of the digital tools, the available toolbox for architects can be expanded.

PURPOSE:

An investigation of how to implement 3D tools in an architectural design process and how they can contribute in the development of a design proposal.

AIM:

The aim being to create a design proposal of the spire of Notre Dame using 3D scanning, 3D modeling and 3D printing.

FOCUS

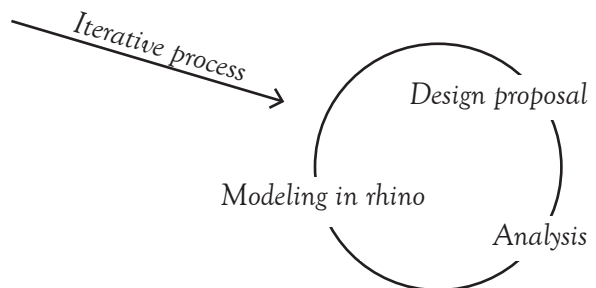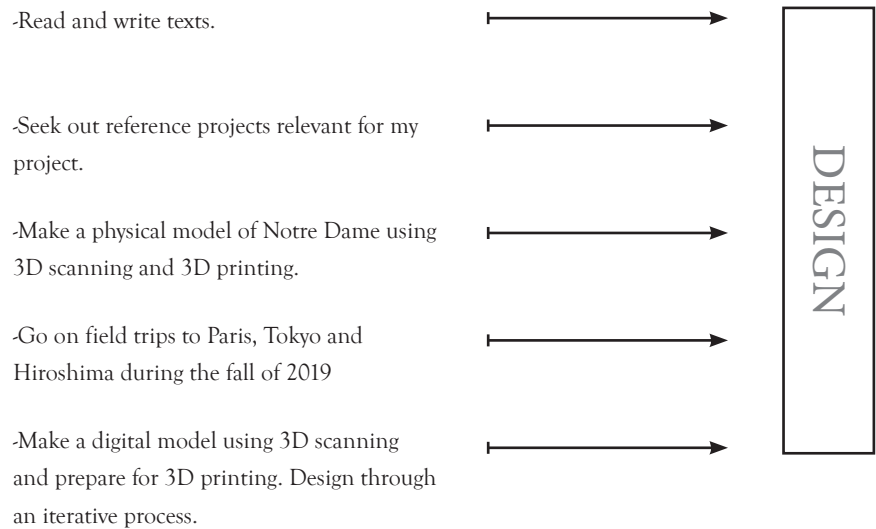*Thesis Question & Delimitation*

THESIS QUESTION:

How can the capacities of 3D scanning and 3D modeling be used to develop a design proposal of a 3D printed resurrected spire at Notre Dame de Paris?

DELIMITATION:

I have concentrated my proposal to the damaged spire of Notre Dame without elaborating a new design of the collapsed roof.

METHOD

Parallel work

-Read and write texts.

-Seek out reference projects relevant for my project.

-Make a physical model of Notre Dame using 3D scanning and 3D printing.

-Go on field trips to Paris, Tokyo and Hiroshima during the fall of 2019

-Make a digital model using 3D scanning and prepare for 3D printing. Design through an iterative process.

DESIGN

Iterative process

Design proposal

Modeling in rhino

Analysis

FIELD TRIPS

Paris, Tokyo & Hiroshima

Paris

Visit the building and get feeling of the amount of damage the fire caused.

Tokyo

Visit Koishikawa Annex at the University of Tokyo Museum of Architecture and the exhibition ARCHITECTONICA.

Hiroshima

Visit the Hiroshima Museum of Contemporary Art and their special exhibition called "~~IMPOSSIBLE~~ ARCHITECTURE: ANOTHER HISTORY OF ARCHITECTURE".

IGNORANCE & SURPRISE

Brave the unknown

"Offering unexpected moments of surprise."

As a starting point to this project much inspiration has been taken from the text Brave the unknown by Matthias Gross (Gross, 2010). The book discusses the subject of ignorance and surprise, the act of welcoming the unexpected through an unleashed process.We aspire surprising events in research since that opens up for unexpected knowledge and outcomes. Also in the creative works of art, ignorance towards the conscious mind is used.

An unexpected experience is important for the viewer or audience to make it memorable and to awake new feelings and thought of mind.

Architecture can both be seen as a romantic idea of creating something with a poetic sense and as a rational and controlled process. However, with the Gross text in mind, some sort of awareness of a possible surprise has to be cared for, whether you seek it through experiment or cope with it when needed.

02: REFERENCE PROJECTS

DIGITAL GROTESQUE II

Michael Hansmeyer & Benjamin Dillenburger, 2017

Digital Grotesque II is an artwork that explores new territory between the creator and the computer, in which the computer becomes an active designing partner that can expand beyond the imagination of the designer.

A highly detailed architectural structure is generated by the computer and 3D printed in sandstone. The block is actually hundreds of square meters compressed surface, millions of branches are growing and folding again and again.

At the heart of this artwork is the generated script of highly detailed sculptural designs with a grotesque expression.

The creator is not in charge of the appearance of every detail but only controlling the overall conceptual design, therefore some of the details was a surprise even for the designer. The details are everything as well as nothing. What makes a whole bringing them together is important to the expression, no one is irreplaceable but we still need them all.

"The resulting architecture is at once disorientating, intriguing, and evocative without being prescriptive. It inhabits a space between the man-made and the natural, between order and chaos, offering unexpected moments of surprise."
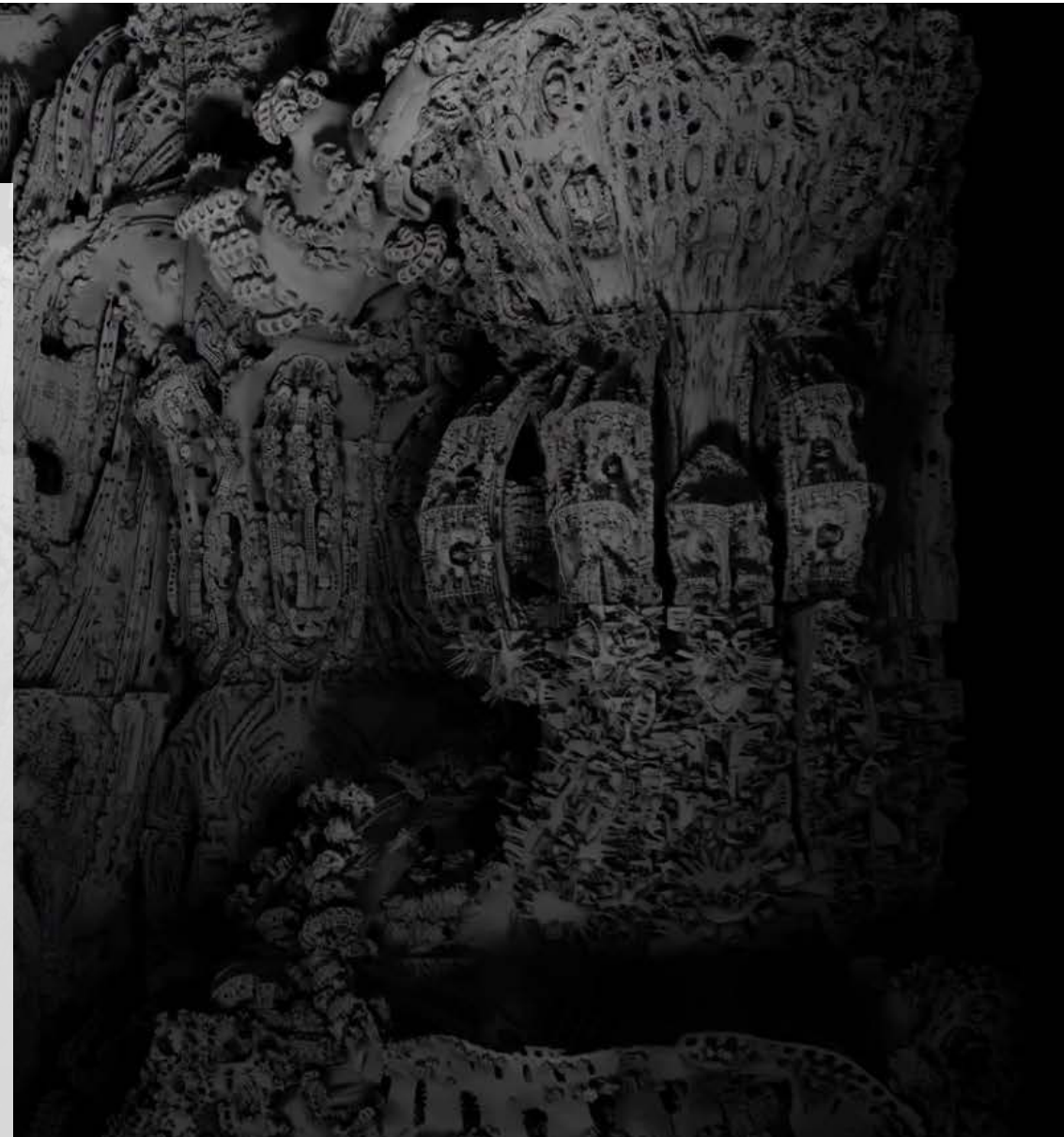*(Dillenburger, 2017)*

Figure 1. Grotto II, (Kaufmann & Gehring, 2019). Reprinted with permission.

HELSINKI GUGGENHEIM MUSEUM

Mark Foster Gage, 2014

On my trip to Japan I visited the Hiroshima Museum of Contemporary Art and their special exhibition called "IMPOSSIBLE ARCHITECTURE: ANOTHER HISTORY OF ARCHITECTURE". It displayed a collection of architectural project that never have been realized, not because it is practically impossible but due to social condition and restrictions as well as being created to make a critical statement rather than being a built proposal.

This proposal is constructed from randomly downloaded objects from different online sources. The conceptual idea of this is that any previously symbolic agenda or relationship between the recycled objects ceases to exist.

The distinct entities get emphasized but the individual figures lose any associations of symbolic content in favor of the creation of a new and highly complex form of architectural aesthetic structure.

"It mysteriously hints at, but in no way reveals, the curious and varied importance of the artistic contents within." (Mark Foster Gage Architects, 2014)

Figure 2. Helsinki Guggenheim, (Marc Foster Gage, 2014). Reprinted with permission.

MEMORIES OF ARCHITECTURE

Fumio Matsumoto

"Memories of Architecture" is part of a larger showcase called "ARCHITECTONICA". This permanent exhibit is taking place in the Koishikawa Annex at the University of Tokyo Museum of Architecture.

As society and technology both evolve rapidly over time, the way we design and represent architecture is also in a constant state of transformation.

The Japanese architect Fumio Matsumoto have used this emerging technology to pay tribute to iconic buildings from around the world and history. In the exhibit "Memories of Architecture," Matsumoto manages to gather more than 30 famous structures into one 3D printed object.

The model is printed on a scale of 1: 300 and the architectural works shown blend together from old to new. The work contains all types of styles, starting with ancient Egypt until works of today. The project highlights different aspects of these different structures, such as facades, exterior shapes, interior spaces and structures.

Fumio Matsumoto said about the project:

> *"While it is not a comprehensive overview of architectural history, it does illustrate some significant trends over time, such as the shift from massive to minute forms and from enclosed to open spaces." (Matsumoto, 2017)*
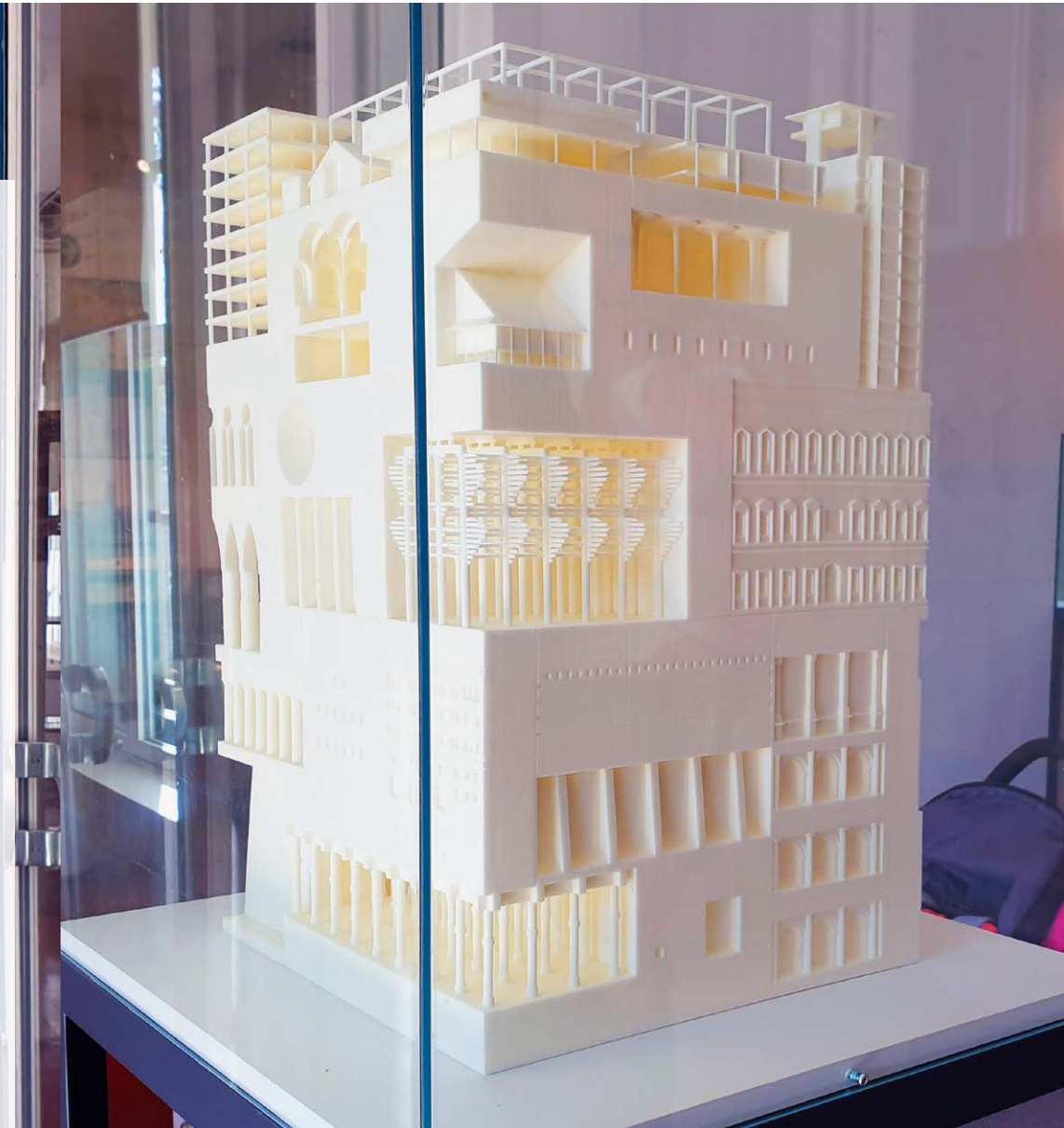

Figure 3. Memories of Architecture, (Photograph taken by author, 2019).

ARCHITECTURE OF SHELLS

Equiangular spiral & Accretionary growth

There is a special exhibition next to the exhibition of "ARCHITECTONICA" called "Architecture of Shells". The aim of the exhibition is to, from an architectural point of view show the diversity and the uniformity of various shells.

The spiral is a shape we can find in nature and the spiral shell structure is created by living creatures. The growth pattern of the shell is described using two keywords, equiangular spiral and accretionary growth.

It is equiangular when the shell expands in an constant angle in relation to the center of the spiral.

Accretionary growth is a growth pattern where parts are formed and then never change their shape or size. It grows when shell elements are added to its surface which can be compared to the way we build architectural systems from different components.

Figure 4. Memories of Architecture, (The University Museum of Tokyo, 2019). Reprinted with permission.

REFERENCE PROJECTS

03: INVESTIGATION

DIGITAL TOOLS

3D Scanning

When using the technology of 3D scanning you will end up with a digital version of the object or the environment you're collecting data from. The 3D model consists of a point cloud of geometric samples on the surface of the subject. These points can then be used to extrapolate the shape of the subject which is called reconstruction. 3D scanning can be based on many different technologies.

Photogrammetry is the extraction of three dimensional measurements from recorded two dimensional data. The technology isn't new though the facilities to use this method today is getting easier and better. With a camera phone, smaller objects can be captured and translated into digital models. Similar to the camera a 3D scanner collects information captured by a lens about the surface. Instead of getting color information of the surface the 3D scanner captures distance information for each point of the surface within its field of view. This information make it possible to recreate a digital 3D model.

When scanning buildings, spaces and landscapes, laser scanning is often used. It combines controlled steering of laser beams with a laser rangefinder which is used to determine the distance to a surface and back by measuring the time it takes for the laser to travel. With this technique you can rapidly capture the shape of a surface and by combining many of these surface-models a full 3D model can be created. With laser scans it is possible to measure spaces with an high accuracy. The scan can result in billions of points that creates a three dimensional cloud. Also, a camera can be attached to the equipment giving each point the accurate color for a more realistic model.
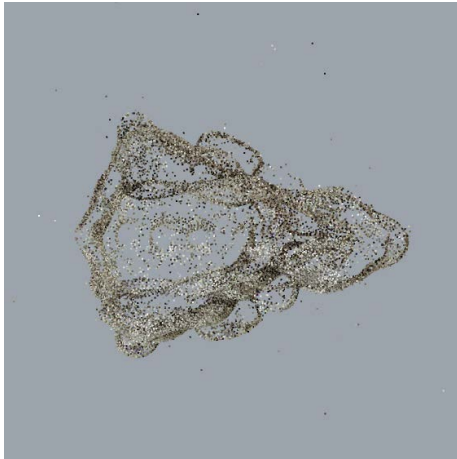
Andrew Tallon made a immense work gathering data by laser scanning the whole interior of Notre Dame in 2010. A method that gives us more accuracy of how the building is constructed than we ever had before. Also, there are plenty of scanned object from Notre Dame online.

Figure 5. VR Notre Dame project, (Periskop.Cloud, 2019). Reprinted with permission.

Screen capture from Rhino

SCANNED GARGOYLE

From photos to point cloud

This is a point cloud made from photographs of a miniature of a famous gargoyle situated on Notre Dame. Pictures where taken from many different angles around the whole statue in order to extract a 3D model.

In the end this model weren't used in the result of the project but served as a way to become familiar with the technique of 3D scanning.

DIGITAL TOOLS

3D Printing

The 3D printing process builds three-dimensional objects from a computer-aided design. This method also called additive manufacturing, works by adding, joining or solidify materials layer by layer.

The development and research within 3D printing is constantly updated. New techniques, materials and methods are being tried out. Some processes of 3D printing are viable enough to be used in industrial production.

One thing to be aware of in using 3D printing is that it has no natural form, not like the texture of wood or a stone's density.

3D printed objects can have a surface and texture that is formed by the many layers from the printing process and that can be the main characteristic of the resulting product, but the ability to produce very complex shapes or geometries in every scale makes the possibilities endless.

Gothic buildings such as Notre Dame has an extreme amount of detailing rarely seen in modern buildings. 3D printing makes it possible to create extraordinary and unique detailing in large scale.
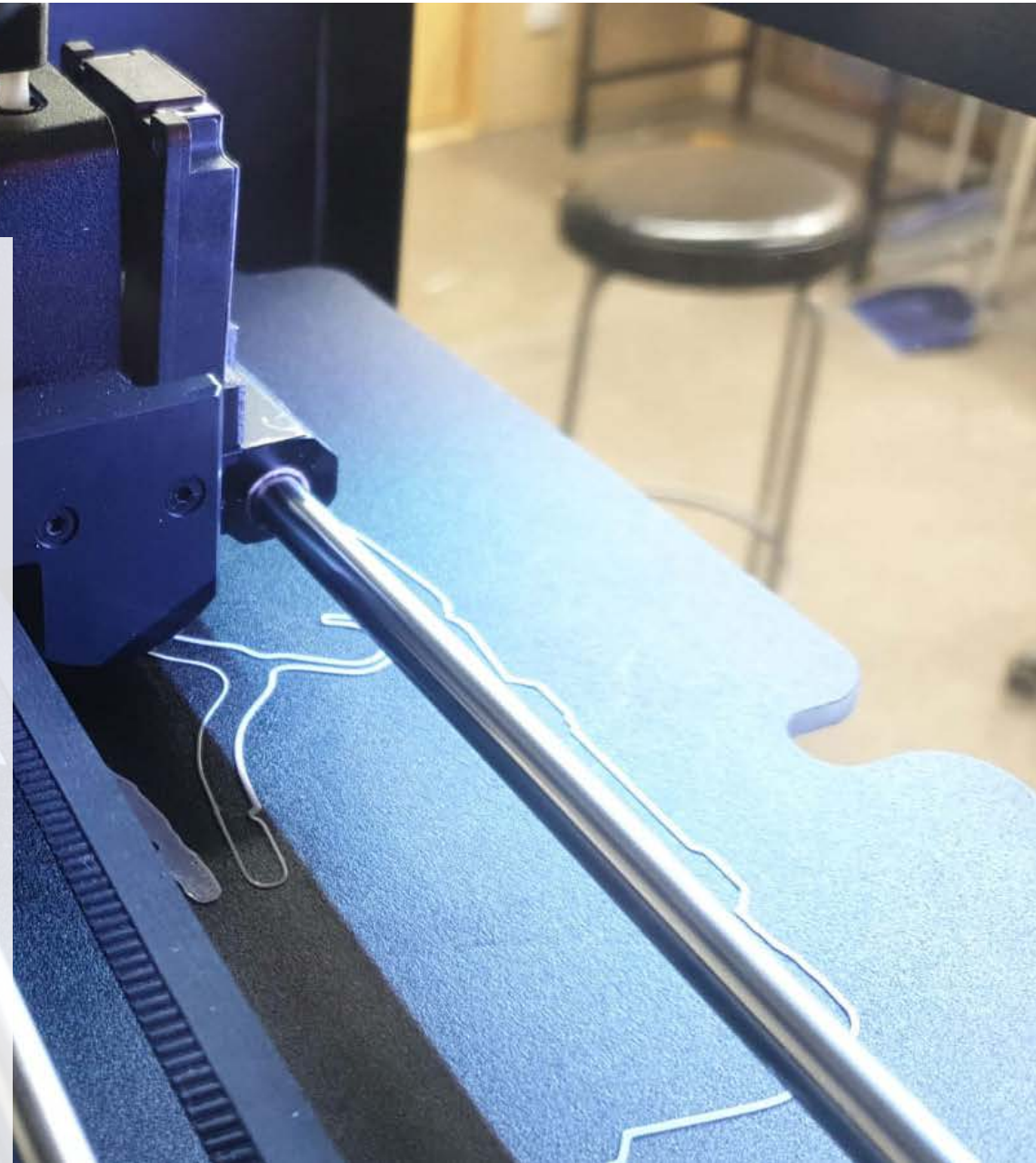
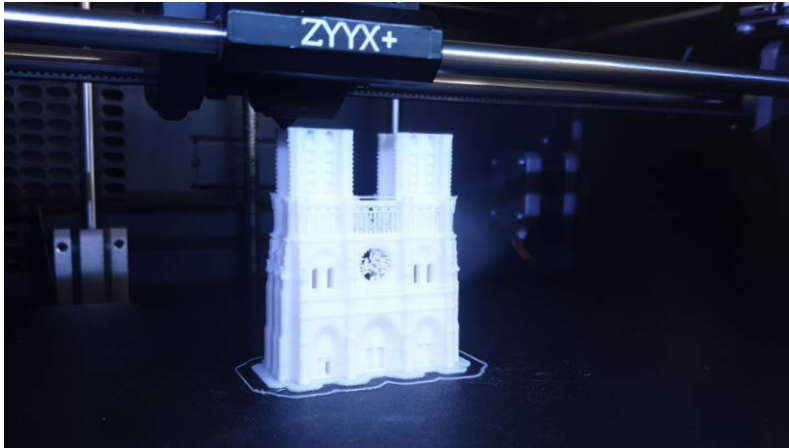*Figure 6.* 3D printer, (Photograph taken by author, 2019).

INVESTIGATION

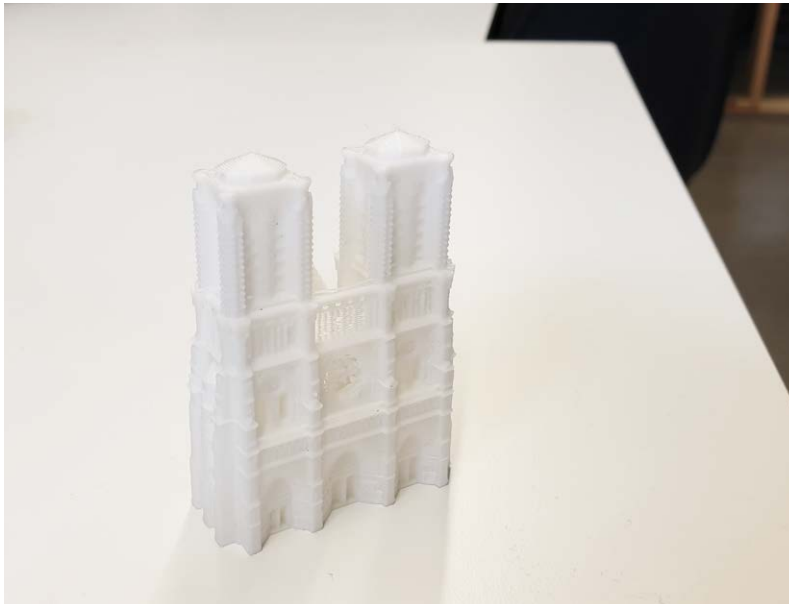*Figure* 7. 3D printer, (Photograph taken by author, 2019).

Figure 8. 3D printed towers, (Photograph taken by author, 2019).

PRINTED TOWERS

To print a digital 3D model

This is early test prints made with a 3D printer. The towers of Notre Dame was found online while other test prints were created from my own 3D scans. The exported files where then processed in the 3D printer slicing application Ultimaker Cura.

There are many things to considerate when working with 3D printing.

The tolerance level that seems to have perfect fitted seams in the digital version will be altered when printed. It is important to take this in consideration when combining the printed object with an existing one.

The textures of the print will be affected by the choice of material and printing settings. Also the tool-path will in some cases be shown. The stability can differ a lot between different setting of one print. Sometimes a lower quality will bring out an unexpected quality of the result.

DIGITAL TOOLS & ARCHITECTURAL ETHICS

The death of Drawing

David Ross Scheer is an architect and author, and his blog post The Death of Drawing describes the architect's complicated relationship with new technology. It highlights the overall relationship between technology and architectural ethics.

Scheer assumes that the architect has the ability to contribute ethically to the design process in architecture. It's something that the technology, according to Scheer, can not do. To add ethics, the architect must question and illustrate how different, in many cases technical decisions, affect people.

In architecture's collaboration with technology, it is therefore the architect's task to demand the true purpose of the technology. Ethics is something that is not included in the definition of technology that only takes into account functional and economic performance for maximum power and minimal cost. The ethical issues that the architect intends to take into account is neglected when you let the numbers decide. The difficulty of reconciling ethics with technology is largely due to the fact that the result of ethical considerations can rarely be calculated.

The architect's role has changed, says Scheer. The architect's relation to a project can no longer be the same now that the conditions are different. What we risk losing is the dynamic that occurs when the pen, with its ability to abstractly convey a message, meets the paper. Finally, Scheer is still hopeful. Architects must embrace the technology's many possibilities and abilities and learn how to control them. The architect needs to acquire new knowledge and with new tools learn to explore and develop ideas and not let the technology control. (Scheer, 2014)

ARCHITECTURE ORNAMENT

About the article by Douglas Murphy

In the article "The new Architecture Ornament" written by Douglas Murphy, the subject of ornamenting in a digital age is discussed with many views and opinions being presented. (Some of the representatives in the discussion are Greg Lynn, Oliver Domeisen and Neil Spiller.)

The article discuss how we today can see many variations of architecture with surfaces being cladded with patterns and different prints, cuts and structures. It seems to be a way for architects to express something creative and artistic to an otherwise flat and boring box. It is also discussed to be a counter reaction to the smooth and abstract digital architecture that is designed using "parametric" scripting which claims it has optimizing performances and efficiency as an argument for its' shape. But this is meeting criticism for giving parametric design methods too much credit, it's just a tool and can't be anything more than just that. The decorated surfaces meets criticism for only acting as a wallpaper to an otherwise uninteresting shape.

So the question remains, how could we use the digital tools in a successful way.

Figure 9. Facade of John Lewis Department Store and Cineplex in Leicester by FOA, (ASVL3, 2008). CC BY 3.0

04: NOTRE DAME

SITE

Notre Dame de Paris

On 15 April 2019, just before 18:20, a fire broke out beneath the roof of Notre Dame de Paris cathedral in Paris. There was a very strong reaction worldwide after the news of the fire in Notre Dame. I believe that one unique factor was that we had no one to blame for this event. We also realized that even what we think is everlasting can be very fragile.

Notre Dame has a monumental value to history that makes the discussion of how to deal with the damage much more complicated. People were frightened by the tragic event and from there, an increased eagerness combined with new opportunities resulted in thousands of suggestions and dedication on how to proceed.

A lot of information such as images, scans and 3D models is to be found online. It set an example of the strength of our digitalized community. There has been many speculative rumors about using existing laser scans, 3D scans and even 3D models from video games in the restoration of Notre Dame. Rumors that has been declined by those responsible for the project.

The importance of the architect's responsibility is emphasized in a situation where the future of a beloved building is at stake. This sentimental atmosphere of right and wrong is very interesting to me and is one of the reasons why I chose to work with Notre Dame.

Figure 10. Fire, (Ouda, 2019). CC BY-SA 4.0

NOTRE DAME

Figure 11. Firefighters at the Notre Dame, (Cangadoba, 2019). CC BY-SA 4.0

Figure 12. Spire on Fire, (Guillaume, L 2019). CC BY-SA 4.0

NOTRE DAME

IMMORTAL HISTORICAL ARCHITECTURE

To experience a digital version of the world

Everywhere there are people with a camera at hand ready to capture their surroundings. There is a huge possible network of data that is ready to be assembled and recreated into a digital version of reality. The game industry nevertheless have detailed and properly rendered 3D models that is very life like. At the event of the fire of Notre Dame there were a massive interest from the digital community in reconstructing the damaged cathedral with help from these types of data. There are people investigating the possibility of making a full VR experience inside Notre Dame with this method, making a visit possible without the real place being accessible.

Thanks to the point cloud we have unique and detailed information on how the building was constructed. We have the numbers in millimeters and know the exact space of the interior cathedral. What we do not know and can not recreate is the art of the craftsmanship. We've lost wood from trees that was cut down 850 years ago, trees that were about 300-400 years old. There is no way we can rebuild that amount of treasure this fire demolished but we can let people visit the past with virtual reality and in a sense make it stand immortal against any future danger.

There is a bigger connection between how we experience the digitally created environments and how we experience the real world. In the game Assassin's Creed Unity for example, there are very life like renders of the city of Paris that plays out in the 18th century. Here we can experience the city in a fast and flexible way where the essential buildings that still define the city today are fully accessible. We get a clean image of the full potential of the beauty of Paris without the distraction of tourist dense streets. We can move around freely, even climb the wall of Notre Dame and get close up views of what is impossible to experience

in real life. We can see every detail, every statue, every brick. These two worlds, the digital and the real world could in many ways compliment each other. In this case the digital world give us freedom to really see every detail and explore it in every angle. It give us the opportunity to experience Notre Dame in a different time of history.

Assassin's Creed Unity Notre Dame Viewpoint

RELIGIOUS MONUMENT

The Crown of Thorns

One of the object that was saved from the fire was the Crown of Thorns. In one episode of the series "The story of God" Morgan Freeman visit Notre Dame de Paris and gets a rare opportunity to see the Crown of Thorns up close. When asking "What if it is not the right one" he gets the answer from the priest showing him the crown that the most important thing is that we have an actual object that might have been on Jesus Christ's head. It reminds us that he did exist and that he is a part of our history. (National Geographic, 2019)

The same principle is applicable on Notre Dame. Many parts of the building has at one point or the other been destroyed and rebuilt. Of course there's a value of something being original but over time we often forget what is. New parts blend in together with the old and becomes a part of history. If we believe the priest about the Crown of Thorns the meaning and value of places and objects that we consider sacred is its symbolic representation of history.

CHANGE OVER TIME

Events in the life of historic buildings

During the years, centuries really, Notre Dame has gone through many changes. Some have strengthen its characteristics we associate it with today, others destroying historical features. This is not unique to this building, changes affect all historic buildings. Original parts are rare and we don't need that much time to get used to them and take things for granted. The Notre Dame spire is one example and people were devastated when it collapsed in the 2019 fire. What most people do not know is that the original spire was one of the last elements to complete the building and it remained intact for 500 years until it was deconstructed in 1786 to be replaced in the 19th century. This means that the spire that we saw fall in April 2019 was about 200 years and quite young for Notre Dame's lifetime. In general, this does not make us less unhappy about the fact that the spire is gone and many Parisians feel that it will not be the same if the spire is recreated.

Despite this, I have decided in my project proposal not to recreate the spiral in the same way as before but to make a new addition to the cathedral using 3D scanning and 3D printing.
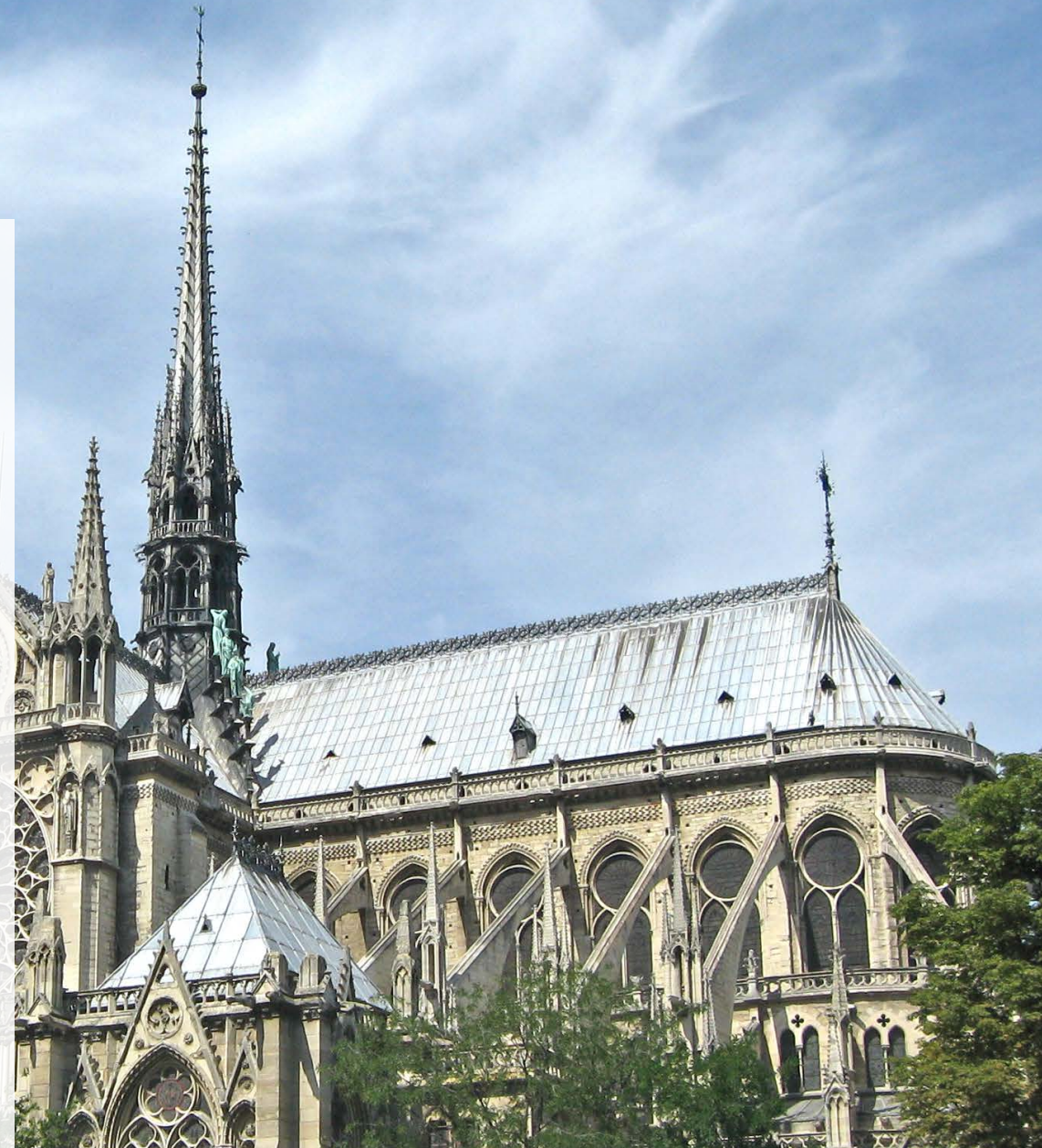

Figure 14. View of Cathedrale Notre-Dame de Paris from the river, (Madhurantakam, 2019). CC BY-SA 3.0

NOTRE DAME

Figure 15. Arches, (Sansi, O, 2016). CC BY-SA 4.0

Figure 16. Rose window, (Dietmar Rabich, 2014). CC BY-SA 4.0
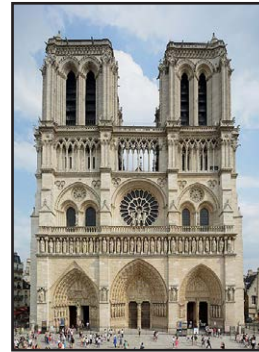

Figure 17. West view, (Haas, 2013) CC BY-SA 3.0

Figure 18. Entrance, (Dietmar Rabich, 2014). CC BY-SA 4.0

1160　　　　　1180　　　　　1200　　　　　1220　　　　　1240　　　　　1260　　1345

1163

Cornerstone laid for Notre Dame de Paris.

1182

Apse and choir completed.

1225

Western facade completed.

1250

The original spire was built. Western towers and north rose window completed.

1160

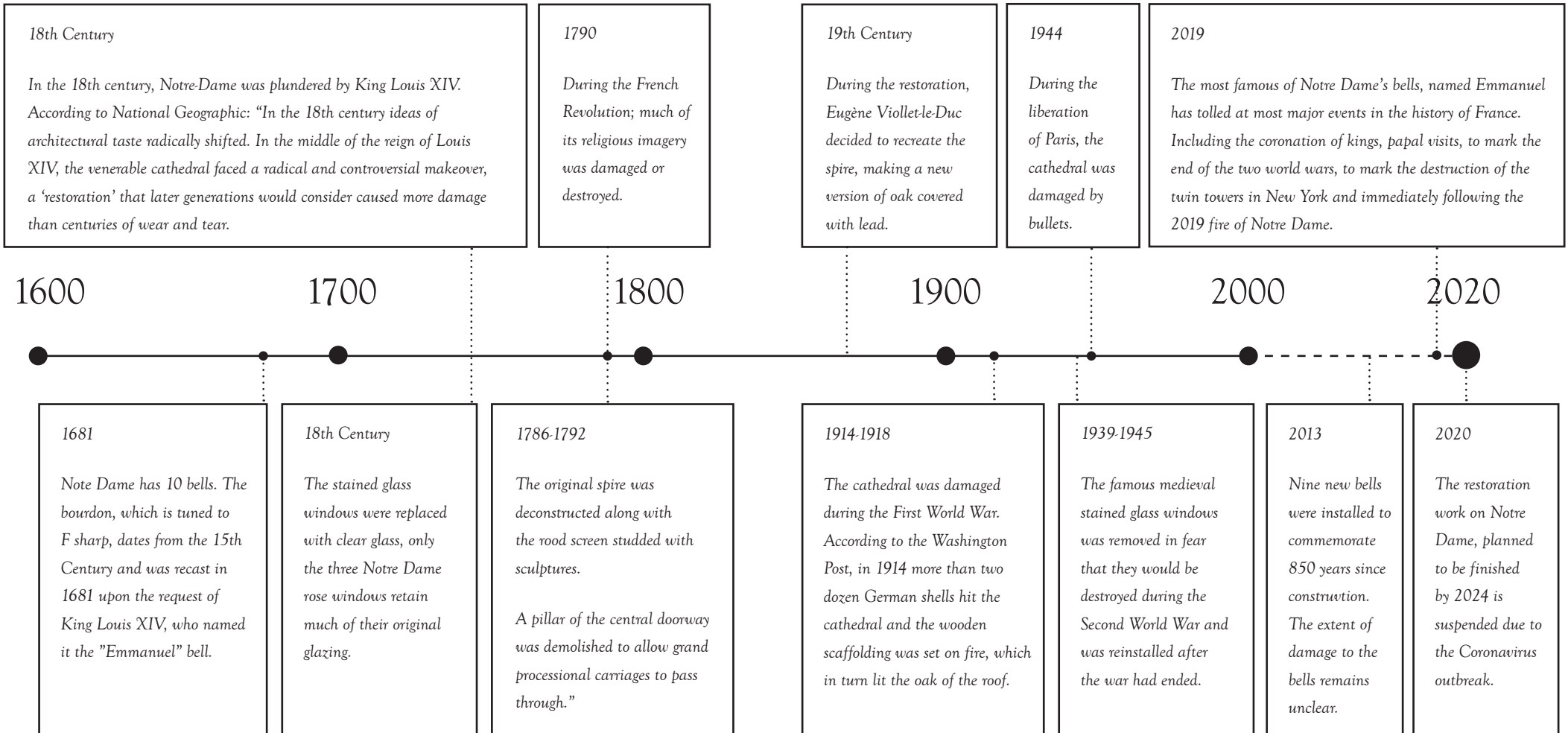Maurice de Sully ordered the original cathedral demolished.

1182-1190

The last three bays in the nave, the side aisles and the tributes were constructed.

1200

Work bagan on western facade and rose windows installed.

1240

The gargoyles were designed to divide the torrent of water which poured from the roof after rain, and to project it outwards as far as possible from the buttresses and the walls and windows where it might erode the mortar binding the stone. They were also designed to be a decorative element of the architecture.
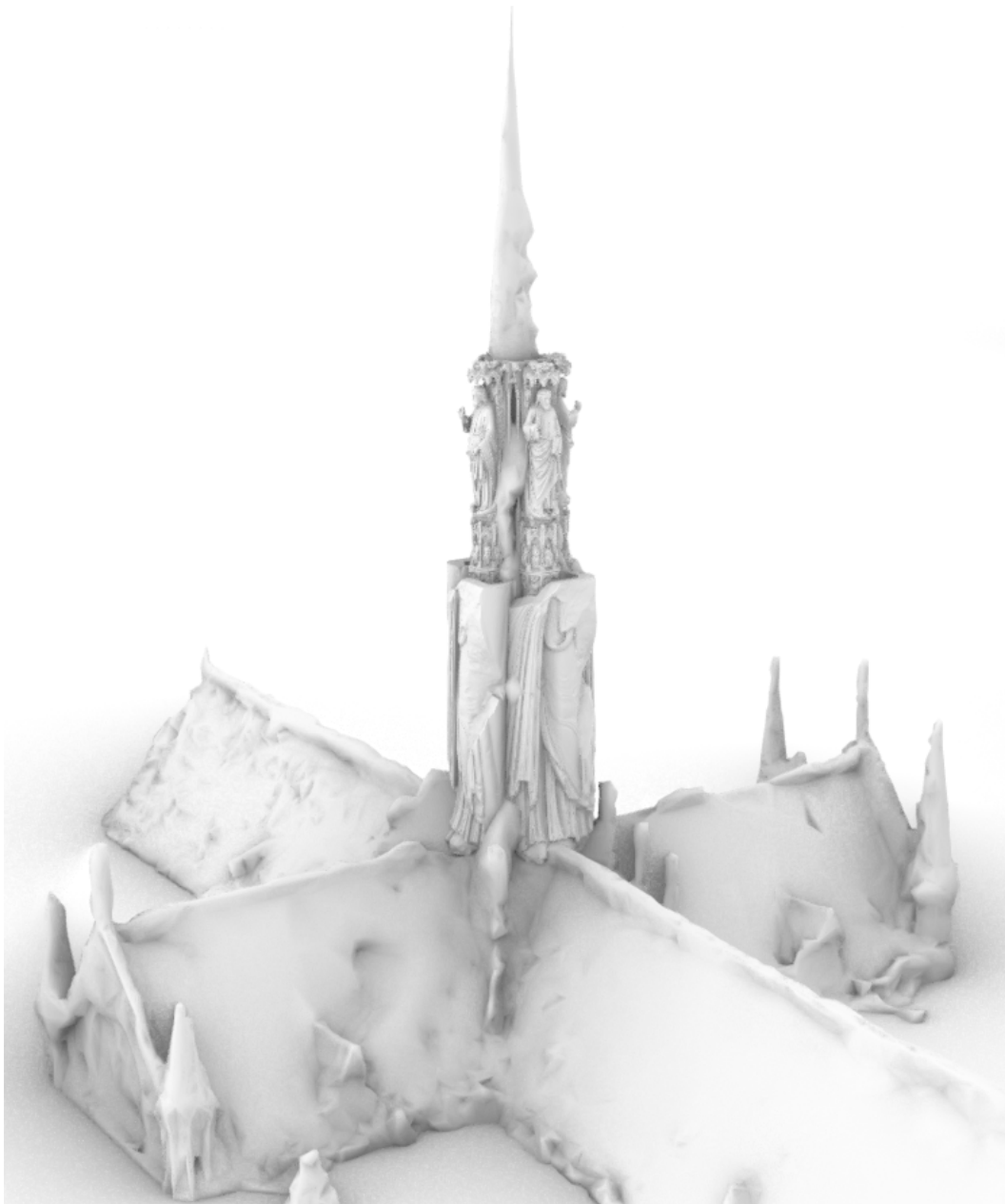
1250-1345

Building work on the cathedral was completed.

TIMELINE

18th Century

In the 18th century, Notre-Dame was plundered by King Louis XIV. According to National Geographic: "In the 18th century ideas of architectural taste radically shifted. In the middle of the reign of Louis XIV, the venerable cathedral faced a radical and controversial makeover, a 'restoration' that later generations would consider caused more damage than centuries of wear and tear.

1790

During the French Revolution; much of its religious imagery was damaged or destroyed.

19th Century

During the restoration, Eugène Viollet-le-Duc decided to recreate the spire, making a new version of oak covered with lead.

1944

During the liberation of Paris, the cathedral was damaged by bullets.

2019

The most famous of Notre Dame's bells, named Emmanuel has tolled at most major events in the history of France. Including the coronation of kings, papal visits, to mark the end of the two world wars, to mark the destruction of the twin towers in New York and immediately following the 2019 fire of Notre Dame.

1600   1700   1800   1900   2000   2020

1681

Note Dame has 10 bells. The bourdon, which is tuned to F sharp, dates from the 15th Century and was recast in 1681 upon the request of King Louis XIV, who named it the "Emmanuel" bell.

18th Century

The stained glass windows were replaced with clear glass, only the three Notre Dame rose windows retain much of their original glazing.

1786-1792

The original spire was deconstructed along with the rood screen studded with sculptures.

A pillar of the central doorway was demolished to allow grand processional carriages to pass through."

1914-1918

The cathedral was damaged during the First World War. According to the Washington Post, in 1914 more than two dozen German shells hit the cathedral and the wooden scaffolding was set on fire, which in turn lit the oak of the roof.

1939-1945

The famous medieval stained glass windows was removed in fear that they would be destroyed during the Second World War and was reinstalled after the war had ended.

2013

Nine new bells were installed to commemorate 850 years since construvtion. The extent of damage to the bells remains unclear.

2020

The restoration work on Notre Dame, planned to be finished by 2024 is suspended due to the Coronavirus outbreak.

05: PROJECT

Early design model of the spire

PROJECT

Concept & Method

When I researched reference projects and trends, one process that was used repeatedly and discussed as "future technique" was assembling smaller pieces into one unit.

This inspired me to the extent where I chose to use it as a concept for creating the spire, assembling pieces of, or entire sculptures from Notre Dame together.

Creating the spire I've been using an iterative process working with a 3D model of the new spire in Rhino. I have made proposals by combining the scans into different compositions by giving different commands to the computer. Then I analyzed the results of the digital process and then went back to modeling in Rhino.

Design proposal

Modeling in rhino

Analysis
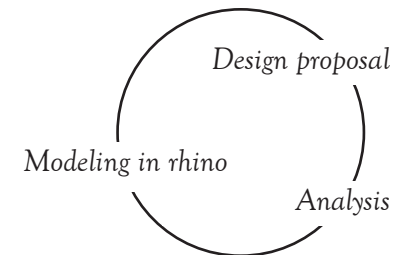
SCANNED OBJECTS ONLINE

Available objects from Notre Dame

Notre Dame Cathedral will be shut down for restorations for many years. During my visit in Paris is was impossible to get close to the building but from across the river I could see the void where the spire used to rise.

Since I were unable to make my own scans on site I have used models that represent various statues at Notre Dame de Paris Cathedral available for download online.

Figure 19. Statues acéphales, (Dalbéra, 2013). CC BY 2.0

Saint Peter

This is the lower part of a statue from Notre-Dame de Paris. It was removed in 1793-1794 CE, then rediscovered in 1839 in a street named rue de la Santé, where it was used as a milestone.

Christ on the trumeau

As the resurrected Christ, the so-called Beau Dieu, he has triumphed over evil, represented by the two beasts (lion and snake) under his feet. His left hand holds a book while the right hand is raised in blessing. He towers above those entering in the portal and stares off into the distance.
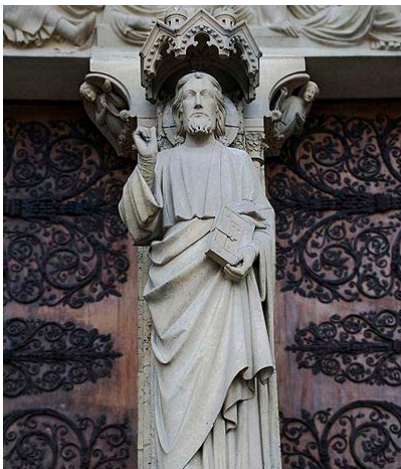
Figure 20. Le Beau Dieu, (Jebulon, 2011). CC0 1.0
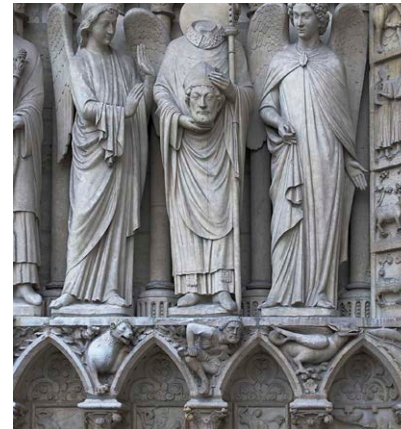
Figure 21. Saint Denis, (Jebulon, 2011). CC0 1.0

Unknown statue

Saint Constantine the Great and Saint Denis (Dionysius) holding his head, surrounded by angels. Neo-Gothic statues on the main facade of the Notre Dame Cathedral.

Under Dionysis' feet you can see the Unknown Statue. To the right is the model of the statue.

Saint John the Baptist

Saint John the Baptist and Saint Stephen, Western facade left Portal (the Virgin portal) of Notre-Dame de Paris, France.
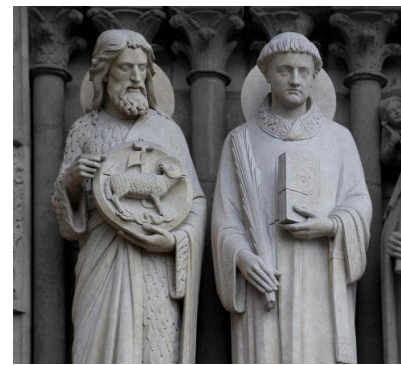
Figure 22. Saint John the Baptist, (Jebulon, 2011). CC0 1.0

PROJECT

| Fixed mesh | Four statues put in a circle | Scaled down to small model | Small model put inside big model | Small model subtracted from big model |
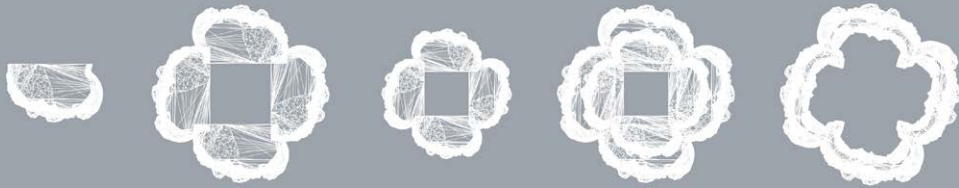
EARLY PROCESS OF THE SPIRE

Saint Peter

At the beginning of the process of creating a proposal for the spire, the Saint Peter statue was used in ambition to create the hollow bottom part of the spire.

The model was first mended, closed and made watertight. The aim was to use this strategy and work towards a perfect digital model with a closed mesh. The result of this work was a cylinder shaped volume with the shape of Saint Peter statue both inside and outside.
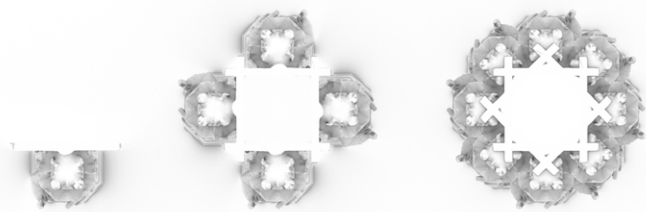
EARLY PROCESS OF THE SPIRE

Christus on the Trumeau

The scan of *Christ on the Trumeau* statue
was cleaned up and damaged parts were
removed. I wanted to merge it into a regular
shape where all the small details of this
model could work together.

The resulting shape has a similar form as
the previous model of Saint Peter. The
appearance of this 3D model is very much
intact in relation to the original statue.
In this state I don't think it has a very
interesting appearance. It lack irregularity
that could make it more captivating.

Shaded

Original mesh

Added object to boolean

Water tight mesh

Rendered

Original mesh

Added object to boolean

Water tight mesh
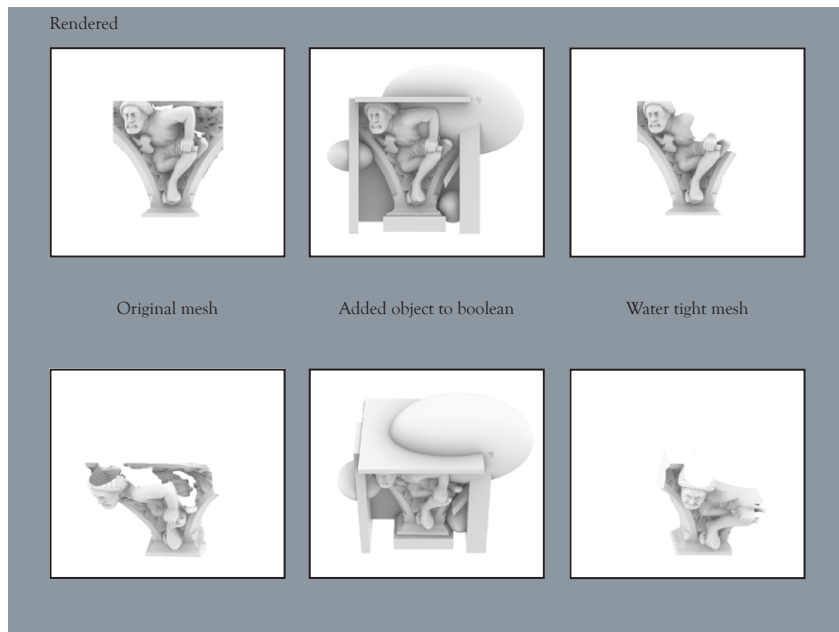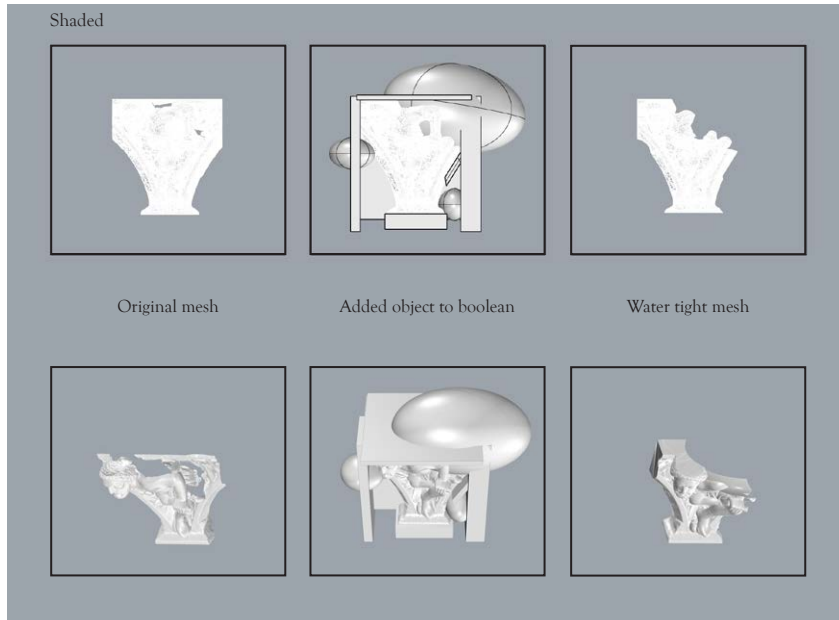
MEND THE MESH

"Unknown Statue"

This model was very incomplete with massive holes and parts missing. The images show the process of how I made it a closed model using different objects to cover and mend every damaged part of the surface.

In the process of fixing the model some parts were lost and the appearance changed slightly. In my opinion this only makes the model more interesting and the shape transforms into something more unperedictable.
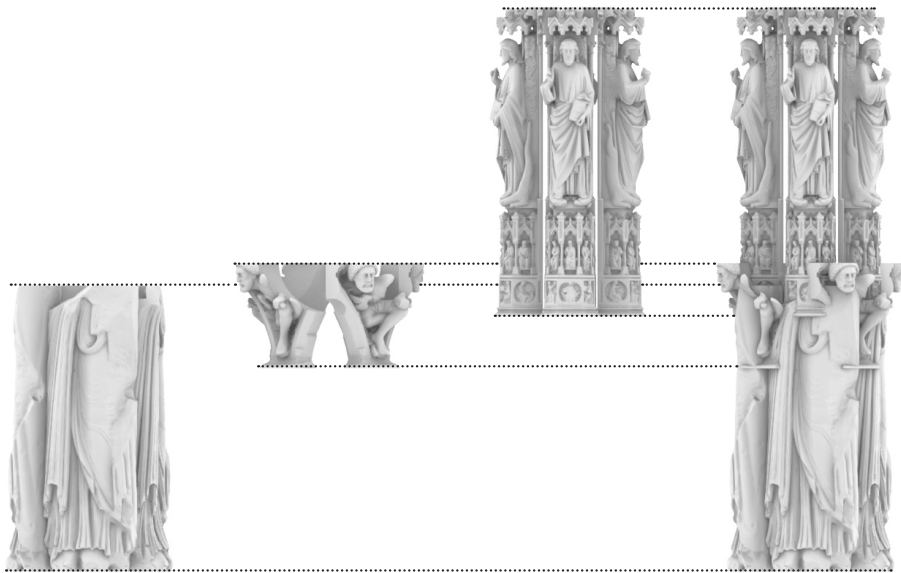
WATERTIGHT AMBITION

Merged Objects

The result of this merged model have some interesting parts. As mentioned before, the statue of "Christ on the Trumeau" is too complete in its appearance which makes it balanced in itself but not when assembled together with the other models. On the other hand, the way the "Unknown Statue" is sticking out of the headless "Saint Peter Statue" is much more intriguing.

The objects are merged together in a way that made the model watertight. This method is very time consuming and with my level of knowledge it became an obstacle to design in a creative and free way.

CONCLUSION OF EARLY PROCESS

New findings

In my previous experience of working with 3D models and preparing them for printing I used another slicing software than I have been using in this project. (Now Cura, before Simplify 3D). I assumed the circumstances would be the same and that the model had to be watertight to be printed which I at this point of the process learned it didn't have to be. This resulted in a much faster design process where the quality of the scanned model did not need to be taken into account to the same extent. This experience gave me a new tool for trying out more complex compositions.
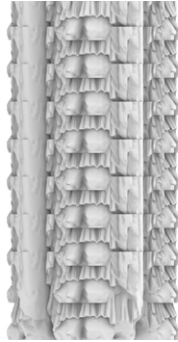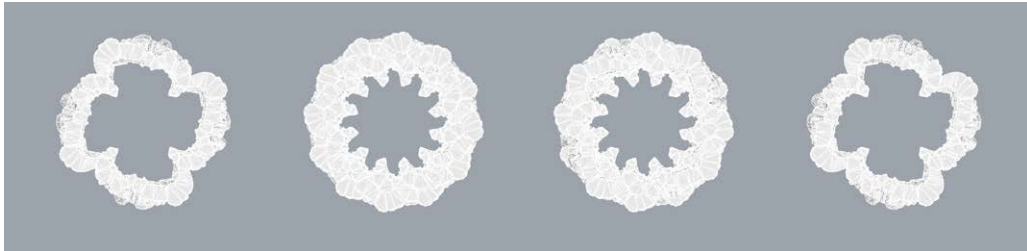
MULTIPLICATION & ROTATION

Saint Peter Statue

The lower part of the Saint Peter Statue can be considered to have the most interesting pattern and shape. I isolated this part, multiplied it in various ways and stacked it on top of each other. Small variations of positioning give the model different appearances.

(These compositions where not used in the final result.)
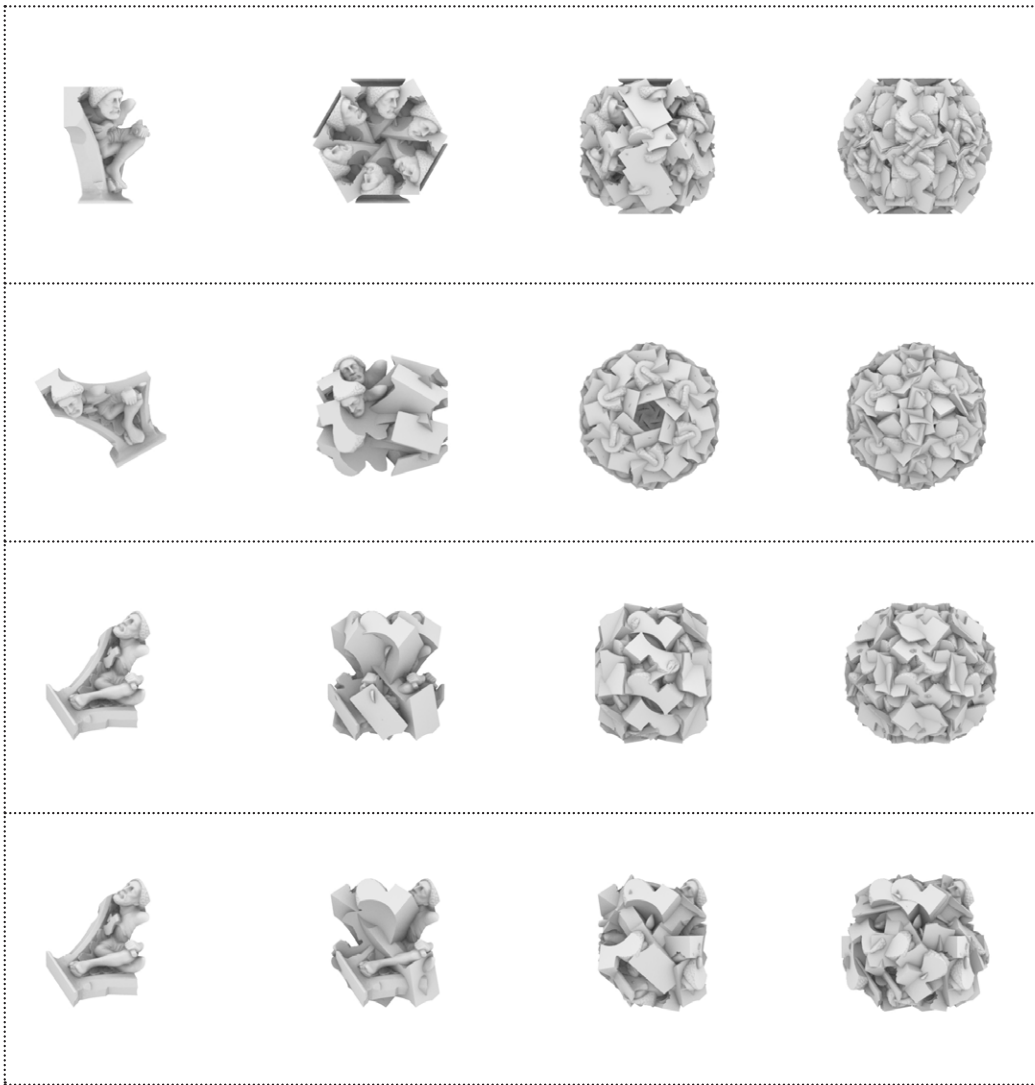
TWIST & TURN

"Unknown Statue"

The "Unknown Statue" is here nudged and rotated in various ways to experiment with various expressions. It is no longer possible to foresee the outcome of data entered into the program and an element of surprise occurs. Consequently I ceased control over the actual result, only being able to monitor the variables generating the development of the final design.
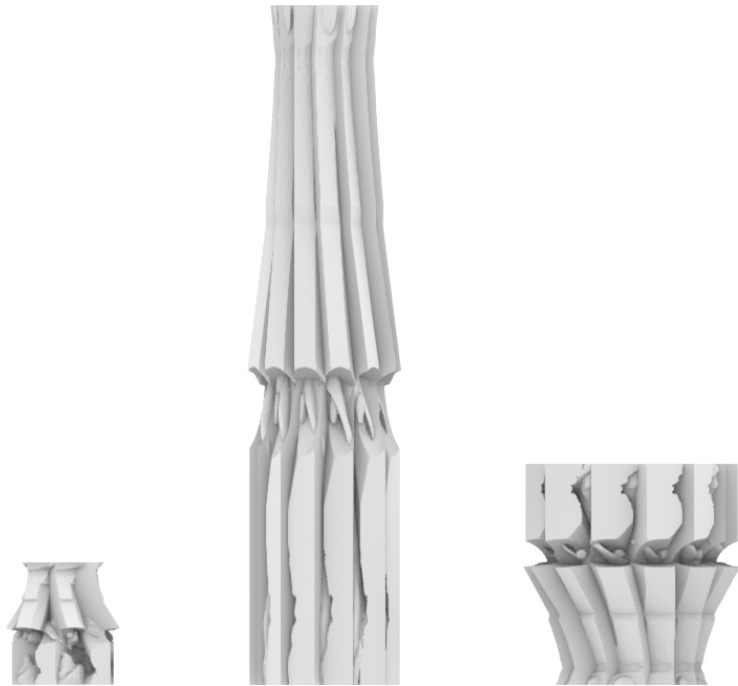
DRAG & MIRROR

"Unknown Statue"

The model was rotated, extended and
mirrored in different variations to later
function as the top part of the spire.

IGNORE DEFECTS

Saint John the Baptist

Earlier in the process I made an attempt to fix this scan but came to the conclusion that it wouldn't work. When I then started to ignore irregularities and overlaps in the composition, I also decided to use this scan even though it is only a shell and not a closed mesh.

For this object, it will be much harder to adjust the settings to control the quality of the printed object. This was the biggest shortage in order to make a successful print of this statue.
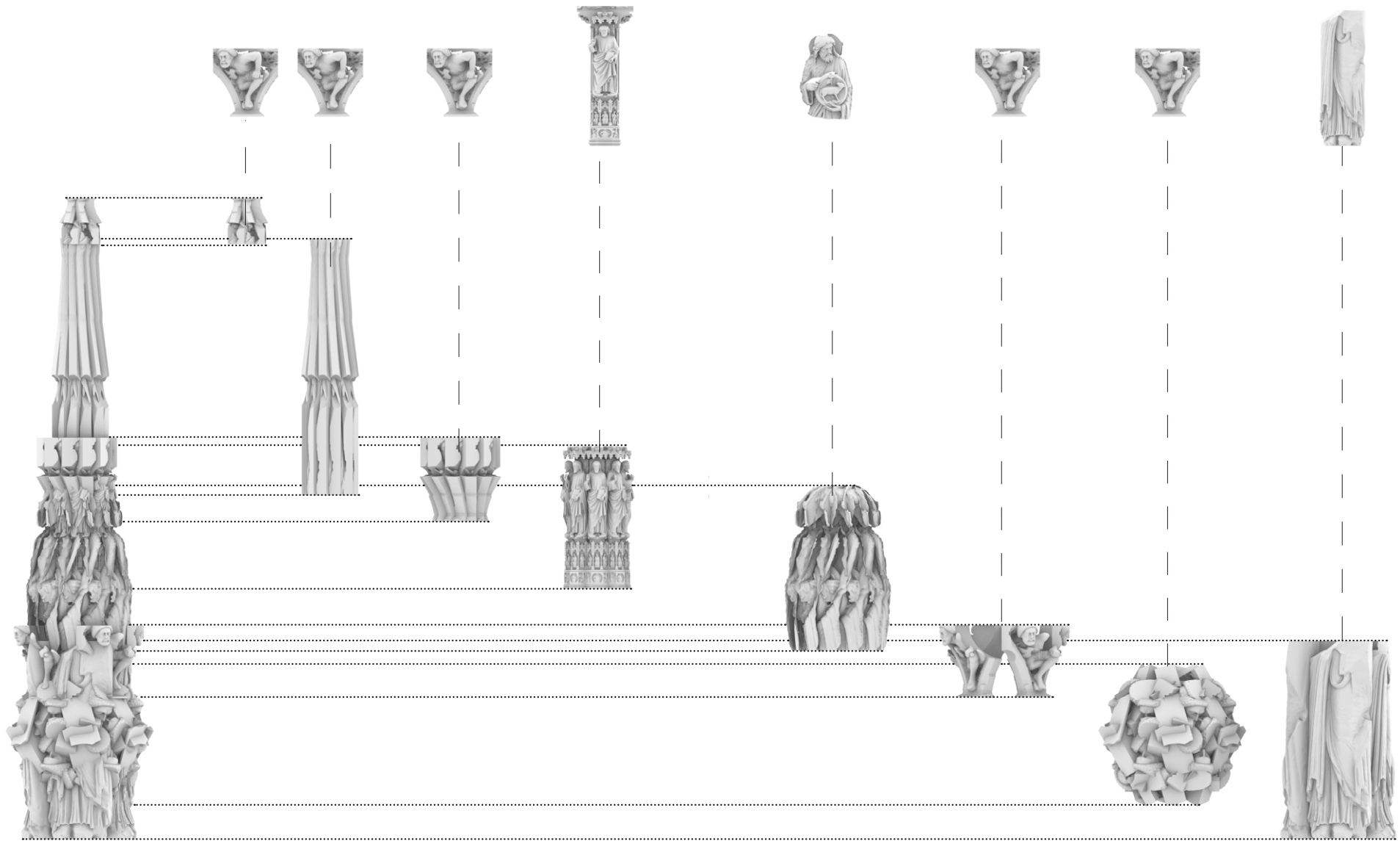
Visualization of the modification of each statue and how the
spire is sectioned in different themes, to create an appearance
of a random assembly of the spire.
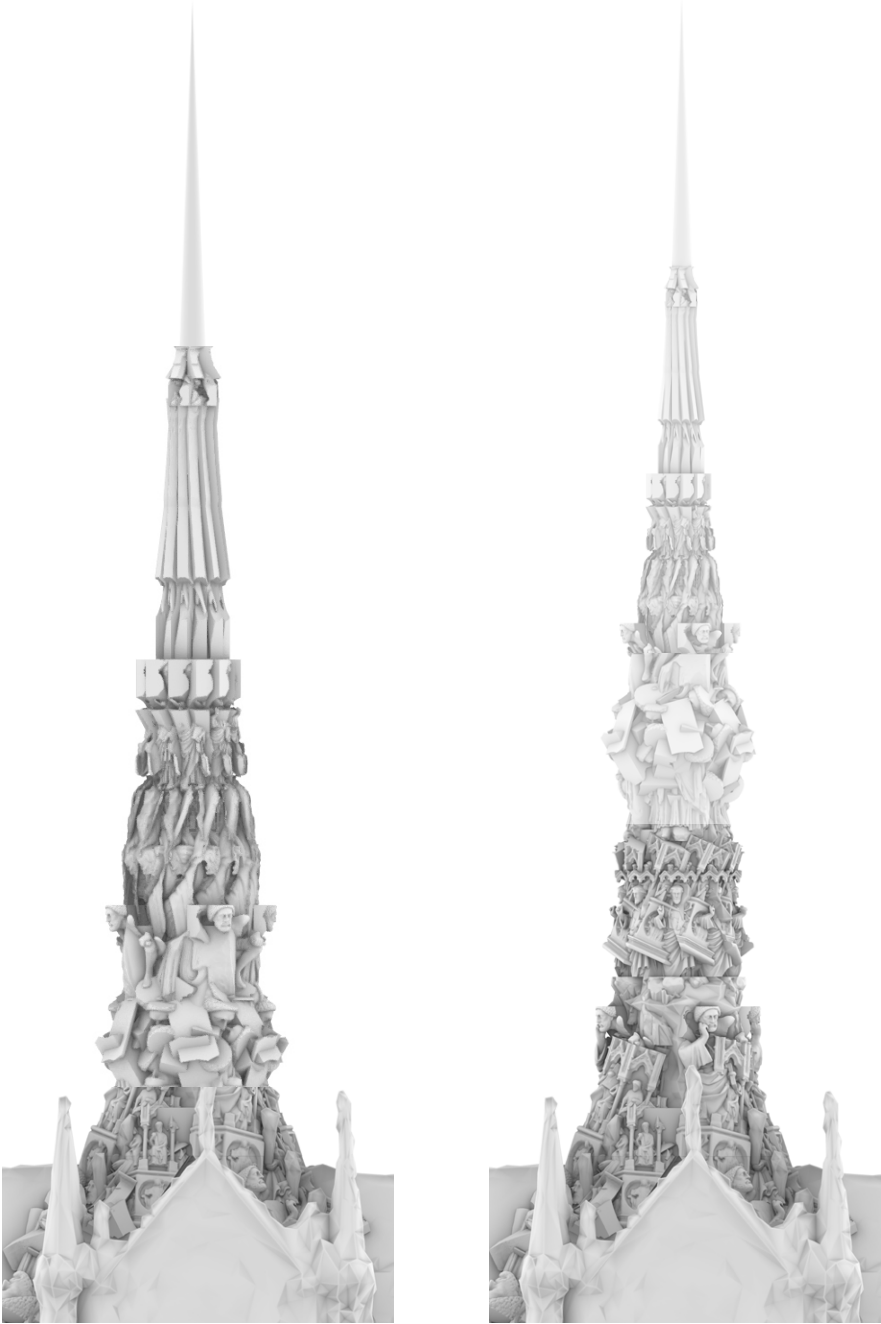
REFLECTION OF PROCESS

Importance of Scale

At this stage of the process the format of the spire is starting to shape. The combined model makes every component in itself lose value when the structure as a whole gradually develops. By adding more objects to the structure and lowering the scale of the unit it loses its original expression and the impact of the individual unit becomes less dominant. It also gives the whole object or design new qualities.

This image illustrates the importance of scale and finding a harmonized balance between detail, unit and structure.The balance between opposites is what makes the expression interesting. Order and chaos, big scale and small scale, clear motif and undefined motif.
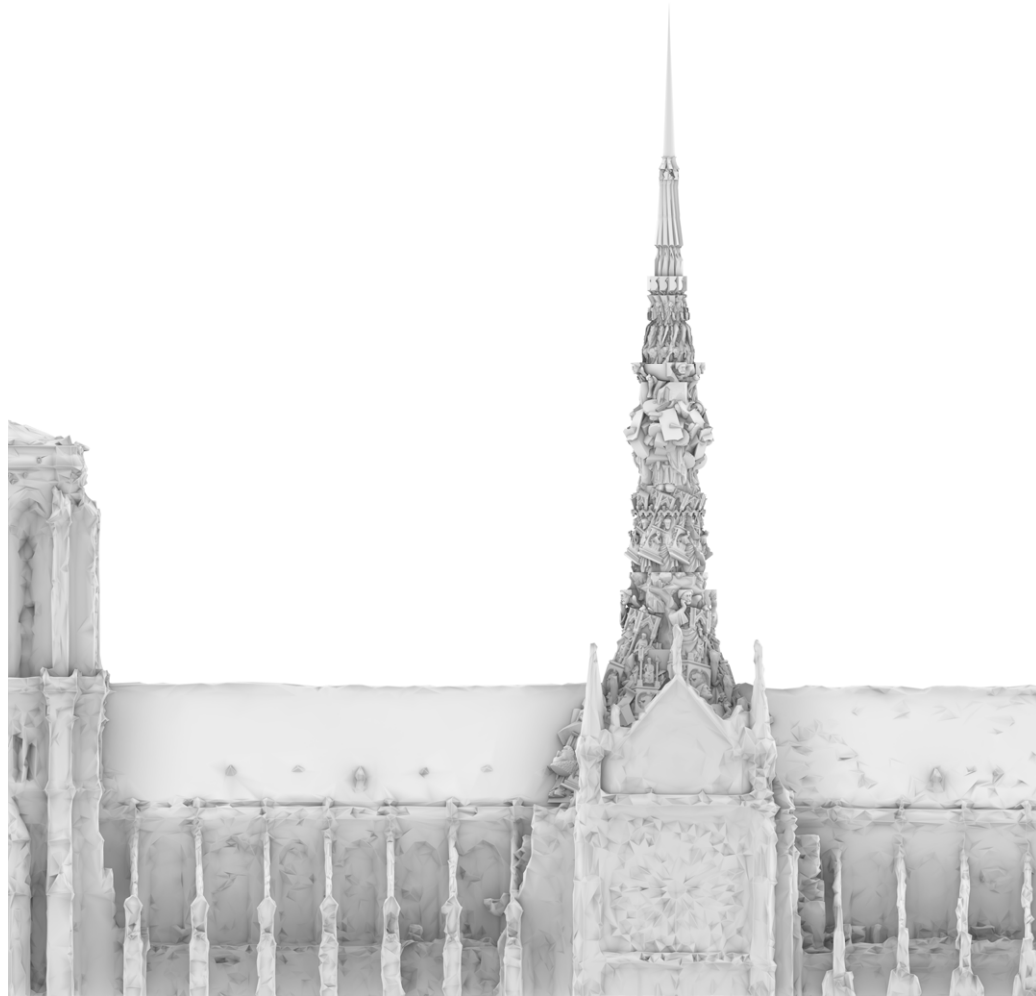
FINISHED DESIGN

Design proposal

I realized during the process the importance of the moments when I as the creator announce my role in the process, and the moments when the participation is set aside.

To allow myself to figure out the potential and the style of the tools I chose to use, I set aside any possible idea of how the final design would turn out. I wanted the result to be a combination of unexpected events and conscious decisions. My active involvement in the design is found both in the actions I've taken and the ones I decided to overlook.
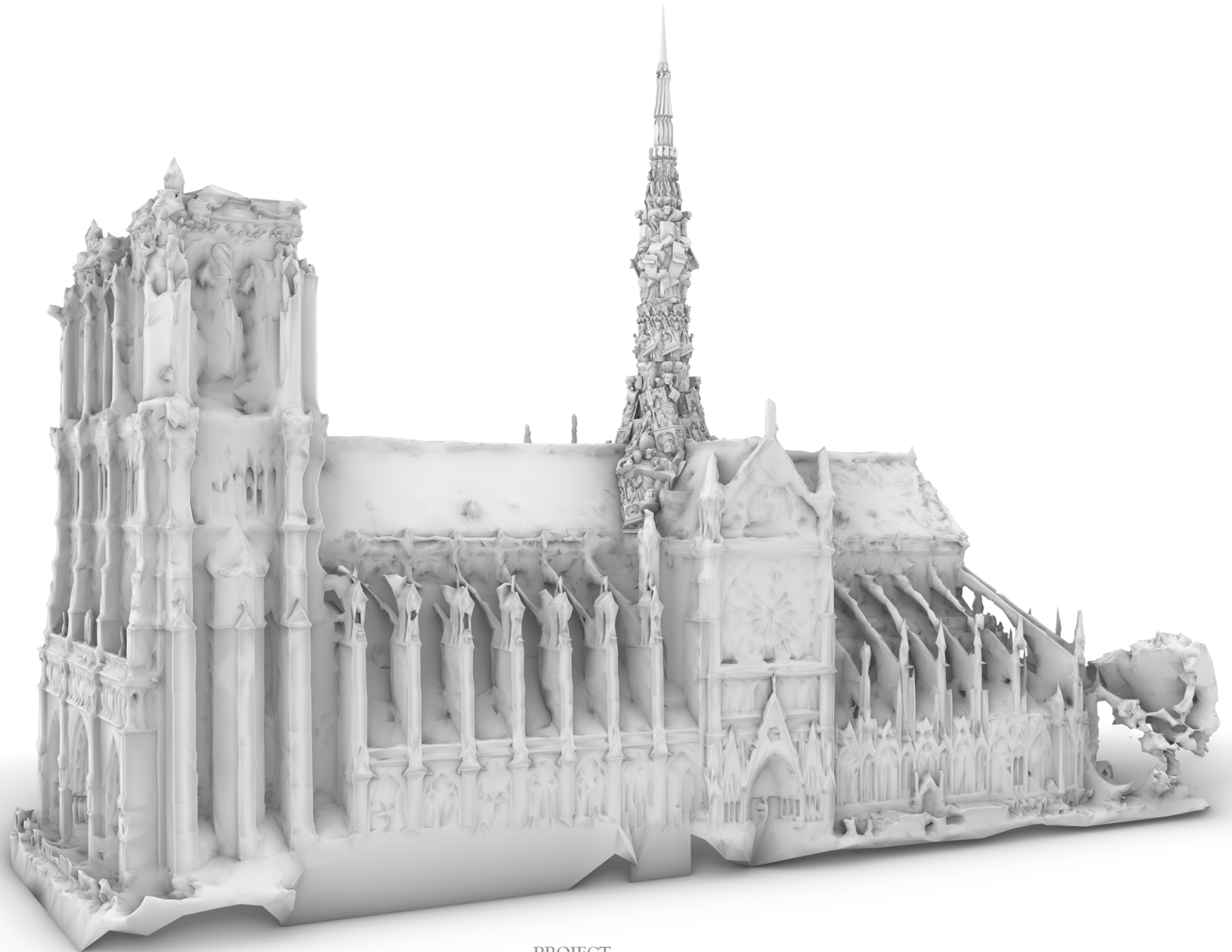
PROJECT
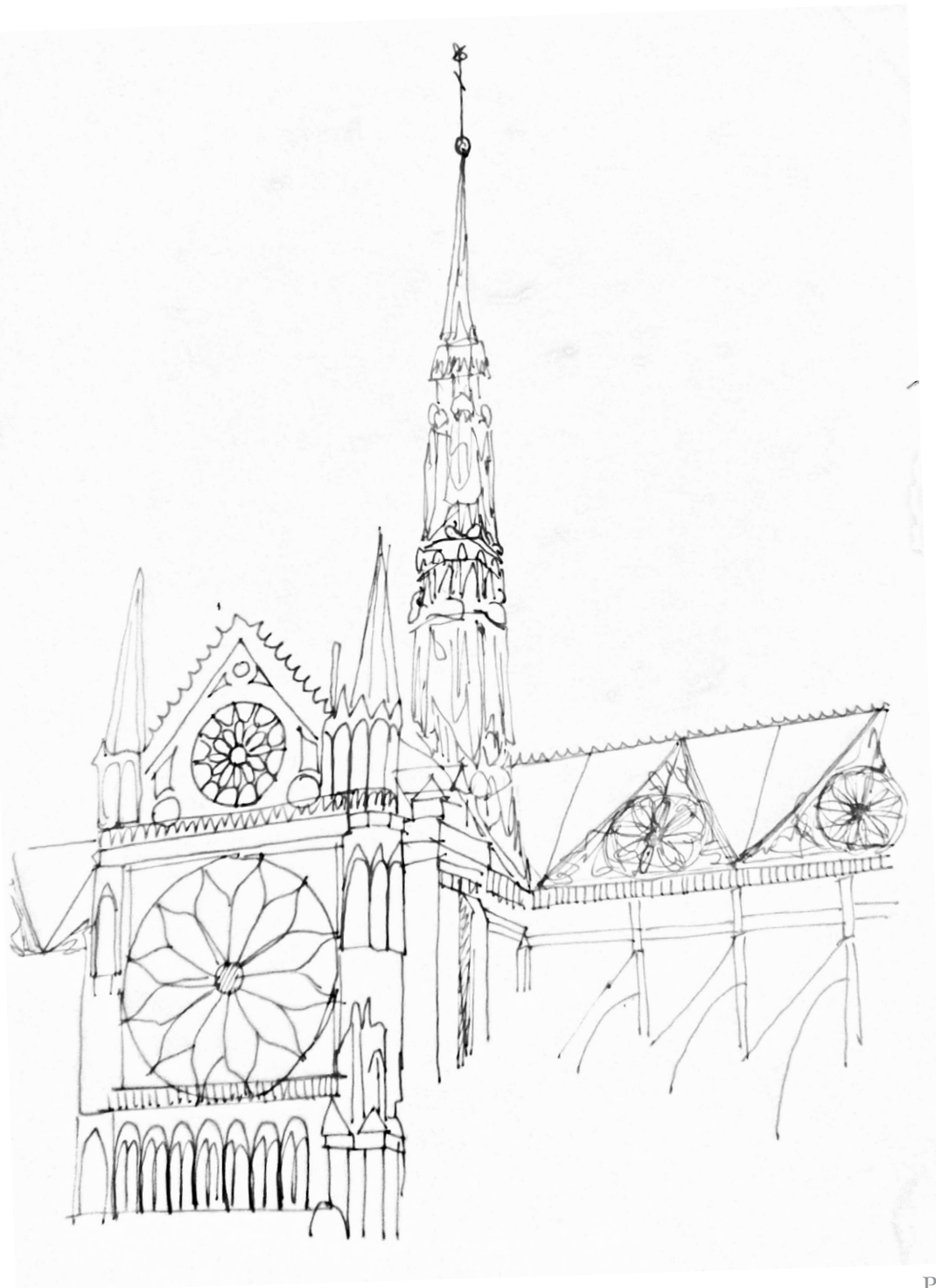
STICK TO THE TOOL

Draw by hand

In my process I've also tried to use tools that I'm more familiar with. By doing so, I've observed a difficulty in combining the two.

Changing the tool means changing the rules that apply and in this case draw by hand didn't promote the development of the design. The tools are too different and have different strengths and they didn't complete each other in this design process because of the difficulty of translating the drawn image to 3D information.
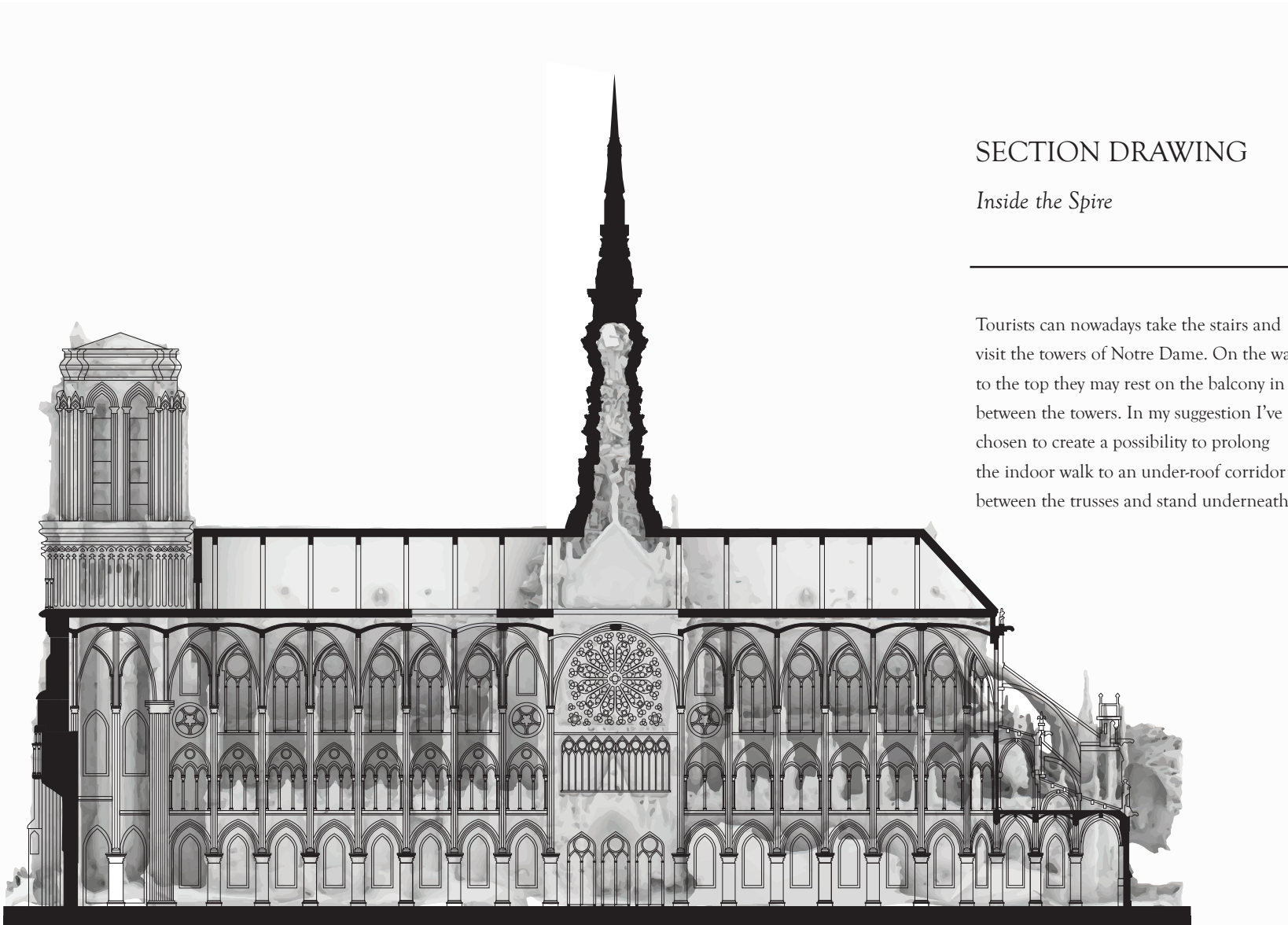
SECTION DRAWING

Inside the Spire

Tourists can nowadays take the stairs and visit the towers of Notre Dame. On the way to the top they may rest on the balcony in between the towers. In my suggestion I've chosen to create a possibility to prolong the indoor walk to an under-roof corridor between the trusses and stand underneath the spire. In the center, there will be a lit view of the inside of the spire. During the fire the inside arches collapsed and left two holes in the roof. I will leave them open to become a visual portal from inside the roof to the chathedral hall.

06: PHYSICAL MODEL
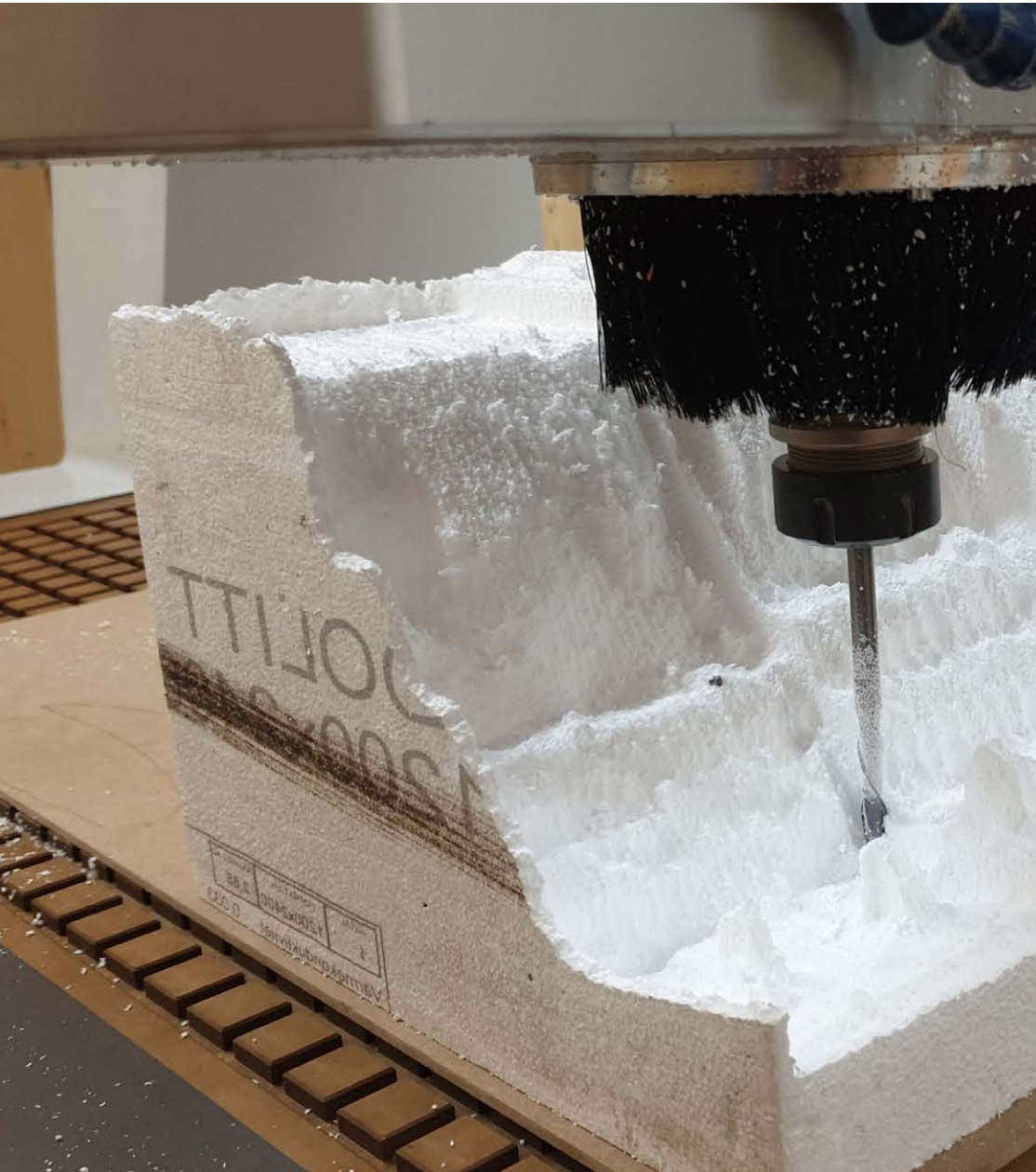
MAKING THE CATHEDRAL

From 3D scan to physical model

The 3D scans of the full chathedral available online aren't perfect but give a great digital representation of the actual building.
The information of the surface combined with color details of the texture makes it visually alike. I've been using this type of model when printing the complete base of the cathedral in scale 1:100 with a milling machine in plastic foam.
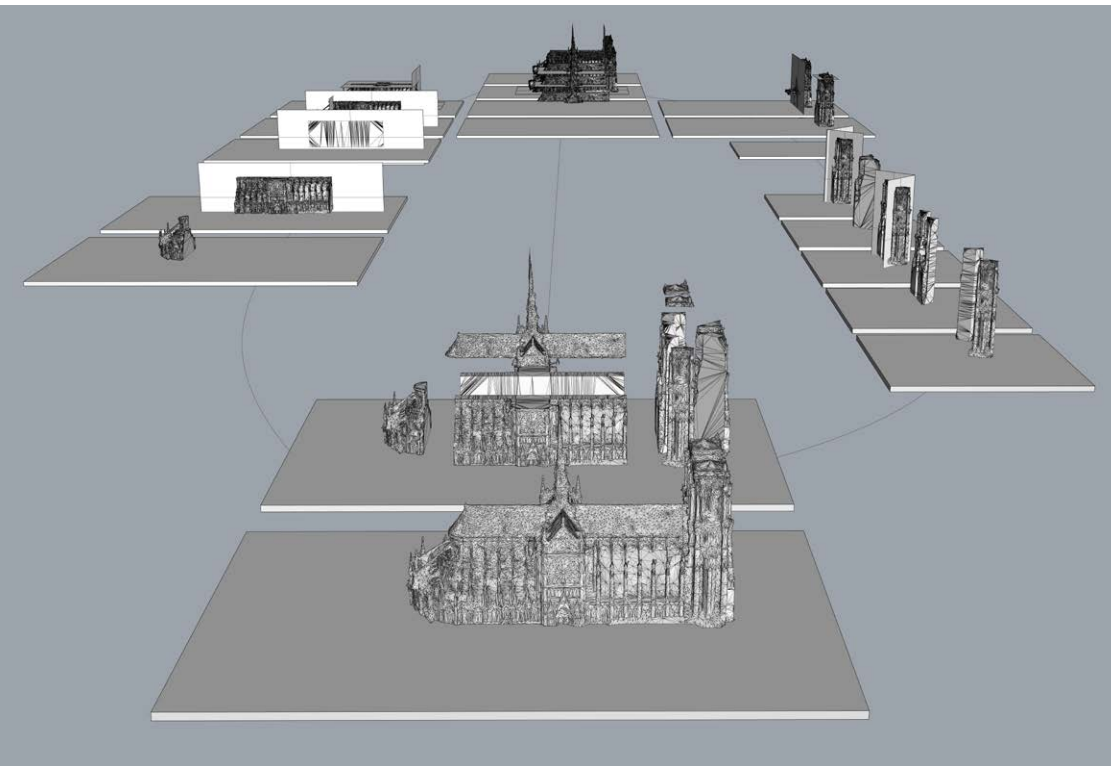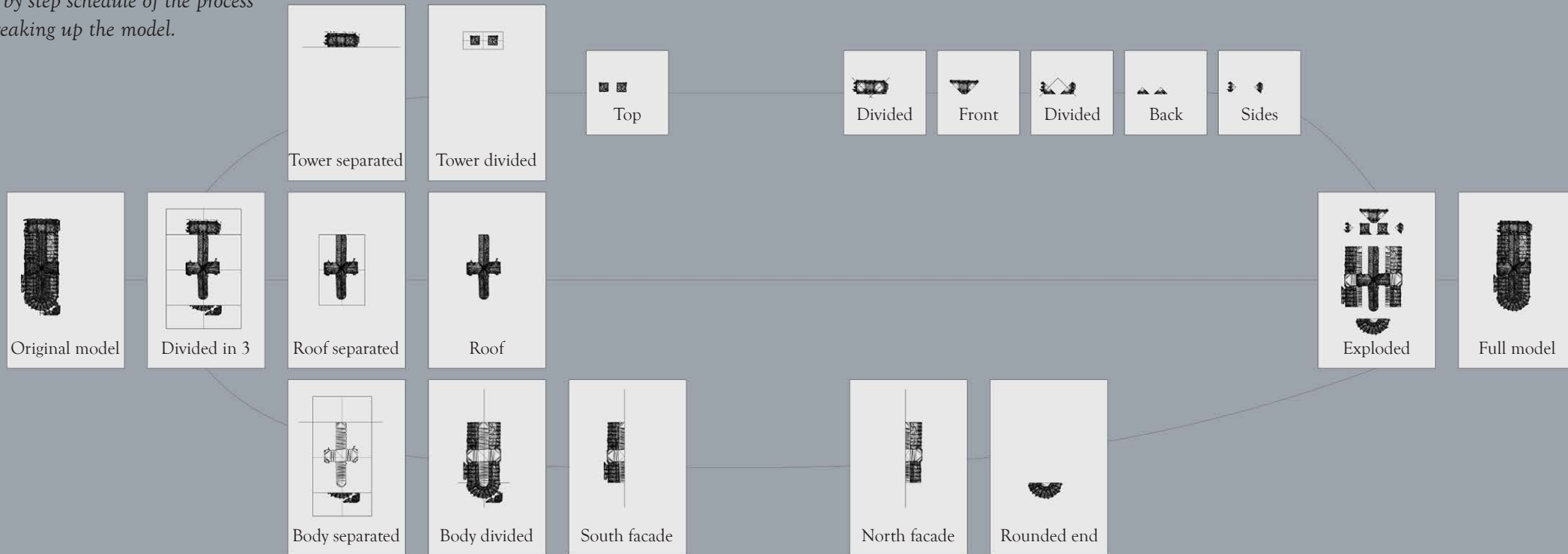
3D MODEL

Preparation for print

The model was first made watertight by
closing the bottom part. To make it possible
to print out the model in the milling
machine every facade has to be placed flat
on the base with the detailing upwards. To
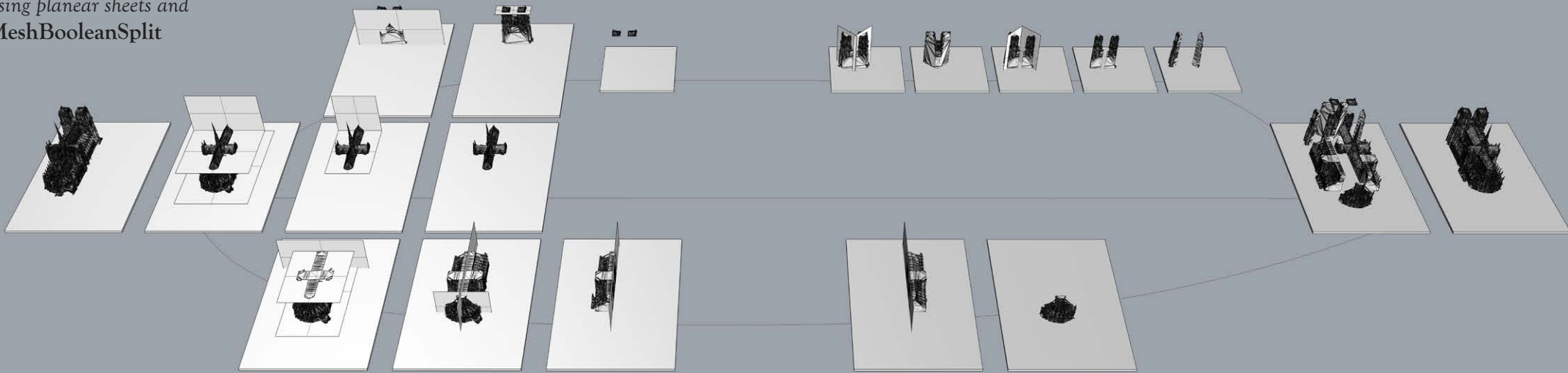achieve this, I had to break the model apart
in smaller components.

MODEL PREPARATION

Step by step schedule of the process
of breaking up the model.

Tower separated

Tower divided

Top

Divided

Front

Divided

Back

Sides

Original model

Divided in 3

Roof separated

Roof

Exploded

Full model

Body separated

Body divided

South facade

North facade

Rounded end

PHYSICAL MODEL

MODEL PREPARATION

*The model was sectioned
using planear sheets and*
MeshBooleanSplit
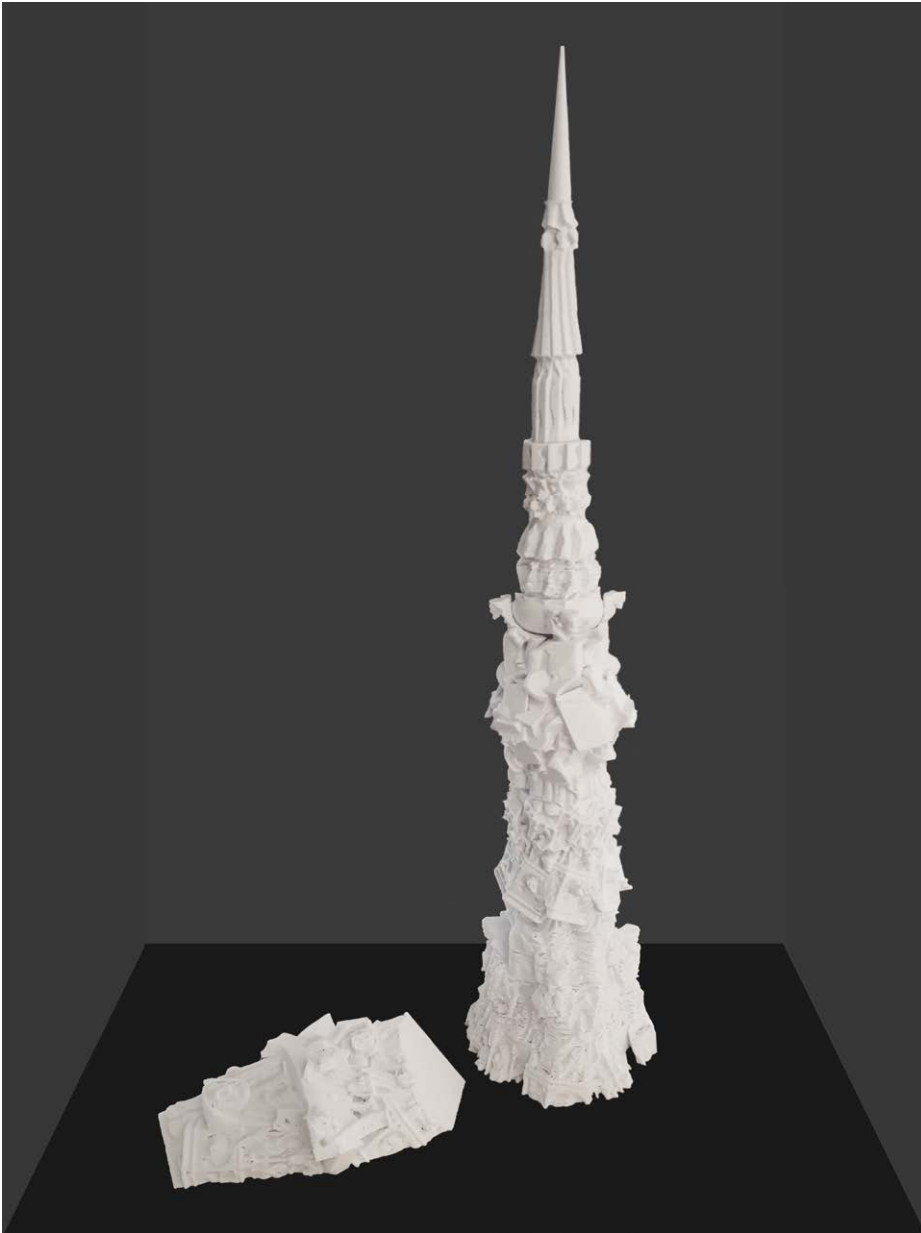

PHYSICAL MODEL

PHYSICAL MODEL

Print in the milling machine

When the parts had been printed in the milling machine they were altered and glued together.

PRINTING THE SPIRE

Preparation for print

It is possible to print the complete spire in one piece but since the 3D printer has size limitations I had to section the model in nine parts.

The model was exported as an stl file and imported to the software application Cura. In Cura I had to manipulate the settings to make it suitable for the chosen scale which is 1:100.

PHYSICAL MODEL

SYMBOLISM

Resurrection of the Spire

_____

The idea of the new spire is an imaginary resurrection of the fallen elements - a visual image of God reaching down through the roof with his hand, collecting all fallen elements together and pulling them back towards the sky, maintaining the random, chaotic positions in which the elements were laying on the ground.

The top of the spire is finalised with a slight counter-clockwise rotation to give the impression of a manual touch before the last part of the material leaves God's rising hand. This gives the design a preserved memory of the devastating fire the cathedral was experiencing in 2019.

The elements suitable for the spire was chosen with inspiration from the event that actually occurred on site. The roof collapsed with thousands of objects, statues, ornaments, beams and other construction elements. To reintroduce different statues from the Notre Dame in the design is therefor logical in that sense.

PHYSICAL MODEL

ASSEMBLED DETAILS

*From detail to completeness*

The design aims to achieve a balance between the individual units, the entire experience of the spire and the cathedral as a whole. Using digital tools makes it possible to create endless types of ornating details, and complex figures. When handling that complexity in an aesthetical context, it has to be in proportion with a good deal of care for the objects, the ethical aspects of the monument and paying attention to the scaling aspect to avoid an unsatisfying result.

Through the idea of a resurrection of the spire through arising statues, ornaments and symbols, the design implements and pay respect to the religious role of the building.

When observing the spire closely one can identify the ornamentations, the faces of the figures, their complex mutual order, the progressive fade into a less complicated design the higher you reach and the finalizing rotation before the spire peaks.

The aim of the design is to create a look that would fit in the perception of the cathedral observed by far.
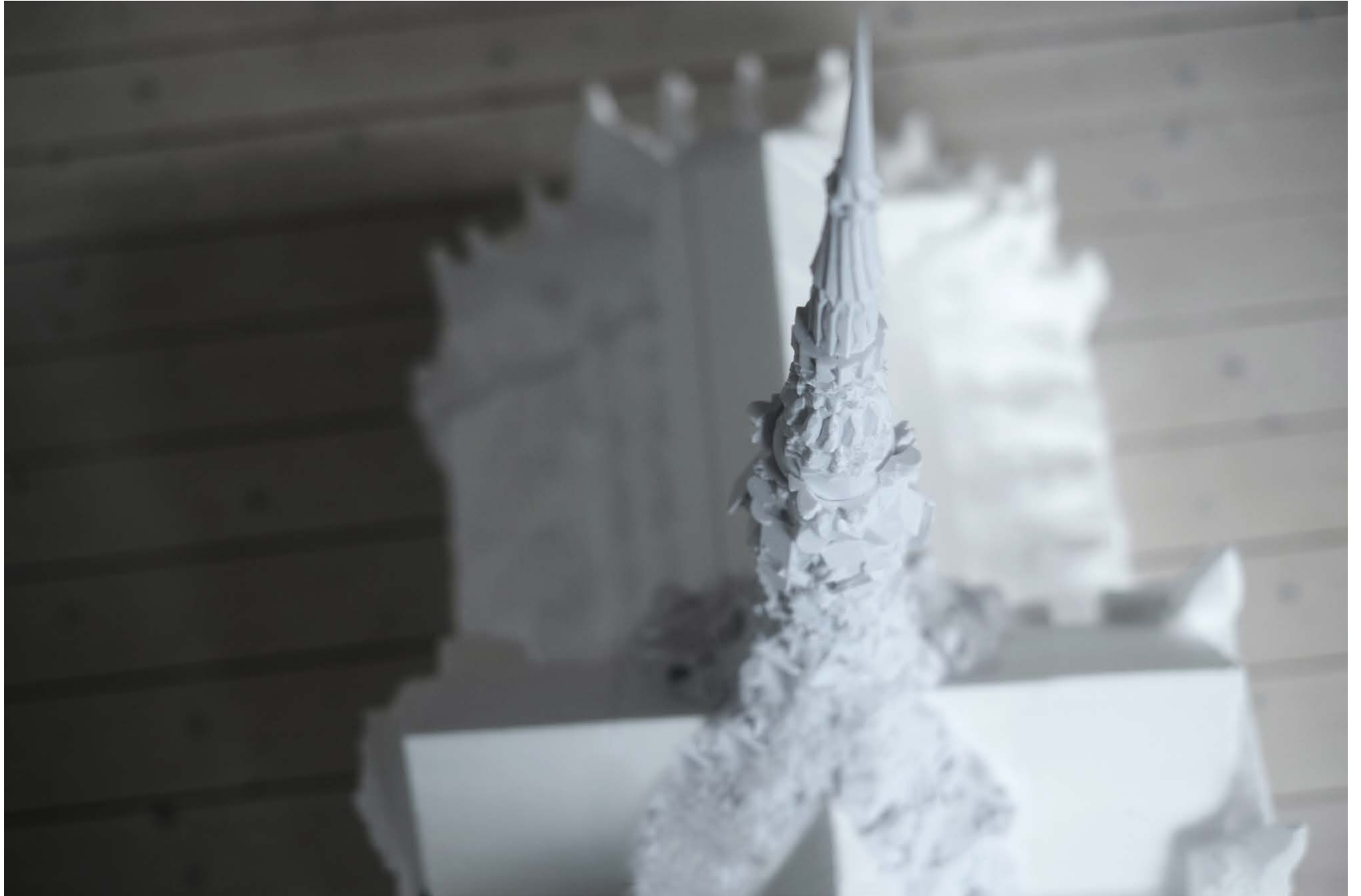
PHYSICAL MODEL

PHYSICAL MODEL

PHYSICAL MODEL

07: DISCUSSION

DISCUSSION

When talking about digital tools we often mention the endless possibilities they enable. We are not bound to the same rules we are used to outside of the digital world and we must navigate in a new field of expertise.

When I chose to work with 3D scanning and 3D printing, I set the frames of what my design could become. I wrongly thought that my design of the spire could be anything, which is not the same as having endless possibilities. Every digital tool has its own strength and limitation which we as architects have to be aware of. When combining different tools, the style of the architecture will be influenced.

When I analyzed some of the reference projects mentioned in the article The New Architecture Ornament, I drew the conclusion that they have tried to integrate modern techniques to the process of creating decorative architecture. It is an attempt to take on digital tools without paying attention to their full potential and the result becomes unsatisfying. The process becomes dynamic first when the tools are approached with an allowance of letting them be more than just a tool. This is achieved by using them in a way where the result is characterized by the specific properties of the tool.

Looking at my design of the spire, I do not see what I expected at the start. The design is influenced by the design-tool that I have been using and it has a very expressive and powerful appearance. The design is combining the historical aspect with the modern and is interesting to the observant who notices the complexity of the design and the historical aspect. My goal was never to make a realistic spire for Notre Dame, but to examine how we can use 3D scanning and 3D printing when we are combining it with a historical building.

The structures and shapes of digitally inspired design proposals are often compared to styles from historical eras.

Some seek out historical ornamentation to find inspiration but it's important to find the balance between trying to recreate historical values and illuminate the effect of the chosen digital tool. In the reference project Digital Grotesque, Hansmeyer has found a beautiful balance between the two. It expresses the feeling of looking at something familiar that has been manipulated to the point where it's unrecognizable. In the description of one of his projects it says: "Neither foreign nor familiar". I think this embrace the essence of what we should strive towards when creating architectural projects using this type of technique where the design strategy and the resulting design becomes creatively free.

Helsinki Guggenheim Museum is based on anonymous units disconnected from the site. The project is based on the concept where individual figures have no intentional symbolic agenda in favor of the whole image. This project has a strategy to lose value of the unit. In my design I have a similar ambition to decrease value of the component by lowering the scale, an ambition that makes overall impression of the design much more interesting with all hidden details.

I believe that how we choose to express ourselves about technology have an impact on our understanding of how we can use digital tools, such as 3D scanning, 3D modelling and 3D printing. In the text by David Ross Scheer he speaks of technology as a calculating tool, but when looking at the project of Digital Grotesque II it expresses technology to be a thinking tool and a designing companion. Looking at technology as thinking machines makes the collaboration between human and computer completely different and more complex. Computers can become our assistants rather than just a shortcut to the result.

We as architects have the possibility to lose some of the control and let the machines handle parts of the process as long as we incorporate a type of mindset where we are not forcing the tool to do something it is not aimed for.

Designs controlled by the mind of machines means that we don't have to understand the logic behind. Therefore, seeing the machines as a thinking object is more accurate than only seeing it as a calculating tool.

An important aspect is how we must choose when we are in control of the process and when we are not. We can manage a highly detailed model where we can free ourselves from designing every single part. In my process I have made a conscious decision to use details from Notre Dame. The reason for doing so is to connect the use of 3D scanning to the chosen site. The specific selection of details was out of my control since I was unable to scan the objects myself and I was therefore limited by the online supply.

In the process of manipulating the 3D models I have strived towards an uncontrolled process where I've put in data that have generated different movements and multiplications of the model. I have then evaluated the result and composed the units to a complete model of the spire.

To have the option to choose to control every outcome or not is key to how we should use digital tools. We have to find the balance between having control and surrender it. This kind of design process where you are guided by the power of the digital tool requires much consideration and knowledge about the opportunities and limitations of the design tool to obtain the aesthetical desired outcome.

DISCUSSION

08: CONCLUSION

CONCLUSION

Digital tools possess promising capabilities in the creative process of making architecture. Understanding the opportunities they open for as well as being aware of how they imprint the design result is important to be able to obtain the desired outcome.

When designing with these digital tools, it is crucial to adopt their characteristics to the extent where we can welcome an unexpected result as an uncontrolled ingredient in the architectural design process and let the tool undertake the role of a design companion.

09: REFERENCES

TEXT REFERENCES

Dillenburger, B. (2017) *Digital Grotesque II.* Retrieved from http://www.michael-hansmeyer.com/digital-grotesque-II

Gross, M. (2010). *Ignorance and Surprise: science, society, and ecological design.* Cambridge, Massachusetts: The MIT Press MFGA. (2014) *Helsinki Guggenheim Museum.* Retrieved from https://www.mfga.com/helsinki-guggenheim

Murphy, D. (2016) *The New Architecture Ornament.* Retrieved from https://www.iconeye.com/architecture/features/item/4218-the-new-architecture-ornament

National Geographic. (2019) *Inside Notre Dame | The Story of God.* Retrieved from https://www.youtube.com/watch?v=PnZFfj6VNvY

Sasaki, T. (2019). *Architecture of Shells.* Retrieved from http://www.um.u-tokyo.ac.jp/architectonica/kai_en.html?utm_medium=website&utm_source=archdaily.com

Scheer, D. R. (2014). *Architecture as an Ethics of Technology.* Retrieved from http://deathofdrawing.com/architecture-as-an-ethics-of-technology/

Voon, C. (2018). *Can You Identify the Famous Buildings In This 3D-Printed Model?* Retrieved from https://hyperallergic.com/419111/can-you-identify-the-famous-buildings-in-this-3d-printed-model/

IMAGE REFERENCES

1   Kaufmann & Gehring. (2017). *Grotto II* [Screen capture] Retrieved from http://digital-grotesque.com/concept.html

2   Mark Foster Gage. (2014). *Helsinki Guggenheim,* [Image] Retrieved from owner

3   Pålsson, S. (2019). *Memories of Architecture* [Image]

4   The University Museum of Tokyo (2019). *Architecture of shells.* [Image] Retrieved from http://www.um.u-tokyo.ac.jp/architectonica/kai_en.html

5   Periskop.Cloud. (2019). *VR Notre Dame project* [Screen capture] Retrieved from https://sketchfab.com/3d-models/vr-notre-dame-project-576dd86f11de4aa9ab8069c31c8431e3

6   Pålsson, S. (2019). *3D Printer 1* [Image]

7   Pålsson, S. (2019). *3D printed towers* [Image]

8   Pålsson, S. (2019). *3D Printer 2* [Image]

9   AsVL3. (2008). *John Lewis Department Store* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:John_Lewis_pattened_facade.jpg

10   Ouda, H. (2019). *Fire* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:حريق_كاتدرائية_كنيسة_نوتردام.jpg

11   Cangadoba. (2019). *Firefighters at the Notre Dame* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:NDonFire_8773_(edited).jpg

12   Guillaume, L. (2019). *Spire on Fire* [Online Image] Retrieved from https://en.wikipedia.org/wiki/File:Fl%C3%A8che_en_feu_-_Spire_on_Fire.jpeg

13   CEA. (2011). *Crown of thorns* [Online Image] Retrieved from https://www.flickr.com/photos/centralasian/6303651611/in/album-72157627846458188/

14   Madhurantakam. (2019). *View of Cathedrale from river* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:Notredame_Paris.JPG

15   Sansi, O. (2016). *Arches* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:Vitrales_y_bóveda_de_Notre_Dame_de_París.jpg

16   Rabich, D. (2014). *Rose window* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:Paris,_Notre_Dame_-~_2014_-~_1446.jpg), https://creativecommons.org/licenses/by-sa/4.0/legalcode

17   Haas, P. (2013). *West view* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:Notre-Dame_de_Paris_2013-07-24.jpg

18   Rabich, D. (2014). *Entrance* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:Paris,_Notre_Dame_-~_2014_-~_1349.jpg

19   Dalbéra J-P. (2013). *Statues acéphales* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:Statues_acéphales,_Musée_de_Cluny,_Paris_mai_2013.jpg

20   Jebulon. (2011). *Le Beau Dieu* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:Le_Beau_Dieu_Notre-Dame_de_Paris.jpg

21   Jebulon. (2011). *Saint Denis of Paris between two angels* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:Emperor_and_Saint_Denis_Notre_Dame_Paris.jpg

22   Jebulon. (2011). *Saint John the Baptist and Saint Stephen* [Online Image] Retrieved from https://commons.wikimedia.org/wiki/File:Saint_Jean_Baptiste_Saint_Etienne_Notre_   Dame_Paris_a.jpg

A SPECIAL THANK TO: