A Digital Tool to Understand the Pictorial Procedures of 17th century Realism

Francesca Di Cicco[1], Lisa Wiersma[2], Maarten Wijntjes[1], Joris Dik[1], Jeroen Stumpel[2], and Sylvia Pont[1]

[1] Delft University of Technology, Delft, The Netherlands
[2] Utrecht University, Utrecht, The Netherlands

Abstract. To unveil the mystery of the exquisitely rendered materials in Dutch 17th century paintings, we need to understand the pictorial procedures of this period. We focused on the Dutch master Jan de Heem, known for his highly convincing still-lifes. We reconstructed his systematic multi-layered approach to paint grapes, based on pigment distribution maps, layers stratigraphy, and a 17th century textual source. We digitised the layers reconstruction to access the temporal information of the painting procedure. We combined the layers via optical mixing into a digital tool that can be used to answer "what if" art historical questions about the painting composition, by editing the order, weight and colour of the layers.

Keywords: Optical mixing · Convincing rendering · Painting reconstruction · Jan de Heem

1 Introduction

Dutch Golden Age still life painters are typically acknowledged for their meticulous rendering of reality, especially regarding material properties. How were these successfully painted? And where and how could knowledge about this procedure be applied today? With the help of a digital tool, we aim to answer our research questions. Also, we aim to serve the development of rendering reality in computer graphics [1].

Jan de Heem (1606-1684) is considered to be one of the greatest masters of the Dutch Golden Age, especially known for his fruits and flowers [2]. His technique consisted of a multi-layered systematic approach, which was shown by Wallert [3, 4] to match the painting recipe given by Willem Beurs (1656-ca.1711) in the treatise *The big world painted small* [5].

Can his technique disclose the convincing visual effects he was able to achieve? Understanding the painting procedures underlying the masterful rendering of materials in 17th century Dutch paintings, is still a challenge in art history (but see [6, 7]). We addressed this question by combining a scientifically truthful reconstruction of paintings, based on chemical data and the abovementioned art historical written source, with imaging science to develop a digital visualisation tool for the painting procedure of Jan de Heem. In the field of technical

Fig. 1. Jan Davidsz. de Heem (a)*Festoon of Fruits and Flowers*, 1660–1670, oil on canvas, ©Rijksmuseum; (b)*Garland of Fruit and Flowers*, 1650–1660, oil on canvas, ©Mauritshuis.

art history, painting methods are usually investigated by the use of diagnostic techniques to identify the pigments and layers beneath the visible surface. The development of non-destructive imaging methods, like X-ray and infrared-based techniques (see [8] for an exhaustive review), gave access to a wealth of knowledge about paintings stratigraphy and pigments distribution.

We made use of such chemical data to reproduce the red grapes from two paintings by De Heem (Fig. 1). We collected data from cross-sections [3], MA-XRF scans [9] and OCT scans, and referred to Beurs' recipe for the order of the layers.

2 Digitalisation of the Layers Building-up

The reconstruction process entailed that a skilled painter (the second author) followed the recipe using oil paint and template drawings for the De Heem grapes' outline. To reconstruct the temporal information of the multi-layered painting procedure of De Heem, we acquired high resolution digital photographs of the reconstruction process at intervals of 10 seconds, in a controlled environment with constant lighting.

The reconstructed sequences of layers are shown in Fig. 2. Since we aim to

Fig. 2. Sequence of layers reconstruction of red grapes in *Festoon of Fruits and Flowers*. Paintings reconstruction by Lisa Wiersma.

understand the success of the procedure, we need to access both the individual layers and their combination. In order to see the visual effect of each layer, one could paint the image several times leaving out one layer each time. But this would lead to inconsistent results given the impossibility to repaint the same image over and over with exactly the same colour mixtures and brushstrokes. The new versions of the painting may unconsciously be adapted to the fact that one step was being deliberately skipped.

To overcome these issues, we built an interface using optical mixing [10], which is an image combination process that recalls the systematic layering procedure used by painters [11]. The elements combined in the optical mixing tool were obtained by subtracting the first reconstructed image in Fig. 2 from the second, the second from the third, etc. The individual elements corresponding to the steps of the recipe are shown in Fig. 3.

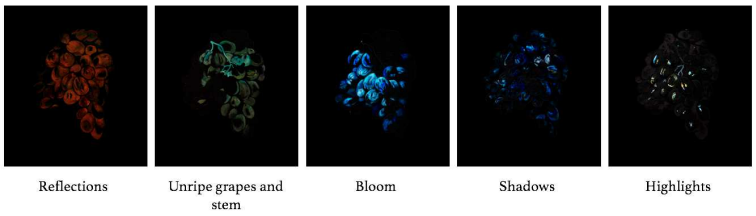

Fig. 3. Sequence of elements obtained from the layers reconstruction and combined in the optical mixing.

3 The Tool Applications

Several approaches have been used in literature to decompose images into layers via for example vectorization [12], segmentation [13], the Porter-Duff "over" operation [14, 15] or the physical Kubelka-Munk model [16, 17]. The retrieval of layers is usually done with the main intent of allowing image editing and manipulation.

Similarly, the aim of our layers' reconstruction was not only to see the building-up of the paintings, but also to provide a tool to explore and open up new possibilities for art historical investigation. The sliders can be used to manipulate and adjust the weights of the layers and therefore change the final appearance of the painting. For example, we can see what the painting would have looked like if the layer of vermilion would not have been applied (Fig. 4a). And what if the grapes would have been painted without the bloom layer (Fig. 4b)? Please note that the weights of all layers can be changed between 0 and 100%, allowing also subtle variations that correspond to layers thickness variations. Skipping one of the steps of De Heem's systematic procedure affects the final rendering and the realistic illusion.

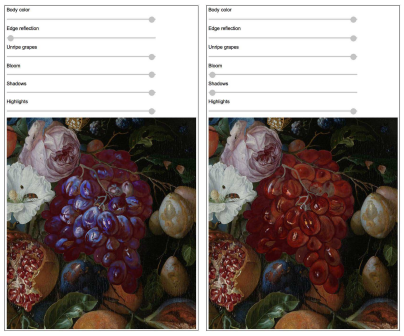

Fig. 4. Optical mixing interface for manipulation of the layers' weights. (a) Final appearance of the grapes without the second layer that corresponds to the edge reflections; (b) Final appearance of the grapes when the bloom and the shadow layers are removed. The reproduction is superposed on the real painting.

Understanding the contribution of each layer to the convincing representation of materials is an extremely interesting question not only for art historians but also for perception scientists. We assume that every layer resonates with a certain perceived material attribute and that the layer may contain the key image cues of that material attribute. Once we have access to the digitalised layers, we can also perform different types of manipulation operations, like colour editing. We can thus enable the use of counterfactual painting process scenarios to improve the knowledge and insights into the success and failure of pictorial steps. Our tool can be used by artists and art historians, conservators, scientists and a broader audience to find out how a masterpiece was made. In the context of museums, our tool can be applied for an interactive experience of the artwork. Finally, the tool can prove to be particularly useful in the field of art conservation and restoration. For example, when restoring a discoloured or damaged image, the colour editing possibilities offered by the tool can be used to check the relevance of additions or alterations.

4 Conclusions

By using the tool in visual perception experiments, we have proved that the compelling realism of Jan de Heem roots in a pictorial formula, consisting of the systematic application of necessary layers. De Heem was a meticulous and efficient painter: all the steps he made and that were described in the 17^{th} century textual source were relevant. The computational result is an imaging technique beyond pixel values, showing actual colour layers which are editable. The assets of the digital tool, the clear-cut visualisation, practice, and testing of the Old Master's successful colour formulas, are of relevance to an interdisciplinary audience that consists of scientists, scholars, (digital) artists and interested lay persons.

Acknowledgements

This work is part of the research program NICAS "Recipes and Realities" with project number 628.007.005, which is partly financed by the Netherlands Organization for Scientific Research (NWO) and partly by Delft University of Technology. Maarten Wijntjes was financed by the VIDI project "Visual communication of material properties", number 276.54.001.

References

1. Ferwerda, J. A.: Three varieties of realism in computer graphics. Proc. SPIE 5007, Human Vision and Electronic Imaging VIII (2003).
2. Houbraken, A.: De groote schouburgh der Nederlantsche konstschilders en schilderessen. Amsterdam: B.M. Israel (1976).
3. Wallert, A.: Still lifes: techniques and style, An examination of paintings of the Rijksmuseum. Rijksmuseum, Waanders (1999).
4. Wallert, A.: De Groote Waereld in 't Kleen Geschildert (The Big World Painted Small): a Dutch 17th century treatise on oil painting technique. In: The Artist's Process: Technology and Interpretation. London: Archetype (2012).
5. Beurs, W., Scholz, M.T.: The big world painted small. Los Angeles: The Getty Research Institute (In preparation).
6. Vandivere, A.: From the ground up. Surface and sub-surface effects in fifteenth- and sixteenth-century Netherlandish paintings. PhD thesis, University of. Amsterdam (2013).
7. Bol, M.: Oil and the translucent: varnishing and glazing in practice, recipes and historiography, 1100-1600. PhD thesis, Utrecht University (2012).
8. Legrand, S., Vanmeert, F., Snickt, G.V.D., Alfeld, M., Nolf, W.D., Dik, J., Janssens, K.: Examination of historical paintings by state-of-the-art hyperspectral imaging methods: from scanning infra-red spectroscopy to computed X-ray laminography. Heritage Science 2(1) (2014) 1-11.
9. Keyser, N.D., Snickt, G.V.D., Loon, A.V., Legrand, S., Wallert, A.: Jan Davidsz. de Heem (1606-1684): a technical examination of fruit and flower still lifes combining MA-XRF scanning, cross-section analysis and technical historical sources. Heritage Science 5(38) (2017) 1-13.
10. Pont, S., Koenderink, J., Doorn, A., Wijntjes, M., te Pas, S.: Mixing material modes. Proceedings of SPIE-IS&T Electronic Imaging, 8291, 82910D (2012).
11. Zhang, F., de Ridder, H., Fleming, R.W., Pont, S.: Matmix 1.0: Using optical mixing to probe visual material perception. Journal of Vision 16(6) (2016) 1-18.
12. Favreau, J.D., Lafarge, F., Bousseau, A.: Photo2clipart: Image abstraction and vectorization using layered linear gradients. ACM Transactions on Graphics 36(6) (2017) 1-11.
13. Aksoy, Y., Aydin, T.O., Smolic, A., Pollefeys, M.: Unmixing-based soft color segmentation for image manipulation. ACM Transactions on Graphics 36(2) (2017) 1-19.
14. Porter, T., Duff, T.: Compositing digital images. ACM SIGGRAPH Computer Graphics 18(3) (1984) 253-259.
15. Tan, J., Lien, J.M., Gingold, Y.: Decomposing images into layers via RGB-space geometry. ACM Transactions on Graphics 36(1) (2016) 1-14.

16. Kubelka, P., Munk, F.: An article on optics of paint layers. Zeitschrift für Technische Physik 12 (1931) 593-601.
17. Tan, J., Dvorožnák, M., Sýkora, D., Gingold, Y.: Decomposing time-lapse paintings into layers. ACM Transactions on Graphics 34(4) (2015) 1-10.