Smart Wardrobe System Based on Android Platform

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***Abstract*—the recognition and color processing of video complex object is now a research focus in contemporary computer science, the technology is widely used in various areas of society. In this article, we individually designed the system framework of Android-based client and OpenStack-based SSH server, the system has achieved functions include the management of personal clothes, dress collocation, intelligent recommendation based on user's stature, user's similarity, dress pattern, real-time weather and other multi-dimensional factors and so forth. We established database for data storage and backup in both server-side and client-side and designed a complete data synchronization mechanism, so the real-time data can be synchronized to the local as user switches the device and account. Some frequently used data in the mobile terminal has a local cache in different ways and as a result the user can still use all the basic functions offline. The works with high complexity like image computation are all processed at server-side mounted on a cloud computing platform. In this system, basic data including garments and matches are all users' information assets, and a large-scale small data will take shape when the number of users reaches a certain level. The system protects their privacy.**

Keywords-Android; small data; cloud compute; clothing optimization; system design

I. BACKGROUND

In recent years, with the rapid development of technology and the deepening of informationization, "man, machine and material" triple world keeps interacting in cyberspace and produced a large amount of data [1], which gave birth to the numerous studies on numerous data, the core of these studies can be divided into data processing, data mining and data analysis [2], [3], the purpose is to quickly extract useful data from large amounts of data to promote data-driven decision-making [4]. As an important part of those massive data, image data hides a large number of important, critical events and phenomena, how to extract, refine and visualize information is research and application hotspot among various fields [5]. This technology also plays an important role in dressing part of people's daily life, especially for women with emphasis on everyday clothing, they spend a lot of energy on clothes' match and management. As life is getting better, almost every woman has a lot of garments in wardrobe. Using modern information technology to realize intelligent management and optimal match on various garments, and establishing a simple and practical software system is expected by most women.

There are two types of current application which has function of trying on clothes. One runs on normal device like laptop and mobile phone, can be divided into 2D and 3D realization. 2D ones usually realized by face transplant in photo or manually drag and drop garment picture on the model. 3D realization generally use common 3D human model to try dressing, has strong sense of the game, user can hardly have the real feeling of trying dressing, lacks personalization.

Another one runs on a medium-sized equipment using infrared and other sensors, the effect is realistic but it visualized in 2D and costs much with the lack of universality.

On the other hand, research on the wardrobe intelligent algorithm in recent years are increasingly tended to combine with current popular technology like machine learning, cloud computing, big data and so forth. They usually extract data at the front-end client, the back-end cloud takes full advantage of computing and storage resources on data mining and data analysis, and finally return learning results or recommended information to the PC, mobile phone, tablet and other intelligent terminal to improve user's experience [6]-[8], Further, some study tried merging dressing into daily social interaction [9]. Data extraction can be divided into three ways: manually input by user, intelligent identification, collect by sensors and embedded chip [10], [11].

This system is a set of software aimed at realizing smart wardrobe, we hope to build a set of intelligent management mechanism for personal clothing, not only for easier life, but also allows users to know more about yourself. These data should be closed and private, and they will form a small-scale data [12] when the number of users reaches a certain level. The effect of match picture in system are automatically generated from real photos captured by user, users can not only easily choose their own clothes to preview the match effect immediately, but also post his/her favorite match on the cloud wardrobe so all users can browse, grade and leave comment. In terms of smart wardrobe, the system will give the best recommended match based on the occasions to attend, real-time weather, physical information, popular dressing skills in cloud wardrobe and so forth. System consists of two parts: SSH server side deployed on the OpenStack cloud platform and Android mobile side, has realized intelligent recommendation and other functions on clothes management and optimal clothes match in high dimensional space. We established a sound data synchronization mechanism, user can switch device and synchronize cloud data any time anywhere. The client side

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has a local cache for base data as users can use all basic functions offline.

II. OVERALL DESIGN

A. System Physical Architecture

System consists of web server, Android front-end, PC front-end, back-end database server, and file storage structure and so on. The server is deployed on OpenStack, and users can access to server on cloud by mobile phone and PC. Architecture diagram is as Figure 1.

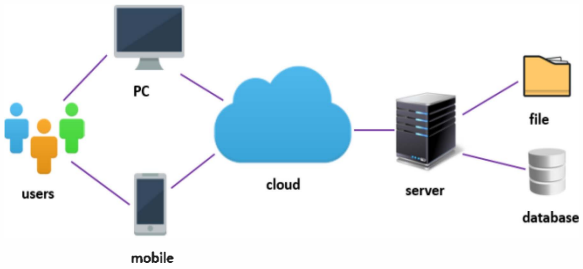

Figure 1. System physical architecture diagram

B. Core Technology

The Android Client and the server are written in Java. Select HTTP as network communication protocol and Tomcat as WEB server. The Android Client uses SQLite database. Development of the server is based on SSH framework, use MySQL as database and take OpenStack as cloud platform.

C. Technical Difficulties and Solutions

Throughout the design and development process, we have encountered a lot of difficulties, mainly listed as follows:

1. How to realize the clothes match based on 2D;
2. Lots of image data generated network traffic problems;
3. Design the mechanism of adding clothes data;
4. User needs to type in a lot of information (body information and clothing information), How to simplify the input procedure.
5. What to recommend and how to recommend.

Correspondingly we made the following solutions:

1. Designed picture match of the three types of clothes (can be extended) based on Android custom drawing.
2. Designed data synchronization mechanism between client and server;
3. Using the Intel RealSense technology to remove the background of clothes picture;
4. One by one to design automatic recognition solution of each input attribute based on image recognition.
5. Defines the recommended content according to two business scenarios, using the analytic hierarchy process to select the recommended results.

For some of the problems in this paper is limited to the length of the overview description.

This paper will give an overview of some solutions.

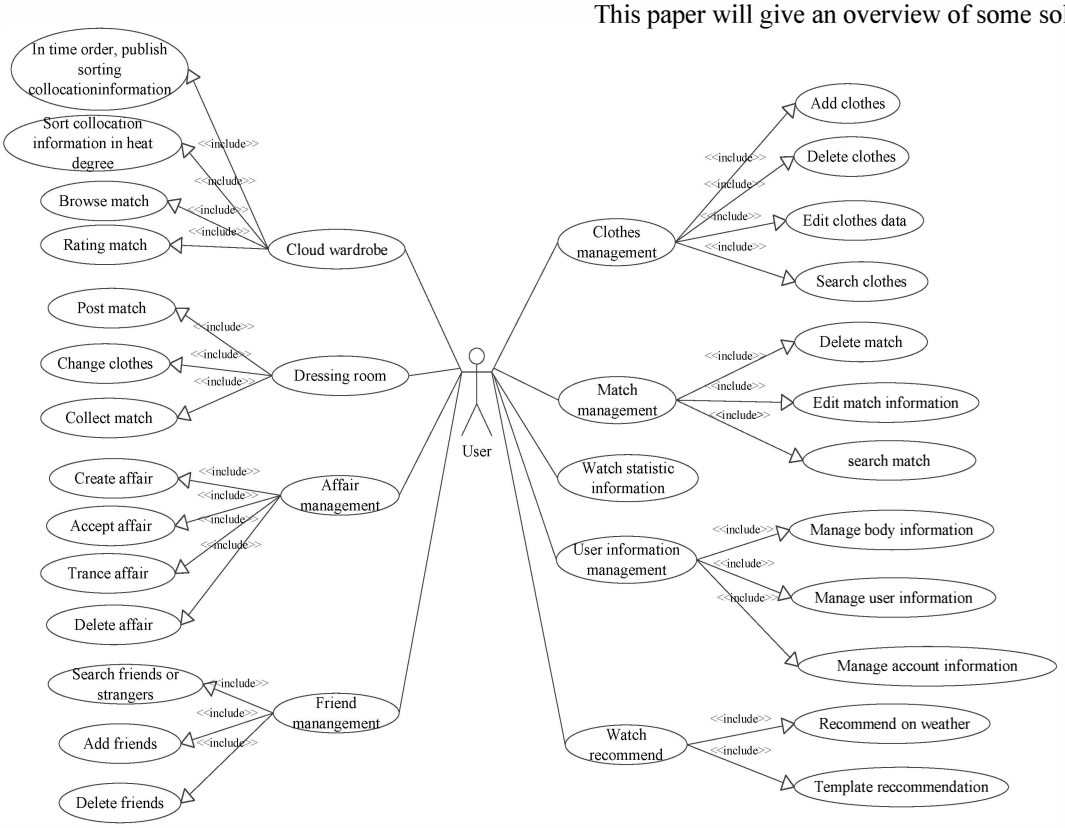

Figure 2. System use case diagram

D. System Use Case Design

The system put emphasis on optimal management and match of users' own clothes. Users can rapidly check detailed data, recommended information and shared data from other users. As Figure 2, users can do 9 kinds of operations: (CRUD: Create, Read, Update and Delete)

- Manage account. (In the login system, three kinds of personal data are binding, account data, body information and user information like nickname, headshots, etc.)
- Manage clothes. (CRUD of personal clothes information)
- Manage collocation. (CRUD of personal collocation information)
- Fitting. (Select clothes in fitting room. Preview collocation effect and push collocations on cloud.)
- Browse Cloud wardrobe. (Selectively watch all users' collocation information, and rate them.)
- Manage friends. (CRD of friend relationship)
- Manage affairs. (CRUD and trace of affair data.)
- Recommend clothes. (Recommend collocation which users are interested in.)
- Statistics of personal information. (Get statistics and analysis of users' information, and show in several ways.)

E. Function Modules Division

The function can be concluded and subdivided from use case diagram. In function part, the system can be divided into 9 modules. It is as in Figure 3.

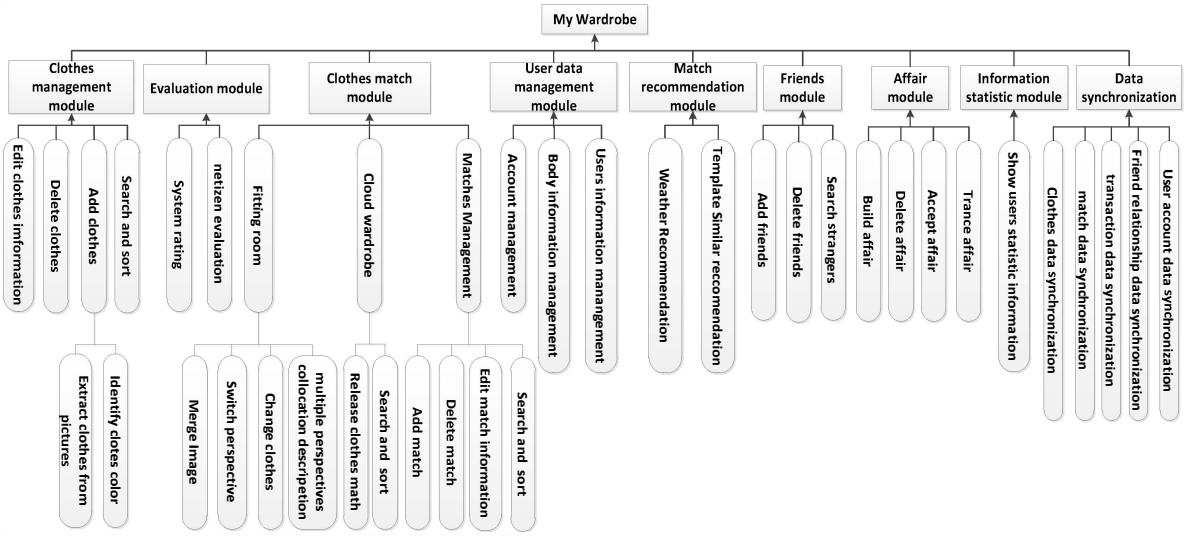

Figure 3. System function modules division diagram

III. FUNCTION AND IMPLEMENTATION

The software consists of eight main modules, they are: clothes management, match management, client information management, evaluation, statistics, friend management, transaction management, and match recommendation. The following describes the function and implementation of these modules.

A. User Data Management Module

Our users have three types of information to manage: login account, the user's body data and application data (nickname, avatar, signature, etc.). The user can use the phone number, email or self-defined account as a username to login system, any one of them can not duplicate the existing data in the database while registering an account. User can manually enter the body message. After entering specific information like measurements of BWH (bust, waist, and hip), height and weight, the system will calculate the user's size, shape category and other information and give dressing recommendations in real time.

B. Clothes Management Module

In this app, by taking photo user can insert three types of clothes (can extend to four and more): top inside garment, top outside garment and bottoms. And the color and some attributes (like pattern) of the garment will be recognized background so that our users don't need to type them in all;

In clothes management page User can quickly search and view their clothes data in multi-dimension by using a variety of conditions on the filter or sort the display. While adding clothes data the user can upload garment picture by taking photos, and the cloud-side will analysis the picture and return color and pattern data of the garment in real-time. Considered the clothes and match data are used frequently in the system, we adopted the single-case model to maintain one static entity. The entity holds these two types of data globally so the user can use these data anywhere in our system.

C. Evaluation Module

This module consists of two parts: systematic review and netizens' evaluation. The systematic review is an assessment

set of match scene, match color and other characteristics of the match. It will be given automatically when the user has completed a new match in the dressing room. The netizens' evaluation is generated when users rating and comment the match data which is posted on the cloud wardrobe by some others.

D. Clothes Matches Module

This module consists of three modules: fitting room module, cloud wardrobe module and personal matches' management.

In fitting room module, user can freely combine his/her own clothes and view the combined images immediately, the program will zoom the garment picture, find the coordinate of each garment's waist line and joint these garment picture. Shown in Figure 4, the user can activate the bar at right side by touching clothes area at the left side and the right list will load corresponding clothes data. By the right list user can view a list of garments' thumbnail and keyword information, click on the garment item in list can load its picture into left canvas to take a try to dress, the scaling and position will be adjusted automatically. User can add some description to the prepared match for either saving the match or posting it on the cloud wardrobe.

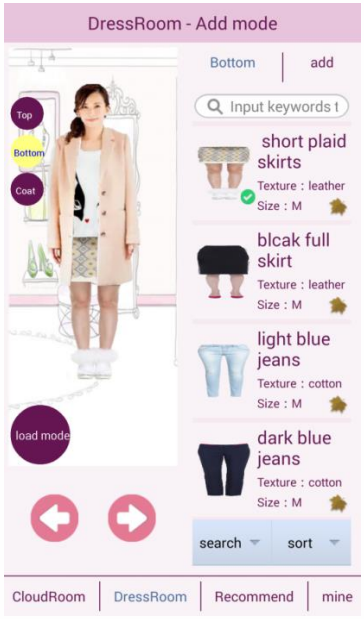

Figure 4. Dress room page

Users can click "my cloth matches" button in navigation page to get to check and manage their matches.

In cloud wardrobe module users can browse posted matches information in the cloud wardrobe. In cloud wardrobe, all data is loaded in a list view, each request to the cloud brings back specific number of ordered match items which will merge with displayed items. User can select two conditions to sort displayed data, namely heat (User Rating) and release date. Take release date for example, specify the number of request items is X, the user pulls up the list view to require the latest X match data from cloud, drop down the list view to require X match data whose post time are earlier than the last item in the list. The request data structure is shown in Table I.

TABLE I. REQUEST DATA STRUCTURE

Parameter	Data Type	Illustration
query condition	String	Table field name in database, directly use this parameter to sort information
Data size	Integer	Number of items returned by the server in one request
Post time	Timestamp	Post time of the first item (latest) or the last item (earliest) in the published data list.

E. Friend Module

The friend relationships in system are mainly used to send and receive transaction. Transaction is used among only acquaintances which determined the friend add behavior should be orientated, to prevent searching strangers, searching by nickname is not allowed, user can only find their friends by searching phone numbers, email or account, because these three information are totally unique. Friend management provides three types of operations: add, delete, and search.

F. Transaction Module

User uses transaction to interact with their friends, there are two types of transactions: selection-based transaction and task-based transaction. The function transaction is positioned to make it free and convenient for user to use garment and match data to interact with friends, the user can choose clothes\match data and send word to designated friends. Some typical scenarios in each type of transaction are shown in Table II. This function mainly works on specifying an accurate description to locate the right clothes.

TABLE II. TYPICAL SCENARIOS IN EACH TYPE OF TRANSACTION

Transaction Type	Scenarios
selection-based	Invite your friends to vote for your clothes\match
task-based	a) Help roommate bring clothes to classroom; b) Do laundry for family member; c) Find clothes for roommate.

G. Recommended Module

This module contains two parts: Weather recommendation and template recommendation. Implementation of weather recommendation:

- Locate user's city by using GPS interface.
- Get weather information of the city from China Weather Network.
- Recommend suitable clothes (user's own clothes) according to current weather of the city user stay in, shown in Figure 5.

Implementation of template recommendation:

- Backend administrators store template data to server database.

- Users choose their favorite dress photo of celebrities, and can have a look if there are combinations of clothes in line with the pattern of their selected model match, as shown in Figure 6.

Figure 5. Weather recommendation page

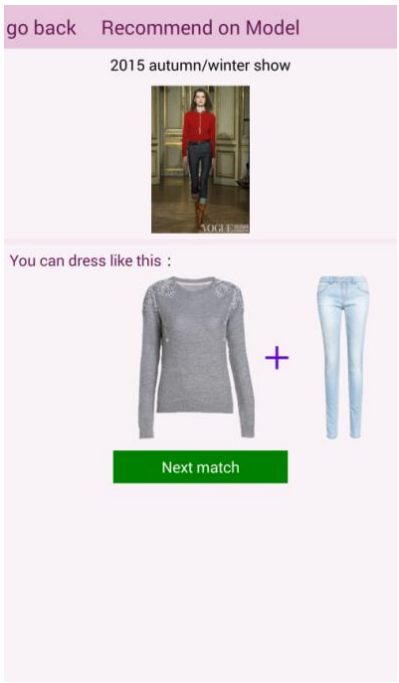

Figure 6. Model recommendation page

H. User Statistics Module

In this module, system will make multi-angle statistical analysis on user's Clothes and match data, and display statistics in different forms, shown in Figure 7.

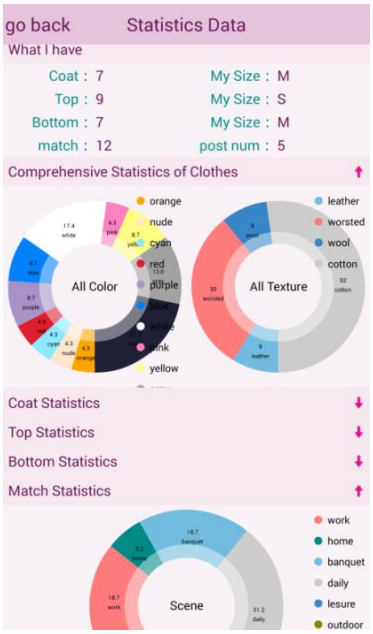

Figure 7. Data statistics page

I. Data Synchronization

If we download all data every time when our user log in, it will cost them a lot of network traffic because primary data in the system is picture (clothes picture, matches picture).

So we design a synchronization mechanism between android client and server to ensure that the client app only update those modified data (new add, edit or delete). Table III is declaration of table field we add to each table, they are used to check if the current data has been modified.

TABLE III. TABLE FIELD FOR MODIFICATION-CHECK

Parameter	Data Type	Illustration
id	integer	Auto-Increment id,primary key
finalTime	Timastamp	Final revise time

IV. INTELLIGENT RECOMMENDATION

People could face with many choices while picking out their clothes to dress on. The weather, the occasion to attend and personal stature are all in the scope of consideration. These factors are interrelated and restrain mutually. In order to make the analysis measurable, we use analytic hierarchy process to help recommend clothes.

Analytic Hierarchy Process (AHP) is a multi-objective decision analysis method which is qualitative and quantitative, systematic and hierarchical. The core purpose of AHP is to transform user's experience-based judgment to quantitative ones. This could enhance the accuracy of decision-making basis. Concrete Implementation can be divided into following five steps.

A. Establish a Hierarchy Model

At first, we hierarchically list the purpose, factors and final decisions by relationship between them, as shown in Figure 8.

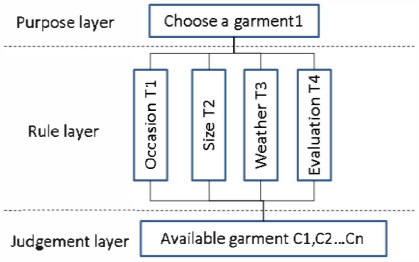

Figure 8. Hierarchical chart

B. Construct the Judgment Matrix and Assign Weights

At this step, we ought to determine the weight of each factor on each hierarchy, here we use consistent matrix to describe them. At first, use nine bits ratio scale (shown in Table IV) to compare every two factors in same hierarchy and generate the judgment matrix. The system has stored user's body information, garment data and dressing record and will adjust the weights of the elements pairwise comparisons while making recommendation.

TABLE IV. THE RATIO SCALE TABLE ABOUT RELATIVE IMPORTANCE

Compare A to B	equal important	a little more important	more important	Much more important	extremely more important
Evaluate value	1	3	5	7	9
remark	Take 2,4,6,8 as intermediate value of the evaluation value. Assume a_{ij} is the compare of i and j, then the compare of j and i is $a_{ji} = 1/a_{ij}$.				

When it comes to the issue of clothes selecting, we ought to separately construct two groups of judgment matrix: factor layer-to-purpose layer and decision layer-to-rule layer judgment matrix.

Table V has shown the first condition.

TABLE V. JUDGMENT MATRIX

	occasion	size	weather	evaluation
occasion	1	4	3	3
size	1/4	1	1/2	1/3
weather	1/3	2	1	1
evaluation	1/3	3	1	1

C. Calculate the Ordered Weight Vector on Monolayer

As the judgment matrix has been constructed, now use each element at last layer as a benchmark, we want to find the most important factor on current layer. By calculate eigenvectors of the maximum characteristic root in judgment matrix, and subject to the normalization process, then we can get a list of ordered weights which indicates the importance between elements on current layer.

Define the column vector of judgments matrix as (1).

$$w = [\overline{W_1}, \overline{W_2}, \dots \overline{W_n},]^T \quad (1)$$

So the normalization process could work as (2).

$$w_i = \overline{W_i} / \sum_{i=1}^{n} \overline{W_i} \quad (2)$$

By the formula: $Aw = \lambda w$, we can work out the characteristic root λ and eigenvector w, in formula, A is the judgment matrix.

D. Calculate the Ordered Weight Vector in Total

At last we need to figure out the significance weight that each factor on judgment layer is to purpose layer.

We assume that the four factors are A1, A2, A3, A4, and the corresponding ordered sequence is a1, a2, a3, a4. And assume that the hierarchy sorting of n clothes of judgments layer (on the base of factor layer) is $b_{1j}, b_{2j} \dots b_{nj}$, the j is from first to fourth element on factor layer. So we could calculate the weight of garment I for the purpose as (3).

$$B_i = \sum_{j=1}^{4} a_j b_{ij} \quad (3)$$

Now we can choose the garment with the maximum B_i to make recommendation.

E. Consistency Check

Actually, the judgment matrix and hierarchy sorting generated in step 3 and step 4 are both subject to consistency test and otherwise we have to adjust some value of judgment matrix to amend the judgment offset.

There are two theorems as follow:

- Consistent matrix of degree n has its only non-zero characteristic root: n.
- Reciprocal judgment matrices A of degree n has its biggest characteristic root λ greater or equal to n, and A is a consistent matrix only when λ equals n.

So we can use λ-n to measure inconsistency degree of the judgment matrix. We define the consistence indicator as (4).

$$CI = \frac{\lambda max - n}{n-1} \quad (4)$$

The matrix has the best consistency when CI = 0 and the inconsistence is more serious once CI is bigger.

For a more objective measurement of CI, we define RI as a random consistency indicator and do the following things:

- Build 500 random judgment matrix and figure out 500 CI values.
- Using (5) to calculate RI and generate the reference table. (Table VI).

$$RI = \frac{CI_1 + CI_2 + \cdots CI_{500}}{500} = \frac{\frac{\lambda_1 + \lambda_2 + \cdots \lambda_{500}}{500} - n}{n-1} \quad (5)$$

TABLE VI. JUDGMENT MATRIX

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.55	0.90	1.12	1.24	1.36	1.42	1.45	1.49	1.52

We think the satisfactory consistence of judgment matrix when $CR = \frac{CI}{RI} < 0.1$. Otherwise we should amend the matrix. In step 4 CR can be calculated by formula (6).

$$CR = \frac{a_1 CI_1 + a_2 CI_2 + \cdots + a_m CI_m}{a_1 RI_1 + a_2 RI_2 + \cdots + a_m RI_m} \quad (6)$$

V. CONCLUSION

The system has achieved satisfactory results since commissioning, and has been used in a range of friends. Some of them gave us a lot of constructive and surprising suggestions. This software has achieved the following practical effects from the conceptual perspective:

- Easy to operate. The system has realized the optimal mix of personal clothing in multi-dimensional space, which is very suitable for individual to choose dress before going out;
- Effective management of personal wardrobe. For those women who have a lot of apparels, the cloud space could help store and manage garments;
- Strengthening user's understanding on his/her garments and dressing. User can get their matches rated by system and friends, refer to dressing recommendation, and check data statistic anytime anywhere, which makes user's dressing choice more reasonable and easily get feedback. All this can effectively improve individual self-cognition and aesthetic confidence;
- Good scalability. Many features of this system can be appropriately modified and applied to different fields in society, such as military, life, chemicals and machinery and so on different areas of expertise.

The local cache mechanism at Android client and the cloud data synchronization pattern is an exploration of the data storage and synchronization. Smart dress match based on organic synthesis of 2D video images is also an effective way exploiting application of image processing technology. On this basis, taking advantage of the 3D video image processing technology will improve system effectiveness and generate significant commercial value.

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