A Proposal of Semantic Analysis based Integrated Multi-Level Search System for Smart TV

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***Abstract*—Aligned with the rapid change of broadcast environment TV is no longer than a passive device to receive a signal of terrestrial television broadcasting. A Smart TV is the new trend of integration of the Internet and Web 2.0 features into the modern television sets and set-top boxes. The users having much experience in a computer want to use a Smart TV alike. However, a Smart TV has yet to provide various user interface devices such as a mouse and a keyboard thus it is needed to develop new search technology to analyze user intents from simple user keyword phrase and search the target contents from the multiple sources including broadcast network and Internet. In this paper, we proposed the framework of semantic analysis based integrated multi-level search system to improve search accuracy and expand search coverage. The proposed system can retrieve the user desirable multimedia contents from various sources at a time by analyzing ambiguous user keywords phrase with ontological knowledge.**

***Index Terms*—Semantic Network, Multi-Level Search, Integrated Search, Smart TV**

I. INTRODUCTION

The Internet technology has evolved very fast over the past several decades, so it has been having a big effect on our daily life such as education, art, game, and broadcast etc. In reality, it is no exaggeration to say Internet is an indispensable infrastructure to lead everyday life these days. Now Internet technology plays a principle role in developing new technologies as well as becoming a fundamental infrastructure to provide various services. As the Internet has been growing up, many technologies have taken another big step forward to a new paradigm shift – the convergence with IT technology. The broadcast technology has also expanded its transmission infrastructure to Internet. TV is no longer than a passive device to receive a signal of terrestrial television broadcasting and now it is evolving into a smart device providing Internet based services [20]. Nowadays we can watch plenty of multimedia contents scattered over the Internet and make use of interactive services including SNS, Internet full browsing, and applications on Smart TV.

While the Smart TV provides multiple services in addition to broadcasting, the fact still remains the major role of TV is to watch multimedia contents either TV shows or payable videos. These days users can get a great deal of multimedia contents from various sources involving broadcasting stations or contents providers on Internet; however, it is quite difficult to find a multimedia content what a user wants to watch using the simple search keywords from the limited UI/UX on TV. We think a TV hasn't still been a good interactive multimedia device with easy input devices such as a mouse and a keyboard to get lots of input data easily from users but a fantastic appliance to watch video contents using a large screen. Therefore it is needed to develop a new search system for Smart TV retrieving target contents easily with ambiguous search keywords from various multimedia sources including broadcast network and Internet. We proposed the semantic analysis based integrated multi-level search system searching considering newly emerged requirements from broadcast environment changes. In the rest of this paper, we present our contributions. In Section II, we present the related works and Section III describes the proposed system, the semantic network based integrated multi-level search system. Then we discuss our current works and future works to improve multimedia search efficiency.

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II. RELATED WORKS

Unlike textual data, whose content can be searched for using text strings, multimedia information retrieval(MIR) is dependent on processes that have either cumbersome requirements for feature comparison (e.g. color or texture) or rely on associated, more easily processable descriptions, selecting aspects of an image or video and expressing them as text, or as concepts from a predefined vocabulary.[17]

The earliest years of MIR were frequently based on computer vision algorithms which focused on feature based similarity search over images, video, and audio. Influential and popular examples of these systems are QBIC [1] and Virage [2], around mid-90s. Within a few years, the basic concept of the similarity search was transferred to several Internet image search engines including Webseek [3] and Webseer [4]. Significant effort was also placed on the direct integration of the feature-based similarity search into enterprises-level databases such as Informix datablades, IBM DB2 Extenders, or Oracle Cartridges [5] to make MIR more accessible to private industry.

In the area of video retrieval, the main focus in the mid-90s was on robust shot boundary detection; the most common approaches involved thresholding the distance between color histograms corresponding to two consecutive frames in a video [1]. Hanjalic et al. [6] proposed a method which overcame the problem of subjective user thresholds. Their approach was not dependent on any manual parameters. It gave a set of key frames based on an objective model for the video information flow. Haas et al. [7] described a method of using the motion within the video to determine the shot boundary locations. Their method outperformed the histogram approaches of the period and also performed semantic classification of the video shots into categories such as zoom-in, zoom-out, pan, and so on. A more recent practitioner's guide to video transition detection is given by Lienhart [8].

Near the turn of the 21st century, researchers noticed that the feature-based similarity search algorithms were not as intuitive or user-friendly as they had expected. One could say that systems built by research scientists were essentially systems which could only be used effectively by scientists. The new direction was geared toward designing systems which would be user-friendly and could bring the vast multimedia knowledge from libraries, databases, and collections to the world. To do this, it was noted that the next evolution of systems would need to understand the semantics of a query, not simply the low-level underlying computational features [18]. This general problem was called "bridging the semantic gap". The semantic gap is the lack of coincidence between the information that one can extract from the visual data and the interpretation that the same data have for a user in a given situation. Techniques for attempting to bridge the semantic gap in multimedia retrieval are followings [19].

A. Automatic Annotation

The current techniques for auto-annotation generally fall into two categories; those that first segment images into regions, or 'blobs' and those that take a more scene-orientated approach, using global information.

Duygulu et al. [9] proposed a method by which a machine translation model was applied to translate between keyword annotations and a discrete vocabulary of clustered 'blobs'. Jeon et al. [10] improved on the results of Duygulu et al. [9] by recasting the problem as cross-lingual information retrieval and applying the Cross-Media Relevance Model (CMRM) to the annotation task. Lavrenko et al. [11] used the Continuous-space Relevance Model (CRM) to build continuous probability density functions to describe the process of generating blob features.

Most of the auto-annotation approaches described above performs annotations in a hard manner; that is, they explicitly apply some number of annotations to an image. A hard auto-annotator can cause problems in retrieval because it may inadvertently annotate with a similar, but wrong label.

B. Semantic Spaces

Instead of applying hard annotations, we have developed an approach in which annotation is performed implicitly in a soft manner. A semantic-space of documents (images) and terms (keywords) is created using a linear algebraic technique. Similar documents and/or terms within this semantic-space share similar positions within the space. Latent Semantic Indexing is a technique originally developed for textual information retrieval. Berry et al [12] described how Latent Semantic Indexing can be used for cross-language retrieval because it ignores both syntax and explicit semantics in the documents being indexed.

C. Semantic Annotation

Early work on semantically describing images using ontologies as a tool for annotating and searching images more intelligently was described by Schreiber et al [13]. Several authors have described efforts to move the MPEG-7 description of multimedia information closer to ontology languages such as RDF and OWL [14, 15].

The aim of using ontologies to describe multimedia resources is to provide well-structured information to improve the accuracy of retrieval. Semantic web technologies also facilitate the integration of heterogeneous information sources and formats. Well-structured information is crucial for providing advanced browsing and visualization facilities, as opposed to more traditional query-based systems.

There are several approaches to semantically annotating multimedia. The aceMedia project [16] is developing a knowledge infrastructure for multimedia analysis, which incorporates a visual description ontology and multimedia structure ontology. They have also developed the M-OntoMat-Annotizer tool that allows users to manually annotate multimedia items with semantic information. Won-Ken Yang at al [21] developed an image description and matching scheme using synthesized spatial and statistical features for recommendation service.

III. SEMANTIC MULTIMEDIA CONTENTS RETRIEVAL FRAMEWORK

The Smart TV has various multimedia content sources such as broadcasting stations and various content providers scattered on Internet. We classified these multimedia content sources into three categories. The first is the local repository managed by Smart TV businesses similar to IPTV businesses such as QOOK TV, B TV, and U+ TV. The second is the EPG (Electronic Programme Guide) repository managing the schedule information of TV program. The third is the global repository such as YouTube having plenty of UCCs.

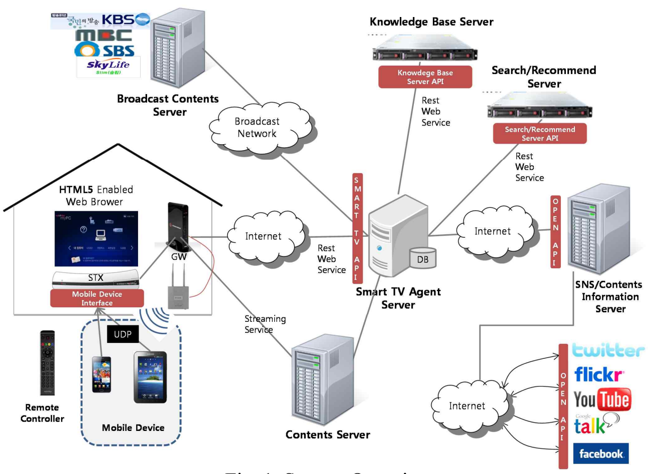

Fig. 1. System Overview

So we designed the semantic network based integrated multi-level search system with three search engines for local repository, EPG repository, and global repository. The proposed system overview is illustrated in Fig. 1. The Smart TV is connected by Internet with back-end search systems including Smart TV agent server, knowledge base server, search/recommend server, contents server, and SNS/contents information server and a user can interact with the Smart TV agent server through a HTML5 enabled web browser.

The Smart TV agent server performs the two-phase search process. In first phase, it analyses the meaning of user search keywords using the knowledge base server and then searches multimedia contents matching with the analyzed search keywords from several contents repositories in second phase. The details of the two-phase search process are followings:

Phase 1: Interpretation of User Keywords

1) The user search keywords phrase entered through the web-based smart TV browser are sent to the Smart TV agent server.
2) The Smart TV agent server parses the blank-separate user search keywords phrase into a list of terms and sends it to the knowledge base server.
3) The knowledge base server finds knowledge objects corresponding to each term from the smart TV agent server.
   a. If it finds several knowledge objects matching with one term, it chooses one with the highest weight.
   b. If it finds nothing, it returns null value to the smart TV agent server.
4) The knowledge base server generates candidate query graphs connecting all possible permutations of knowledge objects.
   a. If it gets dozens of candidate query graphs, it regards the shortest graph as the best result and selects the top-N-best graphs.
   b. It picks out knowledge objects from each best graph and then creates the list of expanded user keywords.
5) The knowledge base server sends the smart TV agent server the interpreted results of user search keyword involving user search keywords, knowledge objects, query graphs and expanded user keywords.

Phase 2: Contents Search

1) The Smart TV agent server sends the interpreted user query to the local repository search engine.
2) The local repository search engine creates a SPARQL query with the best query graph and executes it.
3) The local repository search engine performs grouping, sorting and classifying on the search result sets and appends them to the interpreted user query. It finally returns the interpreted user query to the Smart TV agent server.
4) The Smart TV agent server dispatches the interpreted results to two other search engines, EPG repository search engine and global repository search engine.
5) Each search engine creates query expressions using the interpreted results and contents list.
   a. The EPG repository search engine generates a MySQL query.
   b. The global repository search engine generates queries for web search engines (e.g. YouTube, Daum, Naver, etc.).
6) Two search engines send the Smart TV agent server the search results being grouped, sorted, and classified.
7) The Smart TV agent Server integrates the search results from each search engine and browses it to a user.

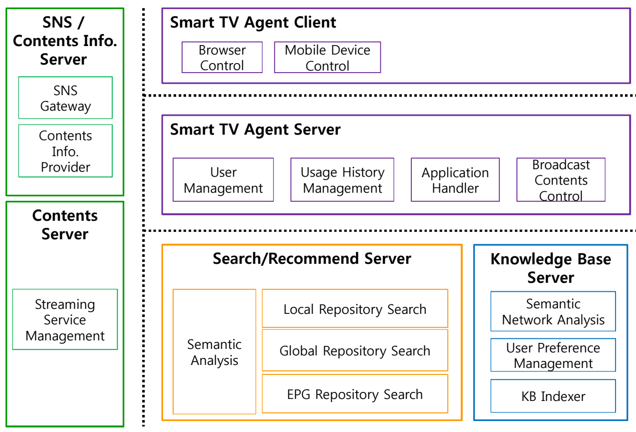

Fig. 2. System Architecture

Fig. 2 presents the architecture of the proposed system consisting of several subsystems. As it shown, each subsystem has several functional software blocks and has close relationship with other subsystems with various interfaces.

A. Smart TV Agent Server

The Smart TV agent server is designed to manage the user profile, watching history and user behavior pattern. It also controls the execution of Smart TV applications and broadcast contents. The functional blocks of the Smart TV agent server are as follows.

User Management

The Smart TV agent server manages user profiles containing user personal information. Some properties representing user preferences involving the favorite genre of movie, TV show, and music are stored in the knowledge base server and used for grouping, sorting, and classifying the search results. The TABLE I describes the data structure of user profile.

TABLE I
USER PROFILE

Name	Type	Description
seq_no	Integer	Sequential number
u_name	String	User name
u_id	String	User id
u_passwd	String	User password
u_sex	String	User sex
u_age	String	User age
u_job	String	User affiliation
f_movie	String[]	Favourite movie genre
f_show	String[]	Favourite TV program genre
f_music	String[]	Favourite music genre
s_id	String[]	User id for SNS
s_passwd	String[]	User password for SNS

User History Management

The Smart TV agent server gets the user's watching history from the Smart TV agent client and stores in the user history database. It conducts the regular time-frequency analysis of user histories collected during a specific period to derive user preference data such as the favorite TV channel, the favorite TV show and the latest watched video from the user history database. It stores the analyzed data in the knowledge base and creates the personalized menu page providing the current TV show on the favorite channel and the current channel list airing the favorite TV show by searching the EPG data with the user preference data.

Broadcast Contents Control

The Smart TV agent server controls broadcast contents and sets the DVR alarm by user request. It delivers user requests to a TV tuner card and changes the channel of terrestrial TV broadcasting and also provides the video recording facility setting it up in user-specified time.

Application Handler

The Smart TV agent server takes charge in handling various applications including a multimedia contents search application so it manages the life cycle of applications and handling the events from users and those applications.

B. Knowledge Base Server

The knowledge base server manages ontology representing metadata of multimedia contents retained in a contents server. We chose five areas of multimedia contents such as movie, soap opera, entertainment show, sports game and music video to implement domain ontology and designed an ontology using the Web Ontology Language (OWL). Fig. 3 shows the examples of film domain ontology. The left section describes the hierarchy of classes and object properties belonged to the film domain. The right section illustrates the description and instances of the Film class. For example, the Film class is a sub class of FilmDomain, Topic and Media class and it has dozens of object properties involving film_country, film_directed_by, film_distributors, and so on.

It is very cumbersome to set up a knowledge base from scratch, so we used a semi-automated tool to migrate contents metadata from a legacy database to the knowledge base server.

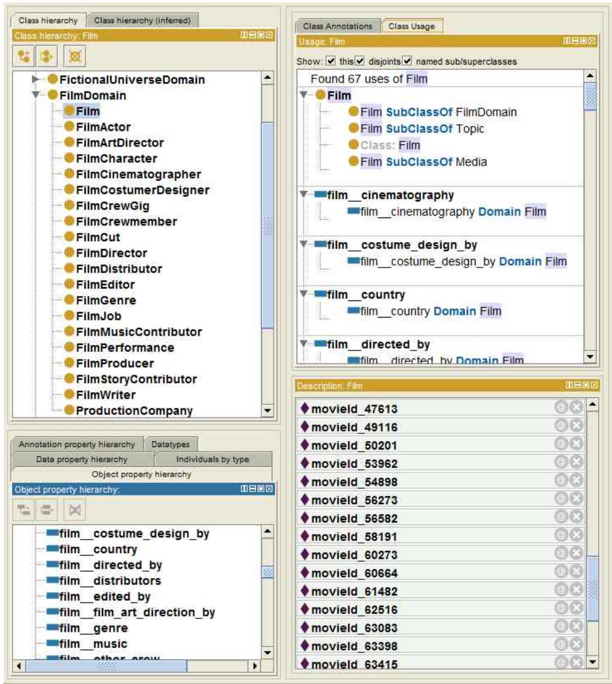

Fig. 3. Examples of the film domain ontology

The functional blocks of the knowledge base server are as follows.

Semantic Network Analysis

The Sematic Network Analysis module analyses the user search keyword referring to ontological knowledge and creates the interpreted user query including analyzing results such as knowledge objects, query graphs and expanded user keywords.

Fig. 4 depicts the interpretation process of user search keywords consisting of keyword phrase stemming, term mapping, query graph constructing and query graph ranking.

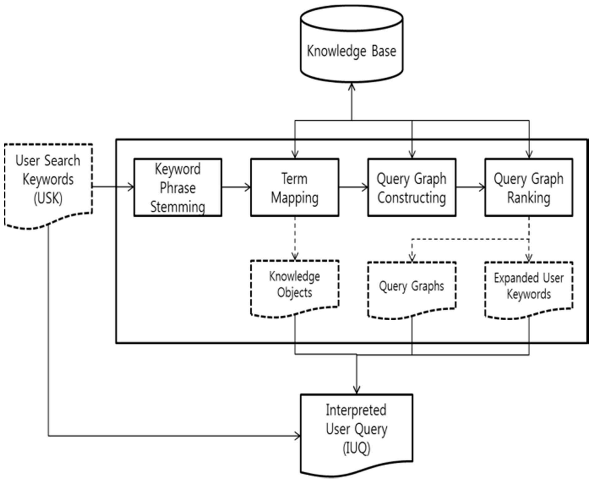

Fig. 4. Interpretation Process of User Search Keywords

- Keyword phrase stemming: it gets the blank-separated user search keywords from the search/recommend server and parses it into a list of terms. In this step, we don't consider the morphological analysis of user query since we assumes the user inputs a query expression form of not natural language but simple keywords.
- Term mapping: the knowledge base server makes indexes of itself with the name and labels of all knowledge objects when it starts up. It finds all knowledge objects corresponding to each term of user search keyword by comparing with the indexes of knowledge base. Sometimes it can have the ambiguity problem having several similar knowledge objects for one term. We ranked the knowledge objects by their pre-defined weight values and chose the highest one.
- Query graph constructing: it builds candidate query graphs connecting all possible permutations of knowledge objects within a pre-defined range (i.e. distance) with no duplicates. It can find new intermediate knowledge objects between user search keywords during query graph generation and make up the query graph including them.
- Query graph ranking: it sorts the candidate query graphs by their ranking points. We assume the closer together knowledge objects are, the stronger the semantic relationship between them, so we choose to use the shortest path model and give higher rank to the shorter query graph than others. After all we select top-N-best query graphs and make the list of expanded user keywords by extracting the labels of knowledge objects having the 'isDummy' value set to zero from those selected query graphs. When we design the ontology, we pre-annotated the knowledge objects being used for user search keywords by setting the 'isDummy' value to zero.

Fig. 5 shows the list of expanded words for the user search keywords, "Seung-Wan Ryu Movie". The knowledge base server makes it from query graphs connecting two knowledge objects, the movie director named Seung-Wan Ryu and the movie.

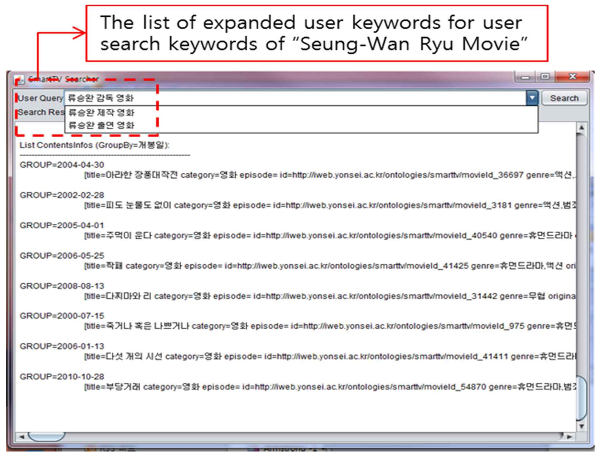

Fig. 5. Examples of the list of expanded user keywords

User Preference Management

The knowledge base server manages user preference data including favorite genre of movie, music, TV show, and favorite actor/actress to be used for grouping, sorting, and classifying the search results. Most of user preference knowledge comes from the user profile information and some of that could be achieved through analysis of user behavior pattern from the Smart TV agent server.

KB indexer

The knowledge base server creates indexes of itself with the name and label of all knowledge objects to ensure efficient performance and updates it periodically to reflect changes of ontology.

C. Search/Recommend Server

The search/recommend server provides three search engines with the interpreted user query arose from the semantic analysis of user search keywords and then searches multimedia contents matching with the interpreted user keywords from several repositories.

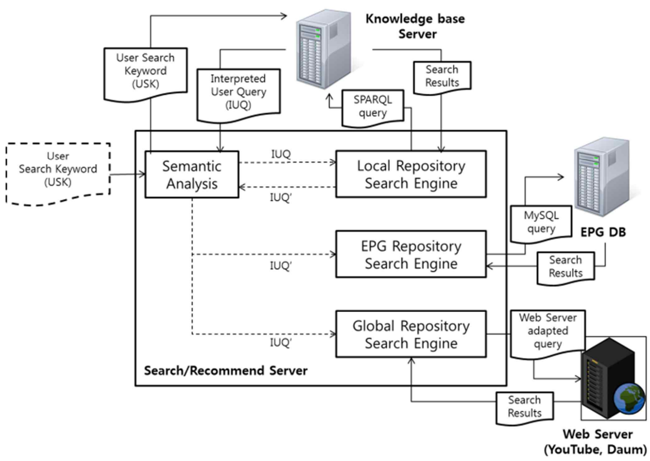

Fig. 6. Search Processing of the Search/Recommend Server

Fig. 6 depicts the searching steps of the search/recommend server. The search/recommend server gets the interpreted user query corresponding to the user search keyword from the knowledge base server and then sends it to the local repository search engine module at first. It receives the interpreted user query appending the search result from the local repository engine module and dispatches it other two search engine modules. After all it integrates all search results from three search engines and sends them to the Smart TV agent server. The functional blocks of the search/recommend server are as follows.

Semantic Analysis

The semantic analysis module gets the user search keywords from the Smart TV agent server and creates the interpreted user query involving user search keywords, knowledge objects, query graphs and expanded user keywords using the semantic analysis based on the ontological knowledge base. It delivers the interpreted user query to three search engines creating suitable forms of query expressions for respective repositories.

Local Repository Search Engine

The local repository search engine module is designed to search multimedia contents matching with the user search keywords in the local repository. First of all it creates a SPARQL query expression with the best query graph of interpreted user query and then executes it to search knowledge objects meeting the conditions represented in the where clause. When it gets the search results it performs grouping, sorting and classifying on them reflecting user preferences. It appends the search result sets, the contents list, to the interpreted user query and sends it to the Smart TV agent server.

EPG Repository Search Engine

The EPG repository search engine module aims to search the broadcast schedule information of target contents in the EPG repository retaining the weekly TV schedule including the four major public TVs and several cable TVs.

TABLE II
EPG DATA STRUCTURE

Name	Type	Description
key	String	Identifier
Channel	String	Channel number
Chname	String	Channel name
Program Title	String	TV show title
subtitle	String	TV show subtitle
StartTime	String	Start time of TV show
endTime	String	End time of TV show
Day	String	Broadcast day of TV show
Synopsis	String	Synopsis of TV show
Summary	String	Summary of TV show
genre	String	Genre of TV show
episodeNumber	String	Episode number of TV series
Directors	List<String>	List of directors
castMembers	List<String>	List of cast members
Uuid	String	Unique identifier of knowledge object
imgUrl	String	URL of TV show poster

It creates a MySQL query expressions with the contents list of interpreted user query and runs it to search the broadcast schedule of the contents list for the next three days. It sorts the search results by start time of TV show and sends them to the Smart TV agent server. The TABLE II shows the data structure of EPG.

Global Repository Search Engine

The global repository search engine module seeks to filter out undesirable search results from web search engines. It creates queries adapted for the two web search engines including YouTube and Daum TV pot with the contents list of interpreted user query and then dispatches queries to them. The respective web search engine searches the UCC (User Created Contents) matching the contents title with the contents list of interpreted user query and then returns them to the global repository search engine.

The global repository search engine conducts following three steps:

- Filtering: It uses the simple term frequency (TF) to filter out unsuitable contents from the search results. It builds the keyword list for each UCC by collecting the tags and tokenized words of content title and then calculates similarity between the keyword list of each UCC and the user search keywords. After performing on all contents it picked out contents having similarity over a specific threshold. We set the threshold value of threshold to 0.3 by experiment results. The following simple expression can be used to estimate a similarity $S(q, c_i)$ of a content item c_i and user query q :

$$S(q, c_i) = n(q \cap c_{i \in N}) / n(q \cup c_{i \in N}) \quad (1)$$

where

c_i = word list of content item i;
q = word list of user query .

- Re-ranking: It conducts re-ranking on the filtered results regarding user query, user preferences and similarity between contents. The following expression can be used to calculate rank point r_i of a content item c_i, user query q and user preference p :

$$S(c_i, c_j) = n(c_{i \in N} \cap c_{j \in N}) / n(c_{i \in N} \cup c_{j \in N}) \quad (2)$$
$$S(c_i) = \sum_{j=1}^{n} S(c_{i \in N}, c_j) \quad (3)$$
$$S'(c_i) = \frac{S(c_{i \in N})}{\mathrm{Max}\, S(C)} \quad (0 \le S'(c_i) \le 1) \quad (4)$$

$$S(p, c_i) = n(p \cap c_{i \in N}) / n(p \cup c_{i \in N}) \quad (5)$$

$$r_i = \alpha \cdot S(q, c_{i \in N}) + \beta \cdot S'(c_{i \in N}) + \gamma \cdot S(p, c_{i \in N}) \quad (6)$$

where

c_i, c_j = word list of content item i, j ;
q = word list of user query;
p = word list of user preference .

In Equation (6), we use the term frequency to estimate all those similarities and set the weight value of α, β and γ to 0.55, 0.35, and 0.1 in succession by experiment results.

- Grouping: It puts the re-ranked results into several groups by contents providers, pre-defined categories and topics. We use content tags to classify them by content providers or categories and applies K-means algorithm to group them by similar topic cluster.

D. *Smart TV Agent Client*

The Smart TV agent client provides a user with web-based interactive user interfaces updating web pages responding to user commands. We think the current remote controllers aren't suitable for interactive user interfaces so we come up with the remote control application executing on the mobile device. The users can handle the Smart TV with the mobile device leaning back in couch. It receives the signal of mobile devices facilitating control of user interfaces using a UDP server and delivers it to the Smart TV agent server.

The Smart TV agent client obtains the user input data from the Smart TV browser and sends the Smart TV agent server those data to be used for creating new web pages. The users can enter various commands through the Smart TV browser; besides they should get some information from the Smart TV agent server occasionally. For example, they are allowed to receive the alarm message set up at specific time for their favorite TV show while they are watching other TV show. We designed to receive information from the Smart TV agent server using WebSocket within a browser.

E. *SNS/Contents Information Server*

The SNS/Contents information server plays a principle role in managing the contents information and social network services. It manages the detail information of a multimedia content like poster, synopsis, director, and actor/actress etc. The Smart TV agent server browses the detail information of the content user chooses to watch. It provides users with facilities utilizing the social network services such as Facebook and Twitter to share opinions about multimedia contents while watching a Smart TV. We build an automatic log-in system for registered users having the account information of social network services in their profiles.

F. *Contents Server*

The contents server takes charge of the seamless multimedia streaming service for the target contents - play, stop, fast forward, and rewind. It takes over the URL of multimedia content as search results or user command from the Smart TV agent Server and plays it after being clicked for watching on the Smart TV browser. It is very important to manage the unique URL for each multimedia content keeping consistency with the knowledge base server since it only recognizes the multimedia content by its URL.

IV. PROTOTYPE SYSTEM

We have developed the prototype system to verify our idea searching multimedia contents from various repositories based on the semantic analysis. We first built up the knowledge base server having over 2,000 multimedia contents of five domains including movie, soap opera, TV show, sports, and music video consisting of 10,000 knowledge objects designed by the ontological schema. Our prototype system has three subsystems involving the Smart TV client system, the Smart TV agent server system, and the contents server system. The Smart TV client system contains the Smart TV agent client and the Smart TV browser supporting HTML5. The Smart TV server system includes the search/recommend server, the knowledge base server, and the smart TV agent server.

The prototype system provides the integrated search results merging the respective search results from three search engines including the local repository search engine, the EPG repository search engine, and the global repository search engine for a user search request.

Fig. 7. The search results of local repository engine

Fig. 7 depicts the list of VoD contents from the local repository search engine. It listed search results for the best interpretation result stemming from the semantic analysis for the user search keyword "Seung-Wan Ryu, Movie". It gives the user the top-N-best interpretation results the user to select one of other interpretation results as the alternative search keywords when the user's not being satisfied with the best one located on the top of the list.

Fig. 8. The search results of EPG repository search engine

Fig. 8 shows the examples of EPG data matching with the user search keywords grouped by channel, broadcast day, and genre from the EPG repository search engine. The user can watch TV show immediately by choosing one or set up alarm to reserve the particular TV show not being on air now.

Fig. 9 represents the list of UCCs from two web search engines involving YouTube and Daum TV pot. We think we are not allowed to control the searching process of those web search engines so we designed the global repository search engine to focus on making the proper query expression and picking up the desirable results. The prototype system gets the search results from the web search engines and filters out the undesired results having low similarities with the user query and classified by the content providers, categories, and topics. The two preceding grouping factors described in the tag information of UCC are static, while the last factor is dynamic. We pick up the frequently used topic words from the description of UCC and then use the K-means algorithm to classify them in similar topic group.

Fig. 9. The search results of global repository search engine

V. CONCLUSIONS

As the Internet technology has been growing up fast, the broadcast environment has been expanded to Internet. Aligned with these trends TV is no longer than a passive device only to receive a signal of terrestrial television broadcasting and it is evolving into a smart device providing Internet based services like a smart phone. A Smart TV is the new trend of integration of the Internet and Web 2.0 features into the modern television sets and set-top boxes. The users having much experience in a computer want to use a Smart TV alike. However, a Smart TV has yet to provide various user interface devices such as a mouse and a keyboard thus it is needed to develop new search technology to analyze user intents from simple user search keywords and search the target contents from multiple sources including broadcast network and Internet.

In this paper, we proposed the framework of semantic analysis based integrated multi-level search system to improve search accuracy and expand search coverage. The proposed system can retrieve the user desirable multimedia contents from various sources at a time by analyzing ambiguous user keywords phrase with ontological knowledge base. We hope that the proposed system will foster the vision of user centered search system to understand user's intent from limited search keywords for beyond Smart TV.

In the future we will implement the knowledge augmentation component and the query graph adjustment component. Especially, the user preference learning from user query history and the social knowledge mining could be other distinctive features of our framework.

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