A Lightweight Protocol between Digital Libraries and Visualization Systems

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ABSTRACT
A lightweight protocol, VIDI, is proposed to enhance the interoperability of digital libraries (DLs) and visualization systems (VIS). VIDI is related to the Open Digital Library project, which encourages a component-based approach to the construction of digital libraries, implemented by extending the Open Archives Initiative Protocol for Metadata Harvesting. VIDI adds in the concept of a registry of transformers to convert between common metadata and visualization formats. Design and implementation discussions of VIDI explain its feasibility, flexibility, and generality.

Keywords
Visualization, Digital Library, VIDI, Protocol, Interoperability, OAI, Open Archives Initiative, Open Digital Library, Transformer, Registry

INTRODUCTION
Most of today's digital libraries (DLs) [1, 2] have simple query interfaces and offer no 'geometric display of data'. Thus, more and more research now is being done in information visualization because of its relevance and advantages in a variety of domains, including in the field of DLs.

Consider the case of coupling visualization with digital library technology, as we have done in the ENVISION-MARIAN project [5, 12]. Then, a visualization system [13] (VIS) communicates with the user to form the request and sends it to the back-end DL. It transforms the unseen internal semantic representation of data into visible geometric displays. However, in such a coupled system, the DL and VIS are usually bound directly to each other; they transfer query and result data in some format that perhaps only they can recognize.

It would be nice if each DL and VIS could be weakly coupled and freely connected, so that the needs of users to access various types of DL using various VIS can be realized as shown in Figure 1. Thus, for example, VIS1 could be used to access DL1 and DL2, and DL2 could be accessed using either VIS1 or VIS2.

VIDI [11], a lightweight protocol extended from the Open Archives Initiative (OAI) Protocol for Metadata Harvesting (OAI-PMH [7]) is proposed. There are two classes of participants in the OAI-PMH framework: data providers and services providers. The available online lists of registered data providers and service providers found at the OAI home page (http://www.openarchives.org/) provide one indication of the growing number of participants in OAI.

Based on the simplicity, wide acceptability, and success of the OAI-PMH, VIDI presents a new solution to achieve interoperability between DL and VIS. VIDI has an interoperability and scalability framework with two participants: DL providers and visualization providers. DL providers administer DLs that support the VIDI protocol as a means of exposing metadata about the content in their systems. Visualization providers issue VIDI protocol requests to the systems of DL providers and use the returned data as a basis for visualization and presenting results to the users. Any VIS that adopts the VIDI protocol could be a *Visualization provider*. Thus, any VIS, such as the SomFrontEnd [6] may register as a *Visualization provider* with its name and the website of its VIDI interface offered to a central open registry. SomFrontEnd is a tool developed by the Artificial Intelligence (AI) Lab at University of Arizona for viewing classification output. In our implementation of the ODL_NP/SOM prototype system, we make SomFrontEnd act as a visualization provider.

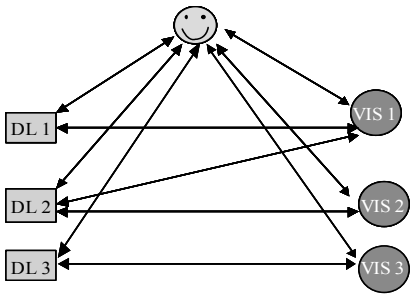

Figure 1. User can access multiple DLs and VIS through the VIDI protocol.

VIDI PROTOCOL

The VIDI protocol extends from OAI-PMH, which defines a mechanism for harvesting XML-formatted metadata from repositories. A *harvester* is a client application that issues OAI-PMH requests, while a *repository* is a network accessible server that can process the six OAI-PMH requests. To support OAI-PMH, the HTTP Post method is recommended for the VIDI implementation because there is no limitation on the length of the arguments for POST. Each VIDI protocol request has one key=value pair that specifies the VIDI protocol request as an OAI-PMH protocol request. Responses to VIDI requests are formatted as HTTP responses with appropriate HTTP header files. Each request returns a Content-Type of text/xml.

This extension of OAI-PMH is an application of the concept of Open Digital Libraries, first expounded in [8], and elaborated in [9]. The ODL approach argues for using lightweight protocols that are well defined for a particular functionality in order to connect the components that make up digital library systems. For VIDI, we expand this concept in order to more easily build integrated DL-VIS environments. In particular, as is shown in Table 1, we adapt two of the five OAI requests, and add in three others (two of which are take-offs on OAI verbs).

Table 1. Comparision of OAI and VIDI Requests

OAI	OAI & VIDI	VIDI
GetRecord	Identify	ListVisdataFormats
ListIdentifiers	ListMetadata-Formats	ListTransformers
ListRecords		RequestResultSet
ListSets		

Unlike OAI-PMH (with six verbs), only five commands are identified and defined in the VIDI protocol. Further, all the commands defined in VIDI, except the *RequestResultSet* command, have options to be issued to either DLs or VIS. The *RequestResultSet* command is the only one for transferring query data. The other four are used for exchanging system information, and can be implemented in Client-Server or Server-Server mode. Their respective roles are:

- *Identify* is used to retrieve system information about a DL and/or a VIS;
- *ListMetadataFormats* is used to retrieve the *metadata formats* available from a DL;
- *ListVisdataFormats* is used to return the data format the VIS understands (called *visdata format*);
- *ListTransformers* is used to retrieve the transformers that the VIS supports in order to transform the *metadata format* to the *visdata format*.

For each of the above request commands, an XML schema is developed for the response format

VIDI IMPLEMENTATION

Implementation of the VIDI protocol is flexible, and can be either in Client-Server or Server-Server mode. The trade-off is between simplicity and functionality. ENVISION_ODL and ENVISION_MARIAN were implemented using Client-Server mode by Wang [11], where the VIS (ENVISION [5, 12]) acts as a client, sending requests to the DL (either ODL [8, 9] or MARIAN [3]). Development of another prototype system ODL_NP/SOM is presented below to illustrate the feasibility, flexibility, and generality of the VIDI protocol. A block diagram for our first attempt to work with NP/SOM is given in Figure 2. The flow graph of the Client-Server protocol implementation is given in Figure 3.

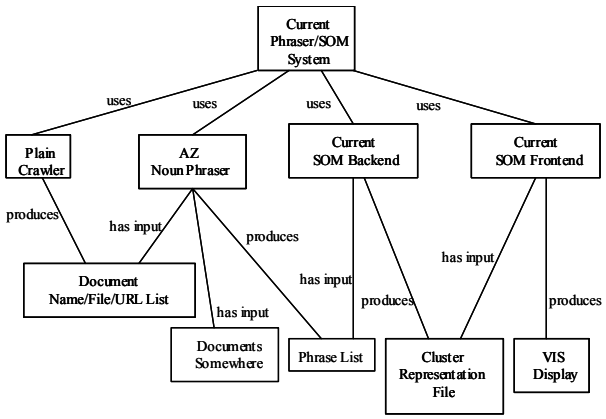

Figure 2. Block diagram of NP & SOM system

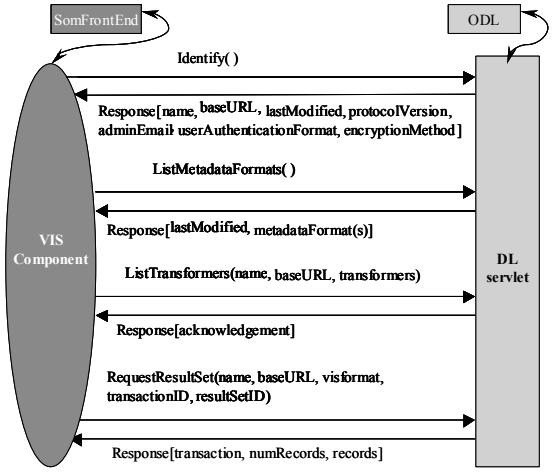

Figure 3. Flow graph of Client-Server protocol implementation

Open Digital Libraries [8, 9] (ODLs) are systems built as networks of extended Open Archives. As is illustrated in Figure 3, VIDI is an extension of the ODL concept to extend beyond DL to also incorporate VIS.

The client functions of VIS are encapsulated in a Java module named *VISComponent*, which implements VIDI requests, sending to the DL servlet. The DL servlet is coded

in Java and is set up to talk with DLs as a proxy. It can respond to request commands from a VIS. The response for *Identify* and *ListMetadataFormats* are static and predetermined by ODL and VIDI. For the *ListTransformers* command, the servlet retrieves the transformer and returns nothing but an acknowledgement. For the *RequestResultSet* request, the servlet retrieves the *resultSetID*, which is a query identifier used to request a result set from the DL.

A transformer plays an important role in the implementation of the VIDI protocol. It can be as simple as an XSLT stylesheet that transforms some specific XML *metadata format* supported by the DL to some XML *visdata format* supported by the VIS. It also can be a location of an application that accepts the data in some specific metadata format and outputs the data in a specific *visdata format*.

Theoretically, if we have *d* DLs supporting *d* different *metadata formats* and *v* VIS systems supporting *v* different *visdata formats*, we would need to code *d*v* transformers for interoperability. However, if there are *m<<d metadata formats* supported by *d* DLs and *n<<v visdata formats* supported by VIS systems, only *m*n* transformers are needed. We plan to register the transformers in an open transformation registry. The registration scheme also could allow a publicly accessible list of VIDI conformant systems, making it easy for both DLs and VIS to discover not only the transformers but also systems with which they could interoperate.

EXAMPLE: NP AND SOM

To illustrate our approach, we consider the visualization of DL content based on an analysis of noun phrases (NPs) and their occurrences, using self-organizing maps (SOMs). Figure 2 illustrates the various parts of such a system, using the form of a concept map.

SomFrontEnd can visualize data generated from the Noun Phrasing (NP [10]) and Kohonen Self-Organizing Map (SOM [4, 6]) applications which were developed by the AI Lab at the University of Arizona. The AZ Noun Phraser is a noun phrase generation tool for extracting high-quality phrases from textual data. SomBackend is a tool for classifying textual documents. In our ODL_NP/SOM prototype system, a chain of servlets is developed to perform transformation. It encapsulates the functions of the AZ Noun Phraser and SomBackend to transform data into a *visdata format* supported by the SomFrontEnd, as shown in Figure 4. Figure 5 illustrates the flow of data in accord with the VIDI protocol. The XML schema for ODL's *metadata format* is based on the Dublin Core Schema, and the XML schema for SomFrontEnd's *visdata format* is based on two files generated from SomBackend.

CONCLUSION AND FUTURE WORK

There are many efforts and applications of the Open Archives Initiative (OAI). For example, the Open Citation Project is working towards becoming a registered service provider with the OAI. Also, the Computing and Information Technology Interactive Digital Education Library (CITIDEL) extends OAI to achieve higher performance across the broad Internet [1].

In this paper we present VIDI, an extended OAI protocol. Our conclusions from this research work are:

- VIDI can enhance the interoperability between visualization systems and digital libraries.
- The feasibility of VIDI can be understood by considering the implementation of the ODL_NP/SOM system.

Future research may include:

- In-depth analysis and additional implementations. These need to be completed in order to thoroughly evaluate the protocol.
- Providing registration service for DL_VIS transformers. These need to be implemented in a secure and convenient fashion so that many of the developers of DL and VIS systems find them convenient and worth supporting and advertising.

We encourage the involvement of other researchers in this field in this project. We hope that the basic idea, enhanced by the comments of others, will lead to greater use of VIS systems in conjunction with DLs.

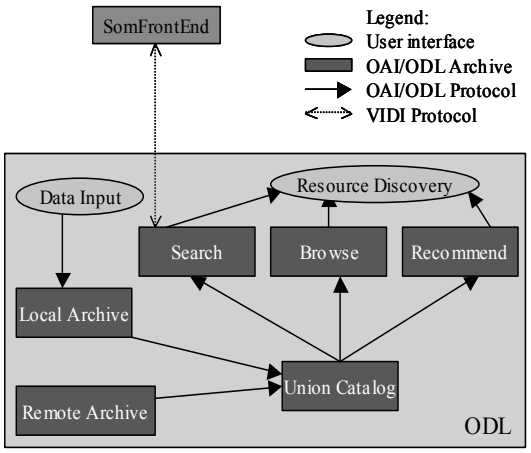

Figure 4. ODL_NP/SOM prototype system

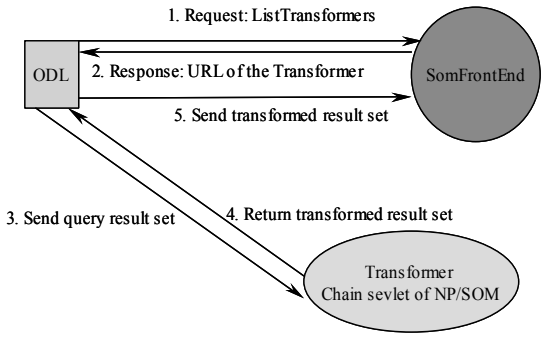

Figure 5. ODL_NP/SOM system

ACKNOWLEDGMENTS

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