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OPPORTUNITY AND CHALLENGE ON FACE RECOGNITION GENERIC TO SPECIFIC FEATURE REPRESENTATION AND RECOGNITION STRATEGY

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Abstract-In this paper, we conduct survey about research in face recognition method. The purposes of this survey paper are to give brief about development challenge and opportunity related with state-of-the-art in face recognition method. Face recognition is multi-area research field covering computer vision, pattern recognition, and biometric. Application of face recognition in many areas such as entertainment, access control mechanism, law enforcement field, population field, security system become one of the factors driving the development of research in the field of face recognition. Recently there were shifting focuses in face recognition research, which is performance evaluation in dataset, that build in uncontrolled environment with very large number of subject. Opportunities and challenges related with the shifting focuses describe and discuss which cover: 1) dataset for face recognition, 2) robust feature extraction and representation, 3) recognition strategy. We also purpose the idea to develop generic-to-specific feature representation and recognition strategy that close to how human recognition identity from face image.
Keywords – face recognition, uncontrolled environment, large number of subject, generic-to-specific feature representation

1. INTRODUCTION

For more than four decades, research on face recognition techniques by computers has become one of the studies in the field of computer vision studied by many researchers [1]. Face recognition closely related to Biometrics, an identity recognition mechanism using physical characteristics. Biometrics is a solution to ensure the identity of a person based on "who you are", in contrast to conventional mechanisms based on "what you possess". Various alternative recognition systems that are highly reliable such as fingerprint, retina and palm-hand already implemented for various needs, but recognition based-on face has several advantages. In face recognition, data acquisition mechanisms can be performed without the cooperation of the subject to be identified [1][2][3], in contrast to the recognition system using fingerprints, retinas and palms, where the data acquisition process is highly dependent on the cooperation of the person / subject to be identified. Although data acquisition performed without the cooperation of the subject for identified, the quality of the acquisition data is at an acceptable level for the recognition process. The characteristics of the data acquisition process are not intrusive, which is particularly suitable for the development of seamless search / recognition systems such as surveillance security, border control, forensics, digital entertainment and more [1][2][3]. Another advantage of face-based recognition is the proximity to human identification, where face-based recognition is the most natural form of recognition [4], this is in line with the ultimate goal in the field of computer vision, which synthesizes / mimics the way human recognize object-using sense of sight. Some commercial utilization of face recognition system can be seen in table 1.

Table 1 application of commercial in-app face recognition [1]

Areas	Specific Application
Entertainment	Video game, virtual reality, training program, human-robot-interaction, human-computer-interaction
Smart cards	Driver license, entitlement programs, immigration, national ID, passports, voter registration, welfare fraud
Information security	TV parental control, personal device logon, desktop logon, application security, database security, file encryption, intranet security, internet access, medical records, secure trading terminal
Law enforcement and surveillance	Advance video surveillance, CCTV control, portal control, post event analysis, shoplifting, suspect tracking and investigation

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Common problems in face recognition can be expressed as follows: given a picture (still image or video frame), perform the process of identification or verification of one or more of the subjects contained in the image by using a stored face database [3]. The identification process is a 1: N match process, where the system assigned to recognize the identity of a given image (probe) by checking on a set of identities owned by the system (gallery). If the system guarantees that, the probe must be part of the gallery known as closed-set. Another condition known as the open-set, where the probe is not always a part of the gallery so the system other than recognizing the identity of the probe must also be able to declare an unknown condition (the probe is not in the gallery). The verification process is a 1: 1 match process, in which the system assigned to analyze two face images and decide whether the two images represent the same or different individual. For the verification process, image for testing generally not contain in training data.

The main challenges in face recognition are face image data containing variations of pose, illumination, expression, resolution, variance of acquisition devices and other natural characteristics. This condition raises the problem of fine-grained classification, a condition where the variance in the same class can exceed inter-class variance [5]. LFW is one dataset containing fine-grained classification problems, based on paper [6], the method that provides high performance in LFW can be divided into two categories: wide-model and deep-model. The wide-model approach seeks to provide a representation of the complexity of face image variance with representation on very high dimensions. While the deep-model is a model built through a deep-learning approach with a deep and complex architecture.

Recently there is a change of focus of challenges in the field of face recognition, where the original study conducted on dataset taken in controlled environment with relatively small number of subjects into dataset taken in an uncontrolled environment with a large number of subjects. Uncontrolled environment will provide richer variance condition on face image and increase difficulty in recognition process. Based on a focus shift in face recognition, we tried to review some approaches and techniques that have implemented in the dataset of uncontrolled environments with a large number of subjects. The results of this review are descriptions of challenges and opportunities for researchers in developing face recognition algorithms using datasets in an uncontrolled environment with a large number of subjects (which can be consider to be a sub-set close to real-world condition).

The reminder of the paper organized as follows: section 2 briefly review the development of datasets for face recognition. Face recognition as part of pattern recognition are describe in section 3.The challenges and opportunities in face recognition are discusses in section 4. Finally, in section 5 we are drawing some overall conclusions and recommendation for future research.

2. FACE RECOGNITION DATASET

The availability of a data-set that is public is one of the things needed in benchmarking an algorithm. Given the data-set that is public then the researchers can compare the proposed algorithm with other researchers to see the position of the proposed algorithm. For the face recognition process, there have been several data-sets that are public with large data coverage; the development of some data-sets can be seen in fig.1. Characteristics of some face recognition dataset data that are public or private and taken in an uncontrolled environment can be seen in table 2.

In the early development of data-set of face recognition, the acquisition process was done in a controlled environment such as FERET data-sets and PIE data-sets [6]. With controlled conditions there have been many methods / algorithms that can produce excellent performance in the ideal data-set [7][8][9]. However, when the method / algorithm are used in the implementation process where the acquisition environment is free, the model cannot generalize the uncontrolled environment that effect system performance decreases dramatically.

To provide assurance that performance during implementation is as good as during the experiment, the development of face-recognition data sets is performed in an uncontrolled environment. The FRGCC data-set is one of the defined data-sets taken in an uncontrolled environment with backgrounds in the office, hallway, out-door areas. However the FRGCC data-set retrieval process is done manually with a limited retrieval setting that limits the variance that may occur in real-world (there are still many unseen variability that have not been covered).

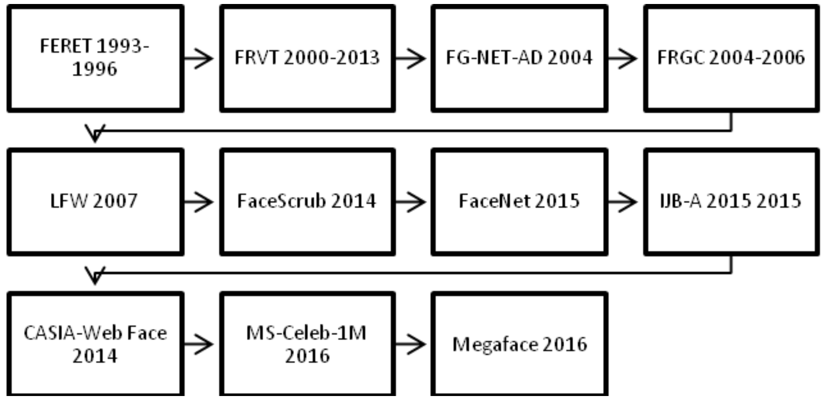

Fig. 1 The Development Of Some Data-Sets For Face Recognition From 1993-2016

The current trend in the construction of face recognition data-sets is through the mechanism of crawling data on the Internet (such as LFW, IJB-A, CasiaWeb, MegaFace, MS-1-Celeb), this mechanism is supported by the development of social media platforms and millennia lifestyle that likes to upload Photos of him through social media (Facebook, Instagram, Flickr). Data collection via the internet provides more number of subject as well as the richer data characteristic in terms of variation of pose, illumination, expression, resolution, variance of acquisition devices and other natural characteristics compared with the manual acquisition .

Table 2 comparisons of face recognition data-sets [10]

No	Data-set	Available	#Photo	#Subject	Year
1	LFW (Labeled Face in the Wild)	Public	13K	5 K	2007
2	CASIA-WebFace 2014	Public	494.414	10.575	2014
3	FaceScrub 2014	Public	100 K	500	2014
4	YouTube Faces	Public	3425 videos	1595 people	2011
5	MegaFace	Public	1.027.060	690.572	2016
6	DeepFace (Facebook) 2014	Private	4.4 Million	4 K	2014
7	FaceNet (Google) 2015	Private	>500 M	>10 M	2015

IEEE Spectrum Edition August 2016, reports that the development trend of face recognition research is aimed at large-scale data-sets (in the order of 1 million individuals). In 2016 researchers from the University of Washington held a competition in face recognition called MegaFace Challenge. Initial results reported on the Challenge MegaFace evaluation, the best performers were in the range of 75% (Google FaceNet), even the algorithms which achieve more than 90% accuracy on other datasets were decreasing in the 60% range and some were only 35% -1 with 1 M distractor). The basic idea of the MegaFace Challenge is that the algorithm in face recognition should be evaluated on public large-scale data sets. This idea also can be seeing in table 2, that indicate currently there is a change of focus of challenges in the field of face recognition, where the original study was conducted on data taken in controlled environment and the number of relatively small subjects into data processing in an uncontrolled environment with a large number of subjects. The most important thing related with dataset used in research that some datasets build for specific tasks, which is verification, or identification process. An ideal face recognition system is expected to have good performance both in identification and verification task.

3. FACE RECOGNITION AS PART OF PATTERN RECOGNITION

Recognizing the identity of a person through the face is one of the natural recognition mechanisms that can be done by humans very easily. The interesting thing about face recognition process is that this process is a very natural process done by human (human pattern) but we cannot understand how human can recognize pattern. One of the pioneering in the development of face recognition systems is Woodrow Bledsoe (1664), who developed a mathematical model in face recognition. Bledsoe (1966a) describes some of the difficulties in the face recognition process, which until now is still relevant for study by many researchers.

"This recognition problem is made difficult by the great variability in head rotation and tilt, lighting intensity and angle, face expression, aging, etc. Some other attempts at face recognition by machine have allowed for little or no variability in these quantities. Yet the method of correlation (or pattern matching) of unprocessed optical data, which is often used by some researchers, is certain to fail in cases where the variability is great. In particular, the correlation is very low between two pictures of the same person with two different head rotations" .Woodrow Bledsoe, 1966 [11]

Challenges in the development of pattern recognition science emerged at the time of the idea that the computer can recognize a person's identity through face images. Broadly speaking the face recognition process is a specific part of pattern recognition. Pattern Recognition (Pattern Recognition) is a discipline that deals with the development of methods / algorithms to perform

the descriptions of objects and the process of classification [12][13]. With the ability to make pattern recognition then humans can do analysis and consideration to take a decision. Hebert Simon one of the Nobel Laureate stated:
"The more relevant pattern at your disposal, the better your decision will be. This is hopeful news to proponents of artificial intelligence, since computers can surely be taught to recognize pattern. ... We need to pay much more explicit attention to teaching pattern recognition" [14].
Hebert Simon's statement shows that the development of methods / algorithms for representing objects into patterns is the key to making computers able to imitate the workings of humans that help improve the quality of human life. Broadly speaking, the pattern recognition approach divided into three, namely: Statistics, Structural or Syntactic and Semantics. The pattern recognition approach is not independent in principle, fig.2; in the sense of a pattern recognition system can contain multiple mutually supportive approaches.

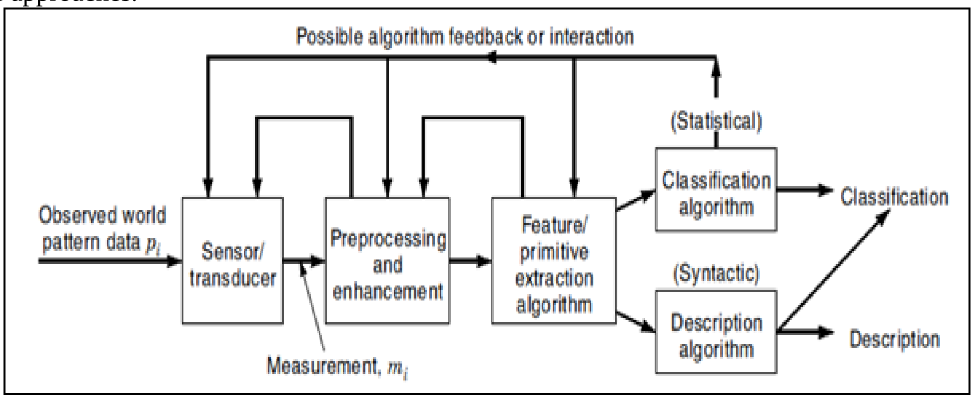

Fig. 2 Pattern Recognition System Elements [15] Reprinted from Generic Pattern Recognition System Element, John Wiley & Sons, 1992

A. Statistical Approach

In the statistical approach, the pattern represented in the form of a feature, which contain a numerical value in a dimension space, where the pattern of the same object will form a compact area in the dimensional space and reside in an area separate from the other object [11]. The region formed from the pattern mapping will provide a description of the decision boundary for making the decision [13]. In the statistical approach, the decision boundary is determined by the probability function of the pattern distribution that has been established or obtained by the learning process. The form of the decision boundary used can be either linear or non-linear. [15] [11] [13] In the statistical approach, the size of the feature for each object is described as having the same dimension and the relationship between feature are not considered so that the results of the introduction are difficult to explain through human logic and system performance is highly dependent on the distribution of training results data. The weakness in the statistical approach is the ability to overcome the emerging variance of an object arising from differences in illumination, differences in acquisition devices, differences in data acquisition orientation, natural changes in objects over time. This is because, in the statistical approach the feature / feature considered as a single entity of data so that the variance is likely to map data to the wrong decision boundary [13].

B. Structural/Syntactic Approach

The consideration of a structural/syntactic approach is the understanding that a pattern can be described and interpreted as an organization/hierarchy of a more primitive sub pattern (pattern primitive). The method in the structural approach consists of syntactic analysis and structural matching. The syntactic method of analysis is developed based on formal language theory whereas structural matching is developed based on the mathematical relation contained in the pattern-primitive. The challenge in the structural / syntactic approach is to design the pattern-primitive used to generate object representation [13]. Through a structural approach, the size of the representation for each object can be different and allows for combinatorial combustion in the representation size. It will require a large measure of training data and computational resources [11].The representation of the object in the structural / syntactic approach can be a string, graph, tree, PDL (Picture Description Language) where the inference process can use grammar, finite-state-automata approach, string matching, Hopfield network, matching graph / tree [13][15].

C. Semantic Approach

Statistical and structural / syntactic approaches demonstrate good performance in application in various fields, but the classic problem of whether the recognition process has successfully mimicked human work remains unanswered. A semantic approach aims are to produce a recognition system where the recognition results and processes easy to be understood / traced by humans. The initial stage in the semantic approach is to map / build relationships between feature in the semantic representation (High-Level Feature) with low-level features (statistics or structural) [16] [17] [18]. The limitation of low-level features in representing features makes semantic approach very difficult to implement in open-domain applications [16] [18].

The greatest challenge in the semantic approach of object recognition is how to generate a semantic feature in which the feature is a common understanding/ perception for everyone. One of the proposed semantic-based vague image representation (SVIR) mechanisms by mapping pixel data into primitive forms that have semantic meanings such as circular, sloping, triangular [19], but it can be said that the domain of application of mechanism This will be limited to some special applications. In the face recognition field, one of the proposed semantic-based recognition frameworks is the semantic face graph-based Fourier Descriptor [20], which includes matching and yields face caricature. Initial testing on small datasets shows a promising performance. Another development of the application of semantic approaches used to building a mapping system of the forms / components on the face into words / languages that can help the user to perform face reconstruction based on the visual semantic data available and selected by the user [21].

4. OPPORTUNITY AND CHALLENGE

This section discusses the opportunities and challenges in developing a face recognition system on elements: datasets for face recognition, feature extraction and representation, recognition strategy.

A. Dataset for Face Recognition

Encouraged by the growing availability of data, a question arises as to the impact of image quality available on the development of face recognition systems. This is discussed in [22], which review of image quality and its impact on face recognition system performance. Two of measurement proposed called Discriminability Index (DI) for the quality of enrollment and Reliability Index (RI) data, for data quality during testing. Discriminability index (DI) is calculated by likelihood probability approach based on similarity in data used for enrollment. Each data enrollment will have a DI value; DI value is used as one of the guidelines at the time of matching process where a high DI image will have higher matching scores. The measurement of RI was done by searching the outlier data that was tested by using Q-test. At the time of data assessment that has RI value that is under certain threshold then the data is removed from data testing so that the amount of data testing will decrease.

Another interesting thing to look at is whether we need to collect large amounts of face data to produce a reliable face recognition system. Considering the cost and time needed to download face images and manually labeled identity is a expensive and also exhausting task. An alternative way offered to enrich the content of training data is to use data augmentation and face synthesis techniques [23][24]. Respectively, there were two different approach using face synthesis techniques which are: 1) produced frontal faces which are presumably better aligned and easier to compare [23], 2) produce new image with different appearance variations in pose, shape and expression [24]. The goal of data augmentation and face synthesis techniques is to develop effective face recognition system on condition there were limited / small scales training dataset to provide good performance during testing on large scale datasets and also in implementation (real-world condition).

A large number of data that has been collected in several dataset can be considered a breakthrough in an attempt to reduce the gap between experimental data and real-world conditions. This condition poses challenges and opportunities for researchers in utilizing large-scale data to formulate a robust and powerful feature extraction method for face recognition task.

B. Feature Extraction and Representation

Feature extraction and representation became a key element in developing face recognition systems, such as those exposed by Woodrow Bledsoe and Hebert Simon. The goal of feature extraction and representation is to produce a robust feature despite the existing data contains high variations in pose, lighting, device difference, face attribute, biological factors such as age. The face feature is expected to contain information that differentiates between individuals and other individuals. Associated with the extraction process of face recognition feature, there are two main approaches in feature extraction process: feature-based / local feature and holistic (consisting of statistical approach and AI approach).

Characteristics of data in an uncontrolled environment with a large number of subjects create a fine-grained classification problem making it difficult to produce good recognition performance. The Labeled Face in the Wild (LFW) dataset, released in 2007, is one of the pioneers of data-sets with a large number of subjects (+ -5000 subjects) and data taken on uncontrolled environmental conditions (data collected over the internet). In recent years, the performance of the face recognition that used LFW dataset algorithm has increased significantly; reported performance by some researchers has exceeded 95%, show in table 3, with two categories: wide-model and deep-model. However, in conditions where the tests were performed on data-sets with large scale and distractor (not-for-recognize subject) numbers, MegaFace Challenge, there was a significant decrease in performance for facial recognition algorithms with high performance on LFW. The preliminary evaluation results from the MegaFace Challenge provide an illustration that under uncontrolled environmental conditions with a large number of subjects the problem of generating a robust feature for recognition is still an open-problem in the face recognition field.

Table 3several research result in lfw

No	Feature Extraction Method / System name	Model Category	Best performance reported
1	High-Dimension LBP [25]	Wide-model	95.17%
2	Gausiian Face [26]	Wide-model	98.52%

3	MRF-Fusion-CSKDA [27]	Wide-model	98.94%
4	High-Dimensional Gabor [28]	Wide-model	95.25%
5	MDML-DCP [29]	Wide-model	95.58%
6	DeepFace [30]	Deep-model	97.35%
7	DeepID [31]	Deep-model	97.45%
6	FaceNet [32]	Deep-model	99.63%

A wide-model and deep-model approach that has demonstrated good performance can be used to build a combination of features to produce robust features and overcome the existing data variance. Fusion approach can be done with an early-fusion scheme (at the level of feature) or a late-fusion scheme (at the decision-making level). Opportunities and challenges in combining several features are to determine the features that can complement each other to provide a more discriminator feature.

One of the challenges in developing face recognition systems is to convince people of the truth and validity of the process. In implementation in the field of forensic investigation, the outcome must be communicated verbally to the jury or judge [33]. The feature extraction with wide-model and deep-model approach is more intended as machine consumption compared to humans so that the resulting output is a numerical score used to indicate whether or not the probe data with gallery is match. To bridge the needs of face recognition that can be communicated verbally with the existing facial recognition system, it needs a comprehensive feature extraction process. The meaning of the extraction of comprehensive features in question is that the algorithm to be developed has the working principle of expanding and completing the point of view to be able to produce an appropriate and complementary representation of the characteristics. The combination of wide-model, deep-model and semantic-based extraction approach becomes a realistic choice to produce a high-accuracy facial recognition system and can provide verbal descriptions that can be understood by humans.

C. Recognition Strategy

The recognition process is the final stage of the face recognition system, where the end result of the recognition can be: 1) identification the identity of the probe image, or whether the probe image is registered in the database, and 2) verification, match decision between pair face image. In this section, we will mainly discuss the recognition strategy for the identification process.

With the large number of subject in the gallery, the main challenge for identification is not only the accuracy but also the time process. Conventional recognition for identification conduct a 1: N matching that will provide N 1:1 score to make decision for identity, this mechanism will take a long time depend on the gallery size. The question that arises is how do we speed-up the identification process regarding the large gallery size? One approach that can be used to overcome this problem is by using indexing and tree base search; it will reduce the size of solution space (similar with route search process) and speedup the recognition process.

The development search strategy for indexing and tree based search highly dependent on the feature representation provide by feature extraction process. We plan to develop a face representation that contains information from the general level to the specific level of a person's face; we named it as generic-to-specific feature representation. With the availability of generic-to-specific feature representation, the recognition strategy to be performed can mimic the workings of humans in the selection process. Suppose that in the case of choosing a partner, humans begin by setting general criteria for example: age, ethnicity, occupation and others to filter out the available options. The same process can be done in recognition task (identification), where the process of recognition is done by cascade recognition that begins with generic matching by filtering the suspected list (gallery) base-on the gender-ethnic-age-eye color of probe data; it will narrow the solution space for specific matching process. This search mechanism will provide a verbal explanation, understandable to humans, of how the search process performed. Related with feature extraction and representation section, combination of wide-model, deep-model and semantic-based extraction approach, it can be expected that semantic features such as: gender, ethnic, age, face shape, scar, etc., will be at the generic level and the features of deep-model and wide-model are at a specific level.

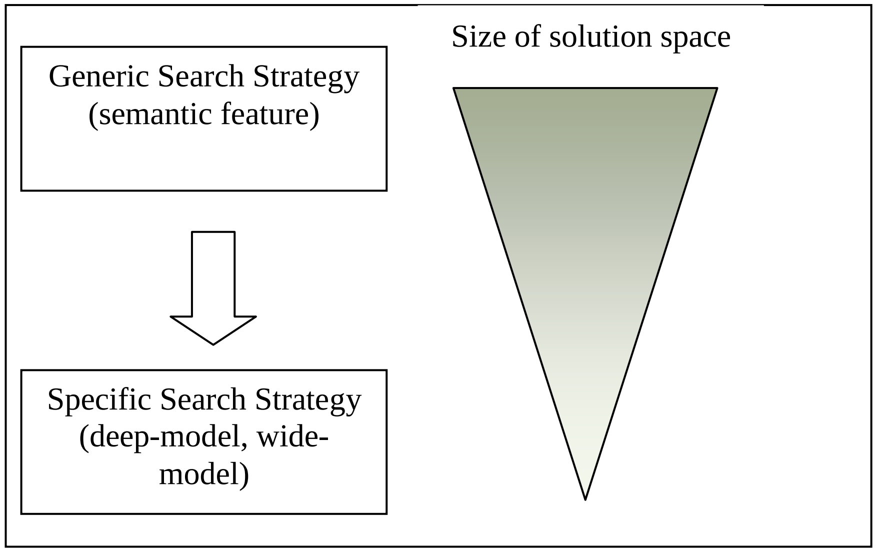

Fig. 3 Illustration of Recognition Strategy for Identification

5. CONCLUSIONS

In this paper we have reviewed the development of face recognition especially on the development of benchmark datasets and feature extraction approaches. From the results of the review we can convey that the classical challenges in face recognition, how to handle high variations in pose, lighting, and device difference, face attribute, biological factors such as age, are still relevant to examined more deeply. The existence of a gap between the mechanisms of recognition by humans versus machine became an interesting aspect for future studied, especially in face recognition. We plan to develop a generic-to-specific feature representation by combine wide-model, deep-model and semantic-based extraction approach to support recognition process (identification) that can provide an explanations about the inside process to convince people of the truth and validity of the process. Finally we believe that the development of large scale dataset in uncontrolled, comprehensive feature extraction and recognition strategy approach that closer to how human work, promise to take research in face recognition field to the next level.

6. ACKNOWLEDGMENT

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