Interactive Makeup Tutorial Using Face Tracking and Augmented Reality on Mobile Devices

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***Abstract*—This work presents an interactive application for makeup tutorials, targeted to mobile devices based on the Android platform. The application uses Augmented Reality to ease the execution of a set of steps of a given tutorial. By tracking the user's face, the application can display where a given makeup should be applied in each step. Users can also contribute by creating their own tutorials. Our results showed that this application is effective in helping users to learn or follow a makeup procedure, in which most of them agreed that they spent less time than expected by following the interactive tutorial, that it is easy to use and that they were satisfied with the results of the application.**

Keywords-face tracking; augmented reality; makeup tutorial; mobile devices; interactivity

I. INTRODUCTION

The global beauty market has proven its ability to achieve stable and continuous growth as well as its resilience even under unfavorable economic circumstances [1]. This market is expected to reach $265 billion in 2017 [2]. This growth is mostly driven by emerging markets, such as China and Brazil, which offer great potential for expansion due to rising incomes and increasing demand for better products.

The cosmetics sector in Brazil has been growing 10% per year. Some of the reasons for this steady growth are the economic rise of D and E classes and the emergence of women in the work force. Continuous new product launches and increased life expectancy (which enhances the desire to prolong youth) also play an important role in the strengthening of this sector. In addition, Brazil holds the third position in the world ranking of Personal Care with 9.70% market share, behind only United States and Japan, respectively [3].

Following this trend, many bloggers have achieved considerable success by publishing makeup tutorials on their personal weblogs. Blogs are even becoming more professional and establishing partnerships with the cosmetic industry [4][5][6].

Nowadays, with the advancement of computational technology and popularization of mobile devices [7], applications aiming at helping users to appropriately use makeup products have been developed for both Android and iOS, as well as for web-based platforms. However, neither existing blogs nor most current mobile applications provide real-time feedback or interaction with the users.

This work presents an interactive application for makeup tutorials, targeted to mobile devices based on the Android platform. The application uses AR to ease the execution of a set of steps of a given tutorial. By tracking the user's face, the application can display where a given makeup should be applied in each step. Users can also contribute by creating their own tutorials. A usability experiment showed that this application is effective in helping users to learn or follow a makeup procedure, in which most of them agreed that they spent less time than expected by following the interactive tutorial, that it is easy to use and that they were satisfied with the results of the application.

The remainder of this paper is structured as follows. Section II discusses related works on makeup applications and face tracking for AR. Section III details the proposed interactive makeup tutorial application. Section IV presents the results obtained with the application, along with results from a user study. Finally, Section V concludes the paper and provides future work directions.

II. RELATED WORK

This section describes existing face tracking methods that are suitable for AR systems and existing applications that help users to apply makeup.

A. *Face Tracking for AR Systems*

In some application scenarios, AR systems need to superimpose virtual content onto the user face. In order to do this, they have to perform real-time face detection and tracking.

Some AR applications simply use 2D tracking techniques that provide an area of the image where the target is located, such as the Viola-Jones [8] and the Tracking-Learning-Detection (TLD) [9] methods. Such techniques give information about the 2D location and scale of the tracked faces, but are not able to estimate head orientation. In contrast, some methods are able to perform full 6DOF head tracking, such as the Constrained Local Model (CLM) [10][11], the Discriminative Random Regression Forests (DRRF) [12] and the faceshift [13] techniques.

Face trackers can also be classified as rigid or non-rigid [11]. While rigid methods focus on estimating only head location (and possibly orientation) [8][9][12], non-rigid methods are also able to track the position of face landmarks such as eyes, nose and mouth [10][11][13].

B. *Makeup Applications*

Many applications enable users to try new products and give themselves a virtual makeover. Those applications may also encourage online purchases, which opens up new commercial opportunities for companies [14][15].

As an example, the Modiface application detects user's skin profile using a collection of Facebook or uploaded photos [16]. This application enables users to try on makeup products, skin-care effects, anti-aging treatments, different celebrity hairstyles and nail colors on photos through a web browser. It also helps the user to better understand his or her own skin and suggests products for purchase.

In addition, Modiface has launched a photorealistic 3D AR beauty mirror, which is heralded to transform beauty shopping. This mirror simulates makeup products and how they look on users without having to upload a photo. This application has been launched in partnership with Sephora, the leading beauty retailer [17]. Following this trend, Panasonic [18] launched its version of the virtual makeup mirror that identifies and assesses users with facial recognition technology as well as provides recommendations on which makeup they should use. Currently, this version is available for cosmetic retailers only.

Such as the example of Sephora virtual makeup mirror, there are other applications developed by the companies themselves or in partnership with technology experts [19], and some of them are designed for mobile devices [20]. There are also mobile applications designed to address specific makeup items. For instance, in [21], users can find a large collection of pictures of eye makeup.

Although very useful, online tutorials sometimes lack interaction features. For instance, it is noticeable that the application of some makeup products may vary according to user's skin and face formats. These aspects can be compromised when watching video tutorials since the presenter may not be familiar with user's specific needs.

As an attempt to promote more interaction with users, it was noticed that most makeup applications enable users to try on cosmetic products and receive personalized recommendation of products based on photographs recognition. The makeup mirrors described in this section are examples of applications that use AR technology to provide more interaction with users by applying makeup products to their own faces without the need to upload photos. However, these solutions are currently available only for cosmetic retailers. Therefore, they are not accessible for larger amounts of users.

III. INTERACTIVE MAKEUP TUTORIAL APPLICATION

The lack of interactivity present in most existing makeup applications was one of the primary motivations for developing our makeup tutorial. Being a mobile application, the proposed work targets a large user base, providing accessibility to an otherwise scarce category of applications. Major concepts and tools used on the prototype are described in this section.

In short, the system is based on three main components:

- The mobile application (running on an Android device);
- A collection of tutorials (the content to be displayed);
- A tutorial editor (running on any Java SE platform).

The system architecture was designed in a way to allow a clear separation between the application and the content to be displayed. They are independent, being possible to create new content externally to update the mobile application without needing to change the application code. Specialized knowledge on computer programming is not necessary, as well.

A. *Face Tracking*

Qualcomm Snapdragon SDK for Android [22] is used for performing real-time face tracking on the mobile device. In order to use the SDK, a mobile device powered with Android 4.0.3 or later and Snapdragon S4, 200, 400, 600, or 800 is required. The SDK offers facial processing and recognition functionalities, such as blink detection, gaze tracking, smile value and face orientation. In addition, it also provides the 2D location of the face area, eyes, mouth and face landmarks bounds, as illustrated in Fig. 1. The bounds of the face landmarks that are retrieved by the SDK are listed in Table I.

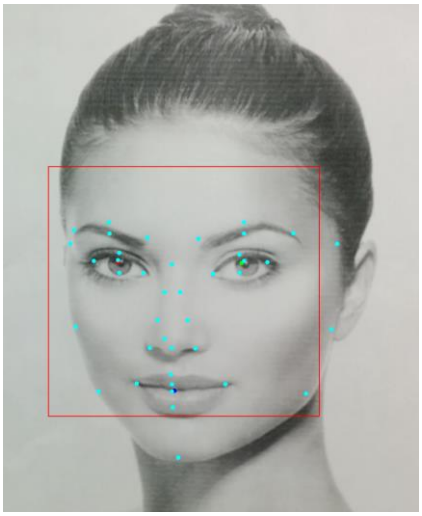


Figure 1. Facial features detected by Qualcomm Snapdragon SDK for Android: face area (red rectangle), left eye (red dot), right eye (green dot), mouth (dark blue dot) and face landmarks bounds (cyan dots).

TABLE I. FACE LANDMARKS BOUNDS DETECTED BY QUALCOMM SNAPDRAGON SDK FOR ANDROID

Landmarks	Bounds
Mouth	1. Left; 2. Right; 3. Upper lip top; 4. Upper lip bottom; 5. Lower lip top; 6. Lower lip bottom.
Left and right eyebrows	1. Left; 2. Right; 3. Top; 4. Bottom.
Left and right ears	1. Top; 2. Bottom.
Left and right eyes	1. Left; 2. Right; 3. Top; 4. Bottom; 5. Center pupil.
Chin	1. Left; 2. Right; 3. Center.
Nose	1. Bridge; 2. Center; 3. Tip; 4. Lower left; 5. Lower right; 6. Middle left; 7. Middle right; 8. Upper left; 9. Upper right.

B. *Mapping Tutorial Content to User Face*

The tutorial content was generated using a stock photo, chosen for makeup placement on Adobe Photoshop. The makeup was placed on a separate layer, on top of the stock photo layer. This layer is then used as the image displayed on the application, as shown in Fig. 2.

Figure 2. (a) Stock photo used. (b) Makeup applied on a layer on top of the photo. (c) Resulting layer image.

When using the application, once the user's facial data is obtained, it is possible to manipulate it and display the AR content on the screen – where and how a given makeup should be applied by the user. Key information about the face – such as the space occupied by it, or the space occupied by the mouth and eyes – is gathered as bounding rectangles, in order to make a rough estimate of where a makeup product should be displayed.

The points given by the facial data are used as the rectangle's points. For the face, the Facial Processing API of the Snapdragon SDK already possesses the borders of the detected face area. For the mouth bounding rectangle, the left edge is given by the x coordinate of the right bound of the mouth, the top edge is given by the y coordinate of the upper lip top bound, the right edge is given by the x coordinate of the left bound of the mouth and the bottom edge is given by the y coordinate of the lower lip bottom bound. For the eyes bounding rectangle, the left edge is given by the x coordinate of the left bound of the right eye, the top edge is given by the y coordinate of the top bound of the left eye, the right edge is given by the x coordinate of the left bound of the left eye and the bottom edge is given by the y coordinate of the bottom edge of the left eye. A screenshot of the application illustrating the resulting rectangles from the gathered points is shown in Fig. 3.

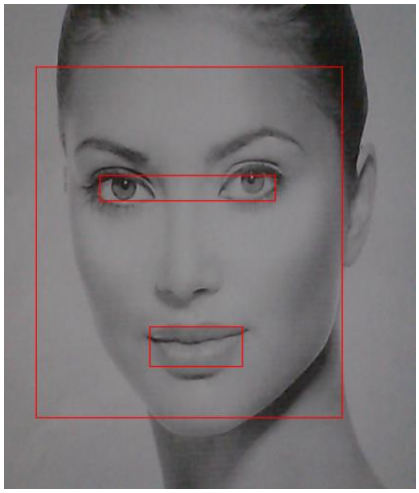


Figure 3. Bounding box rectangles of face, eyes and mouth computed from face landmarks bounds.

The way the bounding rectangles are computed do not take into account the orientation of the face; for optimal experience, it is recommended to keep the user's head facing the camera as straight as possible.

The application then displays, within one of the retrieved rectangles, a semi-transparent image of the makeup's effect around a specific area, indicating where the user should apply the product. The Android's Canvas API provides the necessary drawing functions for this purpose. In addition, the rectangle's position can be offset depending on the current tutorial step.

C. *Tutorial Content Generation*

The internal file format adopted for the tutorials is intuitive, in order to ease the creation of new content to be displayed by the application. Internally, a tutorial consists of a folder with two parts: an Extensible Markup Language (XML) file and a set of images.

The image set is formed by two distinct groups: a set of product images and a collection of overlay masks. The product images represent the specific cosmetics or items (such as a brush or pencil) that must be used in each step of the tutorial. The overlay images are used as virtual content in the AR application and guide the user during the tutorial. The usage of these files will be detailed later.

The XML file has the whole structure for one tutorial. It contains the description of each step to be executed, with all the necessary information, including:

- Which actions must be executed during the tutorial;
- What is the execution order;
- Which item must be used, and how, for each step;
- Where in the face the step action should be executed;
- How to organize and show these data, in order to augment the user reality.

Each XML file describes the steps to be performed in order to guide the user during the execution of the tutorial. This file consists of a list of structures, describing the tutorial steps. Each step in the file has a set of associated data. A sample XML file is given below:

```
<tutorial>
        ...
        <step>
                <product-image>
                        products/po.png
                </product-image>
                <overlay>
                        Tutorial/03.png
                </overlay>
                <product-name>Pó</product-name>
                <instruction>
                        Aplique aos poucos.
                        Se necessário,
                        Aplique no pescoço.
                </instruction>
                <reference>
                        bounding_box_face
                </reference>
                <offset>0</offset>
        </step>
        ...
</tutorial>
```

Each step has the following components:

- Product image: the path to an image file of the cosmetics to be used;
- Overlay image: the path to an image file of the overlay mask;
- Product name: a string describing the product;
- Instruction: a string with instructions for the user;
- Reference: a symbolic value to guide the overlay positioning;
- Offset: an integer value to guide the overlay positioning.

The `instruction` field contains the text to be displayed to the user in the respective step. It has directions to be followed by the user. The steps can also indicate some procedure or action to be performed, such as the way to apply a concealer powder or how to remove the excess after the application.

The two `product` fields have information about the item to be used. The `product-image` and `product-name` fields point to an image file and a name, respectively, to be displayed along with its usage description in a text box. Their purpose is to help on the identification of the correct item to be applied by the end user. Fig. 4 shows an example of a product image.

The `reference` field indicates the area in the user face where the virtual content must be displayed. It is a symbolic value, which can be `bounding_box_face`, `bounding_box_eyes` or `bounding_box_mouth`.

The `overlay` field points to another image file. Its goal is to indicate, visually, the locations where the cosmetics should be applied by the user, or even where some procedure should take place. Each image consists of some set of indicators over a transparent background. The overlay indicators are designed to be superimposed onto the images that are being captured by the device camera. The overlay images are then resized and drawn over the user face, based also on the `reference` parameter.

There is an example of overlay on Fig. 4. In the system, the background is transparent and the highlighted areas are the information that will be overlaid onto the camera images. This way, the user always has a feedback over the location where some action must be executed.

The overlay mask can be applied over the entire face or on some specific area, such as the mouth or the eyes. The way this overlay must be drawn is indicated by the `reference` field.

(a) (b)

Figure 4. (a) Face powder, associated with the `product-image` field of one of the steps. (b) Overlay sample, which illustrates the application spots for the powder makeup.

Finally, the `offset` field indicates the vertical shift for the overlay in relation to the user face. This field is useful to assist in the proper adjustment for the application position of the overlay image. For instance, if the user has to execute an action in the region immediately below the eyes, this parameter can help to indicate the correct position.

Content creation for the tool can be easily done. The minimum requirement is a simple plain text editor to create XML files, plus a set of graphic images to guide the user. However, this requires the user to know the internal format of the XML tags adopted by our system.

In order to ease content generation, a tutorial editor was implemented in standard Java SE. Hence, it can be executed in a common personal computer running any operating system with a regular Java Virtual Machine. The editor ensures the tutorial files will use the correct internal format, respecting all tags and structure expected by the mobile application.

The usage is very simple. A user creates one tutorial step at a time. It is just a matter of filling all the necessary fields and adding the step to the tutorial, as shown in Fig. 5. After all steps are set, the final tutorial can be created.

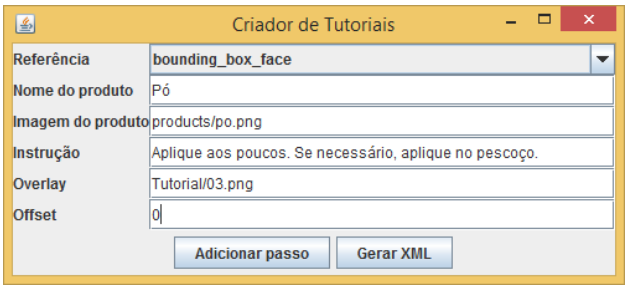


Figure 5. Tutorial content creator.

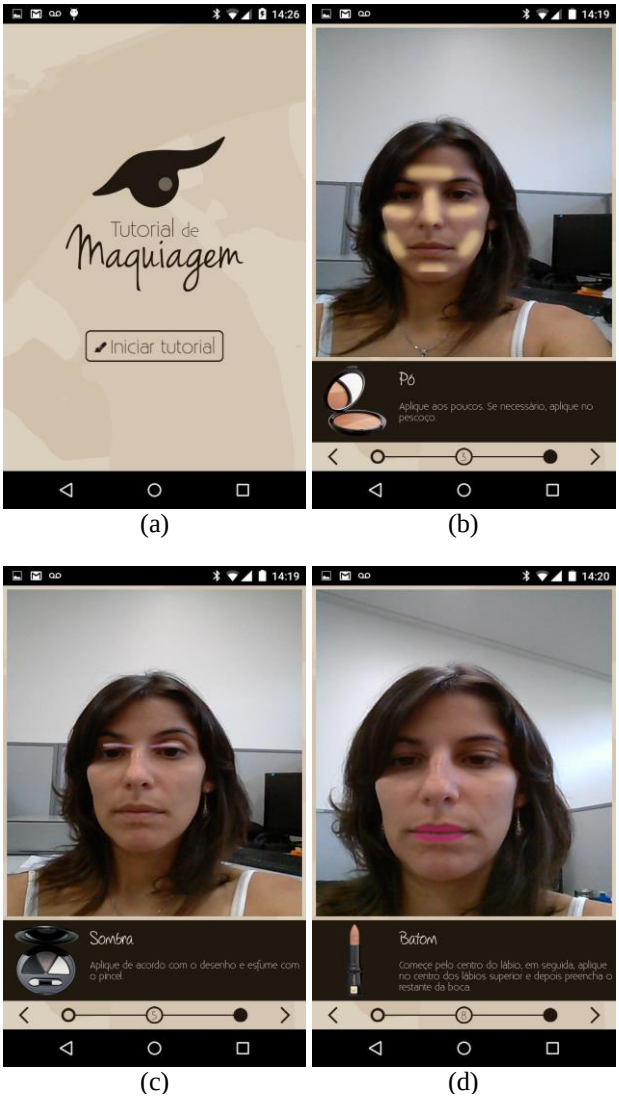
The isolation between the content and the system has all the advantages related to low coupling between modules. The advantages of using a tool to build tutorials in an independent way are:

- It is possible for regular users to create content for the application;
- It is possible to add new tutorials to a mobile device, as needed;
- It allows the tutorials to be modified and updated, without the need to reinstall the mobile application or to update its code;
- It allows modifications and updates for the application, without affecting the content (as long as the XML format does not change);
- There is no need to learn a new technology (or programming) in order to create relevant content for the application.

This last advantage is particularly important for application users, because appropriate content can be created by the users who are experts in the subject. Hence, in order to have high-quality content, it is imperative to ease the creation and update process.

IV. Results

Since Android was chosen as the target platform for the application, the Java language was used. The application is composed by two screens, as shown in Fig. 6.



(a) (b)

(c) (d)

Figure 6. Application screenshots. (a) Initial screen. (b-d) Tutorial screen, displaying three of the steps of the tutorial.

As stated before, the prototype was developed for Snapdragon-powered devices. Specifically, a Google Nexus 5 phone (which contains a Snapdragon 800 processor) was used as a test suite, while a Samsung Galaxy S4 phone (which contains a Snapdragon 600 processor) was used for user validation. Google Nexus 5 has the latest Android version (5.0 - Lollipop) and Samsung Galaxy S4 has the Jelly Bean (4.3) version.

The Android SDK, developed by Google, which contains various APIs for the operating system, was also used. Specifically, the Canvas API was used for the overlay mask superposition. For XML content parsing, the Oracle's SAXParser API was used.

Regarding application performance, the Snapdragon SDK has been optimized on the used devices. Thus, there were little notable performance hiccups, and the facial processing is done efficiently and robustly. The devices with an older processor (200 and 400) show poor performance, in contrast.

A. User Study Description

In order to investigate the potential of the interactive tutorial proposed in this work, a user study was carried out with eight women, aged 19-39 years old, and with varying levels of expertise in makeup usage. The user study proposed aims to delve into how users respond to this new form of interaction with makeup tutorial as well as to compare it with a more traditional one, in this case, the video tutorials available online.

The tests consisted on each participant applying everyday basic makeup following a two minute online tutorial with nine steps, and, in another moment, applying similar makeup using the interactive tutorial proposed.

In the interactive tutorial phase, the user should follow a certain number of steps (close to the number of steps of the video tutorial) also applying everyday makeup on herself. This interactive tutorial had eight steps as listed below:

- Apply the foundation. If necessary, apply also to the neck;
- Apply the concealer only where the correction is needed. Scumble it smoothly;
- Apply lightly the powder. If necessary, apply also to the neck;
- Apply the blush to the cheekbones;
- Apply the eye shadow accordingly to the content shown on the device screen and scumble with a brush;
- Apply the mascara from the root to the end of the eye;
- Apply the eyeliner on the upper eyelid, close to the eyelashes root. Outline the outside of the eyelashes, scumble with a cotton swab and remove any excess;
- Apply the lipstick starting from the center of the upper lip and fill in the rest.

The order of the two test case steps was inverted with half of the users (four of them started with the interactive tutorial) in order to mitigate possible influences of one tutorial on the other.

After undergoing the test case, each participant had to answer a form that consisted on seven affirmative sentences regarding the user experience during the experiment as listed below:

- The video tutorial could be easily followed and understood;
- The interactive tutorial could be easily followed and understood;
- It was spent more time than necessary to watch and execute the video tutorial steps;
- It was spent more time than necessary to watch and execute the interactive tutorial steps;
- I was satisfied with the results of the makeup application after following the video tutorial;
- I was satisfied with the results of the makeup application after following the interactive tutorial;
- The arrangement of the content on my own face facilitated the makeup application.

Participants were expected to state their agreement degree using a Likert scale that ranges from 1 to 5 (1 being "strongly disagree" and 5 "strongly agree") for each statement. Finally, users were required to answer an open question giving their suggestions and criticism about the tutorial developed.

B. User Study Results

The study aimed to analyze three usability criteria regarding the application: easiness of use, expected time taken and user satisfaction. Based on the results shown in Fig. 7, it can be observed that the average score for the interactive tutorial was 4.375, compared to 3.875 of the video version. Only three participants strongly agreed on this statement regarding the video tutorial and one of them strongly disagreed on the easiness of following the video tutorial. Six users agreed (with five agreeing strongly) and two remained indifferent on how easy the interactive tutorial was to follow and understand.

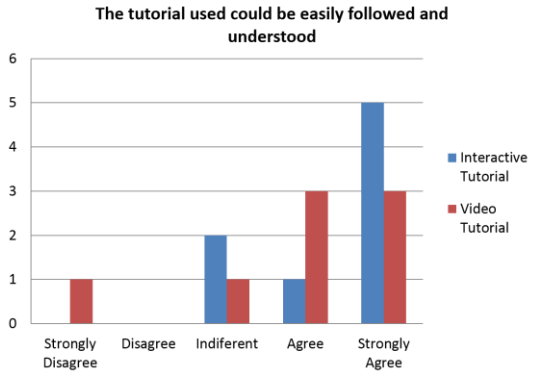


Figure 7. Comparison of easiness of use between the interactive and video tutorial.

Regarding the time spent to execute the steps, the results are shown in Fig. 8. Users disagreed that they spent more time than expected to watch and execute the steps in the interactive tutorial; only one user remained indifferent. The average score was 1.625. In the video tutorial, the average score was 3.25. Most users were neutral; this could be due to the fact that they are possibly more used to video tutorials.

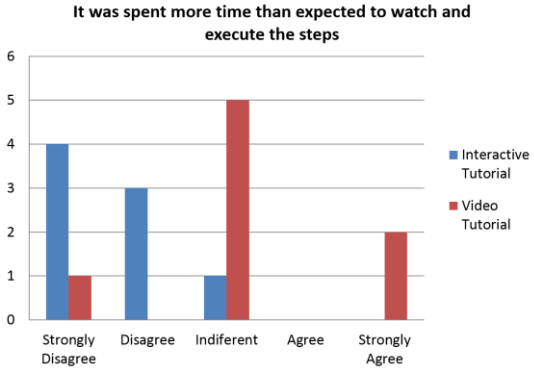


Figure 8. Comparison of expected time spent between the interactive and video tutorial.

Regarding user satisfaction with the results of the makeup tutorials, Fig. 9 shows that the reaction was largely positive for both versions. One user strongly disagreed with the feeling of satisfaction the video tutorial results offered. Six out of eight women agreed with the interactive tutorial results, with the average score being 4.25, while four out of eight agreed with the video tutorial results, the average being 3.5.

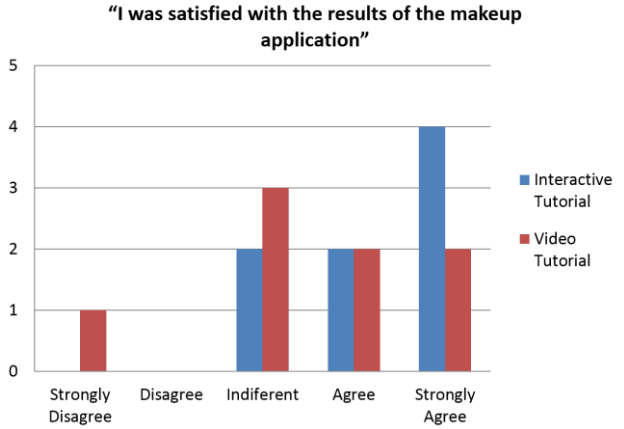


Figure 9. Comparison of the feeling of satisfaction with the results of the applied makeup between the interactive and video tutorial.

Finally, it was analyzed if the content displayed by the interactive application facilitated the makeup application process, as shown in Fig. 10. While one user disagreeing strongly and saying that the positioning of the content was exaggerated and unrealistic, the average score this question obtained was 3.875, which indicates that most of the users agreed that the arrangement was sufficiently clear to ease the makeup application aided by the interactive tutorial.

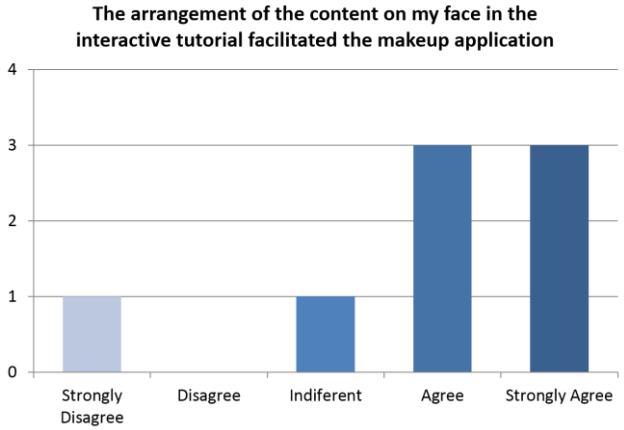


Figure 10. Analysis of the interactive tutorial's effectiveness on the makeup's application.

From the comments and suggestions, it was perceived that some of the instructions were unclear. While the area to apply the makeup was easy to understand, it was not clear which specific motions users had to execute, as it varies from product to product. This can be improved with more specific text instructions.

Users also felt that more makeup products are needed, as their usages are often not easy enough to understand. Other comments mentioned that more makeup styles would be interesting to learn. To address these needs, other tutorials can be designed in order to help users to learn how to use other products or how to create new makeup styles.

Given the fact that both the interactive application and its tutorial content were prototypes, the overall results were very encouraging, especially when considering that the application was compared to a professional makeup training video.

V. Conclusions and Future Works

This work proposed an interactive form of makeup tutorial through AR in order to help the user and teach new styles of makeup.

The data obtained in the user study showed that the system is in fact useful for what it is proposed. Most of the users that experimented the interactive tutorial agreed, in some level, that the process of applying makeup was easier with the assistance of AR.

Regarding the total time for the makeup application process, most users needed less time than they expected when following the interactive tutorial. Conversely, it is interesting to notice that when using the video version, few users needed less time than expected. Hence, considering users' perception, these data suggest that the interactive tutorial is helpful to speed up the makeup application.

As future work, taking into account face orientation when gathering tracking data and using more face landmarks for other types of overlays would improve system effectiveness. Also, improving the precision when matching the person's face and the overlays is important for some types of overlay – for example, the images are often poorly superimposed in the eyes region. Another improvement is to try to detect skin tone [23], in order to be able to suggest products and tutorials specifically tailored to the physical characteristics of the user. In order to support such suggestions in the tutorial, it is also necessary to improve the file format, by adding information about skin tone description. The tutorial editor can also be changed accordingly to allow the edition of skin tone data.

Another addition would be displaying animations over the user's face that illustrate a specific method of applying the makeup in the current step.

Finally, it may be interesting to execute another experiment with more tutorials and a larger set of users, and to allow them to use the content creation tool to produce the tutorials. This may allow to better understanding the potential strengths and weaknesses of the system.

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