

A New Data Cube System for the Multi-dimensional Analysis of News Videos

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Abstract— To devise a new paradigm for the analysis of news videos which can provide the multi-dimensional analysis of a topic in a new video, we propose a novel data cube model, viz., *NVideoCube*, which is able to manage systematically a news topic and analyze the news videos according to chronological view, categories, and news programs. It provides viewers with various facilities on the news videos such as 1) showing the evolution of a certain news videos in a topic with respect to the abstract time level; 2) catching a snapshot of the evolution of news in a certain period; 3) providing the evolution and highlights of news by topics according to each broadcaster. The validity of our approach is illustrated by a scenario based example.

Keywords— data cube, data warehouse, news video, OLAP, similarity matrix

I. INTRODUCTION

At present, video materials and video services are more available than ever. In particular, with the growing popularity of digital news video, the numbers of collections of news video databases have recently exploded. Consequently, news videos are valuable to data analysts, information providers, and TV consumers, because of their information richness [1]. Therefore, news video databases were the subject of extensive research over the past decade, to develop effective and efficient tools for manipulation and analysis of news videos.

According to the recent research literature, most research focus on the intra-structural analysis of news video such as news video parsing, indexing of browsing and retrieval of news video [1-8]. Concerning shot boundary detection, Z. Cernekova *et al.* [2] proposed a shot boundary detection method based on mutual information (MI) and joint entropy (JE). They used MI and JE for detecting abrupt cuts and gradual transitions, respectively. X. Ling *et al.* [3] suggested a three-step shot boundary detection method based on SVM, which consists of three modules and operates sequentially. It firstly abstracts the reordered frame sequence (RFS) and detects abrupt cuts using SVM, and then detects gradual transitions by temporal multi-resolution analysis of RFS. As to anchor shot detection, A. Hanjalic *et al.* [4] proposed an approach for template-based anchor shot detection by using sequence-own video shots as the template for detecting anchor shots of that sequence. X. Luan *et al.* [5] proposed an anchor shot detection method based on clustering, viz., AnchorClu. After fast clustering of a shot's key frames, some clusters

including the anchorperson cluster can be obtained. Then via some proper rules, the anchorperson cluster is selected.

Nevertheless, there are also ongoing attempts to analyze the inter-structure of news videos such as topic threading [9-10] and auto-documenting [11-12]: The topic threading is a method that provides the users with the ability to interactively track up and down a topic of interest by selecting topic threads. Ide *et al.* [9] introduced a method to classify news stories into one of predefined topics using words extracted from closed caption and to extract topic threads. On the other hand, the auto-documenting is to generate a documentary automatically, which is a summarization of a topic. Wu *et al.* [12] proposed a novel threading approach for the topic tree construction and auto-documenting through textual-visual concepts which can provide the semantic organization of news stories allowing viewers to navigate and interpret a topic. Until now, it is however in a relatively early stage to analyze the inter-structure of news video.

A data cube has been proved a powerful model to efficiently handle Online Analytical Processing (OLAP) queries on large data collections that are multi-dimensional in nature [13]. A data cube allows data to be modeled and viewed in multiple dimensions which are the perspectives or entities with respect to which an organization wants to keep records. Traditional data cube deals with numeric measures such as count, sum and average [13]. However, data cube has been recently extending to new domains such as text documents [13-14], graphs [15-16], and multimedia data [17].

The primary concern of this paper is to devise a new paradigm for the analysis of news videos which can provide the multi-dimensional analysis of a topic in a new video by means of data cube structure. In general, people have their own interests when watching news videos. Someone might be interested in economic issues and the other one in politics. Thus, retrieval and analysis of news stories with respect to their interest is more appropriate. For the specific example, when searching news stories related to the topic "The Second Summit of South and North Korea in 2007", it is fascinating if the system can provide a retrieval of news stories belonging to the economy category with abstract time level (e.g., before, during, and after summit), rather than just showing whole items and leaving the viewers alone.

In this paper, we propose a novel data cube model for a framework of news video analysis, viz., *NVideoCube*, which is

able to manage systematically a news topic and analyze the news videos according to chronological view, categories, and news programs. Since our model is intrinsically based on a database, it is free to use all facilities provided in a database such as an information retrieval by means of SQL and some basic statistic information. Moreover, due to a similarity matrix and a data cube structure supporting standard OLAP operations, it provides various facilities on the news videos such as 1) showing the novel stories and the evolution of a certain news topic with respect to the abstract time level (i.e., newly emerging theme, evolving stories, and closing stories); 2) catching a snapshot of the evolution of news in a certain period of time; 3) providing the evolution and highlights of news by topics according to each broadcaster. Since news broadcasters may have different view-points on the special issues in general, it is meaningful to provide the evolution and highlights of the news topic according to each broadcaster.

An *NVideoCube* has some peculiar features comparing to the traditional data cube structure in two major ways. First, the measure of each cell in a data cube is not a scalar aggregate but a list of news stories at each abstract level. Second, view model of each cell in a data cube provides an evolution and highlights of news video in a topic. The overall framework of a proposed data cube model is presented in Fig. 1.

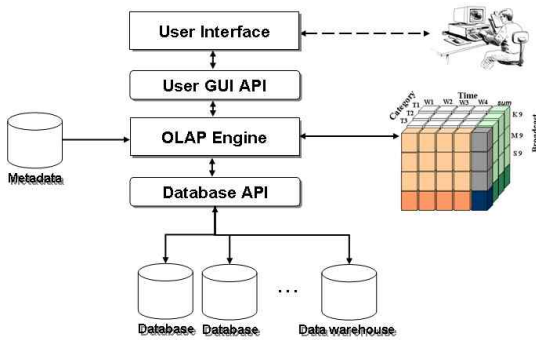


Figure 1. The framework of a data cube model of news video

The rest of this paper is organized as follows. In Section II, we briefly summarize the preprocessing steps for news video data cube and present a novel data cube model (*NVideoCube*) for news video analysis in Section III. An intuitive graphic user interface which supports SQL and OLAP operations is introduced in Section IV. In Section V, we present a scenario based example to clarify the validity of our approach. Finally, in Section VI, we conclude with a brief summary and suggest future research directions.

II. THE PREPROCESSING FOR *NVIDEOCUBE*

In this Section, we briefly summarize the preprocessing steps for constructing video cube which can be seen in [18]. It consists of two main steps: news video story parsing and topic clustering. The news video story parsing is to partition a news video into news stories. The topic clustering is the process of clustering news stories into topics. Fig. 2 illustrates the preprocessing steps for *NVideoCube*.

The first step of preprocessing is the news video story parsing which consists of three main components: shot boundary detection, anchor shot detection, and news story segmentation. We developed a Kernel-ART which combines the adaptive resonance theory (ART) and the mercer kernel, to detect a shot boundary effectively. We also devised Multi-phase Anchor Shot Detection (MASD), which consists of three modules and operates sequentially: 1) Skin color detection module for reducing candidate face regions; 2) Face detection module for finding key-frames with a facial data; 3) One class SVM module for determining the anchor shots using a support vector data description (SVDD). Once anchor shots in news video streams were found, it is relatively straightforward to generate a news story. A news video typically starts with highlight shots, and then, each story follows with an anchor shot and news content shots, and finally concludes with reports on sports or weather forecasting. The simplest means to generate a news video story is implemented based on the temporal location of each anchor shot. The one of core steps towards constructing *NVideoCube* is topic clustering. The co-clustering [12] is employed in this paper for clustering of time-evolving news story topics with transcripts and key-frames.

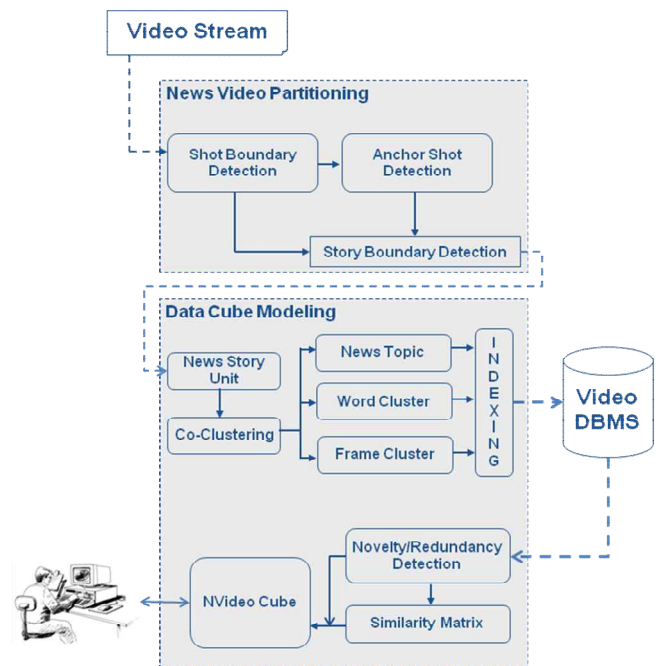


Figure 2. The overall architecture of news video cube

III. DATACUBE MODEL-*NVIDEOCUBE*

In this Section, we propose a novel data cube model for a framework of news video analysis, viz., *NVideoCube*, which is able to analyze the news videos according to chronological view, categories, and news producers.

A. Multidimensional Data Model

In a multidimensional model, the information is organized with according to dimension and fact. In general terms, dimensions are the perspectives or entities with respect to

which an organization wants to keep records. In *NVideoCube*, we keep records of the news video stories with respect to the dimensions such as *time*, *category*, and *broadcast*. A 3-D view of a *NVideoCube* is shown in Fig. 3.

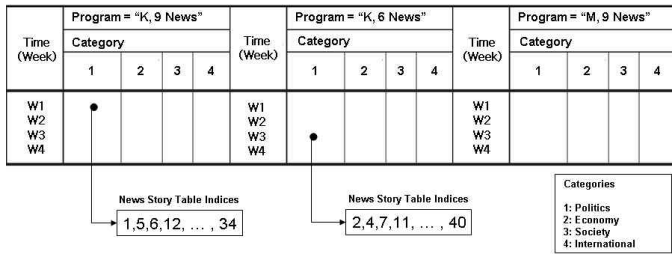


Figure 3. A 3-D view of *NVideoCube*

Each dimension has a table associated with it, called a dimension table, which further describes the dimension. The fact table contains the names of facts, or measures, as well as keys to each of the related dimension tables. The data types of facts are in general numerical measures. However, in *NVideoCube*, facts are considered to be the news video stories. Consequently, we define three dimension tables: *time*, *category* and *broadcast*, and one fact table: *news*. The star schema (the most common type for a multidimensional model) for an *NVideoCube* is presented in Fig. 4.

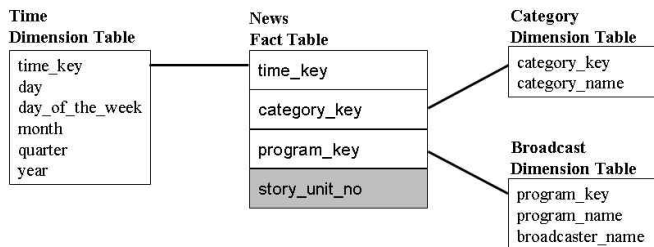


Figure 4. A star schema of *NVideoCube*

A concept hierarchy defines a sequence of mapping from a set of low-level concepts to higher-level, more general concepts and so allows interactive mining at multiple levels of abstraction. The dimension *broadcast* is described by the attributes *program_key*, *program_name*, and *broadcaster_name*. These attributes are related by a total order, forming a concept hierarchy such as "*program_name* < *broadcaster_name*" as shown in Fig. 5(a). Alternatively, a partial order, forming lattice, for the *time* dimension based on the attributes *day*, *week*, *month*, *quarter*, and *year* is "*day* < {*month* < *quarter* ; *week*} < *year*". This lattice structure is shown in Fig. 5(b).

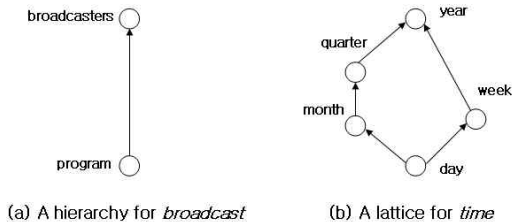


Figure 5. Hierarchical and lattice structures of attributes in dimensions

The dimension *category* is described by the attributes *category_key* and *category_name*. An attribute *category_name* has one of pre-defined categories which are provided by broadcasters. Table I shows the pre-defined values for *category_key* and *category_name*.

TABLE I. THE PRE-DEFINED VALUES FOR ATTRIBUTES *CATEGORY_KEY* AND *CATEGORY_NAME* IN *CATEGORY* DIMENSION TABLE

Category key	Category name
1	Politics
2	Economy
3	Society
4	International
5	Inter-Korea
6	Arts/Cultures
7	Science/Technology
8	Health/Sports

The primary concern in constructing a data cube for news videos is to devise an effective and efficient method for computing summaries of news stories. Notice that the value of measure in a fact table is not numerical data here, but news story unit number, *story_unit_no*, which is unique sequence number of publication order. The attribute *story_unit_no* represents the news story itself and index of similarity matrix which will be explained in detail later. It is also used in a meta-data table as a primary key. That means that the typical aggregate functions of data cube such as distributive, algebraic, and holistic function can't be used freely here. Thus, in *NVideoCube*, aggregate operation is defined by a list of the news stories that is a set of values in *story_unit_no*.

Given a set of dimensions, we can construct a lattice of cuboids (Fig. 6(a)), each showing the data at a different level of summarization. The cuboid holding the lowest level of summarization is called the base cuboid. The 0-D cuboid, which holds the highest level of summarization, is called the apex cuboid. The lattice of cuboids is then referred to as a data cube (Fig. 6(b)). Fig. 6 shows a lattice of cuboids forming a data cube for the dimensions *time*, *category* and *broadcast*.

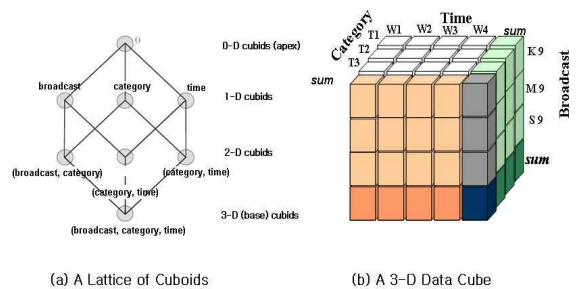


Figure 6. The data cube model of *NVideoCube*

B. Metadata and Similarity Matrix

News video is a complex object. As a result, it is necessary to employ more rich data structure to describe the news story in detail. The meta-data is used to store the descriptions of news stories such as publication date, news title, key-words, key-frames, and location of news video clip. It is used for a view

model for each cell in data cube. Fig. 7 shows the scheme of meta-data table, News Meta, and the example of detailed view model of a news story.

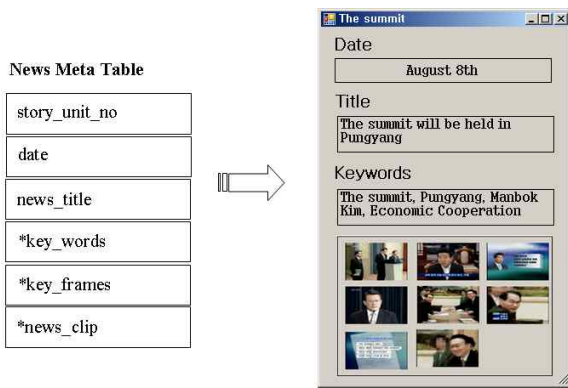


Figure 7. A Meta data table and example of view

In news videos, news stories record the gradual changes of a topic over time, i.e., new themes emerging over time. Some themes evolve slowly while others remain intact through a topic. In this paper, we classify news stories into two classes [12]: novel story and evolving story. The novel story is defined as a newly emerging theme and the evolving stories as a gradually changing news stories corresponding to a novel story. Our system presents novel stories at first for rapid interpreting and analyzing a topic and provides evolving stories pertained to chosen novel story for further analysis. In order to provide such facilities, we employ an additional auxiliary data structure, similarity matrix (SM). For building SM , we use the cosine of the angle between two news story vectors S_i and S_j as a similarity measure [12].

$$SM(S_i, S_j) = \frac{\sum_{k=1}^m w_k(S_i)w_k(S_j) + \sum_{l=1}^n v_l(S_i)v_l(S_j)}{\sqrt{\sum_{k=1}^m w_k(S_i)^2 \sum_{k=1}^m w_k(S_j)^2} \sqrt{\sum_{l=1}^n v_l(S_i)^2 \sum_{l=1}^n v_l(S_j)^2}} \quad (1)$$

where, $w_k(S_i)$ is the weight of word w_k in news story S_i and $v_l(S_i)$ is the weight of key-frame v_l in news story S_i .

IV. GRAPHIC USER INTERFACE AND VIEW MODEL

The user interface of *NVideoCube* aims at providing the users with easy and intuitive way to use all of SQL and OLAP operations.

A. Graphic user interface of the *NVideoCube*

We propose a graphic user interface of *NVideoCube*, viz., *CubeNavigator*, to provide the users with access to the news stories by SQL and standard OLAP operations. It consists of two components: operation panel and view window. Fig. 8 shows the graphic user interface (*CubeNavigator*).

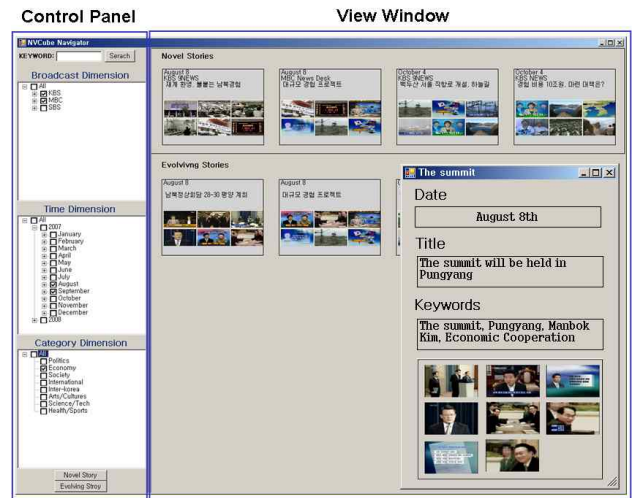


Figure 8. The graphic user interface (*CubeNavigator*)

The left side of the user interface is a control panel which supports standard OLAP operations and key-word based retrieval. In a control panel, a text box and button “search” provide key-word based search. First, a user inputs a query term. Then the interface returns news stories in chronological order corresponding to the query term. Three treeview controls and two button controls are for OLAP queries. Each treeview control is corresponding to the dimension *broadcaster*, *time* and *category*, respectively which will be described in the next subsection. The right side of the user interface displays the date, the news program/broadcaster, the title, and the key-frames corresponding to the retrieved news stories. The proposed system presents novel stories at first for rapid interpreting and analyzing a topic by clicking button “novel story”. Then, the user selects an interesting novel story and browsing evolving stories, by clicking button “evolving story”, which are pertained to chosen novel story for further analysis. If a user wants to see more detailed information of a news story, by double clicking the story sub-nail, a user launches the pop-up window that provides the information from meta-data.

B. OLAP operations and analysis

The proposed graphic user interface *CubeNavigator* supports the standard OLAP operations such as roll-up, drill-down, slicing, and dicing by checking the check boxes in treeview controls corresponding to dimensions. In this subsection, we discuss the implementation of the basic OLAP operations applied to the *NVideoCube*.

The roll-up and the drill-down operations refer to the possibility for the user to change interactively the level of aggregation of the analyzed data. As to rolling-up, the user goes up the levels and obtains more general information. Drilling-down is the reverse of rolling-up. It navigates from less detailed data to more detailed data. The roll-up and the drill-down can be realized by either climbing up or stepping down a concept hierarchy for a dimension. The *CubeNavigator* allows the user to refine the level of detail by selecting the check boxes in a dimension. Fig. 9 shows the example of the roll-up and the drill-down operations performed on the central

cube by climbing up and stepping down a concept hierarchy for *broadcast* defined as "program_name < broadcaster_name".

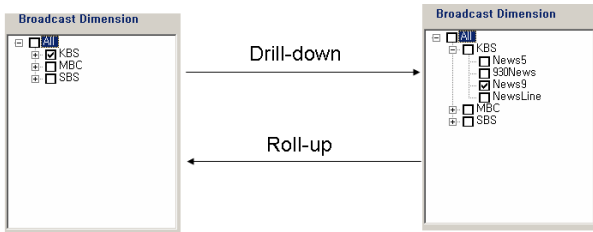
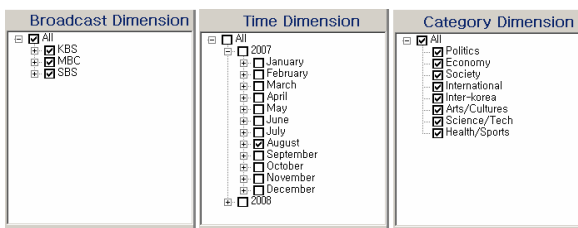


Figure 9. An example of the roll-up and the drill-down operations

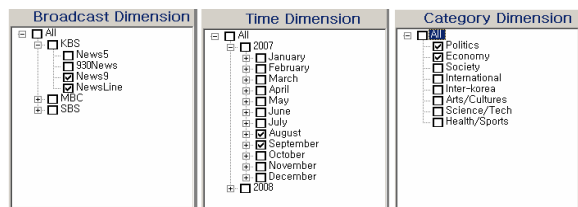
The slice operation performs a selection on one dimension of the given cube, resulting in a subcube, and obtains a two-dimensional view. Fig. 10 shows a slice operation where the news stories are selected from central cube for the dimension *time* using the time = "August 2007".



Slice for time = "August 2007"

Figure 10. An example of slice operation: Slice for time = "August 2007"

The dice operation defines a subcube by performing a selection on two or more dimensions. Fig. 11 shows a dice operation on the central cube based on the following selection criteria that involve three dimensions: (broadcast = "New9, KBS" and "NewsLine, KBS") and (time = "August 2007" and "September 2007") and (category = "Politics" and "Economy").



Dice for broadcast = "News9, KBS and NewLine, KBS"
AND time = "August 2007 and September 2007"
AND category = "Politics and Economy"

Figure 11. An example of dice operation: Dice for broadcast = "News9, KBS and NewLine, KBS" AND time = "August 2007 and September 2007" AND category = "Politics and Economy"

C. View Model and Access to News Stories

As stated above, the *CubeNavigator* generates view model for aggregated news stories according to the novel stories and evolving stories. Each news story in aggregated list (AL) is compared with all previously delivered news stories in AL to find the most similar news story using similarity matrix SM .

This comparison can be accomplished by finding index of maximal values in each row of the similarity matrix SM . If a maximal value is less than the threshold value, we consider the news story as a novel story (i.e., newly emerging theme). Otherwise, we consider the news story as an evolving news story and link the news story to the most similar news story. The main process to generate the view model in each aggregated news stories is presented in Algorithm 1.

Algorithm 1. BuildView

Input: Similarity matrix SM , Aggregation list AL .

Output: Novel story list NL , Evolving story list EL .

Method:

1. Set the first news story in AL to novel story and add to NL . Create a $EL(1)$, $k=1$, and link to first element in NL .
2. Find $M_i = \arg \max_{1 \leq j \leq i-1} SM_{ij}$, for the i -th news story in AL .
3. If the $M_i \leq \text{threshold}$, set the i -th news story to novel story and add to NL . Create a $EL(k++)$ and link to first element in NL . Else, set the i -th news story to evolving story and add to $EL(k)$ which include j -th news story.
4. Go to the step 2, until i less than # of elements in AL .
5. Output NL and EL .

V. CASE STUDIES

Now, we present a scenario based example to clarify the validity of our approach. For a case study, we collected a sample dataset including news video clips and their scripts from the two main Korean broadcasting stations, namely, KBS and MBC from August 8th to October 6th 2007. The topic of dataset is "The Second Summit of South and North Korea in 2007". We use both videos and scripts for our experiments. A dataset is described in details in Table II.

TABLE II. A DATASET FOR A CASE STUDY

	Descriptions		
Topic of dataset	The Second Summit of South and North Korea in 2007		
Collection Dates	August 8th, 9th, 10th October 1st, 2nd, 3rd, 4th, 5th, 6th		
No. of Stories	KBS	MBC	TOTAL
	142	146	288

A. Build View Model

To demonstrate how a view model is constructed, we use a dataset consisting of 15 news stories about the first announcement of the summit between South and North Korea on August 8th 2007 from KBS. A similarity matrix SM , which is generated using equation (1), is shown in Fig. 12.

In this experiment, the threshold value for a novel story was set to 0.5. With algorithm 1, we obtained 8 novel stories and 7 evolving stories. The novel stories are 1, 2, 3, 5, 6, 9, 10, and 11, and the evolving stories are 4, 7, 8, 12, 13, 14, and 15. Only 2 novel stories (2 and 10) have evolving stories. We can find the sub topics or special issues by selecting novel story and

obtain the important issues by finding the novel stories containing many evolving stories. Note that story 2 ("A director of national intelligence visited North Korea ") is a big issue. In this case study, we can see that KBS has focused on the accomplishment process of the summit on August 8th when is the day of first announcement of summit.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.000														
2	0.418	1.000													
3	0.265	0.572	1.000												
4	0.488	0.530	0.335	1.000											
5	0.383	0.424	0.372	0.426	1.000										
6	0.372	0.350	0.107	0.368	0.248	1.000									
7	0.525	0.524	0.413	0.607	0.514	0.352	1.000								
8	0.371	0.345	0.501	0.324	0.418	0.174	0.552	1.000							
9	0.151	0.201	0.269	0.269	0.231	0.105	0.290	0.213	1.000						
10	0.234	0.263	0.353	0.292	0.309	0.152	0.410	0.361	0.213	1.000					
11	0.295	0.259	0.450	0.266	0.311	0.154	0.414	0.285	0.466	0.337	1.000				
12	0.247	0.285	0.342	0.276	0.348	0.104	0.381	0.360	0.205	0.376	0.439	1.000			
13	0.372	0.217	0.305	0.267	0.315	0.103	0.408	0.270	0.163	0.215	0.344	0.231	1.000		
14	0.388	0.347	0.459	0.333	0.447	0.128	0.549	0.233	0.288	0.401	0.551	0.383	0.559	1.000	
15	0.414	0.480	0.360	0.438	0.370	0.354	0.611	0.688	0.309	0.340	0.399	0.364	0.231	0.409	1.000

Figure 12. The partial example of similarity matrix SM

B. Retrieval of Economic Issues in the Summit

To analyze the major issues about the summit in view of the time level (i.e., before summit, during summit, and after summit), we retrieved news stories according to each time level and extract the novel stories by applying both roll-up and dice OLAP operations. Then, we found that the three main issues are addressed at each time level: nuclear, NLL, and economical cooperation between South and North. By retrieving news stories in a topic with respected to "Economy" category, total 29 news stories on "economical cooperation" is retrieved and 4 novel stories are obtained. The retrieved novel stories are shown in Fig. 13. By applying roll-up and slice OLAP operations, we also found that the first two issues, "The economic world expect the cooperation with North Korea" and "Huge economical cooperation between two Korea" is firstly emerged before summit, and Issue 3 and Issue 4 are emerged during summit and after summit respectively.

Issue 1

August 8th
KBS 9 News
The Economic World Expect



Issue 2

August 8th
MBC News Desk
Huge Economic Cooperation



Issue 3

October 4th
KBS 9 News
Airline between Seoul and Mt. Bakdoo



Issue 4

October 5th
KBS 9 News
The Cost for Economic Cooperation



Figure 13. Novel stories in economy category

VI. CONCLUSIONS

In this paper, we proposed a novel data cube model for a framework of news video analysis, viz., *NVideoCube*, which is able to analyze the news videos according to *chronological view*, *category*, and *broadcaster*. It provides viewers with various facilities on the news videos such as 1) showing the evolution of a certain news videos in a topic with respect to the

abstract time level; 2) catching a snapshot of the evolution of news in a certain period; 3) providing the evolution and highlights of news by topics according to each broadcaster. The validity of our approach is illustrated by a scenario based example.

For the future work, we will concern the video data mining of news videos.

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