

# FUSION OF GEOSPATIAL MULTIMEDIA INFORMATION

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## 1. Objectives

The fusion of geospatial multimedia information from diversified sources in a heterogeneous information system is a challenging research topic of great practical significance. With the rapid expansion of the wired and wireless networks, a large number of soft real-time, hard real-time and non-real-time sources of information need to be quickly processed, checked for consistency, structured and distributed to the various agencies and people involved in geospatial information handling. In addition to geospatial multimedia databases, it is also anticipated that numerous web sites on the World Wide Web will become rich sources of geospatial multimedia information.

However, since too much information is available, geospatial multimedia information related to an important event could be missed because people are unable to track the manifestations of an unfolding event across multimedia sources over time. What is needed, from the information technology viewpoint, is an *active multimedia information system* capable of processing and filtering geospatial multimedia information, checking for semantic consistency, discovering important events, and structuring the relevant geospatial multimedia information for distribution.

We describe a framework for the human- and system-directed discovery, fusion and retrieval of geospatial multimedia information so that important events can be discovered and relevant geospatial multimedia information retrieved. This approach is based upon the observation that a significant event often manifests itself in different media over time. Therefore, if we can index such manifestations and dynamically link them to one another, then we can check for consistency. This dynamic indexing technique is based upon the theory of active indexing [1], which was developed as a result of [Dr. S. K. Chang's](#) prior research supported by NSF. Dr. Chang is an experienced researcher with many grants and contracts from NSF, DOD and other funding agencies. He is a leader in visual information systems and visual languages with over two hundred publications.

## 2. Proposed Approach for Human- and System-Directed Information Fusion

Information sources such as camera, sensors, computers or human beings usually provide continuous streams of information, which are collected and stored as data in multimedia databases. Such data need to be abstracted into various forms of abstractions, so that the processing, consistency analysis and combination of abstracted information becomes possible. Finally, the abstracted information needs to be integrated and transformed into fused knowledge. These three levels of information form a hierarchy, but at any given moment there is the continuous transformation of data into abstracted information and then into fused knowledge.

In our approach, this transformation is effected by the coordinated efforts of the **user**, the **query processor**, the **reasoners**, and the **active index system**. The user is capable of controlling the sources to influence the type of data being collected. For example, the user may turn on or turn off the video camera or manually control the positioning of the camera. Data are then transformed into abstracted information through the use of the active indices which also serve as filters to weed out unwanted data. The active index system is a message-based system. It receives input data as messages, processes them, and sends abstracted information as its output to storage. At the same time, it also sends messages to the reasoners, so that the reasoners can perform spatial/temporal reasoning based upon the abstracted information to generate fused knowledge or updated abstracted information in the form of assertions. The query processor then uses data, abstracted information and fused knowledge, to answer user's queries.

### 2.1. Formal Definition and Example of Semantic Consistency

In order to address the problem of information fusion, a clear definition of semantic consistency is necessary. Our definition is different from the usual definitions of semantic consistency in database theory or in AI theory, because we believe the problem of consistency for information fusion must be first addressed at the level of characteristic patterns detected in media objects. This is where the active multimedia information system can make the most impact in drastically reducing the amount of information that ultimately must be handled by human operators.

We define consistency functions to check the consistency among media objects of the *same* media type, by concentrating on their characteristic patterns. For example, two assertions "there is a tank in the target area" and "there is no tank in the target area" can be checked for consistency, and two images of the same target area can also be checked for consistency. These consistency functions are media-specific and domain-specific. For example, to check whether two aerial photographic images are consistent, the consistency function will verify whether the two images contain similar *characteristic patterns* such as tanks. For different application domains, different consistency functions are needed.

To check whether media objects of *different* media types are consistent, they need to be transformed into media objects of the same media type so that the media-specific, domain-specific consistency function can be applied. Our viewpoint is that each object is characterized by some characteristic patterns that can be transformed into characteristic patterns in different media type. For example, the characteristic pattern is a tank pattern in the image media, which is transformed into the word "tank" in the keyword media. The consistency function can then be applied to the characteristic patterns of objects of the same media type.

Let  $o_j^i$  be the  $j^{\text{th}}$  object of media type  $M^i$ . Let  $c_k^i$  be the  $k^{\text{th}}$  characteristic pattern detected in an object  $o_j^i$  of media type  $M^i$ . Let  $C^i$  denote the set of all such characteristic patterns of media type  $M^i$ . Let  $T_{1,2}$  be the transformation that maps characteristic patterns detected in

objects of media type  $M^1$  to characteristic patterns of media type  $M^2$ .

For each media type  $M^i$  there is a consistency function  $K_i$  which is a mapping from  $2^{C^i}$  (the space of all subsets of characteristic patterns in media type  $M^i$ ) to  $\{T, F\}$ . In other words it verifies that a set of characteristic patterns of media type  $M^i$  are consistent.

A characteristic pattern  $c^1_k$  of media type  $M^1$  is consistent with respect to media type  $M^2$  if the transformed characteristic pattern  $T_{1,2}(c^1_k)$  is consistent with the set  $C^2$  of all characteristic patterns of media type  $M^2$ , i.e.  $K_2(T_{1,2}(c^1_k) \text{ union } C^2) = T$ . A characteristic pattern  $c^1_k$  is consistent if it is consistent with respect to all media types  $M^i$ .

As an example, an aerial photographic image of media type  $M^1$  is examined and a possible tank is detected. This is a characteristic pattern  $c^1_1$ . The keywords describing findings of the intelligence officer is of media type  $M^2$ . The transformation  $T_{1,2}$  maps characteristic pattern  $c^1_1$  to  $T_{1,2}(c^1_1)$ , which could be the keyword "tank". If the consistency function  $K_2$  verifies that the finding "tank" is consistent with other findings, then the characteristic pattern  $c^1_1$  is consistent with respect to media type  $M^2$ . If we can also verify that  $c^1_1$  is consistent with other patterns detected in media  $M^1$ , and suppose the information space contains only objects of these two media types, then we have verified that  $c^1_1$  is consistent.

In this example the transformation function is simply the labeling of characteristic patterns. The "tank" characteristic pattern is the pattern detected by a pattern recognizer. There are image processing algorithms which will produce characteristic patterns. We can use similarity functions as consistency functions to determine whether the inputs are all within a certain distance.

## 2.2. Active Index for Dynamic Information Linking

In our approach of human- and system-directed information fusion, the human can define index cells for the detection of significant events. The system can generate additional index cells to monitor significant events. We now describe the concept of the index cell, which is the fundamental building block of an active index.

An *index cell* (ic) accepts input messages and performs some actions. It then posts an output message to a group of output index cells. Depending upon the internal state of the index cell and the input messages, the index cell can post different messages to different groups of output index cells. Therefore the connection between an index cell and its output cells is not static, but dynamic.

An index cell can be either *live* or *dead*. If the cell is in a special internal state called the *dead state*, it is considered dead. If the cell is in any other state, it is considered live. The entire collection of index cells, either live or dead, forms the *index cell base* (ICB). This index cell base ICB may consist of infinitely many cells, but the set of live cells is finite and forms the *active index* (IX).

When an index cell posts an output message to a group of output index cells, these output index cells are activated. If an output index cell is in a dead state, it will transit to the initial state and become a live cell, and its timer will be initialized (see below). On the other hand, if the output index cell is already a live cell, its current state will not be affected, but its timer will be re-initialized. The output index cells, once activated, may or may not accept the posted output message. The first output index cell that accepts the output message will remove this message from the output list of the current cell. (In case of a race, the outcome is nondeterministic.) If no output index cell accepts the posted output message, this message will stay indefinitely in the output list of the current cell.

After its computation, the index cell may remain active (live) or de-activate itself (dead). An index cell may also become dead, if no other index cells (including itself) post messages to it. There is a built-in timer, and the cell will de-activate itself if the remaining time is used up before any message is received. This parameter - the time for the cell to remain live- is re-initialized each time it receives a new message and thus is once more activated. Thus a cell may become dead if it does not receive any message after a prespecified time.

Although there can be many index cells, these cells may be all similar. For example, we may want to attach an index cell to an image, so that when a certain feature is detected, a message is sent to the index cell which will perform predetermined actions such as prefetching other images. If there are ten such images, then there can be ten such index cells, but they are all similar. These similar index cells can be specified by an *index cell type*, and the individual cells are the instances of the index cell type.

We developed a tool called the *IC\_Builder*, which helps the designer construct index cell types using a graphical user interface. The index system is managed by the *IC\_Manager* which can run on a Unix workstation or on any PC with Windows. An active index is a dynamically changing net. As shown in [1] the active index can be used to realize Petri nets, generalized Petri nets (G-nets), B-trees, etc. But its primary purpose is to serve as a dynamic index. One important result is that we can now deal with systems of over ten thousand index cells. In other words, **the active index approach can really scale up for realistic applications**. An application of this model is to improve the efficiency of on-line information retrieval in hyperspace by *prefetching*. The active index technique is used to describe the associated knowledge and to support automatic knowledge-based information retrieval. A prototype of an intelligent WWW client system has been developed. Experiment results show that a greater retrieval and navigation efficiency can be obtained.

The dynamic information linking proceeds as follows. The input data can be regarded as input messages to the active index and processed by the actions (such as pattern recognition routines) associated with the first-level index cells. If no significant characteristic patterns are detected, the processed abstracted information will be stored. If, on the other hand, some significant characteristic patterns are detected, the second-level index cells will be activated to perform horizontal reasoning to combine abstracted information from different sources. If the horizontal reasoner reports that the new finding is consistent with other findings, these consistent findings can be fused into knowledge by activating the third-level index cells. The simplest form of fusion is the generation of a report listing all the consistent findings, which may be quite adequate for such media as keywords or assertions. For multisensory images, data fusion techniques can be applied. Since three levels of index cells are now activated and dynamically linked together, they constitute a vertical reasoner to efficiently process future findings of a similar nature. Another viewpoint is to regard the dynamically linked active index cells

as an *active filter* to report on similar findings efficiently.

### 3. Deliverables and Expected Outcomes

We are building an experimental active multimedia information system which can be customized for geospatial information fusion and management for use by federal agencies involved with spatial and multidimensional data management. During this three-year effort, we intend to experiment with both general applications and web-specific applications, and evaluate the prototype system using applications provided by agencies such as the Defense Mapping Agency. The AMIS prototype is WWW-savvy and works on the Internet. When the user poses *latent queries* beforehand, the user is defining significant events for the active information system to detect and to monitor. By the application of vertical/horizontal reasoning using active index, the AMIS system can detect significant events and create information links dynamically.

This research will lead to better understanding on the problem of fusion of geospatial information. The expected outcomes include new techniques to design active indexes, horizontal reasoners, vertical reasoners and query processor so that they can be coordinated to detect significant events that are emerging in time, and to create consistently fused knowledge to answer user's queries.

#### Reference:

[1] S. K. Chang, "[Towards a Theory of Active Index](#)", Journal of Visual Languages and Computing, Vol. 6, No. 1, March 1995, 101-118. (Figures 1-3. [click here](#). Figure 4. [click here](#). Figure 5. [click here](#). Figure 6. [click here](#). Figure 7. [click here](#).)