A Multilingual, Multimodal Digital Video Library System

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ABSTRACT

This paper presents the *iVIEW system*, a multi-lingual, multi-modal digital video content management system for intelligent searching and access of English and Chinese video contents. *iVIEW* allows full content indexing, searching and retrieval of multi-lingual text, audio and video material. It consists image processing techniques for scenes and scene changes analyses, speech processing techniques for audio signal transcriptions, and multi-lingual natural language processing techniques for word relevance determination. *iVIEW* can host multi-lingual contents and allow multi-modal search. It facilitate content developers to perform multi-modal information processing of rich video media and to construct XML-based multimedia representation in enhancing multi-modal indexing and searching capabilities, so that the end users can enjoy viewing flexible and seamless delivery of multimedia contents in various browsing tools and devices.

Categories and Subject Descriptors

H.3.7 [**Information Storage and Retrieval**]: Digital Library – *Standards, Systems issues, User issues.*

General Terms

Design, Management.

Keywords

Multi-Modal Interactions, Middleware and Browser Interactions, Browser on Mobile Devices, Multimedia Management and Support, Applications.

1. INTRODUCTION

Videos represent rich media over World Wide Web. Video contents can be explored and engaged in historical documents, museum artifacts, tourism information, scientific and entertainment films, news clips, courseware presentations, edutainment material, and virtual reality applications. They enrich the Web not only by the enhancement of its knowledge base but

by an effective delivery and exchange of knowledge with dynamic user interfaces. Video information processing requires rigorous schemes for appropriate delivery of its rich contents over Web and mobile Web.

The information that can be extracted from a video includes video streams, scene changes, camera motions, text detection, face detection, object recognition, word relevance statistics, transcript generation, and audio level tracking. The techniques involved in composing videos into vast digital video libraries for content-based retrieval are provided in the literature [1].

Video information processing includes, among others, speech recognition, optical character recognition (OCR), text detection, and face recognition. The basic theory for speech recognition is hidden Markov models (HMMs) [2]. In developing practical systems, speech recognition can be specially tailored to broadcast news transcription [3] spoken document retrieval [4], and speaker identification [5].

Optical character recognition (OCR) is a subject for many years' research [6], [7]. More recently, [8] describes hierarchical OCR, a character recognition methodology that achieves high speed and accuracy by using a multi-resolution and hierarchical feature space. [9] proposes a prototype extraction method for document-specific OCR systems. The method automatically generates training samples from un-segmented text images and the corresponding transcripts. [10] presents a neural network classification scheme based on an enhanced multi-layer perception (MLP) and describe an end-to-end system for form-based handprint OCR applications designed by the National Institute of Standards and Technology (NIST) Visual Image Processing Group.

Before OCR can be applied to videos for text generation, text has to be detected in the videos first. Some research work has been performed in text detection on videos. [11] implements a scale-space feature extractor that feeds an artificial neural processor to detect text blocks. The text-tracking scheme consists of two modules: a sum of squared difference (SSD) based module to find the initial position and a contour-based module to refine the position. In [12] text is first detected using multi-scale texture segmentation and spatial cohesion constraints, then cleaned up and extracted using a histogram-based binarization algorithm. [13] describes a system for detecting, tracking, and extracting artificial and scene text in MPEG-1 video. [14] proposes a text detection and segmentation algorithm that is designed for application to color images with complicated background. [15] describes a method for detection and representation of text in video segments. The method consists of seven steps: channel separation, image

enhancement, edge detection, edge filtering, character detection, text box detection, and text line detection.

Object detection and recognition are essential to content-based searching on videos, among which face recognition is of the major interest. As one of the earliest work, [16] projects face images onto a feature space ("face space") that best encodes the variation among known face images. The face space is defined by the "eigenfaces", which are the eigenvectors of the set of faces; they do not necessarily correspond to isolated features such as eyes, ears, and noses. The framework provides the ability to learn to recognize new faces in an unsupervised manner. [17] computes the frame bounds for the particular case of 2D Gabor wavelets and derives the conditions under which a set of continuous 2D Gabor wavelets will provide a complete representation of any image, particularly face images. [18] presents a system for recognizing human faces from single images out of a large database containing one image per person. Faces are represented by labeled graphs, based on a Gabor wavelet transforms. Image graphs of new faces are extracted by an elastic graph matching process and can be compared by a simple similarity function. [19] develops a face recognition algorithm that is insensitive to large variation in lighting direction and facial expression. The projection method is based on Fisher's Linear Discriminant and produces well separated classes in a low-dimensional subspace, even under severe variation in lighting and facial expressions. Finally, a comparative study of three recently proposed algorithms for face recognition, eigenface, auto-association and classification neural nets, and elastic matching, can be found in [20].

Integration of these techniques is also an important direction on video-based research. [21] presents algorithms that improve the interactivity of on-line lecture presentation by the use of optical character recognition and speech recognition technologies. [22] describes a scheme to combine the results of audio and face identification for multimedia indexing and retrieval. Audio analysis consists of speech and speaker recognition derived from a broadcast news video clip. [23] develops Named Faces, a fully functional automated system that builds a large database of name-face association pairs from broadcast news. Faces found in the video where superimposed names were recognized are tracked, extracted, and associated with the superimposed text. With Named Faces, users can submit queries to find names for faces in video images.

The major integration effort for digital video research and system development, however, is the Informedia project [24]. The Informedia Digital Video Library project provides a technological foundation for full content indexing and retrieval of video and audio media. It describes three technologies involved in creating a digital video library. Image processing analyzes scenes, speech processing transcribes the audio signal, and natural language processing determines word relevance. The integration of these technologies enables us to include vast amounts of video data in the library. Surrogates, summaries and visualizations have been developed and evaluated for accessing a digital video library containing thousands of documents and terabytes of data. Although Informedia represents a key milestone in digital video library archival and retrieval integration technique, it was not originally designed for Web-readiness, interoperability, and wireless accessibility.

In this paper we describe the design and development of *iVIEW*, an Intelligent Video over InternEt and Wireless access system. Similar to the Informedia project, we integrate a variety of video analyzing and managing techniques, including speech recognition, face recognition, object identification, video caption extraction, and geographic information representation, to provide content-based indexing and retrieval of videos to users using various browsing devices. The major advantages of *iVIEW* over Informedia are three fold: (1) *iVIEW* is designed on Web-based architecture with flexible client-server interactions, scalable multi-modal media information processing and retrieval, and multilingual capabilities. (2) *iVIEW* facilitates an XML-based media data exchange format for interoperability among heterogeneous video data representations. (3) *iVIEW* constitutes dynamic and flexible user interfaces sensitive to client devices capacity and access schemes over wired and wireless networks. The details are described in the following sections.

2. RESEARCH MOTIVATION, OBJECTIVES AND SYSTEM REQUIREMENT

In the previous section a number of techniques for the video information extractions are described. Not only is the accuracy of these techniques a key to the success of a digital library, but the increasing number of different techniques affect the design of an "open" digital video library system to a great extend. The scalability issue of the digital library in terms of adding new extraction components is also very challenging. When a new extraction method is developed and included in the video library, it implies a series of newly added indexing and presentation functions. Particularly, a generic framework for presentation and visualization of video information is curial to the deployment of the digital library over the Web. Before getting into the details of the client browser for *iVIEW*, we first provide a short overview on the design methodology of the system.

The *iVIEW* system is based on an open architecture methodology and Web application models to achieve the following targets:

- To provide an open architecture that can ease the overhead of integrating different video processing, searching, indexing and presentation of various digital video library functions.

- To increase the reusability of the information extracted form the videos, including information interchange between distributed video libraries and different publishing media.

- To allow single processing and extraction of video information and multiple delivery and presentation of the video contents to different computing platforms and devices.

The above objectives are achieved via the following methods: (1) modality concepts of the digital video library functions and video information life-cycles; (2) the collaboration of the video information processing modules; and (3) a generic framework for presentation and visualization of video information.

2.1 Modality Concept

We define a modality as a domain or type of information that can be extracted from the video. Examples are the text generated by speech recognition and the human identity by face recognition. The set of functions that a modality supports in the digital library applications is called the modality dimension. Typical processes are video information extraction, indexing and presentation. For different modality dimensions, the requirements for the whole series of library functions may be totally different. Compare, for example, the query input for a text search and a face search, where the former is a string while the latter is picture. The text indexing method is quite different from the face indexing method. Furthermore, at the front-end interface of the presentation client, a text visualization tool is also very different from the human face visualization tool in their layouts, content displays, and presentation styles. Although the implementation of individual modality dimension will be different, their "life-cycle" is similar to each other and can be grouped as follows:

- Video Information Processing
- Information Repository
- Indexing and Searching
- Visualization and Presentation

By introducing the modality concept, the integration interface and information exchange of different modality dimensions can be easily identified. This provides an efficient way to adding different new modality dimensions into the system without losing the flexibilities.

2.2 Collaboration of the Video Information Processing Modules

Video information processing is the content creation step for the digital video library. The collaboration of different video information extraction techniques is at the information exchange level, mainly including knowledge cross-referencing and knowledge enrichment.

For some video processing techniques, the accuracy of the recognition process can be increased by cross-referencing information generated by other modality dimensions. For example, to identify a human face in the video, the face recognition technique can be the primarily extracted modality information. On the other hand, the on-screen title of the person's name, when available, can be recognized and served as the cross-reference knowledge for identification of the person. An example of knowledge enrichment is the geographical naming process. The

geographical naming database represents a knowledge repository of geographical names of countries, states, cities, and other identities. By applying this information to the text recognized from the speech recognition, the knowledge encapsulated in the text can be enriched.

However, difficulties still arise, as no single developer can provide all the video processing modules. There should be a standard way for different modules or developers to understand each other. At the same time, this standard should be flexible enough to maintain the openness required in the Web.

2.3 Generic Presentation and Visualization Framework

Individual modality dimension has its own interface requirements and the presentation method may be unique for each dimension. A generic presentation and visualization framework is required to coordinating different presentation modules. Different from the video information processing, the coordination between the presentation and visualization modules are at the event levels, such as time synchronization and user events.

Another requirement of the framework is a transparent encapsulation of the delivery platforms. Desktop PCs, personal digital assistants and mobile devices pose different restriction for various needs in presentation and visualization. The proposed
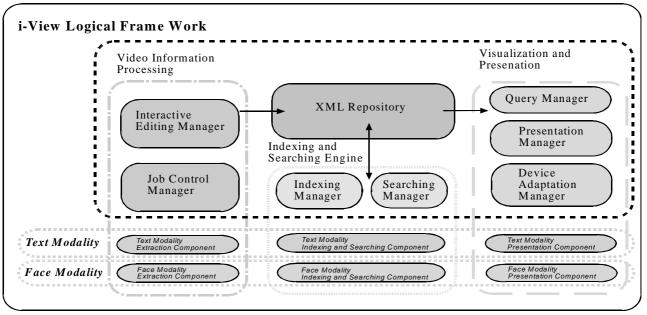

Figure 1: The *iVIEW* Logical Framework

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framework should be able to adapt to different configurations without additional installations or considerable overheads.

3. iVIEW Overall Architecture

The *iVIEW* system is a solution that attempts to achieve the objectives and system requirements posted in the previous section. Figure 1 shows the overall architecture of *iVIEW* system. The system is composed of three major subsystems: Video Information Processing (VIP) Subsystem, Searching and Indexing Subsystem, and Visualization and Presentation Subsystem.

The VIP Subsystem handles multi-modal information extracted from a video file. The multi-modal information is organized in an XML format. The VIP Subsystem processes video in two modes. An offline mode coordinated by the Job Control Manager schedules video recording and launches jobs to process the video file offline. An online interactive mode provides a user interface for a content editor to monitor the process and view the results. Therefore, human intervention and correction of the file is available.

The Indexing and Searching Subsystem is responsible for video information indexing and searching. A file containing an XML format structure that describes and associates multi-modal information is produced from each video file. This XML file is indexed for multi-modal searching through the Indexing Manager. For each query, the search engine will return a set of XML files that matches the query.

The Visualization and Presentation Subsystem handles query results, sets visualization mechanisms, and delivers multi-modal presentations in time-synchronized manner. The Device Adaptation Manager automatically detects client device features and bandwidth capacities for appropriate and efficient content delivery.

If we view the information flow in Figure 1 from left to right, multi-modal information (text modal, image modal, face modal, etc) can be extracted, processed, stored and then indexed. Information can be searched by individual modal dimension or a composite of multiple modal dimensions in logical relations. After the searching process, multi-modal information is presented to the end users.

Each modal dimension is processed, preserved and correlated with other dimensions throughout the end-to-end video processing. The *iVIEW* system is designed to apply a unified scheme for processing different modal dimensions. Therefore, we can add a new modality dimension to the whole system seamlessly, including extraction, processing, indexing, searching or presentation of the new modal dimension. It facilitates the integration of newly obtained techniques on evolving modal information.

The details of these three major subsystems and their associate modal processing techniques are discussed in the following sessions.

4. Video Information Processing (VIP)

The Video Information Processing is the first processing step in the *iVIEW* system. The information contained in the video is extracted and recognized by a series of processes. The VIP is implemented on the Microsoft Windows 2000 platform. Figure 2 shows the overview of the VIP. Starting from the information channel contained in the digital video, going through the analysis and recognition processes, the primary information is generated. Followed by the knowledge enrichment and knowledge cross-referencing processes, the secondary information or the modality information is produced using the primary information as input.

Using the face modal dimension as an example, the VIP consists of two processes, the face recognition from the video information channel and the knowledge cross-referencing with text modal information to generate named face information. The text modal information is obtained by the Video OCR processes where the on-screen words are being recognized. Together with the language processor to identify the name (a proper noun) inside the text modality, the name information is then cross-referenced with face modality to generate the named face.
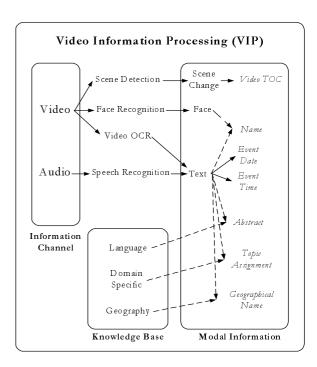

Figure 2: Overview of the video information processing.

The number of analysis or recognition processes is different in each modal dimension. For example, the text modality dimension has two major recognition processes, the video OCR and the speech recognition. But the face modal has one recognition process only. The primary text modal information is stored in XML format similar to the following structure:

```
<modality name="text">
  <text start="0s" end="5s">Hong Kong is a beautiful
place.</text>
  <text start="5s" end="7.5s">You can find</text>
  <text start="7.5s" end="9s">the best clothing
here.</text>
</modal>
```

Figure 3: Sample XML of a modality

Each modality dimension manages its own XML DTD or XML schema. The DTD would be extended, if knowledge enrichment or cross-referencing is applied. In the above example, the geographical name process will extend the XML as follows:

```
<modality name="text">

  <text start="0s" end="5s">

    <geoname>Hong Kong</geoname> is a beautiful
place.</text>

  <text start="5s" end="7.5s">You can find</text>

  <text start="7.5s" end="9s">the best clothing
here.</text>

</modal>
```

Figure 4: Sample XML after knowledge enrichment

By extending the XML DTD, the new tag that represents new modality information is added to the original XML file. The new modality dimension, in this example the geoname, can be treated as an extended-modality dimension of the parent text modality dimension. As defined in the previous section, a modal dimension consists of the presentation and visualization process. The geoname modal dimension uses a visual map as the presentation media. The corresponding geographical names in the video can also be visualized via the same map. The rendering process of geoname in the XML part, therefore, is governed by the geoname XML DTD. In other words the rendering process of geoname only needs to "understand" the geoname XML DTD, not the whole XML DTD.

For two independent modality dimensions, text and scene change, the XML part will be combined as follows to form the final XML document. Figure 6 shows the snapshot of VIP after scene change processing.

```
<modal name="text">

  <text start="0s" end="5s">

    <geoname>Hong Kong</geoname> is a beautiful
place.</text>

  <text start="5s" end="7.5s">You can find</text>

  <text start="7.5s" end="9s">the best clothing
here.</text>

</modal>
<modality name="scene change">

  <scene start="0s" end="20s" src="/101.jpg"/>

  <scene start="20s" end="33s" src="/102.jpg"/>

</modal>
```

Figure 5: Sample XML of two modalities

Figure 6: Snapshot of the VIP for Scene Changes

5. XML Search Engine

Resembling the Web search engine, we have developed an XML search engine for the digital video library. The search engine is divided into two parts, the XML repository and the searching and indexing subsystem. The XML documents that represent the information extracted from the VIP are in general very static. They are not frequently modified. Thus an XML repository server is a natural way to manage XML documents. Using the HTTP protocol, clients can obtain the XML documents by sending the HTTP GET request with specified URLs. Updates of the XML documents are through the HTTP PUT mechanism. Enhanced access control is implemented to avoid un-legitimate updates.
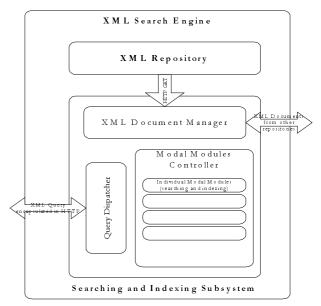

Figure 7: Overview of the Searching and Indexing Subsystem

Differ from a database solution of the XML search engine, the indexing part of the XML documents are handled by individual modal process as illustrated in Figure 7. Each modality dimension would implement the Searching and Indexing Subsystem

according to the specification of the module that governs the interface and function requirements. The basic functions include module management, query management of specific modal domains, indexing of the modality information and resource management. For example, the face modality dimension will use a high dimension tree data structure for indexing, but the text modality dimension may only need an inverted tree implementation. Beside the performance consideration of the search engine, this loadable module design also makes the subsystem more easily scaleable in terms of functionality.

To support multi-modal search, the multi-modal query from the client is passed to the query dispatcher. The dispatcher decodes the request and passes the sub-query to individual modality modules. After the individual results are returned, the dispatcher combines the search results into a summary reply and sends it back to the client.

6. VISUALIZATION AND PRESENTATION SUBSYSTEM

6.1 Background
The *iVIEW* Visualization and Presentation Subsystem, or simply the client, handles multi-modal query, visualization of the result set and presentation of multimedia contents dynamically over the Web. It is also customized for visualization and presentation over wireless devices, encapsulating the capability to synchronize among various modal dimensions at the content presentation stage.

Client design can directly affect user experience; therefore, it plays a significant role in digital video library deployment. Previous research and implementation work in this area includes [25], [26], [27]. Our goal is to develop a client with multilingual, multi-windows, and multi-device (including wireless) support. We have implemented the client subsystem based on the following approaches:

- A Java applet using our proposed architecture supporting multilingual, multimodal and Web-ready information processing and presentation.
- A Web-based client for Internet and wireless access.
- A Windows CE native application for wireless access.

Due to the cross-platform nature of Java, our Java applet client is browser interoperable. XML is employed for the client-server communication. Schemas of our XML messages focus on context-aware presentation. We recognize that the context-aware presentation has several advantages over the existing media presentation standards like SMIL and SAMI. The content awareness capability of the client leads to the scalable handling of media presentation, which is a key for designing generic browser architecture to suit different platform capabilities from desktops to mobile devices. The client can associate its own corresponding control interface to handle a particular modal of information.

6.2 Java Applet Implementation for Internet Deployment
Our chief reference implementation is programmed as a Java applet (See Figure 8). The Java applet's nature makes the system accessible through any Web browser. We have verified the system's compatibility with Microsoft Internet Explorer 5 and

Netscape 4. We make use of JAXP 1.0 as the XML Parser. Java Media Framework (JMF) 2.1 is employed for playing streaming video. With the usage of plug-ins in JMF, we currently support two popular streaming video formats including Quicktime and Real. The Microsoft Media format is not supported in our Java client as there does not yet exists any JMF plug-in that supports Microsoft Media format.

Figure 8: A Screen Shot of the iVIEW Java Client

Basically, the *iVIEW* client is a component-based subsystem composed of a set of infrastructure components and presentation components. The infrastructure components provide services for client-server message communication and time synchronization among different presentation components by message passing. The presentation components accept messages passed from the infrastructure components and generate the required presentation result. This component-based approach makes the system scalable to support a potential expansion of additional modal dimensions. Figure 9 shows the architecture of the Visualization and Presentation subsystem. Infrastructure components are in shaded color.

The client-server communication message is coded in XML through HTTP. The XML is embedded into an HTTP POST message. Using HTTP enjoys the advantage that the service is seldom blocked by firewalls [28]. It also facilitates the deployment of an application to content providers or data centers. Although it does not conform to XML query standard, the message in XML is already self-explanatory. Once a search result is attained, the media description in XML is obtained from the server. The client parses the XML using Document Object Model (DOM). The infrastructure gets the media time through playing the video. The recorded media time is then matched with the media description to seek the event that a presentation component needs to perform at a particular time.

The message dispatcher dispatches media events to different presentation components according to a component registry. The component registry records the presentation components that the client system runs. Consequently, video information is only processed once from VIP, while multiple deliveries of the video contents can be facilitated for different demands depending on client devices and platforms.
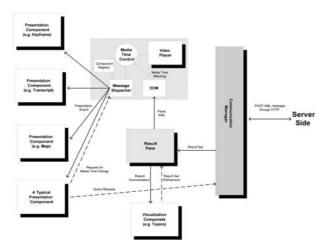
Figure 9: iVIEW Visualization and Presentation Subsystem Architecture

The *iVIEW* Java client has a multi-windows user interface. In the query window, a user can type in the keywords for text query, and a set of matched results represented by the poster images is shown in Figure 10. A tool-tip floating box shows the abstracts of a video clip when the mouse points to its poster image. A sample query and result is listed on Figures 11 and 12, respectively.

Figure 10: Java Applet Client Query and Result Set

```
<query>
 <relation logic="and">
  <item id="1" modal="text">
   <text>government</text>
  </item>
  <item id="2" modal="text">
   <text>policy</text>
  </item>
  <item id="3" modal="map">
   <mapstart longitude="100" latitude="60" />
   <mapend longitude="120" latitude="90" />
  </item>
 </relation>
</query>
```

Figure 11: A Sample Multi-modal Query in XML

```
<result path="/iview/data/">
 <item id="1" video="236" score="100">
  <abstract>.....</abstract>
 </item>
 <item id="2" video="206" score="95">
  <abstract>.....</abstract>
 </item>
 <item id="3" video="102" score="88">
  <abstract>.....</abstract>
 </item>
 .....
</result>
```

Figure 12: A Sample Result set in XML

The result set may be large in many cases; it is a difficult task for a user to select her desired result out of the many. Therefore, visible categorization of each element of the result set can aid the user to refine the large result set. The result set can be visualized in different views by summarizing them in different aspects. [29] has contributed to various summarization techniques. Those techniques include classification by geographical locations, timeline, visualization by example (VIBE) and topics assignment.

Figure 13 illustrates a screen shot of *iVIEW* Java Applet Client result set categorized in topics. Each result element is assigned to one or multiple predefined topics. The topics are the text tag arranged in a circular shape. A point within the circle represents a result. The spatial displacement of a point is related to its closeness to each topic. When the mouse is over a point, a floating tool-tip will appear to indicate the related topic of this point. A user can drag the mouse to highlight a rectangular area that contains the results that she is interest in. The result set will then confine to the selected results.
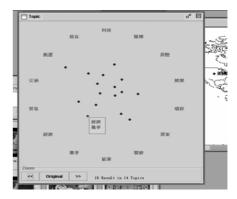

Figure 13: Result Set Visualization in Topics

After the user selected her target video clip, the user can right-click to play, view filmstrips or transcript of the video clip. The matched items are highlighted with different colors, as seen in Figure 14. The video clip and all other presentation components are presented in a synchronized manner.

Figure 14: All modals are presented in synchronized manner and with matched items highlighted

In general all *iVIEW* presentation components support four general interface functions:

1. Initialization
   iVIEW client shows all matched items when the video media initializes. For example, a map shows all matched geographical locations when a video starts to play.

2. Passive Synchronization
   A particular piece of information will be highlighted when the media time is matched. For example, a geographical name is further highlighted when the location is mentioned in the video clip.

3. Active Synchronization
   Through a user action, a presentation component can change the media time to a particular point. For example, when a user clicks on a particular filmstrip, the video, and also other presentation components, are re-synchronized to the time when that filmstrip occurs.

4. Search Input
   A presentation component can be inversely used as an input domain for searching. For example, a user can search video by highlighting certain geographical locations (as shown in Figure 15).
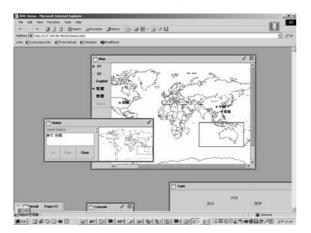

Figure 15: The Map Component Can Serve for Presentation as Well as Query Input

7. CONCLUSIONS

We present our design and implementation of *iVIEW* as an intelligent digital video content management system for video searching and access over Internet and wireless devices for multi-lingual contents. The *iVIEW* system allows full content indexing, searching and retrieval of text, audio and video material in both English and Chinese. *iVIEW* is consist of components for video information processing, searching and indexing, and visualization and presentation. This paper describes the detailed infrastructure of *iVIEW*, demonstrates its system characteristics, and provides customer evaluation on its user interface and performance. The design of *iVIEW* is characterized by its device-adaptable client implementation and flexible, dynamic user interfaces. *iVIEW* integrates multi-modal video information extraction techniques into Web-based environments, and provides an XML-based, end-to-end processing of video-based media contents that can be readily delivered over WWW and mobile devices. It can facilitate the development of large-scale digital video libraries so that multi-lingual, multi-media, and multi-modal contents can be exchanged freely and interoperated seamlessly.

8. ACKNOWLEDGMENTS

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