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New Strategy for Comprehending the Significance of 3D Characteristics of Fingerprint, Correlation with 2D Model and Bridging in Between

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Abstract: ***Our goal in this research is to demonstrate the bold outlines of our contemporary approach to the fingerprint. This approach includes multiple steps that require further refinement and investigation. We have come to the conclusion that the importance of 3D modeling of the fingerprint is perquisite to understand how the fingerprint is generated and could open a new frontier in forensic science.***

Keywords: Forensic medicine, digital imprint, 3D models, Photoshop, CSIpix® Software, 3D scanning

1. Introduction

Forensic medicine plays a crucial part in the justice process and low empowerment [1]. Identification of the fingerprint remains the cornerstone process in the major disciplines of forensic science. Many methods have been used to document this piece of evidence [2]. Digital acquisition had been developed to produce better results than the classic ways. In the new methods direct acquisition of the fingerprint is done via specialized sensors or cameras. Nevertheless, some of these processes still includes the traditional method [3].

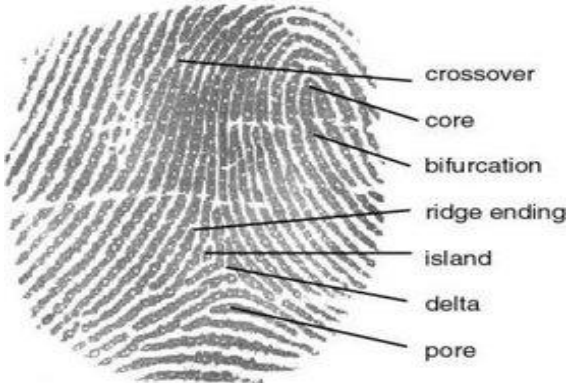


Figure 1: Main features of the fingerprint

Direct digital methods utilizing digital sensors is a part of a system that requires resources which are not always available. One of the important drawbacks of these systems is the need for specialized team for maintaining and operating such framework. The input and output of these systems are mostly difficult to manipulate outside the system as it is in most cases trade secrets. The sensor itself had limited data capturing capacity as well as its software in its abilities to modify or manipulate the acquired images. [4]

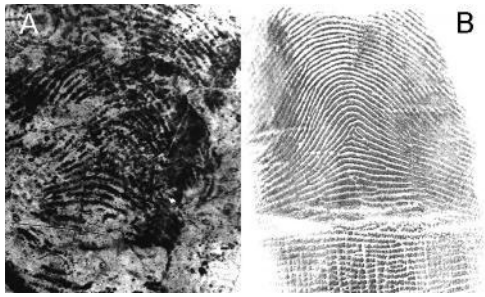


Figure 2: The fingerprint in reality might be very difficult to be correlated to a closer one in the database.

Traditional imprint acquisition is simply a messy process with problems of archiving and data transfer. We here present a very simple alternative method with very robust equipment, both software and hardware with extremely ease of use and very appealing and simple learning curvature. The equipment is plug and plays without need to use any additional human resources. One of these methods includes pressing finger on a flat surface other include direct photo capturing. One of the main advantages of phone photo capturing is the ability to capture undistributed finger geometry [5].

Other works herethat we are presenting provide a glance of how the finger is producing the imprint when pressed against a surface.

2. Methods and discussions

2.1 Comparison between different 2d capturing methods

We used these tools to capture 2d fingerprint.

- Scanner in the all-in-one printer Epson model (WF-C5710) to capture the fingerprint.

Figure 3: The used scanner is built in with this printer.

This device is very productive with nearly zero maintenance need, with easy to set up device processes. It prints at relatively excellent speed. It had direct and indirect WI-FI capability making it suitable for multiple users to use it at the same time.

Another method was capturing the fingerprint using an android phone (Redmi Note 10 5G) by simple application colored powder applied to the fingerprint area then use this phone to capture the photo.

Many trials had been attempted to get the best results, one of them we had tried another way by rubbing the finger with black powder that filled the furrows between the ridges of the fingerprint.

Figure 4: The camera is 48 MP, f/1.8, 26mm (wide), 1/2.0", 0.8µm, PDAF.

In both the cases, either using scanner or the android camera, manytrials had been tried to get the best results in comparison to the next mostly used way.

- Classic method of fingerprint acquisition had been made, then the results had peen digitized.

The three results had been compared using photoshop 2022 edition and specialized software for fingerprint comparison.

Figure 5: The used commercial software

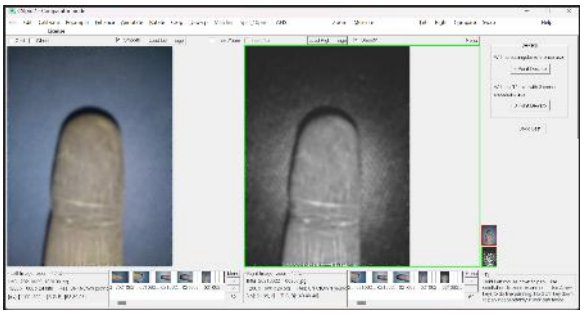


Figure 6: The used specialized software

Editing of the photos inside photoshop is not comparable in any way to specialized software in term of ease simplicity and maneuverability.

Manipulation of the photo via transform command inside of photoshop provides extremely powerful manipulation of the photo and correction of any deformity suspected which could be aided by using calibrated frame.

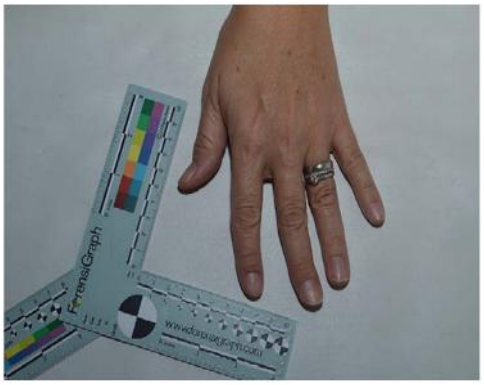


Figure 7: Forensic scale

Telescopic lenses are advisable forensic sciences due to their ability to limit the distortion of scale in relative to the image depth. The frame is needed only in the case of phone photo capturing, although we had not done it, but it is a prerequisite in forensic despite as its wo standardize the process. Capability of coloring of the layers will add very useful visual aid. Adaptability to multiple screens is very advanced in photoshop so that the user can enlarge the workspace.Intuitive GUI and keyboard shortcuts are very useful.

Layer transparency and masking could facilitate matching by superimposition of each layer over the other

method.Aiding tags could be highly customized to indicate matched fingerprint elements over the two photos. We compared photoshop 2023 edition and cis pix, which is a specialized tool for crime scene fingerprint comparison. The first method involved 2 fingers imprinted taken at different occasions.

The finger imprint was taken in the same methods used at the court evidence collection before jurisdiction then scanned.

The new algorithm includes.

- Direct scanning of the whole palm is put on the glass part of the scanner.
- The scanning software allows customization of the scanning protocol which aids in giving consistent results across all cases.The details scanned by the scanner are fascinating with the capacity of capturing color, and with calibration is possible the skin tone could be used further to define more criteria of differentiation between what seems close imprint. We suggest putting a piece of non-reflective black clothes over the scanner or making the room dark to get better colors.
- The capturing ability of the scanners not just the flat part of the finger or palm but with the edges also (scanner had the ability to capture the object although it is not in direct contact with scanning glass).
- The better results yielded from the scanner when accompanied with the easy to be manipulated correction tools of the photoshop with easy-to-use interface enable the user to bring better result to reality in lesstime.
- No need to do paperwork, as all the process is digital.
- Archiving is very practical.
- Any error or suboptimal results could be corrected immediately.

Figure 8: This photo taken by the android phone (price about 350$) had been photoshopped. Although the periphery of the imprint is not clear but the inside seems to be clear

Figure 9: This is the previous photo but had not been manipulated by photoshop and the quality of picture is not the same as that acquired by the scanner but still give better features than the classic method.

Figure 10: This figure and next three photos show the best used setting for exporting from Photoshop and the resultant file size. These photos are taken by the scanner where give very fine details even pores had been captured. This is the original photo with best setting.

Figure 11: The JPEG compression method due to having multiple colors have largest size relatively.

Figure 12: The GIF and PNG extensions are closer to each other due to less color carried within the image. Although in case PNG richer information could be held

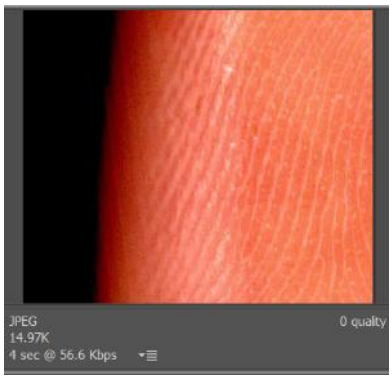


Figure 13: The JPEG compression method had the lowest resolution although it retains good number of details due to the marked contrast between different element of the fingerprint photo.

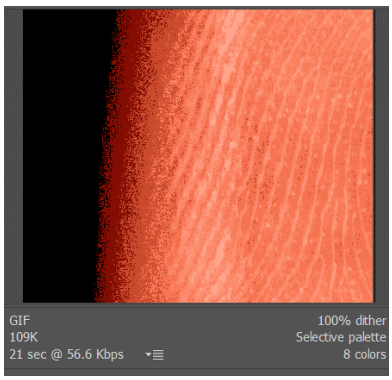


Figure 14: The GIF compression method, although had not yielded better compression, hasn't provided any better reduction in the size.

Figure 15: This had been told with the GIF method give low qualities

All these photos give an impression about achieving and how the changing of the file setting to reduce the size will affect the resultant quality.

Figure 16: Original B/W scanner. It gives less information about details

Each color had3 values

- Hue
- Saturation
- brightness

Neglecting the hue could make 2 colors similar so B/W scanning is contraindicated.

Figure 17: This is a B/W scanner modified by Photoshop.

It clearly shows the importance of the color to aid the researcher to delineate the parts of the imprint. Modern AI could be used to do such a job.

Figure 18: Original colored photo from the scanner

The details are fascinating and multiple colors will aid in differentiation between different fingerprint parts. The blanching of some regions is clear which should be correlated to mechanicalproperties of different finger tissues. The response is not the same in all regions.

Figure 19: Photoshopped color scanned fingerprint where details had been enhanced clearly.

Figure 20: This is a maximum possible enlargement of part of the scanned fingerprint showing the great intricate details and how the pore is clearly seen.

The compressed ridges closer to the center which is toward the lower right corner are shown which easily differentiated from the uncompressed closer to the periphery.

Figure 21: Skin creases are clearly shown, only an expensive prestigious camera with macro lens and best lighting could give these results. The used method could be said to substitute this equipment.

Although calibration of the colors inside the scanner has not been investigated but it is prudent to consider. Colors identification will empower fingerprint identification further any new horizon could be scoped. Skin tone is one of the physical characteristics that can be measured and approached parametrically.

The background with the scanning could be uniform or evenone could turn the light off and make a very dark room at the time of the scanning as the scanner closing cover is designed to receive papers this that to preclude its full closure. This will make the process more consistent and color casting from environment could lead to different color representation.

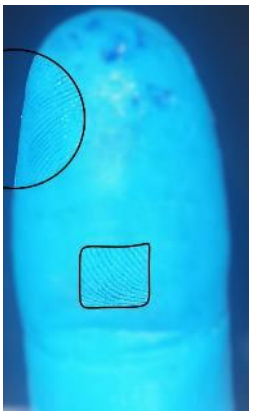


Figure 22: This a photo of the silicone replica of the fingertip with clear representation of different region especially ridges and furrows of the skin

This model was used to simulate fingerprint taking by the classical method that includes stamping.The mold making method if the used material had lower viscosity will produce sharper details with less distortion of the finger tissues.

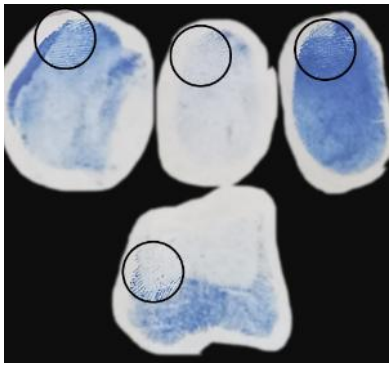


Figure 23: The upper three photos for the real fingerprint for the same finger show clearly the variability between different trials.

Skin surface energy is very complex andneeds more experimentationand is totallyout of the scope of this paper. In contrast to this method of fingerprint capturing, we had many trails using the desktopscanner, all of them are consistent in quality.

The single photo in the lower part showsa print taken using the silicone replica by rolling method. Direct pressing method is notapplicable due to the total stiffness of the material, but softer materials could be tried. Silicone which is used to make this model is hydrophobic material that repels the water-based ink, nevertheless this replica yielded sharper results in the classical fingerprint taking. Different materials could be tried to simulate real skin.

2.1 Comparison between 3D capturing methods

In order to understand the 2D fingerprint, we should have comprehensive knowledge of the 3D fingerprint [6]. Our current part of our work is to provide the best way to acquire the 3D model and build a road map to study the dynamic fingerprint [7].

The fingerprint, especially latent, ranges from ideal condition where it was taken in a good condition at court or an equivalent print in case of crime scene where the condition is suboptimal and only part of the evidence is available and critical decision is to be taken based on this piece of evidence. Our study of fingertip distortion includes the simple case, while we might study other conditions where the finger is pressing against a non-flat surface, or the finger contacts the rigid surface in motion or at the periphery not in the center. Direct 3D scanning had been done which was regarded as the benchmark of our 3D fingerprint work when the finger is not distorted.

The capability of 3d scanner to capture the color will add additional differentiation ability, and colored 3D model could be obtained but we didn't get it.

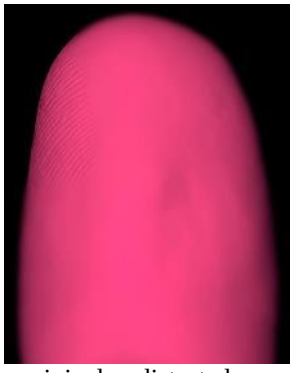


Figure 24: The original undistorted scanned fingerprint

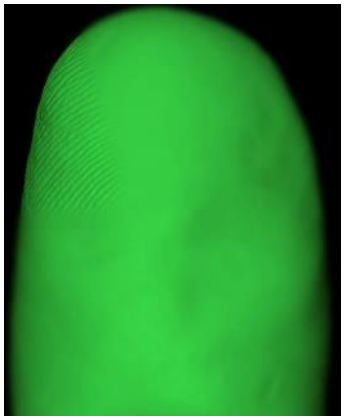


Figure 25: The scanned cast fingers

We had her effect of 3D distortion from the impression and casting. The cast is most probably capable of highly accurately representing the -ve impression, but to which extent the impression itself will represent the real model is a questionable matter. This mostly depends upon the fluidity or viscosity of the impression material.

The deformation of the fingertip after any procedure should be taken into consideration. The soft tissue deformation needs to be volumetrically correlated.

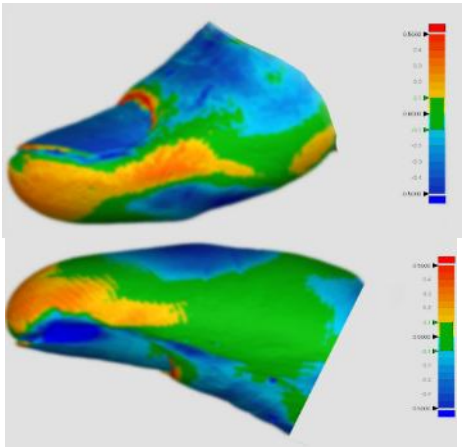


Figure 26: CAQ is a crucial process that is used to ascertain the comparison process

The duplicating material used clearly resulted in some sort of distortion. Are the finger pad had fixed shape or even could had diurnal cycle should be investigated deeply.We had applied skin safe silicone molding material to make a live impression and used a fine grade high strength plaster of

Paris material to cast the original replica. This replica had been scanned and a digital copy also obtained.

The next photos represent how we could make photos from the 3D model to simulate camera capturing.In the case of software photo capturing, we had the model of the camera orientation and the intrinsic criteria of the camera which could be selected to simulate the same real camera for better parametric comparison.

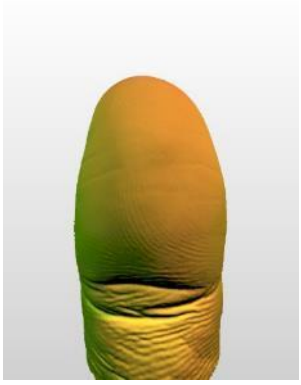


Figure 27: Focal length 10 distance from camera 10

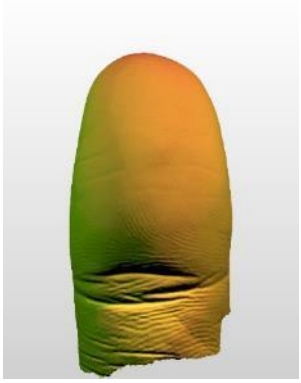


Figure 28: Focal length 50 distance from camera 100.

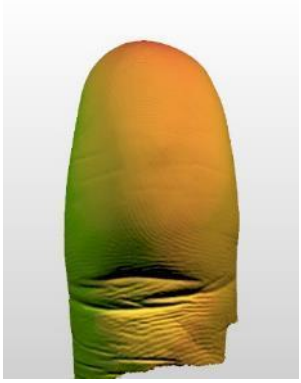


Figure 29: Focal length 100 distance from camera 200

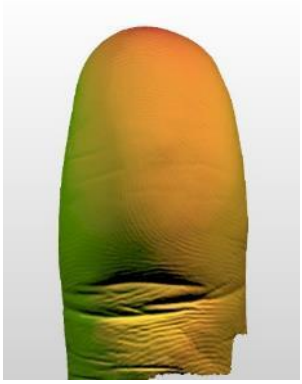


Figure 30: Parallel view distance 100 from camera

2.2 Presenting introductory model of the 3D fingertip distortion due to pressure on flat surface

For the first time we introduce 3D virtual fingertip FEM related to forensic sciences. This model was based upon the real model geometry [8].

In order to get the fingerprint in case of distortion due to compression on a flat surface to get the imprint, which is done in what we called classic method, we had to brush the finger with silicone molding material and take the impression while the material was still soft, we compressed a flat surface. We got the negative copy. Then we get the positive distorted 3d copy by using the special plaster of Paris for casting. This distorted cast finger had been 3D scanned. Another model was taken from the undistorted original 3D scanned model.

The finding with this method was:

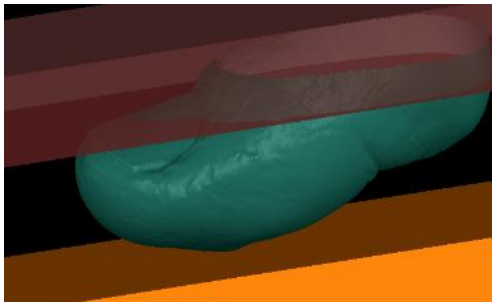


Figure 31: This is the best 3D arrangement we suggested to be used in fingerprint simulation.

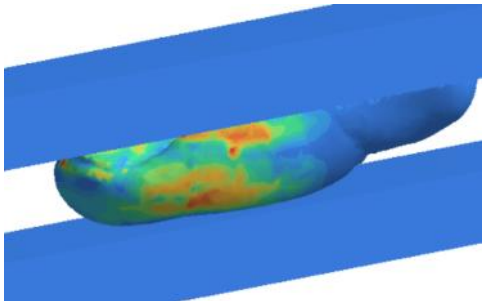


Figure 32: This is the resultant strain of the fingerprint of the FEM

In the virtual arrangement we had suggested pushing the finger pad by the lower flat surface, which is supported by another surface integrated with the material of the finger

itself. This is a hollow model. The effect of the distal phalangeal bone on the FEM had been neglected. Although it had great anatomical impact on the function the replica validation is chosen according to the final deformation not by just trying to represent the same anatomical elements. Finite element models should be assumed as well as scrutinized carefully.

Our model is based on a real model not engineering closed shape and the resultant shape was compared to the real distorted model, where we returned and refined and redefined the input virtual model to get virtual output as close as possible to the distorted physical model.

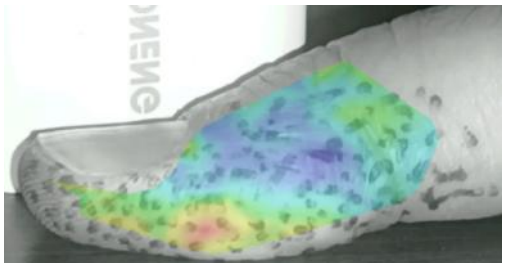


Figure 33: This is the resultant strain of the real model

The proximity of the real model to the FEM could represent a validation method. And in our experiment, we could say we had reached a good agreement between the 2 models.

2.3 Both distorted 3D models (physical and virtual) had been compared to each other to verify the numerical simulation

In order to provide insight into the fingerprint we need to get another model to be used in physical experimentation. We had used non silicone molding material (alginate) and then poured the negative impression with the low-densitysoft silicone material [9]. We had taken a fingerprint by this method and compared it to the previous three models.

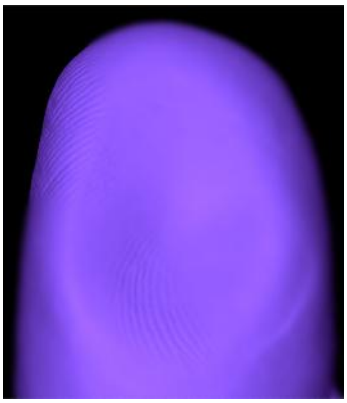


Figure 34: The distorted real model, the parts of the imprint is clear and central Invagination or concavity due to the effect of the impression material is clear.

In all the next photos we had blurred the imprint due to many issues and according to the interest of the person whom his imprint was studied

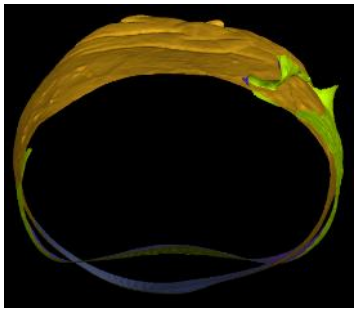


Figure 35: Cross section of superimposition of the models (deformed and original undistorted finger).

This indicates the complex deformation of the finger pad to pressure. The response could be authentic which could be essential in gripping. This could enlighten the response of the palm of the foot to the pressure.

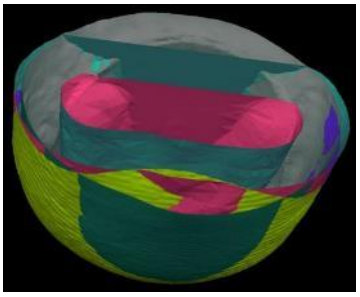


Figure 36: Superimposing of the three models

This represents cross section through the three models [10].

- Original undistorted model (green)
- Real distorted model (yellow)
- FEM represent the distortion after application of pressure from flat surface.

The cad model was representedby a solidcontinuous model first. This had produced results that are highly unrealistic according to the author's opinion. Wehad chosen to represent it by a hollowed model due to more appropriate and closer results to the real model. A finger pad is not a simple compressible tissue but a very complex associated with very complex neurosensory feedback.

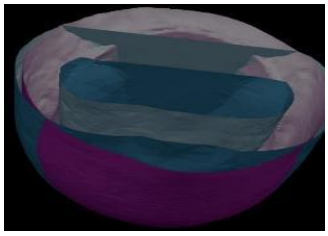


Figure 37: This is cross section through the original and FEM

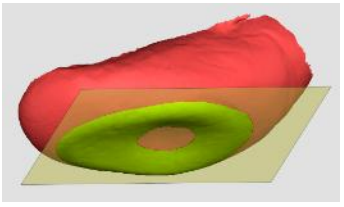


Figure 38: The concept of the fingerprint plane should be defined well.

This region should be defined well and related to the original undistorted fingerprint as well as to the fingertip to understand the most important part of the tissues that needed to be studied and the tissue is deforming.

This region should be taken seriously to further discern the mechanism of final fingerprint formation and all our work is to reach a concept that how this region is being generated during pressing of the finger against a surface. This is the most important part of our work, and all next works should be culminated in perfection of this step. This concavity is clear, although it was caused by what could be regarded as entrapment of the impression material that had not escaped from at the periphery. This unique ability of fingertip to attain this shape shows the underlying extremely complex mechanical properties.

2.4 Importanceof vectorization of 2D and 3D graphics

In case of 2D and 3D graphics we had two drawing categories [11]:

- pixel based drawing in case of 2D and point based in case 3D.
- vector based 2d drawings and surface like nurbs in case of 3D.

Figure 39: Part of the 3D fingerprint to be vectorized.

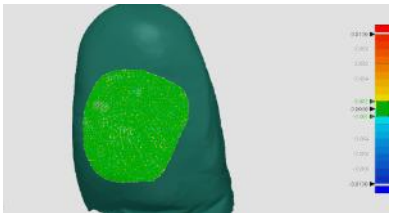


Figure 40: The resultant surface and the mesh surface are very close to each other.

Figure 41: The mesh is like pixels-based photos.

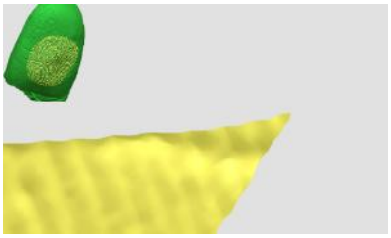


Figure 42: Surface which is higher in size but very smooth and will not be affected by manipulation, as it is vector based.

Figure 43: Surface over the mesh

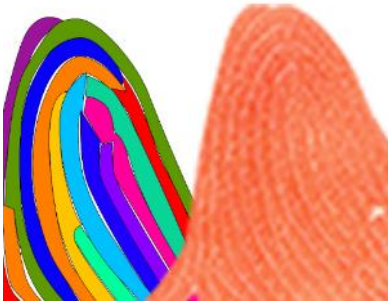


Figure 44: This is clear compression between the realtor and vector image.

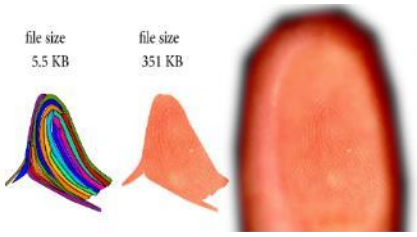


Figure 45: Size comparison indicating clear superiority of the vector.

Figure 46This is the splines the represents the summit of the ridges.

Figure 47: This is the splines the represents the summit of the ridges.

Figure 48: This is just to show the clarity of the 3D vector for the imprint.

The size of the curves file is 392 KB while original file 3D file is about 10 MB for the same model. The 3Dsplines could be meshed as well as meshes could yield 3D splines, but most times this process is manually done.

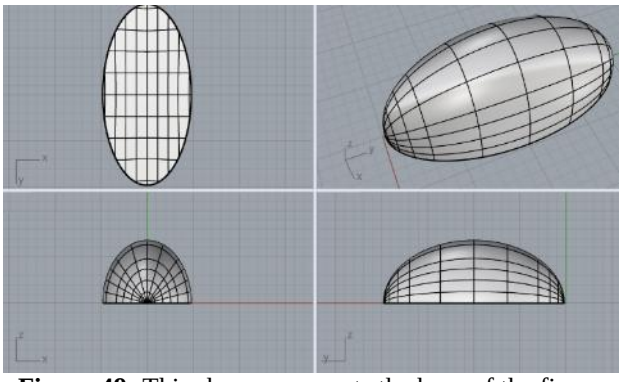
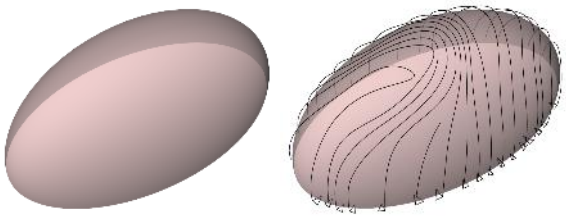
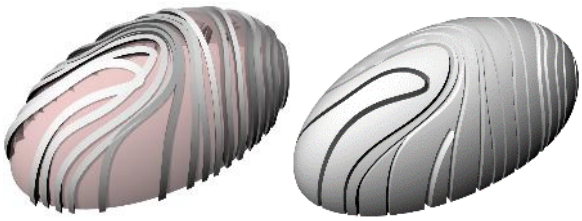


Figure 49: This shape represents the base of the finger before making the furrows like grooves

The shape is epsoloid and the grid in the background show clearly the dimensions.



These curves clearly show the paths that will harbor the future furrows. The lower triangles will represent the cross section of the furrows, and both could be controlled parametrically.



This is a true parametric fingerprint model as all its elements could be modified according to.

3. Conclusion

Now we had these types of fingerprints to be analyzed.

1) Scanned by desktop scanner (distorted)
2) Photographed undistorted fingerprint by camera
3) Finger print we had taken by silicone replica classic, and photo captured by camera.
4) Fingerprint taken by classic method
5) In software photo capturing of the 3d scanned undistorted finer and comparison with the photo taken for the real fingerprint (in point 2)
6) In software photo capturing of the 3d canned distorted fingerprints and compare it to that taken by desktop scanner (in the point 1)

In this paper, we presented these topics and showed our work. Our 2D and 3Dmodels showed clearly:

1) Importance of photo capturing (camera and scanner) against traditional fingerprint acquisition
2) 3d fingerprint acquisition method and comparison between the two methods, direct scanning, and scan of the casted replica of the finger
3) 3d acquisition of the Deformation of the fingerprint
4) Providence of the fingerprint physical model
5) Virtual model deformation (numerical simulation with calculations of Strain of the physical model and virtual model
6) importance of verification to make the virtual model correspondent to the real model. Configuration of the 3D model (whether contain solid component or voids or different layers …. etc.) is measured according to its results not to the opinions of any author.
7) Importance of comprehensive knowledge about 2D and 3D acquisition methods, post-acquisition processing and importance of collaboration with other specialties such as mechanical engineering, in other word multidisciplinary approach, to produce consistent method of analyzing

4. Next Work

1) Making an agreement with a government entity for widespread application of this work.
2) Production of refined physical model and study different real scenarios simulating fingerprint generation.
3) We will try to do a more refined digital model and advanced FEM with consideration of the presence of the distal phalangeal bone and refine the current numerical model. Providing an equivalence between the physical model and digital model will help to understand how the 3d finger model will produce the 2d fingerprint.

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Author Profile

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