The use of photogrammetry in the conservation of painted outdoor sculpture

Adressing Jean Dubuffet's Jardin d'Email


Publication date
2021

Document Version
Final published version

Published in
Future Talks 019

License
Article 25fa Dutch Copyright Act (https://www.openaccess.nl/en/in-the-netherlands/you-share-we-take-care)

Link to publication

Citation for published version (APA):
FUTURE TALKS
019
SURFACES.
LECTURES AND WORKSHOPS ON TECHNOLOGY
AND CONSERVATION OF THE MODERN

TIM BECHTHOLD
EDITOR

DIE NEUE SAMMLUNG
THE DESIGN MUSEUM
THEY’VE GOT PLASTIC CHRISTMAS TREES NOW. THEY’RE HARD TO TELL FROM THE REAL ALUMINUM ONES.
MILTON BERLE
CONTENT

008 PREFACE
BY ANGELIKA NOLLERT

009 LECTURES
010 NOW YOU SEE IT, NOW YOU DON’T: CONSERVATION OF LARRY BELL’S SHADOWS
BY ELLEN MOODY, MEGAN RANDALL, LYNDA ZYCHERMAN, ANA MARTINS

012 LET’S STICK TOGETHER – THE BONDING OF SILICONE RUBBER AND ITS CHALLENGES
BY SATENIK AESCHI, GERDA KALTENBRUNER, MARTINA PFENNINGER LEPAGE

014 SURFACE DEPOSITS ON FAUX LEATHER. THE KEM WEBER AIR LINE CHAIR
BY KATE WIGHT TYLER

015 THE USE OF PHOTOGRAMMETRY IN THE CONSERVATION OF PAINTED OUTDOOR SCULPTURE: ASSESSING JEAN DUBUFFET’S JARDIN D’ÉMAIL
BY ALICE WATKINS, SUSANNE KENSCHE, SANNEKE STIGTER, JITTE WAAGEN, TIJM LANJOUW

016 TANGLING WITH ‘IRON SPAGHETTI’. RESEARCH INTO AND RESTORATION OF ABRADED METAL IN JEAN TINGUELY’S MÉTA-HARMONIE II (1979)
BY MARCUS BROECKER, CAROLE MAÎTRE

017 THE FUTURE OF RESPONSIVE SURFACES IN THE LIQUID MODERNITY
BY KATIA GASPARINI, ALESSANDRO PREMIER

018 LIKE A SECOND SKIN – WRAPPING KATHARINA FRITSCH’S SCULPTURES WITH A DELICATE MATTE SURFACE
BY CHRISTINA ROBENS, GERDA KALTENBRUNER, KARIN STEINER

019 AQUEOUS CLEANING METHODS FOR HYPERREALIST SILICONE RUBBER SCULPTURES
BY LAURA WOLFKAMP, EVELYNE SNIJERS, SUZAN DE GROOT

020 SHINE ON! POLISHING AS A TREATMENT FOR ABRADED HIGH-GLOSS SCULPTURES
BY HEDWIG BRAAM, EVELYNE SNIJERS

021 WHO SAID POLISHING IS EASY? ... AND A CASE OF LÜDERS LINES
BY ELEONORA E. NAGY, WILLIAM ZAHNER, DAN J. GIEBER

022 TITANIC, ‘QUICK AND DIRTY’. NIR SPECTROSCOPY FOR THE IDENTIFICATION OF PLASTICS
BY SUSANNE BRUNNER, MARTIN MACH

023 INVESTIGATIONS IN THE CONSERVATION OF AN ART PIECE WITH STRETCHED RUBBER LATEX
BY JULIA SAWITZKI

024 RESEARCH AND STUDIES ON THE CONSERVATION OF HIGH-PRESSURE DECORATIVE LAMINATES: A CASE STUDY
BY ELISA ZACCAGNINI, GRAZIA DE CESARE, MARCELLA IOIELE, MAURO TORRE, FRANCESCA VALENTINI

025 ENERGIA BY FORTUNATO DEPERO
THE REDISCOVERY OF AN INDUSTRIAL MATERIAL FOR FURNITURE VENEERS AND WORKS OF ART: BUXUS™
BY SARA ABRAM, TIZIANA CAVALieri, BARBARA FERRANi, ROSANNA PIERRITTO, TOMMASO POLi, FRANCA VARALLO, BEATRICE ZUCCHelli

104 COLOURED PLATES

122 IMPACT BREAK BEHAVIOUR OF PMMa SHEET: WHEN DAMAGED SURFACES TELL A STORY
BY LISETT IRELAND

132 PITFALLS OF TRANSPARENCY. INVESTIGATING BONDING DEFECTS AND FAILURES IN TRANSPARENT POLY(METHYL METHACRYLATE) OBJECTS
BY ANNA LAGANi, MICHAEL DOUTRE, SUZAN DE GROOT, HENk VAN KEULEN, MELISSA DAVID, ODILE MADDEn, MICHAEL SCHILLING, MAARTEN VAN BOMMEL

208 PROJECT PLASTICS: SHAPING THE PLASTIC IDENTIFICATION TOOL
BY CARIEN VAN AUBEL, OLIVIA VAN BOOLEN, SUZAN DE GROOT, HENk VAN KEULEN, LYDIA BIEERKE

262 KEYNOTE

264 WORKSHOPS

270 SPEED MENTORING SESSION

273 SUPPLIERS AND REFERENCES

292 PHOTO CREDITS

309 IMPRINT
"We’re all like little ants who scurry around with the materials that are at hand right now. Each generation finds new materials. It’s just evolution, isn’t it?"

Beth Orton

This quote highlights the leading interest of our conservation department, and thus the core theme of the FUTURE TALKS: The characterisation and change of material and technologies in design and art of the 20th and 21st centuries.

Naturally, this topic is first approached superficially, i.e. from the surface. Both the user of a design object – let’s take an armchair upholstered in imitation leather from the 1930s as an example (read p. 30) - and the art collector with a penchant for hyperrealistic sculptures (read p. 146), derive their enthusiasm essentially from the design and materiality of the surface materials, be they PVC as in the former case or finely structured silicones in the latter example.

THE SURFACE AS A DESIGNED INTERFACE BETWEEN OBJECT AND ENVIRONMENT

It is no wonder that the conservator’s attention is also essentially focused on the surface appearance of the object. Here not only are traces of manufacture readable; the investigative expert’s eye can also recognise characteristic structures of use and ageing.

THE SURFACE AS AN INFORMATION CARRIER

Reading and understanding the surface is thus the basic prerequisite for an adequate conception of suitable conservation and restoration measures.

THE SURFACE AS ELEMENTARY BASIS FOR DECISION-MAKING

Now no one should wonder why we made the topic of surfaces the focus of the FUTURE TALKS 019 conference, held from October 23 to 25, 2019.

AFTER 5 PREVIOUS CONFERENCES, THIS WAS TO BE THE THE MOST SUCCESSFUL EVENT IN OUR SERIES SO FAR.

With 300 participants from 26 nations a great deal of international interest could be noticed, the content of which has been condensed in this book. The present post-pandemic can also be read as an indicator for current research projects and an increasing expertise worldwide.

THE FUTURE TALKS 019 CONFERENCE WAS A COLOURFUL – THIS TIME – A RED BOUQUET OF:

11 speed lectures, 26 talks, 1 keynote, 1 panel talk, 1 speed mentoring session, an impressive list of 20 different workshops spots where the participant could experience the challenging nature of surfaces and not to forget our legendary evening reception at one of Munich’s most futurist spots the BLITZ Club.

THE PROGRAMME WAS OUR MOST AMBITIOUS SO FAR

As mentioned above the quality and the success of a conservation treatment is closely connected to a deeper understanding of technology and material and thus with a broad network of different sparring partners. Unfortunately, the voice of the designer is still too often neglected. A somehow surprising fact, given that both designers and conservators are circling on similar questions: the material and the technology.

In this context we were delighted to have a keynote from Christiane Sauer, architect and professor for materials and design at the Weisssenese School of Art and Design in Berlin. Christiane Sauer gave us exciting insights into experimental material research.

Another highlight was the Panel Talk between Simone Farresin, one of the two protagonists of Studio Forma Fantasma and Sarah Dorkenwald, designer, essayist and design theorist. This talk illuminated the Oeuvre of the Amsterdam based studio which is internationally renowned for their use of provocative experimental materials, investigations and explorations in the creation of design. This conversation is still available at our homepage at: https://dnstdm.de/publictalk-studioformafantasma/

Another brilliant occasion to broaden the network was the Speed Mentoring Session. Here participants of the conference could meet and chat with 10 established professionals in short term slots (read p. 270).

Together with the last five editions, this book provides a perfect insight into important research projects and relevant topics on the conservation of the modern over the last 10 years.

Die Neue Sammlung as a museum is happy and very grateful for this FUTURE TALKS formate. Here the scientific research of our house meets for an international exchange with experts and personalities of conservation and design and finds success in public communication. The questions about material and technologies in design and art of the 20th and 21st centuries are as important for our museum as the presentation of objects.

The idea, concept and realisation of the FUTURE TALKS lies in hands of Tim Bechthold, Head of our Conservation Department. To him and his team Julia Demeter, Helena Ernst and Christian Huber great thanks to their profound commitment and perfect execution this conference series came to life and ever-lasting youth.

It is moving and quite motivating that after ten years the idea and the formate of this event is not just alive but still growing. We are very grateful for this!

This conference / publication wouldn’t have been possible without the support of the following people and institutions. Therefore we would like to thank:

The editorial board which invested a lot of spare time and enthusiasm to contribute considerably to the quality of this book.

All authors for providing their interesting contributions and the patience to keep the ball, even if it took sometimes longer than expected.

Felix Kempf. His visual design of the FUTURE TALKS has created a strong and memorable corporate identity, that this publication is not just another collection of scientific papers.

Last but not least to our sponsors and their generous support: Wuestenrot Stiftung, Schoofsche Stiftung, Definer und Johann, Kremer Pigmente, Quittenbaum and Plank.

By the time this publication appears, the seventh conference – »FUTURE TALKS 021. Smart Solutions in the Conservation of the Modern« - will already be underway. In view of the Corona pandemic, this time in a digital format.

It is helpful to have this alternative but we are all looking forward to welcoming you back in real life next time at the FUTURE TALKS 023!

ANGELIKA NOLLERT
DIRECTOR GENERAL, DIE NEUE SAMMLUNG
THE DESIGN MUSEUM
ABSTRACT
This research evaluates the use of innovative imaging technologies to aid the conservation of large-scale contemporary painted outdoor sculpture. It explores photogrammetry and image-based 3D modelling as tools during the conservation of Jardin d’émail (1974) by Jean Dubuffet (1901-1985), owned by the Kröller-Müller Museum.

In partnership with the 4D Research Lab at the University of Amsterdam, 3D digital models of the sculpture and two scale-models were created. This research assesses the effectiveness of using 3D digital models to inform the repainting of the sculpture’s black lines on white background as part of the treatment process. The use of photogrammetry to document the patterns and forms of the sculpture and scale-models is also evaluated. The creation of 3D digital models from the photogrammetric data allows for deviation analysis to be carried out, highlighting where areas of the scale-model and sculpture deviate significantly. The 3D models were uploaded on an app for use on tablets to enable responsive access during treatment. This research showed that photogrammetry is not only useful for large scale sculpture documentation, but can also aid the treatment of outdoor sculpture by producing geometrically accurate representations of the scale-model to be used as a reference during repainting.

KEYWORDS
Photogrammetry, image-based modelling, structure-from-motion, painted outdoor sculpture, Jean Dubuffet

INTRODUCTION
Painted outdoor sculpture is under constant threat by the outdoor environment, meaning that repainting is often a necessary part of conservation maintenance (Beerkens and Learner 2014). Before carrying out such a treatment, documentation of the original state is highly important to act as a reference for repainting. However, the documentation of outdoor sculptures can be a challenging task, especially when the sculpture is extremely large, has a textured surface, or has harder-to-reach areas. A sculpture which displays these issues is Jardin d’émail (1974) by Jean Dubuffet (1901-1985). The sculpture is painted white with hand-painted black markings based on the design of a 1:10 scale-model made by the artist. At 600 m² it is one of the largest hand-painted sculptures in Europe which visitors can enter and walk on. Due to this interactive feature and exposure to the outdoor environment, it has a known history of overpainting. The conservation treatment in 2019 stripped back years of overpaint, revealing original hand-painted markings. It is intended that the sculpture is repainted based on the design of the scale-model. Documenting the found markings and scale-model is crucial for ensuring repainting is as accurate as possible to Dubuffet’s intended design. Similarly, the documentation should function as a practical tool when it comes to repainting.

A solution to the issue of documenting outdoor sculpture for repainting can be met with innovative technologies such as photogrammetry, which uses photographs to create 3D models. This technique is being used more frequently in the heritage sector as the main piece of hardware (a reliable digital camera) is becoming more affordable. The objective of this research is to see how photogrammetry can aid treatment decision-making of repainting Jardin d’émail.

JARDIN D’ÉMAIL
Jean Dubuffet’s Jardin d’émail (Figure 1) is an interactive outdoor sculpture that was first envisioned by the artist in a scale-model made of glass-fibre reinforced polyester in 1968. The scale-model depicts an elevated white terrain covered by a network of black lines (Figure 2). In 1969, plans were made for a 1:10 enlargement of the scale-model to a sculpture at the Kröller-Müller Museum. For the enlargement, Dubuffet worked with architect Jöel Polvpe to ensure that the idea and design copied the scale-model from 1968 as close as possible. An architectural model was made, depicting the necessary elevations for the sculpture (Figure 2). The main structure of the sculpture
CURRENT STATE OF RESEARCH
CONSERVATION PRACTICE OF PAINTED OUTDOOR SCULPTURE

Frederike Breder’s thesis ‘Auffenskulpturen mit Farbfassung’ (Breder 2006) focuses on the restorative treatment of contemporary painted outdoor sculpture, of which Dubuffet’s Jardin d’émail is a case-study. In it, Breder references the issues that can come from repainting when the artist’s wishes have faded from memory, and the shifted black lines of the sculpture. Breder’s research highlights the problems that can occur without access to good documentation and states the need for conservation to repaint the sculpture using the scale-model and archival photographs. Breder also found that the original 1974 lines match the scale-model very accurately.

Derek Pullen and Jackie Heuman give a comprehensive outline of developments in modern outdoor sculpture conservation in ‘Modern and Contemporary Outdoor Sculpture Conservation: Challenges and Advances’ (Pullen and Heuman, 2007: 9).

Their statement that the documentation methods of photogrammetry and laser scanning are currently being explored and highlight the utility of these approaches in improving treatment records for individual sculptures (Pullen and Heuman, 2007: 9).

Major issues facing outdoor sculpture and what is required for their conservation has been outlined in ‘Contemporary Outdoor Sculpture: Challenges and Advances,’ (Beerkens and Learner 2014) stating that maintenance and repainting is often necessary. Gwynne Ryan of the Hirshhorn Museum discusses how the repainting cycles of outdoor painted sculpture allow for reevaluation of past treatments to occur (Ryan 2014: 10).

The importance of documentation is also stressed. Julia Lidolf and Peter von Bartheld call for a form of documentation that describes the process of producing an artwork as precisely as possible (Lidolf and von Bartheld 2014: 81).

Issues specific to painted outdoor sculpture have been broadly examined in ‘Conserving Outdoor Sculpture’ (Considine, 2010). The challenges involved with conserving painted outdoor sculpture are listed within to include: determining original appearance, understanding the artist’s intent and communicating colour (Considine, 2010: 125). Within all the case studies, a collaborative approach to repainting is stressed which involves conservators, curators, the artist estate and paint manufacturers. Although most case studies focus on choosing the correct colour than recreating hand-painted patterns, questions about original appearance and artist’s intent are relevant. These issues surrounding the conservation of painted outdoor sculpture are widely acknowledged, however the use of photogrammetry to help with treatment options has so far not been discussed in detail.

PHOTOGRAMMETRY AND IMAGE-BASED MODELLING

To create a 3D model using photogrammetry, a series of overlapping images of the subject is taken. These images are then uploaded into software that uses advanced image analysis algorithms to reconstruct camera angle and position (Waagen and Lanjouw 2018). Whilst this technique has not been commonly used for contemporary outdoor sculpture, it is increasingly being used as a method of documentation in other heritage sectors such as archaeology and historical interiors.
Historic England’s ‘Photogrammetric Applications for Cultural Heritage’ gives an explanation into the general workflow that must be taken in order to achieve a 3D model, explaining the main concepts, skills, issues and challenges that a heritage professional will encounter by using photogrammetry (Historic England 2017). This publication is useful for this research in proving that there are both benefits and drawbacks to using this technique for conservation. The level of detail needed to capture the faint black lines of *Jardin d’émail* may be higher than some other heritage needs, and so it will be beneficial to see how this technique can be useful for the conservation of contemporary hand-painted sculpture.

**OBJECTIVES AND QUESTIONS**

The objective of this research is to assess the use of photogrammetry for the treatment of painted outdoor sculpture in two phases. First, in exploring its capabilities for advanced documentation. Second, to see how the photogrammetric data can then be used practically for treatment. The following questions will be answered: How can photogrammetry be used to inform conservation practice of painted outdoor sculptures?

- Can photogrammetry accurately capture the original pattern?
- How can it inform treatment decision-making?
- What are the strengths and weaknesses of using photogrammetry in conservation practice?

**EXPERIMENTAL METHODS AND RESULTS**

To assess the utility of photogrammetry for the treatment of large outdoor sculpture, a multi-disciplinary methodological approach was undertaken. Literature and archival research investigated photogrammetry and image-based modelling, painted outdoor sculpture and Dubuffet’s oeuvre.

To understand the art-making process, interviews were carried out between the head conservator of sculpture and modern art at the Kröller-Müller Museum, Susanne Kensche and Dubuffet’s assistant, Richard Dhoedt, for which the author was present. An interview was also conducted between the author and Susanne Kensche, to ensure that this research produces a useful tool for the museum. From these interviews it was found that photogrammetry could benefit the 2019 treatment of *Jardin d’émail*. The use of a portable, 3D digital model could be used during the repainting treatment. Dubuffet’s assistant Dhoedt explained that during the painting of the lines in 1974 it was a struggle that they only had one model acting as a reference. He explained that it was difficult to have to keep going back and forth to the model. This further clarified to Susanne Kensche that photogrammetry will help the museum effectively work on the sculpture and not miss out any lines, as was done previously.

In preparation for the photogrammetric scan, printable targets were placed on the sculpture, scale-model and architectural model and around their perimeters. For *Jardin d’émail*, a DJI Phantom 3 drone was used which has a camera attached to its base, controlled by a tablet attached to a control pad. Using the tablet, the ISO and shutter speed of the camera were set to automatic. A test flight was carried out to ensure the images captured were of good quality and that there was no distortion. The drone was flown at two altitudes above the sculpture, detailed shots were taken at 2.80 m, whilst an overview shot was taken at 8.25 m. The drone stopped to take a photograph every meter. Oblique and angled photographs were also taken to capture the surface structure and the perimeter of the sculpture. For the scale-model and architectural model, a Nikon D5300 was attached to a stabilisation pole. After ensuring that the white drone by Jitte Waagen. The scale-model and architectural model were photographed with an SLR camera by Tijn Lanjouw. This is the first step in creating a scanned photogrammetric model of both the outdoor sculpture and scale-models.

**THE PROCESS OF CREATING A PHOTOGRAMMETRIC MODEL**

The practical application of photogrammetry and image-based modelling is conducted in partnership with the 4D Research Lab of the University of Amsterdam. The following section outlines the aim, method and results of the experimental process.

To begin, aerial images were taken of *Jardin d’émail* with a drone by Jitte Waagen. The scale-model and architectural model were photographed with an SLR camera by Tijn Lanjouw. This is the first step in creating a scanned photogrammetric model of both the outdoor sculpture and scale-models.
balance and shutter speed were appropriately set and the model was in focus, a series of overlapping photographs were taken in aerial and oblique view, at a distance of 1 m (+/- 10 cm).

**POST-PROCESSING RESULTS USING AGISOFT METASHAPE**

3D models of Jardin d’email, the scale-model and the architectural model were made by Jitte Waagen and Tijm Lanjouw. Analysis of these 3D models can help the treatment process, as any deviation in the surface structure between the scale-model and outdoor sculpture can be highlighted. The photographs taken of the sculpture, scale-model and architectural model were first checked to ensure all images were in focus with appropriate lighting. The images were then imported into Metsahape which makes an estimation of image quality. To begin, alignment optimisation is carried out to detect the markers (targets) and correct their position. The software then identifies the tie-points.

A sparse point cloud is generated. The cameras are then optimised, and the reprojection error is calculated. A dense point cloud can then be calculated, followed by a mesh, onto which the texture can be applied. At this point the 3D model has been made and can be exported for further analysis.

The results of the modelling process proved photogrammetry can capture the original pattern of the uncovered black lines. This is possible because of the 0.2 cm resolution that photogrammetry offers (every pixel is covering 2 mm of the object) which gives a high accuracy of the captured geometry. The reprojection error is the average error between a measured point in a 3D model and the projected point on an image. The error was computed to be only 1.2 pixel when experienced in image distance, which indicates that the 3D model is a very close representation of the artwork. The resulting 3D models are highly accurate and detailed (Figure 5). Agisoft Metashape allows for 3D models to be exported in various formats that are accessible on a range of devices and platforms. As such, this enables the museum to have a clear and detailed view of the scale-model to help with the repainting process, therefore informing treatment decision-making.

**DEVIA TION ANALYSIS WITH CLOU D COMPARE**

Once a 3D model is made it can undergo further analysis. As the scale-model is intended to be used for the repainting of the black lines it is important to know if there were any deviations between it and the sculpture, which would influence treatment decision-making.

CloudCompare is an open-source software that enables the point clouds of two different 3D models to be analysed for deviation and similarities (CloudCompare, n.d.). Deviation analysis between the 3D models was carried out by Tijm Lanjouw, in the following sequence; (FIRST) the scale-model and architectural model, (SECOND) the scale-model and outdoor sculpture and (THIRD) the architectural model and the outdoor sculpture.

To compare the point clouds, they are first aligned. This means manually moving the second model onto the same position as the first model. For the comparison between the scale-model, architectural model and the outdoor sculpture, the two models were scaled up to match the size of the sculpture. CloudCompare then automatically aligns the two point clouds to find a best fit.

CloudCompare then calculates the distance between the two point clouds. The result shows any deviation between two aligned models. The software finally generates a heat-map indicating the areas of similarity and deviation.

This detailed deviation analysis allows for more information about the making-process, the sculpture’s material history and what can be highlighted. A visual inspection between the scale-model and architectural model shows the two models to be made from the same mould, or the same cast. This sheds light on how far the point cloud (Figure 6a). This can also be used to find a best fit. Deviation analysis between the sculpture and the two models showed that in general, the scale-model closely follows the shape of both models, with over half of the models only deviating between 0-3 cm from the sculpture (Figure 6a). However, a large difference between the scale-model and the sculpture can be observed in the centre-north region. Here the scale-model deviates by an elevation upwards of 30cm from the sculpture (Figure 6b). This result will certainly inform treatment decision-making, as problem areas such as this can be noted before repainting begins.

**TESTING 3D MODEL ON SCULPTURE WITH THE APP “EMBD3”**

Uploading the 3D scale-model onto the open source app Emb3d provides a practical and portable reference tool for the repainting process. Emb3d is available on both mobile and tablet. The physical scale-model is used for repainting the black lines on Jardin d’email, so access to a digital version should make the process more efficient.

The 3D reconstruction of the scale model was uploaded to Emb3d, which enables the offline viewing of 3D models on a tablet or phone (Emb3d, n.d.). The digital model was taken to the sculpture, so its use in the repainting process could be evaluated. To test the tool, lines were drawn onto the sculpture using the 3D model on the tablet as a reference. The technique was evaluated on accuracy, how long it took, and whether it was possible to estimate line thickness, angle and position. General strengths and weaknesses of the approach were also noted. The drawing of the test lines was carried out by the author and fellow trainee conservator Laura Wolffkamp of the University of Amsterdam. CloudCompare.

Testing the 3D model on the sculpture allowed for a practical assessment of the technique. It was found that treatment decision-making is improved, as the conservator can make a comparison of the digitised scale-model to their hand. Therefore, they are able to immediately correct mistakes from deviating from the course of the scale-model. Equally, more points of view are possible than with the original scale-model. For instance, the conservator can stand on an area of the sculpture they are aiming to paint on, and at the same time view a zoomed-in birds-eye-view of this area.

However, it was found that it is possible to look at the tablet too much, meaning that the painted line can risk not flowing as Dubuffet would have wanted. Similarly, it can be difficult to judge the edges of the model, particularly how far the line overlaps a corner. As the scale-model was found to be not the same as the sculpture it can also be difficult to see where the lines should go, and as a result accuracy is not improved. A suggested improvement for the 3D model which could increase accuracy is to include a scale-bar that can indicate how thick the lines should be.

It was noted that different people work in different ways, and that one conservator may prefer to use the original scale-model over the 3D model on the tablet. New digital tools and approaches can enhance treatments, but the “affordability” of digital equipment is an issue to keep in mind (Morgan & Wright 2018). Overall, having the 3D model on the tablet has its benefits and will increase the speed at which inaccuracies are identified, but it should be used alongside the knowledge of the artist assistant and the original scale-model.

**DISCUSSION**

In evaluating the utility of photogrammetry it is important to assess its strengths and weaknesses with the conservator in mind. From the results it is clear that for a conservator, photogrammetry sits at the top of the scale as it requires little hardware needed for photogrammetry. The software used for this research, Agisoft Metashape, has a simple interface and a conservator would be able to work it if they spent the time...
learning how to. Margins of error can come from the photogra-
phs that are taken, and whether the targets are placed accurately,
which is something the conservator should keep in mind.

However, the technique can become expensive. Whilst an
educational licence of Agisoft Metashape is 300 Euro, the pro-
fessional licence is between 1,500 and 2,000 Euro. To run the
software, a computer or laptop with a good processor and
graphics card is needed. Although this particular software
option can be expensive, there are plenty of open-source alternatives
which enable the creation of 3D models such as Meshroom and
Visual SfM. Yet, these open-source programmes typically require
more than one piece of software to complete the entire process.

Another point to keep in mind is that the modelling process
can be time consuming, with a higher-end 3D model taking on
average between 3-9 hours to make from start to finish. The
exact time depends on the size of the model being made and the
specifications of the graphics card within the computer.

To be specific, when creating the 3D model of the scale-
model, manually editing the target points took 1 hour,
converting the sparse point cloud into a dense point cloud
took 2 hours, building the mesh took 3 hours and blending the
textures took 0.5 hour. A large sculpture, such as Jardin d’émail
captured according to the resolution and accuracy requirements
of this research, will take a few days to process on a computer
with two processors. However, it is possible to run the modelling
software and carry out other tasks whilst the model loads. It is
also possible to stagger tasks and let the programme run over-
night. Alternatively, it is possible to sacrifice the accuracy of the
end result for processing speed. It is therefore important for the
conservator to determine what level of accuracy is needed for
the documentation or treatment being carried out.

As the technique could likely be outsourced to a company
or professional specialising in photogrammetry, it is important
to ask the following questions: do we value every aspect of the
process the same? Is it difficult to communicate your wishes?
Do they understand the point? By posing these questions, both
parties have a clear understanding of what needs to be achieved.

The 4D Research Lab explained that it might be possible for
parts of a large sculpture to be missed in the photogrammetry
process if the photographer is not properly briefed. As a result, it
is important for the conservator to fully understand the process
even if it is being outsourced. Both parties need to have a clear
brief and be involved throughout to avoid any information loss
from miscommunication.

CONCLUSION
Aside from mere documentation, photogrammetry can be used
to inform conservation practice of painted outdoor sculpture
by enabling a clear, geometrically accurate representation of
the scale-model to be used as reference during the repainting
process. This allows for a direct comparison between the
scale-model and sculpture to be made, and any later mistakes
to be immediately recognised and altered. Further analysis on
the photogrammetric data showed areas of deviation between
the scale-model and the sculpture, which will allow appropri-
ate planning to take place before repainting begins. The main
strengths are the accuracy of depiction within digital 3D models
and the fact that it is an incredible piece of documentation. The
main weaknesses are the time and resources taken to produce
the 3D digital model. It is up to the practising conservator to
weigh up the benefits and drawbacks that such a technique will
bring. Overall, this research has shown that photogrammetry
can be a useful tool when repainting outdoor sculpture. The
3D model of the scale-model was successfully used to carry out
the repainting of Jardin d’émail between February – May 2020.

ACKNOWLEDGEMENTS
The main author would like to thank the following for the help
and support with this research. To the 4D Research Lab at the
University of Amsterdam for facilitating this research with their
knowledge and expertise in image-based modelling; Jitte Waag-
gen and Tijm Laniouw. Equally, to the Kröller-Müller Museum
for funding the analysis of Jardin d’émail; Susanne Kensche,
Tanja de Boer, Marcel van de Sande and Marjon Gemmeke.
Finally, to the University of Amsterdam, particularly Sannieke
Stijger for supervising this research, and equally to Evelyne Sui-
ders, Katja van de Braak, Ellen Jansen, Professor Ella Hend-
riks, Professor Maarten van Bommel, Laura Wolfkamp, Claire
Molgaat Laurin and Hedwig Baam for their advice and support.

ENDNOTES
(1) The conservation treatment of repainting the lines on
the sculpture was completed in May 2020.
(2) The architectural model was also referred to as
a ‘working model’.
(3) Interview between Kröller-Müller Museum and
Fondation Dubuffet. Participants: Richard Hoehdt, Sophie
Webel, Susanne Kensche, Marcel van de Sande,
Tanja de Boer, Marjon Gemmeke, Alice Watkins,
(4) Interview between Susanne Kensche and Alice Watkins,
(5) A tie-point is a feature that you can clearly identify in two
or more images.
(6) A point cloud is a set of data points in space representing
a 3D shape or object.
(7) Camera optimisation is when the camera’s orientation is
calibrated to improve accuracy and reduce the
reprojection error.
Fig. 6a. Deviation analysis between *Jardin d’émail* and the architectural model using CloudCompare.
Credit: Tijm Lanjouw, November 2018.

Fig. 6b. Deviation analysis between *Jardin d’émail* and the scale-model using CloudCompare.
Credit: Tijm Lanjouw, November 2018.
