

Introduction to libURBI for Urbi 1.x

(book compiled from 682M)

Matthieu Nottale

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by Matthieu Nottale

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Chapter 1. Introduction

Liburbi-c++ is a library designed to encapsulate an URBI connection. It handles the TCP connection with the URBI server, and the dispatching of messages it sends. The library is thread-safe and reentrant.

The library consists of two C++ classes, `UClient` and `USyncClient`, and a few helpful functions.

We expect the reader to be a bit familiar with the URBI syntax.

Chapter 2. Getting started

Connecting

To connect to an URBI server, simply create a new instance of `UClient` (or `USyncClient` if you want to use the synchronous functions described below), passing the name or the address of the server as the first parameter, and optionally the port as the second parameter:

```
UClient * client = new UClient("myrobot.ensta.fr");

//a wrapper is also available in the urbi namespace:
UClient * client = urbi::connect("myrobot.ensta.fr");
```

The constructor will start an independent thread that will listen for incoming messages from the URBI server.

You can check if the connection was successfully established by calling the `error` function, which returns a zero value on success, or a nonzero error code in case of failure.

Sending URBI commands

The method `send` is the simplest way to send commands to the URBI server. It accepts a syntax similar to the `printf` function. To send a sequence of commands without risk of having another thread sending commands at the same time, the `lockSend` and `unlockSend` methods can be used to lock and then unlock the send buffer.

```
int sleeptime = 50;

client->send("motoron;");

client->lockSend(); //send() call by other threads will be blocked from this
                  //point until unlockSend is called

for (float val=0; val<=1; val+=0.05)
    client->send("neck.val = %f;wait (%d);", val, sleeptime);

client->unlockSend();
```

Alternatively, the `UClient` class inherits from `ostream`, so you can use the `<<` operator:

```
client << "headPan.val = " <<12 << urbi::comma;
```

The constants 'comma', 'semicolon', 'pipe' and 'parallel' are defined in the `urbi` namespace for ',', ';', '|' and '&' respectively.

A third possible way is to use the URBI macro, which uses the default connection (the first connection created with your program):

```
URBI((
    headPan.val = 12 ,
    echo "coucou" | speaker.play("test.wav") & leds.val = 1
));
```

```
//note the absence of double-quotes to delimit the URBI code
//the double-parenthesis are required
URBI() << "headPan.val = " << 12 << urbi::semicolon;
```

The function `urbi::setDefaultClientUClient *cl)` can be used to change the default client.

Sending binary data.

To send binary data to the robot, the method `sendBin` must be used. It takes as parameters the buffer to send and its size, and optionnaly a header.

```
client->sendBin(soundData, soundDataSize, "speaker.val = BIN %d raw 2 16000 16 1
soundDataSize);
```

Sending a sound

Although you could use `sendBin` to play a sound on the robot, a specific and efficient method has been written for this purpose: `sendSound`.

```
client->sendSound(sound, "endsound");
```

The first parameter is a `USound` structure describing the sound to send. The second is an optionnal tag that will be used by the server to issue a "stop" system message when the sound has finished playing. The function `convert` can be used to convert between various sound formats.

There is no limit to the size of the sound buffer, since it will be automatically cut into small chunks by the library. The data is copied by the library: the `USound` parameter and its associated data can be safely freed as soon as the function returns.

Chapter 3. Receiving

Most of the messages received from the URBI server are the results of a previously sent command. The mechanism of URBI tags enables to link a message to its reply: with each command is associated a tag, and this tag is repeated in the reply message. The `UClient` class handles the reception of those messages in the independant thread created by the constructor, parses them and fills a `UMessage` structure. Callback functions with an associated tag can be registered with the method `registerCallback`: each time a message with this tag is sent by the server, the callback function will be called with a `UMessage` structure as a parameter. The two basic forms of `registerCallback` are:

```
typedef UCallbackAction (*UCallback)           (const UMessage &msg);
typedef UCallbackAction (*UCustomCallback)     (void * callbackData, const UMessage &msg);

UCallbackID setCallback (UCallback cb, const char *tag)
UCallbackID setCallback (UCustomCallback cb, void *callbackData, const char *tag)
```

The first parameter is always a pointer to the function to call. `callbackData` is a pointer that will be given back to the callback function each time it is called. The callback function must return `URBI_CONTINUE`, or `URBI_REMOVE`, in which case the function will be unregistered.

A few examples:

```
UCallbackAction onImage(const UMessage &msg) {
//Test if someone has used your tag or an error message has been received
    if (msg.type != MESSAGE_DATA || ((UImage)msg).imageFormat == IMAGE_UNKNOWN)
        return URBI_CONTINUE;
    UImage img = (UImage)msg;
    msg.client.printf("Image of size (%d,%d) received from server at %d\n",img.width, img.height);

    unsigned char *image = new unsigned char[img.width*img.height*3];
    int sz = img.width*img.height*3;

    if (img.imageFormat == IMAGE_JPEG)
        convertJPEGtoRGB((const byte *) img.data, img.size, (byte *) image, sz); //pr
    if (img.imageFormat == IMAGE_YCbCr)
        convertYCrCbtoRGB((const byte *) img.data, img.size, (byte *) image); //pr

    myDisplayRGBImage(image, img.width, img.height);
    delete image;
    return URBI_CONTINUE;
}

UCallbackAction onSound(const UMessage &msg) {
    if (msg.type != MESSAGE_DATA || USound(msg).soundFormat == SOUND_UNKNOWN)
        return URBI_CONTINUE;

    //convert the sound to a wav 16KHz 16bit.
    USound snd;
    snd.soundFormat = SOUND_WAV;
    snd.rate = 16000;
    snd.sampleSize = 16;
    snd.sampleFormat = SAMPLE_SIGNED;
    snd.channels = 0; //take the value from source
    snd.data = 0;
```

```

    snd.size = 0;
    convert((USound)msg, snd); //this function is provided by liburbi
    myPlayWAV(snd.data, snd.size);
    return URBI_CONTINUE;
}

UCallbackAction onJoint(const UMessage &msg) {
    if (msg.type != MESSAGE_DATA || ((UValue)msg).type != DATA_DOUBLE)
        return URBI_CONTINUE;
    msg.client.printf("The joint value is %lf\n", UValue(msg).val);
    return URBI_CONTINUE;
}

int main(int argc, const char * argv[]) {
    UClient * cl = new UClient(argv[1]);
    if (cl->error()) urbi::exit(1); //portability call explained below
    cl->setCallback(&onImage, "img");
    cl->setCallback(&onSound, "snd");
    cl->setCallback(&onJoint, "joint");
    cl->send("img: camera.val;");
    cl->send("loop snd: micro.val,");
    cl->send("joint: headPan.val;");
    urbi::execute(); //portability call explained below
}

```

UMessage

The UMessage structure is capable of storing the informations contained in any kind of URBI message by using a "type" field and an UValue (union of type-dependant structures). These two structures are defined as follows:

```

class UMessage
{
public:
    /// Connection from which originated the message.
    UAbstractClient &client;
    /// Server-side timestamp.
    int timestamp;
    /// Associated tag.
    std::string tag;

    UMessageType type;

    urbi::UValue *value;
    std::string message;
    /// Raw message without the binary data.
    std::string rawMessage;
};

```

UValue

```

class UValue
{
public:
    UDataType type;
    ufloat val; // value if of type DATA_DOUBLE
}

```

```

union
{
    std::string      *stringValue;    // value if of type DATA_STRING
    UBinary          *binary;        // value if of type DATA_BINARY
    UList            *list;          // value if of type DATA_LIST
    UObjectStruct    *object;        // value if of type DATA_OBJ
};
}

```

The type field `UMessageType` can be `MESSAGE_SYSTEM`, `MESSAGE_ERROR` or `MESSAGE_DATA`. If the type is `MESSAGE_DATA`, the message contains an `UValue`. The `UValue` itself contains an `UDataType` which can take the values: `DATA_DOUBLE`, `DATA_STRING`, `DATA_BINARY`, `DATA_LIST`, `DATA_OBJECT`, `DATA_VOID`. Depending of this field, the corresponding value in the union will be set. If the `UValue` is of the binary type, it contains an `UBinary` structure defined hereafter. The `UBinaryType` in the `UBinary` structure will give additional informations on the type of data (`BINARY_NONE`, `BINARY_UNKNOWN`, `BINARY_IMAGE`, `BINARY_SOUND`), and the appropriate sound or image structure will be filled.

UBinary

```

class UBinary
{
public:
    UBinaryType  type;
    union
    {
        struct
        {
            void *data; /// binary data
            int  size;
        } common;
        UImage image;
        USound sound;
    };
}

```

USound

```

class USound {
public:
    char      *data;          // pointer to sound data
    int       size;          // total size in byte
    int       channels;      // number of audio channels
    int       rate;          // rate in Hertz
    int       sampleSize;    // sample size in bit
    USoundFormat  soundFormat; // format of the sound data
                                // (SOUND_RAW, SOUND_WAV, SOUND_MP3...)
    USoundSampleFormat  sampleFormat; // sample format
};

```

UImage

```

class UImage {
public:

```

```
char          *data;          // pointer to image data
int           size;          // image size in byte
int           width, height;  // size of the image
UImageFormat imageFormat;    // IMAGE_RGB, IMAGE_YCbCr, IMAGE_JPEG
};
```

Template versions of `registerCallback` are also defined. They allow to set callbacks on member functions, with from 0 to 4 custom parameters of any type (including pointers and references). The only constraint on the function signature is that it must return a `UCallbackAction`, and take a `const UMessage&` as its last parameter. A few examples:

```
class Test {
public:
    UCallbackAction onJoint(int value, const UMessage &msg);
};

UCallbackAction Test::onJoint(int value, const UMessage &msg) {
    msg.client.printf("got a message at %d with tag %s, our int is %d\n",msg.time, value);
    return URBI_REMOVE; //unregister ourself
}

int main(int argc, const char * argv[]) {
    Test *a = new Test();
    UClient * cl= new UClient(argv[1]);
    if (cl->error()) urbi::exit(1);
    cl->setCallback(*a, &Test::onJoint, 12, "tag");
    cl->send("tag: headPan.val;");
    urbi::execute();
}
```

Chapter 4. Synchronous operations

The derived class `USyncClient` implements methods to synchronously get the result of URBI commands. You must be aware that these functions are less efficient, and that they are not easily portable.

Reading the value of a device

To get the value of a device, you can use the method `syncGetDevice` or `syncGetNormalizedDevice`. The first parameter is the name of the device (for instance, "neck"), the second is a double that is filled with the received value. The difference between the two methods is that `syncGetDevice` retrieves the value with a "val" command, whereas `syncGetNormalizedDevice` uses "valn" (see `urbidoc.html` for more details about "val" and "valn").

```
double neckVal;  
syncClient->syncGetDevice("neck", neckVal);
```

Getting an image

You can use the method `syncGetImage` to synchronously get an image. The method will send the appropriate command, and wait for the result, thus blocking your thread until the image is received.

```
client->send("camera.resolution = 0;camera.gain = 2;");  
int width, height;  
client->syncGetImage("camera", myBuffer, myBufferSize, IMAGE_JPEG, URBI_TRANSMIT_
```

The first parameter is the name of the camera device. The second is the buffer (void*) which will be filled with the image data. The third must be an integer variable equal to the size of the buffer. The function will set this variable to the size of the data. If the buffer is too small, data will be truncated.

The fourth parameter is the format in which you want to receive the image data. Possible values are `IMAGE_RGB` for a raw RGB 24 bit per pixel image, `IMAGE_PPM` for a PPM file, `IMAGE_YCbCr` for raw YCbCr data, and `IMAGE_JPEG` for a jpeg-compressed file.

The fifth parameter can be either `URBI_TRANSMIT_JPEG` or `URBI_TRANSMIT_YCbCr` and specifies how the image will be transmitted between the robot and the client. Transmitting JPEG images increases the frame rate and should be used for better performances.

Finally the width and height parameters are filled with the width and height of the image on return.

Getting sound

The method `syncGetSound` can be used to get a sound sample of any length from the server.

```
client->syncGetSound("micro", duration, sound);
```

The first parameter is the name of the device from which to request sound, the second is the duration requested, in milliseconds. Sound is a `USound` structure that will be filled with the recorded sound on output.

Chapter 5. Conversion functions

We also have included a few functions to convert between different image and sound formats. The usage of the image conversion functions is pretty straightforward:

```
int convertRGBtoYCrCb(const byte* source, int sourcelen, byte* dest);
int convertYCrCbtoRGB(const byte* source, int sourcelen, byte* dest);
int convertJPEGtoYCrCb(const byte* source, int sourcelen, byte* dest, int &size);
int convertJPEGtoRGB(const byte* source, int sourcelen, byte* dest, int &size);
```

The *size* parameter must be set to the size of the destination buffer. On return it will be set to the size of the output data.

To convert between different sound formats, the function `convert` can be used. It takes two `USound` structures as its parameters. The two audio formats currently supported are `SOUND_RAW` and `SOUND_WAV`, but support for compressed sound formats such as Ogg Vorbis and MP3 is planned.. If any field is set to zero in the destination structure, the corresponding value from the source sound will be used.

Chapter 6. Putting it all together: some examples

Have a look at the examples, in the "example" or "utils" directory of the liburbi distribution. It currently contains:

- **urbiimage**: Display the images taken by the camera in realtime, or save a snapshot to a file.
- **urbisound**: Play the sound from the robot's microphone on the computer speaker, or record it to a file.
- **urbisendsound**: Play a wav file from the computer, on the robot, converting it if necessary.
- **urbiping**: Send the URBI command 'ping' at regular intervals to measure latency.
- **urbibandwidth**: Measure the effective bandwidth.
- **urbisend**: Send a set of commands contained in a file to the robot.
- **urbirecord**: Record all the movements of the robot to a file.
- **urbiplay**: Play a file recorded with **urbirecord**, or dump it in a human-readable form.
- **urbimirror**: Copy the movements of a robot on an other robot. Same as piping urbirecord to urbiplay, but with less latency.
- **urbiscale**: Change the speed of a file recorded with **urbirecord**.
- **urbireverse**: Reverse a file recorded with **urbirecord**.
- **urbicycle**: Detects and extract cycles in a file recorded with **urbirecord**.
- **urbiballtrackinghead**: Port of the OPEN-R ballTrackingHead example to URBI.

Each program when invoked with no option will display its command line syntax and additional informations when appropriate.

Chapter 7. Programming hints

- Except if what you are doing is trivial, try not to use the sync* functions. They are less efficient than the asynchronous ones.
- The callback functions should return as fast as possible, since all callbacks are called by the same thread. If you have time-consuming operations, you should spawn an other thread and use synchronisation mechanisms such as semaphores or mutexes.

Chapter 8. Portability functions

When other versions of the `liburbi` will be available, (in particular an OPEN-R version that will allow programs to run on the robot), it will be possible to compile the same code for both libraries, if a few rules are respected:

- Do not use `USyncClient`.
- Use the `printf` method of `UClient` instead of the standard version.
- Use the `getCurrentTime` method of `UClient` instead of functions from the `stdlib`.
- Use the `urbi::exit` function (in the "urbi" namespace) instead of `exit`.
- At the end of your `main`, call `urbi::execute`.
- Do not use threads, or any function call not implemented in the OPEN-R version of `stdlib`.

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