Virtual Reality for Skin Exploration

Marie-Danielle Vazquez-Duchêne
BASF Beauty Care Solutions
France SAS,
3, rue de Seichamps, CS 71040
Pulnoy, 54272 Essey-lès-Nancy
Cedex, France
Tel 33 (0)3 83 29 08 02
marie-danielle.vazquez-
duchene@basf.com

Christophe Mion
Scalable Graphics,
615 rue du Jardin Botanique,
54600 Vandœuvre les Nancy,
France
Tel 33 (0)3 83 59 30 71
christophe@scalablegraph
ics.com

Solène Mine
BASF Beauty Care Solutions
France SAS,
3, rue de Seichamps, CS 71040
Pulnoy, 54272 Essey-lès-Nancy
Cedex, France
Tel 33 (0)3 83 29 08 02
solene.mine@basf.com

Olga Freis
BASF Beauty Care Solutions
France SAS,
3, rue de Seichamps, CS
71040 Pulnoy, 54272 Essey-lès-
Nancy Cedex, France
Tel 33 (0)3 83 29 08 02
olga.freis@basf.com

Christine Jeanmaire
BASF Beauty Care Solutions
France SAS,
3, rue de Seichamps, CS 71040
Pulnoy, 54272 Essey-lès-Nancy
Cedex, France
Tel 33 (0)3 83 29 08 02
christine.jeanmaire@basf.
com

Gilles Pauly
BASF Beauty Care Solutions
France SAS, 3, rue de
Seichamps, CS 71040 Pulnoy,
54272 Essey-lès-Nancy Cedex,
France
Tel 33 (0)3 83 29 08 02
gilles.pauly@basf.com

Alain Denis
BASF Beauty Care Solutions
France SAS,
32, rue Saint Jean de Dieu,
69007 Lyon, France
Tel 33 (0)4 72 76 60 00
alain.denis@basf.com

ABSTRACT

Background: We have developed and set up the SkinExplorer™ platform, a new tool to exploit and rebuild serial confocal images into 3D numerical models [1, 2]. The acquisitions using confocal microscopy allow visualizing cutaneous components as elastic fibers, melanocytes and keratinocytes etc... These diversified sources of data participate to create numerical 3D volume models with high quality of visualization.

Objective: To create a Virtual Reality (VR) experience, to communicate and change the perception of skin structures by virtualization mode.

Methods: The use of ART TRACKPACK system and ART SMARTTRACK device allow us to valorize new sensory images for the volumetric rendering of the 3D skin models.

Results: We increase the perception and the understanding of skin components organization.

Conclusion: The SkinExplorer™ platform seems to be a promising system for exploring the skin.

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1. INTRODUCTION

In global sense, the virtual reality (VR) experience can be described and summarized as a real-time computer graphic simulation of realistic situation with interaction, immersion and sensory feedback. Mary Rasmussen and her team have contributed to set up Virtual Reality in Medicine Laboratory at the University of Illinois to solve anatomical disorders and to manage large quantity of microscopical data [8, 9]. Blood vessels in retinoblastoma were reconstructed and visualized by using the ImmersaDesk (Fakespace, Ontario, Canada) and holding a wand for manipulation and exploration of the reconstructed retinoblastoma.

We suppose that the VR experience can bring new information in the microanatomy of the skin. Related to investigations in skin knowledge, the VR experience will offer a new observation way and will provide a range of viewpoints. Cutaneous components are naturally concealed from our sight by the skin surface.

To figure out and build a virtual skin world, cutaneous components are placed and form a part of virtual environment. This environment contributes as one of the keys of the skin microstructural organization understanding and exploration.

Numerical simulations of the skin bring alternative to re-study optical and mechanical properties [3, 4].

The virtual skin world corresponds to a set of 3D reconstructed cutaneous components scaling up microscopic data to a scientific visualization into a 3D screen or 3D display as a helmet. The 3D models in the simulated environment are built from serial histologic sections of skin biopsies from surgical operation. 3D reconstructions and appropriate renderings have come first to transforming the hidden microscopic situation into a micro realistic field of exploration by the use of the SkinExplorer™ platform.

The skin components are not visible to naked eye and can achieve large volumes in terms of microscopical data. These data correspond to the acquisition of numerous images which cover a wide field of investigation. This enormous quantity of data needs memory and specific strategy to display on screen voxels with volumetric rendering as works on the Visible Human [7, 10]. These parameters are also required in 3D for visualization, simulation and quantification of targeted molecule by specific staining in hair [11] and skin [1, 2, 5, 15].

2. VIRTUALIZATION OF THE SKIN

The virtualization is a way of treating high quantity of data in 3D space and can give a new sight of the skin anatomy by numerical simulation which can be manipulated or dynamically deformed [2].

Firstly, the immersion must be the best possible to avoid visual discomfort and to achieve the easiest exploration of the 3D objects in the virtualization scene.

Secondly, the interactivity should bring 3D advantages in terms of actions without any destruction of the numerical model. Since the creation of the SkinExplorer™ platform, the immersion and the interactivity have been considered as major keys. It has been arranged and improved to facilitate the perception of the virtual skin environment because the cutaneous components are not directly visible to the naked eye.

Currently, we are still working on increasing the immersion sensation as mental and physical aspects.

The feeling of involvement plays a considerable role to achieve a presence feeling in a VR experience. The choice of 3D models and its pertinence are essentials to capture the user attention and to ensure an optimal mental immersion. For the physical immersion part, the participation of the user is strengthened by tracking its movement [5].

3. MATERIALS AND METHODS

3.1 Context

The acquired images by fluorescence confocal microscopy are modified by some pre and post-treatments. A 2D matching of several stacks of images from the same sections is performed by key points selection. After the matching step, a 3D alignment is generated around each interface level between the end image of the n section and the start image of the n+1 section [1]. Finally, volumetric visualization is obtained and manipulated to observe it with the flystick. This platform is dedicated to understand how cutaneous components act inside the skin, and its main use corresponds to the observation like a new generation of visual tool which enables to arrange the puzzle pieces in the right order.

Over the last 2 decades, many devices allow obtaining 2D images and classical imaging analysis of skin components as cells, elastin or collagen fibers. For example, on melanocyte, cell responsible of the pigmentation of the skin, some histological

images (Figure 1) give us information of the stellate structure of the melanocyte, its organization with other environmental cells. These results have been exploited from the sixties until today. Since 2000, we reconstruct 3D single microscopical stack (Figure 2) and since 2010, we are able to reconstruct bigger volumetric visualization. The skin is obviously well known in surface but not in its depth even a lot of effective methods and instruments for assessment of the skin have been developed and brought to the market.

Figure 1: 2D image of a melanocyte stained for melanin (black) using the classical histochemical techniques of Fontana-Masson silver staining. Orange circle: melanocyte body. Blue stars: its dendritic arms. The melanin production is visible on this histological section (7 μm-thick, included in paraffin), observed from photonic microscope and captured by camera. This melanocyte is surrounding by keratinocytes (white arrow).

The SkinExplorer™ platform is not used for training, but for observation and for understanding how cutaneous component act inside the skin. The main purpose is to visualize the complexity of the skin 3D network associated with multiple interactions between cells and macromolecules that compose the extracellular matrix or between the macromolecules themselves.

Figure 2: Melanocytes (green) in epidermis (the superficial part of the skin in red) from 2D reconstructed image (a) to 3D representations (b) with an extracted part (c and d). These results were obtained from confocal microscope in a simultaneous acquisition and computerized captures (20 μm-thick, frozen section).

Now the virtual reality enables us to see in volume the dendritic arms organization of the melanocyte (Figure 3) that is unobvious to guess in an excellent 2D histological image (Figure 1). Assets of the virtual reality can be summarized by a collaborative exploration for several researchers on project and to allow us to discuss on points of interest. The main advantages on the melanocyte study are exhibited in a previous publication [5].

Moreover, this technology offers up-graded and adapted microanatomy knowledge of the skin and gives new information to plan and even orientate studies. These studies concern always data obtained by instruments. The evaluation phase has begun with researchers and some customers. The various observations and commentaries of project participants are shared between them to clear thinking and take decisions about the project.

Figure 3: In epidermis, three melanocytes are well visible in VR experience with their dendritic arms (in green, pink arrow heads), and nuclear part (yellow pins) among keratinocyte cells (in red, white flowers) and their nuclear part (in blue, straight yellow arrows). At the dermis level, some elastic fibers (in red, green circles) surround the fibroblasts where only the nuclear part is stained (in blue, zig-zag yellow arrows), (30 µm-thick, frozen section).

3.2. Technical approach

We have developed an immersive application, which targets in the first place two kinds of systems: one based on a large-screen 3D TV, and the other one based on a desktop 3D display for every-day use in a more limited space. Thanks to a careful design, we rely on the same software base for the two systems. For the tracking and interaction aspects, we have chosen to complete the 3D TV environment with an ART SMARTTRACK tracking system and an ART Flystick3 interaction device on one hand, and the desktop 3D display with a Microsoft Kinect system on the other hand. For both cases, we have chosen to complement the traditional 3D-widget based Graphical User Interface (GUI) with a companion GUI running on a touch interactive remote device. The interaction with the ART system and the 3D TV is accomplished by tracking the user head's position thanks to trackers positioned on the 3D glasses and the navigation in the 3D skin model is performed in the direction of a virtual ray pointed by the Flystick3; this virtual ray is also used to select markers in the 3D volume or to interact with the 3D widgets of the GUI. The interaction with the Kinect and the desktop 3D display is done by tracking the face of the user to determine the position and the orientation of his eyes, allowing the inter-ocular distance to be computed automatically, and the navigation in the volume is done with a joystick or with the mouse.

Both systems are augmented with a network-based GUI running on a remote device and communicating with the application through TCP/IP sockets. This GUI allows the user to enter data into the application through the virtual keyboard of the remote device or to edit the 2D transfer functions of the volume rendering algorithm for example.

The interaction with the tracking systems is accomplished through the Virtual Reality Peripheral Network library [6], which opens the support of other systems in the future (Figure 4).

Figure 4: Schematic drawing of the technical approach with 2 m³ of tracking space between the SMARTTRACK device and the user wearing the 3D glasses and the flystick 2 in front of the screen.

Finally, we use auto-oriented 3D widgets included in the 3D world to allow the user to augment the skin volume with notes for storing information, which is saved along as the user exits the application, or to allow the user to interactively modify the 2D transfer function.

We have chosen these tools for various reasons. The transportable advantage is the main point with its fiability and its manipulation space leads us to fix this cited approach.

4. CONCLUSION

The construction of 3D numerical models for medical training, therapy and rehabilitation are popular in the whole medical world [8, 9]. These medical simulators are developed to learn the right behavior or gesture and surgical movements with virtual scalpel for example. The knowhow and use of VR experience in the medical area are considered as investigations seeking improvements and excellence [12, 13, 14]. The SkinExplorerTM platform as a real-time physical platform offers now to live a VR experience which brings another way to learn about the ultrastructure and the complexity of the skin (Figure 5).

Figure 5: Example of skin interactive exploration by virtual reality mode (a) with a camera way, from the top view (b, white square), at the level of the blue point, we enter inside the skin to travel between the elastic fibers (c, blue circle) at middle depth of the 3D skin model and navigate with the compass (d) to the bottom (e) of the 3D skin model.

We can manipulate this big volume of 40 serial histological sections of a young human skin post-treated and compressed by multi-resolution visualization and converted into VR application. This platform of virtual reality could provide a real benefit in science and medicine for a better understanding of the intricacies and complexity of the biological 3D networks such as vascular or neuronal systems. The next step in future work is 3D warping in real-time volume data with preservation of its topology.

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