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"New 3D detection algorithms using the last generation fringe projection scanner: A novel full face wrinkle depth classification and distribution index for ageing evaluation."

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1. Introduction

Facial perception is one of the most important functions used by humans to socialize and adapt. This ability has specific pathways in the brain, and it looks to be already present in newborns despite his limited eyesight [1,2]. In fact, humans can be considered experts in processing faces.

As humans, we use this ability to recognize gender, race, emotions, speech, and age and it is so specific that the recognition performance drops disproportionately when an inverted face is presented [2]. Based on skin facial topography, our human brain is able to estimate the age of a subject simply by looking at a face. The human brain can recognize the appearance of wrinkles (although we do not exactly need to count them), the texture homogeneity (although we do not need to touch it), the depth of the wrinkles (although we will not measure them), the color aspects of the skin (although we do not need to measure it precisely) and of course the laxity or lack of firmness or elasticity of the skin, particularly when we perform movements.

Several previous works proposed that the impression of the face could be a biomarker for ageing [1], and others proposed that the aged aspect specifically if it looks older than the true age is associated with an increased mortality [3]. Therefore, the youthful aspect of the face is a relevant health and wellbeing parameter and a target for cosmetic products that aim to improve its aspect.

From the attributes that can be modified, the facial topography is one of the most important that occurs with ageing. As face is a highly exposed part of skin it makes extrinsic ageing occur faster than other body parts. This effect has an impact on how humans interact with each other and how they can subjectively calculate the age of their counterpart.

Several methods exist to evaluate facial topography, from contact methods such as skin replicas, to several 3D scanners based on fringe projection technology [4]. The latest progress in fringe projection technology opens the possibility to acquire full-face images with such performance and resolution that fine lines, wrinkles and folds can be measured at the same time with one single acquisition. However, new sensitive algorithms must be used to create new parameters that focus on the full-face evaluation instead of only specific areas.

The aim of this study was to define these new analysis algorithms and parameters obtained through the analysis of faces, acquired from an advanced stereo fringes projection images and compare them with the age range of adult subjects.

2. Materials and Methods

A group of 150 women with ages ranging from 18 to 75 years old and phototypes ranging from II to IV, gave their informed written consent to participate in this study. All the subjects follow the standard procedures of PhD Trials® clinical evaluation, and the study had the approval of an Independent Ethical Committee and the approval of the Portuguese Medicines Authority, Infarmed IP (RNEC nº:635477).
In order to evaluate the performance of the analysis algorithm we defined six age ranges. The distribution of subjects through the age range was as follows:

Group 1: 18 to 24 years old, 25 subjects (mean age: 21,7 y.old)
Group 2: 25 to 34 years old, 25 subjects (mean age: 29,5 y.old)
Group 3: 35 to 44 years old, 25 subjects (mean age: 39,2 y.old)
Group 4: 45 to 54 years old, 25 subjects (mean age: 48,4 y.old)
Group 5: 55 to 64 years old, 25 subjects (mean age: 59,5 y.old)
Group 6: 65 to 75 years old, 25 subjects (mean age: 69,7 y.old)

Facial acquisitions were performed using a 3D stereo fringe projection scanner (AEVA-HE[2], Eotech, France) installed on the new semi-automatic bench VISIOTOP, with the Large (250) field of view. The acquisition protocol was standardized to be similar to all the subjects. To reduce facial variability other than age, several non-inclusion criteria were respected namely the BMI lower than 30, absence of any particular pathology with influence on facial skin and absence of any cosmetic product 7 days before the measurement and absence of any aesthetic procedure on the face. The 3D data was acquired with high resolution and specific areas were analyzed and correlated with the full-face detection algorithm. Analysis was performed on the selected areas and was compared to the full-face analysis within each age range to show the evolution of fine lines and wrinkles over age. The specific areas selected on the face were the forehead, the crow's feet, the cheekbones, the eyelids, the undereye, the cheeks, the nasolabial and the peri-oral. The full-face analysis covers all these regions of interest.

A new algorithm has been developed to detect and classify all these lines according to their depth, and therefore to be able to see the change before and after an anti-ageing cosmetic product application. The new algorithm was based on a progressive (multiple) deviation analysis which reveals features depth followed by image segmentation to detect the features inside a depth range. The features analysis was limited to three main class ranges as follows (table 1). A new index was also created by dividing the features of each class to the total density.

Table 1. Class distribution of features

Class 1	Class 2	Class 3
Skin texture and fine lines	Mid-range wrinkles (similar to the crow's feet ones)	Deep wrinkles or folds (similar to Nasolabial fold)

A previous algorithm was already developed, but no correlation with the depth measured on the extracted areas could be made, which leaves the ranges of the different classes at the discretion of the users.

The new algorithm uses an intelligent and smart filter where the maximum deviation in Z (cordal deviation) is strictly limited to a given value. This allows to filter the original data until the maximum deviation is reached. For each class, the original data is therefore filtered to the lowest value of the class (100 µm for class 1, 200 µm for class 2 and 600 µm for class 3). The filtered data is compared to the original, and a depth segmentation using the class range is used to detect the features (25 to 100 µm for class1, 100 to 200 µm for class 2 and 200 to 500 µm for class 3).
Data preparation consists to remove from the analysis, region which may create bias to the detection of the feature like eyebrows, skin hairs, lips center line, philtrum and lips to cheek line.

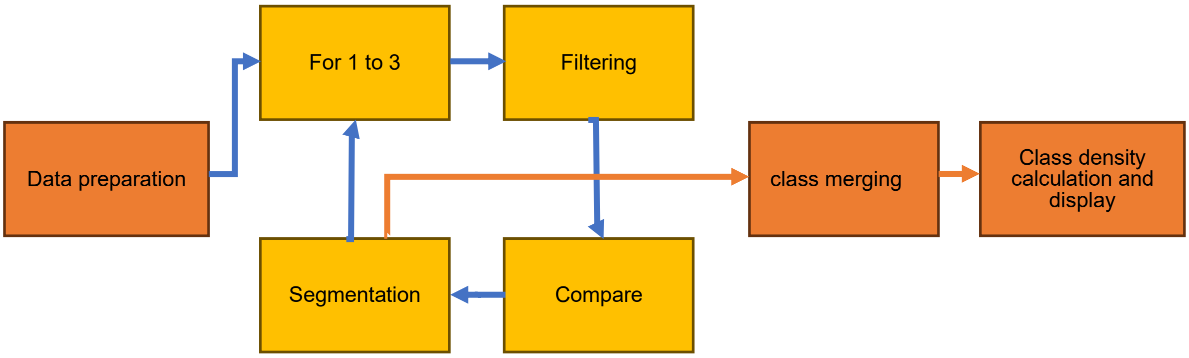


Figure 1. Flow process of the full face detection algorithm

Statistical analysis of the results was performed by using nonparametric statistical tests (paired or non-paired). SPSS 23 (IBM) was used for all the statistical analysis and 95% significance level was adopted.

3. Results

Figure 1 shows the evolution of features density by evaluation area. The main results show that features density of Class 1 is increasing linearly with age, while in Class 2 there is a high increase in the features density after group IV of the class range (after 54 years old), except for eyelid densities, where the increase starts much earlier, after group III (after 34 years old). For Class III this evolution follows a similar pattern, with a high increase in the features density in the group V and VI of age ranges, except for the eyelid features densities, where the changes start again much earlier (again after 34 years old).

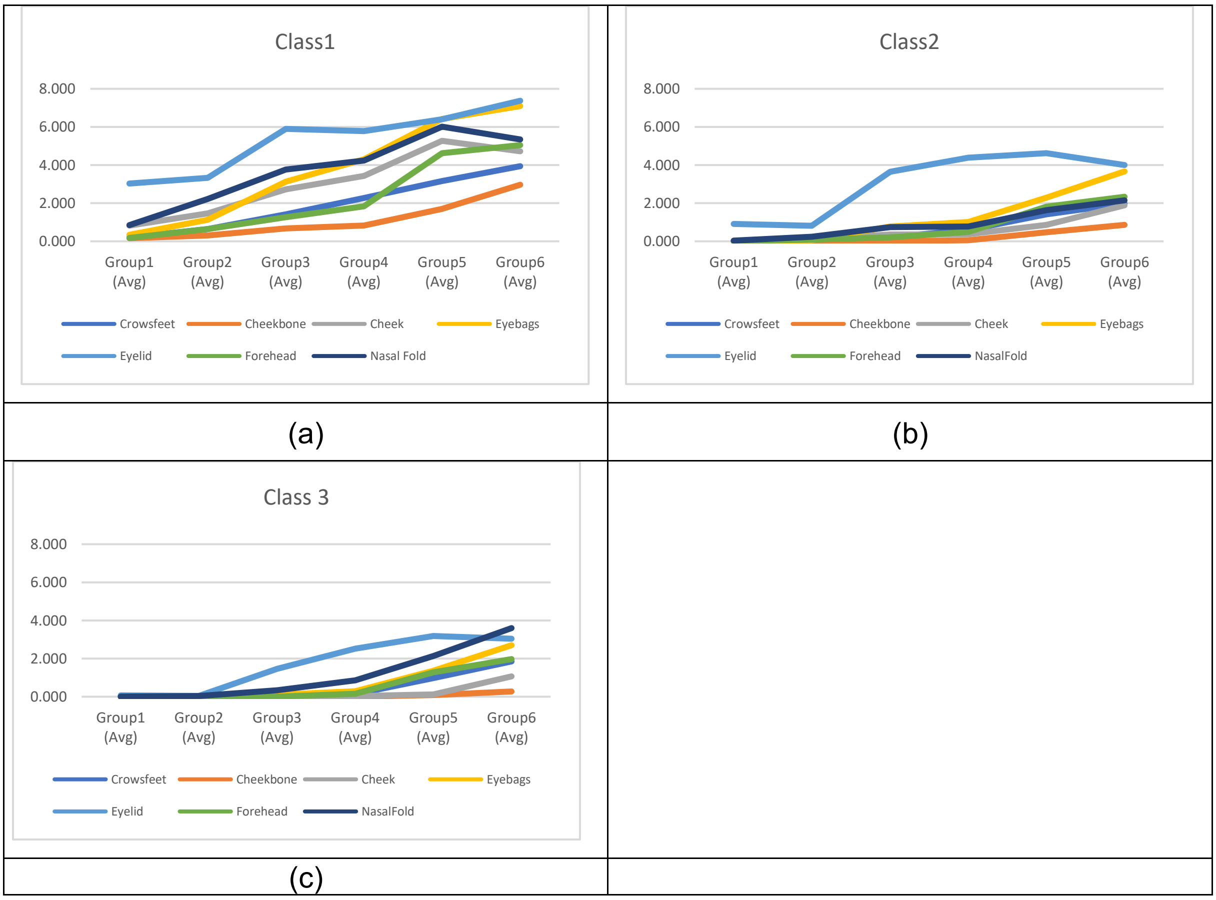
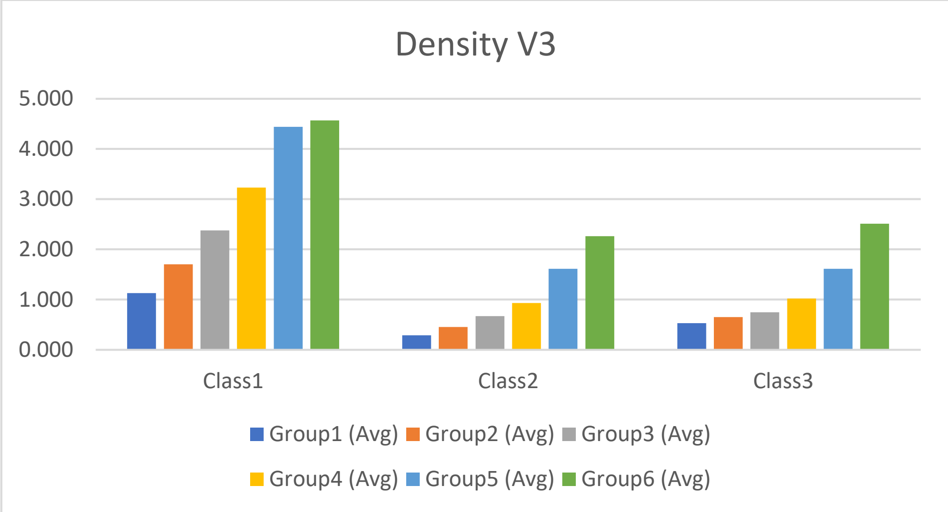
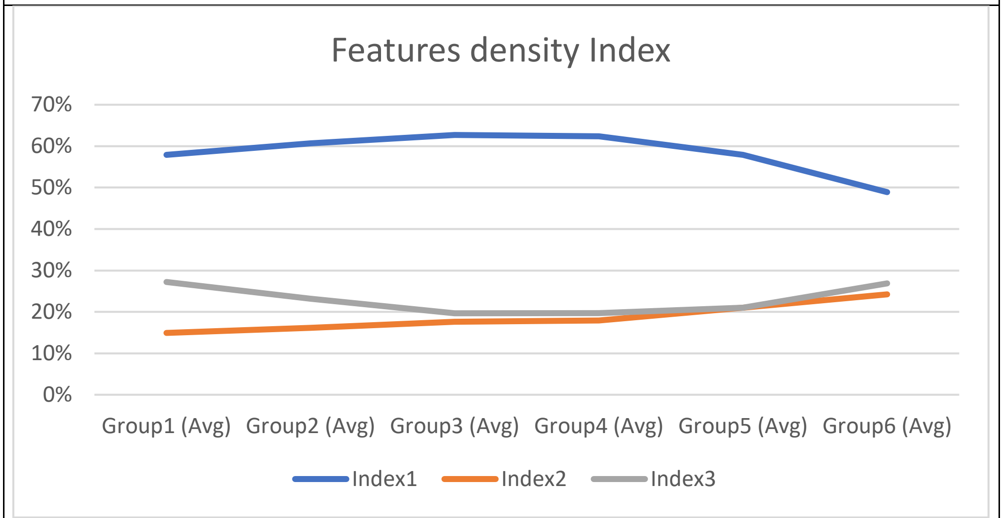


Figure 1. features density by area. a) Densities of texture and fine lines; b) Densities of wrinkles; c) Densities of folds

When applying the full-face detection algorithm to the 3D data we observe a linear statistically significant increase of the features density for the Class I features, except for the increase between the groups V and VI. For class II and III the increase occurs mainly after group ages IV (Figure 2 a). The new index obtained by using the ratio of each individual class density over the total density is more sensitive and relevant to ageing effects distribution on the face (figure 2b). It will also be more pertinent to evaluate anti-ageing product efficacy. The facial algorithm also provides qualitative images to illustrate this distribution of feature classes (Figure 3).

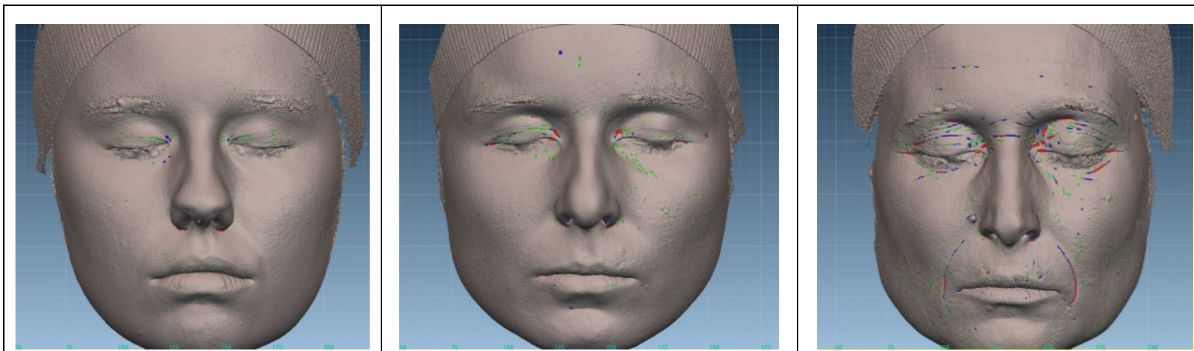


(a)

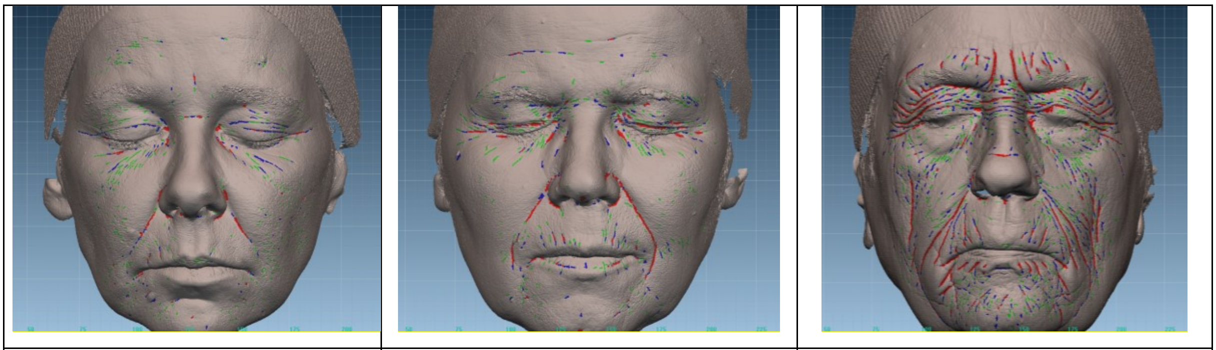


(b)

Figure 2. A) Full face density distributed by class; B) New features density index



(a)	(b)	(c)



(d)	(e)	(f)

Figure 3. Examples of the full face detection algorithm by age group: a) Group I; b) Group II; c) Group III; d) Group IV; e) Group V; f) Group VI. Line color represents the classes: Blue: Class 1; Green: Class II; Red: Class 3

4. Discussion

The new algorithm uses a progressive and controlled reference for each of the classes obtained and is applicable on full resolution 3D data (FULL) which has more detailed features.

The reference used for class 3 does not avoid acute shape area detection which is accentuated by 3D model resolution, but noise and hairy areas are removed from detection more effectively, this way increasing the detection capacity of the algorithm. The procedure is optimized for a full 3D model and takes less than 3 minutes to perform, a significant time reduction than other tested algorithms, which need almost 10 minutes to compute in the same conditions.

We observe that in the full-face detection algorithm there is no mixing of classes on a wrinkle object except if the class can change along the same ride according to its local depth. The algorithm works on a complete face as well as on a topography.

The detected depths correspond to the data of the object detection on the topographies. They also correspond between the detection on the face and the topography of the local area.

The detection sensitivity is much better because it is targeted on classes, especially on class I, which must only represent fine lines.

In terms of skin topography changes over age, it is interesting to see that, although there is an expected increase in features after 54 years old, there is already a significant change after 34 years old on the eyelid area, probably due to skin characteristics as this can be a more exposed and less protected area. These results show that anti-ageing products should target the eyelids much earlier than general anti-ageing skin care products, to prevent the appearance of changes in this area.

5. Conclusion

The new detection algorithm responds well in terms of sensitivity and relevance to demonstrate the analysis of wrinkles classes on the whole face according to age. The objective was to show that this analysis will make it possible to objectify the effectiveness of anti-aging products or treatments. The new class indices will allow us to see the transfer of wrinkle objects to lower classes that can rejuvenate the skin. Finally, an interesting conclusion is that anti-ageing products targeting eyelid area should be started much earlier than general anti-ageing skincare products.

6) References

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