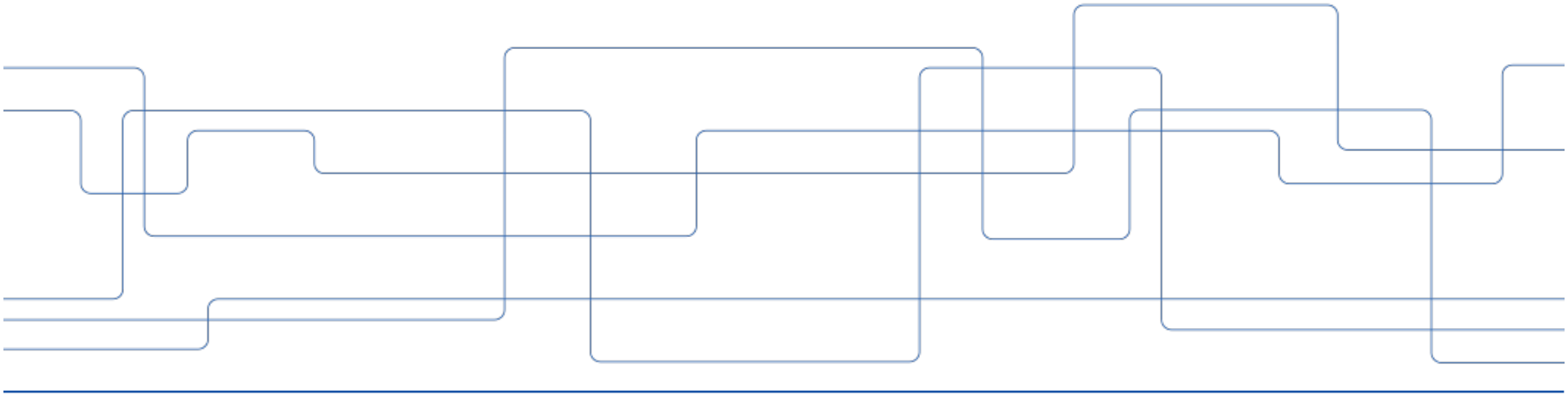
KTH ROYAL INSTITUTE OF TECHNOLOGY

Refactoring Kanki - Towards a Modern Native iRODS Client Implementation

Ilari Korhonen
PDC Center for High Performance Computing, KTH
The 13th Annual iRODS User Group Meeting, June 10th, 2021



Background

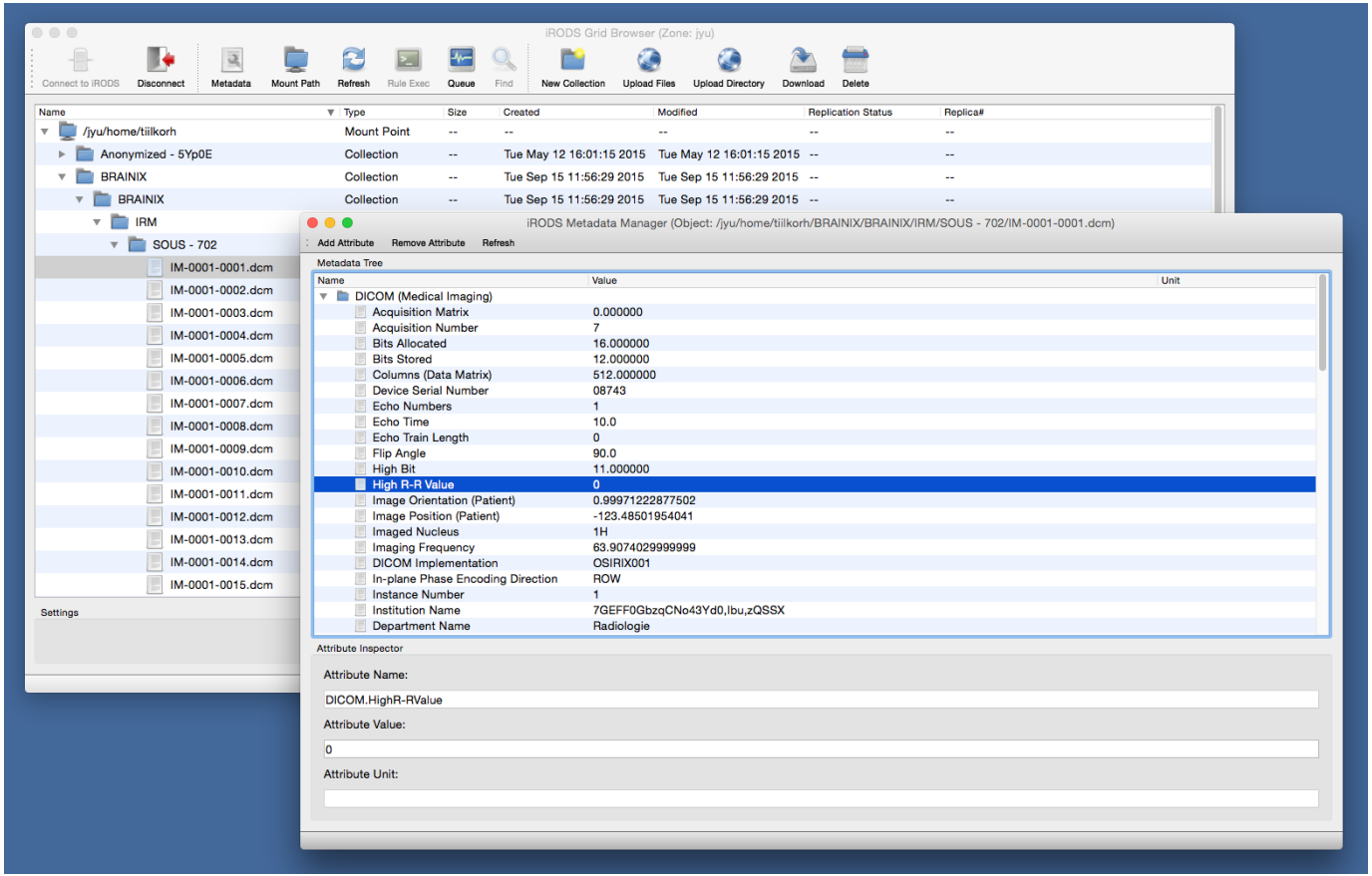
- The Kanki project was started by me back in 2014 at my previous job while working with research IT at University of Jyväskylä, Finland.
- Problem was that there was (and as far as I know, still is) no other (even relatively current) native iRODS client with a graphical user interface, which could be deployed for all the major desktop platforms, Mac, Windows and Linux/X11.
- After presenting at the iRODS UGM 2015, Kanki was open sourced by the university (BSD 3-Clause) and has been available in GitHub at URL:

  https://github.com/ilarik/kanki-irodsclient

- Sadly, since lack of time at my current work, at KTH, there has been modest progress since 2016, up until recently.
- The work was picked up again in late 2020 in collaboration with the iRODS Consortium and we have started the process of refactoring the client-side interfaces in the code from the old C-compatible APIs into a fully-fledged C++17 object-oriented interface.

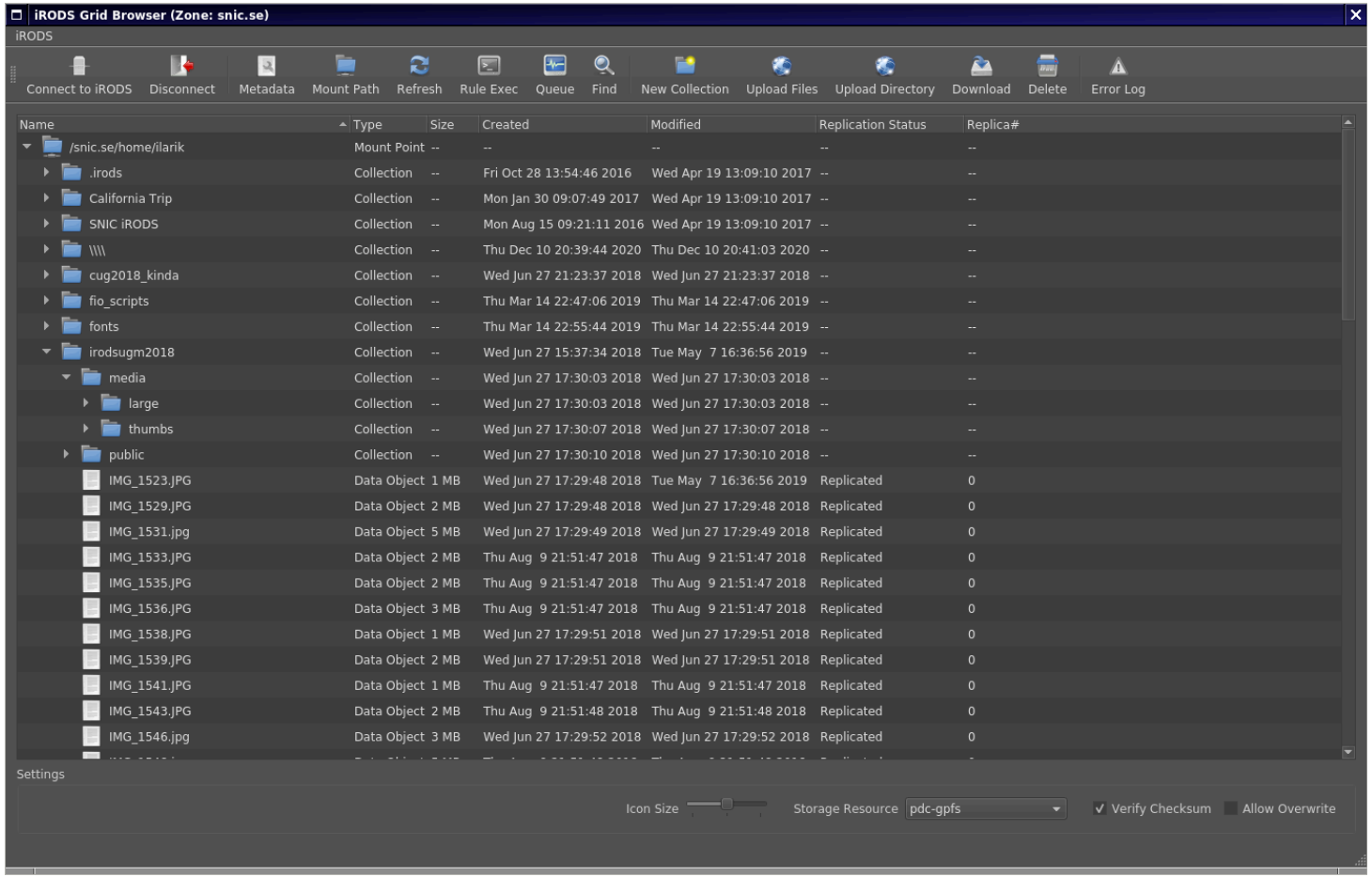
About Kanki

- Written fully in C++ on top of the Qt framework, which makes the vast majority of the code already fully portable across Linux / MacOS / Windows / …
- Feature set includes the basic iRODS operations, a customisable metadata editor, for which one can write a (simple) schema definition (to be improved!), also an extensible iRODS search UI with the full capabilities of GenQuery.
- Uses the native iRODS client library for iRODS connectivity - in practise this means that one can build Kanki where Qt and `irods-icommands` are supported.
- Supports all the same authentication and transfer mechanisms as `icommands`, however UI support for configuring the authentication needs to be improved.
- Previous packaged builds were built against iRODS 4.1.x.
- From the development branches in GitHub, one can build it against 4-2-stable on Linux, currently. We are working on the MacOS build with the good people at University of Arizona / CyVerse.


iRODS Grid Browser (Zone: jyu)
Connect to iRODS
Disconnect
Metadata
Mount Path
Refresh
Rule Exec
Queue
Find
New Collection
Upload Files
Upload Directory
Download
Delete
Name
Type
Size
Created
Modified
Replication Status
Replica#
/jyu/home/tiilkorh
Mount Point
Anonymized - 5Yp0E
Collection
Tue May 12 16:01:15 2015
BRAINIX
Tue Sep 15 11:56:29 2015
IRM
SOUS - 702
IM-0001-0001.dcm
IM-0001-0002.dcm
IM-0001-0003.dcm
IM-0001-0004.dcm
IM-0001-0005.dcm
IM-0001-0006.dcm
IM-0001-0007.dcm
IM-0001-0008.dcm
IM-0001-0009.dcm
IM-0001-0010.dcm
IM-0001-0011.dcm
IM-0001-0012.dcm
IM-0001-0013.dcm
IM-0001-0014.dcm
IM-0001-0015.dcm
Settings
iRODS Metadata Manager (Object: /jyu/home/tiilkorh/BRAINIX/BRAINIX/IRM/SOUS - 702/IM-0001-0001.dcm)
Add Attribute
Remove Attribute
Refresh
Metadata Tree
Value
Unit
DICOM (Medical Imaging)
Acquisition Matrix 0.000000
Acquisition Number 7
Bits Allocated 16.000000
Bits Stored 12.000000
Columns (Data Matrix) 512.000000
Device Serial Number 08743
Echo Numbers 1
Echo Time 10.0
Echo Train Length 0
Flip Angle 90.0
High Bit 11.000000
High R-R Value 0
Image Orientation (Patient) 0.9997122877502
Image Position (Patient) -123.48501954041
Imaged Nucleus 1H
Imaging Frequency 63.9074029999999
DICOM Implementation OSIRIX001
In-plane Phase Encoding Direction ROW
Instance Number 1
Institution Name 7GEFF0GbzqCNo43Yd0,lbu,zQSSX
Department Name Radiologie
Attribute Inspector
Attribute Name:
DICOM.HighR-RValue
Attribute Value:
0
Attribute Unit:

The Future

- Since version 4.0.0 iRODS has been gradually refactored into a C++ code base, from the old iRODS 3.3.1 pure C code, but the client-side libraries so far have remained almost fully C-compatible - up until recently.
- This new development not only changes the API interface in the code from a procedural to an object-oriented one but also introduces new functionalities, including *connection pooling* and client-side *thread pool* management - in a coherent fashion within the client framework.
- Previously, introducing parallelism within a single iRODS client session has been a source of pain, due to the structure of an agent process and its synchronous nature.
- Nowadays parallelism in the server processes is increasing. Additionally, the introduction of facilities in the client library supporting asynchronous execution of tasks, makes it possible to painlessly run tasks in parallel, asynchronously.


iRODS Grid Browser (Zone: snic.se)
iRODS
Connect to iRODS
Disconnect
Metadata
Mount Path
Refresh
Rule Exec
Queue
Find
New Collection
Upload Files
Upload Directory
Download
Delete
Error Log
Name
Type
Size
Created
Modified
Replication Status
Replica#
/snic.se/home/ilarik
Mount Point
.irods
Collection
Fri Oct 28 13:54:46 2016
Wed Apr 19 13:09:10 2017
California Trip
Mon Jan 30 09:07:49 2017
SNIC iRODS
Mon Aug 15 09:21:11 2016
\\\\
Thu Dec 10 20:39:44 2020
Thu Dec 10 20:41:03 2020
cug2018_kinda
Wed Jun 27 21:23:37 2018
fio_scripts
Thu Mar 14 22:47:06 2019
fonts
Thu Mar 14 22:55:44 2019
irodsugm2018
Wed Jun 27 15:37:34 2018
Tue May 7 16:36:56 2019
media
Wed Jun 27 17:30:03 2018
large
thumbs
Wed Jun 27 17:30:07 2018
public
Wed Jun 27 17:30:10 2018
IMG_1523.JPG
Data Object
1 MB
Replicated
0
IMG_1529.JPG
2 MB
IMG_1531.jpg
5 MB
Wed Jun 27 17:29:49 2018
IMG_1533.JPG
Thu Aug 9 21:51:47 2018
IMG_1535.JPG
IMG_1536.JPG
3 MB
IMG_1538.JPG
Wed Jun 27 17:29:51 2018
IMG_1539.JPG
IMG_1541.JPG
IMG_1543.JPG
Thu Aug 9 21:51:48 2018
IMG_1546.jpg
Wed Jun 27 17:29:52 2018
Settings
Icon Size
Storage Resource
pdc-gpfs
Verify Checksum
Allow Overwrite

Connection Pools and Thread Pools

- Newer versions of the iRODS client library include a connection pool facility, using which the client can instantiate and manage *n* simultaneous connections to the same iRODS endpoint.

  `irods::connection_pool + irods::connection_pool::connection_proxy`

- From a successfully established connection pool one can take out a connection and reserve that for a task at hand, releasing the connection afterwards.

- A similar concept of a thread pool has been incorporated into the later client versions, based on Boost ASIO.

  `irods::thread_pool`

- One can instantiate thread pools of *m* threads and spin up worker threads for tasks to be ran in parallel, possibly also “peeling off” connections from a connection pool reserved for the tasks.

New Object-Oriented iRODS APIs

- In addition to the previously mentioned, in the later client versions, many object-oriented APIs have started appearing. In some cases these are “hidden” under the `irods::experimental` namespace.

- Filesystem API (`irods::experimental::filesystem`)
  - previously all C-callable `rc*` functions
  - Kanki interfaced to these via its own intermediate OO interfaces.
- Streaming I/O API (`irods::experimental::io`)
  - previously all C-callable functions, `rcDataObj[open/close/read/write/Lseek]`
  - Kanki had its own streaming API wrapping those.
- Query Builder API (`irods::experimental::query_builder`)
  - previously the C-native iRODS GenQuery interface
  - Kanki had its own C++ query builder interface wrapping all that
- …

Programming Paradigm Changes

Scope-Based Resource Management

- Also known as RAII - Resource Acquisition Is Initialisation.
- Makes it easier to ***not*** leak memory.
- In old-school iRODS client code, data structures were simply regions of contiguous memory, possibly dynamically allocated.
- Pointers to these structures were managed in various ways and places, which leads to confusion and an easy way to end up leaking memory.
- C++ (especially from C++11 and later standards) provide mechanisms for managing the allocation and freeing resources (such as memory) simply by objects being either in or out of scope.
- Examples of this are the use of “smart” pointers and the management of locks, such as a mutex.
- All this makes the code inherently exception safe, since the unwinding of the stack is what enables all of this in the first place. **Exceptions are leveraged heavily in iRODS!**

Programming Paradigm Changes

Functional-Style Programming (Lambda Functions!)

- C++ is a multi-paradigm programming language, also supporting some constructs which enable some aspects of functional programming.
- So called lambda functions (anonymous functions) are perhaps the best example of these.
- Lamda expressions enable functions to be defined as literals and passed along as (anonymous) objects.
- How about a defining a lambda expression which would peel off a connection and performing some work on it, and then shipping this off to a thread pool for (asynchronous) execution?

Example 1

`Kanki::RodsSession::makeColl()`

Before

```
int makeColl(const std::string &collPath,
    bool makeRecursive)
{
    collInp_t theColl;
    int status = 0;
    // preparations omitted

    commMutex.lock();
    status = rcCollCreate(rodsCommPtr, &theColl);
    commMutex.unlock();

    return status;
}
```

After

```
int makeColl(const std::string &collPath,
    bool makeRecursive)
{
    int status = 0;
    // preparations omitted

    std::lock_guard mutexGuard(commMutex);
    namespace fs = irods::experimental::filesystem;
    try {
        fs::client::create_collection(*(commPtr()),
            collPath);
    }
    catch (fs::filesystem_error &e) {
        status = e.code().value();
    }
    return status;
}
```

Example 2

RodsDownloadThread::run()

Before

```
void RodsDownloadThread::run() {
    int status = 0;
    // …
    if (!(status = makeCollObjsList(this->objEntry, &collObjs))) {
        // …
        for (int i = 0; i < collObjs.size(); i++) {
            Kanki::RodsObjEntryPtr curObj = collObjs.at(i);
            if (curObj->objType == DATA_OBJ_T) {
                // …
                if ((status = downloadFile(curObj, dstPath, verify, overwrite)) < 0) {
                    reportError("iRODS get file error", curObj->getObjectFullPath().c_str(), status);
                }
            }
            // …
        }
        // …
    }
}
```

Example 2

RodsDownloadThread::run()

After

```
void RodsDownloadThread::run() {
      int status = 0;
      irods::thread_pool tank(RodsDownloadThread::defaultJobs);

      // …
      if ((status = makeCollObjList(this->objEntry, &collObjs, comm)) < 0)
            reportError("Download failed", this->objEntry->getObjectFullPath().c_str(), status);
      else {
            // …
            for (int i = 0; i < collObjs.size(); i++) {
                  Kanki::RodsObjEntryPtr curObj = collObjs.at(i);
                  if (curObj->objType == DATA_OBJ_T) {
                        irods::thread_pool::post(tank, [=, &status] {
                              Kanki::RodsSession::connection_proxy conn = session->getConnection();
                              if (!conn)
                                    reportError("iRODS connection failure", curObj->getObjectFullPath().c_str(), SYS_SOCK_CONNECT_ERR);
                              else if ((status = getObject(conn, curObj, dstPath, verify, overwrite)) < 0)
                                    reportError("iRODS data stream error", curObj->getObjectFullPath().c_str(), status);
                        });
                  }
                  // …
            }
            // …
      }
      // …
}
```

Example 3

RodsQueueModel

Before

```
RodsQueueModel::RodsQueueModel(/* omitted */) {
     // …
     connect(timer, &QTimer::timeout, this, &RodsQueueModel::refreshQueue);
     timer->start();
}

void RodsQueueModel::refreshQueue() {
     int status = 0;
     Kanki::RodsGenQuery query(this->conn);
     query.addQueryAttribute(COL_RULE_EXEC_ID);
     // …
     query.addQueryCondition(COL_RULE_EXEC_USER_NAME, Kanki::RodsGenQuery::isEqual, conn->rodsUser());
     if ((status = query.execute()) < 0) {
          // report errors to UI
     }
     else {
          // make data live
     }
}
```

Example 3

RodsQueueModel

After

```
RodsQueueModel::RodsQueueModel(/* omitted */) {
    // …
    connect(timer, &QTimer::timeout, this, &RodsQueueModel::launchRefresh);
    timer->start();
}

void RodsQueueModel::launchRefresh() {
    irods::thread_pool::post(tank, [&] { this->refreshQueue(); });
}
```

Example 3

RodsQueueModel

After

```
void RodsQueueModel::refreshQueue() {
     int status = 0;
     std::string queryStr = “SELECT RULE_EXEC_ID, RULE_EXEC_NAME, …”; // omitted
     irods::connection_pool::connection_proxy conn = this->session->getConnection();
     // …
     if (conn) {
          rcComm_t *comm = static_cast<rcComm_t*>(conn);
          try {
               for (const row_type &row : irods::experimental::query_builder().build(*comm, queryStr))
                    tempData.push_back(row);
          }
          catch (const irods::exception &e) {
               status = e.code();
          }
          catch (const std::exception &e) {
               status = SYS_INTERNAL_ERR;
          }
          if (status < 0) {
               // report errors to UI
          }
          else {
               // make data live
          }
     }
}
```

DEMO

- Let’s see if it works!

- Built from the latest commit in GitHub…

Thanks go to

- All of you! For all of these years!

- Special acknowledgements lately:

  - *Alan King*, iRODS Consortium
  - *Kory Draughn*, iRODS Consortium
  - *Terrell Russell*, iRODS Consortium
  - *Jason Coposky*, iRODS Consortium

  - *Tony Edgin*, University of Arizona
  - *Nirav Merchant*, University of Arizona
  - *Jeremy Frady*, University of Arizona