Multi-functional System
Based on Palm Print Feature

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1 Executive Summary

In recent years, some phenomena with significantly negative impacts in campus are becoming increasingly serious and obvious. A typical example is that of cheating in exams. Such phenomena become an obstacle of better education quality and maintaining fair competition atmosphere.

After careful thinking, we found that these serious phenomena have a point in common-IDENTITY VERIFICATION. With a gradual increase in requirement for it, traditional code and photo methods fail to satisfy the need of campus identity verification fully, for it is easy to lose, forget and fabricate. Identification based on biological features therefore comes out to be a much more effective alternative technique in identification of identity.

Filled with sense of obligation to make contributions to education, we create a system, a multi-functional system based on palm print features-INNOBEYOND. The system is named Innobeyond for the reason that it not only comes out to be an innovation work, but a to-be-popular product with multi-practical use, great effect and cost-efficiency as well serving for better education. Innobeyond consists of collection module, eBoxes and a central server. The whole system as well as every component had been tested carefully and proved that it fits user’s requirement in accuracy, effect and cost.

Innovations of Innobeyond lie in the following aspects:

- Palm print verification is first implemented in an embedded system.
- It introduces Open CV kit in preprocessing to quickly get precisely-oriented images.
- It adopts PCA algorithm and combine statistical models with palm print feature extraction, so that the discriminating rate can reach nearly 98.5%.
- The verification process takes less than one second, which highly meets users’ requirement.
- Some subsystems are added based on palm print verification, including consumption subsystem, elective subsystem, library subsystem and medical subsystem. With the powerful system as a whole, we believe we are creating a better educational atmosphere for all!
2 Market Overview

2.1 Problems in the educational field

In recent years, some phenomena with significantly negative impacts in campus are becoming increasingly serious and obvious. A case in point is that cheating in final exams and other important exams is more popular. Another example lies in that some people who get the campus consumption card of others might expend the balance without difficulties. What is more, violence has aroused great concerns on campus security assurance. All of these negatively influence educational environment, order, efficiency and effects. Therefore measures must be taken effectively to reduce these phenomena and create better campus environment and therefore better education.

2.2 System Structure and Significance

![System Structure Diagram]

Figure 1 System Structure
Innobeyond, a Multi-functional System Based on Palm Print Feature

Figure 1 in the previous page not only delineates our three-layered system architecture, but presents the basic structure of innobeyond as well. From the bottom layer upwards, Innobeyond consists of a collection module, eBoxes and a central server.

The collection module is the information source of Innobeyond. It contains a camera box designed by ourselves to collect palm print images of students, and a RF card reader-writer to read or write campus cards.

eBox is responsible for collecting information from the camera box and the RF card reader-writer, and communicating with the central server real-timely. Prominently, it can log on to the website and enter various applications based on palm print feature, such as consumption, borrowing books and so on. This unit runs a custom Windows CE image.

Central server provides server for all the eBoxes. It runs verification algorithm and stores data permanently. Equipped with a complete database and multi-functional console, it can respond to the eBox quickly and correctly.

2.3 Research Conducted for the Project

As traditional methods fail to satisfy the need of campus identity attestation fully, we decide to develop a new but reliable method based on biometrics features. We compared some biometrics features such as finger print, sound and palm print, and found that finger print capturing requires rigor condition such as press and humidity to guarantee precise; sound is not steady, which means it will change along with age, physical condition, environment, etc; while palm print is easy to gain and prove to be steady. That’s why we chose palm print for its advantages in precise and convenience.

2.4 Manufacturing Economically

Innobeyond is a commercially feasible product with a high degree in marketability and manufacturability. Almost all schools can be the initial target market. The cost of each unit with high performance is about $193.5 (shown in Table 1), making it extremely attractive for schools. During the development stage of Innobeyond, we consulted students in our university, and 95% of them showed great interests in Innobeyond. They thought that Innobeyond could at least reduce cheating rate efficiently and make consumption safer and more convenient. It is a symbol that school life has come into a newer and higher level.
So Innobeyond is of great value and granting a high degree of manufacturability, which guarantee its feasibility in real life.

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>camera</td>
<td>$51</td>
</tr>
<tr>
<td>Collection box</td>
<td>$2</td>
</tr>
<tr>
<td>Mouse and keyboard</td>
<td>$12</td>
</tr>
<tr>
<td>RF card reader-writer</td>
<td>$19</td>
</tr>
<tr>
<td>RF card</td>
<td>$0.2</td>
</tr>
<tr>
<td>Ethernet cable</td>
<td>$0.3</td>
</tr>
<tr>
<td>LCD</td>
<td>$110</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$193.5</strong></td>
</tr>
</tbody>
</table>

### 2.5 Performance Requirements

As a tool of identification verification and convenient consumption, the most important thing of Innobeyond is to ensure stability of data and keep it as real time transportation. Undoubtedly, it is an irremissible thing if data is lost or mistaken in the sending or receiving process. In identity verification and consumption, data correctness is a primary requirement. Besides, we should endeavor to make the interface more user-friendly, in order to make operation easier and more convenient. Finally, the more eboxes cover the campus, the better our system performs.

### 2.6 User Experience

From the beginning, we made up our mind to develop a safe and convenient system for students to have a better educational atmosphere, so we keep focusing on users’ experience. Time-wait is the key point we consider. Though users had to spend more than 3 seconds in waiting for the result of identity verification previously, the time-wait now has been reduced to less than one second after several times of improvement.
2.7 Cost-efficiency

Innobeyond is powerful and can be applied to many different situations, especially in security and consumption aspects. Examples are:

1) Application in exams - cribbers reducing

With the help of innobeyond, it is hard to substitute examinee to take the examination, which means it provides fair opportunities to all examinees.

2) Application in consumption at school

In ordinary campus life, consumption is no doubt a universal behavior, but paying by cash is not convenient enough to most of the students. Under Innobeyond, users can use RF cards to consume without security problems due to palm print feature verification (shown in Figure 2). Places for consumption can be canteens, super markets, gymnasiums, etc.

![Consumption Subsystem](image)

3) Application in libraries

Library is an important place for study at school, and a good library management system is crucial in better serving professors and students and therefore improving average academic research ability. With the help of Innobeyond, users can easily manage their userinfo on internet, reserve a book, renew a book, etc and all processes are efficient and safe (shown in figure 3 in the next page).
4) Application in medical treatment

As health knowledge becomes increasingly popular, people are paying greater attention to personal health, but in the past there was no effective way in getting information that is most needed. Now under the system, every user can establish their own userinfo, after which the system will provide reasonable health guide, existing physical problems information, suggestions and the like to users (shown in Figure 4).
5) Application in security inspection

As school violence such as theft and robbery increases, security inspection plays an increasingly essential role. There is instant requirement for security inspection in Labs, dormitories, libraries and so on. Innobeyond can provide an easy, convenient and effective solution to identity verification by using unique palm print features.

6) Application in academic accreditation

As social competition is much fiercer than ever before, forged diplomas are owned by more people who are eager to hunt for good jobs but do not have good education background. With the help of Innobeyond, we can establish a diploma system based on palm print features to identify the validity of each diploma in order to provide fair opportunity to all candidates.

7) Application in elective system

We also provide a subsystem for students to select courses conveniently (shown in Figure 5).

Figure 5  Elective Subsystem
3 Technical Overview

3.1 System Constitution

Innobeyond comprises several main components: collection module, RF card reader-writer, eBox2300, network and central server. Figure 6 shows the components of the client.

![Main Components of the Client](image)

3.1.1 Collection Module

**Camera.** The camera is embedded in the box (shown in figure 7) designed by ourselves. We choose Logitech QuickCamPro 5000 for the reason that Microsoft has provided the driver and application program on WinCE for the camera, which means we can use the driver directly and transplant the application program conveniently.

![Camera Box for Collection](image)

![Palm Position for Collection](image)

**Light.** As the camera is embedded in the collection box and we need a steady illumination, we make a round-light in collection box to achieve lighting

![USBCamera](image)
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requirements.

**Collection box.** We need a collection box that can fix palms position and get a settled focus for the camera, so we design the collection box by ourselves (shown in figure 8 in the previous page). It is proved by experiments that the box is comfortable and efficient.

### 3.1.2 RF Card Reader-writer

As we want to develop lots of applications based on palm print features, we need RF cards to store some individual information, such as IDs, names and so on.

### 3.1.3 eBox2300

eBox2300, running on WinCE platform, is the core module of Innobeyond. One of its tasks is to register and log on to the client web directly. While registering, it receives palm pictures through the USB camera and information inputted from the client, both of which are sent to the central server immediately. Beyond a second, the central server creates palm print feature based on palm image and stores all information in SQL Server database. Meanwhile, the eBox2300 receives the palm feature from the central Server and writes it to an RF card.

While logging in, it receives a palm image through the USB camera and information from RF card through the serial port, both of which are sent to the central server immediately. Within a second, the central server sends the result of whether the incomer is true or false based on the palm print feature. What is more, users can enter plenty of applications based on palm print verification, such as campus consumption, borrowing books from libraries, and so on.

### 3.1.4 Network

Network, the bridge between eBox and the central server with TCP/IP is an important part of our system. Innobeyond has a website that allows students to interact with the system for various applications based on palm print verification, that’s why we have a SQL Server database to support the website in implementing functions mentioned above.

### 3.1.5 Central Server

The PC acts as a server and takes charge of lots of eBoxes. When receiving information from an eBox, it creates a thread to solve it, running preprocessing algorithm and PCA algorithm, and responds to the eBox in a second.
3.2 System Algorithm

Considering the inevitable problem that illuminations and positions are more or less different when taking palm images each time, preprocessing is indispensable.

The preprocessing algorithm we designed is divided into two stages. The first stage includes transformation from RGB mode to gray-level mode, ROI cropping and gray-level equalization (shown in figure 9). The second stage is executed when receiving the palm print image from the logging step, including the image alignment in orientation and position.

As illuminations are various in captured images and images in RGB mode take a large space to store, we need to transform the image mode from RGB to gray-level, and what is more make a histogram equalization to reduce negative impacts of illumination and size of images. Since not all areas of palm print pictures are useful, we need to crop the ROI (region of interest). Figure 10 shows the result obtained after the first stage of preprocessing.
**Image rotation.** We must solve the problem that the angle is more or less different in each capturing.

![Image 1 (in the database)](image1.png)

![Image 2 (to be identified)](image2.png)

Figure 11  Image Rotation

As figure 11 shows, we set two small rectangles A and B in image 1 first, the angle of the line that traverse the two rectangles is 45(135) degree.

In image 2 we search the rectangles A' and B' which match A and B most (shown in Formula 1), and then calculate the angle of the line that traverse rectangles A' and B' (shown in formula 1). Finally, we rotate image 2 according to the calculated angle value.

\[
R(x,y) = \frac{\sum_{x} \sum_{y} [T'(x',y') \times I'(x+x',y+y')]}{\sqrt{\sum_{x} \sum_{y} [T'(x',y')^2] \times \sum_{x} \sum_{y} [I'(x+x',y+y')^2]}}
\]

(Formula 1  Match the Rectangle)

\[
\text{arctan}\left(\frac{y_2 - y_1}{x_2 - x_1}\right) - \text{arctan}\left(\frac{y'_2 - y'_1}{x'_2 - x'_1}\right)
\]

(Formula 2  Calculate the Angle)

**Image translation.** Similarly as image rotation, we adjust the image position and search the rectangle that most matches the one we preset, calculate displace then finally obtain the ROI image on which the PCA algorithm will be executed.
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(Shown in figure 12)

**Figure 12  Image Translation**

**PCA Algorithm**

Through decorrelating each dimension of an image sample, PCA algorithm chooses statistical principal components from the orthogonal space in order to reduce data dimensions. If samples are described as spatial vectors, PCA is the low-dimensional data representation after translation and rotation, it can eliminate the coordinate axis in which the data divergences are lower.

M samples each in \( m \times n \)-dimension compose the image sequence \( I_j (j = 1, 2, \ldots, M) \), whose covariance matrix can be obtained as shown in Formula 3 after rearranging images into \( (m \times n) \times 1 \)-dimension vector sequence \( i_j (j = 1, 2, \ldots, M) \)

\[
G = \frac{1}{M} \sum_{j=1}^{M} (i_j - \mu)(i_j - \mu)^T = \frac{1}{M} XX^T \tag{Formula 3}
\]

(\( \mu = \frac{1}{M} \sum_{j=1}^{M} i_j \) is the mean of image vectors, \( X = [i_1 - \mu, i_2 - \mu, \ldots, i_M - \mu] \)) The feature vectors \( u_i (i = 1, 2, \ldots, k) \) corresponding to the first \( k(k \leq M) \) maximum eigenvalues of \( G \), construct the eigenpalm. Every palm print image sample can be presented by linear combination of the eigenpalm as:

\[
f_j = U_{pca}^T (i_j - \mu) \quad (j = 1, 2, \ldots, M) \tag{Formula 4}
\]
The essence of PCA on palm print images is to eliminate the statistical relativity existing between pixels. In physical sense, the basic unit of PCA description is eigenpalm, through which the feature space is formed, and every palm print image can be seen as a point in the feature space. PCA algorithm can accurately describe the training samples. For the samples that have been trained, PCA can sufficiently retain the information under the lowest dimension.

Therefore, the most essential palm print features can be extracted by using the PCA algorithm.

### 3.3 Development Tools

#### 3.3.1 Platform Builder

Platform Builder for Windows CE 6.0 is used to build and generate the operating system image for the eBox2300.

A “Custom Device” macro is utilized as the basis of the image only when required functions are added to the final image. In order to have desired application files stored in correct directories on start-up, we created custom catalogue items with necessary settings.

#### 3.3.2 Visual Studio 2005

Visual Studio 2005 is used to develop, debug, and deploy all applications, including the control module on eBox2300 and the data-processing module from central server. The reason why we choose it lies in its good ability in transplantation and especially that VS2005 basically accomplishes convenient development and is debugged in embedded platform, the same as that in other general platforms, and greatly fasten our development. With the custom-image SDK, we are able to quickly deploy solutions to the eBox2300 directly through the TCP Connect Transport protocol. Debugging information is noticeably improved in this version, compared with the previous 2003 version, therefore all runtime errors can be quickly identified and assistance for error resolution is easy-to-find.

#### 3.3.3 SQL Server 2005

As we have to store much information, such as ID numbers, names, palm print images, record of consumption and so on, we need a high-performance, available and secure database. Considering that Microsoft SQL Server 2005 provides a new Management Studio which can integrate with Visual Studio 2005 and the
Microsoft .NET common language runtime, all of which help users to build, debug, and operate applications faster and more efficiently, it naturally becomes our first choice.

3.4 Testing

To ensure the reliability and accuracy of our system, Innobeyond was rigorously tested throughout the development process.

We took 150 palm print images from thirty students. Figure 13 shows the testing result. The x-axis represents the threshold and the y-axis represents the accuracy. Red line represents false reject rate and blue line represents false accept rate. From the graph we can see that the false reject rate grows as the false accept rate descends, but it is still higher than 92%, for the precise preprocessing algorithm can reject invader directly.

From the junction of the red line and blue line, we can make a conclusion that the accuracy of innobeyond can reach 98.5%!

![Figure 13 Performance of Innobeyond](image)

Other parts of our system are small-scalely tested too, the results of which showed that every part of the system works well.
4 Team Overview and Project Status

We have been strictly following our plan (shown in figure 14). Up to now, we have completed the system development and basically accomplished all the system functions. In addition, we put forward a new exciting solution that we introduce some more applications based on palm print verification. At present, after the module testing, system linking and debugging, Innobeyond is proved to work efficiently.

A fully functioning prototype has been developed and extensively tested, which comprises the following functions:

a. We have set up a palm print verification subsystem. With precise preprocessing algorithm and powerful PCA algorithm, the accuracy of Innobeyond can reach 98.5%. What is more, the verification process takes less than one second, which is acceptable for the users. This subsystem can be applied to exams and security inspection to reduce the number of cribbers and...
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make students safe.

b. A consumption subsystem is added to our system. After palm print verification, eBox can show the balance of RF card, and the operator can deduct money corresponding to the fee involved. As Innobeyond is online, it can update the database from the central server at once at any time.

c. An elective subsystem is running in our system. Students can select courses they like best and modify information at any time after verifying their identities through their palm prints. Besides, students can have on-line exams smoothly.

d. The library subsystem is another shining point of innobeyond. After checking the campus card on which palm print information is carried, we can see the user’s personal information, after which users can do all kinds of operations such as reserve books, renew books, search books and so on.

e. Medical subsystem is also another component of Innobeyond. According to the campus card, we can take a look at the record of personal health, such as what kinds of illnesses you have suffered before and what you have to pay attention to. What is more, it can provide users a reasonable diet guide and other useful information for better health.

Work Partitioning

Our team worked closely together on all parts of the solution. While each member mainly took charge of one aspect, every single module and algorithm design was completed under cooperation of at least two members.

Licong Zhang, the team leader, handled the eBox, the preprocessing algorithm and took charge of work assignment.

Chengqi Wang was responsible for the PCA algorithm, driver of camera and Video Streams.

Yanhui Xiao was in charge of network, consumption subsystem and library management subsystem.

Dandan Li took charge of RF card reader-writer, elective subsystem, and medical treatment subsystem.
5 Summary

5.1 Conclusion

Innobeyond introduces a reliable identity verification method based on palm print features and expands applications based on it. The system will significantly improve campus environment and consequently benefit a great many students.

Through this project, we gain a lot of experience both in technique and in software management. And finally we want to express our gratitude to our mentor – Xiaoming Ding who gave us a lot of valuable suggestions.

5.2 Future Work

Although Innobeyond is a fully functional and original solution to a well-defined real campus problem, it is acknowledged that there is room for further innovation in order to make the product more marketable.

a. Wireless network can be introduced to our system, for it can make Innobeyond more convenient and expand the target market.

b. A larger database should be tested. As time is limited, we only tested the database that included 30 students, and each student took five palm print images. Though the result of testing is delightful, the database is too small. Therefore we will have a full test in the future work.

c. Still there is an advisable solution that combines the merits of both palm print and sound. It has the advantage of higher reliability and can be applied to different situations. If that could come true, it would be perfect!

d. Due to the time pressure, the four subsystems-consumption subsystem-elective subsystem, library management subsystem and medical treatment subsystem are just made to demonstrate their availability. Though they work well, the database is too small. We will add more information in the next step.
6 Reference

6.1 Books


[2] ICOP Technology Inc. eBox-2300 Windows Embedded CE 6.0 JumpStart guide. We build the image of Win CE with the help of it.


6.2 Web site

[1] http://www.msuniversity.edu.cn/default.aspx We downloaded a lot of sources from this web site.


[3] http://www.gotdotnet.com/workspaces/workspace.aspx?id=0eb87e35-13e4-4fa3-9fde-71e9136f47de We got the camera driver and test written by Microsoft from this web site.


6.3 CD

ebox-2300-MSJK. EBox2300 Windows CE 6.0 Jump Start Video.