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Exposing and Harvesting Metadata Using the OAI Metadata Harvesting Protocol: A Tutorial

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Abstract

In this article I outline the ideas behind the Open Archives Initiative metadata harvesting protocol (OAIMH), and attempt to clarify some common misconceptions. I then consider how the OAIMH protocol can be used to expose and harvest metadata. Perl code examples are given as practical illustration.

1. Introduction

The Open Archives Initiative (OAI) [1] announced the OAI metadata harvesting protocol (OAIMH) v1.0 [2] on 21 January 2001 after a period of pre-release testing. It is intended that the protocol will not be changed until 12-18 months have elapsed from the initial release. This period of stability is designed to allow time for thorough evaluation without the cost of multiple rewrites for early implementers.

The OAIMH protocol was designed as a simple, low-barrier way to achieve interoperability through metadata harvesting. It is still an open question as to exactly how useful metadata sharing will be. However, there is certainly considerable interest in OAI and experience with early OAIMH implementations is encouraging.

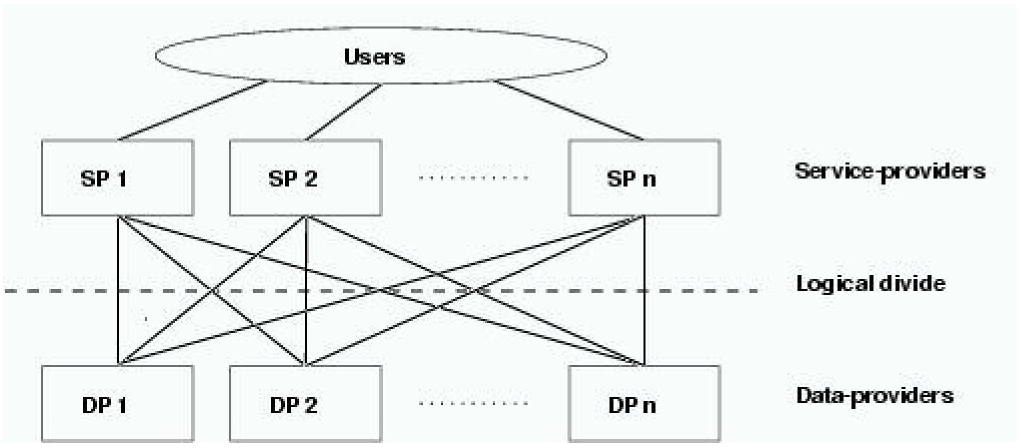
This tutorial is organized in four main sections. In section 2, I hope to clear up some common misconceptions about what OAIMH is. In section 3, I review some of the concepts and assumptions that underly the OAIMH protocol. Then, in the remaining two sections, sections 4 and 5, I consider implementation of the *data-provider* and *service-provider* sides of the OAIMH protocol. Perl code examples are given to implement bare-bones versions of these two interfaces.

It is not my intention to offer a complete description of the OAIMH protocol but instead to describe its use in very practical terms, and to highlight common practice among implementers. A copy of the OAIMH protocol specification [2] should be at hand while reading this tutorial. I will refer to sections within the protocol specification as [2 section2.1] (for section 2.1).

2. What OAIMH Is Not

The most common misconception of OAIMH, as it currently stands, is that it provides mechanisms to expose and harvest full-content (documents, images, ...). This is not true, OAIMH is a protocol for the exchange of *metadata* only. However, it may be that a future OAI protocol will provide facilities for the exchange of full-content.

OAIMH is not about direct interoperability between archives. It is based on a model which puts a very clean divide between data-providers (entities which expose metadata) and service-providers (entities which harvest metadata, presumably with the intention of providing some service).



While the model has a clear divide between data-providers and service-providers, there is nothing to say that one entity cannot be both; Cite Base [3] is one example. The model has an obvious scalability problem if every service-provider is expected to harvest data from every data-provider. It may be that is is not an issue if service-providers are specific to a particular community and thus harvest only from a subset of data-providers. We may also see the creation of aggregators which harvest from a number of data-providers and the re-export this data.

OAIMH is not limited to Dublin Core (DC) [4] metadata. However, since OAI aims to promote interoperability, DC metadata has been adopted as a lowest common-denominator metadata format which all data-providers should support. It is not intended that the requirement to export DC metadata should preclude the use of other metadata sets that may be more appropriate within particular communities. The OAI encourages the development of community-specific standards that provide the functionalities required by specific communities.

3. OAIMH Concepts

3.1. Pull-Only Interaction via HTTP Using XML

Service-providers make requests to data-providers; there is no support for data-provider-driven interaction. All requests and replies occur using the HTTP protocol [5]. Requests may be made using either the HTTP GET or POST methods. All successful replies are encoded in XML [6], and all exception and flow-control replies are indicated by HTTP status codes.

3.2. Verbs

OAIMH protocol requests are made using one of six verbs: `Identify`, `GetRecord`, `ListIdentifiers`, `ListRecords`, `ListSets`, and `ListMetadataFormats`. Some of these verbs accept or require additional parameters to completely specify the request. The verb and any parameters are specified as `key=value` pairs [2 section3.1.1] either in the URL (if the GET method is used), or in the body of the message (if the POST method is used).

3.3. Items, Records and Identifiers

The OAIMH protocol is based on a model of repositories that hold metadata about *items* [2 section2]. The nature of the items is outside the scope of the protocol; they might be electronic documents, artefacts in a museum, people, or almost anything else. The requirement for OAI compliance is that the repository be able to disseminate metadata for these items in one or more formats including Dublin Core (DC).

Metadata is disseminated via the `GetRecord` and `ListRecords` verbs. These requests result in zero or more *records* being returned. A record consists of 2 or 3 parts: a `<header>` container, a `<metadata>` container, and possibly an `<about>` container [2 section2.2].

The metadata for each item has a unique identifier which, when combined with the `metadataPrefix`, acts as a key to extract a metadata record. Note that although all metadata types for an item share the same identifier, the identifier is explicitly *not* an identifier for the item [2 section2.3]. Identifiers may be any valid URI [7] but an optional OAI identifier syntax [2 sectionA2] has been adopted widely. The OAI identifier syntax divides the identifier into three parts separated by colons (:), e.g. `oai:arXiv:hep-lat/0008015` where `` `oai' `` is the scheme, `` `arXiv' `` identifies the repository, and `` `hep-lat/0008015' `` is the identifier within the particular repository.

3.4. Datestamps

The metadata for an item (considered as a whole, not as individual formats) has a datestamp which is the date of last modification. The purpose of the datestamp is to support date-selective harvesting and incremental harvesting in particular. Datestamps are returned in the records returned by a data-provider and may be used as optional arguments to the `ListIdentifiers` and `ListRecords` requests.

The datestamps have the granularity of a day, they are in YYYY-MM-DD format and no time is specified. This simple date format actually creates some additional complexity because the service-provider and data-provider may not be in the same time-zones. This is considered further in section 4.2.

Typically, a service-provider would initially harvest all metadata records from a repository by issuing a `ListRecords` request without `from` or `until` restrictions. Subsequently, the service-provider would issue `ListRecords` requests with a `from` parameter equal to the date of the last harvest.

3.5. Sets

Sets are provided as an *optional* construct for grouping items to support selective harvesting [2 section2.5]. It is not intended that they should provide a mechanism by which a search is implemented, and there is no controlled vocabulary for set names so automated interpretation of set structure is not supported. It should be noted that sets are optional both from the point of view of the data-provider - which may or may not implement sets; and the service-provider - which may ignore any set structure that is exposed. It is not clear whether sets will be widely used and I shall not consider them further in this tutorial.

3.6. Metadata Formats

The OAIMH protocol supports *multiple parallel metadata formats*. Dublin Core (DC) is mandated for lowest common denominator interoperability. The use of other formats within particular communities or for special purposes is encouraged. Within a particular repository, metadata formats are identified by a `metadataPrefix`. Each `metadataPrefix` is associated with the URL of the schema which may be used to validate the metadata records; the URL has cross repository scope. The only globally meaningful `metadataPrefix` is `oai_dc` (for DC), which is associated with the schema at `http://www.openarchives.org/OAI/dc.xsd`.

The `ListMetadataFormats` request will return the `metadataPrefix`, `schema`, and optionally a `metadataNamespace`, for either a particular record or for the whole repository (if no identifier is specified). In the case of the whole repository, all metadata formats supported by the repository are returned. It is not implied that all records are available in all formats.

3.7. Exception Conditions

The OAIMH protocol has very simple exception handling: syntax errors result in HTTP status code 400 replies, and parameters that are invalid or have values that do not match records in the repository result in empty replies. For example, a `ListRecords` request for a date range when there were no changes, or for a metadata format not supported, will result in a reply with header information but no `<record>` elements.

3.8. Flow Control, Load Balancing and Redirection

Flow control is supported with the HTTP retry-after status code 503. This allows a server (data-provider) to tell the harvesting agent (service-provider) to try the request again after some interval. It is left entirely up to the server implementer to determine the conditions under which such a response will be given. The server could base the response on current machine load or limit the frequency at which requests will be serviced from any given IP address. The retry-after response may also be used to handle temporary outages without simply taking the server off-line.

In an environment where one of a set of servers may handle a request, the server may dynamically redirect a request using the HTTP 302 response. To date this has been implemented only by the NACA repository [8].

4. Exposing Metadata

To expose metadata within the OAI, one must implement the data-provider site of the OAIMH protocol. This provides a small set of functions which can be used to extract information about and metadata from the underlying repository.

4.1. Minimal Server Implementation

The Perl files `oai1.pl`, `OAIServer.pm` and `Database.pm` implement a bare-bones data-provider interface. The file `oai1.pl` handles HTTP requests and must be associated with a URL in the web server configuration file; for the Apache [9] web server, the configuration line is `ScriptAlias /oai1 /some/directory/oai1.pl` if the code is in `/some/directory`. It is also possible to run `oai1.pl` from the command line, the request is specified with the `-r` flag, e.g. `./oai1.pl -r 'verb=Identify'`.

The algorithm for `oai1.pl` is simply:

```
read GET, POST or command line request
check syntax of request
if syntax correct
  return XML reply to request
else
  return HTTP 400 error code and message
```

An example of an invalid request is:

```
simeon@fff>./oai1.pl -r 'bad-request'
Status: 400 Malformed request
Content-Type: text/plain

No verb specified!
```

`OAIServer.pm` exports two subroutines, one (`OAICheckRequest`) to check the request against a grammar stored in a data structure, and another (`OAISatisfyRequest`) which calls the appropriate routine to implement the required OAI verb. I will consider each verb in turn.

`Database.pm` is a dummy database interface with a `database' of three records: `record1`, `record2` and `record3`. Metadata for `record1` and `record2` is available in DC format; metadata for `record1` is also available in another format with the `metadataPrefix` `` `wibble` ''; and `record3` is a `deleted' record so no metadata is available.

4.2. Identify

This verb takes no arguments and returns information about a repository [2 section4.2]. The example code implements Identify by simply writing out information from configuration variables. The protocol allows for additional `<description>` blocks which may contain community-specific information. Examples include `<oai-identifier>` which specifies a particular identifier syntax, and `<eprints>` which includes additional information appropriate for the e-print community [2 sectionA2].

4.3. ListSets

This verb takes no arguments and returns the set structure of the repository [2 section4.6]. The example code does not implement any sets so the response is an empty list.

4.4. ListMetadataFormats

This verb may be used either with a `identifier` argument or without any arguments [2 section4.4]. If an `identifier` is specified then the verb returns the metadata formats available for that record. In many cases a repository may be able to disseminate metadata for all records in the same format or formats. In this case the response will be the same if there is no `identifier` argument or if the `identifier` argument specifies any record that exists. The example code implements the general case by calling a routine in the `Database.pm` module to ask what formats are available, and then formats the reply appropriately. For each metadata format, the reply must include a `<metadataPrefix>` (used to specify that format in other requests), and a `<schema>` URL. A `<metadataNamespace>` element may optionally be returned but is not implemented in the example code.

An example request and response is:

```
simeon@fff>./oai1.pl -r 'verb=ListMetadataFormats&identifier=record1'
Content-Type: text/xml

<?xml version="1.0" encoding="UTF-8"?>

<ListMetadataFormats
xmlns="http://www.openarchives.org/OAI/OAI_ListMetadataFormats"

xsi:schemaLocation="http://www.openarchives.org/OAI/1.0/OAI_ListMetadataFormats

http://www.openarchives.org/OAI/1.0/OAI_ListMetadataFormats.xsd">
 <responseDate>2001-05-05T12:27:36-06:00</responseDate>
 <requestURL>http://localhost/oai1?verb=ListMetadataFormats&amp;
             identifier=record1&amp;verb=ListMetadataFormats</requestURL>
 <metadataFormat>
  <metadataPrefix>wibble</metadataPrefix>
  <schema>http://wibble.org/wibble.xsd</schema>
 </metadataFormat>
 <metadataFormat>
  <metadataPrefix>oai_dc</metadataPrefix>
  <schema>http://www.openarchives.org/OAI/dc.xsd</schema>
 </metadataFormat>
</ListMetadataFormats>
```

The response indicates that the record `record1` may be disseminated in either `oai_dc` or `wibble` formats.

4.5. GetRecord

This verb requests metadata for a particular record in a particular format [2 section4.1]. The example code implements this as a call to a subroutine `disseminate` (shared with `ListRecords`) after checking that the record exists.

The record returned consists of two parts if the record is not deleted; a `<header>` block which contains the identifier and the datestamp (the information required for harvesting) and a `<metadata>` block which contains the XML metadata record in the requested format. The `<metadata>` block will be missing if the record is deleted or if the requested metadata format is not available.

For example, a request for `oai_dc` for `record2` would be:

```
simeon@fff>./oai1.pl -r
'verb=GetRecord&identifier=record2&metadataPrefix=oai_dc'
Content-Type: text/xml

<?xml version="1.0" encoding="UTF-8"?>

<GetRecord xmlns="http://www.openarchives.org/OAI/OAI_GetRecord"
  xsi:schemaLocation="http://www.openarchives.org/OAI/1.0/OAI_GetRecord
                      http://www.openarchives.org/OAI/1.0/OAI_GetRecord.xsd">
 <responseDate>2001-05-05T12:50:23-06:00</responseDate>
 <requestURL>http://localhost/oai1?verb=GetRecord&amp;identifier=record2&amp;
             metadataPrefix=oai_dc&amp;verb=GetRecord</requestURL>
 <record>
  <header>
   <identifier>record2</identifier>
   <datestamp>1999-02-12</datestamp>
  </header>
  <metadata>
   <oai_dc xsi:schemaLocation="http://purl.org/dc/elements/1.1/
                               http://www.openarchives.org/OAI/dc.xsd"
           xmlns:xsi="http://www.w3.org/2000/10/XMLSchema-instance"
           xmlns="http://purl.org/dc/elements/1.1/">
    <Title>Item 2</Title>
    <Creator>A N Other</Creator>
   </oai_dc>
  </metadata>
 </record>
</GetRecord>
```

but a request for the unavailable format `wibble` would be:

```
simeon@fff>./oai1.pl -r
'verb=GetRecord&identifier=record2&metadataPrefix=wibble'
Content-Type: text/xml

<?xml version="1.0" encoding="UTF-8"?>

<GetRecord xmlns="http://www.openarchives.org/OAI/OAI_GetRecord"
 xsi:schemaLocation="http://www.openarchives.org/OAI/1.0/OAI_GetRecord
                     http://www.openarchives.org/OAI/1.0/OAI_GetRecord.xsd">
 <responseDate>2001-05-05T12:52:13-06:00</responseDate>
 <requestURL>http://localhost/oai1?verb=GetRecord&amp;
   identifier=record2&amp;metadataPrefix=wibble&amp;verb=GetRecord</requestURL>
 <record>
  <header>
   <identifier>record2</identifier>
   <datestamp>1999-02-12</datestamp>
  </header>
 </record>
</GetRecord>
```

which includes a `<header>` block but no `<metadata>` block.

The protocol also permits the addition of an `<about>` container [2 section2.2] for each record This is provided as a hook for additional information such as rights or terms information. It is not currently used by any of the registered OAI data-providers and is not implemented in the example code.

4.6. ListIdentifiers and ListRecords

ListIdentifiers [2 section4.3] and ListRecords [2 section4.5] both implement a search by date, the difference is whether they return a list of identifiers or complete metadata records in the specified format. The example code implements both of these verbs using the subroutine `listEither` which calls a search by date (`getIdsByDate`) in `Database.pm`.

In the case of ListIdentifiers the output consists of `<identifier>` elements which may include the attribute `status="deleted"` if the record is deleted. An example request without date restriction is:

```
simeon@fff>./oai1.pl -r 'verb=ListIdentifiers'
Content-Type: text/xml

<?xml version="1.0" encoding="UTF-8"?>

<ListIdentifiers xmlns="http://www.openarchives.org/OAI/OAI_ListIdentifiers"
  xsi:schemaLocation="http://www.openarchives.org/OAI/1.0/OAI_ListIdentifiers

http://www.openarchives.org/OAI/1.0/OAI_ListIdentifiers.xsd">
 <responseDate>2001-05-05T12:59:30-06:00</responseDate>
```

```
<requestURL>http://localhost/oai1?verb=ListIdentifiers&amp;verb=ListIdentifiers<
/requestURL>
 <identifier>record1</identifier>
 <identifier>record2</identifier>
 <identifier status="deleted">record3</identifier>
</ListIdentifiers>
```

The response lists the identifiers of the three records in the repository and indicates that `record3` is deleted. If the parameter `until=2000-01-01` were added then only the first two identifiers would be returned since the datestamp of `record3` is 2000-03-13.

In the case of `ListRecords` the output consists of `<record>` blocks similar to those obtained from GetRecord requests. `ListRecords` requests must include a `metadataPrefix` parameter.

4.7. Partial Responses

The OAIMH protocol allows for partial responses [2 section3.4] for all of the list verbs (`ListIdentifiers`, `ListSets`, `ListMetadataFormats` and `ListRecords`). This feature has been implemented by most of the larger registered OAI repositories for the `ListIdentifiers` and `ListRecords` verbs. The example code does not implement this feature.

5. Harvesting Metadata

To harvest metadata within the OAI, one must implement the service-provider site of the OAIMH protocol. I will consider the implementation of a harvester that performs two functions: firstly, harvest all metadata in a particular format, and secondly, harvest all metadata in a particular format that has changed since a given date. These functions are the basis of a system that can create and maintain an up-to-date copy of the metadata from an OAI-compliant repository.

As one of the maintainers of a heavily used archive I am painfully aware of the importance of avoiding inadvertent denial-of-service attacks created by badly written harvesting software. Automated agents should always include a useful user-agent string and a valid e-mail contact address in their HTTP requests. The flow-control elements of the protocol must be respected and careful testing is essential.

5.1. Detecting Changes That Require Manual Intervention

I will assume that the goal is to create software which will run on some schedule so that the local copy of metadata from some set of repositories is kept updated without manual intervention. However, it would be reckless to assume that the details of repositories will not change over time. In order to avoid the need for manual polling to detect such changes, we should ask how they can be detected automatically.

To detect changes other than the addition and deletion of records which are part of normal repository operation, one can compare the response to OAI requests that describe the repository between successive harvests. These requests are `Identify` and probably `ListSets` and `ListMetadataFormats` (for the whole repository as opposed to any single record). For all of the requests we expect the `<responseDate>` to change with each request but for these requests we expect the rest of the response to be unchanged. Note that to do the test correctly one should compare the XML data in such a way that valid transformations, say re-ordering elements, are ignored. However, in practice it is likely to be sufficient (if over sensitive) to do a string comparison of the responses so long as changes in the `<responseDate>` are ignored.

In the example harvester I have included the facility to specify a file containing the `Identify` response from the previous harvest. This is used both to extract the date of the last harvest and to check for changes in that response. I have not implemented a test for changes in the `ListSets` and `ListMetadataFormats` responses.

5.2. Incremental Harvesting

The OAIMH protocol was designed to facilitate incremental harvesting. The idea is that a service-provider will maintain an up-to-date copy of the metadata from a repository by periodically harvesting `changed' records. This is why all records have a datestamp, the date of last modification, associated with them.

The one-day granularity of the datestamp and the possibility of data-providers and service-providers being in different time zones means that there must be some overlap between the date ranges of successive requests [10]. If the service-provider and data-provider share the same time-zone then a one-day overlap is sufficient to ensure that updates are not missed; records might be updated after the harvest on the day of the last harvest, but provided records that have changed on that day are reharvested then no changes will be missed. To cope with different time zones it is necessary to extend this to a two-day overlap if the harvester works with dates local to itself. An alternative strategy, which I prefer, is to use only the dates returned by the repository and thus, by working in the local time zone of the repository, reduce the required overlap to one day.

In the example harvester I implement this last strategy by taking the date of the last harvest from the `<responseDate>` of the stored `Identity` response (the `<responseDate>` must be specified in the local time zone of the repository [2 section3.1.2.1]. This date may then be used as the `from` date (inclusive) for the next `ListRecords` or `ListIdentifiers` request.

5.3. Flow Control and Redirection

The module `OAIGet.pm` examines the HTTP reply for status codes 302 (redirect) and 503 (retry-after). Both replies are handled automatically, a default retry period is assumed if the 503 response does not specify a time (though this is an error on the part of the data-provider). Messages are printed if the verbose option is selected.

5.4. Parsing Replies

OAIMH protocol replies are designed to be self-contained, in part to allow off-line processing thereby separating the harvesting and database-update processes. However, in order to deal with partial responses the harvesting software must be able to parse the responses to all the list requests (`ListIdentifiers`, `ListSets`, `ListMetadataFormats` and `ListRecords`) sufficiently to extract any `resumptionToken` [2 section3.4]. To date, none of the registered OAI compliant repositories give partial responses for `ListSets` and `ListMetadataFormats` requests, but several do for `ListIdentifiers` and `ListRecords` requests.

Perhaps the neatest way to implement a harvester would be to have it recombine partial responses into a complete reply. The example code does not do this but does parse all list requests to look for a `<resumptionToken>` so that further requests can be used to complete the original request.

5.5. An Example Harvester

The files oaiharvest.pl, OAIGet.pm and OAIParser.pm implement a simple harvester that illustrates the points mentioned above. oaiharvest.pl is the executable and accepts a variety of flags, these can be displayed by executing `oaiharvest.pl -h`. The algorithm is:

```
read command line arguments
check options and parameters
issue Identify request
compare response with previous Identify response if given
extract `from' date from command line, previous Identify response or do complete
harvest
LOOP:
  issue ListRecords or ListIdentifiers request
  check for resumptionToken, LOOP if present
```

The subroutine `OAIGet` in OAIGet.pm is used to issue the OAIMH requests and this handles any retry-after or redirect replies. XML parsing is handled by the OAIParser.pm module which extends `XML-Parser`, which itself is based on the `expat` parser.

Let us take as an example, harvesting metadata from the example data-provider code which has be set up at the URL `http://localhost/oai1`. First we would issue a harvest command without any time restriction (to harvest all records). In the examples, I harvest just the identifiers using `ListIdentifiers` requests, the flags `-r` and `-m metadataPrefix` can be used to instruct oaiharvest.pl to issue `ListRecords` requests and to specify a `metadataPrefix` other than `oai_dc`.

```
simeon@fff>mkdir harvest1
simeon@fff>./oaiharvest.pl -d harvest1 http://localhost/oai1

oaiharvest.pl: Harvest from http://localhost/oai1 using POST
OAIGet: Doing POST to http://localhost/oai1 args: verb=Identify
OAIGet: Got 200 OK (479bytes)
oaiharvest.pl: Doing complete harvest.
OAIGet: Doing POST to http://localhost/oai1 args: verb=ListIdentifiers
OAIGet: Got 200 OK (537bytes)
oaiharvest.pl: Got 3 identifiers (running total: 3)
oaiharvest.pl: No resumptionToken, request complete.
oaiharvest.pl: Done.

simeon@fff>ls harvest1
Identify  ListIdentifiers.1
```

If we then do an incremental harvest specifying the file name of the last `Identify` response, `harvest1/Identify`, the harvester checks against this response for changes (none except date) and extracts the date of the last harvest (2001-06-05) to be used as the `from` date for the new harvest.

```
simeon@fff>mkdir harvest2
simeon@fff>./oaiharvest.pl -d harvest2 -i harvest1/Identify
http://localhost/oai1

oaiharvest.pl: Harvest from http://localhost/oai1 using POST
OAIGet: Doing POST to http://localhost/oai1 args: verb=Identify
OAIGet: Got 200 OK (479bytes)
oaiharvest.pl: Identify response unchanged from reference (except date)
oaiharvest.pl: Reading harvest1/Identify to get from date
oaiharvest.pl: Incremental harvest from 2001-06-05 (from harvest1/Identify)
OAIGet: Doing POST to http://localhost/oai1 args: from=2001-06-
05&verb=ListIdentifiers
```

```
OAIGet: Got 200 OK (444bytes)
oaiharvest.pl: Got 0 identifiers (running total: 0)
oaiharvest.pl: No resumptionToken, request complete.
oaiharvest.pl: Done.
```

Since there have been no changes in the database this harvest results in no identifiers being returned.

To extend this example, I then edited the database (`Database.pm`) to add a new record (`record4`) with datestamp `2001-06-05` which simulates the addition of a record after the last harvest but on the same day. I then ran another harvest command.

```
simeon@fff>diff Database.pm~ Database.pm
24c24,26
<   'record3' => [ '2000-03-13', undef ]  #deleted
 -
>   'record3' => [ '2000-03-13', undef ],  #deleted
>   'record4' => [ '2001-06-05', {
>     'oai_dc' => ['Title','Item 4', 'Creator','Someone Else'] } ]

simeon@fff>mkdir harvest3
simeon@fff>./oaiharvest.pl -d harvest3 -i harvest2/Identify
http://localhost/oai1

oaiharvest.pl: Harvest from http://localhost/oai1 using POST
OAIGet: Doing POST to http://localhost/oai1 args: verb=Identify
OAIGet: Got 200 OK (479bytes)
oaiharvest.pl: Identify response unchanged from reference (except date)
oaiharvest.pl: Reading harvest2/Identify to get from date
oaiharvest.pl: Incremental harvest from 2001-06-05 (from harvest2/Identify)
OAIGet: Doing POST to http://localhost/oai1 args: from=2001-06-
05&verb=ListIdentifiers
OAIGet: Got 200 OK (478bytes)
oaiharvest.pl: Got 1 identifiers (running total: 1)
oaiharvest.pl: No resumptionToken, request complete.
oaiharvest.pl: Done.
```

This harvest results in one additional identifier, `record4`, being returned as expected.

Below are two excerpts from harvests from real repositories which illustrate the flow-control features of the protocol. The first is from `arXiv` which uses 503 retry-after replies to enforce a delay between requests. The second if from `NACA` which uses 302 redirect replies to demonstrate a load-sharing scheme.

```
...
OAIGet: Doing POST to http://arXiv.org/oai1 args: verb=ListIdentifiers
OAIGet: Got 503, sleeping for 60 seconds...
OAIGet: Woken again, retrying...
OAIGet: Got 200 OK (27398bytes)
oaiharvest.pl: Got 502 identifiers (running total: 502)
oaiharvest.pl: Got resumptionToken: `1997-02-10___'
OAIGet: Doing POST to http://arXiv.org/oai1 args: resumptionToken=1997-02-
10___&verb=ListIdentifiers
OAIGet: Got 503, sleeping for 60 seconds...
OAIGet: Woken again, retrying...
OAIGet: Got 200 OK (28330bytes)
oaiharvest.pl: Got 520 identifiers (running total: 1022)
oaiharvest.pl: Got resumptionToken: `1997-03-06___'
...

...
OAIGet: Doing POST to http://naca.larc.nasa.gov/oai/ args: verb=ListIdentifiers
OAIGet: Got 302, redirecting to http://buckets.dsi.internet2.edu/naca/oai/?...
```

```
OAIGet: Doing POST to http://buckets.dsi.internet2.edu/naca/oai/ args:
verb=ListIdentifiers
OAIGet: Got 200 OK (336705bytes)
oaiharvest.pl: Got 6352 identifiers (running total: 6352)
...
```

I hope the examples above provide a useful demonstration of some of the features of the OAIMH metadata harvesting. Be sure to exercise caution and restraint when running tests against registered repositories. There is some cost associated with answering OAIMH requests, and recklessly downloading large amounts of data for no good reason is not helpful.

6. Conclusions

The OAIMH protocol has been public for five months now and experience shows that it is adequate for its intended purpose. There are now 30 registered repositories which together expose over 600,000 metadata records. While there are currently just two registered service providers, `arc' [11] and the Repository Explorer [12], there is an increasing number of tools and libraries available to assist in the development of harvesting applications. Publicly available tools and libraries are listed on the OAI web site [13]. This includes Tim Brody's [14] Perl library which is considerably more extensive than the examples presented here.

The uptake of OAI is very encouraging and it is feedback from the current implementers which will shape the next version of the OAIMH protocol. Anyone implementing, or interested in implementing, either side of the OAIMH protocol should subscribe to the `oai-implementers` [15] mailing list. It is a helpful and friendly forum.

Appendix: Example Programs

The example programs are:

- `oai1.pl` and `OAIServer.pm` for the server; and
- `oaiharvest.pl`, `OAIGet.pm` and `OAIParser.pm` for the harvester.

These files are available as a gzipped tar archive: `examples.tar.gz` (10kB), or as a zip archive: `examples.zip` (12kB).

In order to run the example programs, you will require Perl 5.004 or later and the following modules (the precise version I used is given in parenthesis). For the the server:

- XML-Writer (XML-Writer-0.4)

and for the harvester:

- MIME-Base64 (MIME-Base64-2.11)
- URI (URI-1.09)
- HTML-Tagset (HTML-Tagset-3.02)
- HTML-Parser (HTML-Parser-3.11)
- libnet (libnet-1.0703)
- Digest::MD5 (Digest-MD5-2.11)
- LWP (libwww-perl-5.48)
- expat library (expat-1.95.1)
- XML-Parser (XML-Parser-2.30)

All of the above except for `expat` are available from CPAN (`http://www.cpan.org/`) and can be installed with the standard `perl Makefile.PL; make; make test; make install` sequence. There should not be any dependency problems if the modules are installed in the order listed. The `expat` XML parsing library upon which `XML-Parser` relies, is available from Source Forge (`http://sourceforge.net/projects/expat/`).

Before running `oaiharvest.pl` you should first edit the line that defines the variable `$contact` and insert your e-mail address. This will then be specified as the contact address for all HTTP requests and will enable the server maintainer to contact you if there are problems. The example code has been tested only on a Linux system and with the Apache server. While I hope that it will work on other systems this has not been verified.

About the Author

Simeon Warner is one of the maintainers and developers of the arXiv e-print archive. He has been actively involved with the development and implementation of the OAI since its inception.

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[8] NACA - National Advisory Committee for Aeronautics Technical Report Server,
URL: <http://naca.larc.nasa.gov/>

[9] The Apache web server
URL: <http://www.apache.org/>

[10] Harvesting strategies have been discussed on the `oai-implementers` list [15], I have drawn from the comments of Hussein Suleman in particular.

[11] `arc' Cross Archive Searching Service, an OAI *service provider* developed at Old Dominion University,
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[12] The OAI Repository Explorer, an interface to interactively test archives for compliance with the OAIMH protocol, Hussein Suleman (Digital Libraries Research Laboratory, Virginia Tech.),
URL: <http://rocky.dlib.vt.edu/ oai/cgi-bin/Explorer/oai1.0/testoai>

[13] Open Archives Initiative, Tools for Implementers list,
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[14] Perl class library that allow the rapid deployment of an OAI compatible interface to an existing web server/database for OAI server and harvester implementation,
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[15] `oai-implementers`, a mailing list (and archive) for discussing the implementation of the OAIMH protocol,
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