PLAGIARISMA

92% Unique

Total 20565 chars, 3447 words, 171 unique sentence(s).

Results	Query	Domains (original links)
Unique	Pambudi Department of Informatics Universitas Internasional Semen Indonesia Gresik, Indonesia doni	-
23 results	INTRODUCTION In this digital era, the use of electronic devices has been a must	id.scribd.com pt.scribd.com manualzz.com mafiadoc.com pt.scribd.com mafiadoc.com science.gov iceteks.com ar.scribd.com doczz.cz
Unique	There are some methods to do such authentication, including that with biometrics	-
Unique	This requires the users to physically present when the authetication is being processed [1]	-
Unique	Amongst existing biometrics, fingerprint is one of popular modalities to use	-
Unique	As in [2], fingerprint has relatively good evaluation results	-
Unique	In additon, fingerprint is relatively permanence, so it is suitable to use	-
Unique	Nevertheless, this last characteristic has made fingerprint data should be proteccted	-
Unique	This is because, once it is compromised, fingerprint data can not be changed	-
Unique	this is different with the password case	-
104,000 results	The transformation itself is one-way	quizlet.com stackoverflow.com ibm.com studystack.com lightomega.org quora.com
Unique	therefore, the authentication is carried out in the transformed domain	-
Unique	By using these data along with the respective keys, the specified transformation is performed	-

Unique	The resulted transformed data is called cancelable template	-
Unique	It means that a different template can be generated by using different keys	-
Unique	This may occur if, for example, the template has been compromised	-
Unique	At the beginning, the method is introduced by Ratha et al [4]	-
Unique	In this paper, we propose a variation of cancelable fingerprint template method	-
Unique	The rest of the paper is structured as follows	-
Unique	Section 2 describes the previous works which relate to this proposed method	-
Unique	Section 3 explains the proposed method itself	-
Unique	The experimental results and conclusion are provided in Sections 4 and 5, respectively	-
Unique	Since this line crosses the coordinate (0,0), the value of ൌͲ	-
Unique	So, each minutia points results to two projected points	-
Unique	The resulted set is to be the template which is stored in the database	-
Unique	This method is simple and relatively easy to use	-
40 results	However, there are some disadvatages of this method	projectslib.com projectslib.com docshare.tips happylibnet.com docshare.tips adfly-review.ru adfly-review.ru mafiadoc.com 123doc.org zh.scribd.com
633 results	For example, it uses the core point to be the center of fingerprint	patents.google.com researchgate.net patents.google.com mafiadoc.com patents.justia.com dl.acm.org sites.google.com 15minutenews.com patents.com freepatentsonline.com
Unique	Without this core point, the set of template/query can not be generated	-
Unique	Furthermore, the informatioin of core point is difficult to obtain precisely	-
Unique	and, not all fingerprints have the core point [8]	-
Unique	Therefore, in this specific case, the fingerprint template can not be used	-
Unique	Nevertheless, it is still possible to compromise it	-
Unique	In [9], Xi and Hu propose the hierarchical structure check (HSC) to protect fingerprint	-

Unique	So, there are some matching levels	-
Unique	This method may have high accuracy, however, the processing time can be a problem	-
4 results	Furthermore, all fingerprint types may be applicable to it	science.gov science.gov epdf.pub
Unique	Overall, the method consists of some steps: minutiae selection, minutiae transformation, partition and matching	-
10 results	A minutia is randomly selected to be the reference	epdf.pub groundai.com mafiadoc.com mafiadoc.com scribd.com jips-k.org science.gov scribd.com stks.freshpatents.com
Unique	In turns, all minutiae are also the reference sequentially	-
Unique	Minutiae Selection Here, the template is only developed by some minutiae points	-
Unique	This is because too many minutiae may cause the authentication too long	-
Unique	However, too small number of minutiae may also significantly reduce the fingerprint uniqueness	-
Unique	□□□□□□ and □□□□□□ are the allowed minimum and maximum distance, respectively	-
90 results	This process can be depicted in Fig	coursehero.com transtutors.com nature.com chegg.com coursehero.com nature.com
Unique	Firstly, the minutiae are projected into a line (see Fig	-
Unique	The resulted vertical and horizontal projected points along with their orientation are transformed separately	-
3 results	Further transformation is applied to the orientation of the vertical projected points	studylib.net science.gov epdf.pub
Unique	The same process is also applied to the horizontal projected point	-
Unique	T □□□ and T □□□ are the orientation of vertical and horizontal projected points	-
Unique	Partition Different from [8], the index of the partition is not randomized	-
11 results	This is because the order of partitions does not influence the accuracy	happylibnet.com patents.google.com patents.google.com id.123dok.com archive.org pt.scribd.com mafiadoc.com yumpu.com yumpu.com
Unique	Instead, a partition is to estimate the position of those points	-
Unique	and □ □ is the length of each partition, which is fixed to 20	-
Unique	Matching is performed to all vectors of template and query	-

Unique	This means that the corresponding template and query are possibly matched	-
Unique	An example of this process is provided in Fig	-
Unique	Firstly, ୍ର and ୍ଶ of template and query are compared	-
Unique	If they matched, then depth level = 1 (see Fig	-
Unique	6(a)), proceed to one of the neighbor (e	-
Unique	g., ୍ଘ) and compare it with others	-
Unique	6(b)), proceed to one of neighbor of ୍ଘ , and soon	-
Unique	This process finishes when there is no more minutiae match	-
Unique	Let ୍ର and ୍ଶ be the transformed template and query, respectively	-
Unique	Take ର and ଶ from ୍ର and ୍ଶ , respectively	-
Unique	Compare ର and ଶ by applying (6)	-
Unique	If step 4 meets, then take a neighbor point and go to step	-
Unique	As these research, we use 2 impression, each of which comprises 100 fingerprints	-
Unique	Therefore, there are 10000 fingerprint comparison	-
Unique	Those two evaluation represent Genuine Acceptance Rate (GAR) and False Acceptance Rate (FAR), respectively	-
Unique	Performance Let ୍ be the number of selected minutiae resulted from Section III(A)	-
Unique	A minutia is represented by ൭ ̈ ͳ vectors	-
Unique	in turns, a fingerprint is represented by ሺ൭ ̈ ͳሻ vectors	-
Unique	It shows the minimum (Nmin), maximum (Nmax) and average (Navg) numbers of selected minutiae	-
Unique	The size of the template, nevertheless, is only kilo bytes	-
Unique	We believe that this size is not a significant problem for today technology	-
Unique	The result of the experiment is provided in Table II	-
Unique	that is, GAR and FAR are 98% and 0, respectively	-
Unique	Decreasing the depth level raises both GAR and FAR	-

Unique	while increasing depth level reduces GAR and FAR	-
Unique	The Equal Error Rate (EER) of the same data can be plotted in Fig	-
Unique	This is lower than that of [1][8] which is more than 2%	-
65 results	while in [9], the EER is not provided	patents.google.com patents.google.com researchgate.net academia.edu pt.scribd.com archive.org mafiadoc.com slidelegend.com docshare.tips archive.org
Unique	In the real world, the selection of depth level depends on the application purpose	-
Unique	It may focus on either a high GAR, low FAR or equal error level	-
Unique	Security The transformation is one way	-
Unique	Instead, only the distance of the point is stored in the database	-
Unique	Moreover, not all minutiae are used in the transformation	-
Unique	So, their information is not in the template at all	-
Unique	CONCLUSION In this paper, the improvement of the projection-based fingerprint cancelable method is proposed	-
Unique	This method works by comparing the set of template and query vectors	-
Unique	In terms of the security, the stored template is only generated by some minutiae	-
Unique	This has made the transfomed minutiae does not contain all fingerprint information	-
Unique	Prabhakar, Handbook of Fingerprints, London: Springer, 2009	-
Unique	Bolle, "Generating Cancelable Fingerprint Templates," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol	-
26 results	Kim, "Cancelable fingerprint templates using minutiae-based bit-strings," Journal of Network and Computer Applications, vol	yonsei.pure.elsevier.com sciencedirect.com sciencedirect.com issuu.com mafiadoc.com slideshare.net issuu.com researchgate.net hindawi.com mafiadoc.com
Unique	Hu, "Design of alignment-free cancelable fingerprint templates via curtailed circular convolution," Pattern Recognition, vol	-
Unique	[11] Neurotechnology, "Verifinger 5.0," [Online]	-
Unique	978-1-4673-9360-7/15/$31.00 2015 IEEE 84 Improving the Performance of Projection-based Cancelable Fingerprint Template Method Tohari Ahmad	-

Unique	id Tsuyoshi Usagawa HICC Laboratory Kumamoto University Japan Abstract—Biometrics, especially fingerprint, has been popular to	-
Unique	This characteristic, however, is a problem because once it is compromised, fingerprint data can	-
Unique	The conventional cryptographic algorithm may not be able to protect fingerprint data since the	-
Unique	This paper improves the performance of the previous projection-based fingerprint protection method by removing	-
Unique	The experimental result which is done in a public database produces the EER of	-
Unique	Consequently, an authentication process to prove that the one who would like to access	-
Unique	Compared to other methods, such as a system with passwords, biometrics-based authentication has some	-
Unique	For example, it is not easy to duplicate biometrics, which makes its data more	-
Unique	This is in terms of some key factors, such as acceptability, universality, performance and	-
Unique	There are some points where the fingerprint protection can be applied [3], such as	-
Unique	At this last point, the fingerprint data is transformed into another domain such that	-
Unique	In order to do the transformation, it needs to extract the fingerprint to obtain	-
Unique	In further development, some different methods have also been proposed [5] [6] [7] [8]	-
Unique	This is done by exploring the minutiae characteristics, as an improvement of previous research,	-
Unique	RELATED WORKS The research in [8] uses the core point to be the center	-
395 results	These points are aligned to the position of the core point and its orientation	mafiadoc.com patents.google.com patents.google.com b-ok.org peerj.com researchgate.net slidelegend.com docshare.tips id.123dok.com docshare.tips
Unique	The minutiae points are projected to a line [illegible] , where [illegible] are	-
Unique	All minutiae points are projected into the line, parallel to the [illegible] and	-
Unique	get two points but it is hard to reconstruct the original point just by using	-
Unique	All points in the line are grouped based on their position as depicted in	-
Unique	In that example, there are 6 groups which contain 1, 2, 1, 2,	-
Unique	Each group is indexed in a specified order whose number of points constructs	-

Unique	א ẵჼẵ’ are the number of partitions, lenght of partitions and index of each partition,	-
Unique	This set is 85 2015 Seventh International Conference of Soft Computing and Pattern Recognition	-
Unique	In terms of the security, this method is relativley good since the information of	-
5 results	The information of the generated template can be applied to the fake fingerprint by	patents.google.com patents.google.com freepatentsonline.com patentsencyclopedia.com patents.justia.com
Unique	Although it is not enough to reconstruct the original fingerprint just by using both	-
Unique	In the application, it is assumed that both and are confidential which	-
Unique	This is carried out by comparing not only the minutia reference, but also the	-
Unique	In this research, different from [8], the fuzzy vault method is used for protecting	-
Unique	PROPOSED METHOD Different from [8], we develop a method which does not need the	-
Unique	Therefore, the existence of the core point in a fingerprint does not have an	-
Unique	As the result, the difficulty of extracting accurate coordinate and orientation of the core	-
Unique	Therefore, it needs to obtain an enough minutiae number which is able to represent	-
Unique	by using (1) which should meet the requirement in (2), where ᪨ ẵ ᪨ is	-
Unique	᪨ ẵ ᪨ ൌ ?? ?? ?? ?? ?? ?? ?? ?? ?? (1)	-
Unique	Minutiae Transformation As in our previous research [8], the minutiae are projected to the	-
Unique	Different from it, we use a set of keys ൌ ᷿ ள??? ẵ൭ ౚẵ൭	-
Unique	Next, the respective point is translated ள??? according to the obtained orientation, as	-
6 results	The resulted point is projected back to the line and the distance between this	mafiadoc.com science.gov yumpu.com epdf.pub science.gov
Unique	It is worth noting that this translation can be either positive or negative, according	-
Unique	These vertical and horizontal projected points construct a new point (represented by green circle	-
Unique	tresh_r_max tresh_r_min86 2015 Seventh International Conference of Soft Computing and Pattern Recognition (SoCPaR 2015) Let	-

Unique	by vertical and horizontal projected points, and the distance between those vertical and horizontal projected	-
Unique	∇ ᅟᅟ ஈ and ∇ ᅟᅟᅟ are the index of the partition from where vertical	-
Unique	The generated template of a fingerprint can be defined as in (4), where	-
Unique	ǎ∇ ᅟ ᅟ ɡ ᅟ ᅟ ǎ ᅟ ǎT ᅟ ஈ ǎT ᅟ ǎ∇ ᅟ ஈ ǎ∇	-
Unique	In addition, the number of partitions is fixed to 100 in order to cover	-
Unique	Also, there is no threshold of how far those point from the center because	-
Unique	The index of the partitions ∇ is given by using (5), where ᅟ	-
Unique	∇ ᅟ иT ᅟ ᅟ ᅟ T ǎ ᅟ T иT ᅟ ᅟ ᅟ ǎ T	-
Unique	Matching This process is carried out by comparing the set of vector of	-
Unique	(4), and o ஈ is the difference of each of those components between query and	-
Unique	So, we obtain o ᅟ , o ள , o ஈ , o	-
Unique	Inspired by [9], these values are combined along with their respective threshold as depicted	-
Unique	T ஈ oT ᅟᅟᅟ T ᅟ ᅟᅟo∇ ஈ 7) ∇) By employing the method	-
Unique	In addition, at least 40% of the minutiae template have to match to those	-
Unique	Fingerprint template and query are considered to be matched if there are at least	-
Unique	matched point is further checked by improving the capability of [9] to get the depth	-
Unique	Here, we propose the steps as follows: Once this process has been applied, we	-
4 results	If it is higher than the specified threshold, then the minutiae are considered to	mafiadoc.com yumpu.com yumpu.com epdf.pub
Unique	If and of template and query match, then depth level	-
Unique	Take a minutia and from and	-
Unique	If the resulted value is less than the specified threshold, then they match and	-
Unique	If step 4 does not meet, then repeat step 3 until all minutiae of	-
Unique	ijv Figure 5 Features of projected minutiae 87 2015 Seventh International Conference of Soft Computing	-
Unique	EXPERIMENTAL RESULT Similar to [1] [8] [9], we use FVC2002Db2a for testing which is	-

Unique	In order to evaluate the capability to accept a legitimate fingerprint, we compare those	-
Unique	and for evaluating the capability to reject an illegitimate fingerprint, we compare those in	-
Unique	The value of . depends on the minimum (Rmin) and maximum (Rmax) distance values	-
Unique	In the experiment, we specify the minimum distance by 11 as depicted in Table	-
Unique	A high number of generated vectors may need more spaces to store in	-
Unique	It is shown that the best result is obtained when the depth level is	-
Unique	The False Rejection Rate (FRR) is defined as (100%-GAR), which represents the number of	-
Unique	It is depicted that EER is 1% which is reached at about 1.2 of	-
Unique	Eventhough the set of keys is given, it is hard to reconstruct the original	-
Unique	(b) Depth level=2 88 2015 Seventh International Conference of Soft Computing and Pattern Recognition (SoCPaR	-
Unique	In the worst case that the stored template can be revealed, not all fingerprint	-
Unique	In case the number of matched minutiae is higher than the specified threshold, then	-
Unique	Nevertheless, there is still a possibility to further evaluate the query whose value is	-
55 results	This method, which is evaluated by using a public database, has been able to	docs.oracle.com docs.oracle.com resources.mpi-inf.mpg.de researchgate.net academic.oup.com researchgate.net
Unique	Han, "Cartesian and polar transformation-based cancelable fingerprint template," in The 37th Annual Conference of	-
Unique	Bolle, "An Analysis of Minutiae Matching Strength," in Third International Conference on Audio- and	-
Unique	Goi, "A non-invertible Randomized Graph-based Hamming Embedding for generating cancelable fingerprint template," Pattern Recognition	-
Unique	Hu, "Generating cancelable biometric templates using a projection line," in The 11th IEEE International	-
Unique	Hu, "Biometric Mobile Template Protection: A Composite Feature Based Fingerprint Fuzzy Vault," in IEEE	-
Unique	Jain, "On the Individuality of Fingerprints," IEEE Transactions on Pattern Analysis and Machine Intelligence,	-

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978-1-4673-9360-7/15/$31.00 2015 IEEE 84 Improving the Performance of Projection-based Cancelable Fingerprint Template Method Tohari Ahmad Department of Informatics Institut Teknologi Sepuluh Nopember Surabaya, 60111, Indonesia tohari@if.its.ac.id Doni S. Pambudi Department of Informatics Universitas Internasional Semen Indonesia Gresik, Indonesia doni.pambudi@uisi.ac.id Tsuyoshi Usagawa HICC Laboratory Kumamoto University Japan Abstract—Biometrics, especially fingerprint, has been popular to use for authenticating users because it is relatively permanence. This characteristic, however, is a problem because once it is compromised, fingerprint data can not be replaced. The conventional cryptographic algorithm may not be able to protect fingerprint data since the fingerprint scanning result is unstable. This paper improves the performance of the previous projection-based fingerprint protection method by removing the need of the core point and applying further minutiae checking hierarchically. The experimental result which is done in a public database produces the EER of about 1%. Keywords-fingerprint; security; minutiae; privacy; confidentiality I. INTRODUCTION In this digital era, the use of electronic devices has been a must. Consequently, an authentication process to prove that the one who would like to access is really a legitimate user is needed. There are some methods to do such authentication, including that with biometrics. Compared to other methods, such as a system with passwords, biometrics-based authentication has some advantages. For example, it is not easy to duplicate biometrics, which makes its data more secure. This requires the users to physically present when the authetication is being processed [1]. Amongst existing biometrics, fingerprint is one of popular modalities to use. As in [2], fingerprint has relatively good evaluation results. This is in terms of some key factors, such as acceptability, universality, performance and collectivity. In additon, fingerprint is relatively permanence, so it is suitable to use. Nevertheless, this last characteristic has made fingerprint data should be proteccted. This is because, once it is compromised, fingerprint data can not be changed; this is different with the password case. There are some points where the fingerprint protection can be applied [3], such as at the sensor, extractor, matcher and database where the fingerprint template is stored. At this last point, the fingerprint data is transformed into another domain such that it is hard to recognize its original data. The transformation itself is one-way; therefore, the authentication is carried out in the transformed domain. In order to do the transformation, it needs to extract the fingerprint to obtain some features, which can be the coordinate, orientation and type of the minutiae. By using these data along with the respective keys, the specified transformation is performed. The resulted transformed data is called cancelable template. It means that a different template can be generated by using different keys. This may occur if, for example, the template has been compromised. At the beginning, the method is introduced by Ratha et al [4]. In further development, some different methods have also been proposed [5] [6] [7] [8] with their own advantages and disadvantages. In this paper, we propose a variation of cancelable fingerprint template method. This is done by exploring the minutiae characteristics, as an improvement of previous research, especially in [8]. The rest of the paper is structured as follows. Section 2 describes the previous works which relate to this proposed method. Section 3 explains the proposed method itself. The experimental results and conclusion are provided in Sections 4 and 5, respectively. II. RELATED WORKS The research in [8] uses the core point to be the center of a fingerprint area and the minutiae to be the neighboring points. These points are aligned to the position of the core point and its orientation as shown in Figs. 1(a) and 1(b), respectively. The minutiae points are projected to a line , where are abscissa and ordinate of a point in the line, the slope and the constant, respectively. Since this line crosses the coordinate (0,0), the value of . All minutiae points are projected into the line, parallel to the and axis (horizontal and vertical) as illustrated in Fig. 1(c). So, each minutia points results to two projected points. It is worth to note that it is easy to project a point to get two points but it is hard to reconstruct the original point just by using these two points due to many possibilities. All points in the line are grouped based on their position as depicted in Fig. 1(d). In that example, there are 6 groups which contain 1, 2, 1, 2, 1 and 1 points. Each group is indexed in a specified order whose number of points constructs a set , for example. This partitioning step is performed by employing a set of keys , where are the number of partitions, lenght of partitions and index of each partition, respectively. The resulted set is to be the template which is stored in the database. This set is compared to that of the query by using mean absolute error (MAE). This method is simple and relatively easy to use. However, there are some disadvatages of this method. For example, it uses the core point to be the center of fingerprint. Without this core point, the set of template/query can not be generated. Furthermore, the informatioin of core point is difficult to obtain precisely; and, not all fingerprints have the core point [8]. Therefore, in this specific case, the fingerprint template can not be used. In terms of the security, this method is relativley good since the information of the original fingerprint is not stored. Nevertheless, it is still possible to compromise it. The information of the generated template can be applied to the fake fingerprint by using and . Although it is not enough to reconstruct the original fingerprint just by using both data, they may be used to impersonate the authentication system. In the application, it is assumed that both and are confidential which may be secured by other methods. In [9], Xi and Hu propose the hierarchical structure check (HSC) to protect fingerprint. This is carried out by comparing not only the minutia reference, but also the neighbors of neighbor points. So, there are some matching levels. In this research, different from [8], the fuzzy vault method is used for protecting the data. This method may have high accuracy, however, the processing time can be a problem. III. PROPOSED METHOD Different from [8], we develop a method which does not need the core point. Therefore, the existence of the core point in a fingerprint does not have an impact to the authentication process. As the result, the difficulty of extracting accurate coordinate and orientation of the core point can be ignored. Furthermore, all fingerprint types may be applicable to it. Overall, the method consists of some steps: minutiae selection, minutiae transformation, partition and matching. A minutia is randomly selected to be the reference. In turns, all minutiae are also the reference sequentially. A. Minutiae Selection Here, the template is only developed by some minutiae points. This is because too many minutiae may cause the authentication too long. However, too small number of minutiae may also significantly reduce the fingerprint uniqueness. Therefore, it needs to obtain an enough minutiae number which is able to represent the whole fingerprint data. The selection is done by measuring the distance between the reference and all minutiae by using (1) which should meet the requirement in (2), where is the distance between minutiae and , and are the allowed minimum and maximum distance, respectively. In this case, the minimum distance is specified in order to avoid too close projected points in the transformation process (see Section III.B). This process can be depicted in Fig. 2. (1) (2) B. Minutiae Transformation As in our previous research [8], the minutiae are projected to the line which crosses the reference point (in this case is a minutia point). Different from it, we use a set of keys . Firstly, the minutiae are projected into a line (see Fig. 3). The resulted vertical and horizontal projected points along with their orientation are transformed separately. Further transformation is applied to the orientation of the vertical projected points. Next, the respective point is translated according to the obtained orientation, as depicted in Fig. 4. The resulted point is projected back to the line and the distance between this point and the previous one is calculated by using (3). It is worth noting that this translation can be either positive or negative, according to the orientation. The same process is also applied to the horizontal projected point. These vertical and horizontal projected points construct a new point (represented by green circle in Fig. 5). (3) (a) (b) (c) (d) x+ y+ y y = ρx + c x y+ x+ y = ρx + c Figure 1 Points in fingerprint (a) Core and minutiae points (b) Axis in the fingerprint (c) Projected minutiae points (d) Partitioned line Figure 2 Minutiae selection process y x tresh_r_max tresh_r_min Let and be the reference and its neighbor point, respectively; and are the distance between (0,0) and the point constructed by vertical and horizontal projected points, and the distance between those vertical and horizontal projected points; and are the orientation of vertical and horizontal projected points; and are the index of the partition from where vertical and horizontal projected points are located (see Fig. 5). The generated template of a fingerprint can be defined as in (4), where is the number of neighbor points. (4) C. Partition Different from [8], the index of the partition is not randomized. This is because the order of partitions does not influence the accuracy. In addition, the number of partitions is fixed to 100 in order to cover all resulted points. Also, there is no threshold of how far those point from the center because we do not count the number of points in a partition. Instead, a partition is to estimate the position of those points. The index of the partitions is given by using (5), where is the distance between a point and the center; and is the length of each partition, which is fixed to 20. (5) D. Matching This process is carried out by comparing the set of vector of template and query. In general, this comparison follows (6), where is all component of vector in (4), and is the difference of each of those components between query and template. So, we obtain . Inspired by [9], these values are combined along with their respective threshold as depicted in (7), where is the distance between template and query. Matching is performed to all vectors of template and query. (6) (7) By employing the method in [9], the resulted values of are selected. This means that the corresponding template and query are possibly matched. In addition, at least 40% of the minutiae template have to match to those of query with condition that 40% is more than 1 minutiae. Fingerprint template and query are considered to be matched if there are at least 12 points match, as specified in [10]. In case the number of matched points is between 5 and 12, this conditional matched point is further checked by improving the capability of [9] to get the depth level of the minutiae. Here, we propose the steps as follows: Once this process has been applied, we obtain the depth level of the minutiae. If it is higher than the specified threshold, then the minutiae are considered to be matched. An example of this process is provided in Fig. 6. Firstly, and of template and query are compared. If they matched, then depth level = 1 (see Fig. 6(a)), proceed to one of the neighbor (e.g.,) and compare it with others. If and of template and query match, then depth level = 2 (see Fig. 6(b)), proceed to one of neighbor of , and soon. This process finishes when there is no more minutiae match. 1. Let and be the transformed template and query, respectively. Reset 2. Take a minutia and from and with their respective (see (4)) 3. Take and from and , respectively. 4. Compare and by applying (6). If the resulted value is less than the specified threshold, then they match and and are noted. 5. If step 4 does not meet, then repeat step 3 until all minutiae of are processed. 6. If step 4 meets, then take a neighbor point and go to step 2. x y proj v proj h y = ρx + c Figure 3 Projected minutiae x y y = ρx + c θ gp θ trans Figure 4 Translated projected minutiae θ ijh y x d d' r r' θ ijv δ ijh δ ijv Figure 5 Features of projected minutiae IV. EXPERIMENTAL RESULT Similar to [1] [8] [9], we use FVC2002Db2a for testing which is extracted by using Verifinger [11]. As these research, we use 2 impression, each of which comprises 100 fingerprints. In order to evaluate the capability to accept a legitimate fingerprint, we compare those in the first impression to the corresponding fingerprint in the second impression; and for evaluating the capability to reject an illegitimate fingerprint, we compare those in the first impression to all fingerprints in the second impression except the corresponding one. Therefore, there are 10000 fingerprint comparison. Those two evaluation represent Genuine Acceptance Rate (GAR) and False Acceptance Rate (FAR), respectively. A. Performance Let be the number of selected minutiae resulted from Section III(A). A minutia is represented by vectors; in turns, a fingerprint is represented by vectors. The value of depends on the minimum (Rmin) and maximum (Rmax) distance values being determined by the user. In the experiment, we specify the minimum distance by 11 as depicted in Table I. It shows the minimum (Nmin), maximum (Nmax) and average (Navg) numbers of selected minutiae. A high number of generated vectors may need more spaces to store in a database. The size of the template, nevertheless, is only kilo bytes. We believe that this size is not a significant problem for today technology. The result of the experiment is provided in Table II. It is shown that the best result is obtained when the depth level is 7; that is, GAR and FAR are 98% and 0, respectively. Decreasing the depth level raises both GAR and FAR; while increasing depth level reduces GAR and FAR. The Equal Error Rate (EER) of the same data can be plotted in Fig. 7. The False Rejection Rate (FRR) is defined as (100%-GAR), which represents the number of legitimate fingerprints that can not be recognized by the system. It is depicted that EER is 1% which is reached at about 1.2 of depth level. This is lower than that of [1][8] which is more than 2%; while in [9], the EER is not provided. In the real world, the selection of depth level depends on the application purpose. It may focus on either a high GAR, low FAR or equal error level. B. Security The transformation is one way. Eventhough the set of keys is given, it is hard to reconstruct the original fingerprint. This is because there is no exact position of the resulted

TABLE 1 NUMBER OF SELECTED MINUTIAE

Rmin	Rmax	Neighbor minutiae Nmin	Nmax	Navg
11	20	1	5	0.36
11	30	1	8	1.13
11	40	1	13	2.19
11	50	1	19	3.47
11	60	1	21	4.9
11	70	1	24	6.48
11	80	1	28	8.22
11	90	1	32	10.07
11	100	1	37	11.97
11	110	1	39	13.98
11	120	1	46	15.97
11	130	1	50	18.02
11	140	1	52	20

TABLE II GAR AND FAR VALUES OF VARIOUS DEPTH LEVELS

Depth Level	GAR (%)	FAR(%)
1	99	6.6869
2	99	1.303
3	99	0.1919
4	98	0.0202
5	98	0.0101
6	98	0.0101
7	98	0
8	98	0
9	96	0
10	96	0
11	95	0

Figure 7 Equal error rate of the proposed method -2 0 2 4 6 8 05 10 15 Error rate (%) Depth level Equal Error Rate (EER) FRR FAR m 1 m 2 m 3 m 4 m 5 m 6 m 1 m 2 m 3 m 4 m 6 m 5 m 1 m 2 m 3 m 4 m 5 m 6 m 1 m 2 m 3 m 4 m 6 m 5 (a) (b) Figure 6 Depth level checking (a) Depth level=1 (b) Depth level=2 transformed point. Instead, only the distance of the point is stored in the database. Moreover, not all minutiae are used in the transformation. So, their information is not in the template at all. In the worst case that the stored template can be revealed, not all fingerprint information can be obtained by attackers. V. CONCLUSION In this paper, the improvement of the projection-based fingerprint cancelable method is proposed. This method works by comparing the set of template and query vectors. In case the number of matched minutiae is higher than the specified threshold, then the fingerprint matched. Nevertheless, there is still a possibility to further evaluate the query whose value is less than the threshold by using the depth level. This method, which is evaluated by using a public database, has been able to increase the performance, which is represented by GAR, FAR and EER. In terms of the security, the stored template is only generated by some minutiae. This has made the transfomed minutiae does not contain all fingerprint information. REFERENCES [1] T. Ahmad and F. Han, "Cartesian and polar transformation-based cancelable fingerprint template," in The 37th Annual Conference of the IEEE Industrial Electronics Society, Melbourne, Australia, 2011. [2] D. Maltoni, D. Maio, A. Jain and S. Prabhakar, Handbook of Fingerprints, London: Springer, 2009. [3] N. K. Ratha, J. H. Connell and R. M. Bolle, "An Analysis of Minutiae Matching Strength," in Third International Conference on Audio- and Video-Based Biometric Person Authentication, 2001. [4] N. K. Ratha, S. Chikkerur, J. H. Connell and R. M. Bolle, "Generating Cancelable Fingerprint Templates," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 27, no. 4, pp. 561-572, 2007. [5] Z. Jin, M.-H. Lim, A. B. J. Teoh and B.-M. Goi, "A non-invertible Randomized Graph-based Hamming Embedding for generating cancelable fingerprint template," Pattern Recognition Letters, vol. 42, no. 2014, p. 137–147, 2014. [6] C. Lee and J. Kim, "Cancelable fingerprint templates using minutiae-based bit-strings," Journal of Network and Computer Applications, vol. 33, pp. 236-246, 2010. [7] S. Wang and J. Hu, "Design of alignment-free cancelable fingerprint templates via curtailed circular convolution," Pattern Recognition, vol. 47, no. 2014, p. 1321–1329, 2014. [8] T. Ahmad and J. Hu, "Generating cancelable biometric templates using a projection line," in The 11th IEEE International Conference on Control Automation Robotics & Vision, Singapore, 2010. [9] K. Xi and J. Hu, "Biometric Mobile Template Protection: A Composite Feature Based Fingerprint Fuzzy Vault," in IEEE International Conference on Communications, 2009. [10] S. Pankanti, S. Prabhakar and A. Jain, "On the Individuality of Fingerprints," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 24, no. 8, pp. 1010-1025. [11] Neurotechnology, "Verifinger 5.0," [Online]. Available: http://www.neurotechnology.com.