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CyVOD: a novel trinity multimedia social network scheme

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Abstract How to comprehensively explore, improve and deploy multimedia social networks (MSNs) has become a hot topic in the era of emerging pervasive mobile multimedia. More and more MSNs offer a great number of convenient tools, services, and applications for multimedia contents including video and audio that users share willingly and on demand. However, concerns with digital rights management (DRM)-oriented multimedia security, as well as the efficiency of multimedia usage and sharing are meanwhile intensified due to easier distribution and reproduction of multimedia content in a wide range of social networks. The paper proposes a comprehensive framework for multimedia social network, and realized a cross-platform MSN prototype system, named as CyVOD, to support two kinds of DRM modes. The proposed framework effectively protects copyrighted multimedia contents against piracy, and supports a more efficient recommendation system for its better handling of the tradeoff between multimedia security and ease of use.

Keywords Multimedia social network · Security · Digital rights management · Recommendation algorithm · Prototype

1 Introduction

In the past two decades, high-speed broadband Internet, mobile communication networks and multimedia technology have progressed from mere laboratory studies to the commercially applicable technologies. Today, the third and fourth generations of wireless mobile communication systems have covered almost every corner of the globe. In addition, a large number of

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social network sites, tools and services make it possible for people to be connected with the (mobile) Internet via a variety of user terminals, at anytime and in anywhere. As a result, accessing to information on demand to share and exchange data resources become rather convenient, effective and comprehensive. Multimedia social network (MSN) is a typical kind of social network oriented to multimedia sharing and experience, such as Youtube, Vimeo, Flicker, China Youku and Tudou, and so forth.

Unfortunately, security and privacy concerning multimedia communication and digital rights management (DRM) [20, 23] become more and more prominent problems in the emerging multimedia social networks. In order to construct and popularize applications of MSN, essential concerns are the design and development of effective and efficient multimedia recommendation systems while weighing the tradeoff between security and ease of use.

The major contributions of this paper are two folds: one is to propose a novel trinity scheme of multimedia social network that includes multimedia management, social recommendation, and digital rights management enabling both online and offline protection; the other is that we mainly adopted an improved hybrid algorithm of combining collaborative filtering and content-based recommendation for social users/multimedia sharing, in order to meet the needs of users for comprehensive, efficient and secure services of multimedia contents.

The remainders of the paper are organized as follows: Section 2 presented the related studies; the next section proposed a trinity scheme of multimedia social network and improved hybrid recommendation algorithm; Section 4 realized a prototype system and in detail made performance analyses; and finally conclusions were drawn.

2 Related works

We first review the research works related to security, trust management and multimedia recommendation systems for general social networks, and classify them into three major categories.

2.1 Security and privacy of online social networks

While providing the digital society with methods of interaction and information sharing, Online Social Networks (OSNs) give rise to some problems in security and privacy, such as copyright management audio and video, and privacy protection of image [1–3, 8]. Currently, (commercial) OSNs allow users to have controlled access to the shared data without enhanced mechanisms to ensure data privacy in multiuser situations. For that reason, Hongxin Hu et al. [9] proposed a method to resolve the problems regarding the protection of the shared data in multiuser situations, and gave the logical representation of an access control model. Considering it an important feature of large-scale of social networks, Jung Youna et al. [11] then put forward the community-centric property based access control (CPMAC) model on the basis of community-centric role-interaction based access control (CRiBAC) to support the cooperation among users in OSNs. In order to validate its feasibility, a prototype application of this model has been achieved in Facebook. Its applicability has been illustrated by two examples. In addition to the access control problem in social networks, another major challenge that OSNs face is the privacy infringement by OSNs providers or unauthorized users. With regard to such concerns, Raji Fatemeh et al. [5] presented a P2P-OSN framework, which comprises of the function of privacy settings for social activities of users and adaptive

strategies for the purpose of verifying the availability of shared data. This framework correlates the availability of shared contents on P2P-OSN so that controlled access can be distributed. As to ensuring content security in social networks, we developed a transmission path algorithm on the basis of rough set theory. The efficiency and effectiveness of the approach are verified through experiments in the real social network [24].

With regard to personal information disclosure and privacy protection of social media users, Fogues Ricard et al. [7] reported that given the explosive increase of users in the last few years, the current beneficial services of Social Networking Service (SNS), like Facebook and Twitter, become overshadowed by the existence of a privacy hazard while providing convenience and rich experiences to social users. In their work, they listed all privacy hazards that may potentially pose threat to privacy of SNSs users, together with the requirements of privacy mechanism to realize the restraint of threats. Viejo Alexandre et al. [17] indicates that the big data released on social media platforms contains sensitive personal information that can be collected and utilized by external entities for profit. However, the current solutions mainly adopt strict access control means for protection, but do not allow users to discern sensitive and confidential data. Furthermore, current solutions require social media operators to participate to realize the control mechanism; therefore these solutions may not be practical. For this deficiency, they proposed a new scheme to solve the problem. Their scheme can be applied to the privacy protection of current social media platforms by using a software component that is independent of the platform. Here is an automatical test of the sensitive data released by users, so as to establish the privacy-clearing versions for data. Besides, it can read the security credentials provided by users to content-release owners and only display a limited range of content and information to users, resulting in supporting transparent access to the sensitive content that need privacy protection. Finally, this solution has been successfully applied to two global social websites: Twitter and PatientsLikeMe.

2.2 Trust management in social networks

Trust has a profound influence upon the formation and development of online communities in social networks. Hence, an accurate trust assessment method is essential to a robust OSN community. De Meo, Pasquale et al. put forward a quantitative measure of group compactness [13], which takes similarity and trustworthiness among users into account. Furthermore, an algorithm is developed for the optimization of this method. We have also proposed a trust model and assessment method oriented towards multimedia social networks [22]. At the same time, trust prediction is another major topic of social network research. The traditional approach is based on the exploration of the trust topology. However, according to sociology studies and life experiences of people, similar patterns of behaviors and tastes are commonly observed in the same social circle. In order to make full use of auxiliary information in trust evaluation, Jin Huang et al. [10] explored a novel joint social network mining (JSNM) method by aggregating heterogeneous social networks and thus addresses this problem. In addition, research on the evolution of online trust is faced with extraordinary challenges for the available data are mostly acquired through passive observations. For this, A methodology based on theories in social science was proposed [16], in order to support the studies of the evolution of online trust.

Recently, Pasquale and Agreste Santa et al. [13, 14] indicate that social group formation and the dynamic characteristics of topology structure evolution should be understood, and which are in essence. However, in the process of user gathering and community formation, the

trustworthiness relation between users is a greatly important factor. They proposed a measurable method for the degree of group compactness and considered the similarity and trustworthiness between users. Furthermore, they also proposed a novel algorithm to optimize the method. They provided an empirical research result based on real social networks, namely, Epinion, Ciao, and Prosper (a micro-lending site with implicit trust), by introducing centrality metrics to prove the advantage of this new method.

In addition, with regard to large-scale mobile social networking, users may belong to multiple communities or clusters, and overlapping users may play special roles in complex networks. Thereafter, the critical problem is how to assess or explain user trustworthiness [21]. Under such a circumstance, trust inference plays an important role in the trusted social linkage between (mobile) users. To infer the fuzzy trust relation between users in the large-scale social networking of overlapping communities, Shuhong Chen et al. [4] proposed an effective trust inference mechanism based on fuzzy community. This mechanism is called the Kappa-Fuzzy Trust. They then proposed an algorithm to test the community structure of a complex network under fuzzy degree kappa, meanwhile creating a fuzzy implicit social graph. Finally, they assessed the main functions of Kappa-Fuzzy Trust by simulation-based experiments.

2.3 Recommendation system for social networks

Recommendation system plays a key role in MSNs systems and applications. A suitable recommendation method or a high-efficiency algorithm is critical for sharing and distributing multimedia content among users. It is pointed out by Yu, Seok Jong [19] that due to the diversity of individual characteristics, the previous recommendation algorithms show unstable performances when facing various users. For this, they presented a dynamic competitive recommendation algorithm based on the competition of multiple component algorithms to provide constantly stable recommendations in social networks. Considering the inapplicability of traditional recommendation methods in a Web3.0 environment, Sohn et al. proposed a more reliable and precise content recommendation method through analyzing social networks [15]. Based on the analyses on both social networks and semantic concepts, Yunhong Xu et al. [18] come up with a personalized recommendation method targeting at researchers, for whom eligible research partners are searched and recommended for the purpose of promoting explorations and exchanges of knowledge.

As the killer application of social media and networking, recommendation systems based on social trust have been widely studied and applied. In this field, a personalized recommendation system can provide a good opportunity for the more efficient and wider interactions between the community members. The trust model based on user behavior has been proven useful, and this kind of models generally uses the interaction of a member with other members to calculate social trust value. However, Nepal Surya et al. [12] indicates that these current models significantly neglect the interactions of those members with whom a member has interacted; this phenomenon is also named as the “friendship effect.” The results of social science and behavioral science research show that the behavior of community members has a significant effect on friends. Therefore, they described a trust communication model based on associations that combines individuals with the behavior of their friends, and focused on three key dependency factors in trust propagation: the density of interactions, the degree of separation, and the decay of friendship effect. The final goal of this model is to realize the accuracy of the recommendation system.

To sum up, the available studies of multimedia social networks mainly aim at a certain single aspect on security, trust and intelligent recommendation. By contrast, there is still a lack of exploring the combination of all the aforementioned functionalities and an applicable prototype with efficiency and efficacy.

3 A trinity scheme of multimedia social network

We proposed a novel multimedia social network scheme, and it is an integrated system with diverse functionalities of online resources publishing, authorization management, usage control and license transfer, as well as multimedia/friend recommendation and socializing. Both online and offline modes of digital rights management are particularly highlighted in the scheme. The online DRM is achieved by access control mechanism, and the offline one allows users to download the audio/video to their mobile devices, protecting their digital rights of multimedia in Android mobile terminals. Furthermore, by setting usage control policies, login rights are limited only to users who meet specific security conditions. In this way, multimedia resources' security is better achieved. The misuse and unauthorized sharing of resources are prevented by means of regulating the authorization of digital content. In this way, the protection of digital copyrights of audio and video resources can be ensured. In addition to DRM, the interactions among users and between users and the system are fully refined and employed. The platform adopts an improved collaborative filtering recommendation algorithm, which is a combination of the recommendation algorithms for both social users and multimedia recommendations based on multimedia content attributes and features.

3.1 Design of system architecture and main functions

In this scheme, Browser/Server (B/S) mode is employed to build the trinity MSN, as is shown in Fig. 1. (Mobile) users could access to multimedia content stored in multimedia server by any browser, and DRM system server retrieves the requested content from database as well as checks authority of it, meanwhile requesting related digital rights when the copyrights attribute is needed. If users want to protect the digital contents that they upload, it will be achieved by using a proxy server with re-encryption key [6]. Front-end and back-end systems are two key aspects of the proposed scheme. The front-end is designed for mobile terminal users to have access to multimedia content by means of offline downloading a full version of encrypted digital content, freely pushing digital media content and online previewing. And then, after purchasing and sharing of the digital copyrights, user could play multimedia resources they previously got. Additionally, the front-end also enables several main functions like user's friends adding and recommendation, audio/video content recommendation and commenting, and secure login of the trusted users. Back-end is mainly used to publish multimedia audio and video, set access control policies and authorization rules, as well as mange all attribute items of the registered users and multimedia resources, including users' trust value.

Besides, the front-end and back-end systems aim at different kinds of user. The former is oriented to general users, including the registered and guest, while the back-end is specially for

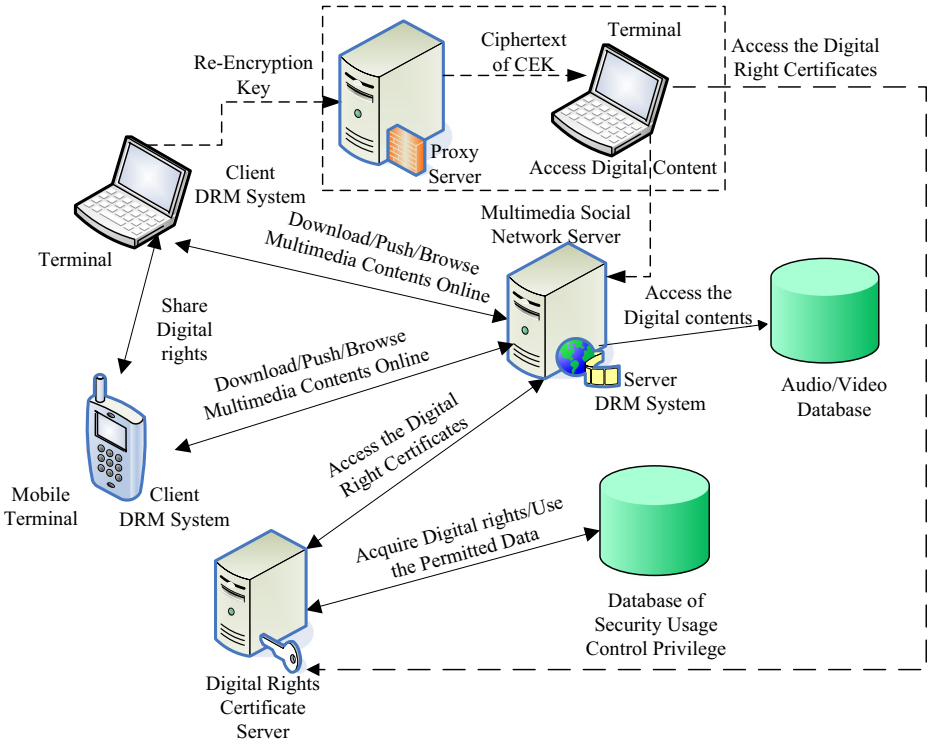

Fig. 1 The trinity architecture of multimedia social network combing online and offline

administrator. Generic users are allowed to register, log in, search, preview and download the full encrypted version, purchase or transfer the digital license for copyrighted AV, together with uploading and sharing their own audio and video. With the authority of setting access privileges for those uploaded content, illegal usage and unauthorized distribution would be firmly prevented. For administrators, they could modify, delete, retrieve and execute an audit of multimedia content that users uploaded, and, moreover, administrators are allowed to control and remove of common users. More importantly, administrators also set the secure login policies so that the suspected user, whose trust value is lower than a preset threshold of trust level, would be rejected upon login from the front-end system.

3.2 Improved recommendation algorithm

Existing personalized recommendation algorithms have their respective pros and cons. In order to improve their accuracy and efficiency, some recommendation algorithms were designed as a hybrid recommendation. Among these recommendation algorithms, collaborative filtering recommendation and content-based recommendation are the most widely applied. Recommendation based on the content does not suffer cold start and sparse-data problem, but the result of the algorithm is merely related to the original interests of the user, and it's too hard to find new interests of the user. The collaborative filtering recommendation algorithm finds the target user's interests in the basis of similar users (k-nearest neighbors), while the kind of algorithms

exhibits typical cold start and sparse-data problems. Therefore, we proposed an improved hybrid recommendation to fully consider advantages of both collaborative filtering and content-based recommendation algorithms.

3.2.1 The algorithm design

Specific steps of the improved hybrid algorithm are listed as follows:

(1) Collecting playing records of all users, and then builds a user-item matrix, as shown in Eq. (3–1).

$$R(m,n) = \begin{bmatrix} R_{11}, R_{12}, \cdots\cdots, R_{1n} \\ R_{21}, R_{22}, \cdots\cdots, R_{2n} \\ \vdots \quad \vdots \quad \cdots\cdots \quad \vdots \\ R_{m1}, R_{m2}, \cdots\cdots, R_{mn} \end{bmatrix} \tag{3–1}$$

Whereas, rows represent all items and columns represent all users. Each row data represents a user's playing records to all content items. If the playing time of user m is greater than 30% of the total length of the played item, then $R_{mn} = 1$, else $R_{mn} = 0$.

(2) Looking for the nearest neighbor set. In the user-item matrix, each row donates an n-dimensional vector of a user,and we compute similarities between these vectors by cosine-similarity in Eq. (3–2).

$$\cos(u,v) = \frac{v_u \times v_v}{|v_u| \times |v_v|} \tag{3–2}$$

v_u indicates the corresponding row of user u, v_v indicates the corresponding row of user v, cos(u,v) representing cosine similarity between user u and user v. The similarity of cos(u,v) is larger, the more similar between users u and v. By ranking cos(u,v) from high to low, the Top-*K* become the nearest neighbors of the target user. Meanwhile, the Top-*N* nearest neighbors are recommended to the target user, i.e., friends of similar interests in the recommendation mode

(3) Building the interest model of user. According to the target user's playing records, we compute frequency of key attributes (for instance, we compute frequency of singer and type of music) that the target user has played.

(4) Looking for the set to be recommended. In the user-item matrix, looking for the set that the target user's playing record is 0 and the nearest neighbors' playing record is 1. Then, in term of the frequency of key attributes in Step (3), we further compute the total frequency equal to a sum of every attribute's frequency. Finally, we rank the total frequency, and the Top-N_1 audios/videos would be recommended to the target user.

The pseudo-code of the improved collaborative filtering recommendation algorithm is shown in Fig. 2:

```
Input：
    sum                                  //The total number of playing record
    U[i]                                 //The i^th user
    Content[m]                           //The m^th audio/video
Output：userID; contentID
for(i=0;i<N;i++)
{for(m=0;m<M;m++)
 return U-C[i,m];                        // Building the user-item matrix
}
if(i<N)
{for(j=0;j<N;j++)
 {Cos (U-C[i],U-C[j])= (U-C[i])×(U-C[j]) / |U-C[i]|×|U-C[j]| ;}
                                         //Computing the similarity between user i and user j
rank Cos (U-C[i],U-C[j];                 //Ranking the similarity from high to low
return userID;                           //Returning the Top-N nearest neighbors
}
if（m<M）
{
  author.weight=sum[author]/sum; //The weight of author of content that the target user has played
  type.weight=sum[type]/sum;     //The weight of type of content that the target user has played
}
if(i<N&&m<M)
{ for (j=0;j<K;j++)
{
     if(U-C[i,m].playrecord=0&& U-C[j,m].playrecord=1)
  Content[m].weight<-author.weight+type.weight;//Computing the weight of content that the nearest
                                         //neighbors have played but the target hasn't played
  }
  rank Content[m].weight;                //Ranking the weight from high to low
  return contentID;                      //Returning contentID to be recommend
}
```

Fig. 2 Improved hybrid recommendation algorithm

3.3 Digital rights management for mobile multimedia

In this scheme, the functions of the multimedia digital rights management system cover the complete lifecycle of multimedia content, from the encryption, publishing and secure licensing of digital rights, to the decryption of digital content, sharing of digital rights and usage control of digital content on mobile terminals. By referring to the OMA DRM V2.0 international standards, our DRM system framework is thus developed, as shown in Fig. 3. This system is a typical end-to-end platform for secure transmission of digital media and comprises the server and client. The functions of the server are encryption, packaging and publishing of digital content as well as license generation and distribution. As for the terminal equipment on the client, the decryption, usage control and presenting of the downloaded digital media content are achieved through a mobile DRM player.

The DRM system is comprised of several modules. In the server, there are a module for the encryption of audios and videos, a module for the publishing of digital content and a module for the generation and distribution of license, as opposed to the digital content playing module and digital right sharing module in the client. Both the server and the client support cross-platform operations. The system is applicable on PCs, mobile intelligent terminals, and operational in operating systems like Windows, Linux, Android, as well as supportive of online Web access. Sharing of digital rights among terminal equipment is supported on mobile/stationary clients. In addition, common multimedia file formats, such as RMVB, RM, WMA, WMV, AVI, MKV, MP3, MP4, FLV, 3GP are all usable. Furthermore, the separation of

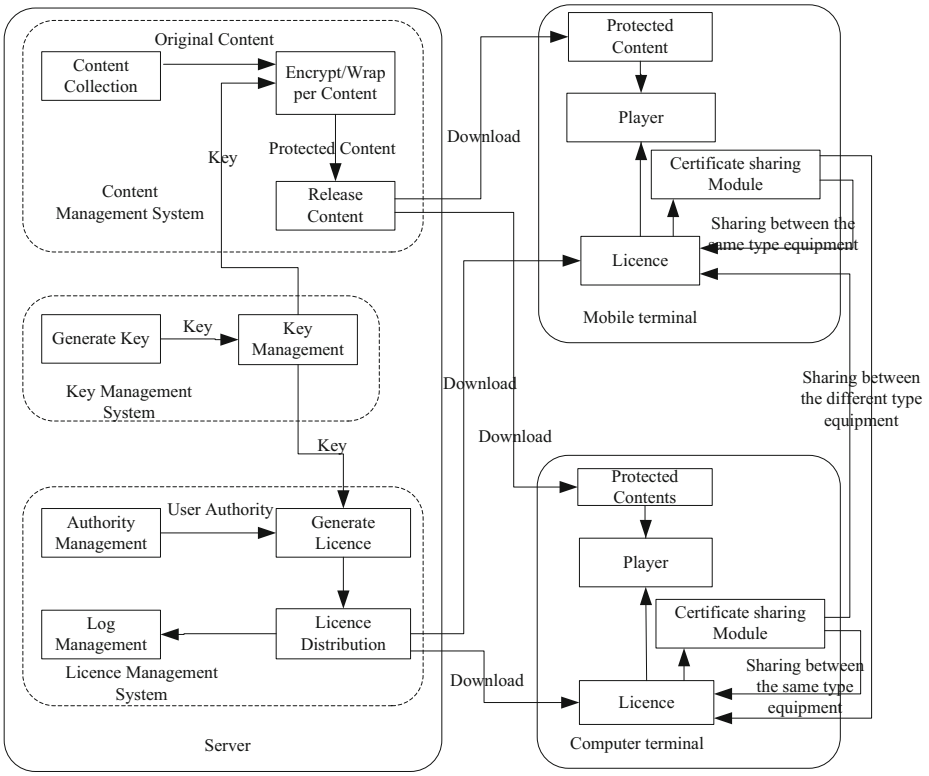

Fig. 3 Framework of DRM subsystem

multimedia content and digital rights, and of DRM player's kernel and graphic user interface (GUI), as well as the binding of license with the information of the hardware of terminal equipment, are achieved in the system. In this way, the security, reliability and controllability of offline audios and videos are ensured and cross-platform sharing is supported.

4 A prototype system realization and analyses

4.1 Prototype system realization

In term of the trinity scheme mentioned above, a Chinese multimedia social application, CyVOD MSN, was realized and deployed, as shown in Fig. 4. It presents the other two functional subsystem of trinity, i.e., content recommendation and digital rights management, respectively. In Fig. 4, the left columns of the user interface are the recommended audios and videos closely related to the presently rendering content. Besides, at the bottom of the interface is the major function area for digital rights management and multimedia security, where the purchasing of digital rights (licensing), downloading of digital rights (licensing) and downloading of the fully encrypted versions can be performed.

Fig. 4 Recommendation (*left*) and DRM (*bottom*) functions of CyVOD MSN

4.2 Comparisons and analyses of typical MSNs

4.2.1 Experimental results and analysis of hybrid recommendation

With regards to the improved recommendation algorithm, it is so important to select the appropriate evaluation metrics. Considering accuracy and completeness of the evaluation, this paper selected accuracy rate and recall rate as measurable metrics of the improved hybrid algorithm. Accuracy rate indicates that the number of a user's likes in the recommendation list accounted for the proportion of the length of the recommendation list. The metric is shown in Eq. (3–3).

$$P_L = \frac{N_L}{L} \tag{3–3}$$

Whereas, L refers to the length of the recommendation list, and N_L refers to the number of a user's likes in the recommendation list.

Recall rate represents that the number of a user's likes in the recommendation list accounted for the proportion of the number of a user's likes of all audio/video in the system, as shown by Eq. (3–4).

$$R_L = \frac{N_L}{M} \tag{3–4}$$

Whereas, M refers to the number of a user's likes in the test set.

Recall rate and accuracy are generally very important for the evaluation of the recommendation results, while they often conflict with each other. For example, when the length of

recommendation list increases from 10 to 20, recall rate increases, the accuracy reduces. Therefore the paper adopted a comprehensive evaluation index *F-measure* to evaluate the improved recommendation algorithm, as shown in Eq. (3–5).

$$F\text{-}measure = \frac{2P_L R_L}{P_L + R_L} \tag{3–5}$$

The experiment mainly focuses on the comparison between the improved hybrid algorithm and the previous content-based recommendation algorithm applied in CyVOD. The user's playing record is divided into two portions, and 80% is the training data set, 20% test data set. The lengths of recommendation lists are based on 10, 15, 20, 25, respectively. And, the comparison diagrams are illustrated by Fig. 5(a)–(c).

From the comparison diagrams shown above, we can conclude that the improved hybrid algorithm enabling collaborative filtering recommendation performs much better than the merely content-based recommendation one in CyVOD, from the aspect of accuracy, recall rate and *F-measure*.

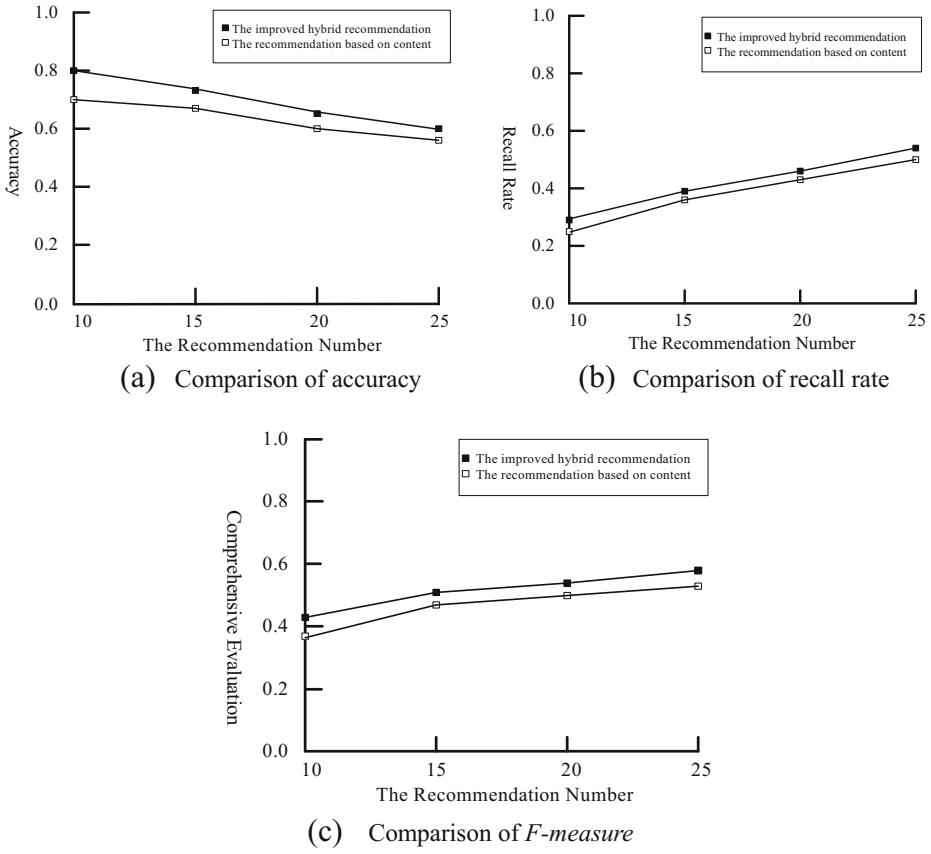

Fig. 5 Comparison diagrams from three aspects on accuracy, recall rate and F-measure. **a** Comparison of accuracy. **b** Comparison of recall rate. **c** Comparison of *F-measure*

4.2.2 Functionalities comparison and analysis

Existing and representative multimedia social networks and DRM systems, including Youtube, Google+, Flicker, Tudou, and Windows Media DRM, were selected for comparison with CyVOD. The differences are concluded as follows: First of all, CyVOD allows users to download audios/videos to their mobile devices and realize offline usage control, protecting copyrights of the downloaded content. Some general players, such as Windows Media DRM, only have the offline mode, meanwhile others only have online mode. CyVOD supports the encryption and packaging of audios and videos, while the others have no such function except for Windows Media DRM. Secondly, trusted and secure login of the user is possible with CyVOD, but all the other multimedia social networks do not support it. As for the sharing of digital rights, only CyVOD supports this function while the rest of them do not. Especially, only CyVOD enables all three functions of multimedia management with secure encryption, digital rights sharing and content/user recommendation. Compared with the typical multimedia social networks and DRM scheme, the scheme of this study is advanced in security performance and functional features concerning content security of digital media, special media players, digital right sharing, secure login and cross-platform operation, as shown in Table 1.

Table 1 is only involved with functional comparisons between CyVOD and the typical multimedia social networks and DRM scheme. And the proposed scheme realized most functional features than the typical multimedia social networks and DRM scheme. But there are still many deficiencies in CyVOD. We will further improve performances of CyVOD in the future research works. The extensive research works on the proposed architecture include: 1) explore social media users' behavior and mental diction based on situation analytics, and it will be further applied to the content/user recommendations for CyVOD, enhancing the accuracy and efficiency and providing more personalize recommendation results. 2) research and design an attributes-based access control policy, so as to protect digital copyrights of social media more effectively in term of media/users' characteristics.

Table 1 Comparisons between CyVOD MSN and others

Functional characteristics	Youtube	Google+	Flicker	Tudou	Windows media DRM	CyVOD
Multimedia management with secure encryption	No	No	No	No	Yes	Yes
Digital rights sharing	No	No	No	No	Yes	Yes
Content/User recommendation	Yes	Yes	Yes	Yes	N/B	Yes
Trusted login	No	No	No	No	No	Yes
Enabled access mode	Online	Online	Online	Online	Offline	Both Offline and Online
Cross platform	Web, Android, iPhone	Web, iPhone	Web, iPhone	Web	Windows	Windows, Linux, Android, Web

5 Conclusions

In this article, we proposed a holistic trinity scheme of multimedia social network, developed an improved hybrid recommendation algorithm by combing collaborative filtering and content-based recommendation, and constructed a prototype system called CyVOD. Both online and offline modes of mobile multimedia DRM are applied to the realized platform. Digital rights management is achieved by means of encrypting digital content and controlled access rights. Moreover, security policies that verify the identities of users are adopted for the purpose of preventing illegal users from malicious transmission of digital content. The improved hybrid recommendation algorithm used in CyVOD has improved recommendation accuracy in comparison with the merely content-based methods. One of the next research works and extensions is to explore social media users' behavior and mental diction based on situational analytics, and it would be further applied to the hybrid recommendation algorithm. Besides, other research efforts include both the further enhancement copyrighted multimedia security and the ease of use for users' media experiences by using deep learning intelligence and soft computing technologies.

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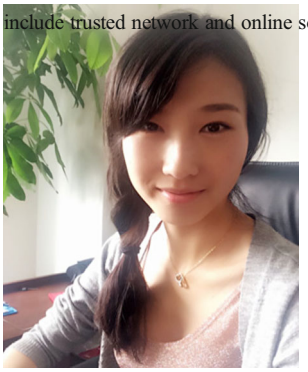

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