An Interactive Tool for Speed up the Analysis of UV Images of Stradivari Violins

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Abstract. UV fluorescence photography is widely use in the study of artworks, in particular for the analysis of historical musical instruments. This technique allows seeing important details which cannot be observed with visible light, such as retouching, different paints coats or worn areas. The complexity of the interpretation of the surface of a violin is proportional to its state of preservation: more alterations correspond to a more wide range of colors. We designed an interactive tool able to help the scientist to understand the composition of the surface and in particular the distribution of the colors on the entire instrument, avoiding perception illusion. The result is achieved using a quantized histogram in HSV color space. The tests were performed on UV imagery of the Stradivari violins collection stored by "Museo del Violino" in Cremona.

Keywords: Cultural heritage · Violin · UV fluorescence · Histogram analysis

1 Introduction

UV (Ultraviolet) fluorescence photography is widely use in the study of artworks, in particular for the analysis of historical musical instruments. This technique allows seeing important details which cannot be observed with visible light, such as retouching, different paints coats or worn areas. UV radiation penetrates only superficial levels, so underlying paint coats are not detected; however the analysis of UV fluorescence images gives some clues to apply more precise not destructive techniques, such as XRF (X-Ray Fluorescence spectroscopy)[1] and FTIR (Fourier Transform Infrared spectroscopy)[2], that allow to get information respectively about chemical elements presence and organic and inorganic compounds. Different substances interact in different ways with UV illumination, showing different and typical fluorescence colors, for example a yellow fluorescence

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means oils, a green one protein substances such as casein, and so on (complete overview of this technique is in [3]). However it is not so simple analyze an UV photo of a historical violin. The complexity of the interpretation is proportional to the state of preservation of the instrument: more alterations correspond to a more wide range of hues and to possible overlapping ranges of colors.

For this reason we designed an automatic tool, based on the analysis of the image in HSV color space, able to help the scientist to understand the composition of the surface and in particular the distribution of the colors on the entire instrument.

The previous version of this tool [4] works in a semi-automatic way and it was planned for helping expert users to achieve a precise detection on regions of interest avoiding perception illusion (the standard way to analyze such data is in fact based only on human visual interpretation). The tool was able to highlight all the areas of the surface with the same color starting from a sample chosen by the user. The detection is precise and allows a great level of flexibility due to several tolerance thresholds (default values was computed by statistical analysis on a sample dataset). However the user needs a good expertize of the problem for reaching quickly good results, since it is important to choose a valid input area and good thresholds. So the tool is useful for helping the users in analyzing the images, but it can not produce an objective classification due the dependence to subjective choices. Its main goal is to find the occurrence of specific details/colors not clearly visible with the naked eye, but it is not designed for a classification of the entire surface, that can need a long time also for expert people.

This paper presents a new and more general solution able to overcome these constraints. For obtaining a more objective detection of the colors the analysis considers multiple images at a time. A quantized histogram of the entire surface of the instrument is computed, and starting from these data the exact distribution of all colors/materials present on a violin is retrieved. The histogram uses the HSV color space and its quantization is designed to compensate small alterations in saturation and brightness, so it can be used also for studying the occurrence of particular hues on different instruments photographed in different times.

All the tests were performed on UV imagery of the Stradivari violins collection preserved by "Museo del Violino" in Cremona.

The paper is organized as follow: section 2 describes the photographic set used; section 3 describes the proposed method of surface analysis; section 4 shows the results of the tests performed on four Stradivari violins; finally section 5 draws some conclusions.

2 Photographic Setup

A dedicated photographic set (Fig. 1) was prepared following the protocol for the UV induced fluorescence photography created by British Museum as part of CHARISMA project[5]. In particular we used a Nikon D4 camera with 50mm lens, two wood lamps of 40 Watt for providing the UV illumination, and a Kodak 2e gelatin filter, as an alternative to the Schott KV418 currently dismissed.

The backdrop is black for maximize the quality of the UV photos. For each main views of each instrument (front, back, left side and right side) a visible and a UV photo was taken. It is important to guarantee a perfect overlapping between the two kind of images in order to simplify following analysis. A rotating platform, controlled by a computer, was used for moving the violin in order to maintain always the same angles of rotation during different photographic sessions. All the photo was acquired at the same distance, so the proportion of the instrument is always respected.

Fig. 1. The photographic set used for acquisition.

Visible images were acquired with an aperture size of f/10, ISO 100 and an exposure time computed in function of the camera light meter. The illumination in this case was provided by two softbox leds (T = 5400K). UV fluoresce images were acquired with an aperture size of f/10, as for visible, but with ISO 400 and an exposure time of 30 seconds to compensate the low illumination power of the UV lamps.

3 Surface Analysis

Color histogram quantization is a standard and very effective way to retrieve similar images in large databases [6]. This technique can be apply to any kind of color space, depending on the needs; in particular the use of HSV color space, a model closer to human perception, proves to be very efficient [7]. The basic idea of the histogram quantization is to group the wide range of colors of each image

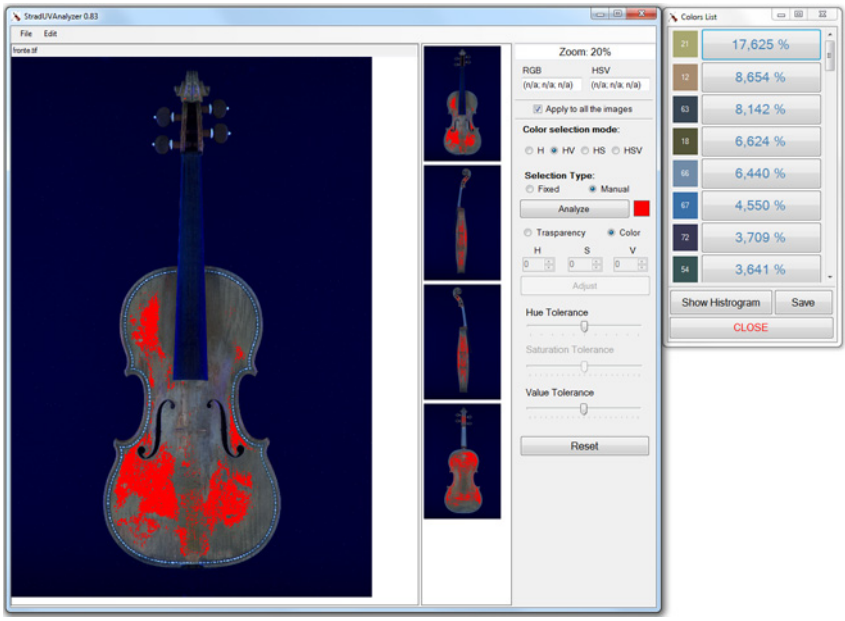

Fig. 2. Execution of the program on Stradivari Hellier (1679)

into a small set of main colors, in order to speed up the research and compare the data in a more objective way.

This approach can be very useful also in our case. As said in the previous sections, historical violins have undergone many modifications and repairs during the centuries, so their surface in UV fluorescence can show a large range of small color variations, that can mix up the interpretation of their composition. Using a well designed quantized histogram in HSV space it is possible to minimize these differences and extract the main colors distribution on the entire instrument.

3.1 HSV Histogram Quantization

For understanding the correct way to subdivide the color space we made a series of statistical analysis on a set of UV images of Stradivari violins. As expected, the more important component is the Hue, while Saturation and Value are less crucial. This behavior is coherent with the characteristic of the fluorescence technique and of the analyzed objects: variations of the pure hues mark directly variation in substances or materials, while variations in saturation and in value are less correlated with them, but can be useful refinements factors. Moreover these two channels are also more influenced by ambient changes so it is better to reduce their contribution in the detection. In fact, even if the photographic set is a controlled environment, some variations between photos are possible due to slight differences in the size of the instruments, or small changes in the angle of incidence of the lamps, or the presence of very reflective paint coats.

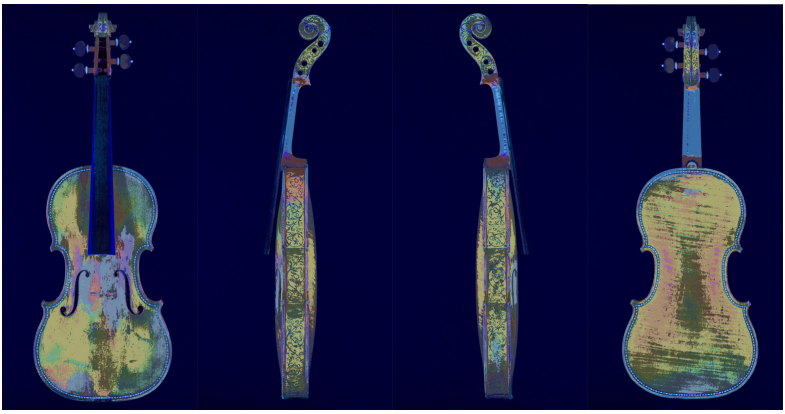

Fig. 3. Quantized histogram of Stradivari Hellier mapped on its surface.

So the chosen quantization of the color space is the follow: 16 bins of Hue; 3 of Saturation (high, medium and low); 3 of Value (high, medium and low). Hues ranges are equals because, even if there are less frequent colors in our testing photos, the current sample set is yet too small to generalize this kind of consideration. Since we want to keep the possibility to analyze different instruments at the same time, we choose to maintain this distribution. However, even if is out of main topic of this work, we consider the possibility to use an irregular quantization scheme for better handle cases in which there is a high concentration of hues in a small range.

Finally, to overcome the possible presence of salt & pepper noise introduced by the high exposure time needed for UV photography and by the presence of the Wratten Filter, a median filter is applied to all the images before the computation of the quantized histogram. At the same time the background, always of the same known color, is excluded a priori from the analysis.

3.2 User Interaction

Our goal is to supply to the researchers an intuitive instrument to quickly analyze and visualize the regions of interest on the surface of the violins. Figure 2 shows the user interface of the tool and the result of the execution on the Stradivari Hellier. The analysis was performed on the four main views (front, back, left side, right side), so all the surface was considered. The right menu shows all the colors in descending frequency order, with their percentage respect to the total. Selecting a color it is possible to see where is placed on one or on all the sides (see the main windows of the interface) and also in what view is more diffused. Two kind of visualizations are available: highlight a single color at a time (Fig. 2) or directly map the entire histogram (or part of it) on the surface (Fig. 3).

The output can be saved as a series of images and then used as a sort of guide for subsequent analysis with more precise technique, like XRF and FTIR, on the

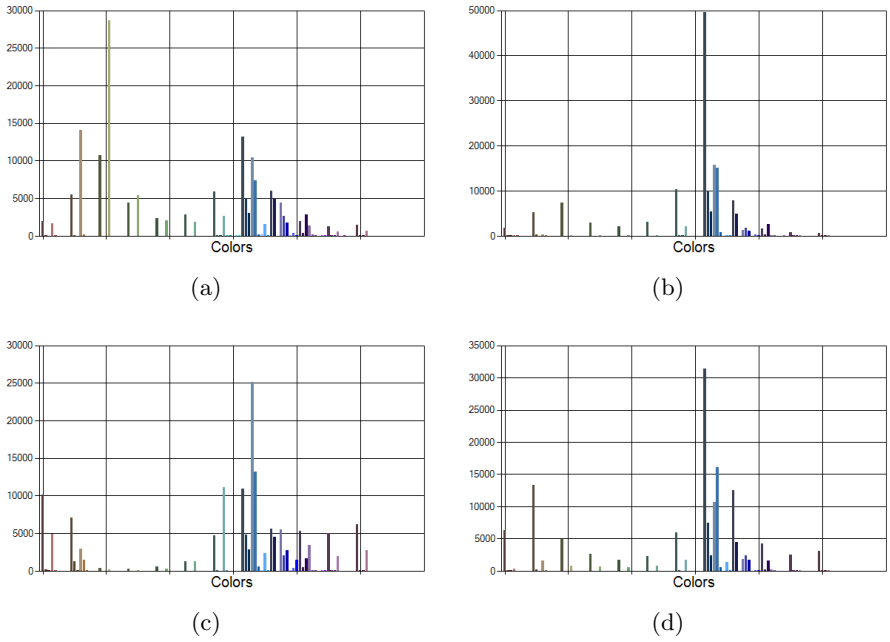

Fig. 4. Final histograms of studied Stradivari violins (on X-axis hues are ordered from red to violet tonalities): (a) Hellier (1679); (b) Cremonese (1715); (c) Vesuvius (1727); (d) Scotland (1734).

real instrument. Historical violins, as art works, must generally be conserved on stable conditions of humidity and temperature so their availability for deep studies is very limited. Highlighting zones with the same hue it is possible to avoid the repetition of tests on similar areas, and so speed up the analysis.

The original detection version [4], based on manual selection of input samples, is still available (see central menu on Fig. 2) in case the user needs to retrieve some specific details present only on one side of the instrument, that obviously will be lost in a global analysis of the surface.

4 Results

This section shows the overall analysis of the tests made on four Stradivari violins of the historical collection of Museo del Violino: Hellier (1679), Cremonese (1715), Vesuvius (1727) and Scotland University (1734).

The four quantized histograms can be seen in Fig. 4. It is interesting to notice that each of them has a unique distribution of colors depending by its state on conservation. The Hellier in particular presents a concentration of brown and yellows hues higher than the other three instruments, that instead show a higher frequency of blue and green colors. This discrepancy is probably related to the

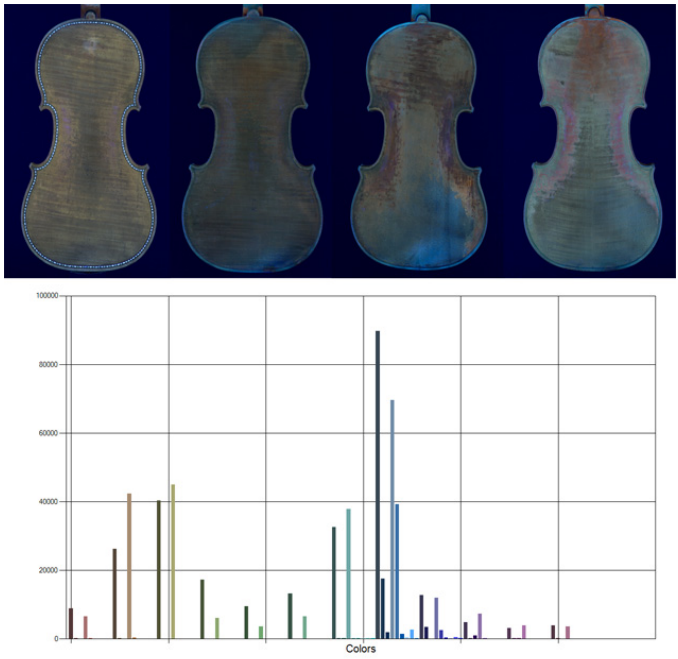

Fig. 5. Combined histogram of the four Stradivari's back plates

fact that the Hellier is the least used and best conserved violin of the four, so it has a more high levels of original paint coats.

The study of these histograms can be very useful for the point of view of preservation. Each of them freezes the actual state of an instrument. So, repeating the experiments periodically, it is possible to evaluate how it evolves in time. At difference of other art objects in fact, historical violins are not only preserved but also actually played, so they can be undergone heavy structural modifications and then need of repairs.

Figure 5 shows an example of the combined histogram obtained analyzing four back plates of different violins instead of four views of the same one. This kind of analysis permits the user to find the most frequent colors on a set of instruments, such information can mark the presence of recurrent substances.

The quantized histogram compensates the discrepancy in illumination between photos taken in different times and shows an objective distribution of the colors on the surfaces. The analysis of the data allows to the restorer to check if a particular color is placed in the same position on all the backs, a clue of a possible original paint coats or of a recurrent element in instrument of different times. A more refined analysis of the backs able to discriminates the distribution and a quantitative measure of the warn areas is actually under study.

5 Conclusions

Currently a common task for researchers and restorers is the analysis of UV images of historical instruments. Up to now the are only tools that use false color visualization or image enhancement techniques, but at the end the analysis is demanded to a pure visual interpretation. This paper describes a new interactive solution to speed up this kind of work. The chosen approach exploits the use of quantized histogram, a well known techniques generally adopted in the field of image retrieval.

Tests made on four Stradivari violins, show that the proposed method is able to give clear and objective information about the color distribution on the surface, avoiding perceptual illusions.

Refinements of the quantization process, adjusting the range distribution, will be made at growing of sample set of UV images. The limited time of availability of the instruments involves a long period to achieve a large set of data.

A comparative analysis between colors detected by the UV analysis and the presence of organic materials detected with FTIR technique is currently under study.

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References

1. Echard, J.P.: In situ multi-element analyses by energy-dispersive X-ray fluorescence on varnishes of historical violins. Spectrochimica Acta Part B **59**, 1663–1667 (2004)
2. Bertrand, L., Robinet, L., Cohen, S., Sandt, C., Le Ho, A., Soulier, B., Lattuati-Derieux, A., Echard, J.P.: Identification of the finishing technique of an early eighteenth century musical instrument using FTIR spectromicroscopy. Analytical and Bioanalytical Chemistry **399**(9), 3025–3032 (2010)
3. Bitossi, G., Giorgi, R., Mauro, M., Salvadori, B., Dei, L.: Spectroscopic Techniques in Cultural Heritage Conservation: A Survey. Applied Spectroscopy Reviews **40**(3), 187–228 (2005)
4. Dondi, P., Lombardi, L., Malagodi, M., Licchelli, M., Rovetta, T., Invernizzi, C.: Semi automatic system for UV images analysis of historical musical instruments.In: Proc. SPIE 9527, Optics for Arts, Architecture, and Archaeology V, 95270H (2015)
5. Dyer, J., Verri, G., Cupitt, J.: Multispectral Imaging in Reflectance and Photo-induced Luminescence modes: A User Manual. The British Museum, Charisma Project, pp. 81–85 (2013)
6. Meskaldji, K.; Boucherkha, S.; Chikhi, S.: Color quantization and its impact on color histogram based image retrieval accuracy. In: Proc. of First International Conference on The Networked Digital Technologies, NDT 2009, pp. 515–517 (2009)
7. Hsueh S.; Wu, H.: Building Specified Web-Searching Image Database Using Quantization-Color-Size Histogram, In: Proc. of International Symposium on Computer, Consumer and Control (IS3C), pp. 694–697 (2012)