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FIRST: Face Identity Recognition in SmarT Bank

Qianmu Li
School of Computer Science Technology and Engineering, Nanjing University of Science and Technology, Nanjing, China
qianmu@njust.edu.cn

Tao Li
School of Computer Science, Florida International University, Miami, FL 33199, U.S.A.
taoli@cs.fiu.edu

Bin Xia
School of Computer Science Technology and Engineering, Nanjing University of Science and Technology, Nanjing, China
bxia@cs.fiu.edu

Ming Ni
School of Computer Science Technology and Engineering, Nanjing University of Science and Technology, Nanjing, China
mni@cs.fiu.edu

Xiaoqian Liu
School of Computer Science Technology and Engineering, Nanjing University of Science and Technology, Nanjing, China
xialiu@cs.fiu.edu

Qifeng Zhou
Automation Department, Xiamen University, Xiamen, China
zhouqf@xmu.edu.cn

Yong Qi
School of Computer Science Technology and Engineering, Nanjing University of Science and Technology, Nanjing, China njqiyong2003@yahoo.com.cn

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The rapid development of information era has influenced to realize the notion of *Smart Bank* via approaches like paperless services and interactive self-service systems. Since the traditional methods of identity verification are insecure and cumbersome for supporting these services, *Smart Bank* has been questioned. To overcome the limitations of current identity verification, it is imperative to explore an effective recognition strategy considering the trade-off between security and customer experience, which can conveniently collect identity information and accurately distinguish people. However, few research and existing systems have been reported for an integrated solution of identity verification satisfying convenient and secure banking environment.

In this paper, we propose, implement, and deploy an integrated system named FIRST(Face Identity Recognition in SmarT Bank), which is a customized platform for the identity verification via face recognition in *Smart Bank*. FIRST uses Gabor surface feature and Fisherfaces, which can provide accurate face recognition within acceptable training time. For information acquisition, our system employs the patch-based face quality assessment, which efficiently extracts valuable faces(i.e., front face) from video streams. Furthermore, FIRST provides a distributed environment to effectively manage recognition tasks and massive data. Since March 2015, FIRST has been successfully deployed on 1800 self-service terminals in Jiangsu Province by ABC(Agriculture Bank of China)[a], and is under deployment by State Grid in China.

Keywords: FIRST; identity verification; Smart Bank; integrated platform; Big Data.

1. Introduction

Banks are important components of financial system and have a huge impact on the national economies. However, the traditional business model of banks(e.g., counter service) hardly satisfies customers' demands such as long wait-times. To this end, banks are concentrating on introducing better workflows and modern technology services such as automated teller machines(ATMs). The attempt to utilize the benefits of modern technology has introduced the novel concept of *Smart Bank*, such as video banking, mobile banking, and electronic relationship management. These intelligent and self-service methods can provide customers with convenient services, however, the secure strategy for transaction, such as identity verification, becomes an important challenge in the banking environment.

Facing the challenge of transaction security, people have employed lots of strategies for identity verification, such as password, signature, and personal ID. However, in practice, the password and signature can be easily leaked and imitated, and even the government-issued ID Card which is unique and hard to be duplicated also has potential threats where the misusing of the lost or stolen ID Cards will betray the *Smart Bank* services like the self-service unit.

To overcome the limitations of existing identity verification, we present an effective solution to construct a *Smart Bank*, by employing face recognition [17, 7] as the supplementary strategy of identity verification to improve the service security. The overview of the solution is illustrated in Fig 1. The major components of the solution are:

- *ATM.* To prevent the potential threat such as password leaking and large cash withdrawals, besides the visitor, other people near ATMs will be observed. If any abnormal behavior (e.g., deliberately obscured face or multi-

[a]News: http://goo.gl/QeZmuR;
Application Video: https://goo.gl/FMZ6sk

face) was detected, ATM will decline the current transaction, and raise warnings to inform the monitoring center.

- *Counter*. In counter services, as a supplementary method of identity verification, face recognition can assist bank staff in verifying visitors and record the transaction process.
- *Entrance*. By employing face recognition, the visitor can be instantly recognized and verified when he(she) steps into the bank. Then, according to the personal information, the staff who has ever served the visitor will provide him(her) with appropriate guide. On the other hand, if the profiles of people near the entrance are not stored in the bank database, their behaviors will be tracked for checking whether they are potential customers or not.
- *Vault*. As the most important security area, the permission to vault is strictly managed. The face recognition, in this area, is used as a supplementary identity verification strategy, and also for tracking the number of people entering and leaving the vault.
- *Office*. In this area, face recognition provides staff with an efficient solution to conveniently access the office, without the password or ID Card.
- *Cash Van*. By combining face and plate recognition with RFID technology [19] and smart tripwire technique, the security system can guarantee the parking garage for the cash van. In addition, the real-time monitor, which detects strange movements, is provided while the cash van is under working.

However, there is a significant application gap between the practice and technologies of face recognition, due to numerous data, verification rate, and efficiency of response.

To bridge the gap, it is imperative to construct an integrated identity verification platform to achieve the effective practical application in complex banking environment. Lots of verification strategies have been employed in various domains, and have been getting matured [13, 20]. However, few research and existing products have been published on providing an effective identity verification in banking environment with an integrated solution or verification support platform to improve the customer experience and to protect the transaction security. The objective of FIRST is to build such a cloud-based platform to bridge this gap.

1.1. *Challenges and Proposed Solutions*

According to the report published by Central Bank of China: by the end of 2014, the number of ATM has reached 0.6419 million, which was increased of 18.25% compared with 0.52 million by 2013 [1]. Furthermore, RBR (Retail Business Review) indicates that the global ATM holding capacity will greatly increase to 4 million by 2019, especially in Asia [2]. The booming self-service terminals represent the rapid development of self-service, however, they are often compromised by security vulnerabilities. The numerous self-service terminals, which are dispersed and working

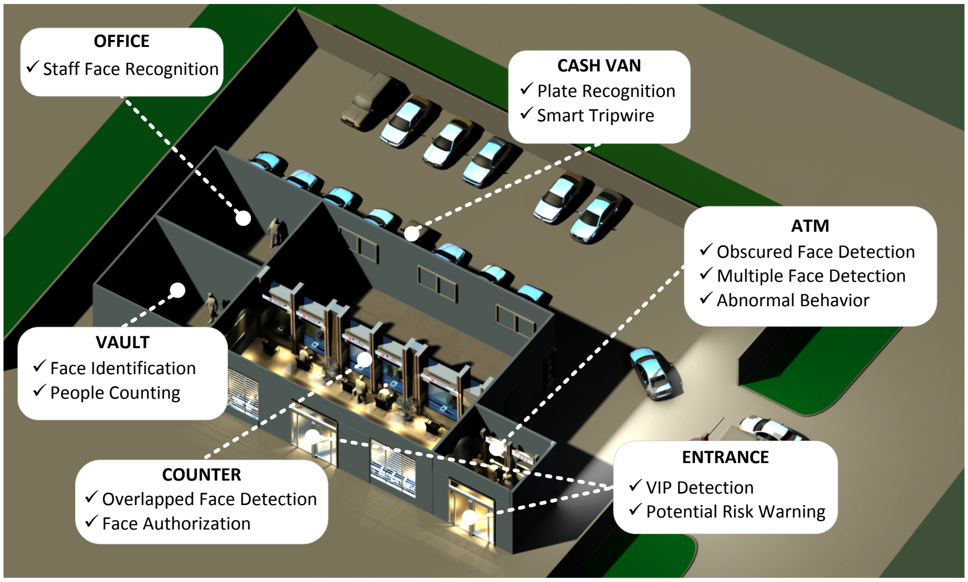

Fig. 1. Smart Bank Solution

all day, are difficult to manage and monitor.

The numerous visitor flow, dispersed spots, and high security requirement, all of these conditions show a great challenge to transfer counters services to self-services for optimizing the efficiency and effectiveness of business. Based on our long-term research with the data from ABC(Agriculture Bank of China), we have identified three big challenges, and also proposed the corresponding solutions.

Challenge 1. How to efficiently select the most valuable faces from information streams collected by video cameras?

In practice, it is impossible to analyze each frame of video streams collected by cameras at every moment, and it is too time-consuming to transmit videos for the real-time response requirement of banks. Hence, it is imperative to address the problem of selecting valuable faces for recognition. To handle the complex demand of banking environment in Challenge 1, we employ a face quality assessment algorithm [32] to evaluate each frame, and only those valuable frames are uploaded for face recognition. In addition, based on different security levels of identity verification, the number of uploaded personal faces can be dynamically adjusted.

Challenge 2. What is the appropriate identity verification strategy to meet the demands of the complex banking environment?

Existing products, such as FACE++ [12], are mostly utilized in the domain of check-in, where the face dataset only contains a fixed and small set of people. The verification strategy should be effective and scalable for the growing customer data.

Thus, it demands that the recognition model can be efficiently trained or updated dynamically(e.g., Online Learning).

To address this problem, we utilize the Gabor surface feature [34] to represent faces and Fisherface [3, 22] to distinguish different faces. The effectiveness of Gabor surface feature, which is an LBP-based(Local Binary Pattern) strategy including gradient and magnitude information, has been fully proved by [11, 34]. In comparison to the existing deep learning based approaches [25, 24, 36], Fisherfaces [3] can effectively reduce the dimension of features and classify samples in subspace using Fisher's Linear Discriminant. It spends much less time on training models, and also is able to dynamically add a small number of new faces without re-train the subspace.

Challenge 3. With the employment of face recognition system, how to collaborate with all sensors setting in banks? Facing the booming data, which is collected at every moment, how to store and make use of the data for improving the quality of services?

As we mentioned above, the current monitoring system is dispersed, and requires lots of manual intervention. Furthermore, the collected videos and images are valuable for the improvement of banking business, such as optimizing the layout based on user habits and evaluating security accidents. Hence, it is imperative to develop an integrated system, which can efficiently handle requests from each terminal and effectively manage booming data collected at every moment.

To address this problem, we design and implement a *Recognition Support Platform* based on FIU-Miner, which is an integrated and distributed system [35]. *Recognition Support Platform* provides a series of functionalities, which can systematically conduct booming concurrent tasks and conveniently manage vast amounts of data. Furthermore, the collected data (e.g., faces and videos) can be classified based on different defined events, and analyzed using appropriate machine learning approaches.

Our proposed recognition platform FIRST is a user-friendly and scalable system, which supports algorithm customization and event definition, for the complex face recognition tasks in banking environment. Since March 2015, FIRST has been successfully deployed on 1800 self-service terminals in Jiangsu Province by ABC(Agriculture Bank of China)[b], and is under deployment by State Grid in China.

1.2. *Roadmap*

The rest of this paper is organized as follows. In Section 2, we describe the overview of our proposed system, starting from the system architecture, followed by introducing details of *Face Recognition Module*, including data preprocesser, face recog-

[b]News: http://goo.gl/QeZmuR;
Application Video: https://goo.gl/FMZ6sk

nitioner, and result manager. Section 3 introduces the face quality assessment algorithm, which can efficiently select the valuable faces from video steams for recognition, and flexibly adjust the capacity of uploaded images based on different practical environments. In Section 4, we present the workflow of Fisherfaces face recognition based on Gabor surface feature, where faces can be effectively distinguished using this representation. Section 5 describes an integrated infrastructure of system, which supports *Face Recognition Module* and effectively manage tasks and data. In Section 6, we show the system deployment, in which system performance is evaluated and some practices are presented. Finally, Section 8 concludes this paper.

2. System Architecture Overview

The system architecture of FIRST is shown in Fig 2. The overall framework is composed of two major components: *Recognition Support Platform* (including *Physical Resource Layer*, *Computing Resource Layer*, and *Task Management Layer*) and *Face Recognition Module.*

Recognition Support Platform acts as the core infrastructure of FIRST and provides an integrated and user-friendly system framework for face recognition in the distributed environment. Based on *Recognition Support Platform*, each recognition task is configured and arranged as workflow, and is scheduled by the system. We will describe this concept in Section 5. Meanwhile, *Face Recognition Module*, which consists of three important sections, including *data preprocesser*, *face recognitioner*, and *result manager*, plays a key role in FIRST. This module provides integrated solutions of face recognition, and feedbacks in the vivid visualization. Details on the module is provided in Section 4 by presenting a step-by-step face recognition.

2.1. *Recognition Support Platform*

Traditional face recognition products and existing researches have three crucial limitations in practical application [13, 20, 34]: (1) They only have stand-alone applications or APIs of web-service, which provide basic functionalities of face recognition; (2) They do not provide the interaction with official department for authorized data; (3) They consider less on the development of system, such as the storage of large amount of faces and the concurrency of increasing requests.

To overcome these limitations, the recognition support platform utilizes the large scale data mining architecture called FIU-Miner [35]. Compared with the limitations of existing products, the recognition support platform offers the following advantages:

- *Integrated system architecture.* Besides the related face recognition algorithms, the task management and physical resource modules are integrated in our system. The cloud server is developed as a full service system integrator specializing in efficient resource storage, effective job management, and accurate face recognition.

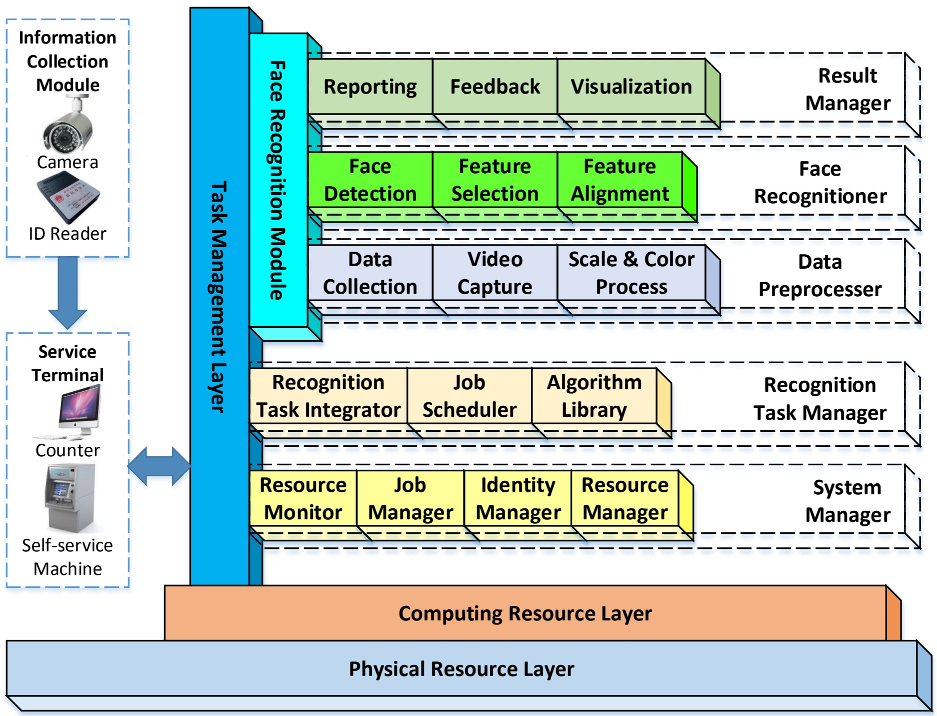

Fig. 2. System Architecture

- *Professional data support.* The official personal information is provided by the governmental department in real time. The result manager incorporates these authorized information to generate professional reports for diverse needs.
- *Effective task and resource management.* To address the increasing concurrent requests, the priority of tasks is evaluated by various conditions such as maximum response time, server load balance, and estimating time consumption. We extract features of each face from the data and represent them as indices for efficient search [9].

2.2. *Face Recognition Module*

2.2.1. *Data Preprocesser*

In this module, the *data collection* and *scale and color process* mainly provide clear materials to ensure the accuracy of recognition in *face recognitioner*.

Data Collection preprocesses the meta-data from video streams, and provides distinct images containing valuable information. Since it will directly affect the responding efficiency of system, collecting and processing valuable data in limited time becomes a big challenge. Fortunately, Viola et al. [29] proposed a detection architecture, which is capable of processing the video streams swiftly while maintaining the high detection rates. Furthermore, with the advancement of new researches, these algorithms achieve the desired accuracy and speed, and some of them even support face tracking [18]. Based on these technologies, *data collection* is able to upload the most valuable images within least transmission resources.

Image Process provides lots of approaches, which improve the image quality, to ensure the reliability of recognition. Including the redundancies (noise) elimination and image enhancement, this step can filter the environmental interference effectively and efficiently. Thus, the appropriate *image process* allows the system to detect faces among the complex background, and accurately extract features without redundancies.

2.2.2. *Face Recognitioner*

After receiving the preprocessed image selected from video streams, *face recognitioner* extracts faces and compares them with their corresponding ID-face (i.e., image data from authorized ID card). All approaches in the algorithm library, including the detection, feature extraction, and alignment, can be well organized as integrated procedures in this module. *Face recognitioner* mainly consists of the following functions:

Face Detection is a basic technology to discover faces from the image, including the position, size, and orientation. The detection algorithms are mainly based on the priori and posterior knowledge (e.g., statistics). Considering the application environment in this paper, the later one is more appropriate. Based on the detection algorithm using boosted features [28], the face can be rapidly detected in low-resolution environment.

Feature Extraction contributes in the following ways: (1) searching for the description to distinguish faces; and (2) decreasing the dimension of data while maintaining the difference between faces. In the extraction process, we should be aware of following aspects: (1) the face is non-rigid object, thus, the same person will have different colors and facial expressions; and (2) shelters from non-biometric objects (e.g., glasses, hairs, or jewelries) will bring more challenges [26]. By selecting and grouping robust face features, this module can enhance the efficiency of extraction, and address the problems of shelters.

Feature Alignment is the procedure of face verification (i.e., analyze the similarity) and face match (i.e., feature classification), based on the analytic results from *feature extraction*. However, different alignment algorithms may show totally different results based on the same feature representation. Hence, to tackle the limitation of individual method, several strategies are deployed in our system and users can flexibly configure them.

2.2.3. *Result Manager*

The results of face recognition can be displayed in three types: (1) simple feedback; (2) visualization; (3) comprehensive report. *Simple feedback* just provides 'TRUE' or 'FALSE' for each face recognition task. Since the feedback is so lightweight, it is always employed in the high prior task which needs swift response. Different from the *simple feedback*, *Visualization* is designed for the demand of monitoring, and users can recheck the event, which has high security level. *Comprehensive report* collects all events during the period, and combines with results from *simple feedback* and *visualization* as a summarization.

3. Face Quality Assessment

The efficiency of collecting data is imperative in applications. For example, if a VIP was recognized as soon as he(she) stepped into the bank, the staff, who is specialized in corresponding business or has served him(her) before, will provide him(her) attentive services. Furthermore, increasing the recognition speed cannot only decrease the service time, but also detect the potential security risk. However, it is a challenge to extract the most informative snapshot from video streams. Especially, our system is deployed on the cloud, the size of uploaded images directly affects the efficiency.

The issue of key frame selection for video summarization has been studied in the 1990s [6], and many innovative works have been proposed recently [8, 27, 4]. These studies have attempted to extract the visual features from the video (e.g., gray histogram and color information of RGB channels), and to select the valuable images as the abstract of video. Furthermore, [32] has suggested that quality of face image should also be incorporated for video-based face recognition. As observed in Table 1, the recognitions, which have higher verification rate, basically include two characteristics: (1) upright face and posture; and (2) high resolution. The former one can be solved by optimizing the position of camera, however, the latter one is a trade-off problem between the accuracy and efficiency.

In our system, to optimize the selection of uploaded images while maintaining the accuracy, it is necessary to discover the most valuable faces which satisfy the following conditions: (1) the uploaded images contain all faces which are appeared in camera view; (2) the data needs to be as small as possible; (3) each face in uploaded images should be representative. Inspired by [32], we propose a face quality assessment to filter uploaded faces, while maintaining the efficiency. More details of the algorithm is shown in Alg 1.

As shown in Alg 1: (1) Step 1 is to reduce the difference (e.g., the skin tones) between given frames based on the logarithm normalization that can effectively magnify low-intensity pixels while compressing high-intensity ones [5]; (2) for adapting to the variations between faces, Step 2 is to normalize each patch to obey the normal distribution [33]; (3) Step 3 is to retain the low-frequency components containing the facial textures, which contain the personal specific information [33]; (4) based

Algorithm 1 Face Quality Assessment

Input:

F: the frame of video streams;
M: the count of patches;
m: the size of each patch;
t: the size of overlapping pixels;
c: the count of low-frequency components.

Output:

$Q(F)$: the quality value of the given frame F.

1: Firstly, we employ the logarithm normalization to reduce the dynamic range of the given frame F:

$$F_{log}(x, y) = ln(F(x, y) + 1),$$

where $F(x, y)$ represents the pixel intensity at the coordinate (x, y) of F.

2: The normalized frame (image) F_{log} is averagely divided into M overlapping and $m{*}m$-pixel patches, where each patch overlaps adjacent ones by t pixels.

3: Extract 2D-DCT (Discrete Cosine Transform) feature vectors from each patch, and top c low-frequency components are retained excluding the 0-th DCT one.

4: The probability of the feature vector x_l of the corresponding patch located at l is calculated utilizing the location specific probabilistic model:

$$p(x_l|\mu_l, \sum_l) = \frac{exp[-\frac{1}{2}(x_l-\mu_l)^T \sum_l^{-1}(x_l-\mu_l)]}{(2\pi)^{\frac{d}{2}}|\sum_l|^{\frac{1}{2}}},$$

where μ_l and $\sum_l$ are the mean and covariance matrix of a normal distribution, respectively.

5: The overall quality value Q of the given frame F is calculated by:

$$Q(F) = \sum_{l=1}^{N} log(p(x_l|\mu_l, \sum_l)).$$

on the 2D-DCT feature vectors extracted from the patches in Step 3, Step 4 is to calculate the probability of patches' feature vectors using the specific probabilistic model, where the model is trained using frontal faces with the fixed scales; (5) In Step 5, we evaluate the face quality of the frame using the probability of each patch's feature vector calculated in Step 4. The higher quality score $Q(F)$ represents the better frame quality that has the most valuable faces.

4. Fisherfaces Face Recognition

The advancement of computing systems has influenced modern banks to incorporate interactive self-services. This provides efficient customer support and reduces human interventions. However, in practice, banks have to limit the categories of advanced services, since the identity verification is vulnerable. To address this problem, an important challenge is to employ a 'password', which is unique, unable to be stolen, and conveniently memorized.

In recent years, the increasing number of researches about face recognition have been studied [36, 23, 10]. People found that, as a biometric feature, the face information has the following advantages in identity verification: (1)conform to human recognition habits; (2)complete official database; (3)healthy non-contact verification; (4)collected covertly and concurrently. Thus, many face recognition products have been developed in our daily lives, such as check-in system. However, due to extreme security concerns, only few application for face verification is designed, implemented, and deployed for banking environment. This is our huge motivation to improve traditional face recognition strategy for adapting the corresponding requirement.

Based on the existing mature researches on face recognition and the demands of modern banking environment, we are encouraged to design and implement an effective and integrated framework of face recognition. Fig 3 shows the workflow of training and verifying faces based on Fisherfaces, in which hollow and solid notations respectively present training and verifying processes.

As shown in Fig 3, *Face Recognition Module* has four major functionalities to extract features representing faces:(1)*ASMLibrary*, which is a fast face alignment algorithm [30]; (2)*Homomorphic Filtering and Histogram Specification* that addresses the effect of illumination; (3)*Gabor Surface Feature* presents faces using the information of Gabor magnitude pictures [34]; (4)*Fisherfaces(LDA)* intends to calculate the eigenvector for projecting faces in subspace [3, 15]. Fisherfaces, which is the core of our face recognition module, utilizes a class specific linear method, Fisher's Linear Discriminant(FLD), for dimensionality reduction and classification in the reduced feature space. The idea of FLD is straightforward: samples that have same classes should cluster closely, while ones that have different classes should be as far as possible from each other in lower dimensions. To this end, FLD is to find the combination of features for representations and maximizes the ratio of the between-class and the within-class scatters. In comparison to the deep learning based approaches [25, 24, 36], FLD can effectively reduce the dimension of features and spend much less time on training model. Facing the rapid update of customer information in the banking environment, FLD is able to dynamically add a small number of new faces without re-train the subspace.

5. Distributed Cloud Servers

Existing products, such as, Face++ [12], have accurate verification rate and convenient online API. However, facing the high demand of security in banking environment, safer recognition strategy, more multiple concurrent requests [37], and more flexible resource management should be considered in the system. Hence, in order to guarantee the effective operation of *Face Recognition Module* and to satisfy the corresponding demand, the distributed cloud server is designed and integrated into FIRST [35].

As shown in Fig 2, the infrastructure of system, which is also called *Recognition Support Platform*, mainly contains two modules: *Physical Resource Layer* and *Task*

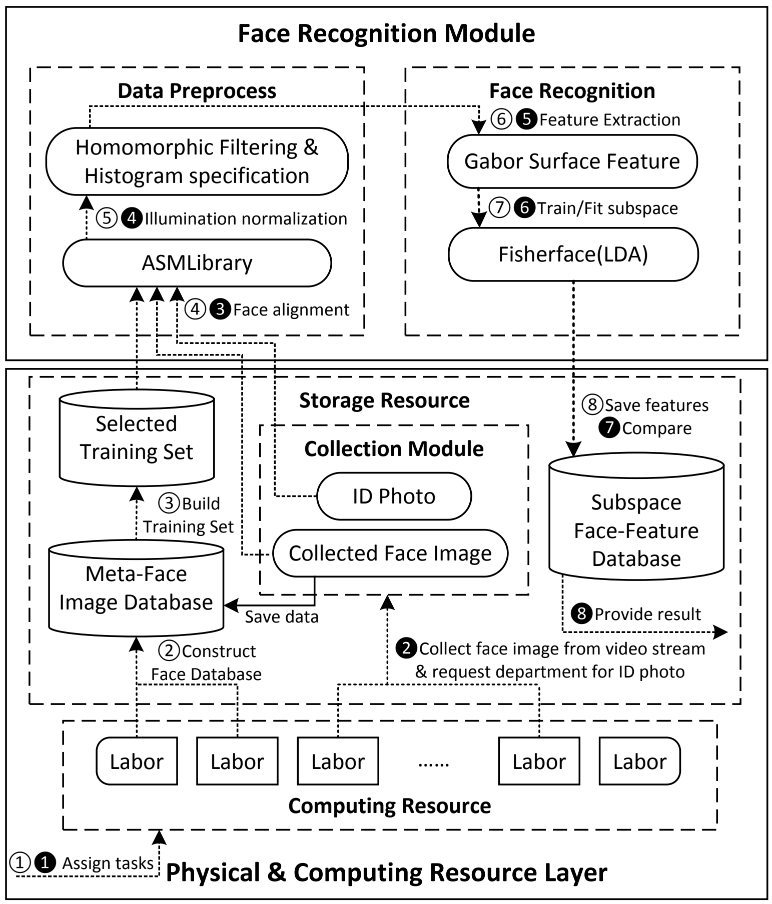

Fig. 3. The workflow of training/verifying faces

Management Layer. Fig 4 presents the mechanism of *Recognition Support Platform*.

5.1. *Task Management Layer*

In this section, we provide the step-by-step workflow (See Fig 4 for systematically introducing the mechanism of Task Management Layer. As mentioned above, various algorithms [14, 30] registered in *Algorithm Library*, can be freely picked by users for the configuration of face recognition. After selecting the recognition algorithm and defining the security event, *Recognition Task Integrator* conducts a test to validate the integrated module. If this integrated module passed the validation, FIRST will process the upcoming request employing the new combination of algorithms. If

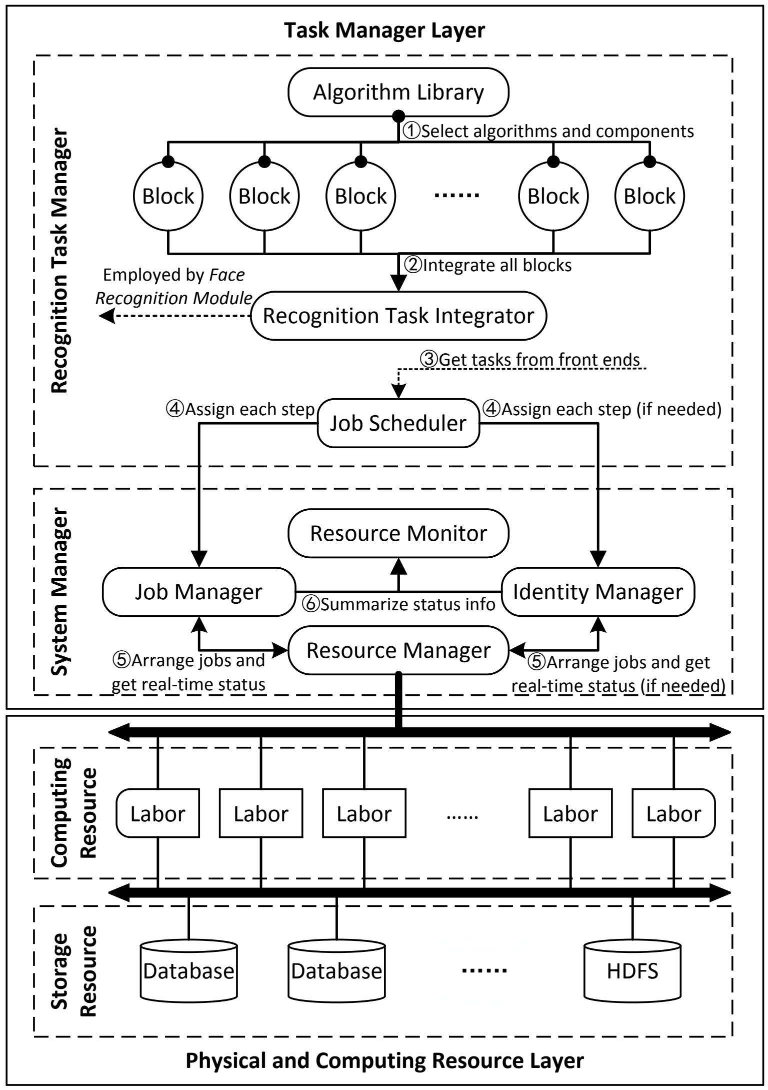

Fig. 4. The mechanism of Recognition Support Platform

the result of validation did not meet the application requirements, the combination will be reconstructed automatically.

With each coming task request, *Job Scheduler* will estimate the time consumption and resource, and assign the corresponding job to idle *Labor(s)*, which is(are) under management of *Resource Manager*. Actually, in practical applications, each task may demand different running time and priorities. Moreover, with the booming requests, the increasing I/O cost will greatly decrease the efficiency of decomposing tasks. To address these challenges, FIRST adapts the concept of FIU-Miner [35] and considers the following strategies:

- the priority of task (i.e., high requirement of response).
- the estimated data size transmitted during the entire process of task.
- the time consumption of each step in the task.
- the current state of each *Labor*, including maximum supported computing environment and current computing load.

In addition, the strategies also can be flexibly configured by users based on different practical demands.

After the assignment of tasks, running jobs can be monitored by *Resource Monitor*, where the status information is available from *Job Manager* and *Identity Manager*. In the system manager, *Job Manager* is responsible for tracking of the recognition task from sensors, while *Identity Manager* manages the identity query from the governmental department. Finally, the complete task, as shown in *Resource Monitor*, will send the corresponding result to *Result Manager* in *Face Recognition Module* for visualization.

Table 1. The workflow of training/verifying faces

Group	Dataset	False Acceptance Rate			
		10^{-5}	10^{-4}	10^{-3}	10^{-2}
Test-1	Life-photo[1]	0.0000%	49.7602%	61.5108%	66.4868%
	ID-LR	17.3913%	33.7945%	51.3834%	69.9605%
Test-1	Life-photo[1]	0.0000%	49.7602%	61.5108%	66.4868%
	ID-LR	17.3913%	33.7945%	51.3834%	69.9605%
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	ID-LR	17.3913%	33.7945%	51.3834%	69.9605%

[1] Life-photo: photos by smart phone or camera; ID-LR/HR is short for ID Card with Low Resolution/ High Resolution; ID-formal: photos which the official department provides. The rank of resolution is: ID-formal > ID-HR > ID-LR > Life-photo.

Table 2. The Irregular Faces in ORL

No.	File ID	No.	File ID	No.	File ID
S1	001, 009	S2	011, 019	S3	025, 029
S4	032, 036	S5	044, 046	S6	057, 058
S7	062, 067	S8	075, 077	S9	084, 085
S10	094, 095	S11	106, 107	S12	113, 119
S13	121, 126	S14	130, 138	S15	146, 149
S16	150, 151	S17	165, 168	S18	172, 178
S19	183, 187	S20	192, 199	S21	204, 208
S22	216, 219	S23	220, 226	S24	233, 238
S25	244, 249	S26	256, 257	S27	260, 269
S28	277, 279	S29	280, 285	S30	295, 297
S31	302, 308	S32	310, 312	S33	322, 326
S34	336, 339	S35	343, 349	S36	351, 359
S37	362, 369	S38	371, 372	S39	387, 389
S40	391, 397				

Table 3. The evaluating criterion in ATM and complex datasets

Criteria	ATM[1]	Complex
Input/Output Images	10/6	400/97
Input/Output Faces	2/2	40/40
Iteration Maximum/Actual	54/31	4180/2172
Average Consumption	0.134s	0.2704s
Input/Output Irregular Faces	4/4	80/22
Hit of Irregular Faces	100%	81.8%
Fault Recognition	0	0

[1] ATM Dataset simulates the environment where people utilize self-service terminals, and Complex Dataset tends to simulate the practical situation in banks.

5.2. *Physical and Computing Resource Layer*

In FIRST, *Physical and Computing Resource Layer* mainly integrates the computing and storage resources, which are respectively quantified by the number of *Labors* and the capacity of databases. To effectively manage *Labors* mounted in

Fig. 5. Samples of Dataset

the computing resource, the related information (e.g., computing power, running status) is collected by *Resource Manger*. Based on the *Labors* management of *Resource Manger*, the computing resources can be maximumly utilized, while *Labors* can fairly share all storage resources (e.g., databases and HDFS) [16, 31].

6. System Deployment

In this section, FIRST was evaluated for its performance and the system practices. The evaluation demonstrates that, FIRST can effectively address the challenge of identity verification, and meet the basic demand of applications in Smart Bank. In addition, the application of FIRST increases the categories of advanced business in self-service, and efficiently decreases the waiting time for counter service.

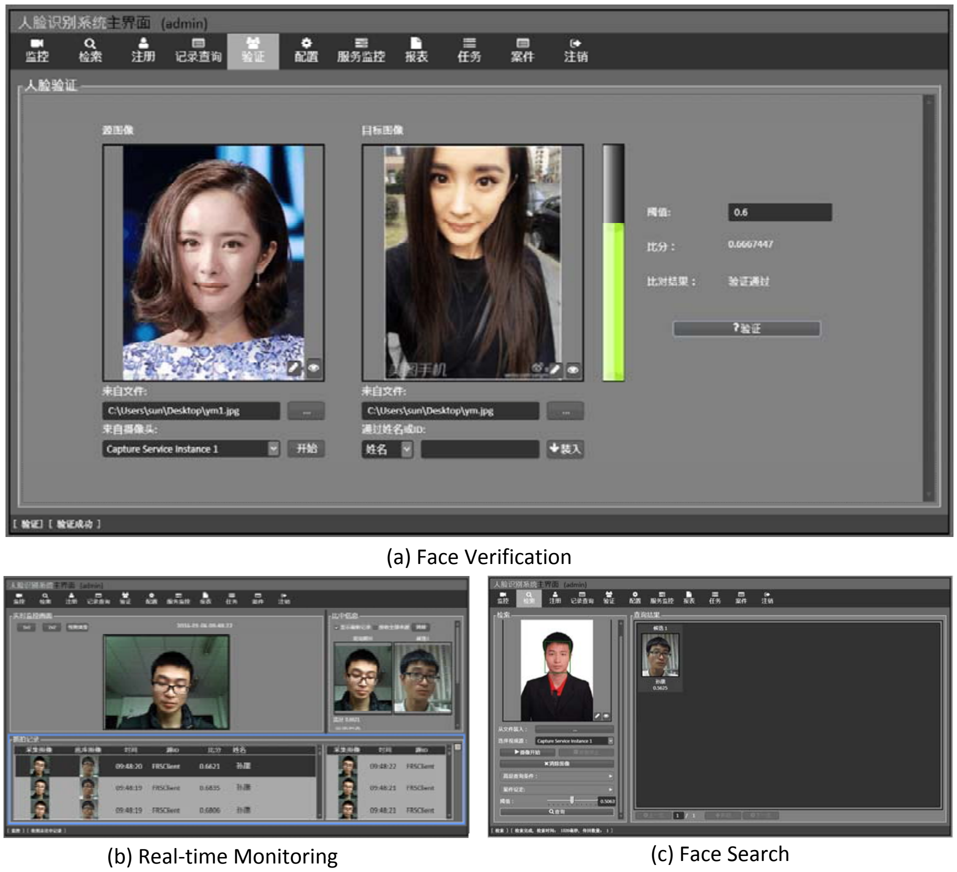


Fig. 6. FIRST User Interface

6.1. *System performance*

6.1.1. *Face Quality Assessment*

Since the privacy of ABC customers, to validate the face quality assessment strategy, we employ the selection strategy on two public datasets: (1) the ATM dataset[c] represents the simulation of self-services in front of ATM, which has 5 images for each person (as shown in Fig 5a), and (2) the complex dataset contains 400 images for 40 people, which is used to simulate the crowded environment. In this paper, the complex dataset is derived from ORL face database which consists of photos taken between 1992 and 1994 at the Cambridge University Computer Laboratory [21], and Fig 5b represents S1 samples in ORL.

[c]The faces in this dataset are collected from two employees of our project team. The photos are taken in five angles with different facial expressions.

Since irregular faces are not defined in the complex dataset, we artificially extract the most two dissimilar faces in the dataset of each person, which are shown in Table 2. After labeling the faces, these images are processed by patch-based face quality assessment module for selecting the valuable faces. Table 3 represents the related criteria of our face selection algorithm under the ATM and complex datasets.

As observed in Table 3, FIRST can recognize a face within 0.134s and 0.2704s in the simple (ATM) environment and the complex environment respectively. In addition, our strategy filters more input images in the complex dataset than in the ATM dataset, while maintaining the similar time consumption and verification accuracy. The experiment shows that: (1) 97 (24.3%) faces are uploaded from the complex dataset, where each person averagely has 2.4 images, while all people are recognized; (2) our strategy distinguishes all irregular faces in the ATM dataset, and uploads remaining images (6 of 10). In other words, based on the network condition, we can dynamically adjust the size of uploaded files considering the trade-off between the recognition accuracy and the efficiency of system. If more images could be uploaded within the limit time, the verification accuracy will be guaranteed with these additional data. Otherwise, *face quality assessment* will discard these redundant face images.

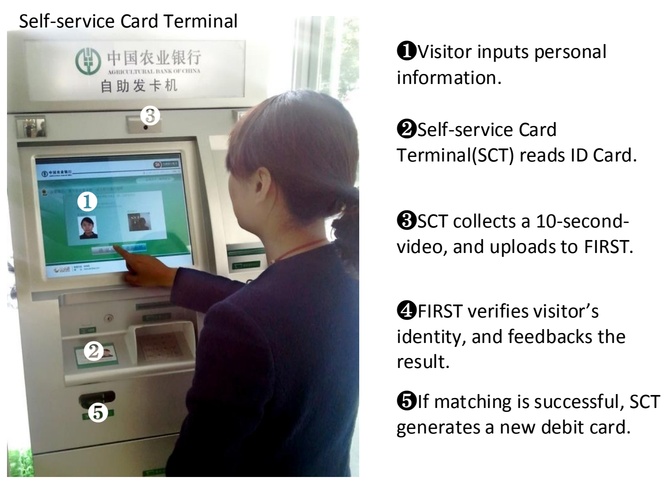
6.1.2. *Fisherfaces Face Recognition*

By using ensemble algorithms to process faces, which are respectively collected from video stream and official department, our proposed *Face Recognition Module* can achieve a good performance in different environments. Table 1 shows our face recognition performance utilizing photos, which are in different sizes and styles. As shown in Table 1, if the personal image from official department is used for comparison, the verification rate of our strategy can nearly reach 100%, when the false acceptance rate is at 10^{-4}.

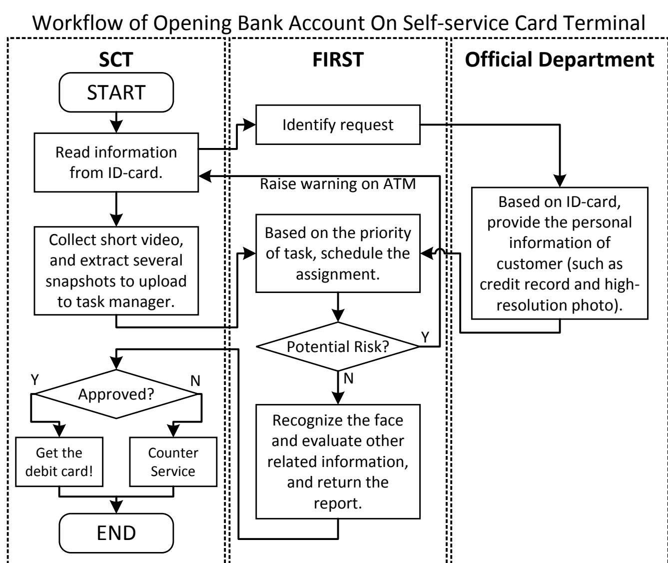
6.2. *Deployment practice*

FIRST has been successfully applied in various Agriculture Bank of China's self-services, such as Self-service Card and Super Counter Terminals. We show three representative application scenarios in banks. Fig 7 presents the practice of FIRST in opening a bank account on Self-service Card Terminals of Agriculture Bank of China. For the bank, as shown in Fig 7b, FIRST will request for authorized personal ID image from official department and compare the image with faces uploaded by Self-service Card Terminals, then return the result of verification. For the visitor, as shown in Fig 7a, she just needs to follow three steps(Step 1-3), then can instantly have her bank account instead of waiting for counter service. On the other hand, FIRST can not only improve the security of self-service, but also assist bank staff in decision making. Fig 8 and Fig 9 illustrate the practice of FIRST in counter service and Super Counter Terminals, respectively. The long-continuous-time work will accumulate the fatigue and decrease the verification efficiency of bank staff.

Thus, FIRST is used as an auxiliary decision system for assisting bank staff in verifying visitors, then they can confirm the identity of visitors based on the verification results from FIRST(e.g., Fig 6).



(a) Practice of Self-service Card Terminals



(b) Workflow of Opening Bank Account

Fig. 7. Application Scenario I: Opening Bank Account on Self-service Card Terminals

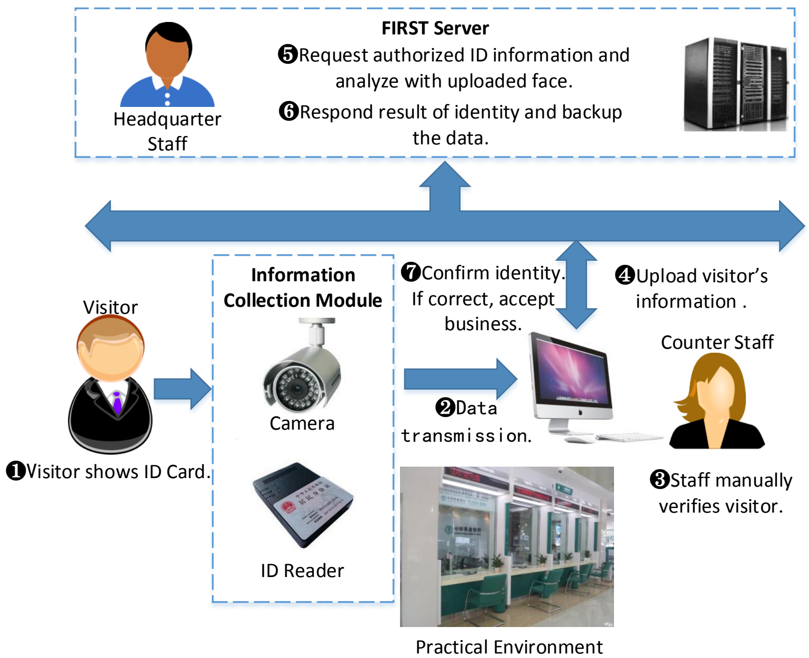


Fig. 8. Application Scenario II: Counter Service

Since March 2015, FIRST has been successfully deployed on 1800 self-service terminals in Jiangsu Province by ABC (Agriculture Bank of China)[d], and is under deployment for a security cooperation project by State Grid in China. The investment of this project has reached 2 million RMB. By taking advantage of FIRST, the efficiency of business in Agriculture Bank of China was sharply increased, and also generate great social benefits.

[d]News: http://goo.gl/QeZmuR;
Application Video: https://goo.gl/FMZ6sk

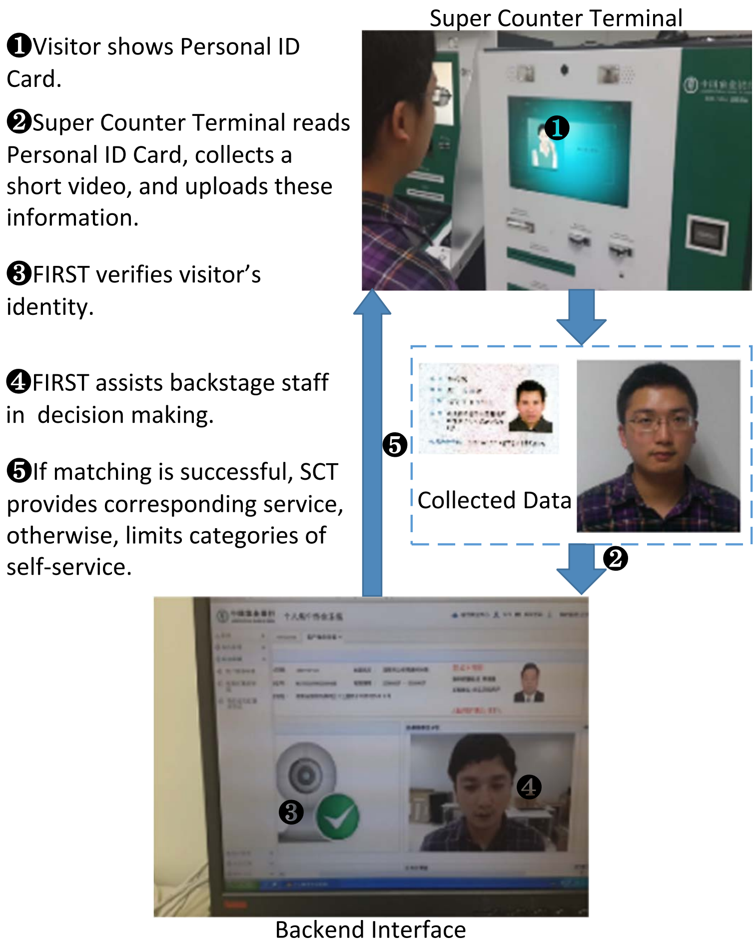


Fig. 9. Application Scenario III: Super Counter Terminals

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8. Conclusion

In this paper, we proposed an integrated framework called FIRST, which has been deployed in 1800 self-service terminals of ABC. As a customized platform, FIRST can flexibly employ combinations of algorithms to assist the identity verification via the face recognition in security-sensitive applications. The achievement of deployment shows that our proposed framework can effectively improve the quality and efficiency of banking services while protecting the security of the transaction. The improved efficacy of banking service shows that the integrated solution considering the technology of face recognition is mature enough to bridge the gap between researches and applications of identity verification.

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