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A Conceptual Study of Forgery of 3D Fingerprints and Its Threat to Biometric Security Systems

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Abstract:

With the increasing use of a wide Varity biometric systems in day-to-day work, fingerprints are used for a numerous identity verification application such as ID cards, access control, clock in for attendance, at airport for immigration and security, banks for verification, to unlock phones and laptops and many more. Fingerprints is one of the most widely used biometric system for authentication. The widespread use of fingerprints encourages forgers to create biometric fingerprints as well. Although forgery is less common in these circumstances, it has a significant impact on dactyloscopy.Furthermore, with the advancement of technologies like as 3D printing, the usage of a fingerprint biometric system could represent a security hazard.The primary goal of this research was to investigate fingerprint forgery using dummy fingers manufactured from 3D printed molds and gelatin and glycerin casts.The results were quite shocking that the fingerprints created with these casts were identifiable with the help of the Automated Fingerprint Identification System (AFIS). Also, the dummy finger made with gelatin and glycerin could unlock the phones and the door to restricted area. As a result, the findings of this study emphasize the gravity of the challenge and its impact on the biometric security industry, as well as advice for how law enforcement agencies should deal with such difficulties.One of the suggestions authors gave is that the sensors could be made more sensitive by detecting the heartbeat or body temperature to differentiate between human skin (real finger) and other materials (dummy finger).

Key words: Fingerprints,Biometric systems, Fingerprints forgery, 3D printing, security, dummy finger, AFIS, sensitive sensors.

1. Introduction:

Friction ridge skin impressions were used as identity proof in China as early as 300 B.C., and in Japan around 702 A.D.,in United states since 1902 and in Dubai (UAE) since 1979 [1,2].There has been progress in the adoption of fingerprint technologies for many uses since then.Fingerprints were developed as a form of individualization and an effective forensic and investigative tool of incalculable worth as a result of several studies, research, and experimentations. Researched have revealed that fingerprints are distinctive and persistent. People continue to study any science as time goes on, and that science grows and becomes better understood. [1, 3].

The science of fingerprints has been used since over 100 years to identify the suspects and solve crime and it remains an extremely valuable tool for forensic science and law enforcement.It also helps the investigators to "track down the criminal's record, their previous arrests and convictions, to aid in sentencing, probation, parole, and pardoning decisions" [3,

4]. Along with its use in criminal identification purposes, fingerprints have also been used in identifying the deceased, in legal documents, in conducting background checks including applications for employment, defense security clearance, concealed weapon permits, in providing biometric security for example, for accessing secured areas or secured systems, at the airports for immigrations or in banks for authentication and as a form of password to unlock the phones and laptops [4].

Fingerprints are widely used in Biometrics and its extensive use motivates imposters and fraudsters to forge fingerprints and frame someone or bypass the security systemsand further encourages forgers to create fake biometric fingerprints as well. [5]. Forged latent prints are the prints of innocent people planted at the crime scene or in other words prints exists on the surface but are deposited by person other than whose prints they are [6]. The first fingerprint forgery was recorded to happen in 1920s [5,6]. Fingerprint forgery can be done with various techniques as mentioned in literature such as mold and cast method where a cast of the fingerprint is made from the mold, transfer method where the fingerprints are transferred from one surface to other using wax paper or saran wrap like materials, or with metal plate etching method where the fingerprints are etched on the metal plates and the latent prints and the known prints are the exact replica of each other [7,8].

With the increasing theft of identity in today's world, use of biometric security systems based on fingerprints for authentication have a growing importance in protection and granting access to restricted areas. The fake finger and fingerprints are divided into two types: cooperative and non- cooperative. The notion behind the cooperative technique is that the finger is placed in a Play Doh-like material to create a false impression of the fingerprint's shape. The forms are then put onto materials such as gelatin or silicone, which can mimic the unique fingerprint characteristics [9].Dummy fingermade with different materials like silicone and gelatinmolds can be used to forge someone's fingerprint and can deceive the biometric security systems. This process is called spoofing [9,10].Also, 3D printing can be used to make casts for dummy fingers. 3D printing is a process of making three dimensional solid objects from a digital file or in other words 3D printing is an innovative technology that lets one create a physical object from a digital model. All one needs to do is make a design, transfer the file to a 3D printer and then that object can be created with 3D effects [10,11]. So, the scanned fingerprint file can be transferred to the 3D printer and then the output obtained will be like a 3D fingerwhich can be used to make dummy finger or if the texture is like human skin, it can be used itself as a dummy finger to implant fingerprints.

The major goal of this research was to understand if 3D printed counterfeit fingerprints could be searched by AFIS and what kind of results might be obtained.The second goal was to study the effects of dummy fingerprints to access the security system and the threat it poses to the security world and the 3D scanners.

2. Materials and Methods:

2.1 Materials:

2.1.1 Substrate: Ceramic tiles were used as a non-porous surface and white paper was used as a porous surface to laydown fingerprints to study the forgeryand its results.

2.1.2 Matrix: Sebum and oil from the face serve as a matrix for transferring fingerprints to paper. Blood was also used as a matrix for transferring fingerprints to paper and developing them with Amido black. The blood was obtained with the assistance of the Dubai Police Clinic. The dummy finger was made with gelatin and glycerin as a matrix; therefore, no additional matrix was necessary.

2.1.3 Glassware and other requirements: The latex was spread on the 3D printed Fingerprint with a blower and brush. To construct the dummy finger, the components were mixed in a microwave-safe basin with a spatula. To give the dummy finger the color of human skin, "POREfessional shine-vanishing PRO powder" was employed. To keep the mold from breaking, Johnson & Johnson Baby talcum powder was utilized. After the substance was poured into the latex cast, paper clamp clips (binder clips) were used to hang the dummy finger to dry. To speed up the latex drying process, a hair dryer was employed.

2.1.4 Other ingredients and Techniques: The study used a ten-digit fingerprint card, and an appropriate fingerprint was chosen from it using the Automated Fingerprint Identification System (AFIS). The fingerprint that was chosen was then printed in three dimensions. After that, the 3D printed finger was utilized to imitate a real one. Molds were then constructed using SIRCHIE's All-purpose evidence recovery kit (Accutrans), and the cast was made with the same material. The prints were then laid down on various surfaces using this cast.

FEVICOL MR (general purpose), MONSTER LIQUID LATEX (General Purpose), Glycerin USP, BELL'S GLYCERIN B.P, and DAVIS GELATINE (Clear and Unflavored) were used to prepare a dummy finger.

"HI-FI" Latent print powder, Heavy Black (volcano) was used to develop the forged prints and to lift the prints from ceramic tiles, lift tapes called "Lightning lifts" were used. "NinhydrinHT HFE-7100" pump spray was used to develop forged prints on white paper. Amido black was used to develop the forged blood prints.All these chemical supplies used are manufactured by SIRCHIE.

2.2. Methodology:

2.2.1 Preparation ofCast: Accutrans was first spread on a flat surface in an area slightly larger than the first finger joint. The finger was then placed on the spread and lifted. For around 30 minutes, the preparation was allowed to dry. This method was used to prepare the mold. Accutrans was applied to this dry mold once more, and it was left to dry for another 20 minutes. This was done to avoid inverting the print. The cast was removed from the mold once it had dried. This was the mold that was used to make fingerprints on paper with the help of facial oil, sebum, and blood.

2.2.2 3D printing of scanned fingerprint: Firstly, a good quality ten-digit fingerprint card was downloaded from the Dubai Police Automated Fingerprint Identification System (AFIS). One fingerprint was selected from the downloaded card and subjected to high resolution scanning. This scanned fingerprint was sent to the company called 3D SYSTEMSwhere the 3D print offingerprint was created. The 3D printed fingerprint was not similar to human skin and so, it was used as a mold to create the dummy finger in the next step.

2.2.3 Preparation of Dummy finger: First, baby powder was applied on the 3D printed fingerprintand then latex was applied on the mold and left for approximately 15 minutes to dry. Baby powder was applied to avoid breakage when the latex layers are separated from the mold. Drying was accelerated using a hair dryer. Three successive layers of latex were applied after each layer dried. The consistency of the latex was maintained to make even thickness in all three applications. After the latex layers dried, again baby powder was applied to it and then they were separated from the 3D finger and the dried latex layers acted as the mold again. This is because the fingerprint would be inverted and needs to be reversed to match the 3D printed fingerprint. Gelatin and glycerin were mixed in equal proportions. One tablespoon gelatin, one tablespoon glycerin and twotablespoons of water were added in a microwave safe bowl and mixed with a spatula andthen it was heated in the microwave for 15 seconds. This is done to melt the gelatin. Mixture was heated until the crystals weremelted. Once the crystals melted, the POREfessional shine-vanishing PRO powder benefit was added to the mixture to give human skin color. Then, again the mixture was microwaved for 10 seconds to get an even mixture.After that the mixture was evenly mixed,it was poured into the latex mold and was hung on a stand using paper clamp clips for around 3 hours to dry completely. Sometimes it takes more time to dry so, longer it is allowed to dry better it is. After the mixture was completely dried, it was removed from the latex mold. This dried mixture in the form of the finger is the dummy finger which was used as cast to lay the prints. So, the preparation of the dummy finger took approximately 4 hours to reach the final product. The dummy finger looked like as shown in figure 1.

Figure 1: The final appearance of the dummy finger prepared with the aid of gelatin and glycerin.

2.3. Experimentation:

2.3.1 Forgery using the cast made from Accutrans:

We applied the oil and sebum from the face of the individual to the fingerprint cast. This cast was further loaded with matrix and was then touched on to the paper twice. Each time matrix was applied before touching the substrate. The prints were allowed to settle for an hour and then developed using the Ninhydrin chemical method. These developed prints were then scanned and searched through the Dubai Police Automated Fingerprint Identification System (AFIS) and results were obtained as discussed in the results section.

The second forgery was done using the same type of cast, but the matrix, in this case, was blood. The cast was touched in blood and then touched onto the paper. Six such impressions were made on the paper and before making each impression, the cast was touched with blood to keep the print consistent throughout. These forged prints were allowed to dry for an hour before they were developed using Amido Black dye. These developed forged prints were again scanned and searched through the Dubai Police Automated Fingerprint Identification System (AFIS) and results were obtained as discussed in the results section.

2.3.2. Forgery using the Dummy finger as the cast:

As the dummy finger was made with gelatin and glycerin, they acted as a matrix and no additional matrix was applied before laying the prints on the substrate. Over Twenty prints were laid on a ceramic tile and were allowed to dry for different time intervals ranging between five minutes to an hour. After complete drying, the prints were then developed using black fingerprint powder and lifted using lift tapes. These lifts were scanned and searched through the Dubai Police AFIS. Results are discussed in the results section.

This dummy finger was also used as a cast to access the biometric security system that is the door to access the secured area in the Fingerprint Department of Dubai Police. The dummy finger was of the author as the author has the access to the secured area. It was placed by a lab assistant on the biometric scanner to check if the system recognized the dummy finger and gave access to the secured area. Also, the dummy finger was used to unlock the smartphone. The author set his fingerprint as the password to unlock the phone and then the dummy finger made from the author's finger was used to check the fingerprint recognition system of the phone. For this "I Phone, Samsung and Huawei" brand smartphones were used. Results are discussed in the results section.

3. Results:

Accutrans created a smooth cast that was free of air bubbles and artefacts. The texture of 3D printed fingerprints resembled that of a real finger, but not that of human skin. It was tough, so it served as a mold for the dummy finger. The only issue with the dummy finger preparation was the stability of the ingredients utilized. The components don't last long, and the dummy fingers disintegrates approximately after three weeks.

The forged prints laid on the paper with the cast made from Accutrans were developed using the Ninhydrin chemical method, but the prints were spotty and dotted. The ridges appeared were broken. These prints were searched through the database and a candidate list was provided by the AFIS. The prints were

not of very good quality but there was a hit, and the prints were identified. The forged prints made from cast of Accutrans using blood as matrix and developed using amido black were of good quality in comparison the previous prints. These prints were also searched through the database and were identified to the person whose finger cast was created.The results are shown in figure 2. The forged prints made with dummy finger were laid on ceramic tile and were developed using Fingerprint powder. These prints were searched through the database and a candidate list was provided by the AFIS once again. These prints were of very good quality and the prints were positively identified.The results are shown in figure 3.

Figure 2: Forged fingerprint made with Accutrans and searched through the database (AFIS) resulted in a positive Identification.

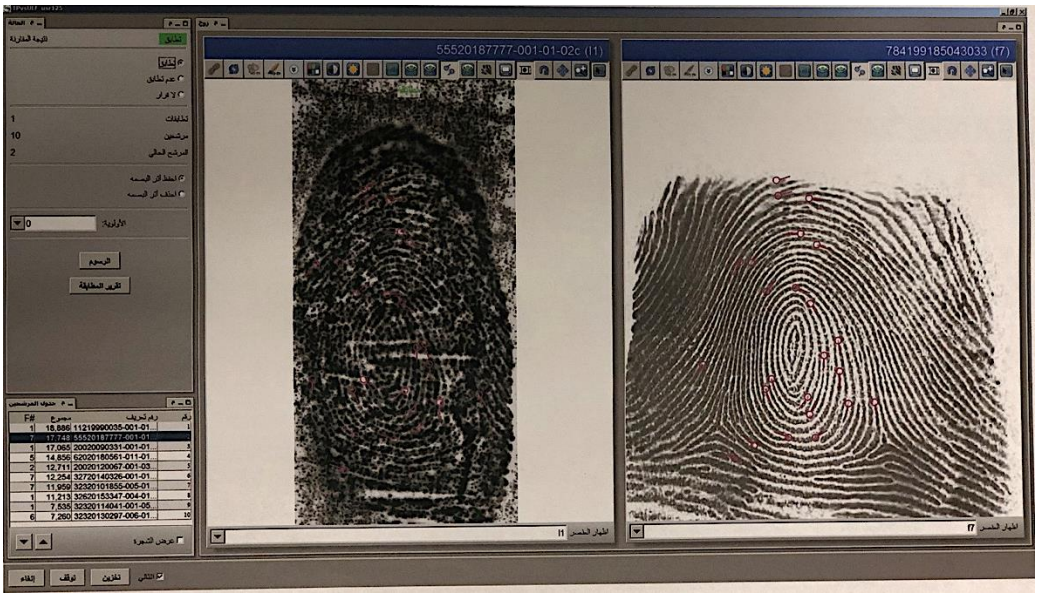

Figure 3: Forged fingerprint made with dummy finger and searched through the database (AFIS) resulted in a positive Identification.

For the biometric system, access was obtained to the secured area using the dummy finger. It was very easy to unlock "I-phone, and Samsung smartphone", whereas the unlocking of "HuaweiSmartphone" happened with some difficulty, the attempt was successful only once.

4. Discussion:

The main aim of the study was to study the forgery of the fingerprints by 3D Printing and using a dummy finger to ascertainthat if the 3D Printed finger and the molds can be used in further forgeries or as an evidence implantation to frame an innocent person. Also, another objective was to study its efficacy in bypassing the biometric security systems. For these objectives, the authors tried various methods as discussed in the methodology above.

Passwords were the conventional authentication technique for computers and networks. However, passwords can be stolen, and biometric authentication appears to be a solution to this problem these days. Biometrics is physical and behavioral features of a person that can be used to digitally identify them and allow access to systems, equipment, or data.Facial recognition, retina scanning, voice recognition, and fingerprint authentication are all options for biometric authentication. One of the most prevalent methods is fingerprint authentication. With the advancement of technology, fingerprint authentication has spread to a wide range of devices, including laptops, smartphones, padlocks, and even encrypted USB drives. The fact of the matter is that each person's fingerprints are unique [12-14, 21]

However, the increasing use of fingerprint authentication and technologies such as 3D printing pose a threat to security[15]. Craig Williams, who runs Talos says, "It does not take a significant amount of money to bypass fingerprint-based authentication for most vendor". "The fact that home 3D printing technology can reach a resolution that makes fingerprints less secure than they were 10 years ago is concerning, because everyone can access these printers. But it is still not easy. It still takes a significant amount of effort and the ability to capture the print" [15,16]. The full access of fingerprints is not always possible. Fingerprints can be forged by transferring from one surface to other but to transfer it to a suitable surface for scanning and getting it 3D printed is difficult and the results are not always accurate.

Authors had access to Automated Fingerprint Identification System and with the authorization of the Head of the Department of the Fingerprints section of Dubai Police, a ten-digit fingerprint card was downloaded and used to create a 3D print of a specific fingerprint from the thiscard. The specific finger from the ten-

digit fingerprint card was then scanned and sent to the 3D systems company to obtain the 3D print of it. The 3D printed fingerprint's texture was quite hard. The company did not have any material which would imitate human skin, sothe 3D printed fingerprint was used to develop dummy finger using different materials that would be near like human skin.In the near future, Dubai Police has a plan to build its own 3D laboratory for forensics to perform more tests and research. The challenges faced with 3D printing was not only the texture but also the size and dimensions of the 3D printed fingerprint. To create a fingerprint that would be similar to real fingerprint, the mold should have the same dimensions and size as the real fingerprint on the finger. This could eliminate any doubt that the impression was created by dummy finger and also the spacing in between the ridges and minutiae plays an important role while searching them through the AFIS database.It can be understood that the fingerprint created is good or similar to real fingerprint when the dimensions were as expected by the fingerprint recognition system. There were various attempts made to reach the perfect 3D printed fingerprint. The issues faced were inverted print, color reversal and way too off the dimensions. This was overcome with various attempts of 3D printing again and again.

Here, for the dummy finger, author chose gelatin and glycerin as the main ingredients. Gelatin has similar characteristics as that of keratin protein which is present in human skin. This was one of the main reasons to use gelatin as one of the main ingredients [16,17]. Gelatin is soluble in aqueous solutions of polyhydric alcohols such as glycerol. Glycerin is the commercial name of glycerol. Also, gelatin granules get swollen when added to cold water and on heating swollen particles dissolve to form a solution. The formation of thermo-reversible gels is one of the gelatin's most important properties that makes it more useful. When aqueous solution of gelatin is cooled at approximately 35-40ºC, it increases in viscosity and then forms gel. The gel strength of gelatin plays a major role in giving the shape and desired structure. Glycerin has the properties of hygroscopicity, and low vapor pressure, a combination that produces outstanding humectancy and plasticity [17,18]. Because of these properties of gelatin and glycerin, author used them to make the dummy finger. Also, the ability of glycerin to absorb moisture from the air helped to avoid adding any matrix to the dummy finger before laying any prints.

There wereother several issues faced while making the dummy finger. The time of drying was one of the major factors. If gelatin were not allowed to dry completely, it would not reach up to its maximum gel strength and the dummy finger would melt. So, providing maximum time to dry is one of the key factors to give proper shape to the finger. This dummy finger started to bubble and shed after three weeks as studied. The possible reason could be the storage and temperature conditions that needs to be investigated further. Gelatin is preserved well if stored in cool temperatures or refrigerators but here in this case it was allowed to settle at room temperature all the time. This could have been the reason for dummy finger's destruction.Care must be taken in making the dummy finger because the 3D print is like the actual finger and latex mold made with the help of the 3D print would be an inverted impression. So, this latex print cannot be used to lay impressions as it would not match the actual print. To solve this issue of inverted prints were subjected to create the final cast with gelatin and glycerin, which acted same as the real finger both in terms of ridge characteristics as well as texture simulating the human skin.

The fingerprint cast was also made using Accutrans. When the impression was laid in the accutrans it appeared just like the real fingerprint but when that would be used as a cast to plant fingerprints then it would act as an inverted impression. So, this first impression in Accutrans was used as the mold and when it dried, again the mold was filled with Accutrans. When this second layer of Accutrans dried, it was separated from the first layer, and this acted as a cast to lay prints on the desired surface. One more method was attempted to make cast which is not mentioned in the methods section because it was a failure. Mold was prepared by laying an impression in the Accutrans and when it dried,

the cast was made using glue from the glue gun. When the glue dried, it was separated from the mold of Accutrans. The cast was very soft and did not have texture like human skin. Also, when blood was used as matrix to leave prints on paper, the cast was destroyed. The glue cast absorbed the blood and became softer and was completely destroyed therefore, couldn't be used for the study.

After all the casts were made, the goal was to try laying impressions with them, develop them using appropriate chemicals and take photograph or scan the prints and finally run them through AFIS to check whether the forged prints get a hit in the system. All the forged impressions were searched in the AFIS, and they were all identified within the list of candidates sent back by AFIS. With these results it was clear that forged prints can be identified without any challenges. In future research projects would be done to identify the differences between the latent impressions and the forged impressions.

The second goal of the study was to check if the dummy finger would let bypass the biometric security system which used fingerprint as the sole source for unlocking. With the increasing use of fingerprint authentication and advancement in the field of technology like 3D printing of fingerprint, authentication poses a great threat to the security world [18]. One of the authors tried to access his own "I-phone" by using the dummy finger and could easily unlock it in the first trial. He also tried to access "Samsung and Huawei phones" of other co-workers with their permission and was able to unlock them. These two brands were difficult to break-in in the first trials. Samsung was easy to unlock than Hawaii but, for Hawaii only 1 attempt was successful. Multiple attempts were required to unlock them. In the opinion of authors, this could be both a help to the law enforcement and a threat to the biometric security world. For example it could help the police to unlock a phone of a deceased person under legal frame work or any live person who refuses to cooperate in the criminal procedure where he is the prime suspect and trying to hide evidence that could help the police then this can be used. For example, the crime can have serious repercussionson the society at large or have a national security issue such as terrorist act then this technique would be of great help. But if in the wrong hands this technique would pose a threat as forging fingerprints could get the criminal access to the database or secured information or entry to restricted areas. This is still difficult because he or she should have access to the fingerprints of the person whose fingerprints he or she is trying to forge. But it is not impossible.

In conclusion, the authors said that this research study would help the fingerprint scanning companies to develop methods that would improve the accuracy of the scanning devices. It will help the companies to build better technology and reading devices and develop algorithms which would protect the system from the attacks of dummy fingerprints. May be something like the sensors being more sensitive to human skin and have the ability to differentiate between the human skin and other fake or imitating materials. One of the suggestion authors gave is the sensors could be made more sensitive by detecting the heartbeat or body temperature to differentiate between human skin and other materials.

5. Conclusion:

The research project was started with a goal to study if the casts and dummy finger made by 3D printed fingerprints be used to lay prints on various surfaces and can that be detected and also can the dummy finger give access to biometric system. The results showed that it is possible though not easily. In the authors opinion, the increasing development in 3D printing technology, has an impact on fingerprint authentication. But with the limitations like the size of the 3D printed fingerprint should be exactly the same as the real fingerprints, it is difficult because it requires access to various high-end technologies like electronic microscopes to measure the spacings before 3D printing. This research project would help the companies build robust fingerprint scanning devices.

A future study would be conducted on detailed study about the differences between the

forged impressions and genuine impressions using 3D printed fingerprints once the resources are available.

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