Resource Index

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Introduction

The Resource Index is the Fedora module that provides the infrastructure for indexing relationships among objects and their components. Examples of relationships between digital objects include well-known management relationships such as the part-whole links between individual chapters and a book, and semantic relationships useful in digital library organization such as those expressed within the Functional Requirements for Bibliographic Records (FRBR).

Fedora expresses relationships by defining a base relationship ontology Fedora Relationships using RDFS and provides a slot in the digital object abstraction for RDF expression of relationships based on this ontology. Assertions from other ontologies may also be included along with the base Fedora relationships. All relationships are represented as a graph that can be queried using an RDF query language. The query interface to the Resource Index is exposed as a Web service risearch.

Implementation

The Fedora object model can be abstractly viewed as a directed graph, consisting of *internal* arcs that relate digital object nodes to their dissemination nodes and *external* arcs between digital objects. The Resource Index is a Fedora service that allows storage and query of this graph. The Resource Index is automatically updated whenever an object is added or modified.

The Resource Index builds on the RDF primitives build within the semantic web community. Fedora supplies a base relationship ontology Fedora Relationships (defining a core set of internal and external relationships) that can co-exist with domain-specific relationship ontologies from other namespaces. Each digital object's external relationships to other digital objects are expressing in RDF/XML within a reserved Datastream in the respective object. A relationship graph over the digital objects in the repository can then be derived by merging the internal relationships implied by the Fedora object model with the external relationships explicitly stated in their relationship Datastreams.

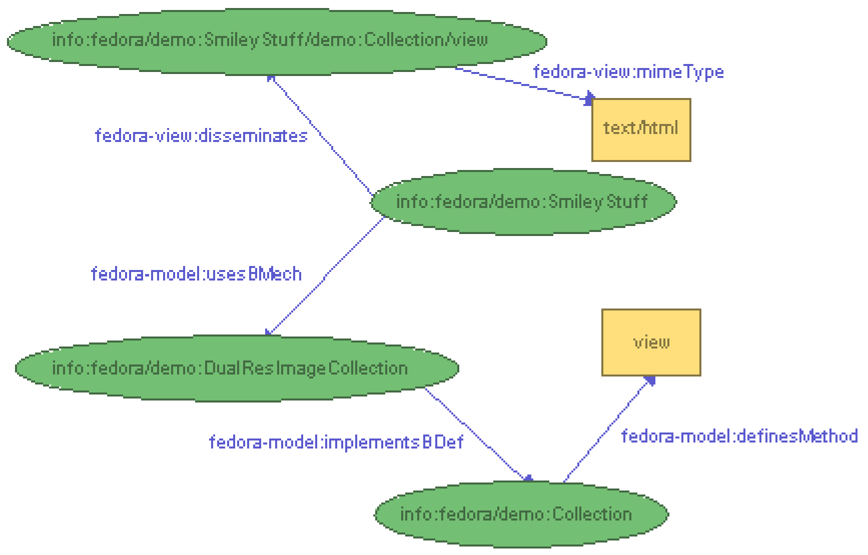
System Relationships & Properties

The Fedora base ontology describes such relations and properties as the behavior definition implemented, behavior mechanism used, creation date, state, and mime-type.

In the figure below, the graph (abbreviated for clarity) represents three objects in the repository. The object "demo:SmileyStuff" uses the Service Deployment "demo:dualResImageCollection", which in turn implements the Service Definition "demo:Collection".

Note

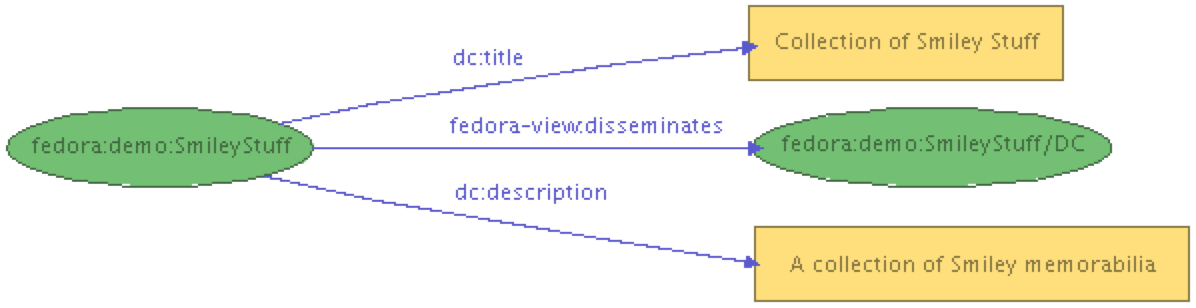
The following picture has not yet been updated to conform with the Fedora 3 ontology. However, it is useful for demonstrating the general concepts described in this section.


info:fedora/demo:SmileyStuff/demo:Collection/view
fedora-view:mimeType
text/html
fedora-view:disseminates
info:fedora/demo:SmileyStuff
fedora-model:usesBMech
view
info:fedora/demo:DualResImageCollection
fedora-model:implementsBDef
fedora-model:definesMethod
info:fedora/demo:Collection

Dublin Core statements, as shown in the figure below, are automatically extracted from an object's DC Datastream and inserted into the Resource Index Datastream, as shown in the figure below:

Note

The following picture has not yet been updated to conform with the Fedora 3 ontology. However, it is useful for demonstrating the general concepts described in this section.


Collection of Smiley Stuff
dc:title
fedora:demo:SmileyStuff
fedora-view:disseminates
fedora:demo:SmileyStuff/DC
dc:description
A collection of Smiley memorabilia

User-defined Relationships

The Resource Index will automatically index object-to-object relationships defined in the RELS-EXT Datastream and datastream relationships defined in the RELS-INT datastream. Please consult Digital Object Relationships for more information.

Configuration

Please note that many configuration changes require a full rebuild of the Resource Index to ensure consistency. For example, turning the Resource Index service off and on again will result in an inconsistent state, as the Resource Index will know nothing about the digital objects created or modified while the service was not operating. Similarly, enabling full-text indexing Full-Text after the repository has already been populated will only add new objects to the full-text model. In general, the only safe configuration changes to make on a running repository are limited to the performance-related pool, buffer and flush parameters. In all cases, configuration changes require a restart of the Fedora server before taking effect.

The Resource Index is configured within two sections of `fedora.fcfg`, `module` and `datastore`.

Module Configuration

The Resource Index module is configured with `fedora.fcfg`. Here's an example of a Resource Index module configuration that uses Mulgara with delayed updates:

```
<module role="fedora.server.resourceIndex.ResourceIndex"
        class="fedora.server.resourceIndex.ResourceIndexModule">
  <param name="level" value="1"/>
  <param name="datastore" value="localMulgaraTriplestore"/>
  <param name="syncUpdates" value="false"/>
</module>
```

Here's another example, this time using MPTStore with immediate updates:

```
<module role="fedora.server.resourceIndex.ResourceIndex"
        class="fedora.server.resourceIndex.ResourceIndexModule">
  <param name="level" value="1"/>
  <param name="datastore" value="localPostgresMPTTriplestore"/>
  <param name="syncUpdates" value="true"/>
</module>
```

An explanation of the parameters and their possible values:

- **level** – Sets the operating level of the Resource Index.
    - 0 – Off: the Resource Index will not load at server startup.
    - 1 – On: the Resource Index will index system properties, inter & intra-object relationships, and user-defined relationships.
- **datastore** – The id of the datastore to use with the Resource Index. The referenced datastore must assert a connectorClassName parameter with a valid Trippi Connector class.
- **syncUpdates** – Whether to flush the triple buffer before returning from object modification operations. This defaults to false. Specifying this as true will ensure that RI queries immediately reflect the latest triples. Specifying false will not provide this guarantee, but can reduce roundtrip time for API-M operations (especially when using Mulgara).

Mulgara Datastore Configuration

The example datastore configuration below (with the path parameter modified for the installation environment) would provide a local Mulgara triplestore that buffers up to 20,000 triples in memory at a time or waits for 5 seconds of buffer inactivity before flushing them to disk. Because writing triples to disk is a relatively expensive operation, the buffer takes advantage of Mulgara's bulk update handler to ingest a mass of triples at a time. The performance gain is significant during a bulk ingest of objects. The size or inactivity interval of the buffer may be adjusted according to performance needs and physical memory capacity.

```
<datastore id="localMulgaraTriplestore">
  <param name="connectorClassName" value="org.trippi.impl.mulgara.MulgaraConnector"/>
  <param name="remote" value="false"/>
  <param name="path" value="/opt/fedora/store/resourceIndex"/>
  <param name="serverName" value="fedora"/>
  <param name="modelName" value="ri"/>
  <param name="poolInitialSize" value="3"/>
  <param name="poolMaxGrowth" value="-1"/>
  <param name="readOnly" value="false"/>
  <param name="autoCreate" value="true"/>
  <param name="autoTextIndex" value="false"/>
  <param name="memoryBuffer" value="true"/>
  <param name="autoFlushDormantSeconds" value="5"/>
  <param name="autoFlushBufferSize" value="20000"/>
  <param name="bufferSafeCapacity" value="40000"/>
  <param name="bufferFlushBatchSize" value="20000"/>
</datastore>
```

An explanation of the parameters and their possible values follows. Certain parameters require other parameters, as indicated in the hierarchy below. Optional parameters are also indicated below. As noted previously, many of these parameters, with the exception of the pool, buffer, and flush parameters, cannot be changed on a running repository without a full rebuild of the Resource Index.

- **connectorClassName** – The name of the Trippi Connector class used to communicate with the triplestore. When using Mulgara, the value should be as follows:
    - org.trippi.impl.mulgara.MulgaraConnector
- **remote** – Tells the connector to communicate with Mulgara in remote or local mode.
    - true – If remote is true, the host parameter must be specified.
        - host – The hostname where Mulgara is running. The hostname can be specified as an argument when starting Mulgara, e.g. java -jar mulgara-2.0.0.jar -k localhost
        - port – The rmi port Mulgara is running on (default is 1099).
    - false – If remote is false, path parameter must be specified.
        - path – The local path to the main triplestore directory.
- **serverName** – The server name for rmi binding. When configuring a remote instance of Mulgara, the server name defaults to "server1". To change this default, use the "-s" argument, e.g. java -jar mulgara-2.0.0.jar -s fedora

- **modelName** – The name of the model to use.
- **poolInitialSize** – The initial size of the session pool used for queries. Note: A value of 0 will cause the Resource Index to operate in synchronized mode: concurrent read/write requests are put in a queue and handled in FIFO order; this will severely impair performance and is only intended for debugging.
- **poolMaxGrowth** – Maximum number of additional sessions the pool may add. If specified as -1, no limit will be placed on pool growth.
- **poolSpareSessions** – The number of spare sessions to proactively make available. If unspecified, this defaults to 0, which means that additional sessions will only be created as needed. Note that if poolMaxGrowth is 0, the value of this parameter is inconsequential.
- **readOnly** – Whether the triplestore should be read-only. Most Fedora repositories will set this to false.
    - true - No additional parameters need to be set if readOnly is true.
    - false - The following parameters must also be set if readOnly is false.
        - autocreate – Whether to create the model if it doesn't already exist. At startup, the model will be automatically created. In addition, an XML schema datatyped model named "xsd" will also be automatically created.
            - true
            - false
        - autoTextIndex – Whether to propagate adds/deletes to a full-text Full-Text model automatically. While a very useful feature, enabling full-text indexing adds significantly to object ingest times. If true, the text model will be named modelName-fullText. Note that if this is true and autoCreate is true, the text model will also be created if it doesn't already exist.
            - true
            - false
        - memoryBuffer – Whether to use a memory buffer or a database buffer for write operations. The buffer is where triples are stored before they're actually written. Normally, a memory buffer will be sufficient. However, in certain server environments, a database buffer is the better option, offering higher capacity and persistence.
            - true
            - false
                - dbDriver – The JDBC driver class name. This must be in the classpath.
                    - com.mysql.jdbc.Driver
                    - com.mckoi.JDBCDriver
                    - oracle.jdbc.driver.OracleDriver
                - dbURL – The JDBC URL for the database. Examples: For MySQL, jdbc:mysql://localhost/mydb would use the local database named mydb. For McKoi, jdbc:mckoi://localhost:9157/ would use the local database at port 9157. For oracle, jdbc:oracle:thin:@localhost:1521:mydb would use the thin driver to connect to the local database named mydb at port 1521.
                - dbUsername – The database username.
                - dbPassword – The password for the db user.
                - dbTableName – The table for buffered triple updates. This table must already exist with the following five columns: num (a large numeric type), action (char(1)), subject, predicate, and object (all large varchar or text types).
        - autoFlushDormantSeconds – Seconds of buffer inactivity that will trigger an auto-flush. If this threshold is reached, flushing will occur in the background, during which time the buffer is still available for writing.
        - autoFlushBufferSize – The size at which the buffer should be auto-flushed. If this threshold is reached, flushing will occur in the background, during which time the buffer is still available for writing.
        - bufferSafeCapacity – The maximum size the buffer can reach before being forcibly flushed. If this threshold is reached, flushing will occur in the foreground and the buffer will be locked for writing until it is finished. This should be larger than autoFlushBufferSize.
        - bufferFlushBatchSize – The number of updates to send to the triplestore at a time. This should be the same size as, or smaller than autoFlushBufferSize.

Remote Mulgara Datastore Configuration

Instead of using the Mulgara instance embedded in Fedora a separate instance of Mulgara can be used, running in its own JVM (which can be on a different server). This may give performance advantages as the resources for the Mulgara JVM can then be configured separately from Fedora itself, and the data files can be located on separate storage.

Mulgara can be downloaded from the Mulgara download page.

Use the same version of Mulgara that Fedora uses - this can be determined from the libraries included in the Fedora web application, which will include a jar file mulgara-core.x.y.z.jar - use version "x.y.z" of Mulgara (it is possible to use other versions but this will involve updating the Mulgara and Trippi libraries that Fedora uses - and any dependencies). Fedora 3.3 uses Mulgara version 2.1.4.

An example datastore configuration for a remote Mulgara instance follows. The Resource Index module must be configured to use this datastore.

```
<datastore id="remoteMulgaraTriplestore">
  <param name="connectorClassName" value="org.trippi.impl.mulgara.MulgaraConnector"/>
  <param name="remote" value="true"/>
  <param name="host" value="localhost"/>
  <param name="port" value="1099"/>
  <param name="serverName" value="fedora"/>
  <param name="modelName" value="ri"/>
  <param name="poolInitialSize" value="3"/>
  <param name="poolMaxGrowth" value="-1"/>
  <param name="readOnly" value="false"/>
  <param name="autoCreate" value="true"/>
  <param name="autoTextIndex" value="false"/>
  <param name="memoryBuffer" value="true"/>
  <param name="autoFlushDormantSeconds" value="5"/>
  <param name="autoFlushBufferSize" value="20000"/>
  <param name="bufferSafeCapacity" value="40000"/>
  <param name="bufferFlushBatchSize" value="20000"/>
</datastore>
```

The parameters for this are largely the same as for a local Mulgara datastore; except **remote** is specified as "true", and **host** and **port** have been specified for the RMI connection to the remote Mulgara instance. The **serverName** parameter must match the server name that Mulgara is configured to use (by default this is "server1", the examples below configure Mulgara instead to use "fedora" as the server name).

Starting and Stopping Mulgara

The Mulgara website has documentation on starting and stopping Mulgara and on command line parameters.

An example command for starting Mulgara is

```
java -jar mulgara-x.y.z.jar -p 8088 -u 8089 -s fedora
```

This configures Mulgara to start using ports 8088 and 8089 for the web user interface as Mulgara's default ports for the Web UI will conflict with Tomcat. Alternatively start Mulgara using `--nohttp` to disable the Web UI. The server name is specified as "fedora" to match the Fedora datastore configuration.

By default Mulgara stores its data in a folder relative to where it was started, instead this can be specified with a `--path` parameter.

Mulgara can be stopped using a command line interrupt, by pressing **Control-C**. Alternatively it can be run using `nohup`, and the following command can then be used to stop Mulgara:

```
java -jar mulgara-x.y.z.jar -x
```

MPTStore Datastore Configuration

The example datastore configuration below would provide a local MPTStore triplestore backed by Postgresql.

```
<datastore id="localPostgresMPTTriplestore">
  <comment>
    Example local MPTStore backed by Postgres.
    To use this triplestore for the Resource Index:
    1) In fedora.fcfg, change the "datastore" parameter of the
       ResourceIndex module to localPostgresMPTTriplestore.
    2) Login to your Postgres server as an administrative user and
       run the following commands:
         CREATE ROLE "fedoraAdmin" LOGIN PASSWORD 'fedoraAdmin'
           NOINHERIT CREATEDB
           VALID UNTIL 'infinity';
         CREATE DATABASE "riTriples"
           WITH ENCODING='SQL_ASCII'
           OWNER="fedoraAdmin";
    3) Make sure you can login to your Postgres server as fedoraAdmin.
    4) Download the appropriate Postgres JDBC 3 driver from
       http://jdbc.postgresql.org/download.html
       and make sure it's accessible to your servlet container.
       If you're running Tomcat, putting it in common/lib/ will work.
  </comment>
  <param name="connectorClassName" value="org.trippi.impl.mpt.MPTConnector"/>
  <param name="ddlGenerator" value="org.nsdl.mptstore.impl.postgres.PostgresDDLGenerator"/>
  <param name="jdbcDriver" value="org.postgresql.Driver"/>
  <param name="jdbcURL" value="jdbc:postgresql://localhost/riTriples"/>
  <param name="username" value="fedoraAdmin"/>
  <param name="password" value="fedoraAdmin"/>
  <param name="poolInitialSize" value="3"/>
  <param name="poolMaxSize" value="10"/>
  <param name="backslashIsEscape" value="true"/>
  <param name="fetchSize" value="1000"/>
  <param name="autoFlushDormantSeconds" value="5"/>
  <param name="autoFlushBufferSize" value="1000"/>
  <param name="bufferFlushBatchSize" value="1000"/>
  <param name="bufferSafeCapacity" value="2000"/>
</datastore>
```

Search Interface

The Resource Index Search interface is exposed in a REST architectural style, providing a stateless query interface that accepts queries by value or by reference Fedora Relationships.

The query interface to the Resource Index currently supports two RDF query languages, iTQL (Mulgara-only), and SPO (Mulgara and MPTStore). Support for SPARQL is planned for a future release.

Please consult the Resource Index Search documentation for more information.

Resource Index Demo

Demonstration objects that utilize the Resource Index are included in the Fedora distribution. Please see the Demonstrations documentation for more information.

Fedora Guide To Triples (and estimator for size of Resource Index)

To understand what triples are indexed in the Fedora Resource Index, and to estimate the size of your Mulgara triplestore consult document named Triples in the Resource Index.

Related Materials

- Fedora: An Architecture for Complex Objects and their Relationships, Carl Lagoze, Sandy Payette, Edwin Shin, and Chris Wilper, 2004.
- Mulgara Full-Text Models
- Fedora Relationship Ontology
- Resource Index Search

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