

# Interactive change of lighting in the portrait images

**Srđan Marković**

BSc, digital artist,  
UI/UX Designer  
Serbia

**Marija Obradović**

Faculty of Civil Engineering,  
University of Belgrade  
Serbia

**Alexandros Demetriades**

Experiential designer  
ADDSPACE Design Studio, Nicosia  
Cyprus

*We are facing a number of applications for altering portrait photographs using the help of artificial intelligence. Apart from the entertainment purposes, modern computer technologies can also help us get dynamic effects from static images, an example of which is the subject of this study. Dealing with the change of lighting in portraits photographs through real-time rendering, this paper provides a method of obtaining an image with variable light source that affects the facial features generated on the basis of the face tracking data acquired from the existing static photograph. Thus, we get a portrait with altered light, as if such a source was present at the actual moment of photographing. This method aims to improve or even change the visual experience when viewing the image, so that its further application corresponds to the given context.*

**Keywords:** depth map, normal map, lighting, face recognition, rendering.

## 1. INTRODUCTION

Visualization, in computer graphics, encompasses a wide range of graphic representations, from displaying the simplest mathematical functions, to generating virtual 2D images, 3D models and animations, all the way to virtual reality and in recent years the ever-increasing augmented reality. Presentation of the visualized imagery goes a step further, representing a whole set of procedures that make an image or a model displayed in the desired way, realistically or with certain artistic effects, usually highlighting the object or information relevant for the purpose in matter.

Nowadays, more and more attention is being paid to the presentation of not only virtual models and images, but also of real photo and video materials in order to make them more interesting, appealing or meaningful. It has come a long way from mere photo-editing in programs for such a purpose using various artistic filters. There are several applications that process images resembling different artistic styles, for example [1-3].

In this paper, we give a method of obtaining an image with a changeable source of light effecting the elevated artificial facial features generated from facial tracking data of a given static portrait photograph, i.e. the picture with an altered direction of light, as if such a source of light was present at the moment the photograph was taken. This way, we can alter the expression of the photograph itself, increase or decrease dramatic effects, e.g. add the characteristics of certain artistic styles, or other desired corollaries of the desired atmosphere.

## 2. REALIZATION OF INTERACTIVE RELIGHTING

The development of computer vision and related techni-

ques, such as object and pattern recognition, face detection or augmented reality, has caused a great shift in the field of visualization. A large number of applications, mainly for smartphones, has been developed in the last couple of years, using the achievements of advanced facial recognition techniques, for example: facial tracking. Some of them use this technique to display user's augmented face with a variety of graphic add-ons [3] Fig. 1.

However, apart from entertainment, computer visualization techniques can be used for other purposes, from scientific, artistic to educational.

Using techniques of computer graphics: depth and normal map, we can make 2D image, such as a user's portrait, appear exposed to the changes of light, as if the light source is moving in the room (or in the exterior). In this way, we change not only the user's environment virtually, but we also affect which parts of the face will be exposed to the light or remain in the shadow, hiding and revealing unevenness, bumps and dents within the static image and giving it dynamic quality.



**Fig. 1: An Example of smartphone app - filter for augmenting portrait photographs with graphic content [3]**

## 3. PROCEDURE DESCRIPTION

In this section, we give a detailed explanation of the procedure for obtaining relighted portrait images. We

Received: June 2018, Accepted: December 2018.

Correspondence to: Professor Marija Obradović,  
University of Belgrade, Faculty of Civil Engineering,  
Belgrade, Serbia

E-mail: marijao@grf.bg.ac.rs

doi:10.5937/fmet1902326M

© Faculty of Mechanical Engineering, Belgrade. All rights reserved

FME Transactions (2019) 47, 326-330 326

start from a static image which is preferably a photograph of the human face - portrait, given in the frontal position, 'en face'. The generation of the lightning effect is done by the following steps:

## 2.1 Tracking the Facial Features and Retrieving the Tracing Data

To make the lighting adjustable to any portrait, we are going to use the facial tracking process to find the main facial features: nose, mouth, eyes and eyebrows. This helps us to locate the face in the photograph and use the data obtained from the facial tracking to generate the necessary maps (textures) needed in the next steps.

For this particular example, we will use a JavaScript based library called "Clmtrackr". Clmtrackr is a library made by Audun Mathias [4] and serves for fitting facial models onto faces in videos or still images. It is based on the findings in [5], implementing *constrained local models* fitted by *regularized landmark mean-shift*.

It automatically detects faces and tracks the points linked with the facial features in real time, outputting the coordinates of the facial points in a form of a numerated array [4]. The serial numbers of these points are not arbitrary. Each point in Clmtrackr is linked to a certain facial point, so the number associated to it carries the information about the coordinates of this particular point (Fig. 2). Using this, we get control points on characteristic parts of the face.

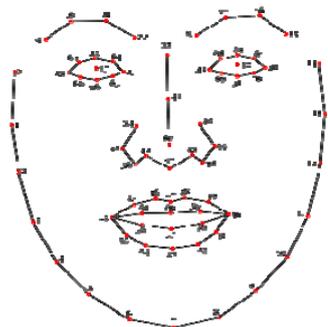


Fig. 2: Clmtrackr – set of connected control points with the numbers associated to the facial points [4]



Fig. 3: Application of the "Clmtrackr" on the actual portrait

In Fig. 3 we shows how facial tracking works by applying "Clmtrackr" on a specific portrait.

For a clearer consideration of the facial tracking method, we give another example in Fig. 4, where it can be seen how the detected points, linked with the associated parts of the face, adjust to the model's changed facial positions given in three different photographs.

In this case, the points generated by facial tracking will be used for mapping a depth map onto the source face.

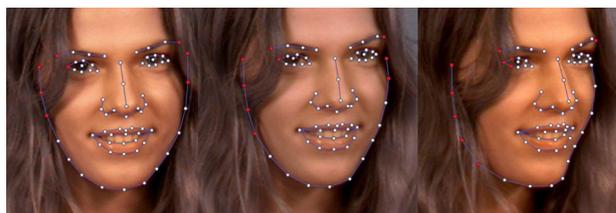


Fig. 4: An annotated face from the MUCT database (<http://www.milbo.org/muct/>[6])

## 2.2 Generating the depth map of the face and mapping it using tracked data

The second step reviews how the points obtained by the facial tracking method are used to place the depth map of an average face on the exact place of the face located by tracking (Fig. 5).

A depth map is a 2D grayscale image that carries information regarding the distance of each pixel from the viewer, i.e. camera, as the brightness value of the corresponding pixel.

The depth map used in this example is based on the standard facial features and provides elevation information in a greyscale format. Although the depth map is generated from the 3D model of an average face, it contains enough common facial details to make it applicable to any face.

The depth map is important in this step, because the intensity of grey defines the z-coordinates of each pixel on the screen. In this case, white designates the furthest, while black designates the nearest points to the camera. This is not obligatory, and it can be changed according to the user's needs (black can mark the furthest and white the closest points).

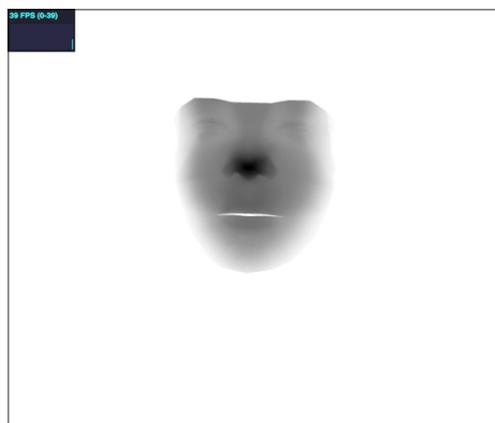


Fig. 5: Depth map of an average face

## 2.3 Generation of Normal Map Based on the Depth Map

The depth map of the face in the portrait, generated in the manner described in above, at the end has to be converted to a normal map (Fig. 6), in order to be susceptible to the impact of artificial light.

The normal map serves to simulate the reflection angles of light rays on uneven surfaces, i.e. to create an impression of lighting and shading of bumps and dents on the given surface [7,8].

The normal map is of great importance to digital designers, whenever it comes to displaying 3D surfaces. Unlike the grayscale depth map, the normal map is described by RGB values and it does not carry distance information, rather information regarding the positions of the normal's vectors of the surface. (An example of the correlation between the 3D object coordinates, the coordinates in RGB and the depth maps can be found in [2]). In the rendering process, the position of normals is substantial. It determines the amount of the surface's shading, which depends precisely on the position and orientation of normals according to the light.

In Fig. 7 and 8 we give an example of copying normals from the sphere and applying them onto a 2D surface - plane, keeping the directions of normals and thus the shading of spherical surface. In this way it is deceiving the eye, convincing it to observe a curved surface that, in fact, does not exist.

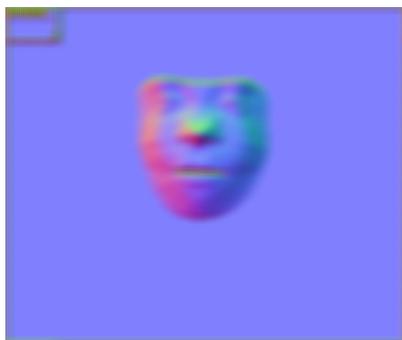


Fig. 6: Normal map

The normal map serves to simulate the reflection angles of light rays on uneven surfaces, i.e. to create an impression of lighting and shading of bumps and dents on the given surface [7,8].

The normal map is of great importance to digital designers, whenever it comes to displaying 3D surfaces. Unlike the grayscale depth map, the normal map is described by RGB values and it does not carry distance information, rather information regarding the positions of the normal's vectors of the surface. (An example of the correlation between the 3D object coordinates, the coordinates in RGB and the depth maps can be found in [2]). In the rendering process, the position of normals is substantial. It determines the amount of the surface's shading, which depends precisely on the position and orientation of normals according to the light.

In Fig. 7 and 8 we give an example of copying normals from the sphere and applying them onto a 2D surface - plane, keeping the directions of normals and thus the shading of spherical surface. In this way it is deceiving the eye, convincing it to observe a curved surface that, in fact, does not exist.

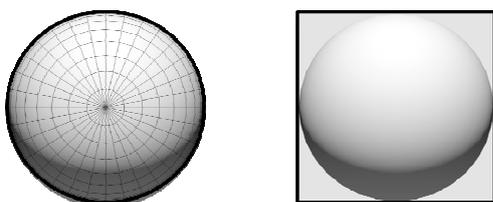


Fig. 7: Normals copied from the sphere and applied to the 2D surface keeps the shading of spherical surface

Each pixel on the map has its RGB value (Fig. 9 left). The normal map converts these RGB values to X, Y, and Z coordinates (Fig. 9 right), by which it defines the direction of the normal vectors.

In the case considered, we proceed from the flat surface (picture). The normal map redirects the rays of the virtual lighting in a way that convinces the viewer that the picture is, in fact, three-dimensional.

The normal map stores the direction values of X, Y and Z axis of the surface normals into the corresponding R, G and B channels of a texture image. The orientation of these normals instructs the rendering environment on how to shade the surface.

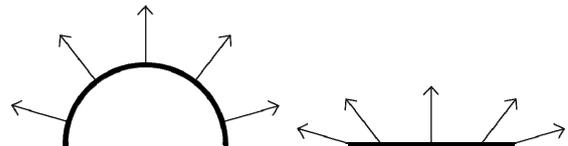


Fig. 8: Simplified 2D representation of the principle of copying normals from a spherical object to a 2D surface

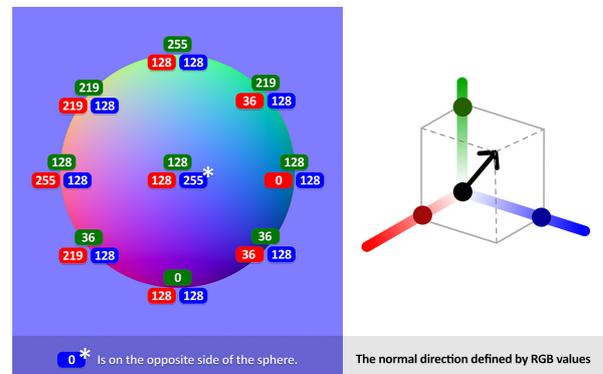


Fig. 9: The normals sphere with numerical RGB values (left) and examples of converting color information into normal vectors (right)

## 2.4 Real-time light rendering

Using the Web GL based application [9,10], we simulate a new lighting, a new direction of illumination, as if we introduced a new light source into the 3D space where the subject was at the time of the photographing (Fig. 10).



Fig. 10: The final results of light altering on the initial portrait photograph

WebGL based application is programmed in JavaScript using Three.js library [11] for real-time rendering. The application has the following features: image loading, face recognition, depth map remapping, depth map to normal map conversion and WebGL

rendering of light shading. For facial tracking and re-mapping it uses the Clamtrackr library. A crucial part of normal map generation is based on the work of Christian Petry [12].

The application uses two bitmap sources for the relighting: a portrait image and the generated normal map.

The final interactive rendering environment is generated in Three.js. The generated 3D light source (which can be interactively positioned in the application's space) relights the object.

With such obtained light we simulate a new lighting, a new direction of illumination, as if we introduced a new light source into 3D space where the subject was at the time of the photographing (Fig. 11).

The generated image can be saved to a disk for further use.

#### 4. EXTENDED APPLICATION OF THE PROCEDURE

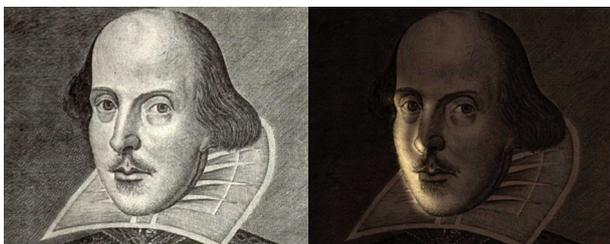
We can test the described procedure on various portrait photographs (made by camera), but it can also be applied on other portrait images, painted portraits or even drawings, if they are realistic enough to make facial tracking possible.

In Fig 11 we give an illustration of the applied relighting procedure on the portrait of J.S. Bach (Elias Gottlob Haussmann, 1746 oil on canvas, [13]), where it can be seen that the change of lighting alters the atmosphere of the painting itself, so that an already Baroque ambience now gains Gothic features.



**Fig 11: Relighted portrait painting of J.S. Bach (Elias Gottlob Haussmann, 1746 oil on canvas) [16]**

A similar transformation can be seen on a graphic that depicts the portrait of William Shakespeare (Martin Droeshout, 1623, engraving, [14]), as in Fig 12.



**Fig 12: Relighted portrait painting of William Shakespeare (Martin Droeshout, 1623, engraving) [15]**

Of course, although applicable in some cases, this procedure is not universally valid for any portrait, which mainly depends on how well the facial features in the image are "catchy" for facial tracking.

#### 5. RESULTS

Based on the described procedure, it is possible to produce, step by step, the impression of the variable artificial lighting of the face in the portrait. We can take any photograph or even artistic image of the face and generate facial tracking data. Using these data, we can map the depth map, and then the normal map, which enables us to affect the lighting of the 'model' through an interactive application we developed for this purpose. This way, we have an impression that the position of the light source inside 3D space is changing, even though we only have a 2D image. Thus, we can not only change the existing photograph in terms of artistic lightening effects, but we can also solve certain visualization problems.

For example, in the cases where a portrait photograph is to be fitted into a background that may be another photograph or a CGI, the common problems with different directions of light sources in these two images occur. By application of the presented method, such situations would be easily solved. Moreover, onto the face in the photograph extra lights can be added, different in direction, intensity, color, softness, etc.

In a similar way, we can make lightening effects that are characteristic for certain artistic styles, not only to the faces in photographs, but also to the portraits from works of art. Baroque effects can be obtained by using sharper shadows and a low intensity light source. Surreal effects can be obtained by changing color and unexpected angles of the light.

However, lighting effects in portrait images do not have to be interpreted from a mere aspect of artistic styles. They can be also considered from the aspect of the symbolic message they transmit, optical-perspective experiments or visual paradoxes [7]. Thus, the scope of analysis and application of the presented procedure is expanded.

We gave just a few hints, but the possibilities of such applications could be endless. The directions for further research could concern the expansion of such kind of relighting to other surfaces, apart from the human face. In the sense that this procedure is applied to the relief of the topographic surface, the application would be considerably wider. For example, we could study the insolation of the terrain, isophotes, isohels and other characteristic features that are directly dependent on sunlight.

#### 6. CONCLUSIONS

Nowadays, there are numerous applications which, using modern methods of computer graphics, computer vision and face recognition, add a variety of entertainment content to the given photograph. However, these procedures can also be used for scientific, design, artistic or educational purposes. The method given in this paper, using facial tracking, depth mapping, normal mapping, and WebGL based application programmed in JavaScript for real-time rendering, shows a possibility of enriching a static image with a dynamic component, by changing the lighting of the face in the photograph. Thus, the purpose of this procedure is to improve or

alter the visual experience of the image, enabling it to correspond to the given context, be it artistic style, designer's presentation, or examination of lighting effects in engineering. Some interesting effects in restyling the image, including enhanced dramatic effects, Baroque style features, etc., can be achieved through this process.

## 7. ACKNOWLEDGEMENT

This research is supported by the MPNTR of Republic of Serbia, grant No III44006.

## 8. REFERENCES

- [1] Adobe: Photoshop Lightroom CC for mobile <https://www.adobe.com/creativecloud/photography.html#x>
- [2] Karan, Branko: Calibration of Kinect-type RGB-D Sensors for Robotic Applications, *FME Transactions*, Vol. 43, No 1, pp. 47-54 (2015).
- [3] Stephen Milborrow, John Morkel, and Fred Nicolls: The MUCT Face Database, The MUCT Landmarks, University Of Cape Town, Dec. 2008, <http://www.milbo.org/muct/muct-landmarks.html>
- [4] Audun Mathias: Javascript library "clmtrackr" <https://github.com/auduno/clmtrackr>
- [5] Nazarov, Rovshen, and John Galletly. "Native browser support for 3D rendering and physics using WebGL, HTML5 and Javascript." BCI (Local) 1036,Thessaloniki, Greece, pp. 21-24, (2013).
- [6] Saragih, Jason M., Simon Lucey, and Jeffrey F. Cohn. "Face alignment through subspace constrained mean-shifts." *Proceedings of the IEEE International Conference on Computer Vision, 2009 IEEE 12th International Conference on.* Ieee, Kyoto, Japan, pp. 1034-1041 (2009).
- [7] Saragih, Jason M., Simon Lucey, and Jeffrey F. Cohn. "Deformable model fitting by regularized landmark mean-shift." *International Journal of Computer Vision* 91, No. 2, pp.200-215. (2011).
- [8] De Rosa, Agostino: Jean François Nicéron: Perspective and Artificial Magic, *FME Transactions*, Vol. 45, No 2, , pp. 215-226.(2017).
- [9] Heidrich, Wolfgang, and Hans-Peter Seidel. "Realistic, hardware-accelerated shading and lighting." In *Proceedings of the 26th annual conference on Computer graphics and interactive techniques*, pp. 171-178. ACM Press/Addison-Wesley Publishing Co., (1999).
- [10] Andersson, Sven, and J. H. O. N. N. Y. Göransson. "Virtual Texturing with WebGL." Master Thesis, Department of Computer Science & Engineering, Chalmers University of Technology, Gothenburg, Sweden, (2012).
- [11] Sloan, Peter-Pike. "Normal mapping for precomputed radiance transfer." In *Proceedings of the 2006 symposium on Interactive 3D graphics and games*, pp. 23-26. ACM, (2006).
- [12] Christian Petry, Online Normal Map Generator <https://github.com/cpetry/NormalMap-Online>
- [13] Tsalakanidou, Filareti, Dimitrios Tzovaras, and Michael G. Strintzis. "Use of depth and colour eigenfaces for face recognition". *Pattern recognition letters* 24.9-10: pp. 1427-1435. (2003)
- [14] TNW: Post-Snapchat, MSQRD's Bob Marley filter is conveniently left out for new users <https://thenextweb.com/apps/2016/04/20/where-did-bob-go/> , 2018/17/04

---

## ИНТЕРАКТИВНА ПРОМЕНА ОСВЕТЉЕЊА У СЛИКАМА ПОРТРЕТА

С. Марковић, М. Обрадовић, А. Деметриадес

Данас постоје бројне апликације за корекције фотографија портрета уз помоћ вештачке интелигенције. Осим у сврху разоноде, савремене рачунарске технологије такође могу да нам послуже и за добијање динамичких ефеката из статичких слика, а један такав пример је предмет ове студије. Бавећи се променом осветљења на фотографијама портрета кроз рендеринг у реалном времену, овај рад даје метод добијања слике са променљивим изворима светлости која утиче на црте лица генерисане на основу података о праћењу лица (facial tracking) прибављених из постојеће статичке фотографије. На овај начин добијамо портрет са накнадно промењеним осветљењем, као да је такав извор светлости био присутан у самом тренутку фотографисања. Циљ поступка је побољшање или чак промена визуелног искуства приликом гледања слике, тако да њена даља примена одговара датом контексту.