FW4SPL Documentation

Release 13.0

IRCAD-IHU

Sep 05, 2018

Contents

CHAPTER 1

Introduction

1.1 Repositories

The fw4spl project is organized around three repositories :

- fw4spl: main repository, contains the core libraries and bundles.
- fw4spl-ar: extension of fw4spl, contains functionalities for augmented reality (video tracking)
- fw4spl-ogre: extension of fw4spl, contains a 3D backend using Ogre3D.

These repositories needs the associated dependencies repository.

- fw4spl-deps

Additionnaly, there is a fourth repository called fw4spl-ext for experimental functionalities and proofs of concept. Please note that on top of fw4spl-deps, it needs an extra deps repository to compile, called fw4spl-ext-deps.

1.2 fw4spl

This repository contains the core libraries and bundles. It is hosted on GitHub.

1.2.1 Features

- **Reader/Writer**
  - **DICOM reader/writer**
    - PACS connection
    - 3D mesh segmentation reader/writer
    - DICOM filter for reader
  - VTK (images and meshes)

  - ITK
  - Atoms (our custom in-out data format)
- **Visualisation**
  - 2D and 3D multi-planar reconstruction
  - volume rendering
  - 3D meshes

1.2.2 Application

VRRender is a medical image and segmentation viewer, containing all the previous features.

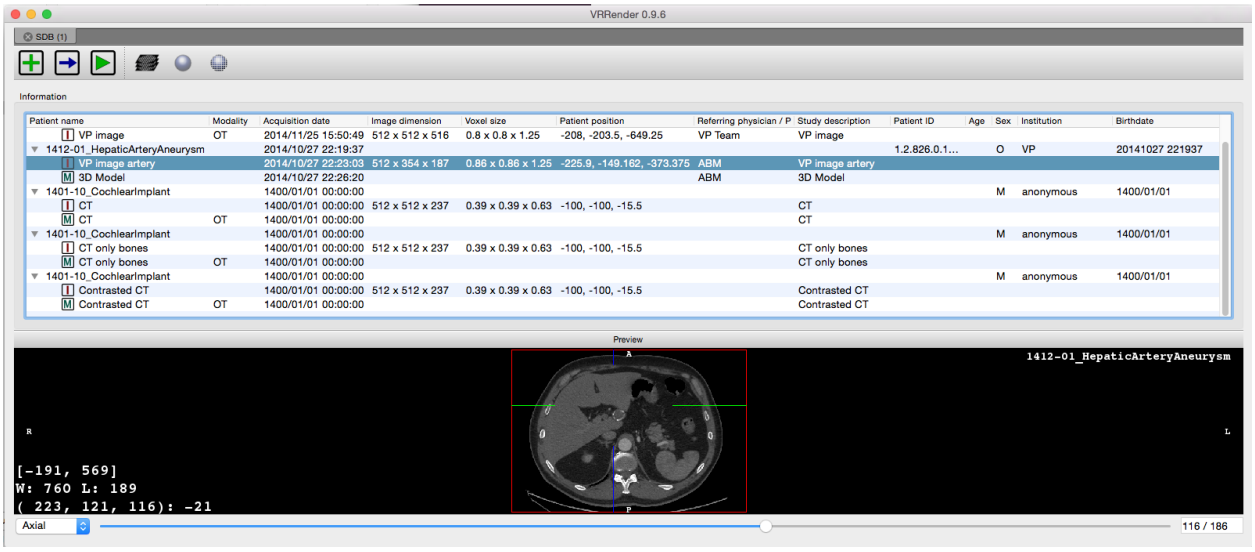


Fig. 1: Main VRRender view.

1.2.3 Tutorials

You can find some tutorials to explain fw4spl concept.

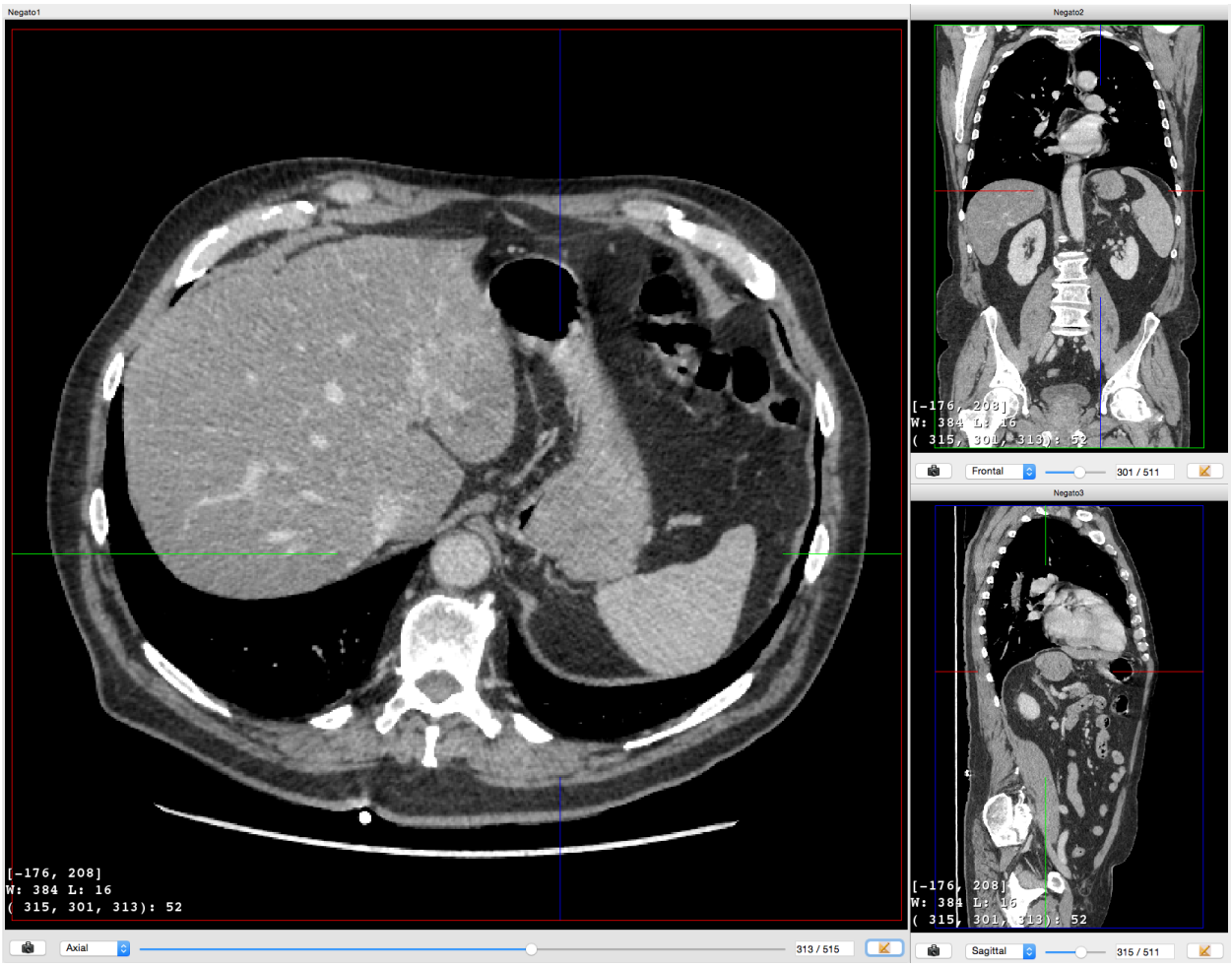


Fig. 2: MPR view of a medical 3D image.

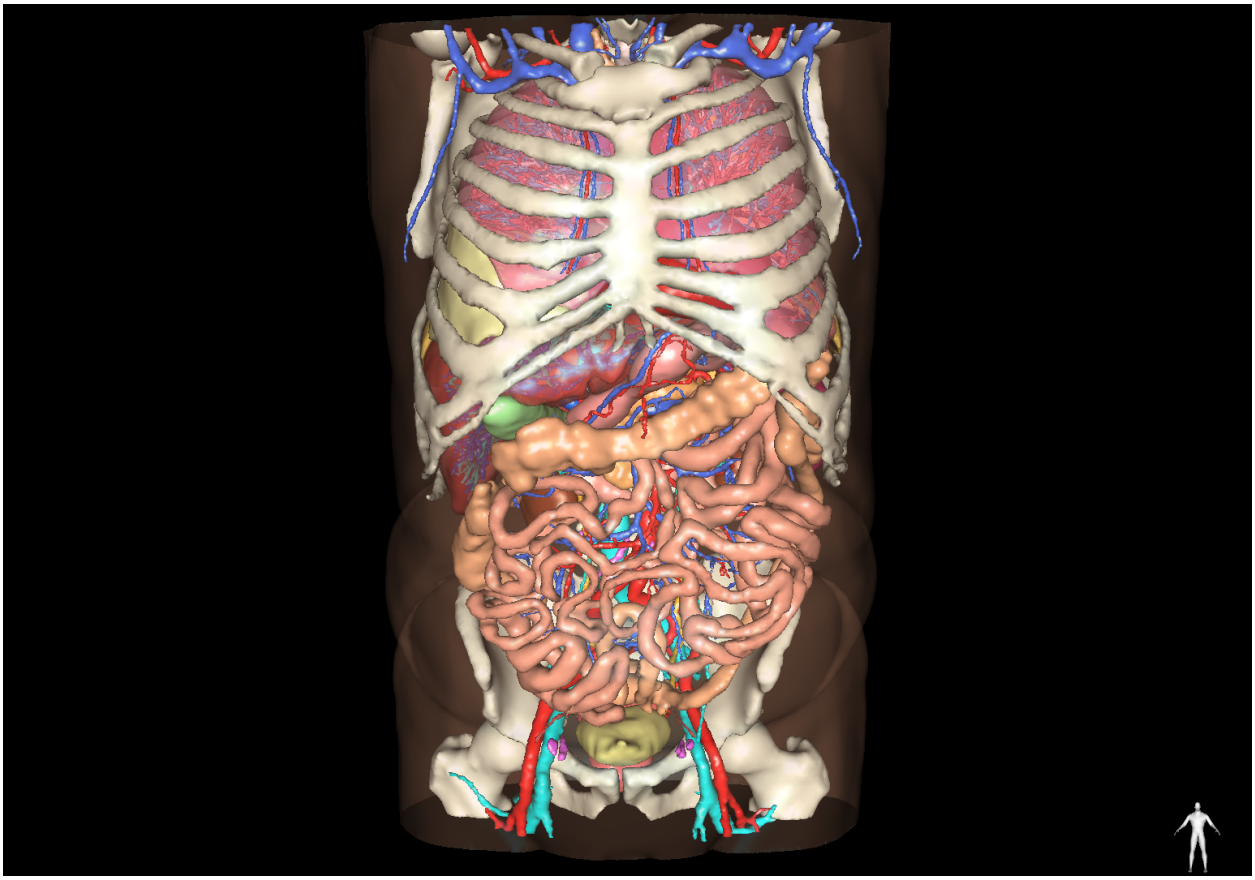


Fig. 3: 3D view of surfacic meshes.

Fig. 4: Volume rendering

Fig. 5: Volume rendering mixed with 3D surfacic meshes.

Name	Concept
Tuto01Basic	Basic application
Tuto02DataServiceBasic	Simple image reading and rendering
Tuto02DataServiceBasicCtrl	Simple image reading and rendering without XML configuration
Tuto03DataService	Image reading and rendering with signal communication
Tuto04SignalSlot	Scene point of view synchronisation with signal communication
Tuto05Mesher	Simple mesher from a 3D image
Tuto06Filter	Simple image filter
Tuto08GenericScene	Scene with multi-object rendering
Tuto09MesherWithGenericScene	Scene with multi-object rendering and simple mesher
Tuto10MatrixTransformInGS	Example of matrix transformation
Tuto11LaunchBasicConfig	Example to launch XML config in application
Tuto12Picker	Example of scene picker
Tuto13Scene2D	Example using the `scene2d` bundle
Tuto14MeshGenerator	Mesh features (point/cell color, normals, . . .)
Tuto15Multithread	Example of multi-threading using fw4spl worker
Tuto16MultithreadConsole	Second example of multi-threading using fw4spl worker without XML configuration
TutoGui	Example of fw4spl gui feature (toolbar, menu, action)
TutoTrianConverterCtrl	Utility converting .trian meshes to .vtk
TutoVectorField	Example of vector field

1.2.4 Examples

Name	Concept
Ex01VolumeRendering	Volume rendering using transfer function
Ex02ImageMix	Blend of two images
Ex03Registration	Simple rigid image-mesh registration
Ex04ImagesRegistration	Simple rigid image-image registration
Ex05Activities	Launch activities using a sequencer
Ex06Dump	Memory managment
Ex07WheelWidget	Wheel widget
Ex08SParameters	Parameters widget

1.3 fw4spl-ar

This repository contains functionalities for augmented reality. It is hosted on GitHub.

1.3.1 Features

This repository brings features for **Augmented Reality**:

- webcam, network video and local video playing based on QtMultimedia,
- mono and stereo camera calibration,
- ArUco optical markers tracking,
- openIGTLink support through clients and servers services,
- TimeLine data, allowing to store buffers of various data (video, matrices, markers, etc. . .). These can be used to synchronize these data accross time.

1.3.2 Applications

ARCalibration

ARCalibration is a user-friendly application to calibrate mono and stereo cameras. This software is a must-have since camera calibration is a mandatory step in any AR application.

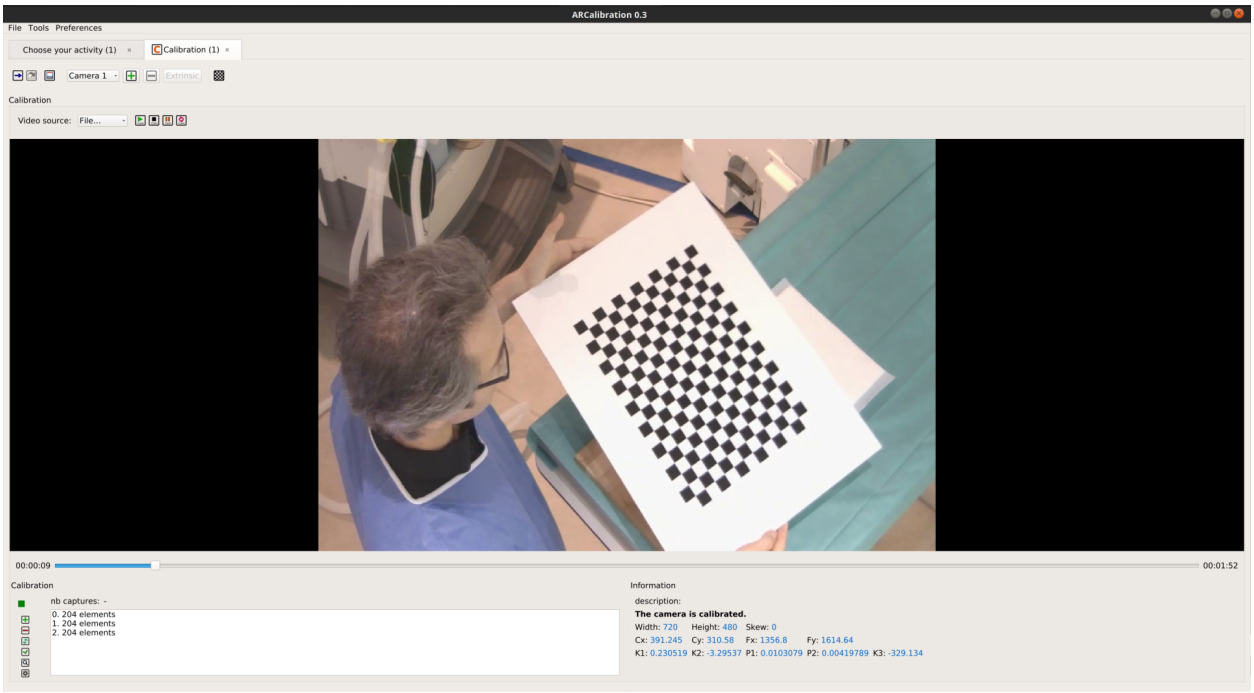


Fig. 6: Mono camera intrinsic calibration.

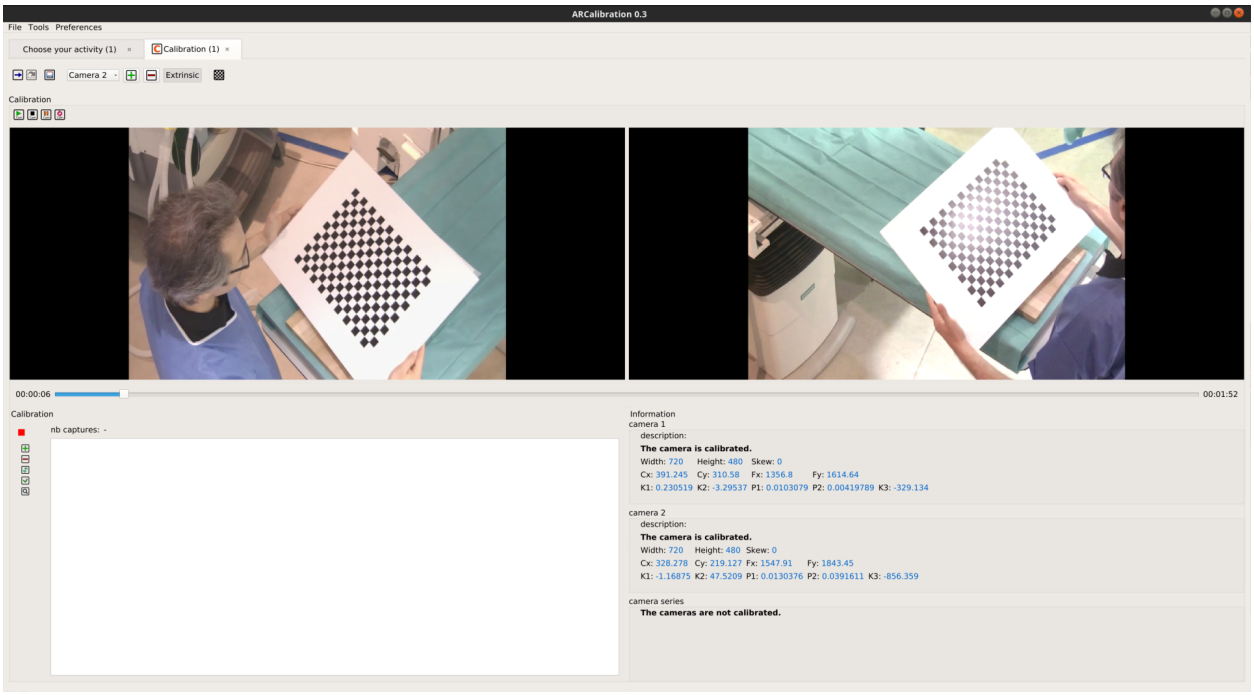


Fig. 7: Stereo camera extrinsic calibration.

Examples

Name	Concept
Ex01VideoTracking	Basic marker tracking on a video
Ex02TimeLine	Basic producer-consumer pattern sample with timeLine data
Ex03Igtl	Example of some of the *openIGTLink* features
Ex04SimpleARCV	AR using a given transform matrix to register a mesh on a camera view
Ex05FrameByFrame	Play a video frame by frame
Ex06RGBDStream	Play a RGBD stream (from a RGBD camera or recorded images)
Ex07RGBDManualAR	
ExSolvePnP	Register a mesh on a video using SolvePnp (with user interaction)
ExStereoARCV	Stereo AR using a given transform matrix to register a mesh on a camera view
ExVideoRecorder	Record a video

1.4 fw4spl-ogre

This repository brings a new 3D rendering backend using Ogre3D. It is hosted on GitHub.

1.4.1 Features

- regular surfacic meshes rendering for reconstruction,
- 2D and 3D negato medical image display with transfer function support,
- Order-independent transparency (several techniques implemented such as Depth-peeling, Weighted-blended order independent transparency, and Hybrid Transparency),
- customizable shaders and parameters edition.

1.4.2 Application

OgreViewer is a demonstration application to show the rendering features of the Ogre3D backend.

Examples

Name	Concept
TutoOgreGeneric-Scene	Simple rendering of image, mesh and texture
ExSimpleARCVOgre	AR using a given transform matrix to register a mesh on a camera view with Ogre rendering
ExOgreRGBDStream	
PoCStereo	

1.5 fw4spl-ext

This repository is dedicated to **experimental code**, that is not yet mature or is likely to change quickly. Only import this repository if you know what you are doing, since stability may not be guaranteed.

It is hosted on GitHub.

1.5.1 Features

- navigation along a spline
- new mesher using the CGoGN library
- ...

1.5.2 Application

VRRenderExt is an application containing the **VRRender** features and also the additional fw4spl-ext features.

1.5.3 Proofs of concept

Name	Concept
PoCMeshManualRegistration	
PoCRegistration	
PoC06Scene2DTF	Simple use of `scene2d` bundle
Training	

CHAPTER 2

Installation

2.1 Installation for Windows

2.1.1 Prerequisites

If not already installed:

1. Install git
2. Optionally you can install GitKraken to manage your repositories
3. Install Visual Studio 2015 Community Be sure to launch it at least once while being logged with your user account. Doing so will ensure that Visual Studio is correctly registered, because otherwise, the build of some dependencies may fail.
4. Install Python 2.7
5. Install CMake
6. Install jom
7. Install ninja

Qt is an external library used in FW4SPL. For the successful compilation of Qt for FW4SPL, please see the following requirements:

- http://wiki.qt.io/Building_Qt_5_from_Git

Source tree layout

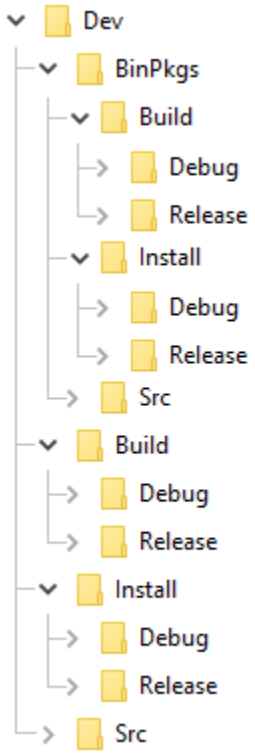
Good practices in FW4SPL recommend to separate source files, build and install folders. So to prepare the development environment:

- Create a development folder (Dev)
- Create a build folder (Dev\Build)

    - Add a sub folder for Debug and Release.
- Create a source folder (Dev\Src)
- Create a install folder (Dev\Install)
    - Add a sub folder for Debug and Release.

To prepare the third party environment:

- Create a third party folder (BinPkgs)
- Create a build folder (BinPkgs\Build)
    - Add a sub folder for Debug and Release.
- Create a source folder (BinPkgs\Src)
- Create an install folder (BinPkgs\Install)
    - Add a sub folder for Debug and Release.



Of course you can name the folders as you wish, or choose a different layout, but keep in mind to not build inside the source directory. This is strongly discouraged by *CMake* authors.

Set the environment for a x64 version. To compile BinPkgs and sources, you must use the 'VS2015 x64 Native Tools Command Prompt'

2.1.2 Dependencies

First, we need first to build the third-party librairies. We will now fetch the scripts that allow to build them and then launch the compilation.

- Clone the following repository in the (BinPkgs/Src) source folder:

  - fw4spl-deps

```
> cd Dev/BinPkgs/Src
> git clone https://github.com/fw4spl-org/fw4spl-deps.git
```

Note: *Optional*: You may also clone extension repositories like fw4spl-ext-deps. Additional dependency repositories must be cloned in the same directory as **fw4spl-deps** and they will be automatically discovered and then can be enabled via CMake.

- Check if all the cloned repositories are on the same branch.
- Update the cloned repositories to the lastest stable tag.

Warning: Be sure to be in the 'VS2015 x64 Native Tools Command Prompt'

Note: Make sure that CMake executable (cmake.exe and cmake-gui.exe) location is present in your PATH environment variable.

- SET PATH=%PATH%;D:\Tools\CMake\bin

Note: Make sure that JOM executable (jom.exe) location is present in your PATH environment variable.

- SET PATH=%PATH%;D:\Tools\jom

- Go into your Build directory (Debug or Release) : here is an example if you want to compile in DEBUG

```
> cd Dev\BinPkgs\Build\Debug
```

- Call cmake-gui by executing command : cmake-gui

```
> cmake-gui
```

Configuration

Note: All the generation options are specified in 'Dependencies generation'

- Set the desired Build directory (e.g. Dev\BinPkgs\Build\Debug or Release)
- Set the desired Source directory (e.g. Dev\BinPkgs\Src\fw4spl-deps)
- Click on "configure".
- During Configure, choose the generator 'NMake Makefiles JOM'.
- Set the following arguments:
  - `CMAKE_INSTALL_PREFIX`: set the install location (e.g. Dev\BinPkgs\Install\Debug or Release).
  - `CMAKE_BUILD_TYPE`: set to Debug or Release.
  - `BUILD_FW4SPL-EXT-DEPS`: allows to enable/disable the **fw4spl-ext-deps** if you cloned it.

- Click on "configure".

Generation

Set the following options (some of the options will be needed for the optional source repositories):

- `ENABLE_AR`: Build **fw4spl-ar** dependencies (OpenCV, PCL, OpenIGTLink...).
- `ENABLE_OGRE`: Build Ogre3D and its dependencies (necessary for **fw4spl-ogre**).
- `ENABLE_CUDA`: Enable CUDA support in some libraries (OpenCV, PCL, libSGM). This requires Cuda library to be installed on the system and present in your PATH.
- `ENABLE_SOFA`: Build sofa.
- `ENABLE_EXTRAS` : Build dependencies that are not used currently in the open-source repositories (Odil, Bullet, realsense, libSGM,...).
- `ENABLE_EXPERIMENTAL_DEPS`: Build experimental libraries (you shouldn't use it, moreover this option is only available with **fw4spl-ext-deps**).
- click on "generate".

Build

- Compile the FW4SPL dependencies using jom in the console:
  - go to the build directory (e.g. Dev\BinPkgs\Build\Debug or Release)
  - Use "jom all" to compile all the dependencies
  - Use "jom name_of_target" to compile only the desired target

```
> cd Dev\\BinPkgs\\Build\\Debug
> jom install
```

- All the generated libraries are in the install directory (e.g. Dev/BinPkgs/Install/Debug or Release)

Note: To prevent any future problems with source generation, ensure that all the libraries have been compiled

---

2.1.3 Source

- **Clone the following repositories in the (DevSrc) source folder:**
  - fw4spl

```
> cd Dev\Src
> git clone https://github.com/fw4spl-org/fw4spl.git
```

Note:

- ***Optional*: You can also clone these extension repositories:**
  - fw4spl-ar contains functionalities for augmented reality (video tracking for instance).
  - fw4spl-ext contains experimental code.

  - fw4spl-ogre contains a 3D backend using Ogre3D.

- Ensure that all the cloned repositories are in the same folder as **fw4spl**. They will be automatically discovered and then can be enabled via CMake.
- Ensure that all the cloned repositories are on the same branch.
- Update the cloned repositories to the same tag.
- Go into your Build directory (Debug or Release) : here is an example if you want to compile in debug:

```
$ cd Dev/Build/Debug
```

Warning: Be sure to be in the 'VS2015 x64 Native Tools Command Prompt'

Note: Make sure that CMake executable (cmake.exe and cmake-gui.exe)location is present in your PATH environment variable.

- SET PATH=%PATH%;D:\Tools\CMake\bin

Note: Make sure that Ninja executable (ninja.exe) location is present in your PATH environment variable.

- SET PATH=%PATH%;D:\Tools\ninja

- Call the cmake-gui.

```
> cmake-gui
```

Configuration

- Set the desired Build directory (e.g. Dev\Build\Debug or Release)
- Set the desired Source directory (e.g. Dev\Src\fw4spl)
- Click on "configure".
- During configure step, choose the generator 'Ninja' to compile FW4SPL sources.

Generation

- Set the following arguments:
  - `ADDITIONAL_PROJECTS`: set the source location of fw4spl-ar, fw4spl-ext and fw4spl-ogre, separated by ";".
  - `CMAKE_INSTALL_PREFIX`: set the install location (e.g. Dev\Install\Debug).
  - `CMAKE_BUILD_TYPE`: set to Debug or Release.
  - `EXTERNAL_LIBRARIES`: set the install path of the dependencies install directory (e.g. Dev\BinPkgs\Install\Debug or Release).
  - `PROJECTS_TO_BUILD`: set the names of the applications to build (see DevSrcApps or DevSrcSamples, ex: VRRender, Tuto01Basic ...), each project should be separated by ";".

  - ECLIPSE_PROJECT: check this box if you want to generate an Eclipse project.
- **If you want to generate installers:**
  - PROJECTS_TO_INSTALL: set the names of the applications you want to install (i.e. VRRender).

Note:

- If PROJECTS_TO_BUILD is empty, all application will be compiled
- If PROJECTS_TO_INSTALL is empty, no application will be installed

---

> **Warning:** Make sure the arguments concerning the compiler (advanced arguments) point to Visual Studio.

- click on "generate".

Build

- Compile the FW4SPL source using ninja in the console:
  - go to the build directory (e.g. Dev\Build\Debug or Release)
  - Use "ninja" if you want to compile all the applications set in CMake.
  - Use "ninja name_of_application" to compile only one of the applications set in CMake.

```
> cd Dev\Build\Debug
> ninja
```

2.1.4 Launch an application

After a successful compilation the application can be launched with the fwlauncher.exe from FW4SPL. Therefore the profile.xml of the application in the build folder has to be passed as argument.

Note: Make sure that the external libraries directory is set to the path (set PATH=<FW4SPL Binpkgs path>\Debug\bin;<FW4SPL Binpkgs path>\Debug\x64\vc12\bin;%PATH%).

```
> cd Dev\Build\Debug
> .\bin\fwlauncher.exe share\MyApplication\profile.xml
```

2.1.5 Generate an installer

After setting the applications for which you want to generate installers in the PROJECTS_TO_INSTALL CMake variable and generating the code, follow these two steps:

- Run *ninja install application_to_install* in the Build directory
- Run *ninja package* in the Build directory

The installer will be generated in the Build directory.

2.1.6 Recommended software

The following programs may be helpful for your developments:

- Eclipse CDT: Eclipse is a multi-OS Integrated Development Environment (IDE) for computer programming.
- Notepad++: Notepad++ is a free source code editor, which is designed with syntax highlighting functionality.
- ConsoleZ: ConsoleZ is an alternative command prompt for Windows, adding more capabilities to the default Windows command prompt. To compile FW4SPL with the console the windows command prompt has to be set in the tab settings.

2.2 Installation for Linux

2.2.1 Prerequisites

If not already installed:

1. Install git
2. Install gcc The minimal version required is 4.8 or clang The minimal version required is 3.5
3. Install Python 2.7
4. Install CMake. The minimal version required is **3.7** if you want to compile with precompiled headers (build twice faster, enabled by default). Otherwise you can use a 3.1 version.
5. Install Ninja

Depending on which linux distribution you use, for example on **Debian/Ubuntu/Mint** you can run the following command to download and install these tools:

```
$ apt-get install build-essential ninja-build python2.7 git cmake
```

Warning: If the **CMake** version of your distribution is not sufficient (Mint 17 for instance ships only the 2.18 version), you can easily grab it on the Kitware website. Download the **binary** version (much easier than compiling yourself), extract it to a folder (i.e. /home/login/software/cmake/) and add the `bin/` folder inside it to your `PATH` environment variable:

```
# ~/.bashrc
export PATH=/home/login/software/cmake/bin:$PATH
```

Few basic development libraries need to be installed first: `zlib`, `iconv`, `jpeg`, `png`, `tiff`, `freetype`, `libxml`, `expat`, and `icu`. On **Mint 18.x** for instance, you can install them using the following command :

```
$ sudo apt-get install libz3-dev libiconv-hook-dev libpng12-dev \
  libjpeg-turbo8-dev libtiff5-dev libfreetype6-dev libxml2-dev \
  libexpat1-dev libicu-dev
```

Next, we also need to install specific development libraries for **Qt**. These requirements are detailed here:

- http://wiki.qt.io/Building_Qt_5_from_Git

Follow the instructions there to install the necessary packages on your system for **Build essentials**, **libxcb** and **QtMultimedia**. For the latter, please note that we use **gstreamer-1.0** by default, so please replace `libgstreamer0.10-dev` and `libgstreamer-plugins-base0.10-dev` by `libgstreamer1.0-dev` and `libgstreamer-plugins-base1.0-dev`. You can safely ignore instructions for QtWebKit and

QtWebEngine, we don't build them. Since we build Qt with openssl support you also need to install `libssl-dev` (be sure that the version is equal or upper to 1.0.0). `libudev-dev` and `libusb-1.0.0-dev` are required by the OpenNI library. Last for VTK we also need the X Toolkit Intrinsics library headers, that you can easily install for instance on a Debian-based distribution with the packages `libxt-dev`, `libxrandr-dev` and `libxaw7-dev`.

If you plan to build extra dependencies, the VLC libraries are also needed, regarding to streaming capabilities, and thus the packages: `libvlc-dev`, `libvlccore-dev` and `vlc-nox`, are required.

Finally, please note that we provide Dockerfile at this link. You can have a look at the Dockerfile to get the precise list of commands needed to install dependencies.

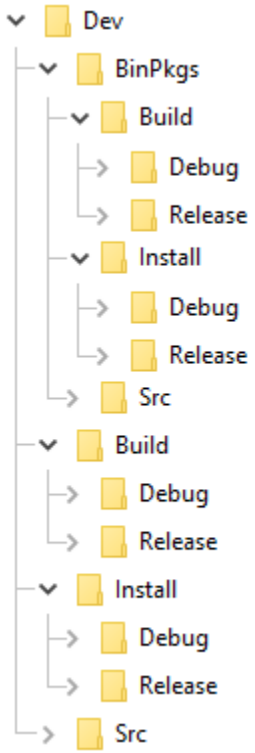
Source tree layout

Good practices in FW4SPL recommend to separate source files, build and install folders. So to prepare the development environment, we propose to follow this layout:

- Create a development folder (Dev)
- Create a build folder (Dev/Build)
  - Add a sub folder for Debug and Release.
- Create a source folder (Dev/Src)
- Create an install folder (Dev/Install)
  - Add a sub folder for Debug and Release.

To prepare the third party environment:

- Create a third party folder (BinPkgs)
- Create a build folder (BinPkgs/Build)
  - Add a sub folder for Debug and Release.
- Create a source folder (BinPkgs/Src)
- Create an install folder (BinPkgs/Install)
  - Add a sub folder for Debug and Release.



Of course you can name the folders as you wish, or choose a different layout, but keep in mind to not build inside the source directory. This is strongly discouraged by *CMake* authors.

2.2.2 Dependencies

First, we need to build the third-party libraries. We will now fetch the scripts that allow to build them and then launch the compilation.

- Clone the following repository in the (BinPkgs/Src) source folder:
  - fw4spl-deps

```
$ cd Dev/BinPkgs/Src
$ git clone https://github.com/fw4spl-org/fw4spl-deps.git
```

Note: *Optional*: You may also clone extension repositories like fw4spl-ext-deps. Additional dependency repositories must be cloned in the same directory as **fw4spl-deps** and they will be automatically discovered and then can be enabled via CMake.

- Ensure that all the cloned repositories are on the same branch.
- Update the cloned repositories to the lastest stable tag.
- Go into your Build directory (Debug or Release) : here is an example if you want to compile in DEBUG

```
$ cd Dev/BinPkgs/Build/Debug
```

Configuration

To build the dependencies, you must configure the project with CMake into the Build folder. As any CMake based project, there are three different ways to perform that.

1. Command-line

In this case, you give all the necessary variables on the command-line in one shot :

```
$ cd Dev/BinPkgs/Build/Debug
$ cmake ../../Src/fw4spl-deps -DCMAKE_INSTALL_PREFIX=Dev/BinPkgs/Install/Debug -
↪DCMAKE_BUILD_TYPE=Debug
```

2. NCurses based editor

This editor allows to set the required each variable in a more interactive way :

```
$ cd Dev/BinPkgs/Build/Debug
$ ccmake ../../Src/fw4spl-deps
```

Then change the following CMake variables:

- `CMAKE_INSTALL_PREFIX`: set the install location, here `Deps/BinPkgs/Install/Debug`
- `CMAKE_BUILD_TYPE`: set the build type 'Debug' or 'Release'
- `ENABLE_SSE_SUPPORT`: enable SSE support. We need that to ensure coherency of the SSE support accross all dependencies. This option will also be forwarded to FW4SPL when building it.
- `BUILD_FW4SPL-EXT-DEPS`: allows to enable/disable the **fw4spl-ext-deps** if you cloned it.

Press *"c"* to configure.

The following options are also available (some of the options will be needed for the optional source repositories):

- ENABLE_AR: Build **fw4spl-ar** dependencies (OpenCV, PCL, OpenIGTLink...).
- ENABLE_OGRE: Build Ogre3D and its dependencies (necessary for **fw4spl-ogre**).
- ENABLE_CUDA: Enable CUDA support in some libraries (OpenCV, PCL, libSGM). This requires Cuda library to be installed on the system.
- ENABLE_SOFA: Build sofa.
- ENABLE_EXTRAS : Build dependencies that are not used currently in the open-source repositories (Odil, Bullet, realsense, libSGM,...).
- ENABLE_EXPERIMENTAL_DEPS: Build experimental libraries (you shouldn't use it, moreover this option is only available with **fw4spl-ext-deps**).

When you're done, generate the code by pressing *"g"* on NCurses based editor or click on "generate" on gui.

Warning: Do not compile debug and release with the same Build and Install folders. If you followed the recommended folder layout, this should be fine.

3. Qt based gui

```
$ cd ~/Dev/BinPkgs/Build/Debug
$ cmake-gui ../../Src/fw4spl-deps
```

You can then edit the same options than with ccmake.

Build

Now you can compile the FW4SPL dependencies with make in the console, it will automatically download, build and install each dependency.

```
$ cd Dev\BinPkgs\Build\Debug
# Adjust the number of cores depending of the CPU cores and the RAM available on your␣
↪computer
$ make -j4 install
```

Warning: Do NOT use ninja to compile the dependencies, it causes conflict with qt compilation.

If you get compilation errors at this step, please ensure you installed all the requirements, especially those for Qt.

2.2.3 Source

- **Clone the following repositories in the (Dev/Src) source folder:**
  - fw4spl

```
$ cd Dev/Src
$ git clone https://github.com/fw4spl-org/fw4spl.git
```

Note:

- ***Optional*: You can also clone these extension repositories:**
  - fw4spl-ar contains functionalities for augmented reality (video tracking for instance).
  - fw4spl-ext contains experimental code.
  - fw4spl-ogre contains a 3D backend using Ogre3D.

- Ensure that all the cloned repositories are in the same folder as **fw4spl**. They will be automatically discovered and then can be enabled via CMake.
- Ensure that all the cloned repositories are on the same branch.
- Update the cloned repositories to the same tag.
- Go into your Build directory (Debug or Release) : here is an example if you want to compile in debug:

```
$ cd Dev/Build/Debug
```

Now you have to configure the project. You can use one of the three tools explained above.

Also, for FW4SPL, we recommend to use the Ninja generator. It builds faster, and is much better for everyday use because of how fast it is at figuring out which files need to be built. In other words, with Ninja the compilation starts instantly whereas Make spends a dozen of seconds to check what should be compiled before actually compiling something. So if you plan to develop with FW4SPL, go with Ninja. If you only want to give a single try, you can live with the standard "Unix Makefiles" generator.

Configuration

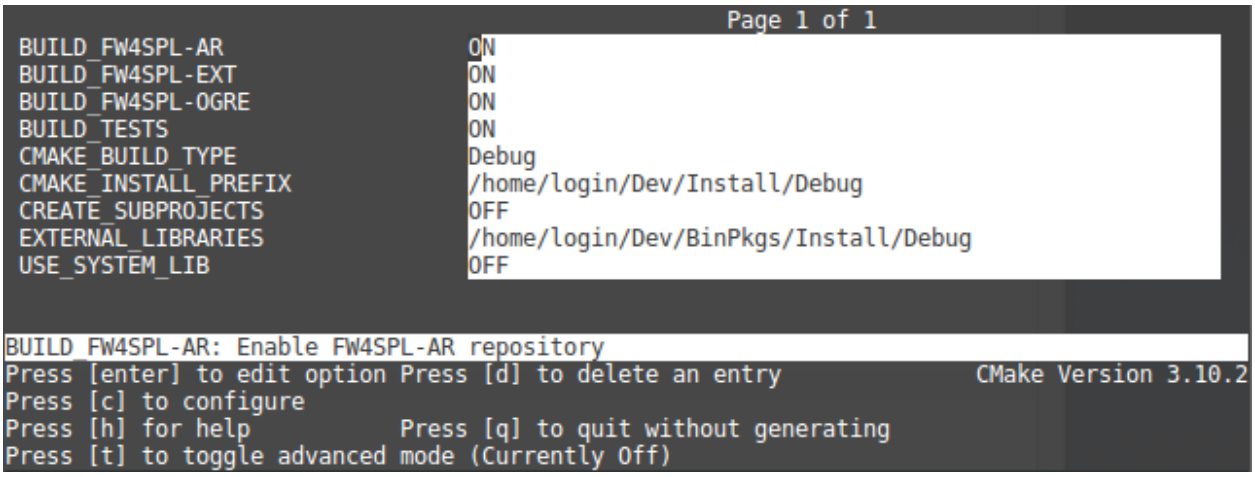
1. NCurses based editor

To use make, here with `ccmake` :

```
$ cd Dev/Build/Debug
$ ccmake ../../Src/fw4spl
```

To use ninja :

```
$ cd Dev/Build/Debug
$ ccmake -G Ninja ../../Src/fw4spl
```



- **Change the following cmake arguments**

  - BUILD_FW4SPL-AR: allow to enable/disable the **fw4spl-ar** repository if you cloned it.
  - BUILD_FW4SPL-EXT: allow to enable/disable the **fw4spl-ext** repository if you cloned it.
  - BUILD_FW4SPL-OGRE: allow to enable/disable the **fw4spl-ogre** repository if you cloned it.
  - CMAKE_INSTALL_PREFIX: set the install location, here ~/Dev/Install/Debug
  - CMAKE_BUILD_TYPE: set the build type 'Debug', 'Release', 'RelWithDebInfo' or 'MinSizeRel'
  - EXTERNAL_LIBRARIES: set the install path of the third party libraries you compiled earlier.(ex : ~/Dev/Install/Debug)
  - PROJECTS_TO_BUILD: set the list of the projects you want to build (ex: VRRender, Tuto01Basic ...), each project should be separated by ";"
  - PROJECTS_TO_INSTALL: set the name of the application to install
- Press *"c"* to configure and then *"g"* to generate the makefiles.

Note:

- If PROJECTS_TO_BUILD is empty, all application will be compiled
- If PROJECTS_TO_INSTALL is empty, no application will be installed

---

Click on "generate".

Note: To generate the projects in release mode, change CMake argument CMAKE_BUILD_TYPE to Release **both** for fw4spl and fw4spl-deps

---

2. Qt based gui

```
$ cd Dev/Build/Debug
$ cmake-gui ../../Src/fw4spl
```

You can then edit the same options than with ccmake.

Build

Then, according to the generator you chose, build FW4SPL with make :

```
$ cd Dev/Build/Debug
# Adjust the number of cores depending of the CPU cores and the RAM available on your␣
↪computer
$ make -j4
```

Or with ninja:

```
$ cd Dev/Build/Debug
$ ninja
```

If you didn't specify anything in PROJECTS_TO_BUILD you may also build specific targets, for instance:

```
$ ninja Tuto01Basic VRRender
```

2.2.4 Launch an application

After a successful compilation the application can be launched with the *fwlauncher* program from FW4SPL. The profile.xml of the application in the build folder has to be passed as argument to the *fwlauncher* call in the console.

```
> cd Dev/Build/Debug
> ./bin/fwlauncher share/MyApplication/profile.xml
```

Example:

```
$ cd /Dev/Build/Debug
$ ./bin/fwlauncher share/VRRender_0-9/profile.xml
```

2.2.5 Recommended software

The following programs may be helpful for your developments:

- Eclipse CDT
- QtCreator

2.3 Installation for MacOSX

2.3.1 Prerequisites

If not already installed:

1. Install Xcode
2. Install git
3. Install CMake. The minimal version required is **3.7** if you want to compile with precompiled headers (build twice faster, enabled by default). Otherwise you can use a 3.1 version.
4. Install Ninja : to use instead of **make**.

For an easy install, you can use the Hombrew project to install missing packages.

```
$ brew install git
$ brew install cmake
$ brew install ninja
```

For Openni dependency, you need libusb

```
$ brew install libusb-compat
```

If you plan to build extra dependencies, the VLC application is also needed.

```
$ brew cask install vlc
```

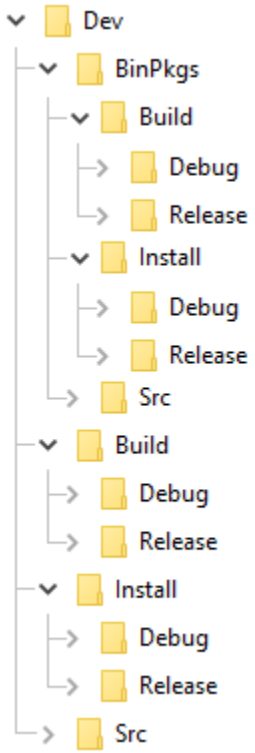
Source tree layout

Good practices in FW4SPL recommend to separate source files, build and install folders. So to prepare the development environment, we propose to follow this layout:

- Create a development folder (Dev)
- Create a build folder (Dev/Build)
  - Add a sub folder for Debug and Release.
- Create a source folder (Dev/Src)
- Create an install folder (Dev/Install)
  - Add a sub folder for Debug and Release.

To prepare the third party environment:

- Create a third party folder (BinPkgs)
- Create a build folder (BinPkgs/Build)
  - Add a sub folder for Debug and Release.
- Create a source folder (BinPkgs/Src)
- Create an install folder (BinPkgs/Install)
  - Add a sub folder for Debug and Release.



Of course you can name the folders as you wish, or choose a different layout, but keep in mind to not build inside the source directory. This is strongly discouraged by *CMake* authors.

2.3.2 Dependencies

First, we need to build the third-party libraries. We will now fetch the scripts that allow to build them and then launch the compilation.

- Clone the following repository in the (BinPkgs/Src) source folder:

  - fw4spl-deps

```
$ cd Dev/BinPkgs/Src
$ git clone https://github.com/fw4spl-org/fw4spl-deps.git
```

Note: *Optional*: You may also clone extension repositories like fw4spl-ext-deps. Additional dependency repositories must be cloned in the same directory as **fw4spl-deps** and they will be automatically discovered and then can be enabled via CMake.

- Ensure that all the cloned repositories are on the same branch.
- Update the cloned repositories to the lastest stable tag.
- Go into your Build directory (Debug or Release) : here is an example if you want to compile in DEBUG

```
$ cd Dev/BinPkgs/Build/Debug
```

Configuration

To build the dependencies, you must configure the project with CMake into the Build folder. As any CMake based project, there are three different ways to perform that.

1. Command-line

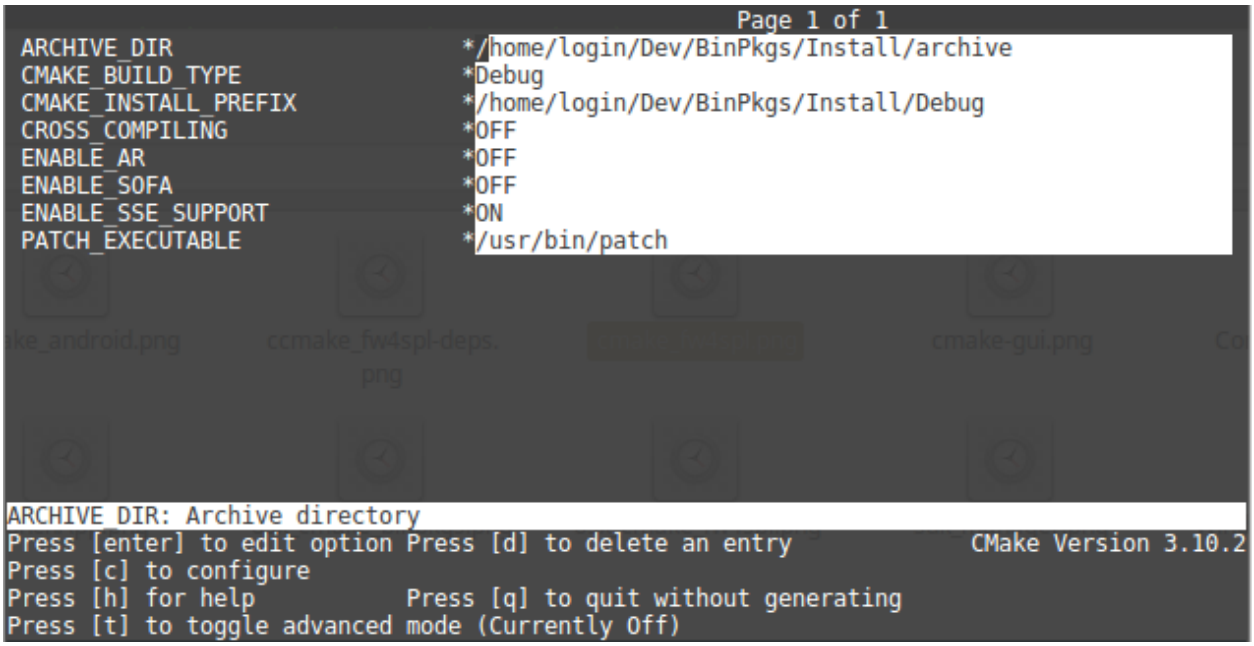
In this case, you give all the necessary variables on the command-line in one shot :

```
$ cd Dev/BinPkgs/Build/Debug
$ cmake ../../Src/fw4spl-deps -DCMAKE_INSTALL_PREFIX=Dev/BinPkgs/Install/Debug -
↪DCMAKE_BUILD_TYPE=Debug
```

2. NCurses based editor

This editor allows to set the required each variable in a more interactive way :

```
$ cd Dev/BinPkgs/Build/Debug
$ ccmake ../../Src/fw4spl-deps
```



Then change the following CMake variables:

- `CMAKE_INSTALL_PREFIX`: set the install location, here `Deps/BinPkgs/Install/Debug`
- `CMAKE_BUILD_TYPE`: set the build type 'Debug' or 'Release'
- `ENABLE_SSE_SUPPORT`: enable SSE support. We need that to ensure coherency of the SSE support accross all dependencies. This option will also be forwarded to FW4SPL when building it.
- `BUILD_FW4SPL-EXT-DEPS`: allows to enable/disable the **fw4spl-ext-deps** if you cloned it.

Press *"c"* to configure.

The following options are also available (some of the options will be needed for the optional source repositories):

- `ENABLE_AR`: Build **fw4spl-ar** dependencies (OpenCV, PCL, OpenIGTLink...).
- `ENABLE_OGRE`: Build Ogre3D and its dependencies (necessary for **fw4spl-ogre**).
- `ENABLE_CUDA`: Enable CUDA support in some libraries (OpenCV, PCL, libSGM). This requires Cuda library to be installed on the system.
- `ENABLE_SOFA`: Build sofa.
- `ENABLE_EXTRAS` : Build dependencies that are not used currently in the open-source repositories (Odil, Bullet, realsense, libSGM,...).
- `ENABLE_EXPERIMENTAL_DEPS`: Build experimental libraries (you shouldn't use it, moreover this option is only available with **fw4spl-ext-deps**).

When you're done, generate the code by pressing *"g"* on NCurses based editor or click on "generate" on gui.

> **Warning:** Do not compile debug and release with the same Build and Install folders. If you followed the recommended folder layout, this should be fine.

3. Qt based gui

```
$ cd ~/Dev/BinPkgs/Build/Debug
$ cmake-gui ../../Src/fw4spl-deps
```

You can then edit the same options than with `ccmake`.

Build

Now you can compile the FW4SPL dependencies with make in the console, it will automaticaly download, build and install each dependency.

```
$ make install
$ make install_tool
```

Warning: Do NOT use ninja to compile the dependencies, it causes conflict with qt compilation.

If you get compilation errors at this step, please ensure you installed all the requirements, especially those for Qt.

2.3.3 Source

- **Clone the following repositories in the (Dev/Src) source folder:**
  - fw4spl

```
$ cd Dev/Src
$ git clone https://github.com/fw4spl-org/fw4spl.git
```

Note:

- ***Optional*: You can also clone these extension repositories:**
  - fw4spl-ar contains functionalities for augmented reality (video tracking for instance).
  - fw4spl-ext contains experimental code.
  - fw4spl-ogre contains a 3D backend using Ogre3D.

- Ensure that all the cloned repositories are in the same folder as **fw4spl**. They will be automatically discovered and then can be enabled via CMake.
- Ensure that all the cloned repositories are on the same branch.
- Update the cloned repositories to the same tag.
- Go into your Build directory (Debug or Release) : here is an example if you want to compile in debug:

```
$ cd Dev/Build/Debug
```

Now you have to configure the project. You can use one of the three tools explained above.

Also, for FW4SPL, we recommend to use the Ninja generator. It builds faster, and is much better for everyday use because of how fast it is at figuring out which files need to be built. In other words, with Ninja the compilation starts instantly whereas Make spends a dozen of seconds to check what should be compiled before actually compiling

something. So if you plan to develop with FW4SPL, go with Ninja. If you only want to give a single try, you can live with the standard "Unix Makefiles" generator.

Configuration

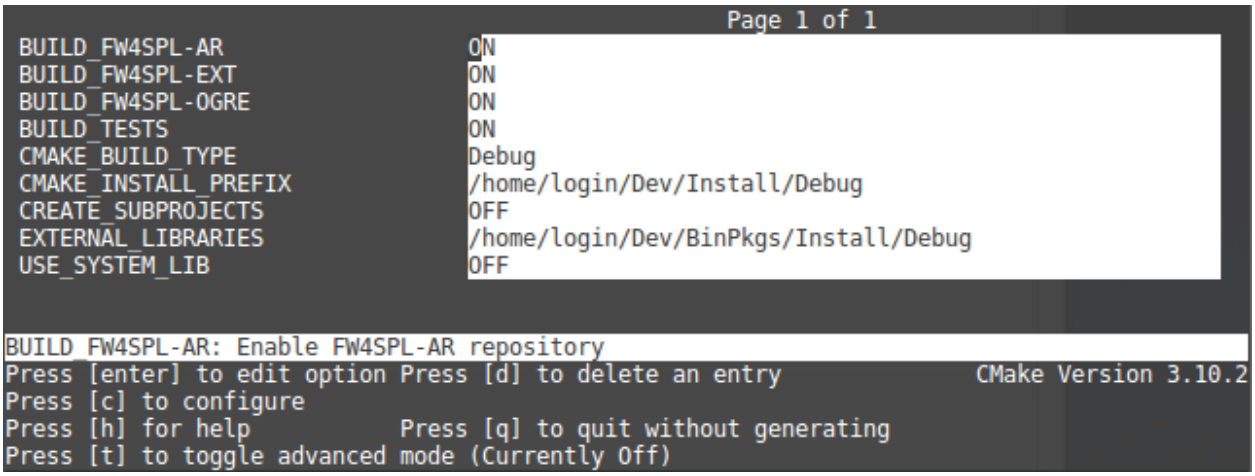
1. NCurses based editor

To use make, here with `ccmake` :

```
$ cd Dev/Build/Debug
$ ccmake ../../Src/fw4spl
```

To use ninja :

```
$ cd Dev/Build/Debug
$ ccmake -G Ninja ../../Src/fw4spl
```



- **Change the following cmake arguments**
  - `BUILD_FW4SPL-AR`: allow to enable/disable the **fw4spl-ar** repository if you cloned it.
  - `BUILD_FW4SPL-EXT`: allow to enable/disable the **fw4spl-ext** repository if you cloned it.
  - `BUILD_FW4SPL-OGRE`: allow to enable/disable the **fw4spl-ogre** repository if you cloned it.
  - `CMAKE_INSTALL_PREFIX`: set the install location, here `~/Dev/Install/Debug`
  - `CMAKE_BUILD_TYPE`: set the build type 'Debug', 'Release', 'RelWithDebInfo' or 'MinSizeRel'
  - `EXTERNAL_LIBRARIES`: set the install path of the third party libraries you compiled earlier.(ex : ~/Dev/Install/Debug)
  - `PROJECTS_TO_BUILD`: set the list of the projects you want to build (ex: VRRender, Tuto01Basic ...), each project should be separated by ";"
  - `PROJECTS_TO_INSTALL`: set the name of the application to install
- Press *"c"* to configure and then *"g"* to generate the makefiles.

Note:

- If `PROJECTS_TO_BUILD` is empty, all application will be compiled

- If PROJECTS_TO_INSTALL is empty, no application will be installed

Click on "generate".

Note: To generate the projects in release mode, change CMake argument CMAKE_BUILD_TYPE to Release **both** for fw4spl and fw4spl-deps

2. Qt based gui

```
$ cd Dev/Build/Debug
$ cmake-gui ../../Src/fw4spl
```

You can then edit the same options than with ccmake.

Build

Then, according to the generator you chose, build FW4SPL with make :

```
$ cd Dev/Build/Debug
# Adjust the number of cores depending of the CPU cores and the RAM available on your␣
↪computer
$ make -j4
```

Or with ninja:

```
$ cd Dev/Build/Debug
$ ninja
```

If you didn't specify anything in PROJECTS_TO_BUILD you may also build specific targets, for instance:

```
$ ninja Tuto01Basic VRRender
```

2.3.4 Launch an application

After a successful compilation the application can be launched with the *fwlauncher* program from FW4SPL. The profile.xml of the application in the build folder has to be passed as argument to the *fwlauncher* call in the console.

```
> cd Dev/Build/Debug
> ./bin/fwlauncher share/MyApplication/profile.xml
```

Example:

```
$ cd /Dev/Build/Debug
$ ./bin/fwlauncher share/VRRender_0-9/profile.xml
```

2.3.5 Recommended software

The following programs may be helpful for your developments:

- **IDE:**

  - Qt creator
  - Eclipse CDT.
- **Versioning tools:**
  - SourceTree

2.4 Installation for Android

This page summarizes the steps to build FW4SPL on Android.

Warning: **Work in progress**

2.4.1 Android environnement

The following tools are necessary:

- JDK >= 6 (JRE only is not sufficient)
- Gradle 2.13 ou more recent

Note: On Linux, openjdk is also reported to work well. You can easily install it with the packaging tools of your favorite distribution.

Note: Since **OSX** 10.10 (Yosemite), JDK 8 is the minimal requirement.

2.4.2 SDK install

The SDK is a set of libraries and development tools necessary to build, test and debug and Android application. The initial archive you will download contains only the basic tools of the SDK. It doesn't contain any version of the API (Android Platform) and doesn't provide the whole set of tools you actually need to develop an application.

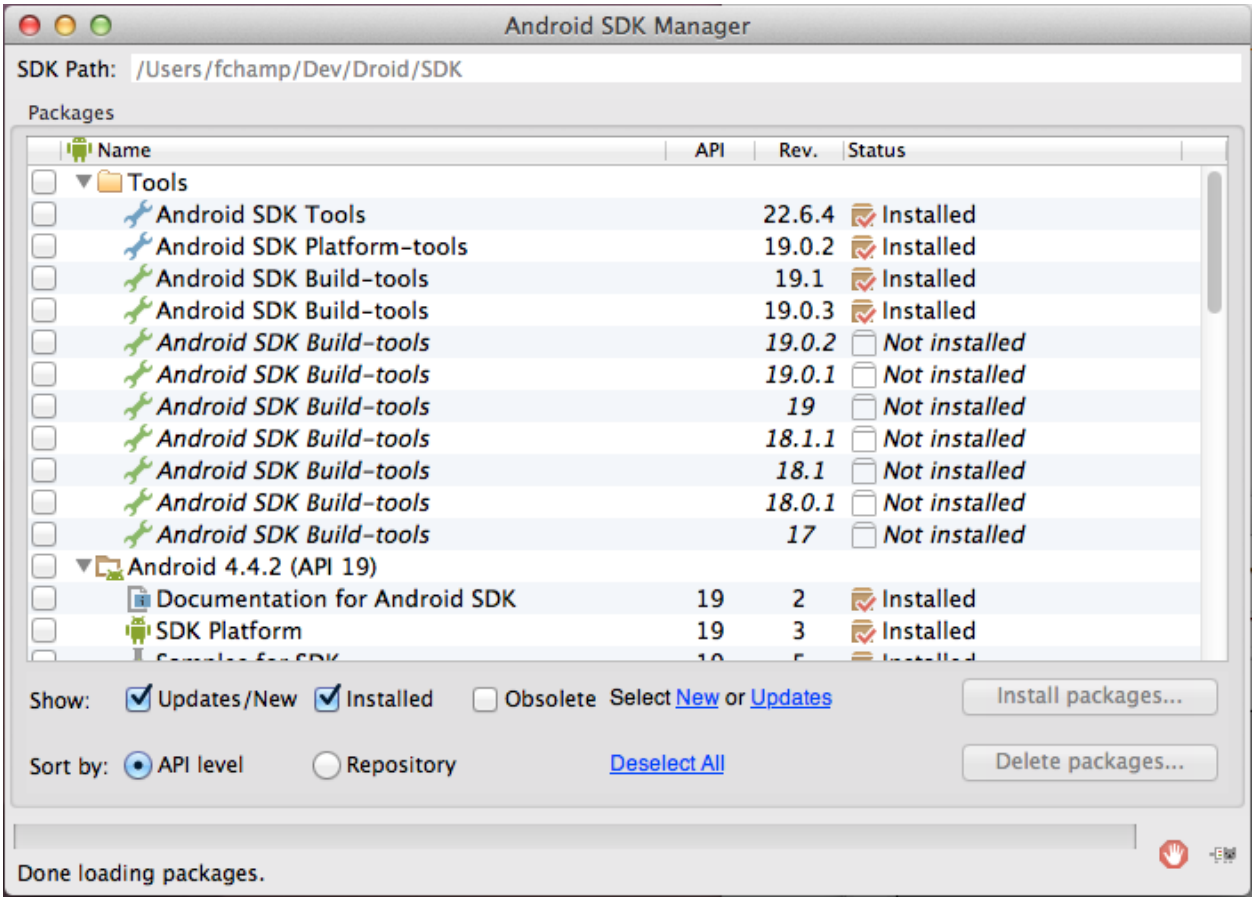
- Download the SDK archive:
  - OSX
  - Linux
  - Windows
- Extract the archive

- Set the environment variable *ANDROID_SDK* to its actual path

```
# i.e for Linux and OSX
export ANDROID_SDK=/ABSOLUTE/PATH/TO/THE/ANDROID_SDK
```

- The **SDK Manager** tool ease the downloading and the management of the different SDK versions, as well as the downloading of the development tools:
  - On Windows, **SDK Manager.exe** is located in the SDK root folder
  - On Linux and OSX, launch the following command in the SDK root folder :

```
./tools/android sdk
```

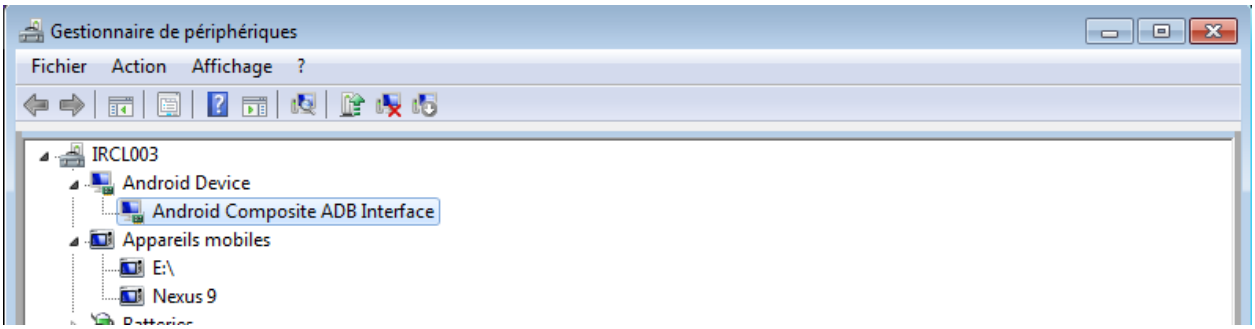


- You can also update the sdk directly through the command line:

```
./tools/android update sdk --no-ui
```

After that, you have to download at least one version of the API and one **Platform-tools** version. The latter contains the build tools (adb, etc...) and are updated independently of the SDK. More informations can be found here.

Warning: For the Windows users, it can be interesting to check that adb is well installed for your device by using the peripheral manager. If it's not the case, please try to update the drivers of your tablet/phone.



2.4.3 NDK install

The NDK is the tool allowing people to develop some parts of your application using *native* code (C/C ++). It also contains the system headers necessary to link successfully your librairies with the latest releases :

- libc (C library) headers
- libm (math library) headers
- JNI interface headers
- libz (Zlib compression) headers
- liblog (Android logging) header
- OpenGL ES 1.1 and OpenGL ES 2.0 (3D graphics libraries) headers
- libjnigraphics (Pixel buffer access) header (for Android 2.2 and above).
- A Minimal set of headers for C++ support
- OpenSL ES native audio libraries
- Android native application APIS

The NDK also provides a build system which will allow you to compile your source code without taking care of the toolchain/platform/CPU/ABI (*ABI = Application Binary Interface*). You have to ensure to have the latest version of the SDK. Indeed, the NDK is compatible with the previous versions of the Android API, but this is not the case for the **Platform tools**.

- Download the NDK for your host platfom here and extract the zip archive.

More informations can be found here.

2.4.4 Configuration for FW4SPL

In order to obtain an Android development environment compatible with FW4SPL and its third-party libraries, you must fulfill the conditions below.

The APIs **<= 8 (Froyo)** are not supported because of compilation error in boost. Thus it is recommended to install the SDK Manager with the following versions versions:

- **Tools:**
  - Android SDK Tools >= 23.0.5.
  - Android SDK Platform-Tools >= 21.
  - Android SDL Build-tools >= 21.0.2.
- **Android 4.4.2 (API 21):**

  - SDK Platform >= 21.
- **On top of that, Qt 5.x does need multiple versions of the API (only download the SDK Platform):**
  - **API 10** and **11** for QtMultimedia.
  - **API 16** for QtBase.

So don't forget to install them before building the FW4SPL deps.

You must also add the following environment variables.

```
ANDROID_NDK=/PATH/TO/NDK
ANDROID_SDK=/PATH/TO/SDK
JAVA_HOME=/PATH/TO/JDK
```

Please remember that JAVA_HOME is the root folder of the JDK and not the binary folder.

Warning: For windows, the path to the JDK binaries (java, javac, etc...) must also be in the PATH environment variable.

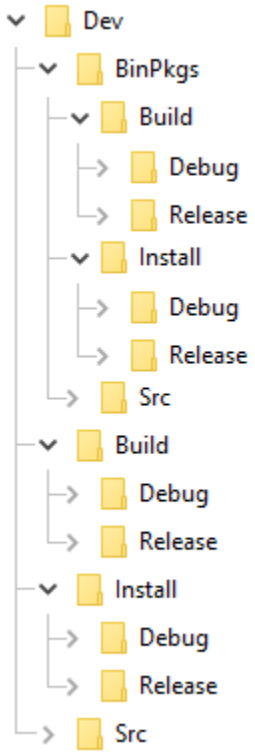
Source tree layout

Good practices in FW4SPL recommend to separate source files, build and install folders. So to prepare the development environment, we propose to follow this layout:

- Create a development folder (Dev)
- Create a build folder (Dev/Build)
  - Add a sub folder for Debug and Release.
- Create a source folder (Dev/Src)
- Create an install folder (Dev/Install)
  - Add a sub folder for Debug and Release.

To prepare the third party environment:

- Create a third party folder (BinPkgs)
- Create a build folder (BinPkgs/Build)
  - Add a sub folder for Debug and Release.
- Create a source folder (BinPkgs/Src)
- Create an install folder (BinPkgs/Install)
  - Add a sub folder for Debug and Release.



Of course you can name the folders as you wish, or choose a different layout, but keep in mind to not build inside the source directory. This is strongly discouraged by *CMake* authors.

2.4.5 Dependencies

First, we need to build the third-party libraries. We will now fetch the scripts that allow to build them and then launch the compilation.

- Clone the following repository in the (BinPkgs/Src) source folder:
  - fw4spl-deps

```
$ cd Dev/BinPkgs/Src
$ git clone https://github.com/fw4spl-org/fw4spl-deps.git
```

Note: *Optional*: You may also clone extension repositories like fw4spl-ext-deps. Additional dependency repositories must be cloned in the same directory as **fw4spl-deps** and they will be automatically discovered and then can be enabled via CMake.

- Ensure that all the cloned repositories are on the same branch.
- Update the cloned repositories to the lastest stable tag.
- Go into your Build directory (Debug or Release) : here is an example if you want to compile in DEBUG

```
$ cd Dev/BinPkgs/Build/Debug
```

Configuration

To build the dependencies, you must configure the project with CMake into the Build folder. As any CMake based project, there are three different ways to perform that.

1. Command-line

In this case, you give all the necessary variables on the command-line in one shot :

```
$ cd Dev/BinPkgs/Build/Debug
$ cmake ../../Src/fw4spl-deps -DCMAKE_INSTALL_PREFIX=Dev/BinPkgs/Install/Debug -
↪DCMAKE_BUILD_TYPE=Debug
```

2. NCurses based editor

This editor allows to set the required each variable in a more interactive way :

```
$ cd Dev/BinPkgs/Build/Debug
$ ccmake ../../Src/fw4spl-deps
```

Then change the following CMake variables:

- `CMAKE_INSTALL_PREFIX`: set the install location, here `Deps/BinPkgs/Install/Debug`
- `CMAKE_BUILD_TYPE`: set the build type 'Debug' or 'Release'
- `ENABLE_SSE_SUPPORT`: enable SSE support. We need that to ensure coherency of the SSE support accross all dependencies. This option will also be forwarded to FW4SPL when building it.
- `BUILD_FW4SPL-EXT-DEPS`: allows to enable/disable the **fw4spl-ext-deps** if you cloned it.

Press *"c"* to configure.

The following options are also available (some of the options will be needed for the optional source repositories):

- ENABLE_AR: Build **fw4spl-ar** dependencies (OpenCV, PCL, OpenIGTLink...).
- ENABLE_OGRE: Build Ogre3D and its dependencies (necessary for **fw4spl-ogre**).
- ENABLE_CUDA: Enable CUDA support in some libraries (OpenCV, PCL, libSGM). This requires Cuda library to be installed on the system.
- ENABLE_SOFA: Build sofa.
- ENABLE_EXTRAS : Build dependencies that are not used currently in the open-source repositories (Odil, Bullet, realsense, libSGM,...).
- ENABLE_EXPERIMENTAL_DEPS: Build experimental libraries (you shouldn't use it, moreover this option is only available with **fw4spl-ext-deps**).

When you're done, generate the code by pressing *"g"* on NCurses based editor or click on "generate" on gui.

Warning: Do not compile debug and release with the same Build and Install folders. If you followed the recommended folder layout, this should be fine.

3. Qt based gui

```
$ cd ~/Dev/BinPkgs/Build/Debug
$ cmake-gui ../../Src/fw4spl-deps
```

You can then edit the same options than with ccmake.

Toolchain

The toolchain allows to cross-compile for Android by specifying all the necessary variables (compiler, target system, etc ...). Currently, the toolchain we use is a modified version of this toochain from the github user taka-no-me (fork of the OpenCV project).

- Download the toolchain:

```
git clone https://github.com/fw4spl-org/android-cmake.git ~/Dev/Droid
```

Project configuration

To build the dependencies, you must configure the project with CMake into the Build folder. As any CMake based project, there are three different ways to perform that.

1. Command-line

In this case, you give all the necessary variables on the command-line in one shot :

```
$ cd ~/Dev/Deps/Build/Debug
$ cmake ../Src/fw4spl-deps -DCMAKE_INSTALL_PREFIX=~/Dev/Deps/Install/Debug -DCMAKE_
↪BUILD_TYPE=Debug -DCROSS_COMPILING=ON -DANDROID_NATIVE_API_LEVEL=21 -DCMAKE_
↪TOOLCHAIN_FILE=~/Dev/Droid/android.toolchain.cmake
```

2. NCurses based editor

This editor allows to set the required each variable in a more interactive way :

```
$ cd ~/Dev/Deps/Build/Debug
$ ccmake ../Src/fw4spl-deps
```

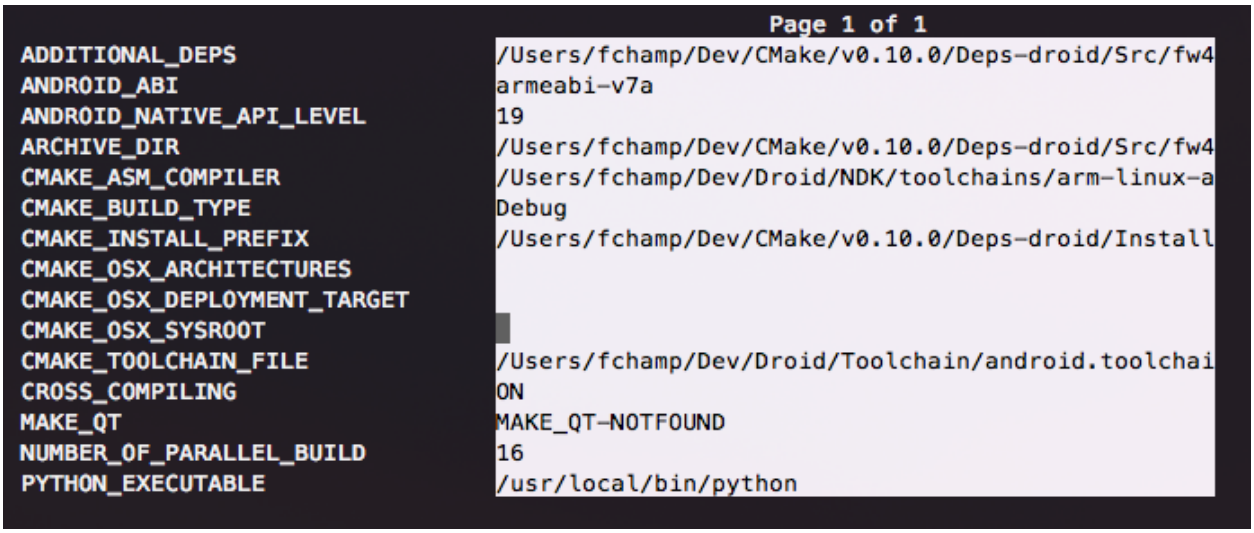
Then change the following CMake variables:

- CMAKE_INSTALL_PREFIX: set the install location, here ~/Dev/Deps/Install/Debug
- CMAKE_BUILD_TYPE: set the build type 'Debug' or 'Release'
- CROSS_COMPILING: set to 'ON'

Press *"c"* to configure. Now you have got two new variables to set:

- ANDROID_NATIVE_API_LEVEL: set to '21'
- CMAKE_TOOLCHAIN_FILE: set to ~/Dev/Droid/android.toolchain.cmake

Press *"c"* to configure and then *"g"* to generate the makefiles.



3. Qt based gui

```
$ cd ~/Dev/Deps/Build/Debug
$ cmake-gui ../Src/fw4spl-deps
```

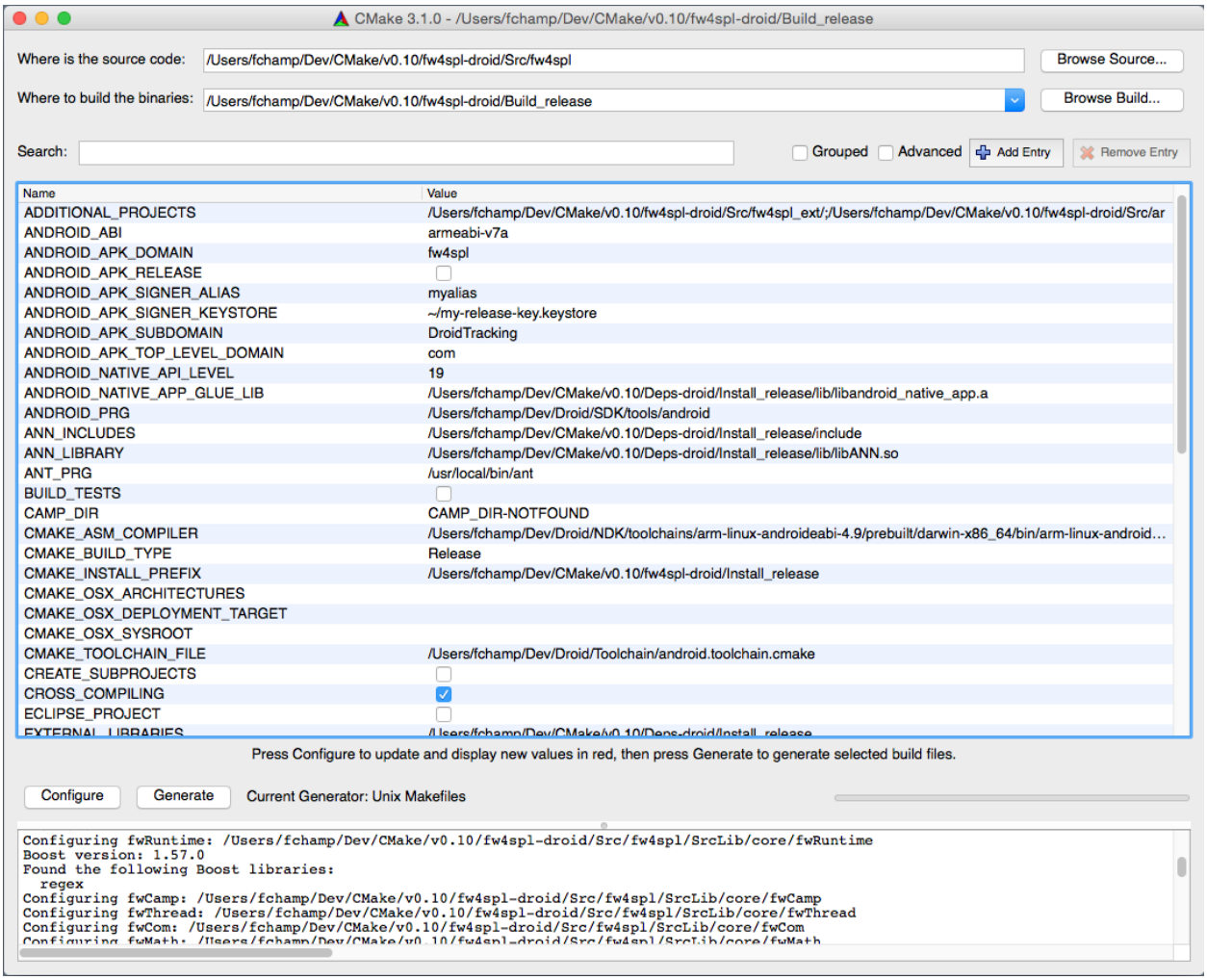
Like ccmake, change the following CMake variables:

- CMAKE_INSTALL_PREFIX: set the install location, here ~/Dev/Deps/Install/Debug
- CMAKE_BUILD_TYPE: set the build type 'Debug' or 'Release'
- CROSS_COMPILING: set to 'ON'

Press *"c"* to configure. Now you have got two new variables to set:

- ANDROID_NATIVE_API_LEVEL: set to '21'
- CMAKE_TOOLCHAIN_FILE: set to ~/Dev/Droid/android.toolchain.cmake

Click on “configure” then “generate”.



Warning: Do not compile debug and release with the same Build and Install folders. If you followed the recommended folder layout, this should be fine.

Warning: For Windows host platform, do not put the `bin/` folder of git in the PATH of your build terminal. It may cause troubles with Qt compilation (some Makefiles are badly generated with simple quotes).

Warning: Do NOT use ninja to compile the dependencies, it causes conflict with qt compilation.

If you get compilation errors at this step, please ensure you installed all the requirements, especially those for Qt.

2.4.6 Source

- **Clone the following repositories in the (Dev/Src) source folder:**

  - fw4spl

```
$ cd Dev/Src
$ git clone https://github.com/fw4spl-org/fw4spl.git
```

Note:

- ***Optional*: You can also clone these extension repositories:**
  - fw4spl-ar contains functionalities for augmented reality (video tracking for instance).
  - fw4spl-ext contains experimental code.
  - fw4spl-ogre contains a 3D backend using Ogre3D.

- Ensure that all the cloned repositories are in the same folder as **fw4spl**. They will be automatically discovered and then can be enabled via CMake.
- Ensure that all the cloned repositories are on the same branch.
- Update the cloned repositories to the same tag.
- Clone fw4spl-droid repository into your source directory:

```
$ cd ..
$ git clone https://github.com/fw4spl-org/fw4spl-droid.git fw4spl-droid
$ cd fw4spl-droid
$ git checkout master
```

Note:

- ***Optional*: You can also clone these extension repositories:**
  - fw4spl-ar contains functionalities for augmented reality (video tracking for instance).
  - fw4spl-ext contains experimental code.
  - fw4spl-ogre contains a 3D backend using Ogre3D.

- Ensure that all the cloned repositories are in the same folder as **fw4spl**. They will be automatically discovered and then can be enabled via CMake.
- Ensure that all the cloned repositories are on the same branch.
- Update the cloned repositories to the same tag.
- Go into your Build directory (Debug or Release) : here is an example if you want to compile in debug:

```
$ cd Dev/Build/Debug
```

Now you have to configure the project. You can use one of the three tools explained above.

Also, for FW4SPL, we recommend to use the Ninja generator. It builds faster, and is much better for everyday use because of how fast it is at figuring out which files need to be built. In other words, with Ninja the compilation starts instantly whereas Make spends a dozen of seconds to check what should be compiled before actually compiling something. So if you plan to develop with FW4SPL, go with Ninja. If you only want to give a single try, you can live with the standard "Unix Makefiles" generator.

Configuration

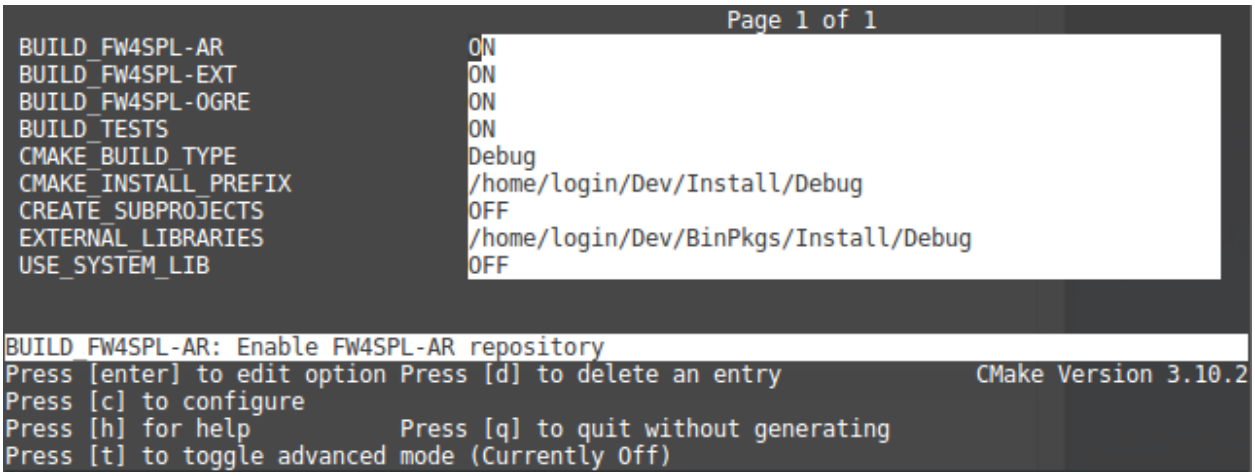
1. NCurses based editor

To use make, here with `ccmake` :

```
$ cd Dev/Build/Debug
$ ccmake ../../Src/fw4spl
```

To use ninja :

```
$ cd Dev/Build/Debug
$ ccmake -G Ninja ../../Src/fw4spl
```



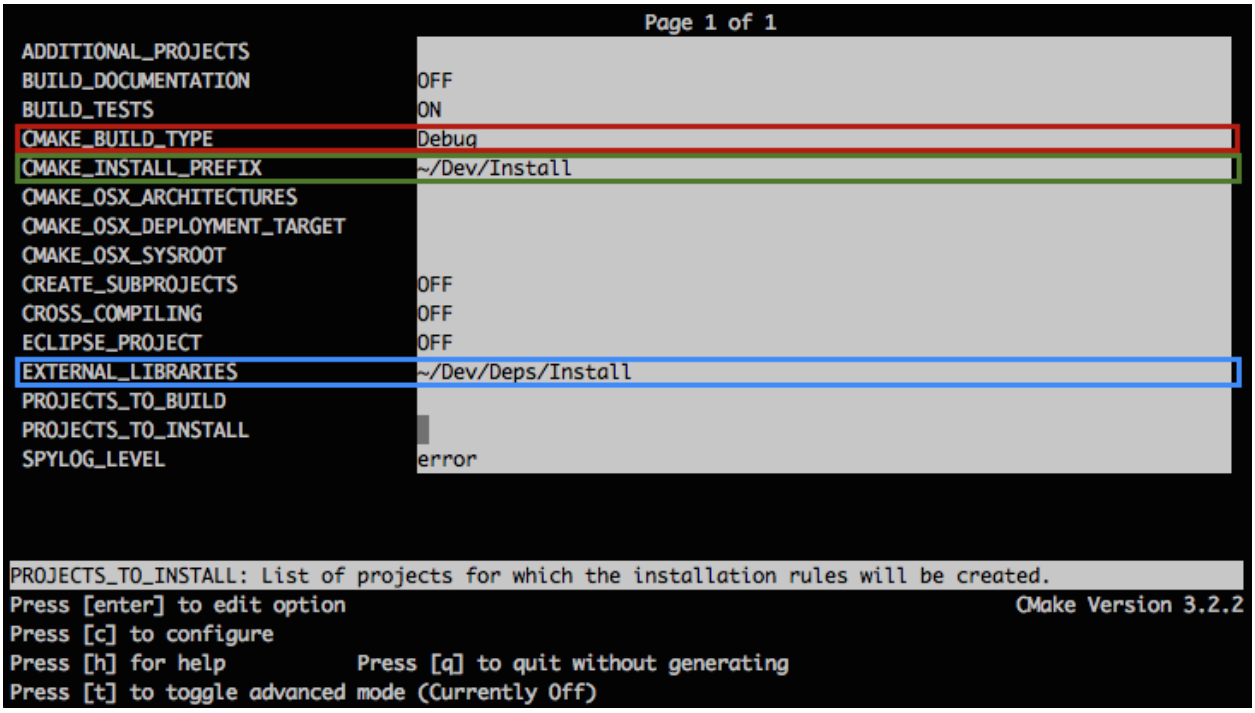
- **Change the following cmake arguments**
  - `CMAKE_INSTALL_PREFIX`: set the install location (~/Dev/Install/Debug or Release)
  - `CMAKE_BUILD_TYPE`: set to Debug or Release
  - `EXTERNAL_LIBRARIES`: set the install path of the third party libraries you compiled before.(ex : ~/Dev/Deps/Install/Debug)
  - `PROJECTS_TO_BUILD`: set the list of the projects you want to build (ex: PoC09Android, . . .), each project should be separated by ";"
  - `PROJECTS_TO_INSTALL`: set the name of the application to install
  - `CROSS_COMPILING`: set to 'ON'

Press *"c"* to configure. Now you have got two new variables to set:

- `ANDROID_NATIVE_API_LEVEL`: set to '21'
- `CMAKE_TOOLCHAIN_FILE`: set to ~/Dev/Droid/android.toolchain.cmake

Note:

- If `PROJECTS_TO_BUILD` is empty, all application will be compiled
- If `PROJECTS_TO_INSTALL` is empty, no application will be installed



Press *"c"* to configure and then *"g"* to generate the makefiles.

Note: To generate the projects in release mode, change CMake argument `CMAKE_BUILD_TYPE` to `Release` **both** for fw4spl and fw4spl-deps

---

Then, according to the generator you chose, build FW4SPL with make :

```
# Adjust the number of cores depending of the CPU cores and the RAM available on your␣
↪computer
$ make -j4
```

Or with ninja:

```
$ ninja
```

If you didn't specify anything in `PROJECTS_TO_BUILD` you may also build specific targets, for instance:

```
$ ninja PoC09Android
```

To deploy the application, connect your Android device to the USB port, be sure that it is in developer mode and that USB debugging is enabled. Then run:

```
$ ninja install
```

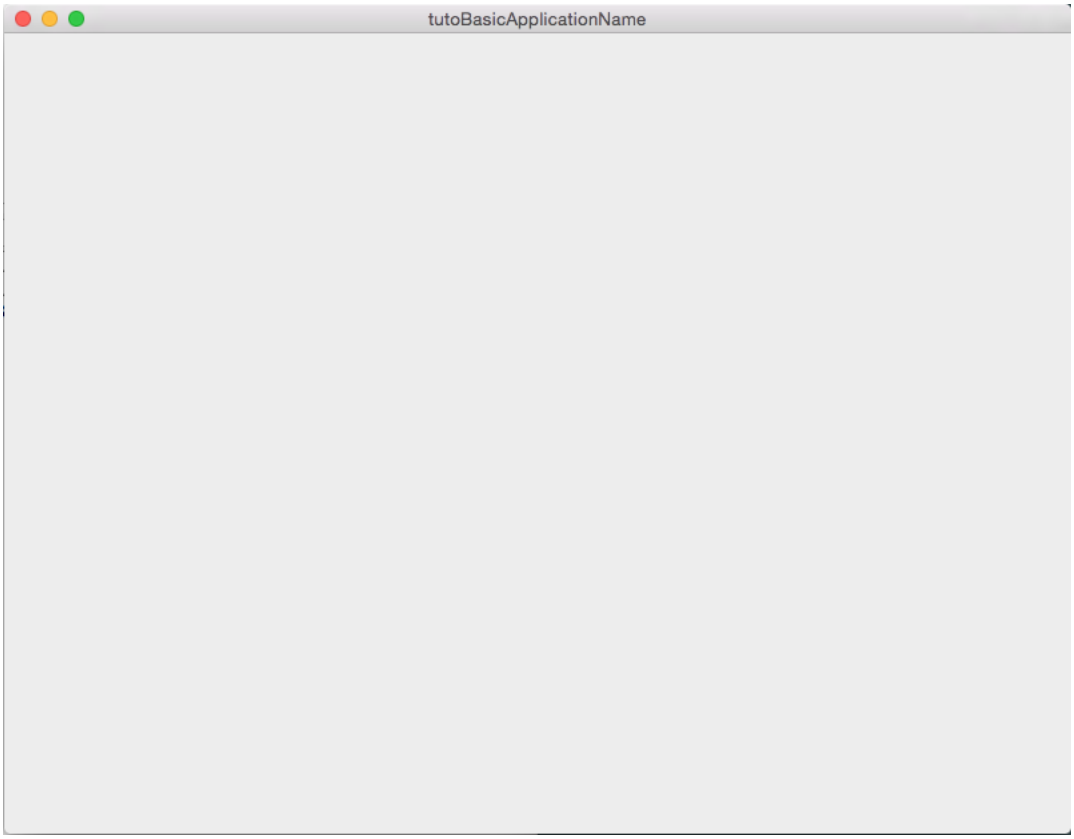
Thanks to **Gradle** and **adb**, the application will be packaged and copied automatically to your device.

CHAPTER 3

Tutorials

3.1 [*Tuto01Basic*] Create an application

The first tutorial represents a basic application that launches a simple empty frame. It introduces the concept of XML application configuration and CMake generation.



3.1.1 Prerequisites

You should have properly installed your fw4spl environment (see *Installation*).

3.1.2 Structure

fw4spl is organized around four elements: the `application`, the `bundle`, the `library` and the `utility`.

The `applications` contain the configuration of the `bundles` (and its services) to launch. The `bundles` contain the cpp implementation of the services, it may also contain some application sub-configuration. The `libraries` contain the data implementation and the code shared with several bundles. The `utilities` are simple executables using the `libraries`.

In this example, we will only explain how to create a basic application with the existing bundles. Further Tutorials will explain how to use and create services and bundles.

A fw4spl application is organized around three main files :

- CMakeLists.txt
- Properties.cmake
- plugin.xml

CMakeLists.txt

The CMakeLists.txt is parsed by CMake. For an application, it should contain the following lines :

```
fwLoadProperties()
generic_install()
```

- `fwLoadProperties()` allows to load Properties.cmake file and thus to build the application
- `generic_install()` allows to generate an installer for the application

Properties.cmake

This file describes the project information and requirements (see *Properties.cmake*) :

```
set( NAME Tuto01Basic )
set( VERSION 0.1 )
set( TYPE APP )
set( DEPENDENCIES  )
set( REQUIREMENTS
    dataReg # to load the data registry
    servicesReg # to load the service registry
    gui # to load gui
    guiQt # to load qt implementation of gui
    fwlauncher # executable to run the application
    appXml # to parse the application configuration
)

# Set application configuration to 'tutoBasicConfig'
bundleParam(appXml PARAM_LIST config PARAM_VALUES tutoBasicConfig)
```

This file contains the minimal requirements to launch an application with a Qt user interface.

Note: The Properties.cmake file of the application is used by CMake to compile the application but also to generate the `profile.xml`, the input file used to launch the application (see *profile.xml*).

The `bundleParam` line defines the parameters to set for a bundle, here it defines the configuration to launch by the appXML bundle, i.e. the application configuration.

plugin.xml

This file is located in the `rc/` directory of the application. It contains the application configuration.

```
<!-- Application name and version (the version is automatically replaced by CMake
     using the version defined in the Properties.cmake) -->
<plugin id="Tuto01Basic" version="@PROJECT_VERSION@">

    <!-- The bundles in requirements are automatically started when this
         Application is launched. -->
    <requirement id="dataReg" />
    <requirement id="servicesReg" />

    <!-- Defines the App-config -->
    <extension implements="::fwServices::registry::AppConfig">
        <id>tutoBasicConfig</id><!-- identifier of the configuration -->
        <config>

            <!-- Frame service -->
            <service uid="myFrame" type="::gui::frame::SDefaultFrame">
                <gui>
                    <frame>
                        <name>tutoBasicApplicationName</name>
                        <icon>Tuto01Basic-0.1/tuto.ico</icon>
                        <minSize width="800" height="600" />
                    </frame>
                </gui>
            </service>

            <start uid="myFrame" /><!-- start the frame service -->

        </config>
    </extension>
</plugin>
```

`<requirement>` lists the bundles that should be loaded before launching the application: the bundle to register data or i/o services (see Requirements).

The `::fwServices::registry::AppConfig` extension defines the configuration of an application:

id: The configuration identifier.

config: Contains the list of objects and services used by the application. For this tutorial, we have no object and only one service `::gui::frame::SDefaultFrame`. There are few others tags that will be described in the next tutorials.

3.1.3 Run

To run the application, you must call the following line into the install or build directory:

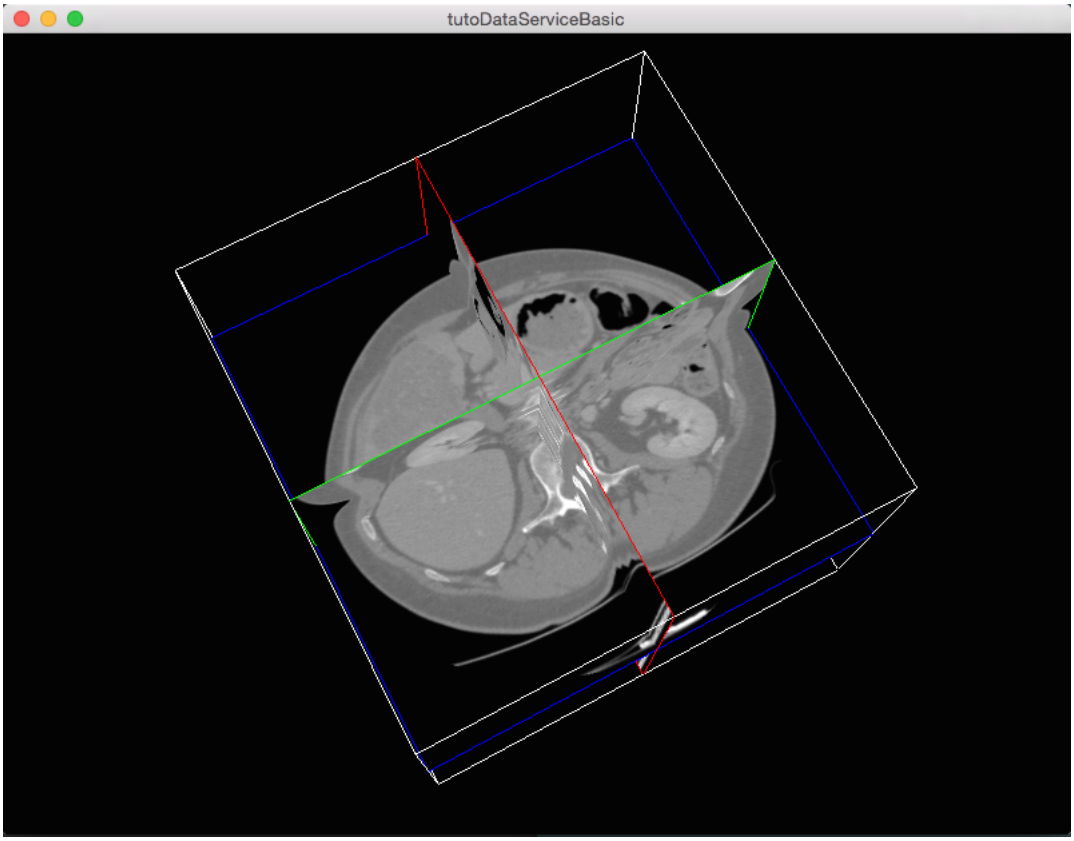
```
bin/fwlauncher share/Tuto01Basic-0.1/profile.xml
```

On Linux and MacOs, you can also use the shortcut (generated for each application):

```
bin/tuto01basic
```

3.2 [*Tuto02DataServiceBasic*] Display an image

The second tutorial represents a basic application that displays a medical 3D image.



3.2.1 Prerequisites

Before reading this tutorial, you should have seen :

- *[Tuto01Basic] Create an application*

3.2.2 Structure

Properties.cmake

This file describes the project information and requirements :

```
set( NAME Tuto02DataServiceBasic )
set( VERSION 0.1 )
set( TYPE APP )
set( DEPENDENCIES  )
set( REQUIREMENTS
    dataReg
    servicesReg
    gui
    guiQt
    ioVTK # contains the reader and writer for VTK files (image and mesh).
    visuVTK # loads VTK rendering library (fwRenderVTK).
    visuVTKQt # contains the vtk Renderer window interactor manager using Qt.
    vtkSimpleNegato # contains a visualization service of medical image.
    fwlauncher
    appXml
)

bundleParam(appXml PARAM_LIST config PARAM_VALUES tutoDataServiceBasicConfig)
```

Note: The Properties.cmake file of the application is used by **CMake_** to compile the application but also to generate the `profile.xml`, the input file used to launch the application (see *profile.xml*).

plugin.xml

This file is located in the `rc/` directory of the application. It defines the services to run.

```
<plugin id="Tuto02DataServiceBasic" version="@PROJECT_VERSION@">

    <!-- The bundles in requirements are automatically started when this
         application is launched. -->
    <requirement id="dataReg" />
    <requirement id="servicesReg" />
    <requirement id="visuVTKQt" />

    <extension implements="::fwServices::registry::AppConfig">
        <id>tutoDataServiceBasicConfig</id>
        <config>

            <!-- In tutoDataServiceBasic, the central data object is a␣
↪::fwData::Image. -->
            <object uid="imageData" type="::fwData::Image" />

            <!--
                Description service of the GUI:
                The ::gui::frame::SDefaultFrame service automatically positions the␣
↪various
                containers in the application main window.
                Here, it declares a container for the 3D rendering service.
```

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```
            -->
            <service uid="mainFrame" type="::gui::frame::SDefaultFrame">
                <gui>
                    <frame>
                        <name>tutoDataServiceBasic</name>
                        <icon>Tuto02DataServiceBasic-0.1/tuto.ico</icon>
                        <minSize width="800" height="600" />
                    </frame>
                </gui>
                <registry>
                    <!-- Associate the container for the rendering service. -->
                    <view sid="myRendering" />
                </registry>
            </service>

            <!--
                Reading service:
                The <file> tag defines the path of the image to load. Here, it is a␣
↪relative
                path from the repository in which you launch the application.
            -->
            <service uid="myReaderPathFile" type="::ioVTK::SImageReader">
                <inout key="data" uid="imageData" />
                <file>../../data/patient1.vtk</file>
            </service>

            <!--
                Visualization service of a 3D medical image:
                This service renders the 3D image.
            -->
            <service uid="myRendering" type="::vtkSimpleNegato::SRenderer">
                <in key="image" uid="imageData" />
            </service>

            <!--
                Definition of the starting order of the different services:
                The frame defines the 3D scene container, so it must be started first.
                The services will be stopped symmetrically in the reverse order.
            -->
            <start uid="mainFrame" />
            <start uid="myReaderPathFile" />
            <start uid="myRendering" />

            <!--
                Definition of the service to update:
                The reading service loads the data on the update.
                The render updates must be called after the reading of the image.
            -->
            <update uid="myReaderPathFile" />
            <update uid="myRendering" />

        </config>
    </extension>

</plugin>
```

For this tutorial, we have only one object `::fwData::Image` and three services:

- `::gui::frame::SDefaultFrame`: frame service
- `::ioVTK::SImageReader`: reader for 3D VTK image
- `::vtkSimpleNegato::SRenderer`: renderer for 3D image

The following order of the configuration elements must be respected:

1. `<object>`
2. `<service>`
3. `<connect>` (see *[Tuto04SignalSlot] Signal-slot communication*)
4. `<start>`
5. `<update>`

Note: To avoid the `<start uid="myRendering" />`, the frame service can automatically start the rendering service: you just need to add the attribute `start="yes"` in the `<view>` tag.

3.2.3 Run

To run the application, you must call the following line in the install or build directory:

```
bin/fwlauncher share/Tuto02DataServiceBasic-0.1/profile.xml
```

3.3 [*Tuto02DataServiceBasicCtrl*] Tuto02 without XML

This tutorial shows the same application as *[Tuto02DataServiceBasic] Display an image* but without using the XML configurations. The services declaration and configuration are written in C++. When looking side-by-side you should see the benefit of using the XML descrption format.

3.3.1 Prerequisites

Before reading this tutorial, you should have seen :

- *[Tuto01Basic] Create an application*
- *[Tuto02DataServiceBasic] Display an image*

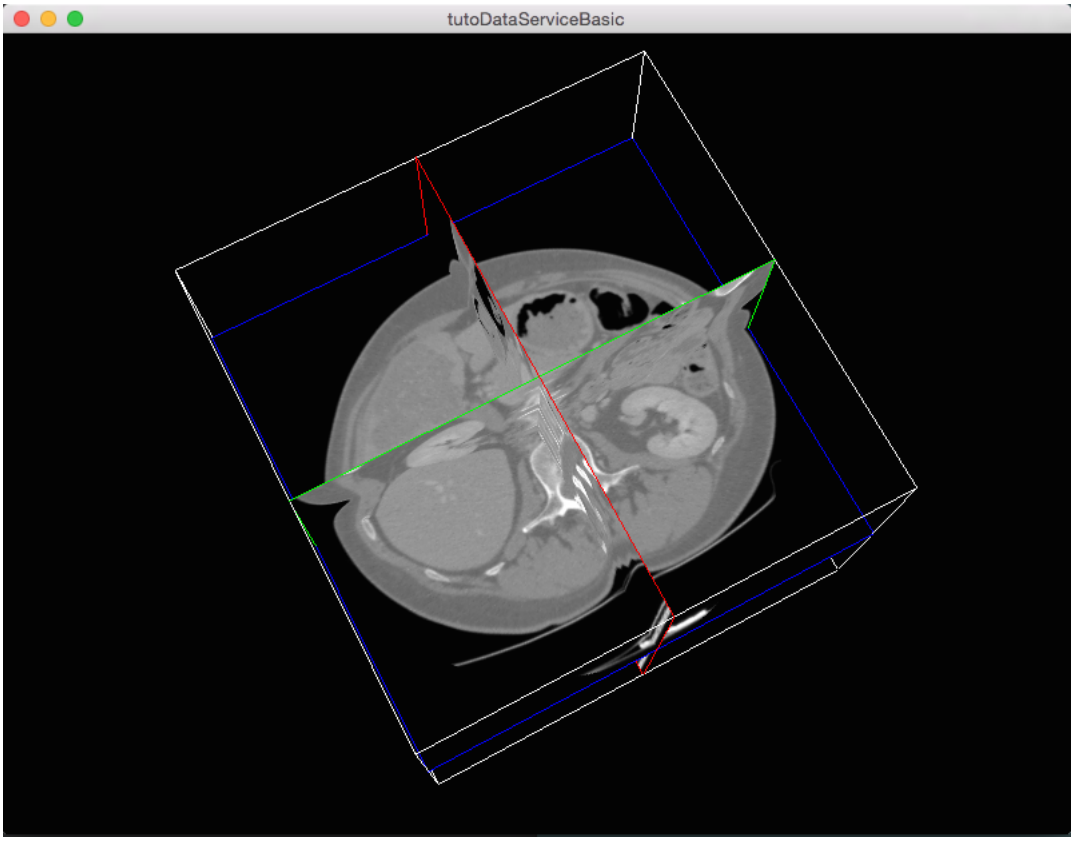
3.3.2 Structure

A C++ application does not need a configuration in the plugin.xml. Here we have chosen to write our application configuration in the first entry point we have in hand, that is, the `initialize` method of the `Plugin` class.

Plugin

The *Plugin* class contains the code that is run when a bundle is started (see *Service bundles*). The declaration of the services should be in the `initialize()` method.

In the header file `Plugin.hpp`:




```
#pragma once

#include "Tuto02DataServiceBasicCtrl/config.hpp"

#include <fwData/Image.hpp>

#include <fwRuntime/Plugin.hpp>

#include <fwServices/IService.hpp>

namespace Tuto02DataServiceBasicCtrl
{

/**
 * @brief   This class is started when the bundles is loaded.
 */
class TUTO02DATASERVICEBASICCTRL_CLASS_API Plugin : public ::fwRuntime::Plugin
{
public:
    /// Constructor.
    TUTO02DATASERVICEBASICCTRL_API Plugin() noexcept;

    /// Destructor. Do nothing.
    TUTO02DATASERVICEBASICCTRL_API ~Plugin() noexcept;

    /// Overrides start method. .
    TUTO02DATASERVICEBASICCTRL_API void start();
```

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```
    /// Overrides stop method. Do nothing
    TUTO02DATASERVICEBASICCTRL_API void stop() noexcept;

    TUTO02DATASERVICEBASICCTRL_API void initialize();

    TUTO02DATASERVICEBASICCTRL_API void uninitialize() noexcept;

private:
    ::fwData::Image::sptr m_image;

    ::fwServices::IService::sptr m_frameSrv;
    ::fwServices::IService::sptr m_renderSrv;
    ::fwServices::IService::sptr m_readerSrv;
};

} // namespace Tuto02DataServiceBasicCtrl
```

In the source file `Plugin.cpp`

```
#include "Tuto02DataServiceBasicCtrl/Plugin.hpp"

#include <fwRuntime/operations.hpp>
#include <fwRuntime/utils/GenericExecutableFactoryRegistrar.hpp>

#include <fwServices/op/Add.hpp>
#include <fwServices/registry/ObjectService.hpp>

namespace Tuto02DataServiceBasicCtrl
{

static ::fwRuntime::utils::GenericExecutableFactoryRegistrar<Plugin> registrar(
↪"::Tuto02DataServiceBasicCtrl::Plugin");

//-----------------------------------------------------------------------------

Plugin::Plugin() noexcept
{
}

//-----------------------------------------------------------------------------

Plugin::~Plugin() noexcept
{
}

//-----------------------------------------------------------------------------

void Plugin::start()
{
}

//-----------------------------------------------------------------------------

void Plugin::initialize()
{
    // create an empty image
```

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```
    m_image = ::fwData::Image::New();

    // create and register the reader service
    m_readerSrv = ::fwServices::add("::ioVTK::SImageReader");
    m_readerSrv->registerInOut(m_image, "data"); // add the in-out image
    // create the reader configuration
    ::fwServices::IService::ConfigType readerCfg;
    readerCfg.put("file", "../../data/patient1.vtk");
    m_readerSrv->setConfiguration( readerCfg );
    m_readerSrv->configure();

    // create and register the render service
    m_renderSrv = ::fwServices::add("::vtkSimpleNegato::SRenderer");
    m_renderSrv->registerInput(m_image, "image"); // add the input image
    m_renderSrv->setID( "myRenderingTuto" ); // set an identifier
    m_renderSrv->configure();

    // create and register frame service
    m_frameSrv = ::fwServices::add("::gui::frame::SDefaultFrame");

    // create the frame configuration
    ::fwServices::IService::ConfigType frameConfig;
    frameConfig.put("gui.frame.name", "tutoDataServiceBasicCtrl");
    frameConfig.put("gui.frame.icon", "Tuto02DataServiceBasicCtrl-0.1/tuto.ico");
    frameConfig.put("gui.frame.minSize.<xmlattr>.width", "800");
    frameConfig.put("gui.frame.minSize.<xmlattr>.height", "600");
    // use the render identifier to display it in the frame
    frameConfig.put("registry.view.<xmlattr>.sid", "myRenderingTuto");

    m_frameSrv->setConfiguration( frameConfig );
    m_frameSrv->configure();

    // start the services
    m_frameSrv->start();
    m_readerSrv->start();
    m_renderSrv->start();

    // update the services
    m_readerSrv->update();
    m_renderSrv->update();
}

//------------------------------------------------------------------------------

void Plugin::stop() noexcept
{
}

//------------------------------------------------------------------------------

void Plugin::uninitialize() noexcept
{
    // stop the services
    m_renderSrv->stop();
    m_readerSrv->stop();
    m_frameSrv->stop();
```

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```
    // unregister the services
    ::fwServices::OSR::unregisterService( m_readerSrv );
    ::fwServices::OSR::unregisterService( m_frameSrv );
    ::fwServices::OSR::unregisterService( m_renderSrv );
    m_image.reset();
}

//------------------------------------------------------------------------------

} // namespace Tuto02DataServiceBasicCtrl
```

- `::fwServices::add(...)` create and register the service in the application.
- `srv->registerInOut(..) or ``srv->registerInput(...)` add the in-out or input data to the service
- `::fwServices::OSR::unregisterService(...)` unregister the service

Properties.cmake

This file describes the project information and requirements :

```
set( NAME Tuto02DataServiceBasicCtrl )
set( VERSION 0.1 )
set( TYPE APP )
set( START ON ) # this app budle must be started when the application launches
set( DEPENDENCIES # libraries needed to compile the C++ application
    fwData
    fwServices
    fwCom
    fwRuntime
)
set( REQUIREMENTS
    gui
    guiQt
    dataReg
    servicesReg
    visuVTK
    visuVTKQt
    ioData
    ioVTK
    vtkSimpleNegato
    fwlauncher
)
```

Note: The Properties.cmake file of the application is used by CMake to compile the application but also to generate the `profile.xml`: the file used to launch the application.

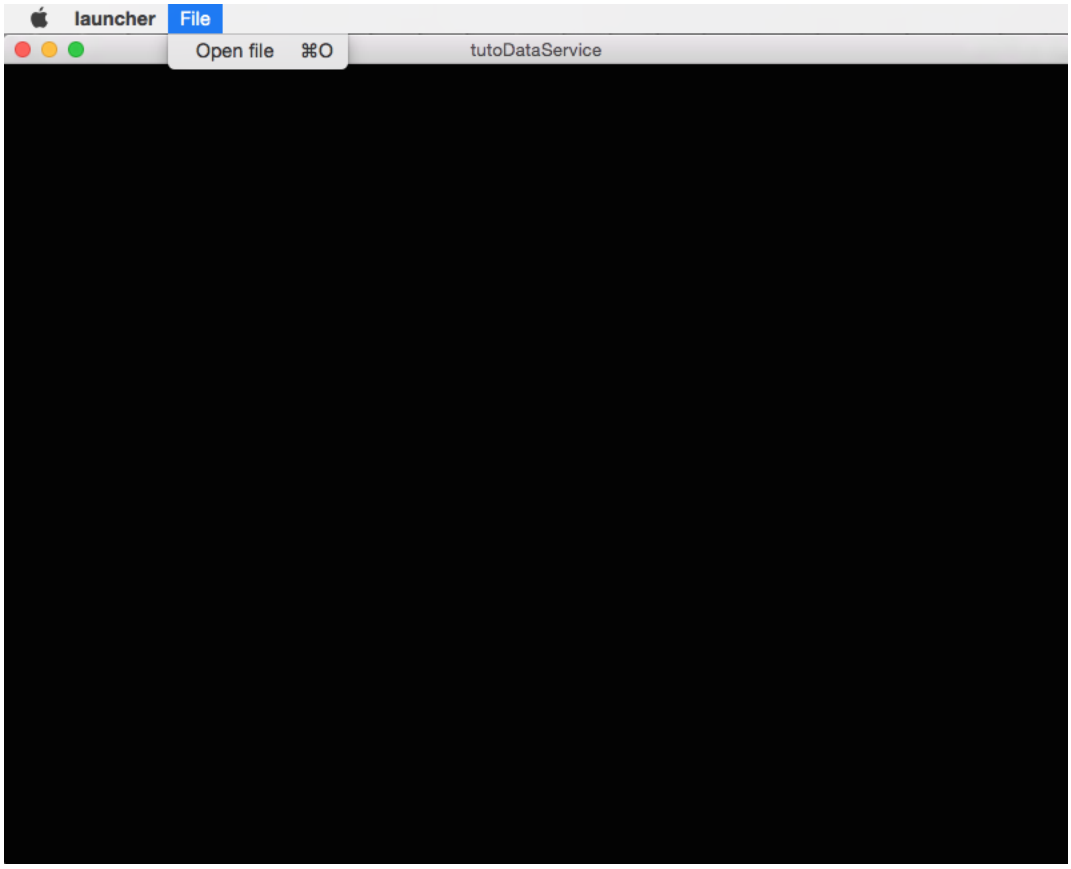
3.3.3 Run

To run the application, you must call the following line in the install or build directory:

```
bin/fwlauncher share/Tuto02DataServiceBasicCtrl-0.1/profile.xml
```

3.4 [*Tuto03DataService*] Display an image with menu

The third tutorial is similar to the previous application, but we add gui services like menus.



3.4.1 Prerequisites

Before reading this tutorial, you should have seen :

- *[Tuto02DataServiceBasic] Display an image*
- *Graphical User Interface*

3.4.2 Structure

Properties.cmake

This file describes the project information and requirements :

```
set( NAME Tuto03DataService )
set( VERSION 0.1 )
set( TYPE APP )
set( DEPENDENCIES  )
set( REQUIREMENTS
    dataReg
    servicesReg
    gui
    guiQt
    ioVTK
    uiIO # contains services to show dialogs for reader/writer selection
    visuVTKQt
    vtkSimpleNegato
    launcher
    appXml
)

bundleParam(appXml PARAM_LIST config PARAM_VALUES tutoDataServiceConfig)
```

Note: The Properties.cmake file of the application is used by CMake to compile the application but also to generate the `profile.xml`: the file used to launch the application.

plugin.xml

This file is in the `rc/` directory of the application. It defines the services to run.

```
<plugin id="Tuto03DataService" version="@PROJECT_VERSION@">

    <requirement id="dataReg" />
    <requirement id="servicesReg" />
    <requirement id="visuVTKQt" />

    <extension implements="::fwServices::registry::AppConfig">
        <id>tutoDataServiceConfig</id>
        <config>

            <!-- The root data object in tutoDataService is a ::fwData::Image. -->
            <object uid="image" type="::fwData::Image" />

            <!-- Frame service:
                The frame creates a container fot the rendering service and a menu␣
↪bar.
                In this tutorial, the gui services will automatically start the␣
↪services they register using the
                'start="yes"' attribute.
            -->
            <service uid="myFrame" type="::gui::frame::SDefaultFrame">
                <gui>
                    <frame>
                        <name>tutoDataService</name>
                        <icon>Tuto03DataService-0.1/tuto.ico</icon>
                        <minSize width="800" height="600" />
                    </frame>
                    <menuBar />
```

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```
                </gui>
                <registry>
                    <menuBar sid="myMenuBar" start="yes" />
                    <view sid="myRendering" start="yes" />
                </registry>
            </service>

            <!--
                Menu bar service:
                This service defines the list of the menus displayed in the menu bar.
                Here, we have only one menu: File
                Each <menu> declared into the <layout> tag, must have its associated
↪<menu> into the <registry> tag.
                The <layout> tags defines the displayed information, whereas the
↪<registry> tags defines the
                services information.
            -->
            <service uid="myMenuBar" type="::gui::aspect::SDefaultMenuBar">
                <gui>
                    <layout>
                        <menu name="File" />
                    </layout>
                </gui>
                <registry>
                    <menu sid="myMenu" start="yes" />
                </registry>
            </service>

            <!--
                Menu service:
                This service defines the actions displayed in the "File" menu.
                Here, it registers two actions: "Open file", and "Quit".
                As in the menu bar service, each <menuItem> declared into the <layout>
↪ tag, must have its
                associated <menuItem> into the <registry> tag.

                It's possible to associate specific attributes for <menuItem> to␣
↪configure their style, shortcut...
                In this tutorial, the attribute 'specialAction' has the value "QUIT".␣
↪On MS Windows, there's no
                impact, but on Mac OS, this value installs the menuItem in the system␣
↪menu bar, and on Linux this
                value installs the default 'Quit' system icon in the menuItem.
            -->
            <service uid="myMenu" type="::gui::aspect::SDefaultMenu">
                <gui>
                    <layout>
                        <menuItem name="Open file" shortcut="Ctrl+O" />
                        <separator />
                        <menuItem name="Quit" specialAction="QUIT" shortcut="Ctrl+Q" /
↪>
                    </layout>
                </gui>
                <registry>
                    <menuItem sid="actionOpenFile" start="yes" />
                    <menuItem sid="actionQuit" start="yes" />
                </registry>
```

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```
            </service>

            <!--
                Quit action:
                The action service (::gui::action::SQuit) is a generic action that␣
↪will close the application
                when the user click on the menuItem "Quit".
            -->
            <service uid="actionQuit" type="::gui::action::SQuit" />

            <!--
                Open file action:
                This service (::gui::action::StarterActionService) is a generic␣
↪action, it starts and update the
                services given in the configuration when the user clicks on the␣
↪action.
                Here, the reader selector will be called when the actions is clicked.
            -->
            <service uid="actionOpenFile" type="::gui::action::SStarter">
                <start uid="myReaderPathFile" />
            </service>

            <!--
                Reader selector dialog:
                This is a generic service that show a dialog to display all the␣
↪reader or writer available for its
                associated data. By default it is configured to show reader. (Note:␣
↪if there is only one reading
                service, it is directly selected without dialog box.)
                Here, it the only reader available to read a ::fwData::Image is␣
↪::ioVTK::ImageReaderService (see
                Tuto02DataServiceBasic), so the selector will not be displayed.
                When the service was chosen, it is started, updated and stopped, so␣
↪the data is read.
            -->
            <service uid="myReaderPathFile" type="::uiIO::editor::SIOSelector" >
                <inout key="data" uid="image" />
            </service>

            <!--
                3D visualization service of medical images:
                Here, the service attribute 'autoConnect="yes"' allows the rendering␣
↪to listen the modification of
                the data image. So, when the image is loaded, the visualization will␣
↪be updated.
            -->
            <service uid="myRendering" type="::vtkSimpleNegato::SRenderer"␣
↪autoConnect="yes" >
                <in key="image" uid="image" />
            </service>

            <!--
                Here, we only start the frame because all the others services are␣
↪managed by the gui service:
                - the frame starts the menu bar and the redering service
                - the menu bar starts the menu services
                - the menus starts the actions
```

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```
            -->
            <start uid="myFrame" />

        </config>
    </extension>
</plugin>
```

The framework provides some gui services:

Frame (`::gui::frame::SDefaultFrame`) This service displays a frame and creates menu bar, tool bar and container for views, rendering service, ...

View (`::gui::view::SDefaultView`) This service creates sub-container and tool bar.

Menu bar (`::gui::aspect::SDefaultMenuSrv`) A menu bar displays menus.

Tool bar (`::gui::aspect::SDefaultToolBarSrv`) A tool bar displays actions, menus and editors.

Menu (`::gui::aspect::SDefaultMenuSrv`) A menu displays actions and sub-menus.

Action (inherited from `::fwGui::IActionSrv`) An action is a service inherited from `::fwGui::IActionSrv`. It is called when the user clicks on the associated tool bar or menu.

Editors (inherited from `::fwGui::editor::IEditor`) An editor is a service inherited from `::fwGui::editor::IEditor`. It is used to creates your own gui container.

3.4.3 Run

To run the application, you must call the following line into the install or build directory:

```
bin/fwlauncher share/Tuto03DataService-0.1/profile.xml
```

3.5 [*Tuto04SignalSlot*] Signal-slot communication

The fourth tutorial explains the communication mechanism with signals and slots.

3.5.1 Prerequisites

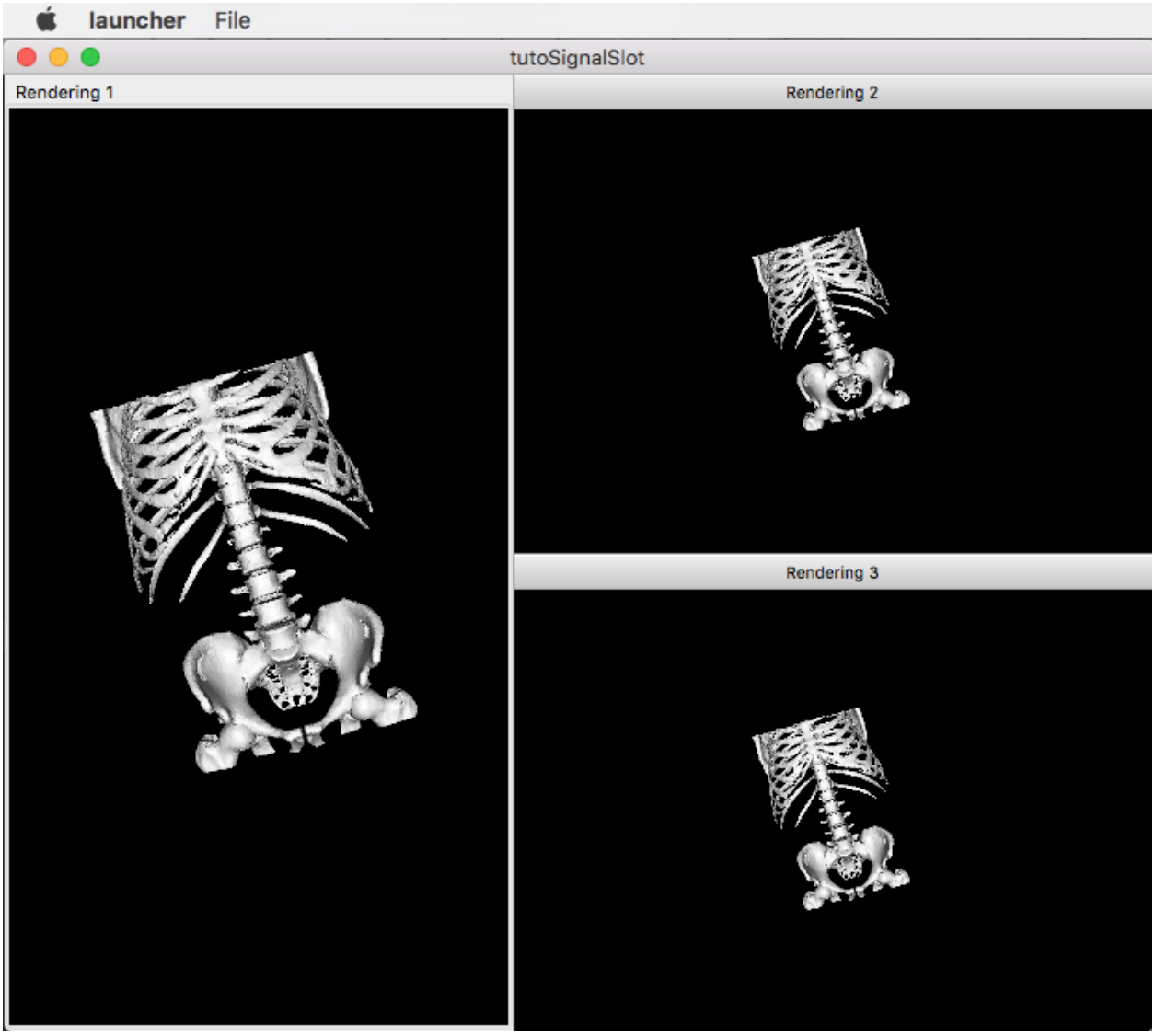
Before reading this tutorial, you should have seen :

- *[Tuto03DataService] Display an image with menu*
- *Signal-slot communication*

3.5.2 Structure

Properties.cmake

This file describes the project information and requirements :


launcher
File
tutoSignalSlot
Rendering 1
Rendering 2
Rendering 3

```
set( NAME Tuto04SignalSlot )
set( VERSION 0.1 )
set( TYPE APP )
set( DEPENDENCIES  )
set( REQUIREMENTS
    dataReg
    servicesReg
    gui
    guiQt
    ioVTK
    uiIO
    visuVTKQt
    vtkSimpleMesh # contains a visualization service of mesh.
    launcher
    appXml
)

bundleParam(appXml PARAM_LIST config PARAM_VALUES tutoSignalSlotConfig)
```

Note: The Properties.cmake file of the application is used by CMake to compile the application but also to generate the `profile.xml`: the file used to launch the application.

plugin.xml

This file is in the `rc/` directory of the application. It defines the services to run.

```
<plugin id="Tuto04SignalSlot" version="@PROJECT_VERSION@">

    <requirement id="dataReg" />
    <requirement id="servicesReg" />
    <requirement id="visuVTKQt" />

    <extension implements="::fwServices::registry::AppConfig">
        <id>tutoSignalSlotConfig</id>
        <config>

            <!-- The main data object is ::fwData::Mesh. -->
            <object uid="mesh" type="::fwData::Mesh" />

            <service uid="myFrame" type="::gui::frame::SDefaultFrame">
                <gui>
                    <frame>
                        <name>tutoSignalSlot</name>
                        <icon>Tuto04SignalSlot-0.1/tuto.ico</icon>
                        <minSize width="720" height="600" />
                    </frame>
                    <menuBar />
                </gui>
                <registry>
                    <menuBar sid="myMenuBar" start="yes" />
                    <view sid="myDefaultView" start="yes" />
                </registry>
            </service>
```

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```
            <service uid="myMenuBar" type="::gui::aspect::SDefaultMenuBar">
                <gui>
                    <layout>
                        <menu name="File" />
                    </layout>
                </gui>
                <registry>
                    <menu sid="myMenuFile" start="yes" />
                </registry>
            </service>

            <!--
                Default view service:
                This service defines the view layout. The type
↪'::fwGui::CardinalLayoutManager' represents a main
                central view and other views at the 'right', 'left', 'bottom' or 'top
↪'.
                Here the application contains a central view at the right.

                Each <view> declared into the <layout> tag, must have its associated
↪<view> into the <registry> tag.
                A minimum window height and a width are given to the two non-central␣
↪views.
            -->
            <service uid="myDefaultView" type="::gui::view::SDefaultView">
                <gui>
                    <layout type="::fwGui::CardinalLayoutManager">
                        <view caption="Rendering 1" align="center" />
                        <view caption="Rendering 2" align="right" minWidth="400"␣
↪minHeight="100" />
                        <view caption="Rendering 3" align="right" minWidth="400"␣
↪minHeight="100" />
                    </layout>
                </gui>
                <registry>
                    <view sid="myRendering1" start="yes" />
                    <view sid="myRendering2" start="yes" />
                    <view sid="myRendering3" start="yes" />
                </registry>
            </service>

            <service uid="myMenuFile" type="::gui::aspect::SDefaultMenu">
                <gui>
                    <layout>
                        <menuItem name="Open file" shortcut="Ctrl+O" />
                        <separator />
                        <menuItem name="Quit" specialAction="QUIT" shortcut="Ctrl+Q" /
↪>
                    </layout>
                </gui>
                <registry>
                    <menuItem sid="actionOpenFile" start="yes" />
                    <menuItem sid="actionQuit" start="yes" />
                </registry>
            </service>

            <service uid="actionOpenFile" type="::gui::action::SStarter">
```

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```
            <start uid="myReaderPathFile" />
        </service>

        <service uid="actionQuit" type="::gui::action::SQuit" />

        <service uid="myReaderPathFile" type="::uiIO::editor::SIOSelector">
            <inout key="data" uid="mesh" />
            <type mode="reader" /><!-- mode is optional (by default it is "reader
↪") -->
        </service>

        <!--
            Visualization services:
            We have three rendering service representing a 3D scene displaying␣
↪the loaded mesh. The scene are
            shown in the windows defines in 'view' service.
        -->
        <service uid="myRendering1" type="::vtkSimpleMesh::SRenderer" autoConnect=
↪"yes" >
            <in key="mesh" uid="mesh" />
        </service>
        <service uid="myRendering2" type="::vtkSimpleMesh::SRenderer" autoConnect=
↪"yes" >
            <in key="mesh" uid="mesh" />
        </service>
        <service uid="myRendering3" type="::vtkSimpleMesh::SRenderer" autoConnect=
↪"yes" >
            <in key="mesh" uid="mesh" />
        </service>

        <!--
            Each 3D scene owns a 3D camera that can be moved by clicking in the␣
↪scene.
            - When the camera move, a signal 'camUpdated' is emitted with the new␣
↪camera information (position,
            focal, view up).
            - To update the camera without clicking, you could call the slot
↪'updateCamPosition'

            Here, we connect each rendering service signal 'camUpdated' to the␣
↪others service slot
            'updateCamPosition', so the cameras are synchronized in each scene.
        -->
        <connect>
            <signal>myRendering1/camUpdated</signal>
            <slot>myRendering2/updateCamPosition</slot>
            <slot>myRendering3/updateCamPosition</slot>
        </connect>

        <connect>
            <signal>myRendering2/camUpdated</signal>
            <slot>myRendering1/updateCamPosition</slot>
            <slot>myRendering3/updateCamPosition</slot>
        </connect>

        <connect>
            <signal>myRendering3/camUpdated</signal>
```

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```
                <slot>myRendering2/updateCamPosition</slot>
                <slot>myRendering1/updateCamPosition</slot>
            </connect>

            <start uid="myFrame" />

        </config>
    </extension>

</plugin>
```

You can also group the signals and all the slots together.

```
<connect>
    <signal>myRenderingTuto1/camUpdated</signal>
    <signal>myRenderingTuto2/camUpdated</signal>
    <signal>myRenderingTuto3/camUpdated</signal>

    <slot>myRenderingTuto1/updateCamPosition</slot>
    <slot>myRenderingTuto2/updateCamPosition</slot>
    <slot>myRenderingTuto3/updateCamPosition</slot>
</proxy>
```

Tip: You can remove a connection to see that a camera in the scene is no longer synchronized.

3.5.3 Signal and slot creation

SRenderer.hpp

```
class VTKSIMPLEMESH_CLASS_API SRenderer : public fwRender::IRender
{
public:
    // .....

    typedef ::boost::shared_array< double > SharedArray;

    typedef ::fwCom::Signal< void (SharedArray, SharedArray, SharedArray) >␣
↪CamUpdatedSignalType;

    // .....

    /// This method is called when the VTK camera position is modified.
    /// It notifies the new camera position.
    void notifyCamPositionUpdated();

protected:
    // ...

    /**
     * @brief Returns proposals to connect service slots to associated object signals,
     * this method is used for obj/srv auto connection
     *
```

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```
     * Connect mesh::s_MODIFIED_SIG to this::s_INIT_PIPELINE_SLOT
     * Connect mesh::s_VERTEX_MODIFIED_SIG to this::s_UPDATE_PIPELINE_SLOT
     */
    VTKSIMPLEMESH_API virtual KeyConnectionsMap getAutoConnections() const override;

private:

    /// Slot: receives new camera information (position, focal, viewUp).
    /// Updates camera with new information.
    void updateCamPosition(SharedArray positionValue,
                           SharedArray focalValue,
                           SharedArray viewUpValue);

    // ....

    /// Signal emitted when camera position is updated.
    CamUpdatedSignalType::sptr m_sigCamUpdated;
}
```

SRenderer.cpp

```
SRenderer::RendererService() noexcept
{
    m_sigCamUpdated = newSignal<CamUpdatedSignalType>("camUpdated");

    newSlot("updateCamPosition", &SRenderer::updateCamPosition, this);
}

//-----------------------------------------------------------------------------

void SRenderer::updateCamPosition(SharedArray positionValue,
                                  SharedArray focalValue,
                                  SharedArray viewUpValue)
{
    vtkCamera* camera = m_render->GetActiveCamera();

    // Update the vtk camera
    camera->SetPosition(positionValue.get());
    camera->SetFocalPoint(focalValue.get());
    camera->SetViewUp(viewUpValue.get());
    camera->SetClippingRange(0.1, 1000000);

    // Render the scene
    m_interactorManager->getInteractor()->Render();
}


//-----------------------------------------------------------------------------

void SRenderer::notifyCamPositionUpdated()
{
    vtkCamera* camera = m_render->GetActiveCamera();

    SharedArray position = SharedArray(new double[3]);
    SharedArray focal    = SharedArray(new double[3]);
```

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```
    SharedArray viewUp    = SharedArray(new double[3]);

    std::copy(camera->GetPosition(), camera->GetPosition()+3, position.get());
    std::copy(camera->GetFocalPoint(), camera->GetFocalPoint()+3, focal.get());
    std::copy(camera->GetViewUp(), camera->GetViewUp()+3, viewUp.get());

    {
        // The Blocker blocks the connection between the "camUpdated" signal and the
        // "updateCamPosition" slot for this instance of service, in order to prevent
        // infinite recursion.
        // The block is released at the end of the scope.
        ::fwCom::Connection::Blocker block(
                            m_sigCamUpdated->getConnection(m_this->slot(
↪"updateCamPosition")));

        // Asynchronous emit of "camUpdated" signal
        m_sigCamUpdated->asyncEmit (position, focal, viewUp);
    }
}

//-----------------------------------------------------------------------------

::fwServices::IService::KeyConnectionsMap SRenderer::getAutoConnections() const
{
    KeyConnectionsMap connections;
    connections.push( s_MESH_KEY, ::fwData::Object::s_MODIFIED_SIG, s_INIT_PIPELINE_
↪SLOT );
    connections.push( s_MESH_KEY, ::fwData::Mesh::s_VERTEX_MODIFIED_SIG, s_UPDATE_
↪PIPELINE_SLOT );
    return connections;
}

//-----------------------------------------------------------------------------

// ......
```

3.5.4 Run

To run the application, you must call the following line into the install or build directory:

```
bin/fwlauncher share/Tuto04SignalSlot-0.1/profile.xml
```

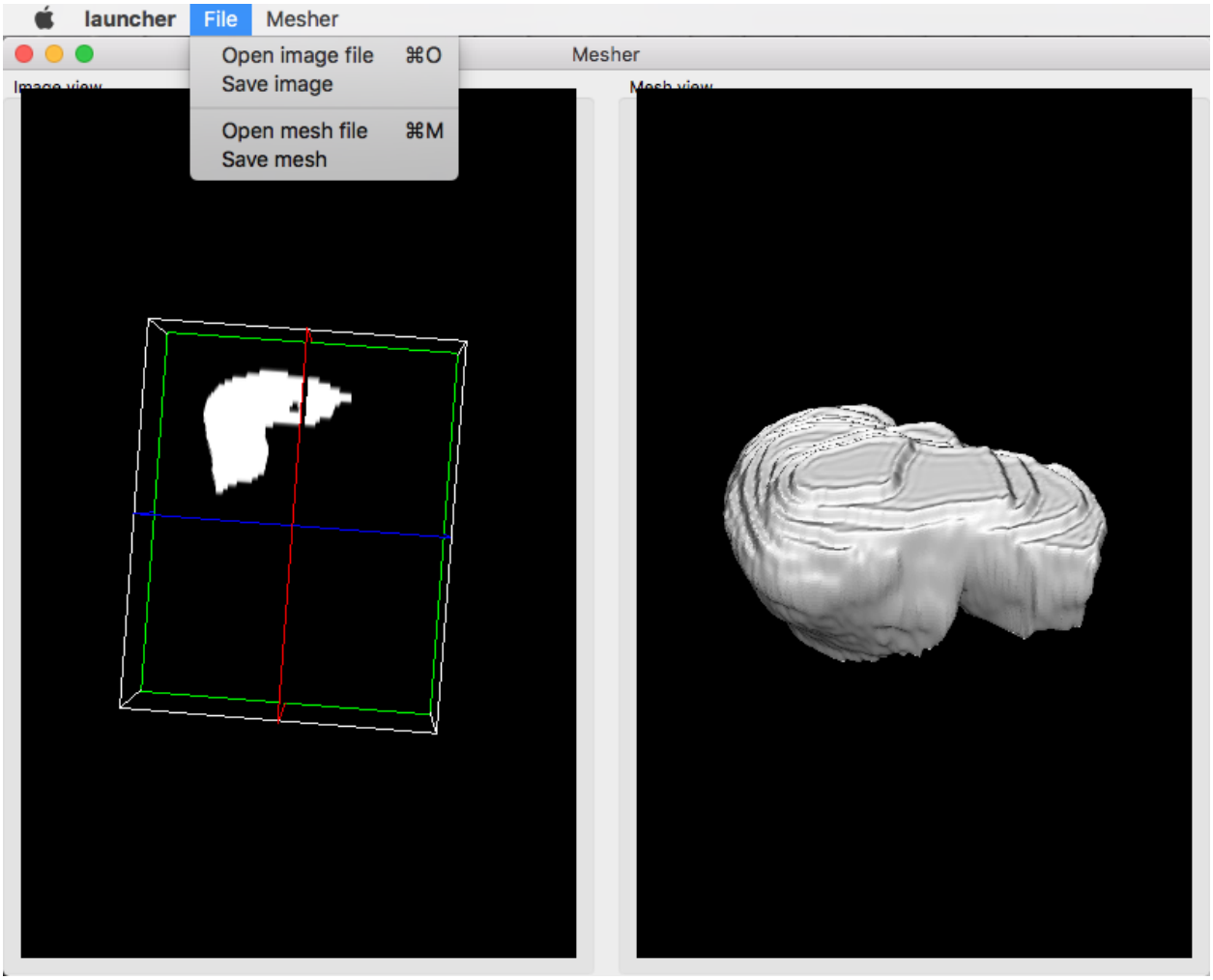
3.6 [*Tuto05Mesher*] Create a mesh from an image

The fifth tutorial explains how to use several objects in an application. This application provides an action to create a mesh from an image mask.

3.6.1 Prerequisites

Before reading this tutorial, you should have seen:

- *[Tuto04SignalSlot] Signal-slot communication*


launcher
File
Mesher
Open image file ⌘O
Save image
Open mesh file ⌘M
Save mesh
Mesher

3.6.2 Structure

Properties.cmake

This file describes the project information and requirements:

```
set( NAME Tuto05Mesher )
set( VERSION 0.1 )
set( TYPE APP )
set( DEPENDENCIES  )
set( REQUIREMENTS
    dataReg
    servicesReg
    gui
    guiQt
    ioVTK
    visuVTKQt
    uiIO
    vtkSimpleNegato
    vtkSimpleMesh
    opVTKMesh # provides services to generate a mesh from an image.
    launcher
    appXml
)

bundleParam(appXml PARAM_LIST config PARAM_VALUES MesherConfig)
```

Note: The Properties.cmake file of the application is used by CMake to compile the application but also to generate the `profile.xml`: the file used to launch the application.

plugin.xml

This file is in the `rc/` directory of the application. It defines the services to run.

```
<plugin id="Tuto05Mesher" version="@PROJECT_VERSION@">

    <requirement id="dataReg" />
    <requirement id="servicesReg" />
    <requirement id="visuVTKQt" />

    <extension implements="::fwServices::registry::AppConfig">
        <id>MesherConfig</id>
        <config>

            <!-- Mesh object associated to the uid 'myMesh' -->
            <object uid="myMesh" type="::fwData::Mesh" />

            <!-- Image object associated to the key 'myImage' -->
            <object uid="myImage" type="::fwData::Image" />

            <!-- Frame & View -->

            <service uid="myFrame" type="::gui::frame::SDefaultFrame">
                <gui>
```

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```
                    <frame>
                        <name>Mesher</name>
                        <icon>Tuto05Mesher-0.1/tuto.ico</icon>
                        <minSize width="800" height="600" />
                    </frame>
                    <menuBar />
                </gui>
                <registry>
                    <menuBar sid="myMenuBar" start="yes" />
                    <view sid="myDefaultView" start="yes" />
                </registry>
            </service>

            <!--
                Default view service:
                The type '::fwGui::LineLayoutManager' represents a layout where the␣
↪view are aligned
                horizontally or vertically (set orientation value 'horizontal' or
↪'vertical').
                It is possible to add a 'proportion' attribute for the <view> to␣
↪defined the proportion
                used by the view compared to the others.
            -->
            <service uid="myDefaultView" type="::gui::view::SDefaultView">
                <gui>
                    <layout type="::fwGui::LineLayoutManager">
                        <orientation value="horizontal" />
                        <view caption="Image view" />
                        <view caption="Mesh view" />
                    </layout>
                </gui>
                <registry>
                    <view sid="RenderingImage" start="yes" />
                    <view sid="RenderingMesh" start="yes" />
                </registry>
            </service>

            <!-- Menu Bar, Menus & Actions -->

            <service uid="myMenuBar" type="::gui::aspect::SDefaultMenuBar">
                <gui>
                    <layout>
                        <menu name="File" />
                        <menu name="Mesher" />
                    </layout>
                </gui>
                <registry>
                    <menu sid="menuFile" start="yes" />
                    <menu sid="menuMesher" start="yes" />
                </registry>
            </service>

            <service uid="menuFile" type="::gui::aspect::SDefaultMenu">
                <gui>
                    <layout>
                        <menuItem name="Open image file" shortcut="Ctrl+O" />
                        <menuItem name="Save image" />
```

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```
                        <separator />
                        <menuItem name="Open mesh file" shortcut="Ctrl+M" />
                        <menuItem name="Save mesh" />
                        <separator />
                        <menuItem name="Quit" specialAction="QUIT" shortcut="Ctrl+Q" /
↪>
                    </layout>
                </gui>
                <registry>
                    <menuItem sid="actionOpenImageFile" start="yes" />
                    <menuItem sid="actionSaveImageFile" start="yes" />
                    <menuItem sid="actionOpenMeshFile" start="yes" />
                    <menuItem sid="actionSaveMeshFile" start="yes" />
                    <menuItem sid="actionQuit" start="yes" />
                </registry>
            </service>

            <service uid="menuMesher" type="::gui::aspect::SDefaultMenu">
                <gui>
                    <layout>
                        <menuItem name="Compute Mesh (VTK)" />
                    </layout>
                </gui>
                <registry>
                    <menuItem sid="actionCreateVTKMesh" start="yes" />
                </registry>
            </service>

            <service uid="actionQuit" type="::gui::action::SQuit" />

            <service uid="actionOpenImageFile" type="::gui::action::SStarter">
                <start uid="readerPathImageFile" />
            </service>

            <service uid="actionSaveImageFile" type="::gui::action::SStarter">
                <start uid="writerImageFile" />
            </service>

            <service uid="actionOpenMeshFile" type="::gui::action::SStarter">
                <start uid="readerPathMeshFile" />
            </service>

            <service uid="actionSaveMeshFile" type="::gui::action::SStarter">
                <start uid="writerMeshFile" />
            </service>

            <service uid="actionCreateVTKMesh" type=
↪"::opVTKMesh::action::SMeshCreation">
                <in key="image" uid="myImage" />
                <inout key="mesh" uid="myMesh" />
                <percentReduction value="0" />
            </service>

            <!-- Add a shortcut in the application (key "v") -->
            <service uid="ActionShortcut" type="::guiQt::SSignalShortcut">
                <config shortcut="v" sid="myDefaultView" />
            </service>
```

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```
            <!--
                Services associated to the Image data :
                Visualization, reading and writing service creation.
            -->
            <service uid="RenderingImage" type="::vtkSimpleNegato::SRenderer"␣
↪autoConnect="yes" >
                <in key="image" uid="myImage" />
            </service>

            <service uid="readerPathImageFile" type="::uiIO::editor::SIOSelector">
                <inout key="data" uid="myImage" />
                <type mode="reader" />
            </service>

            <service uid="writerImageFile" type="::uiIO::editor::SIOSelector">
                <inout key="data" uid="myImage" />
                <type mode="writer" />
            </service>

            <!--
                Services associated to the Mesh data :
                Visualization, reading and writing service creation.
            -->
            <service uid="RenderingMesh" type="::vtkSimpleMesh::SRenderer"␣
↪autoConnect="yes" >
                <in key="mesh" uid="myMesh" />
            </service>

            <service uid="readerPathMeshFile" type="::uiIO::editor::SIOSelector">
                <inout key="data" uid="myMesh" />
                <type mode="reader" />
            </service>

            <service uid="writerMeshFile" type="::uiIO::editor::SIOSelector">
                <inout key="data" uid="myMesh" />
                <type mode="writer" />
            </service>

            <!-- Connect the shortcut "v" to the update slot of 'actionCreateVTKMesh'-
↪->
            <connect>
                <signal>ActionShortcut/activated</signal>
                <slot>actionCreateVTKMesh/update</slot>
            </connect>

            <start uid="myFrame" />
            <start uid="ActionShortcut" />

        </config>
    </extension>
</plugin>
```

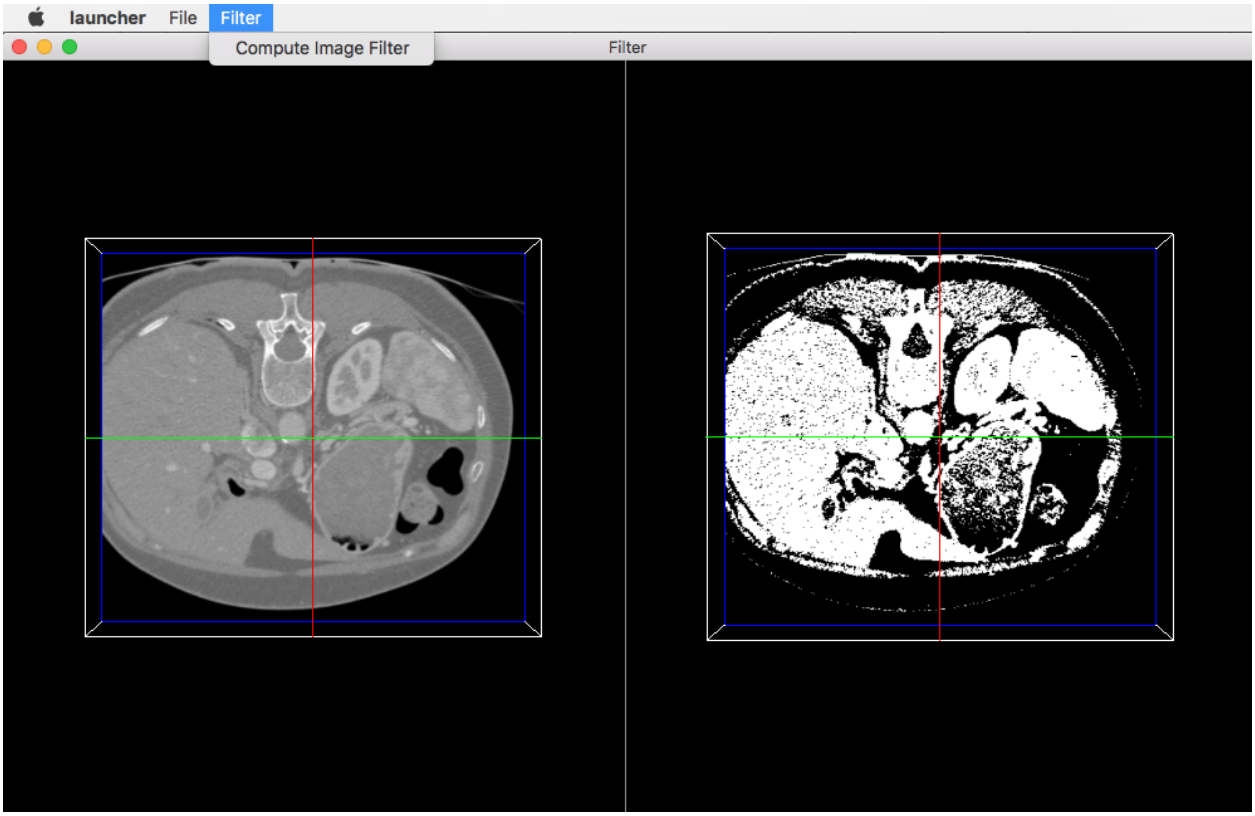
3.6.3 Run

To run the application, you must call the following line into the install or build directory:

```
bin/fwlauncher share/Tuto05Mesher_0-1/profile.xml
```

3.7 [*Tuto06Filter*] Apply a filter on an image

This tutorial explains how to perform a filter on an image. Here, the filter applied on the image is a threshold.



3.7.1 Prerequisites

Before reading this tutorial, you should have seen :

- *[Tuto05Mesher] Create a mesh from an image*

3.7.2 Structure

Properties.cmake

This file describes the project information and requirements :

```
set( NAME Tuto06Filter )
set( VERSION 0.1 )
set( TYPE APP )
set( DEPENDENCIES  )
set( REQUIREMENTS
```

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```
    dataReg
    servicesReg
    gui
    guiQt
    ioVTK
    uiIO
    visuVTKQt
    vtkSimpleNegato
    opImageFilter # bundle containing the action to performs a threshold
    launcher
    appXml
)

bundleParam(appXml PARAM_LIST config PARAM_VALUES FilterConfig)
```

Note: The Properties.cmake file of the application is used by CMake to compile the application but also to generate the `profile.xml`: the file used to launch the application.

plugin.xml

This file is in the `rc/` directory of the application. It defines the services to run.

```
<plugin id="Tuto06Filter" version="@PROJECT_VERSION@">

    <requirement id="dataReg" />
    <requirement id="servicesReg" />
    <requirement id="visuVTKQt" />

    <extension implements="::fwServices::registry::AppConfig">
        <id>FilterConfig</id>
        <config>

            <object uid="myImage1" type="::fwData::Image" />
            <object uid="myImage2" type="::fwData::Image" />

            <!-- Windows & Main Menu -->
            <service uid="myFrame" type="::gui::frame::SDefaultFrame">
                <gui>
                    <frame>
                        <name>Filter</name>
                        <icon>Tuto06Filter-0.1/tuto.ico</icon>
                        <minSize width="720" height="600" />
                    </frame>
                    <menuBar />
                </gui>
                <registry>
                    <menuBar sid="myMenuBar" start="yes" />
                    <view sid="myDefaultView" start="yes" />
                </registry>
            </service>

            <service uid="myMenuBar" type="::gui::aspect::SDefaultMenuBar">
                <gui>
```

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```
                <layout>
                    <menu name="File" />
                    <menu name="Filter" />
                </layout>
            </gui>
            <registry>
                <menu sid="menuFile" start="yes" />
                <menu sid="menuFilter" start="yes" />
            </registry>
        </service>

        <service uid="myDefaultView" type="::gui::view::SDefaultView">
            <gui>
                <layout type="::fwGui::CardinalLayoutManager">
                    <view align="center" />
                    <view align="right" minWidth="500" minHeight="100" />
                </layout>
            </gui>
            <registry>
                <view sid="RenderingImage1" start="yes" />
                <view sid="RenderingImage2" start="yes" />
            </registry>
        </service>

        <!-- Menus -->
        <service uid="menuFile" type="::gui::aspect::SDefaultMenu">
            <gui>
                <layout>
                    <menuItem name="Open image file" shortcut="Ctrl+O" />
                    <separator />
                    <menuItem name="Quit" specialAction="QUIT" shortcut="Ctrl+Q" /
↪>
                </layout>
            </gui>
            <registry>
                <menuItem sid="actionOpenImageFile" start="yes" />
                <menuItem sid="actionQuit" start="yes" />
            </registry>
        </service>

        <service uid="menuFilter" type="::gui::aspect::SDefaultMenu">
            <gui>
                <layout>
                    <menuItem name="Compute Image Filter" />
                </layout>
            </gui>
            <registry>
                <menuItem sid="actionImageFilter" start="yes" />
            </registry>
        </service>

        <!-- Actions -->
        <service uid="actionQuit" type="::gui::action::SQuit" />
        <service uid="actionOpenImageFile" type="::gui::action::SStarter" >
            <start uid="readerPathImageFile" />
        </service>
```

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```
            <!--
                Filter action:
                This action applies a threshold filter. The source image is 'myImage1
↪' and the
                output image is 'myImage2'.
                The two images are declared below.
             -->
            <service uid="actionImageFilter" type="::opImageFilter::action::SThreshold
↪">
                <in key="source" uid="myImage1" />
                <inout key="target" uid="myImage2" />
            </service>

            <!-- Image declaration: -->

            <!--
                1st Image of the composite:
                This is the source image for the filtering.
            -->
            <service uid="RenderingImage1" type="::vtkSimpleNegato::SRenderer"␣
↪autoConnect="yes" >
                <in key="image" uid="myImage1" />
            </service>

            <service uid="readerPathImageFile" type="::uiIO::editor::SIOSelector">
                <inout key="data" uid="myImage1" />
                <type mode="reader" />
            </service>

            <!--
                2nd Image of the composite:
                This is the output image for the filtering.
            -->
            <service uid="RenderingImage2" type="::vtkSimpleNegato::SRenderer"␣
↪autoConnect="yes" >
                <in key="image" uid="myImage2" />
            </service>

            <start uid="myFrame" />

        </config>
    </extension>
</plugin>
```

Filter service

Here, the filter service is inherited from `::fwGui::IActionSrv`, which allows to use this service as an action, in this case as a button. The member function `updating()` is called when clicking on the button. However you can inherit from another type (like `::arServices::IOperator` in fw4spl-ar repository) if you do not need this behavior.

This `updating()` function retrieves the two images and applies the threshold algorithm.

The `::fwData::Image` contains a buffer for pixel values, it is stored as a `void *` to allows several types of pixel (uint8, int8, uint16, int16, double, float ...). To use the image buffer, we need to cast it to the image pixel type. For that, we use the `::fwTools::Dispatcher` class which it allows to invoke a template functor according to the

image type. This is particularly useful when using template based libraries like ITK.

```
void SThreshold::updating() throw ( ::fwTools::Failed )
{
    SLM_TRACE_FUNC();

    // threshold value: the pixel with the value less than 50 will be set to 0, else␣
↪the value is set to the maximum
    // value of the image pixel type.
    const double threshold = 50.0;

    ThresholdFilter::Parameter param; // filter parameters: threshold value, image␣
↪source, image target

    // Get source image
    param.imageIn = this->getInput< ::fwData::Image >("source");
    SLM_ASSERT("'source' key not found", param.imageIn);

    // Get target image
    param.imageOut = this->getInOut< ::fwData::Image >("target");
    SLM_ASSERT("'target' key not found", param.imageOut);

    param.thresholdValue = threshold;

    /*
     * The dispatcher allows to apply the filter on any type of image.
     * It invokes the template functor ThresholdFilter using the image type.
     */
    ::fwTools::DynamicType type = param.imageIn->getPixelType(); // image type

    // Invoke filter functor
    ::fwTools::Dispatcher< ::fwTools::IntrinsicTypes, ThresholdFilter >::invoke( type,
↪ param );

    // Notify that the image target is modified
    auto sig = param.imageOut->signal< ::fwData::Object::ModifiedSignalType >
↪(::fwData::Object::s_MODIFIED_SIG);
    {
        ::fwCom::Connection::Blocker block(sig->getConnection(m_slotUpdate));
        sig->asyncEmit();
    }
}
```

The functor is a *structure* containing a *sub-structure* for the parameters (inputs and outputs) and a template method `operator(parameters)`.

```
/**
 * Functor to apply a threshold filter.
 *
 * The pixel with the value less than the threshold value will be set to 0, else the␣
↪value is set to the maximum
 * value of the image pixel type.
 *
 * The functor provides a template method operator(param) to apply the filter
 */
struct ThresholdFilter
{
    struct Parameter
```

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```
    {
        double thresholdValue; ///< threshold value.
        ::fwData::Image::csptr imageIn; ///< image source
        ::fwData::Image::sptr imageOut; ///< image target: contains the result of the␣
↪filter
    };

    /**
     * @brief Applies the filter
     * @tparam PIXELTYPE image pixel type (uint8, uint16, int8, int16, float, double,␣
↪....)
     */
    template<class PIXELTYPE>
    void operator()(Parameter &param)
    {
        const PIXELTYPE thresholdValue = static_cast<PIXELTYPE>(param.thresholdValue);
        ::fwData::Image::csptr imageIn = param.imageIn;
        ::fwData::Image::sptr imageOut = param.imageOut;
        SLM_ASSERT("Sorry, image must be 3D", imageIn->getNumberOfDimensions() == 3 );
        imageOut->copyInformation(imageIn); // Copy image size, type... without␣
↪copying the buffer
        imageOut->allocate(); // Allocate the image buffer

        ::fwDataTools::helper::ImageGetter imageInHelper(imageIn); // helper used to␣
↪access the image source buffer
        ::fwDataTools::helper::Image imageOutHelper(imageOut); // helper used to␣
↪access the image target buffer

        // Get image buffers
        const PIXELTYPE* buffer1 = (PIXELTYPE*)imageInHelper.getBuffer();
        PIXELTYPE* buffer2       = (PIXELTYPE*)imageOutHelper.getBuffer();

        // Get number of pixels
        const size_t NbPixels = imageIn->getSize()[0] * imageIn->getSize()[1] *␣
↪imageIn->getSize()[2];

        // Fill the target buffer considering the thresholding
        for( size_t i = 0; i<NbPixels; ++i, ++buffer1, ++buffer2 )
        {
            * buffer2 = ( *buffer1 < thresholdValue ) ? 0 : std::numeric_limits
↪<PIXELTYPE>::max();
        }
    }
};
```

3.7.3 Run

To run the application, you must call the following line into the install or build directory:

```
bin/fwlauncher share/Tuto06Filter-0.1/profile.xml
```

3.8 [*Tuto08GenericScene*] Generic scene

This tutorial explains how to use the generic scene.

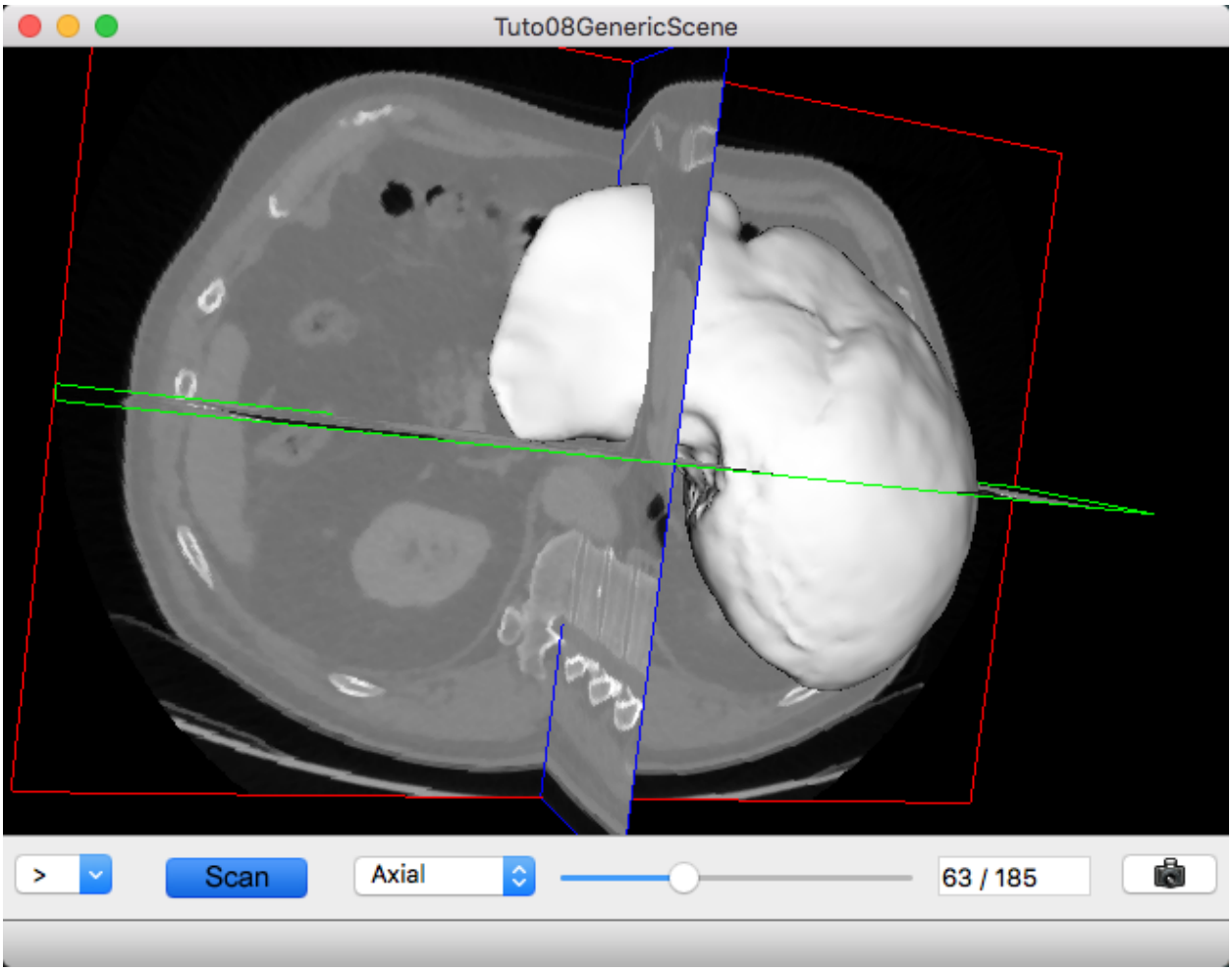

Fig. 1: Image and mesh

3.8.1 Prerequisites

Before reading this tutorial, you should have seen :

- *Generic Scene*
- *[Tuto06Filter] Apply a filter on an image*

3.8.2 Structure

Properties.cmake

This file describes the project information and requirements :

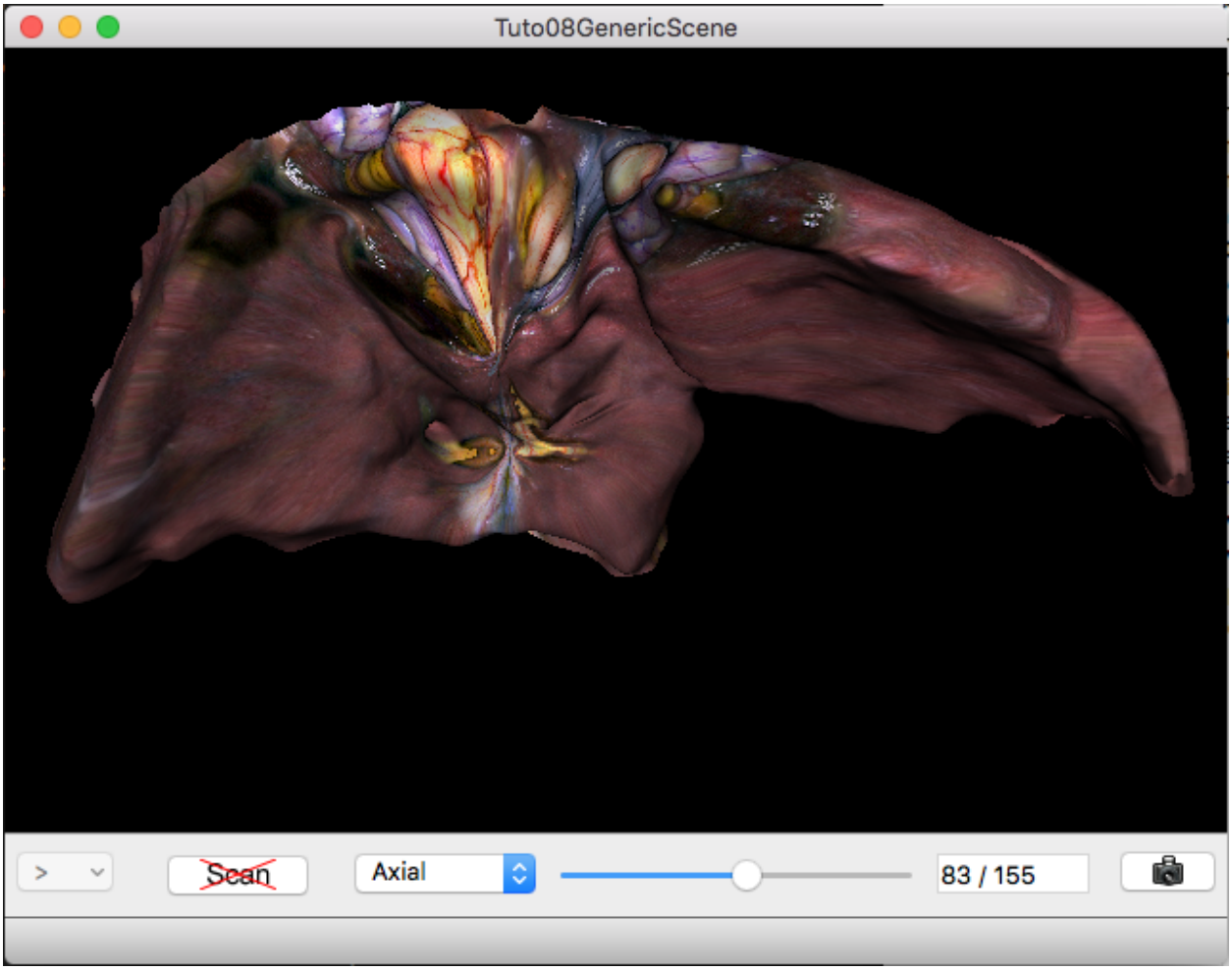

Fig. 2: Mesh with texture

```
set( NAME Tuto08GenericScene )
set( VERSION 0.1 )
set( TYPE APP )
set( UNIQUE TRUE )
set( DEPENDENCIES  )
set( REQUIREMENTS
    dataReg
    servicesReg
    gui
    guiQt
    ioData # contains reader/writer for mesh (.trian) or matrix (.trf)
    ioVTK
    uiIO
    uiVisuQt # contains several editors for visualization
    uiImageQt # contains several editors on image
    visuVTKQt
    visuVTKAdaptor # contains adaptors for the generic scene
    ctrlSelection # contains services to manage object selection (and associated␣
↪services)
    launcher
    appXml
)

bundleParam(appXml PARAM_LIST config PARAM_VALUES Tuto08GenericScene)
```

Note: The Properties.cmake file of the application is used by CMake to compile the application but also to generate the `profile.xml`: the file used to launch the application.

plugin.xml

This file is in the `rc/` directory of the application. It defines the services to run.

```
<!--
    This tutorial shows a VTK scene containing a 3D image and a textured mesh.
    To use this application, you should open a 3D image, a mesh and/or a 2D texture␣
↪image.
-->
<plugin id="Tuto08GenericScene" version="@PROJECT_VERSION@">
    <requirement id="dataReg" />
    <requirement id="servicesReg" />
    <requirement id="visuVTKQt" />
    <extension implements="::fwServices::registry::AppConfig">
        <id>Tuto08GenericScene</id>
        <config>
            <object uid="imageUID" type="::fwData::Image" />
            <object uid="meshUID" type="::fwData::Mesh" />
            <object uid="textureUID" type="::fwData::Image" />
            <service uid="ihm" type="::gui::frame::SDefaultFrame">
                <gui>
                    <frame>
                        <name>Tuto08GenericScene</name>
                        <icon>Tuto08GenericScene-0.1/tuto.ico</icon>
                    </frame>
                    <menuBar/>
```

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```
            </gui>
            <registry>
                <menuBar sid="menuBar" start="yes" />
                <view sid="mainView" start="yes" />
            </registry>
        </service>

        <!-- Status bar used to display the progress bar for reading -->
        <service uid="progressBar" type="::gui::editor::SJobBar" />
        <service uid="menuBar" type="::gui::aspect::SDefaultMenuBar">
            <gui>
                <layout>
                    <menu name="File" />
                </layout>
            </gui>
            <registry>
                <menu sid="menuFile" start="yes" />
            </registry>
        </service>

        <service uid="menuFile" type="::gui::aspect::SDefaultMenu">
            <gui>
                <layout>
                    <menuItem name="Open image" shortcut="Ctrl+I" />
                    <menuItem name="Open mesh" shortcut="Ctrl+M" />
                    <menuItem name="Open texture" shortcut="Ctrl+T" />
                    <separator/>
                    <menuItem name="Quit" specialAction="QUIT" shortcut="Ctrl+Q" /
↪>
                </layout>
            </gui>
            <registry>
                <menuItem sid="actionOpenImage" start="yes" />
                <menuItem sid="actionOpenMesh" start="yes" />
                <menuItem sid="actionOpenTexture" start="yes" />
                <menuItem sid="actionQuit" start="yes" />
            </registry>
        </service>

        <!-- Actions to call readers -->
        <service uid="actionOpenImage" type="::gui::action::SStarter">
            <start uid="imageReader" />
        </service>

        <service uid="actionOpenMesh" type="::gui::action::SStarter">
            <start uid="meshReader" />
        </service>

        <service uid="actionOpenTexture" type="::gui::action::SStarter">
            <start uid="textureReader" />
        </service>

        <!-- Quit action -->
        <service uid="actionQuit" type="::gui::action::SQuit" />
        <!-- main view -->
        <service uid="mainView" type="::gui::view::SDefaultView">
            <gui>
```

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```
                    <layout type="::fwGui::CardinalLayoutManager">
                        <view align="center" />
                        <view align="bottom" minWidth="400" minHeight="30" resizable=
↪"no" />
                    </layout>
                </gui>
                <registry>
                    <view sid="genericScene" start="yes" />
                    <view sid="editorsView" start="yes" />
                </registry>
            </service>

            <!-- View for editors to update image visualization -->
            <service uid="editorsView" type="::gui::view::SDefaultView">
                <gui>
                    <layout type="::fwGui::LineLayoutManager">
                        <orientation value="horizontal" />
                        <view proportion="0" minWidth="30" />
                        <view proportion="0" minWidth="50" />
                        <view proportion="1" />
                        <view proportion="0" minWidth="30" />
                    </layout>
                </gui>
                <registry>
                    <view sid="sliceListEditor" start="yes" />
                    <view sid="showScanEditor" start="yes" />
                    <view sid="sliderIndexEditor" start="yes" />
                    <view sid="snapshotScene1Editor" start="yes" />
                </registry>
            </service>

            <!--
                Editor used for scene snapshot:
                It allows to select the snapshot filename and emits a "snapped"␣
↪signal with this path.
            -->
            <service uid="snapshotScene1Editor" type="::uiVisuQt::SnapshotEditor" />

            <!--
                Generic scene:
                This scene displays a 3D image and a textured mesh.
            -->
            <!-- ************************** Begin generic scene␣
↪************************** -->

            <service uid="genericScene" type="::fwRenderVTK::SRender" autoConnect="yes
↪">
                <scene>
                    <!-- Image picker -->
                    <picker id="myPicker" vtkclass="fwVtkCellPicker" />
                    <!-- Renderer -->
                    <renderer id="default" background="0.0" />

                    <!-- adaptor displayed in the scene -->
                    <adaptor uid="meshAdaptor" />
                    <adaptor uid="textureAdaptor" />
                    <adaptor uid="imageAdaptor" />
```

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```
                    <adaptor uid="snapshotAdaptor" />
                </scene>
            </service>

            <!-- Mesh adaptor -->
            <service uid="meshAdaptor" type="::visuVTKAdaptor::SMesh" autoConnect="yes
↪">
                <in key="mesh" uid="meshUID" />
                <config renderer="default" picker="" uvgen="sphere" />
            </service>

            <!-- Texture adaptor, used by mesh adaptor -->
            <service uid="textureAdaptor" type="::visuVTKAdaptor::STexture"␣
↪autoConnect="yes">
                <inout key="texture" uid="textureUID" />
                <config renderer="default" picker="" filtering="linear" wrapping=
↪"repeat" />
            </service>

            <!-- 3D image negatoscope adaptor -->
            <service uid="imageAdaptor" type="::visuVTKAdaptor::SNegatoMPR"␣
↪autoConnect="yes">
                <inout key="image" uid="imageUID" />
                <config renderer="default" picker="myPicker" mode="3d" slices="3"␣
↪sliceIndex="axial" />
            </service>

            <!-- Snapshot adaptor: creates a snapshot of the scene. It has a slot
↪"snap" that receives a path -->
            <service uid="snapshotAdaptor" type="::visuVTKAdaptor::SSnapshot">
                <config renderer="default" />
            </service>

            <!-- ************************** End generic scene␣
↪************************** -->

            <!-- ***********************************************
                            Displayed objects
                ********************************************** -->
            <!-- Image displayed in the scene -->
            <service uid="imageReader" type="::uiIO::editor::SIOSelector">
                <inout key="data" uid="imageUID" />
                <type mode="reader" />
            </service>

            <!--
                Generic editor representing a menu button.
                It sends a signal with the current selected item.
            -->
            <service uid="sliceListEditor" type="::guiQt::editor::SSelectionMenuButton
↪">
                <toolTip>Manage slice visibility</toolTip><!-- button tooltip -->
                <selected>3</selected><!-- Default selection -->
                <items>
                    <item text="One slice" value="1" /><!-- first item, if selected␣
↪the emitted value is "1" -->
                    <item text="three slices" value="3" /><!-- second item, if␣
↪selected the emitted value is "1" -->
```

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```
            </items>
        </service>

        <!--
            Generic editor representing a simple button with an icon.
            The button can be checkable. In this case it can have a second icon.
            - It emits a signal "clicked" when it is clicked.
            - It emits a signal "toggled" when it is checked/unchecked.

            Here, this editor is used to show or hide the image. It is connected␣
↪to the image adaptor.
        -->
        <service uid="showScanEditor" type="::guiQt::editor::SSignalButton">
            <config>
                <checkable>true</checkable>
                <icon>media-0.1/icons/sliceHide.png</icon>
                <icon2>media-0.1/icons/sliceShow.png</icon2>
                <iconWidth>40</iconWidth>
                <iconHeight>16</iconHeight>
                <checked>true</checked>
            </config>
        </service>

        <!-- Editor representing a slider to navigate into image slices -->
        <service uid="sliderIndexEditor" type=
↪"::uiImageQt::SliceIndexPositionEditor" autoConnect="yes">
            <inout key="image" uid="imageUID" />
            <sliceIndex>axial</sliceIndex>
        </service>

        <!-- texture reader -->
        <service uid="textureReader" type="::uiIO::editor::SIOSelector">
            <inout key="data" uid="textureUID" />
            <type mode="reader" />
        </service>

        <!-- Mesh reader -->
        <service uid="meshReader" type="::uiIO::editor::SIOSelector">
            <inout key="data" uid="meshUID" />
            <type mode="reader" />
        </service>

        <!-- Connects readers to status bar service -->
        <connect>
            <signal>meshReader/jobCreated</signal>
            <slot>progressBar/showJob</slot>
        </connect>

        <connect>
            <signal>imageReader/jobCreated</signal>
            <slot>progressBar/showJob</slot>
        </connect>

        <connect>
            <signal>textureReader/jobCreated</signal>
            <slot>progressBar/showJob</slot>
        </connect>
```

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```
            <!--
                Connects showScanEditor signal "toggled" to sliceListEditor slot
↪"setEnable", this signal and slot
                contains a boolean, so the sliceListEditor can be disabled when the␣
↪image is not displayed.
            -->
            <connect>
                <signal>showScanEditor/toggled</signal>
                <slot>sliceListEditor/setEnabled</slot>
            </connect>

            <!--
                Connection for snapshot:
                connect the editor signal "snapped" to the adaptor slot "snap"
            -->
            <connect>
                <signal>snapshotScene1Editor/snapped</signal>
                <slot>snapshotAdaptor/snap</slot>
            </connect>

            <!--
                Connection for 3D image slice:
                Connect the button (showScanEditor) signal "toggled" to the image␣
↪adaptor (SNegatoMPR)
                slot "showSlice", this signals/slots contains a boolean.
                The image slices will be shown or hidden when the button is checked/
↪unchecked.
            -->
            <connect>
                <signal>showScanEditor/toggled</signal>
                <slot>imageAdaptor/showSlice</slot>
            </connect>

            <!--
                Connection for 3D image slice:
                Connect the menu button (sliceListEditor) signal "selected" to the␣
↪image adaptor
                (SNegatoMPR) slot "updateSliceMode", this signals/slots contains an␣
↪integer.
                This integer defines the number of slice to show (0, 1 or 3).
            -->
            <connect>
                <signal>sliceListEditor/selected</signal>
                <slot>imageAdaptor/updateSliceMode</slot>
            </connect>

            <!--
                Connection for texture:
                The texture will be applied on the mesh when the mesh adaptor is␣
↪started.
            -->
            <connect>
                <signal>meshAdaptor/textureApplied</signal>
                <slot>textureAdaptor/applyTexture</slot>
            </connect>
```

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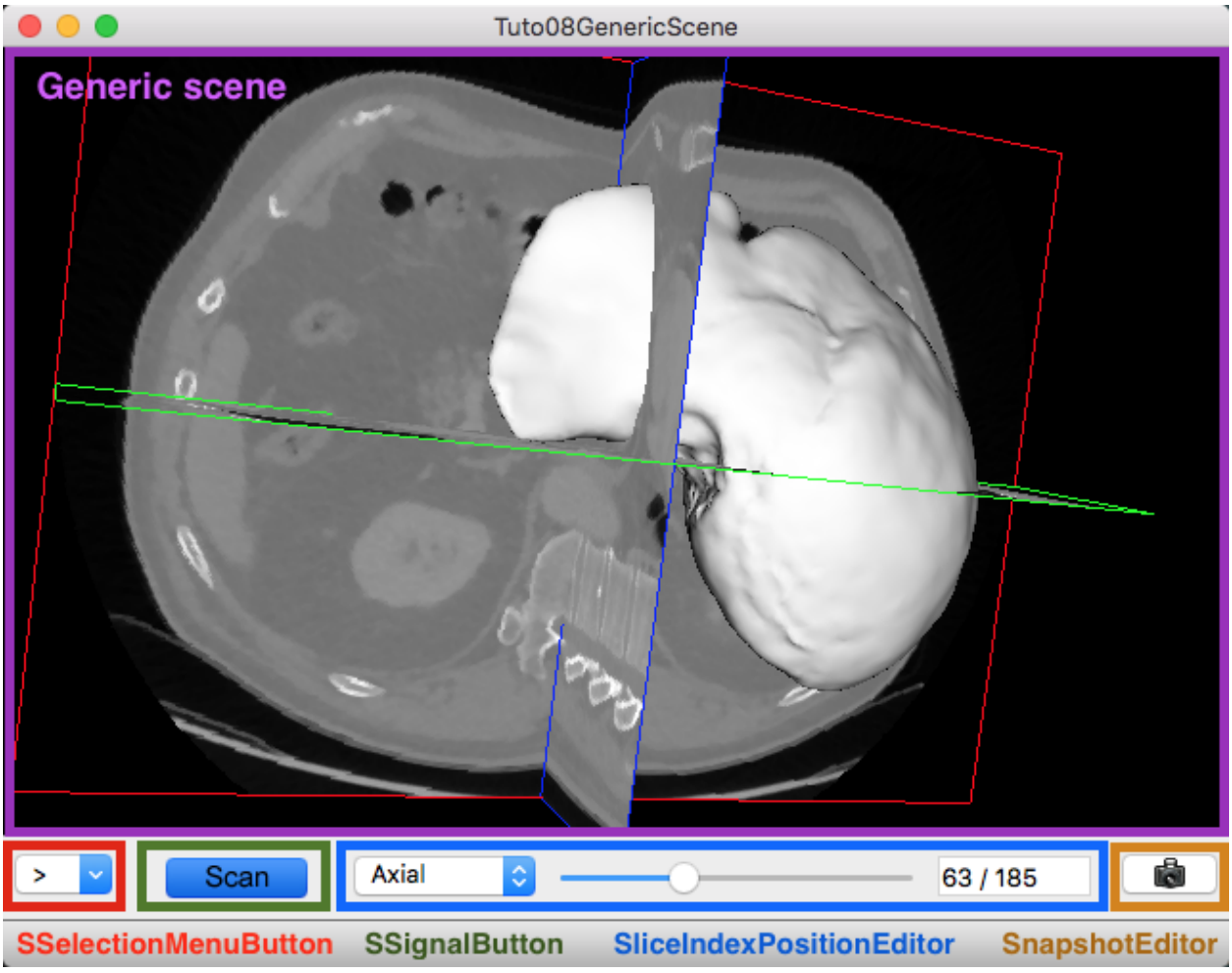
```
            <start uid="ihm" />
            <start uid="progressBar" />

            <!-- genericScene adaptors-->
            <start uid="meshAdaptor" />
            <start uid="textureAdaptor" />
            <start uid="imageAdaptor" />
            <start uid="snapshotAdaptor" />
        </config>
    </extension>
</plugin>
```

GUI

This tutorials use multiple editors to manage the image rendering:

- show/hide image slices
- navigate between the image slices
- snapshot

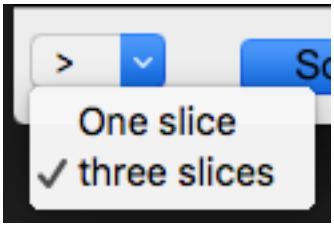


The two editors (`SSelectionMenuButton` and `SSignalButton`) are generic, so we need to configure their behaviour in the xml file.

The editor aspect is defined in the service configuration. They emit signals that must be manually connected to the scene adaptor.

SSelectionMenuButton

This editor displays a menu when the user click on the button. Then the user can select one item.




```
<service uid="selectionMenuButton" impl="::guiQt::editor::SSelectionMenuButton">
    <text>...</text>
    <toolTip>...</toolTip>
    <items>
        <item text="One" value="1" />
        <item text="Two" value="2" />
        <item text="Six" value="6" />
    </items>
    <selected>2</selected>
</service>
```

text (optional, default ">") Text displayed on the button

toolTip (optional) Button tool tip

items List of the menu items

item One item

text The text displayed in the menu

value The value emitted when the item is selected

selected The value of the item selected by default

When the user selects an item, a signal is emitted: the signal is `selected(int selection)`. It sends the value of the selected item.

In our case, we want to change the number of image slices displayed in the scene. So, we need to connect this signal to the image adaptor slot `updateSliceMode(int nbSlice)`.

```
<connect>
    <signal>selectionMenuButton/selected</signal>
    <slot>imageAdaptor/updateSliceMode</slot>
</connect>
```

SSignalButton

This editor shows a simple button.

```
<service uid="signalButton" impl="::guiQt::editor::SSignalButton" >
    <config>
        <checkable>true|false</checkable>
        <text>...</text>
        <icon>...</icon>
        <text2>...</text2>
        <icon2>...</icon2>
        <checked>true|false</checked>
        <iconWidth>...</iconWidth>
        <iconHeight>...</iconHeight>
    </config>
</service>
```

text (optional) Text displayed on the button

icon (optional) Icon displayed on the button

checkable (optional, default: false) If true, the button is checkable

text2 (optional) Text displayed if the button is checked

icon2 (optional) Icon displayed if the button is checked

checked (optional, default: false) If true, the button is checked at start

iconWidth (optional) Icon width

iconHeight (optional) Icon height

This editor provides two signals:

clicked() Emitted when the user click on the button.

toggled(bool checked) Emitted when the button is checked or unchecked.

In our case, we want to show (or hide) the image slices when the button is checked (or unckecked). So, we need to connect the `toogled` signal to the image adaptor slot `showSlice(bool show)`.

```
<connect>
    <signal>signalButton/toggled</signal>
    <slot>imageAdaptor/showSlice</slot>
</connect>
```

3.8.3 Run

To run the application, you must call the following line into the install or build directory:

```
bin/fwlauncher share/Tuto08GenericScene-0.1/profile.xml
```

CHAPTER 4

How-Tos

4.1 How to use CMake with fw4spl ?

4.1.1 Introduction

Fw4spl and its dependencies are built with CMake . Note that the minimal version of cmake to have is 3.9.

Each project (apps, bundles, libs) has two "CMake" files:

- *CMakeLists.txt*
- *Properties.cmake*

4.1.2 CMakeLists.txt

The *CMakeLists.txt* should contain at least the function *fwLoadProperties()* to load the Properties.cmake. But it can also contain others functions useful to link with external libraries.

Here is an example of CMakeLists.txt from guiQt Bundle :

```
fwLoadProperties()

find_package(Qt5 COMPONENTS Core Gui Widgets REQUIRED)


fwInclude(
    ${Qt5Core_INCLUDE_DIRS}
    ${Qt5Gui_INCLUDE_DIRS}
    ${Qt5Widgets_INCLUDE_DIRS}
)

fwLink(
       ${Qt5Core_LIBRARIES}
       ${Qt5Gui_LIBRARIES}
```

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```
        ${Qt5Widgets_LIBRARIES}
)

set_target_properties(${FWPROJECT_NAME} PROPERTIES AUTOMOC TRUE)
```

The first line *fwLoadProperties()* will load the *Properties.cmake* (see explanation in the next section).

The next lines allows to compile with the support of some external libraries (fw4spl-deps), in this example this is Qt. The first thing to do is to discover where Qt is installed. This is done with the regular CMake command `find_package(The_lib COMPONENTS The_component)`. Then we use `fwInclude` to add includes directories to the target, and `fwLink` to link the libraries with your target. Actually if you're accustomed to CMake these two macros are strictly equivalent to:

```
target_include_directories( ${FWPROJECT_NAME} SYSTEM PRIVATE ${Qt5Core_INCLUDE_DIRS} $
↪{Qt5Gui_INCLUDE_DIRS} ${Qt5Widgets_INCLUDE_DIRS} )
target_link_libraries( ${FWPROJECT_NAME} PRIVATE ${Qt5Core_LIBRARIES} ${Qt5Gui_
↪LIBRARIES} ${Qt5Widgets_LIBRARIES} )
```

They are proposed as a convenience so people won't forget for instance to specify *SYSTEM*, which prevents compilation warnings from third-part libraries to be displayed. If the rare case where your bundle may be a dependency of an another one, you can forward the include directories and the libraries with `fwForwardInclude` and `fwForwardLink`, which are still equivalent to `target_include_directories` and `target_link_libraries` CMake commands but with `PUBLIC` set instead of `PRIVATE`.

Eventually, you can also add custom properties to your target with `set_target_properties`.

4.1.3 Properties.cmake

Properties.cmake should contain informations like name, version, dependencies and requirements of the current target.

Here is an example of Properties.cmake from `fwData` library:

```
set( NAME fwData )
set( VERSION 0.1 )
set( TYPE LIBRARY )
set( DEPENDENCIES fwCom fwMemory fwTools )
set( REQUIREMENTS  )
```

NAME: Name of the target

VERSION: Version of the target

TYPE: Define the type of the target:

- APP for an "Application"
- BUNDLE for a "bundle"
- LIBRARY for a "library"
- EXECUTABLE for an executable

DEPENDENCIES: Link the target with the given libraries (see target_link_libraries). The DEPENDENCIES should contain only "library".

REQUIREMENTS: Ensure that the dependencies are built before the targets (see add_dependencies). The REQUIREMENTS should contain only "bundles".

In some Properties.cmake (mostly in applications), you can see the line:

```
bundleParam(appXml PARAM_LIST config PARAM_VALUES tutoBasicConfig)
```

This CMake macro allows to give parameters to a bundle. The parameters are defined like:

```
bundleParam(<bundle>
            PARAM_LIST <param1_name> <param2_name> <param3_name>
            PARAM_VALUES <param1_value> <param2_value> <param3_value>
            )
```

These parameters can be retrieved in the `Plugin.cpp` like:

```
void Plugin::start()
{
    if( this->getBundle()->hasParameter("param1_name") )
    {
        const std::string param1Value = this->getBundle()->getParameterValue("param1_
↪name");
    }
    if( this->getBundle()->hasParameter("param2_name") )
    {
        const std::string param2Value = this->getBundle()->getParameterValue("param2_
↪name");
    }
    // ...
}
```

For the application, this macro defines the main configuration to launch when the application is started.

4.2 How to create a service ?

4.2.1 Implementation

A service is a C++ class inherited from `::fwServices::IService`. It will implement at least the following methods:

- `configuring()`: parses the configuration (usually from the XML)
- `starting()`: initializes the service (creates the gui, retrieves/initializes the data, ...)
- `updating()`: processes
- `stopping()`: clears all (clears the gui, releases the data, ...)

These methods are called by the *configure()*, *start()*, *update()* and *stop()* slots of the base class `IService`.

For the example, we will create a service `SMesher` in a bundle `operators`. The service will have a `::fwData::Image` as input and a `::fwData::Mesh` as output.

The header file `SMesher.hpp` should be in the folder `<src_dir>/bundles/operators/include/operators`:

```
#pragma once

#include "operators/config.hpp"

#include <fwServices/IOperator.hpp>

```

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```
namespace operators
{

/**
 * @brief Generate a ModelSeries from an ImageSeries
 *
 * @section XML XML Configuration
 *
 * @code{.xml}
     <service type="::operators::SMesher">
         <in key="image" uid="..." />
         <out key="mesh" uid="..." />
         <generateNormals>true</generateNormals>
     </service>
   @endcode
 * @subsection Input Input
 * - \b image [::fwData::Image]: image used to generate the mesh.
 * @subsection Output Output
 * - \b mesh [::fwData::Mesh]: generated mesh.
 * @subsection Configuration Configuration
 * - \b generateNormals (optional, default: false): if true, the mesh normals will be␣
↪generated.
 */
class OPERATORS_CLASS_API SMesher : public ::fwServices::IOperator
{
public:
    fwCoreServiceClassDefinitionsMacro((SMesher)(::fwServices::IOperator));

    /// Constructor.
    OPERATORS_API SMesher() noexcept;

    /// Destructor.
    OPERATORS_API virtual ~SMesher() noexcept;

protected:

    /// Parse the configuration to retrieve 'generateNormals' option.
    OPERATORS_API void configuring() override;

    /// Do nothing.
    OPERATORS_API void starting() override;

    /// Generate the mesh.
    OPERATORS_API void updating() override;

    /// Unregister the output
    OPERATORS_API void stopping() override;

private:

    /// Option to generate or not the normals.
    bool m_generateNormals{false};
};

} // namespace operators
```

The file `operators/config.hpp` is automatically generated, it provides `OPERATORS_CLASS_API` and

`OPERATORS_API` macros that allow to expose symbols in the shared library.

Warning: The doxygen section of the service is very important (see *Documentation* Rule: 43), it is parsed by our CMake scripts to register the service properly. The *Input*, *Output* and *InOut* sections must follow the defined format:

- \b `key_name` [`object_type`]: `description`

- *key_name*: the name of the key (used to retrieve the object in the service)
- *object_type*: class of the object with the full namespace (don't forget the `::`)
- *description*: the purpose of this input/output

In the source file `SMesher.cpp` should be in the folder `<src_dir>/bundles/operators/src/operators`:

```
#include "operators/SMesher.hpp"

#include <fwData/Image.hpp>
#include <fwData/Mesh.hpp>

namespace operators
{

static const ::fwServices::IService::KeyType s_IMAGE_INPUT = "image";
static const ::fwServices::IService::KeyType s_MESH_OUTPUT = "mesh";

//-----------------------------------------------------------------------------

SMesher::SMesher() noexcept
{

}

//-----------------------------------------------------------------------------

SMesher::~SMesher() noexcept
{
}

//-----------------------------------------------------------------------------

void SMesher::configuring()
{
    const ConfigType config = this->getConfigTree();
    m_generateNormals = config.get<bool>("generateNormals", false);
}

//-----------------------------------------------------------------------------

void SMesher::starting()
{

}

//-----------------------------------------------------------------------------
```

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```
void SMesher::updating()
{
    // retrieve the image
    ::fwData::Image::csptr image = this->getInput< ::fwData::Image >(s_IMAGE_INPUT);
    SLM_ASSERT("Input '" + s_IMAGE_INPUT + "' is not defined", image);

    ::fwData::Mesh::sptr mesh = ::fwData::Mesh::New();

    // generate the mesh
    // ...

    if (m_generateNormals)
    {
        // ...
    }

    // set the output mesh to be available in the configuration
    this->setOutput(s_MESH_OUTPUT, mesh);
}

//-----------------------------------------------------------------------------

void SMesher::stopping()
{
    // unregister output mesh
    this->setOutput(s_MESH_OUTPUT, nullptr);
}

}// namespace operators
```

4.2.2 Usage

This service is defined in xml configuration like:

```
<extension implements="::fwServices::registry::AppConfig">
<!-- ..... -->

<object uid="image" type="::fwData::Image" />
<object uid="generatedMesh" type="::fwData::Mesh" src="deferred" />

<!-- ..... -->

 <service uid="mesher" type="::operators::SMesher">
     <in key="image" uid="image" />
     <out key="mesh" uid="generatedMesh" />
     <generateNormals>true</generateNormals>
 </service>

 <!-- ..... -->

 <start uid="mesher" />
 <update uid="mesher" />
```

You can also use this service in C++

```
::fwServices::IServices::ConfigType config;
config.add("generateNormals", "true");

::fwServices::IService::sptr mesher = ::fwServices::add("::operators::SMesher");
mesher->registerInput(image, "image") // use to register the input
mesher->setConfiguration(config);
mesher->configure();
mesher->start();
mesher->update();
::fwData::Mesh::sptr obj = mesher->getOutput< ::fwData::Mesh >("mesh");
mesher->stop();
::fwServices::OSR::unregisterService( mesher );
```

4.2.3 Connection

It should be necessary to reimplement `getAutoConnections()` if you want to automatically connect the input data signals to the service. In our example, we want to call `update()` method when the image is modified.

```
IService::KeyConnectionsMap SMesher::getAutoConnections() const
{
    KeyConnectionsMap connections;

    connections.push(s_IMAGE_INPUT, ::fwData::Image::s_MODIFIED_SIG, s_UPDATE_SLOT);

    return connections;
}
```

It connects the `s_MODIFIED_SIG` ("modified") signal of the image with the key `s_IMAGE_INPUT` ("image") with the service slot registered as `s_UPDATE_SLOT` ("update").

To make this connection, you have to add `autoConnect="yes"` in the XML declaration of the service.

```
<service uid="mesher" type="::operators::SMesher">
    <in key="image" uid="image" autoConnect="yes" />
    <out key="mesh" uid="generatedMesh" />
    <generateNormals>true</generateNormals>
</service>
```

In C++ you must register the image with a third parameter as "true":

```
::fwServices::IService::sptr mesher = ::fwServices::add("::operators::SMesher");
mesher->registerInput(image, "image", true) // use to register the input
// ...
```

Tip: If you have some problem to use your service in your application, see *My service is not found*.

4.3 How to create a bundle, a lib, an executable or an application ?

In fw4spl, the bundles, libraries, applications and executables are folders containing:

- [required] two files to generate the *CMake* target: `CMakeLists.txt` and `Properties.cmake` (see *How to use CMake with fw4spl ?*).

- [optional] *include* and *src* folder to contain the header and source files.
- [optional] *rc* folder to contain resources and XML configuration files
- [optional] *test* folder to contain the unit tests

4.3.1 How to create a bundle ?

In fw4spl, you will encounter two types of bundles:

- the bundles containing only XML configurations
- the bundles containing services or other cpp code

It is possible to contain at the same time configurations and services (or C++ code), but for the sake of clarity and reusability we recommend to separate the two.

XML configurations bundles

These bundles does not contain C++ code, they only contain XML files and the required *CMake* files. In the bundle folder, there is only the *CMake* files and the *rc* folder.

CMake files

The CMakeLists.txt contains only `fwLoadProperties()` to load the Properties.cmake

The Properties.cmake defines the bundles needed to launch the configuration (ie. the bundle of all the services present in the configurations).

Example:

```
set( NAME dataManagerConfig )
set( VERSION 0.1 )
set( TYPE BUNDLE )
set( DEPENDENCIES  ) # no dependency

set( REQUIREMENTS # required bundle
    gui
    guiQt
    uiMedDataQt
    uiReconstructionQt
    ctrlSelection
    media
)
```

Configurations

A bundle could contain several configurations, they are in the `plugin.xml` file in the *rc* folder.

```
<plugin id="dataManagerConfig" version="@PROJECT_VERSION@" >

    <requirement id="dataReg" />
    <requirement id="servicesReg" />

    <!-- ... extensions ... -->
```

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```
</plugin>
```

The `@PROJECT_VERSION@` will be automatically replaced by the version defined in the Properties.cmake.

The `<requirement>` tags contain the bundles that must be started before to start your bundle (see https://rawgit.com/fw4spl-org/fw4spl-dox/dev/group__requirement.html).

Then the extensions are defined. There are different types of extensions, the most common are:

- `::fwServices::registry::AppConfig` to define configurations for applications (see *[Tuto01Basic] Create an application*)
- `::fwActivities::registry::Activities` to define activities
- `:fwServices::registry::ServiceConfig` to define configurations of services (mostly used to configure readers/writers)
- `::fwServices::registry::ServiceFactory` to define services

Note: To separate the configuration in several files, you can use `<xi:include href="..." />`

Service bundles

You don't need to create the `plugin.xml` file for the bundle that contains only services, it will be automatically generated. A `CMake` script parses the services macro and doxygen to generate the `::fwServices::registry::ServiceFactory` extension (see *How to create a service ?* and *My service is not found*)

The bundle contains the service header files in the *include* folder and the *source* files in the *src* folder. It must also contain a `Plugin` class used to register the bundle.

The `Plugin.hpp` in the *include* folder should look like:

```
#pragma once

#include <fwRuntime/Plugin.hpp>

namespace myBundle
{

class MYBUNDLE_CLASS_API Plugin : public ::fwRuntime::Plugin
{

public:

    /// Plugin destructor
    ~Plugin() noexcept;

    /// This method is used by runtime to start the bundle.
    void start();

    /// This method is used by runtime to stop the bundle.
    void stop() noexcept;

    /// This method is used by runtime to initialize the bundle.
```

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```
    void initialize();

    /// This method is used by runtime to uninitialize the bundle.
    void uninitialize() noexcept;

};

} // namespace myBundle
```

The `Plugin.cpp` in the *src* folder should be like:

```
#include <fwRuntime/utils/GenericExecutableFactoryRegistrar.hpp>

#include "myBundle/Plugin.hpp"

namespace myBundle
{

//-----------------------------------------------------------------------------

static ::fwRuntime::utils::GenericExecutableFactoryRegistrar<Plugin> registrar(
↪"::myBundle::Plugin");

//-----------------------------------------------------------------------------

Plugin::~Plugin() noexcept
{
}

//-----------------------------------------------------------------------------

void Plugin::start()
{
}

//-----------------------------------------------------------------------------

void Plugin::stop() noexcept
{
}

//-----------------------------------------------------------------------------

void Plugin::initialize()
{
}

//-----------------------------------------------------------------------------

void Plugin::uninitialize() noexcept
{
}

//-----------------------------------------------------------------------------

} // namespace myBundle
```

Warning: The `registrar("::myBundle::Plugin");` is the most important line, it allows to register the bundle to be used in a XML based application.

Don't forget to register the bundle with the correct namespace with '::'.

The methods `start()` and `stop` must be implemented but are usually empty. They are called when the application is started and stopped. The `initialize()` method is executed after the *start* of all the bundles and `uninitialize()` before the *stop*.

4.4 How to create a XML based application ?

In the Tutorials, we explain how to create simple applications. A XML based application, is defined by an "application bundle" (like a bundle but with some differences that we will describe further).

4.4.1 Application bundle

This "application bundle" contains a base configuration to run when the application is launched and lists the required bundles for this configuration.

Like a bundle, the application folder needs the CMake files and a plugin.xml file. The first difference, is that the *Properties.cmake* `TYPE` is `APP` instead of `BUNDLE`. The second difference is the line:

```
bundleParam(appXml PARAM_LIST config PARAM_VALUES tutoDataServiceBasicConfig)
```

It defines the main configuration to be launched by the application (see *Properties.cmake*).

The main configuration should be written in the `plugin.xml` file in a `<extension implements="::fwServices::registry::AppConfig">` tag (see *[Tuto01Basic] Create an application*).

4.4.2 profile.xml

To launch an application, we use:

```
bin/fwlauncher share/<myApplication>_<version>/profile.xml
```

This `profile.xml` file, used as an input of the fwlauncher command, holds a list of all bundles necessary to run an application. We describe the content of this file here for reference, but hopefully you do **not** have to write it yourself. The Properties.cmake of an application generates automatically a `profile.xml`.

Here is for example the `profile.xml` generated for *[Tuto01Basic] Create an application*.

```
<!-- WARNING, this file is GENERATED by FW4SPL CMake-based build system from CMake/
↪build/profile.xml.in -->
<!-- DO NOT EDIT MANUALLY !!! -->

<profile name="Tuto01Basic" version="0.1" check-single-instance="false">

    <activate id="Tuto01Basic" version="0.1" />
    <activate id="appXml" version="0.2" >
        <param id="config" value="tutoBasicConfig" />
    </activate>
```

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```
    <activate id="dataReg" version="0.1" />
    <activate id="gui" version="0.1" />
    <activate id="guiQt" version="0.1" />
    <activate id="servicesReg" version="0.1" />

    <start id="appXml" />
    <start id="guiQt" />

</profile>
```

activate: List of bundles used in this application. We see the parameter given to *appXML* bundle that we wrote in the *Properties.cmake*.

start: List of bundles to start when the application is launched. Basically, there are a few bundles to start at the beginning:

- *appXML*: to launch the configuration
- *guiQt*: to launch the qt event loop for applications with a GUI
- *memory*: to manage image and mesh buffers

The other bundles will be started according to the XML <requirement> tags of the bundles, or when a service is used in an XML configuration and its bundle is not started. That way we only have the minimum number of shared libraries loaded.

4.5 How to add a new Dependency ?

fw4spl dependencies are based on the ExternalProject concept.

The concept is to create custom targets to build projects in external trees. Each project has custom steps for download, update/patch, configure, build and install.

You may want to add a new dependency into fw4spl-deps or you may want to add your own folder of dependencies.

Tip: You need to know that the main CMakeLists.txt is in fw4spl-deps, and you can add as many additional folders as you want. Use the `ADDITONNAL_DEPS` option in cmake to set the path of your custom dependency.

4.5.1 Add a new dependency in fw4spl-deps

Adding a new dependency is quite easy, the only things to do is to add a new folder *myNewDeps* and put a CMakeLists.txt file into it. And you also have to add a add_subdirectory directive in the parent CMakeLists.txt.

The CMakeLists.txt should contain at least:

- cmake_minimum_required(...)
- project(...)
- include(ExternalProject)
- ExternalProject_Add(...)

Here is a simple example from glm :

```
cmake_minimum_required(VERSION 3.0)

project(glmBuilder)

include(ExternalProject)

set(GLM_CMAKE_ARGS ${COMMON_CMAKE_ARGS}
                   -DBUILD_DOXYGEN:BOOL=OFF
)

set(CACHED_URL https://github.com/g-truc/glm/archive/0.9.8.4.tar.gz)

ExternalProject_Add(
    glm
    URL ${CACHED_URL}
    URL_HASH SHA256=a220e60f8711265595be3221e530d632d5823641ecd46a3a54bc174933bff14c
    DOWNLOAD_DIR ${ARCHIVE_DIR}
    INSTALL_DIR ${CMAKE_INSTALL_PREFIX}
    CMAKE_ARGS ${GLM_CMAKE_ARGS}
)
```

The important parts are in the *ExternalProject_Add* function:

- URL: is the download link of the sources
- DOWNLOAD_DIR: The folder where the sources will be stored (set globally for all dependencies)
- DEPENDS: The dependencies of the current library (will be compiled before)
- INSTALL_DIR: The folder in which the library will be installed (set globally for all dependencies)
- CMAKE_ARGS: CMake options for library which have a cmake build system

---

Note: Note that in other script you can have much more options like:

- PATCH_COMMAND
- CONFIGURE_COMMAND
- BUILD_COMMAND
- INSTALL_COMMAND

Refer you to the documentation of ExternalProject for more informations.

4.5.2 Add a custom dependency repository

You may want to add your own folder of dependencies (as fw4spl-ext-deps). In this case your main need to create a CMakeLists.txt in the root of your folder (myDepsFolder/CMakeLists.txt) in order to list the subdirectories of your dependencies.

```
cmake_minimum_required(VERSION 3.1)

project(CustomDeps)

list(APPEND SUBDIRECTORIES myDeps1)
list(APPEND SUBDIRECTORIES myDeps2)
# ...
```

Then when you do a *ccmake* or *cmake-gui* in the build of your dependency, you need to add the path to your custom repository in the `ADDITONNAL_DEPS` option. Then cmake will automatically parse your folder.

4.6 How to fix my bug?

4.6.1 My data is not found

1. Is the data properly written in your XML configuration? Don't forget the `::`.
2. Is the xxDataReg bundle in your application/activity requirement? Where xxDataReg is the bundle that register the library containing your data (dataReg, arDataReg, ...).

4.6.2 My service is not found

1. Is the service properly written in your XML configuration? Dont't forget the `::`?
2. Did you call `cmake` after adding the new files? You need to call `cmake .` in your build repository to ensure that the files are built.
3. Is the bundle of your service added in your application/activity Properties.cmake?
4. Is the bundle properly registered? See *How to create a bundle ?*
5. Is the plugin.xml properly generated?

For example with a bundle named `myBundle` with version `0.2` containing the service `SMyService`: It must be written in `<build_dir>/share/myBundle_0.2/plugin.xml`

```
<!-- WARNING, this file is GENERATED by FW4SPL CMake-based build system from CMake/
↪build/plugin.xml.in -->
<!-- DO NOT EDIT MANUALLY !!! -->

<plugin id="myBundle" class="::myBundle::Plugin" version="0.2" >
    <library name="myBundle" />
    <requirement id="dataReg"/>
    <requirement id="servicesReg"/>

    <extension implements="::fwServices::registry::ServiceFactory">
         <type>::fwServices::IOperator</type>
         <service>::myBundle::SMyService</service>
         <object key="myInput">::fwData::Image</object>
         <desc>My service newly added.</desc>
    </extension>
</plugin>
```

The requirement may be different according to your bundle requirement (in the Properties.cmake). The `<library>` tag is important, it defines that the bundle is associated to a shared library and must be loaded when the bundle is used.

There should be an `extension` tag for each service in your bundle. All the objects of a service should be declared in the `object` tag (if they have any).

The *Plugin.cpp* contains the following line with the proper bundle name (Don't forget the `::`)

```
static ::fwRuntime::utils::GenericExecutableFactoryRegistrar<Plugin> registrar(
↪"::myBundle::Plugin");
```

The register service macro should be present. If you don't have the macro `fwServicesRegisterMacro(...)` in SMyService.cpp, it should be generated in `<build_dir>/myBundle/registerServices.cpp`

```
/* WARNING, this file is GENERATED by FW4SPL CMake-based build system from CMake/
↪build/registerServices.cpp.in
 * DO NOT EDIT MANUALLY !!!
 */

#include <fwData/Image.hpp>
#include "myBundle/myService.hpp"
#include <fwServices/macros.hpp>

fwServicesRegisterMacro( ::fwServices::IOperator, ::myBundle::SMyService )
fwServicesRegisterObjectMacro( ::myBundle::SMyService, ::fwData::Image )
```

All the services of the bundle and their objects should be present in this file.

Note: To generate the `plugin.xml` and the `registerServices.cpp` a `CMake` script will parse the services macro and doxygen. Make sure that they are properly written (see *How to create a service ?*).

4.6.3 My activity is not found

1. Is the bundle containing you activity in your application *Properties.cmake*?
2. Is the `activities` bundle in the requirement of your application *plugin.xml*?

CHAPTER 5

Frequently Asked Questions (FAQ)

5.1 What is fw4spl?

The framework FW4SPL (FrameWork for Software Production) is an open-source framework, developed by IRCAD (research institute against cancer and disease). The purpose of FW4SPL is to ease the creation of applications in the medical imaging field. Therefore it provides features like digital image processing in 2D and 3D, visualization or simulation of medical interactions.

Building an application with FW4SPL only requires to write one or several XML files. Its functionalities can be also extended by writing new components in C++, which is the coding language of the framework.

5.2 What does fw4spl mean?

FW4SPL means FrameWork for Software Production Line. It is also called F4S ("forces").

5.3 What are the features of fw4spl?

FW4SPL is based on a component architecture composed of C++ libraries. The three main concepts of the architecture, explained in the following sections, are:

- object-service concept
- component approach
- signal-slot communication

The framework is multi-platform and runs under Windows, Linux, MacOS and Android. Building an application with FW4SPL only requires to write one or several XML files. Its functionalities can be also extended by writing new components in C++, which is the coding language of the framework.

5.4 Which platforms does fw4spl run on?

This framework can run under Windows, Linux and MacOS and we are working on the Android part.

5.5 Where can I find applications developed with fw4spl ?

Some tutorials are provided with the framework and you can also build *VRRender*, a free visualization software. With *fw4spl-ar* repository, you can also get ARCalibration, a user-friendly camera calibration tool.

5.6 Which prerequistes do I need to develop new services and bundles ?

You must have a good knowledge in C++. Concerning the configuration files, they are written in XML.

5.7 What are the BinPkgs?

The BinPkgs (binary packages) contain all the extern libraries needed by fw4spl. For each BinPkg, a CMakeLists provides the OS specific instructions to build it . They can be downloaded on https://github.com/fw4spl-org/fw4spl-deps.

5.8 Is it difficult to compile an application with fw4spl?

No, it isn't. You just have to compile all the bundles and libraries used by the application. Please follow the *installation instructions* for your platform.

5.9 Why does fw4spl provide a launcher?

The launcher is used to create the entry point of the application. It parses the profile and configuration xml file to build it.

5.10 How can I debug my program ?

First, you can watch the log of the application. Under Windows platform, log messages are saved on filesystem in **SLM.log** file, in the working directory. On other systems, they are displayed in the terminal.

You can increase or decrease the log level of a sub-project in the CMake configuration, by setting the **advanced** variable **SPYLOG_LEVEL_<PROJECT>** (thus you to press 't' in *ccmake* or click of the 'advanced' checkbox in *cmake-gui* to show it).

The allowed values are : ['trace', 'debug', 'info', 'error', 'fatal', 'warning', 'disable']. the value 'trace' gives the maximum of log, whereas 'disable' disables log. The default value is 'error', which is enough in most cases. 'warning' can be useful in some cases. Lower levels are really designed to be activated punctually when debugging a specific piece of code.

Note: Printing many log messages (by activating trace on all sub-projects for ex.) can be very time consuming for the application.

Secondly, you can of course compile your application in Debug mode (set **CMAKE_BUILD_TYPE** to "Debug") and then debug it using **gdb** (Linux/Mac), **QtCreator** (Linux/Mac), **Visual Studio** (Windows) or **Android Studio** (Android).

Thirdly, you can manage the program complexity by reducing the number of activated components (in profile.xml) and the number of created services (in config.xml) to better localize errors.

Fourthly, verify that your profile.xml / plugin.xml and each bundle plugin.xml are well-formed, by using xmllint (command line tool provided by libxml2).

5.11 I have an assertion/fatal message when I launch my program, any idea to correct the problem ?

First, you can read the output message :) and try to solve the problem. In many cases, there are two kind of problems. The program fails to :

- **create the service given in configuration. In this case, four reasons are possibles :**
  - the name of service implementation in *config.xml* contains mistakes
  - the bundle that contains this service is not activated in the profile
  - the bundle plugin.xml, that contains this service, does not declare the service or the declaration contains mistakes.
  - the service is not registered in the Service Factory (forget of macro *fwServicesRegisterMacro(. . .)* in file .cpp)
- manage the configuration of service. In this case, the implementation code in .cpp file (generally configuring() method of service) does not correspond to description code in config.xml (Missing arguments, or not well-formed, or mistakes string parameters).

5.12 Do I need to convert my data object to a ::fwData::Object ?

Do you need to share this data between services ?

- If the answer is no, then you don't need to wrap your data.
- Otherwise, you need to have an object that inherits of ::fwData::Object.

In this latter case, do you need to share this object between different services which use different third-party libraries, i.e. for ::fwData::Image, itk::Image vs vtkImage ?

- If the answer is yes, then you need create a new object like fwData::Image and a wrapping with fwData::Image<=>itk::Image and fwData::Image<=>vtkImage.
- Otherwise, you can just encapsulated an itk::Image in fwData::Image and create an accessor on it. (however, this choice implies that all applications that use fwData::Image need ITK library for running.)

5.13 What is a camp path ?

A **camp path** (also called sesh@ path) is a path used to browse an object (and sub-object) using the introspection (see fwDataCamp and *Serialization*). The path begins with a '@' or a '!'. - `@` : the returned string is the fwID of the sub-object defined by the path. - `!` : the returned string is the value of the sub-object, it works only on String, Integer, Float and Boolean object.

Sadly, we do not have yet a document giving the paths for all existing data. To know how an object can be accessed with a sesh@ path, you can have a look at the corresponding fwDataCamp implementation of the object. For instance, the file *fwDataCamp/Image.cpp* shows :

```
fwCampImplementDataMacro((fwData)(Image))
{
    builder
    .tag("object_version", "2")
    .tag("lib_name", "fwData")
    .base< ::fwData::Object>()
    .property("size", &::fwData::Image::m_size)
    .property("type", &::fwData::Image::m_type)
    .property("spacing", &::fwData::Image::m_spacing)
    .property("origin", &::fwData::Image::m_origin)
    .property("array", &::fwData::Image::m_dataArray)
    .property("nb_components", &::fwData::Image::m_numberOfComponents)
    .property("window_center", &::fwData::Image::m_windowCenter)
    .property("window_width", &::fwData::Image::m_windowWidth)
    ;
}
```

Which means that each property is a reachable by a **camp path**. This is notably used by services in the `ctrlCamp` bundle, like `SExtractObjObj` or `SCopy`. For instance the height of the image can be retrieved using:

```
@size.1
```

5.13.1 Other examples:

To get the image contained in a `::fwData::Composite` with the key `myImage`

```
@values.myImage
```

To get the first reconstruction of a ModelSeries contained in a `::fwData::Composite` with the key `myModel`

```
@values.myModel.reconstruction_db.0
```

CHAPTER 6

Testing

fw4spl uses CTest and CppUnit for unit testing.

6.1 Building

When building fw4spl with CMake, you will need to enable the `BUILD_TESTS` option, e.g. with the `-DBUILD_TESTS=ON` command line option.

6.2 Launching unit tests

In you build directory, you can launch the unit tests with the `ctest` command in the following way:

```
# Launch the tests sequentially
ctest .

# Launch the tests using 4 jobs, similar to the -j option of make
ctest -j 4 .

# You can also use the make or ninja commands to do so
make test

ninja test
```

6.3 Additional data

Additional data need to be download to run all the unit tests. They are available at the following link. You can then specify the directory, where the data are located, with the `FWTEST_DATA_DIR` environment variable.

CHAPTER 7

Coding style

7.1 Terminology

- Rules are mandatory. Any rule can be (exceptionally) exceeded, but if so, it has to be rigorously justified.
- Recommendations are optional.
- **Camel case** is the practice of writing compound words or phrases such that each word or abbreviation begins with a capital letter. In programming languages, **camel case** is assumed to start with a lowercase letter. We will use the term **upper camel case** when it starts with a capital.

```
camelCaseLabel
UpperCamelCaseLabel
```

7.2 Generalities

Rule 44 [Preferred language] English is the preferred language for types, variables, functions naming, and code comments.

Rule 45 [Maximum size of a line] A source code line must not exceed 120 characters.

Rule 46 [Indentation] Use only spaces, and an indent level has four spaces.

7.3 C++ coding

7.3.1 Source and files

Rule 4 [Files tree] Source files must be placed in a folder `src/`. Public header files must be placed in a folder `include/`. Private headers may be placed in a different location.

Rule 5 [Files hierarchy] The file hierarchy should follow the namespace hierarchy. For instance, the implementation of a class `::ns1::ns2::SService` should be put in `src/ns1/ns2/SService.cpp`.

Rule 6 [Files extensions] Header files use the extension `.hpp`.

Implementation files use the extension `.cpp`.

Files containing implementation of "template" classes use the extension `.hxx`.

Recommendation 2 [Only one class per file] It is recommended to declare (or to implement) only one class per file. However tiny classes may be declared inside the same file.

Rule 7 [Includes] Use the right include directive depending on the context. `#include "..."` must be used to import headers from the same module, whereas `#include <...>` must be used to import headers from other modules.

Rule 8 [Include path] The include path is not an absolute path depending on a local file system. A correct include path does respect the letter case of the filenames and folders (since some platforms require it) and uses the character '/' as a separator.

Rule 9 [Protection against multiple inclusions] You must protect your files against multiple inclusions. To this end, use `#pragma once`.

```
#pragma once
```

Recommendation 3 [Independent headers] A header should compile alone. All necessary includes should be contained inside the header itself. In the following sample :

```
// Header.hpp

class Foo
{
public:
    std::string m_string;
}
```

you will be forced to include the file in this way to get a successful build :

```
// Source.hpp

#include <string>
#include "Header.hpp"
```

This is a bad practice, the header should rather be written :

```
// Header.hpp

#include <string>

// Header.hpp
class Foo
{
public:
    std::string m_string;
}
```

So that people can simply include the header :

```
// Source.hpp

#include "Header.hpp"
```

Recommendation 4 [Minimize inclusions] Try to minimize as much as possible inclusions inside a header file. Include only what you use. Use *forward declarations* when you can (i.e. a type or class structure is not referenced inside the header). This will limit dependency between files and reduce compile time. Hiding the implementation can also help to minimize inclusions (see *Hide implementation*)

Rule 10 [Sort headers inclusions] You must sort headers in the following order : same module, framework libraries, bundles, external libraries, standard library. This way, this helps to make each header independent. The rule can be broken if a different include order is necessary to get a successful build.

```
#include "currentModule.hpp"

#include <libSampleB/second.hpp>
#include <libSampleA/first.hpp>
#include <libSampleB/subModule/first.hpp>

#include <Qt/QtGui>
#include <vector>
#include <map>
```

Recommendation 5 [Sort inclusions alphanumerically] In addition to the previous sort, you may sort includes in alphanumerical order, according to the whole path. Thus they will be grouped by module. For a better readability, an empty line can be added between each module.

```
#include "currentModule.hpp"

#include <libSampleA/first.hpp>
#include <libSampleB/second.hpp>

#include <libSampleB/subModule/first.hpp>
#include <libSampleB/subModule/second.hpp>

#include <Qt/QtGui>

#include <map>
#include <vector>
```

7.3.2 Naming conventions

Rule 11 [Class] Class names must be written in upper camel case. It should not repeat a namespace name. For instance `::editor::SCustomEditor` should be rather called `::editor::SCustom`.

Rule 12 [File] The name of the file should be based on the class name defined in it. It must follow the same letter case.

Rule 13 [Namespace] Namespaces must be written in camel case. A comment quoting the namespace must be placed next to the ending '}'.

```
namespace namespaceA
{
namespace namespaceB
{
    class Sample
```

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```
    {
    ...
    };
} // namespace namespaceB
} // namespace namespaceA
```

When referring a namespace, you must put `::` if this is a root namespace, with an exception for `std` namespace. Ex: `::boost::filesystem`.

Rule 14 [Function and method names] Functions and methods names must be written in camel case.

Recommendation 6 [Correct naming of functions] Try as much as possible to help the users of your code by using comprehensive names. You may for instance help them to indicate the cost of a function. A function that executes a search to retrieve an object must not be called like a getter. In this case, it is better to call it `findObjet()` instead of `getObject()`.

Rule 15 [Variable] Variable names must be written in camel case. Members of a class are prefixed with a `m_`.

```
class SampleClass
{
private:
   int m_identifier;
   float m_value;
};
```

Static variables are prefixed with a `s_`.

```
static int s_staticVar;
```

Rule 16 [Constant] Static constant variables must be written in snake_case but in capitals, and follow the previous rule.

```
class SampleClass
{
    static const int s_AAA_BBB_CCC_VALUE = 1;
};
```

Rule 17 [Type] Type names, like classes, must be written in upper camel case.

```
typedef int CustomType;
typedef vector<int> CustomContainer;
```

Rule 18 [Template parameter] Template parameters must be written in capitals. In addition, they must be short and explicit.

```
template< class KEY, class VALUE > class SampleClass
{
    ...
};
```

Rule 19 [Macro] Macros without parameters must be written in capitals. On the contrary, there is no specific rule on macros with parameters.

```
#define CUSTOM_FLAG_A 1
#define CUSTOM_FLAG_B 1

#define CUSTOM_MACRO_A( x ) x
```

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```
#define Custom_Macro_B( x ) x
#define custom_Macro_C( x ) x
#define custom_macro_d( x ) x
```

Rule 20 [Enumerated type] An enumerated type name must be written in upper camel case. Labels must be written in capitals. If a `typedef` is defined, it follows the upper camel case standard.

```
typedef enum SampleEnum
{
    LABEL_1,
    LABEL_2
    ...
} SampleEnumType;
```

Rule 21 [Service] A service implementation is identified by a `S` at the beginning of the class name. Example : `SCustomEditor`. A service interface is identified by a `I` at the beginning of the class name. Example : `IEditor`.

Rule 22 [Signal] A signal name must be prefixed with `sig`. It should be suffixed by a past action (ex: Updated, Triggered, Cancelled, CakeCookedAndBaked). It follows other common variable naming rules (member of a class, etc...).

```
class Sample
{
    SigType::sptr m_sigImageDisplayed;
};
```

Rule 23 [Slot] A slot name must be prefixed with `slot`. It should be suffixed by an imperative order (Ex: Update, Run, Detach, Deliver, OpenWebBrowser, GoToFail). It follows other common variable naming rules (member of a class, etc...).

```
class Sample
{
    SlotType::sptr m_slotDisplayImage;
}
```

7.3.3 Coding rules

Blocks

Rule 24 [Indentation] Code block indentation and bracket positioning follow the Allman style.

```
void function(void)
{
    if(x == y)
    {
        something1();
        something2();
    }
    else
    {
        somethingElse1();
        somethingElse2();
    }
```

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```
    finalThing();
}
```

Rule 25 [Indentation of namespaces] Namespaces are an exception of the previous rule. They should not be indented.

```
namespace namespaceA
{
namespace namespaceB
{
    ...
} // namespace namespaceB
} // namespace namespaceA
```

Rule 26 [Blocks are mandatory] After a control statement (if, else, for, while/do... while, try/catch, switch, foreach, etc...), it is mandatory to open a block, whatever is the number of instructions inside the block.

Rule 27 [Scope] The keywords `public`, `protected` and `private` are not indented, they should be aligned with the keyword `class`.

```
class Sample
{
public:
    ...
private:
    ...
};
```

Class declaration

Recommendation 7 [Only three scope sections] When possible, use only one section of each scope type `public`, `protected` and `private`. They must be declared in this order.

Recommendation 8 [Group class members by type] You may group class members in each scope according to their type: type definitions, constructors, destructor, operators, variables, functions.

Rule 28 [Hide implementation] Avoid non-const public member variables except in very small classes (i.e. a 3D point). The Pimpl idiom may also be helpful to separate the implementation from the declaration.

Recommendation 9 [Hide implementation] Try to put variables as much as possible in the `private` section.

Rule 29 [Accessors] Since you protect your member variables from the outside, you will have to write accessors, named `getXXX()` and `setXXX()`. Getters are always `const`.

Rule 30 [Template class function definition] The function definition of a template class must be defined after the declaration of the class.

```
template < typename TYPE >
class Sample
{
public:
    void function(int i);
};

template < typename TYPE >
inline Sample<TYPE>::function(int i)
{
```

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```
    ...
}
```

Recommendation 10 [Separate template class function definition] In addition of the previous rule, you may put the definition of the function in a `.hxx` file. This file will be included in the implementation file right after the header file (the compile time will be reduced comparing with an inclusion of the `.hxx` in the header file itself).

```
#include <namespaceA/file.hpp>
#include <namespaceA/file.hxx>
```

Initializer list

Rule 31 [One initializer per line] In a class constructor, use the initialization list as much as possible. Place one initializer per line. Constructors of base classes should be placed first, followed by member variables. Do not specify an initializer if it is the default one (empty std::string for instance).

```
SampleClass::SampleClass( const std::string& name, const int value ) :
    BaseClassOne( name ),
    BaseClassTwo( name ),
    m_value( value ),
    m_misc( 10 )
{}
```

Recommendation 11 [Align everything that improves readability] To improve readability, you may align members on one hand and argument lists on the other hand.

```
SampleClass::SampleClass( const std::string& name, const int value ) :
    BaseClassOne  ( name ),
    BaseClassTwo  ( name ),
    m_value       ( value ),
    m_misc        ( 10 )
{}
```

Functions

Rule 32 [Constant reference] Whenever possible, use constant references to pass arguments of non-primitive types. This avoids useless and expensive copies.

```
void badFunction( std::vector<int> array )
{
    ...
}

void goodFunction( const std::vector<int>& array )
{
    ...
}
```

Recommendation 12 [Constant reference for shared pointers] For performance sake, it is preferable to use `const&` to pass arguments of type `::boost::shared_ptr`. It is only useful to pass the pointer by copy if the pointer can be invalidated by an another thread during the function call. If you have any doubt, it is safer to pass the argument by copy.

Rule 33 [Constant functions] Whenever a member function should not modify an attribute of a class, it must be declared as `const`.

```
void readOnlyFunction( const std::vector<int>& array ) const
{
    ...
}
```

Recommendation 13 [Limit use of expression in arguments] When passing arguments, try to limit the use of expressions to the minimum.

```
// This is bad
function( fn1(val1 + val2 / 4 ), fn2( fn3( val3 ), val4) );

// This is better
const float res0 = val1 + val2 / 4;

const float res1 = fn1(res0);
const float res3 = fn3(val3);
const float res2 = fn2(res3, val4);

function( res1 , res2 );
```

Miscellaneous

Rule 34 [Enumerator labels] Each label must be placed on a single line, followed by a comma. If you assign values to labels, align values on the same column.

```
enum OpenFlag
{
    OPEN_SHARE_READ      = 1,
    OPEN_SHARE_WRITE     = 2,
    OPEN_EXISTING        = 4,
};
```

Rule 35 [Use of namespaces] You have to organize your code inside namespaces. By default, you will have at least one namespace for your module (application or bundle). Inside this namespace, it is recommended to split your code into sub-namespaces. This helps notably to prevent naming conflicts.

It is forbidden to use the expression‘‘using namespace‘‘ in header files but it is allowed in implementation files. It is however recommended to use aliases in this latter case.

```
namespace bf = ::boost::filesystem;
```

Rule 36 [Keyword const] Use this keyword as much as possible for variables, parameters and functions. When used for a variable or a parameter, it should be placed on the left of the qualified id, e.g. :

```
const double factor = 1.0;
const auto* pFactor = &factor;
std::vector< const Object* > objectsList;

void func(const Object& param);
```

Recommendation 14 [Keyword auto] Use this keyword as much as possible to improve maintainability and robustness of the code.

Rule 37 [Prefer constants instead of #define] Use a static constant object or an enumeration instead of a `#define`. This will help the compiler to make type checking. You will also be able to check the content of the constants while debugging. You can also define a scope for them, inside the namespace, inside a class, private to a class, etc...

Rule 38 [Prefer references over pointers] When possible, use references instead of pointers, especially for function parameters. Pointer as parameter should only be used if it is considered to have a NULL pointer or when passing a C-like array. If you use a pointer, always check it if is null in the current scope before dereferencing it.

Rule 39 [Type conversion] For type conversion, use the C++ operators which are `static_cast`, `dynamic_cast`, `const_cast` and `reinterpret_cast`. Use them wisely in the appropriate case. You may read this documentation.

Recommendation 15 [Strings to numbers/numbers to string conversion] When converting strings to numbers or numbers to string, prefer the use of boost::lexical_cast.

Recommendation 16 [Exceptions] Exceptions are the preferred mechanism to handle error notifications.

Rule 40 [Explicit integer types] When you do need a specific integer size, use type definitions declared in <cstdint>, for example :

Bits	Signed	Unsigned
8	int8_t	uint8_t
16	int16_t	uint16_t
32	int32_t	uint32_t
64	int64_t	uint64_t

7.4 Documentation

Rule 41 [Document the code] The code must be documented with **Doxygen**, an automated tool to generate documentation.

Rule 42 [Location of the documentation] Every documentation that can be useful to a user must be placed inside the header files. Thus a user of a module can find the declaration of a class and its documentation at the same place. Inside the implementation file, the documentation will give more details about algorithms.

Moreover, every documentation must be placed next to the entity it is refering to, in order to help searching inside the code.

Recommendation 17 [Lightweight documentation] Inside a documentation block, only use necessary tags. This will avoid to overload the documentation and makes it readable. By the way, empty tags will be presented inside the generated documentation and will be useless. Just use an empty line to make a separation inside a documentation block.

Don't indicate parameter types when using `@param` directive. This is useless since it will duplicate information of the function prototype. Also, prefer the use of `///` whenever possible.

Example 1 : Bad documentation block

```
/**
* @brief        A very short description.
*
* A longer description, giving more details about the documented piece
* of code.
*****************************************
* @param
*****************************************
```

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```
* @return
*******************************************
* @exception
*******************************************
* @todo
*******************************************
```

Example 2 : Good documentation block

```
/**
* @brief        A very short description.
*
* A longer description, giving more details about the documented piece
* of code.
*/
```

Example 3 : Function documentation

```
class Sample
{
public:
    /**
    * Retrieve the thing.
    *
    * @return       The thing value.
    */
    const std::string& getThing( void ) const;
    /**
    * @brief        Set the thing.
    *
    * @param        thing   :  The new thing.
    */
    void setThing( const std::string& thing );

private:
    /// stored thing
    std::string     m_thing;
};
```

Recommendation 18 [Structured documentation] Doxygen provides a default structure when you generate the documentation. However, when dealing with a big documented entity, it is often recommended to use the group feature (`@name`). With this feature you will build a logical view of the class interfaces.

Rule 43 [Document service] The service must be properly documented.

This should include first a brief description, then a long description if necessary.

```
/**
 * @brief This is the short description.
 *
 * This is the long description.
 *
```

After that the signals and slots must be documented in two distinct sections.

```
/**
 * ...
```

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```
 * @section Signals Signals
 * - \b signal2(::fwData::Mesh::sptr) : Emitted when the mesh has changed.
 * - \b signal1(std::int64_t) : Emitted when ...
 *
 * @section Slots Slots
 * - \b modified() : Modify the data.
 */
```

Last the xml configuration of the service must be described into a dedicated section. It should indicate first the input, input/outputs and outputs in three subsections. The type and the name of the data should appear along with a short description. A fourth subsection describes the rest of the parameters, and tells if it they are optional or not.

```
/**
 * ...
 * @section XML XML Configuration
 *
 * @code{.xml}
       <service type="::namespace::SService">
           <in key="data1" uid="model" />
           <inout key="data2" uid="mesh" />
           <out key="data3" uid="image2" />
           <out key="data4" uid="image1" />
           <option1>12</option1>
           <option2>12</option2>
       </service>
  @endcode
 * @subsection Input Input
 * - \b data1 [::fwMedData::ModelSeries]: blablabla.
 * @subsection In-Out In-Out
 * - \b data2 [::fwData::Mesh]: blablabla.
 * @subsection Output Output
 * - \b data3 [::fwData::Image]: blablabla.
 * - \b data4 [::fwData::Image]: blablabla.
 * @subsection Configuration Configuration
 * - \b option1 : first option.
 * - \b option2(optional) : second option.
 *
 */
```

The XML documentation is important, it is parsed to register properly the service. The *Input*, *Output* and *InOut* sections must follow the defined format:

- \b `key_name` [`object_type`]: `description`

- *key_name*: the name of the key (used to retrieve the object in the service)
- *object_type*: class of the object with the full namespace (don't forget the `::`)
- *description*: the purpose of this input/output

7.5 XML coding

Rule 48 [Id name] Id should have a semantic name. Avoid id like myXXXXX or customXXXXX. Moreover, id must be written in lower case with an underscore as separator.

```
<service id="generic_scene" />
```

7.6 CMakeLists coding

Rule 1 [Function name] Standard CMake functions and macros should be written in lower case. Each word is generally separated by an underscore (this is a rule of CMake anyway).

```
add_subdirectory("library/")
include_directories(SYSTEM "/usr/local")
```

Rule 2 [Macro name] Custom macros should be written in camel case.

```
fwLoadProperties()
fwLink("boost")
```

Rule 3 [Variable name] Variables should be written in upper case letters separated if needed by underscores.

```
set(VARIABLE_NAME "")
```

Recommendation 1 [Expression in block ending] In the past, CMake enforced to specify the label or expression in block ending, for instance :

```
function(name arg1 arg2)
    ...
    if(expr1)
        ...
    else(expr1)
        ...
    endif(expr1)
    ...
endfunction(name)
```

This is no longer needed in latest CMake versions, and we recommend to use this possibility for the sake of simplicity.

```
function(name arg1 arg2)
    ...
    if(expr1)
        ...
    else()
        ...
    endif()
    ...
endfunction()
```

7.7 Licence

Rule 47 [LGPL] Do not forget to put the LGPL licence block on fw4spl.

```
/* ***** BEGIN LICENSE BLOCK *****
 * FW4SPL - Copyright (C) IRCAD, 2009-2015.
 * Distributed under the terms of the GNU Lesser General Public License (LGPL) as
```

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```
 * published by the Free Software Foundation.
 * ***** END LICENSE BLOCK ***** */
```

CHAPTER 8

Software Architecture Description (SAD)

8.1 General

8.1.1 Introduction

The framework FW4SPL (FrameWork for Software Production) is an open-source framework, developed by IRCAD (research institute against cancer and disease). The purpose of FW4SPL is to ease the creation of applications in the medical imaging field. Therefore it provides features like digital image processing in 2D and 3D, visualization or simulation of medical interactions.

FW4SPL is based on a component architecture composed of C++ libraries. The three main concepts of the architecture, explained in the following sections, are:

- object-service concept
- component approach
- signal-slot communication

The framework is multi-platform and runs under Windows, Linux, MacOS and Android. Building an application with FW4SPL only requires to write one or several XML files. Its functionalities can be also extended by writing new components in C++, which is the coding language of the framework.

This document will introduce the general architecture of FW4SPL.

8.2 Object-Service concept

8.2.1 Introduction

In the *Object Oriented Programming* (OOP) paradigm, an object is an instance of a class which contains the data and the algorithms. For instance, a class Image contains the image buffer, the size and format attributes, along with the methods to process the image, such as reading, writing, visualizing, analyzing, etc.

This design works well, but has some drawbacks. First the code of the class implementation can become very big if you put everything in it, making collaborative work harder. Then if you use different third-party libraries in your methods (for instance DCMTK for I/O, VTK for visualization, OpenCV or ITK for the filtering methods), your class becomes dependent of all of these libraries even if you only need one or two functionalities. If we want something modular, that does not work. Last, because of the two previous points, the maintenance of source code is quite tough.

Instead, FW4SPL proposes an *Object-Service* paradigm where data and algorithms are separated into different code units.

8.2.2 Object

Objects represent data used in the framework. They can be simple (boolean, integer, string, etc.) or advanced structures (image, mesh, video, patient, etc.). They are generic, which means they do not depend on the original input format or the future output format. This way they can used with different third-party libraries, and we provide helper methods to convert them into the corresponding formats.

These object classes contain only data features and their corresponding getter/setter methods.

For instance, the `Image` object:

- contains a buffer pointer, a buffer size, the image's dimension and origin,
- has public setter/getter methods to access these members,
- does not have methods such as reading or writing a buffer

The `fwData` library contains the standard simple and advanced data. It is the main data library of FW4SPL. There is also the `fwMedData` library which contains several structures to store medical data. A data list with a brief description is available in the appendixes.

Creating data

New data must be created as described below.

In the header file (MyData.hpp):

```
class MyData : public ::fwData::Object
{

public :
    fwCoreClassDefinitionsWithFactoryMacro( (MyData)(::fwData::Object),
        (()), ::fwData::factory::New< MyData >) ;


    // Private constructor, required for data factory
    MyData(::fwData::Object::Key key);

    /// Destructor, required for all data
    virtual ~MyData();

    /// Defines shallow copy, required for all data
    void shallowCopy( const Object::csptr& _source );

    /// Defines deep copy, required for all data
    void cachedDeepCopy(const Object::csptr& _source,
                            DeepCopyCacheType &cache);

};
```

In the source file (MyData.cpp), this line must also be added to declare `MyClass` as data of the framework architecture :

```
fwDataRegisterMacro( MyData );
```

8.2.3 Service

A service represents a functionality which uses or modifies data. **It is associated with one or several objects**. For example, a service working on a single image could be a reader, a writer, or a visualization service. A service working on two images could be a filtering service, or a service working on a image and a mesh, a mesher.

Service type

Some service categories exist in FW4SPL. These categories are called *service types* and are represented by an abstract class. The basic service types are:

- `::fwIO::IReader`: base interface for reader services.
- `::fwIO::IWriter`: base interface for writer services.
- `::fwGui::IActionSrv`: base interface to manage action from a button or a menu in the GUI.
- `::fwGui::editor::IEditor`: base interface to create new widgets in the GUI.
- `::fwRender::IRender`: base interface to create new visualization widgets in the GUI.
- `::fwServices::IController`: does nothing in particular but can be considered as a default service type to be implemented by unclassified services.

All services require a type association and must inherit from an abstract type service.

Service methods

Several methods exist to manipulate a service. The main methods are: `configure`, `start`, `stop`, and `update`.

- `configure`: parses the service parameters and analyzes its configuration. For example, this method is used to configure an image file path on the file system for an image reader service.
- `start`: initializes and launches the service (be careful, starting and instantiating a service is not the same thing. For example, for a visualization service, the `start` method instantiates all GUI widgets necessary to visualize the data but the service itself is instantiated before.).
- `stop`: stops the service. For example, for a visualization service, this method detaches and destroys all GUI widgets previously instantiated earlier in the `start` method.
- `update` method is called to perform an action on the data associated with the service. For example, for an image reader service, the service reads the image, converts it and loads it into the associated data.

These methods are mandatory, but can be empty. This is because some services do not need a configuration step, a start/stop process, or an update process.

Service states

These methods must follow a calling sequence. For example, it is not possible to stop a service before starting it. To secure the process, a state machine has been implemented to control the calling sequence.

The calling sequence to manage a service is:

```
MyData::sptr myData = MyData::New();
MyService::sptr mySrv = ::fwService::add("MyService"); // create the service
mySrv->registerInput(myInputData, "inputData");  // register the inputs
mySrv->registerInOut(myInOutData, "modifiedData");

mySrv->setConfiguration( ... ); // set parameters
mySrv->configure(); // check parameters
mySrv->start(); // start the service
mySrv->update(); // update the service
mySrv->stop(); // stop the service
::fwServices::ORS::unregisterService(mySrv); // destroy the service
```

Note: FW4SPL extensively uses std::shared_ptr to handle objects and services. The basic declaration macros of data and services define a typedef `sptr` as an alias to `std::shared_ptr<this_class>` and a typedef `csptr` as an alias to `std::shared_ptr<const this_class>`.

Create a service

A new service must be created as described below (see *How to create a service ?*).

In the header file (MyService.hpp):

```
class MyService : public AbstractServiceType
{
public:

    // Macro to define few important parameters/functions used by the architecture
    fwCoreServiceClassDefinitionsMacro((MyService)(AbstractServiceType));

    // Service constructor
    MyService() noexcept() ;

    // Service destructor.
    virtual ~MyService() noexcept() ;

protected:

    // To configure the service
    void configuring() override;

    // To start the service
    void starting() override;

    // To stop the service
    void stopping() override;

    // To update the service
    void updating() override;
};
```

In the source file, the following lines must also be added to declare `MyService` as a service of the framework architecture:

```
fwServicesRegisterMacro( AbstractServiceType, MyService );
fwServicesRegisterObjectMacro( MyService, MyData )
```

Note: These macros can be automatically generated by cmake in the file `registerServices.cpp`. In this case you should write the correct doxygen of the service XML configuration

Note: When a new service is created, the following functions must be overriden from IService class : `configuring`, `starting`, `stopping` and `updating`. The top level functions from IService class check the service state before any call to the overridden method.

8.2.4 Object and service factories

To instantiate an object or a service, the architecture requires the use of a factory system. In class-based programming, the factory method pattern is a creational pattern which uses factory methods to deal with the problem of creating classes without specifying the exact class that will be created. This is done by creating classes via a factory method, which is either specified in an interface (abstract class) and implemented in child classes (concrete classes) or implemented in a base class (optionally as a template method), which can be overridden when inherited in derivative classes; rather than by a constructor.

Object factory

The `fwData` library has a factory to register and create all objects. The registration is managed by two macros:

```
// in .hpp file
fwCoreClassDefinitionsWithFactoryMacro( (MyData)(::fwData::Object),
    ((), ::fwData::factory::New< MyData >);

// in .cpp file
fwDataRegisterMacro( MyData );
```

Then, there data can be instantiated in two ways:

```
// Direct creation
MyData::sptr obj = MyData::New();

// Factory creation (here obj is an object of type
// MyData, it is then possible to cast it dynamically)
::fwData::Object::sptr obj = ::fwData::factory::New("MyData");
MyData::sptr myData = MyData::dynamicCast(obj);
```

Service factory

The `fwService` library has a factory to register and create all services. The registration is managed by two macros:

```
// in .hpp file
fwCoreServiceClassDefinitionsMacro ((MyService)(AbstractServiceType));

// in .cpp file
```

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```
fwServicesRegisterMacro( AbstractServiceType, MyService );
fwServicesRegisterObjectMacro( MyService, MyData )
```

The service must be created by the factory:

```
::fwServices::registry::ServiceFactory::sptr srvFactory
        = ::fwServices::registry::ServiceFactory::getDefault();

// Factory creation (here srv is a service of type MyService, it is possible to cast␣
↪it)
::fwServices::IService::sptr srv = srvFactory->create("MyService");
```

8.2.5 Object-Service registry (OSR)

The FW4SPL architecture is standardized thanks to:

- Abstract classes `::fwData::Object` and `::fwService::IService`.
- The two factory systems.

In an application, one of the problems is managing the life cycle of a large number of object instances and their services. This problem is solved by the class `::fwServices::registry::ObjectService` which maintains the relationship between objects and services. This class concept is very simple :

```
// OSR is a singleton
class ObjectService
{
public:
    // ...

    // Associates a service to an object
    void registerService ( ::fwData::Object::sptr obj,
                           const ::fwServices::IService::KeyType& objKey,
                           ::fwServices::IService::AccessType access,
                           ::fwServices::IService::sptr service);

    // Associates a service to an input object
    void registerServiceInput( const ::fwData::Object::csptr& object,
                               const ::fwServices::IService::KeyType& objKey,
                               const ::fwServices::IService::sptr& service)



    // Dissociates a service from an object
    void unregisterService ( const ::fwServices::IService::KeyType& objKey,
                             ::fwServices::IService::AccessType access,
                             IService::sptr service )
  // ...
}
```

This registry manages the object-service relationships and guarantees the non-destruction of an object while some services are still working on it.

Each object associated with the service must provide a **key** and an **access type**. The **key** is used to retrieve the object in the service code, while the **access type** tells how the object can be accessed: read, read/write or write.

Example:

```
::fwData::Image::sptr image = ::fwData::Image::New();
::fwData::Mesh::sptr mesh = ::fwData::Mesh::New();
::fwServices::registry::ServiceFactory::sptr srvFactory
        = ::fwServices::registry::ServiceFactory::getDefault();

::fwServices::IService::sptr srv = srvFactory->create("MyService");

::fwServices::OSR::registerService(image, "image",␣
↪::fwServices::IService::AccessType::INOUT, srv);
::fwServices::OSR::registerService(mesh, "mesh",␣
↪::fwServices::IService::AccessType::INPUT, srv);

// ....
::fwServices::OSR::unregisterService(srv);
```

To simplify, you can use an helper that calls this lines and register the inputs and inouts directly to the service:

```
#include <fwServices/op/Add.hpp>

// ...
::fwData::Image::sptr image = ::fwData::Image::New();
::fwData::Mesh::sptr mesh = ::fwData::Mesh::New();
::fwServices::IService::sptr srv = ::fwServices::add("::myBundle::MyService");
srv->registerInOut(image, "image");
srv->registerInput(mesh, "mesh");

// ....
::fwServices::OSR::unregisterService(srv);
```

Object retrieval

Thus, to retrieve the registered objects of a service, there are two different methods :

```
class IService
{
public:
  // ...
  template<class DATATYPE> CSPTR(DATATYPE) getInput( const KeyType& key) const;
  template<class DATATYPE>  SPTR(DATATYPE) getInOut( const KeyType& key) const;
  // ...
};
```

For instance, if we have a `::fwData::Image` registered as `"image"` key with `INOUT` access type, and a `::fwData::Mesh` registered as `"mesh"` key with `IN` access type we can retrieve them in a method of the service this way:

```
::fwData::Image::sptr image = this->getInOut< ::fwData::Image>("image");
::fwData::Mesh::csptr mesh  = this->getInput< ::fwData::Mesh>("mesh");
```

8.2.6 Object access type

How to choose between the different access type for a given data ?

1. **Read-only (*IN*)**

- If you don't modify the data and so that means you can deal with a const pointer on the data, then this is the right choice.

2. **Write-only (*OUT*)**

   - This is a special case when the service will actually create the data. The data doesn't exist before the service creation. At some point, during `start()`, or `update()` or elsewhere, the data is allocated, filled and registered in the OSR :

```
::IService::setOutput(const KeyType& key, const ::fwData::Object::sptr& object);
//..
::fwData::Image::sptr image = ::fwData::Image::New();
this->setOutput("outputImage", image);
```

3. **Read-Write**

   - The object already exists, and you need to modify it.

This topic is explained more widely in the *AppConfig* section.

8.2.7 Object-Service concept example

To conclude, the generic object-service concept is illustrated with this example:

```
// Create an object
::fwData::Object::sptr obj = ::fwData::factory::New("::fwData::Image");

// Create a reader and a view for this object
::fwServices::IService::sptr reader = ::fwServices::add("MyCustomImageReader");
reader->registerInOut(obj, "data");
::fwServices::IService::sptr view = ::fwServices::add("MyCustomImageView");
view->registerInput(obj, "object");

// Configure and start services
reader->setConfiguration ( /* ... */ );
reader->configure();
reader->start();

view->setConfiguration ( /* ... */ );
view->configure();
view->start();

// Execute services
reader->update(); // Read image on filesystem
view->update(); // Refresh visualization with the new image buffer

// Stop services
reader->stop();
view->stop();

// Destroy services
::fwServices::OSR::unregisterService(reader);
::fwServices::OSR::unregisterService(view);
```

This example shows the code to create a small application to read an image and visualize it. You can easily transform this code to build an application which reads and displays a 3D mesh by changing object and services implementation strings only.

However, most applications made with FW4SPL are not built this way. Instead, we use *AppConfig*, which allows to simplify the code above by a declarative approach based on XML files.

8.3 Signal-slot communication

8.3.1 Overview

"Signals and slots" is a language construct introduced in Qt[1] for communication between objects.

The concept is that objects and services(explained in 2.3) can send signals containing event information which can be received by other services using special functions known as slots.

8.3.2 FW4SPL implementation

In the FW4SPL architecture, the library `fwCom` provides a set of tools dedicated to communication. These communications are based on the signal and slot concept.

`fwCom` provides the following features :

- function and method wrapping
- direct slot calling
- asynchronous slot calling
- ability to work with multiple threads
- auto-disconnection of slot and signals
- arguments loss between slots and signals

8.3.3 Slots

Slots are wrappers for functions and class methods that can be attached to a `fwThread::Worker`. The purpose of this class is to provide synchronous and asynchronous mechanisms for method and function calling.

Slots have a common base class : SlotBase. This allows the storage of them in the same container. Slots are designed such that they can be called, even where only the argument type is known.

Examples :

A slot wrapping the function sum, which is a function with the signature int (int, int) :

```
::fwCom::Slot< int (int, int) >::sptr slotSum = ::fwCom::newSlot( &sum );
```

A slot wrapping the function start with signature void() of the object `a` which class type is `A` :

```
::fwCom::Slot< void() >::sptr slotStart = ::fwCom::newSlot(&A::start, &a);
```

Execution of the slots using the run method :

```
slotSum->run(40,2);
slotStart->run();
```

Execution of the slots using the method call, which returns the result of the execution :

[1] http://wiki.qt.io/Qt_signal-slot_quick_start

```
int result = slotSum->call(40,2);
slotStart->call();
```

A slot declaration and execution, through a SlotBase :

```
::fwCom::Slot< size_t (std::string) > slotLen
        = ::fwCom::Slot< size_t (std::string) >::New( &len );
::fwCom::SlotBase::sptr slotBaseLen = slotLen;
::fwCom::SlotBase::sptr slotBaseSum = slotSum;
slotBaseSum->run(40,2);
slotBaseSum->run<int, int>(40,2);

// This one needs the  explicit argument type
slotBaseLen->run<std::string>("R2D2");
result = slotBaseSum->call<int>(40,2);
result = slotBaseSum->call<int, int, int>(40,2);
result = slotBaseLen->call<size_t, std::string>("R2D2");
```

8.3.4 Signals

Signals allow to perform grouped calls on slots. For this purpose, a signal class provides a mechanism to connect slots.

Examples:

The following instruction declares a signal with a void signature.

```
::fwCom::Signal< void() >::sptr sig = ::fwCom::Signal< void() >::New();
```

The connection between a signal and a slot of the same information type:

```
sig->connect(slotStart);
```

The following instruction will trigger the execution of all slots connected to this signal:

```
sig->emit();
```

It is possible to connect multiple slots with the same information type to the same signal and trigger their simultaneous execution.

Signals can take several arguments as a signature which will trigger their connected slots by passing the right arguments.

In the following example a signal is declared of type void(int, int). The signal is connected to two different types of slot, void (int) and int (int, int).

```
using namespace fwCom;
Signal< void(int, int) >::sptr sig2 = Signal< void(int, int) >::New();
Slot< int(int, int) >::sptr    slot1 = Slot< int(int, int) >::New(...);
Slot< void(int) >::sptr        slot2 = Slot< void(int) >::New(...);

sig2->connect(slot1);
sig2->connect(slot2);

sig2->emit(21, 42);
```

Here 2 points need to be highlighted :

- A signal cannot return a value. Consequently their return type is void. Thus, the return value of a slot, triggered by a signal, equally cannot be retrieved.
- To successfully trigger a slot using a signal, the minimum requirement as to the number of arguments or fitting argument types has to be given by the signal. In the last example the slot slot2 only requires one argument of type int, but the signal is emitting two arguments of type int. Because the signal signature fulfills the slot's argument number and argument type, the signal can successfully trigger the slot slot2. The slot slot2 takes the first emitted argument which fits its parameter (here 21, the second argument is ignored).

Disconnection

The disconnect method is called between one signal and one slot, to stop their existing connection. A disconnection assumes a signal slot connection. Once a signal slot connection is disconnected, it cannot be triggered by this signal. Both connection and disconnection of a signal slot connection can be done at any time.

```
sig2->disconnect(slot1);
sig2->emit(21, 42); // do not trigger slot1 anymore
```

The instructions above will cause the execution of slot2. Due to the disconnection between sig2 and slot1, the slot slot1 is not triggered by sig2.

Connection handling

The connection between a slot and a signal returns a connection handler:

```
::fwCom::Connection connection = signal->connect(slot);
```

Each connection handler provides a mechanism which allows a signal slot connection to be disabled temporarily. The slot stays connected to the signal, but it will not be triggered while the connection is blocked :

```
::fwCom::Connection::Blocker lock(connection);
signal->emit();
// 'slot' will not be executed while 'lock' is alive or until lock is
// reset
```

Connection handlers can also be used to disconnect a slot and a signal :

```
connection.disconnect();
// slot is not connected anymore
```

Auto-disconnection

Slots and signals can handle an automatic disconnection :

- on slot destruction : every signal slot connection to this slot will be destroyed
- on signal destruction : every slot connection to the signal will be destroyed

All related connection handlers will be invalidated when an automatic disconnection occurs.

8.3.5 Manage slots or signals in a class

The library `fwCom` provides two helper classes to manage signals or slots in a structure.

HasSlots

The class `HasSlots` offers mapping between a key (string defining the slot name) and a slot. `HasSlots` allows the management of many slots using a map. To use this helper in a class, the class must inherit from `HasSlots` and must register the slots in the constructor:

```
struct ThisClassHasSlots : public HasSlots
{
  typedef Slot< int()> GetValueSlotType;

  ThisClassHasSlots()
  {
      newSlot("sum", &ThisClassHasSlots::sum, this);
      newSlot("getValue", &ThisClassHasSlots::getValue, this);
  }

  int sum(int a, int b)
  {
      return a+b;
  }

  int getValue()
  {
      return 4;
  }
};
```

Then, slots can be used as below :

```
ThisClassHasSlots obj;
obj.slot("sum")->call<int>(5,9);
obj.slot< ThisClassHasSlots::GetValueSlotType >("getValue")->call();
```

HasSignals

The class `HasSignals` provides mapping between a key (string defining the signal name) and a signal. `HasSignals` allows the management of many signals using a map, similar to `HasSlots`. To use this helper in a class, the class must inherit from `HasSignals` as seen below and must register signals in the constructor:

```
struct ThisClassHasSignals : public HasSignals
{
  typedef ::fwCom::Signal< void()> SignalType;

  ThisClassHasSignals()
  {
      newSignal< SignalType >("sig");
  }
};
```

Then, signals can be used as below:

```
ThisClassHasSignals obj;
Slot< void()>::sptr slot = ::fwCom::newSlot(&anyFunction)
obj.signal("sig")->connect( slot );
obj.signal< SignalsTestHasSignals::SignalType >("sig")->emit();
obj.signal("sig")->disconnect( slot );
```

8.3.6 Signals and slots used in objects and services

Signals are used in both objects and services, whereas slots are only used in services. The abstract class `fwData::Object` inherits from the `HasSignals` class as a basis to use signals :

```
class Object : public ::fwCom::HasSignals
{
  /// Key in m_signals map of signal m_sigObjectModified
  static const ::fwCom::Signals::SignalKeyType s_MODIFIED_SIG;
  //...

  /// Type of signal m_sigObjectModified
  typedef ::fwCom::Signal< void ( CSPTR( ::fwServices::ObjectMsg ) ) >
                ObjectModifiedSignalType;

  /// Signal that emits an ObjectMsg when an object is modified
  ObjectModifiedSignalType::sptr m_sigObjectModified;

  Object()
  {
      m_sigObjectModified = newSignal< ObjectModifiedSignalType >(s_MODIFIED_SIG);
      //...
  }
}
```

Moreover the abstract class `fwService::IService` inherits from the `HasSlots` class and the `HasSignals` class, as a basis to communicate through signals and slots. Actually, the methods `start()`, `stop()`, `swap()` and `update()` are all slots. Here is an extract with `update()`:

```
class IService : public ::fwCom::HasSlots, public ::fwCom::HasSignals
{
  typedef ::boost::shared_future< void > SharedFutureType;

  /// Key in m_slots map of slot m_slotUpdate
  static const ::fwCom::Slots::SlotKeyType s_UPDATE_SLOT;

  /// Type of signal m_slotUpdate
  typedef ::fwCom::Slot<SharedFutureType()> UpdateSlotType;

  /// Slot to call update method
  UpdateSlotType::sptr m_slotUpdate;

  IService()
  {
      //...
      m_slotUpdate = newSlot( s_UPDATE_SLOT, &IService::update, this ) ;
      //...
  }

  //...
}
```

To automatically connect object signals and service slots, it is possible to override the method `IService::getAutoConnections()`. Please note that to be effective the attribute "autoConnect" of the service must be set to "yes" in the xml configuration (see *App-config*). The default implementation of this method connect the `s_MODIFIED_SIG` object signal to the `s_UPDATE_SLOT` slot.

```
IService::KeyConnectionsMap IService::getAutoConnections() const
{
    KeyConnectionsMap connections;
    connections.push( "data1", ::fwData::Object::s_MODIFIED_SIG, s_UPDATE_SLOT ) );
    connections.push( "data2", ::fwData::Object::s_MODIFIED_SIG, s_UPDATE_SLOT ) );
    return connections;
}
```

8.3.7 Object signals

Objects have signals that can be used to inform of modifications. The base class `::fwData::Object` has the following signals available.

Objects	Available messages
Object	{`modified`, `addedFields`, `changedFields`, `removedFields`}

Thus all objects in FW4SPL can use the previous signals. Some object classes define extra signals.

Objects	Available messages
Composite	{`addedObjects`, `changedObjects`, `removedObjects`}
Graph	{`updated`}
Image	{`bufferModified`, `landmarkAdded`, `landmarkRemoved`, `landmarkDisplayed`, `distanceAdded`, `distanceRemoved`, `distanceDisplayed`, `sliceIndexModified`, `sliceTypeModified`, `visibilityModified`, `transparencyModified`}
Mesh	{`vertexModified`, `pointColorsModified`, `cellColorsModified`, `pointNormalsModified`, `cellNormalsModified`, `pointTexCoordsModified`, `cellTexCoordsModified`}
ModelSeries	{`reconstructionsAdded`, `reconstructionsRemoved`}
PlaneList	{`planeAdded`, `planeRemoved`, `visibilityModified`}
Plane	{`selected`}
PointList	{`pointAdded`, `pointRemoved`}
Reconstruction	{`meshModified`, `visibilityModified`}
ResectionDB	{`resectionAdded`, `safePartAdded`}
Resection	{`reconstructionAdded`, `pointTexCoordsModified`}
Vector	{`addedObjects`, `removedObjects`}
...	...

8.3.8 Proxy

The class `::fwServices::registry::Proxy` is a communication element and singleton in the architecture. It defines a proxy for signal/slot connections. The proxy concept is used to declare communication channels: all signals registered in a proxy's channel are connected to all slots registered in the same channel. This concept is useful to create multiple connections or when the slots/signals have not yet been created (possible in dynamic programs).

The following shows an example where one signal is connected to several slots:

```
const std::string CHANNEL = "myChannel";

::fwServices::registry::Proxy::sptr proxy
    = ::fwServices::registry::Proxy::getDefault();

::fwCom::Signal< void() >::sptr sig = ::fwCom::Signal< void() >::New();

::fwCom::Slot< void() >::sptr slot1 = ::fwCom::newSlot( &myFunc1 );
::fwCom::Slot< void() >::sptr slot2 = ::fwCom::newSlot( &myFunc2 );
::fwCom::Slot< void() >::sptr slot3 = ::fwCom::newSlot( &myFunc3 );

proxy->connect(CHANNEL, sig);

proxy->connect(CHANNEL, slot1);
proxy->connect(CHANNEL, slot2);
proxy->connect(CHANNEL, slot3);

sig->emit(); // All slots are called
```

8.4 App-config

8.4.1 Dynamic program with factories

As shown in the *Object-Service concept example*, it is easy to change an application's behavior by simply changing the appropriate data and services. For example changing an image visualization application to a 3D model visualization application. Unfortunately, this is limited to applications based on one service and one data, and thus it would be impossible to apply to applications containing multiple services and objects.

To overcome this, the FW4SPL architecture provides a dynamic management of configurations to allow the use of multiple objects and services.

The xml configuration for an application is defined with the extension `::fwServices::registry::AppConfig`.

8.4.2 Dynamic program with application configuration

In the `fwServices` library, an application configuration parser allows to parse XML files and creates and manages objects, services and communications.

```
// The parser
void main (int argc , char * argv [])
{
    string xmlAppConfigPath = argv [1];

    ::fwServices::AppConfigManager::sptr acm
```

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```
            = ::fwServices::AppConfigManager::New();

    acm->setConfig(xmlAppConfigPath);
    acm->create(); // Creates objects and services from config.
    acm->start(); // Starts services specified in config.
    acm->update(); // Updates services specified in config.

    acm->stop(); // Stops services specified in config.
    acm->destroy(); // Destroy all services and then data.
}
```

The following part corresponds to the configuration XML file of the previous *Object-Service concept example*.

```
<object uid="image" type ="::fwData::MyData" />

<service uid="frame" type="DefaultFrame">
    <!-- service configuration -->
</service>

<service uid="view" type="MyCustomImageView">
    <in key="object" uid="image" />
    <!-- service configuration -->
</service>

<service uid="reader" type="MyCustomImageReader">
    <in key="object" uid="image" />
    <!-- service configuration -->
</service>

<!-- view listen now image modification -->
<connect>
    <signal>image/objectModified</signal>
    <slot>view/receive</slot>
</connect>

<start uid="frame" />
<start uid="view"/>
<start uid="reader"/>

<!-- Read the image on filesystem and notify
     the view to refresh is content -->
<update uid ="reader"/>
```

This simple example shows how it is possible to build an application with several objects and services using only a program and its configurations files.

8.4.3 Example

```
<extension implements="::fwServices::registry::AppConfig">
    <id>myAppConfigId</id>
    <parameters>
        <param name="appName" default="my Application" />
        <param name="appIconPath" />
    </parameters>
    <desc>Image Viewer</desc>
```

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```
    <config>

        <object uid="myImage" type="::fwData::Image" />

        <!--
            Description service of the GUI:
            The ::gui::frame::SDefaultFrame service automatically positions the␣
↪various
            containers in the application main window.
            Here, it declares a container for the 3D rendering service.
        -->
        <service uid="myFrame" type="::gui::frame::SDefaultFrame">
            <gui>
                <frame>
                    <name>${appName}</name>
                    <icon>${appIconPath}</icon>
                    <minSize width="800" height="600" />
                </frame>
            </gui>
            <registry>
                <!-- Associate the container for the rendering service. -->
                <view sid="myRendering" />
            </registry>
        </service>

        <!--
            Reading service:
            The <file> tag defines the path of the image to load. Here, it is a␣
↪relative
            path from the repository in which you launch the application.
        -->
        <service uid="myReaderPathFile" type="::ioVTK::SImageReader">
           <inout key="target" uid="myImage" />
           <file>./TutoData/patient1.vtk</file>
        </service>

        <!--
            Visualization service of a 3D medical image:
            This service will render the 3D image.
        -->
        <service uid="myRendering" type="::vtkSimpleNegato::SRenderer">
           <in key="image" uid="myImage" />
        </service>

        <!--
            Definition of the starting order of the different services:
            The frame defines the 3D scene container, so it must be started first.
            The services will be stopped the reverse order compared to the starting␣
↪one.
        -->
        <start uid="myFrame" />
        <start uid="myReaderPathFile" />
        <start uid="myRendering" />

        <!--
            Definition of the service to update:
            The reading service load the data on the update.
```

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```
            The render update must be called after the reading of the image.
        -->
        <update uid="myReaderPathFile" />
        <update uid="myRendering" />

    </config>
</extension>
```

Parameters

id

The id is the configuration identifier, and is thus unique to each configuration.

parameters (optional)

The parameters is a list of the parameters used by the configuration.

- **param:** defines the parameter
  - **name:** parameter name, used as `${paramName}` in the configuration. It will be replaced by the string defined by the service, activity or application that launches the configuration.
  - **default (optional):** default value for the parameter, it is used if the value is not given by the config launcher.

desc (optional)

The description of the application.

Object

the <object> tags define the objects of the AppConfig.

- **uid (optional):** Unique identifier of the object (::fwTools::fwID). If it is not defined, it will be automatically generated.
- **type:** Object type (ex: `::fwData::Image`, `::fwData::Composite`)
- **src (optional, "new" by default)** possible values: "new", "ref", "deferred"
  - **"new"** : defines that the object should be created
  - **"ref"** : defines that the object already exists in the application. The uid must be the same as the first declaration of this object (with "new").
  - **"deferred"** : defines that the object will be created later (by a service).

Specific object configuration

- **matrix (optional):** It works only for `::fwData::TransformationMatrix3D` objects. It defines the value of the matrix.

```
<object uid="matrix" type="::fwData::TransformationMatrix3D">
    <matrix>
    <![CDATA[
        1  0  0  0
        0  1  0  0
        0  0  1  0
        0  0  0  1
    ]]>
    </matrix>
</object>
```

- **value (optional):** Only these objects contain this tag : `::fwData::Boolean`, `::fwData::Integer`, `::fwData::Float` and `::fwData::String`. It allows to define the value of the object.

```
<object type="::fwData::Integer">
    <value>42</value>
</object>
```

- **colors (optional):** Only `::fwData::TransferFunction` contains this tag. It allows to fill the transfer function values.

```
<object type="::fwData::TransferFunction">
    <colors>
        <step color="#ff0000ff" value="1" />
        <step color="#ffff00ff" value="500" />
        <step color="#00ff00ff" value="1000" />
        <step color="#00ffffff" value="1500" />
        <step color="#0000ffff" value="2000" />
        <step color="#000000ff" value="4000" />
    </colors>
</object>
```

- **item (optional):** It defines a sub-object of a composite or a field of any other object.
  - **key:** key of the object
  - **object:** the 'item' tag can only contain 'object' tags that represents the sub-object

```
<item key="myImage">
    <object uid="myImageUid" type="::fwData::Image" />
</item>
```

Service

The <service> tags represent a service working on the object(s). Services list the data the use and how they access them. Some services needs a specific configuration, it is usually described in the doxygen.

- **uid (optional):** Unique identifier of the service. If it is not defined, it will be automatically generated.
- **impl:** Service implementation type (ex: `::ioVTK::SImageReader`)
- **type (optional):** Service type (ex: `::io::IReader`)
- **autoConnect (optional, "no" by default):** Defines if the service receives the signals of the working object
- **worker (optional):** Allows to run the service in another worker (see *Multithreading*)

```
<service uid="mesher" type="::opMesh::SMesher" worker="myWorker">
    <in key="image" uid="imageId" />
    <out key="mesh" uid="meshId" />
</service>
```

- **in:** input object, it is const and cannot be modified
- **inout:** input object that can be modified
- **out:** output object, it must be created by a service and registered with the 'setOutput(key, obj)' method. The output object must be declared as "deferred" in the <object> declaration.
  - **key** : object key used to retrieve the object into the service
  - **uid** : unique identifier of the object declared in the <object> tag
  - **optional** : (optional, default "no", values: "yes" or "no") If "yes", the service can be started even if the object is not present. By definition, the output objects are always optional.

```
::fwData::Image::csptr image = this->getInput< ::fwData::Image >("image");
::fwData::Mesh::sptr mesh = ::fwData::Mesh::New();
// mesher .....
this->setOutput("mesh", mesh);
```

Connection

- **connect (optional):**

  allows to connect one or more signal(s) to one or more slot(s). The signals and slots must be compatible.

  - **channel (optional):** name of the channel use for the connections.

```
<connect channel="myChannel">
    <signal>object_uid/signal_name</signal>
    <slot>service_uid/slot_name</slot>
</connect>
```

Start-up

- **start:** defines the service to start when the AppConfig is launched. The services will be automatically stopped in the reverse order when the AppConfig is stopped.

```
<start uid="service_uid" />
```

The service using "deferred" object as input will be automatically started when the object is created.

- **update:** defines the service to update when the AppConfig is launched.

```
<update uid="service_uid" />
```

8.5 Activities

An activity is defined by the extension `::fwActivities::registry::Activities`. It is used to launch an *AppConfig* with the selected data, it will create a new data `::fwMedData::ActivitySeries` that inherits from

a `fwMedData::Series`.

There is two way to launch an activity: - from a selection of Series contained in a Vector - from a activity wizard

from a selection of Series contained in a Vector:

The service `::activities::action::SActivityLauncher` allows to launch an activity from a selection of Series. Its role is to create the specific Activity associated with the selected data. The Series are contained in a `::fwData::Vector` that can be filled by the user on clicking on the Series selection widget (`::uiMedDataQt::editor::SSelector`)

This action should be followed by the service `guiQt::editor::SDynamicView` : this service listens the action signals and launchs the activity in a new tab.

from the activity wizard:

The editor `::activities::editor::SCreateActivity` and the action `::activities::action::SCreateActivity` propose the list of the available activity for the application, and when the user select one of them it sends a signal with the activity identifier. The activity wizard (`::uiMedDataQt::editor::SActivityWizard`) listen this signal and display a widget to set the required data. The `::fwMedData::ActivitySeries` is created and can be launched by the `guiQt::editor::SDynamicView`.

The process to create the activity with the different services works with signals and slots.

8.5.1 Activity series

The `::fwMedData::ActivitySeries` has a `::fwData::Composite` that contains all the data required by the activity.

```
class FWMEDDATA_CLASS_API ActivitySeries : public ::fwMedData::Series
{
public:

    /// Constructor
    FWMEDDATA_API ActivitySeries();

    /// Destructor
    FWMEDDATA_API virtual ~ActivitySeries();

    /// Defines shallow copy
    FWMEDDATA_API void shallowCopy( const ::fwData::Object::csptr &_source );

    /// Defines deep copy
    FWMEDDATA_API void cachedDeepCopy( const ::fwData::Object::csptr &_source,␣
↪DeepCopyCacheType &cache );

    /**
     * @brief Data container
     * @{ */
    ::fwData::Composite::sptr getData () const;
    void setData(const ::fwData::Composite::sptr & val);
    /**  @} */

    /**
     * @brief Activity configuration identifier
     * @{ */
    const std::string &getActivityConfigId () const;
```

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```
    void setActivityConfigId (const std::string &val);
    /**  @} */

protected:

    /// Activity configuration identifier
    ConfigIdType m_activityConfigId;

    /// Data container
    ::fwData::Composite::sptr m_data;
};
```

8.5.2 Example

```
<extension implements="::fwActivities::registry::Activities">
   <id>myActivityId</id>
   <title>3D Visu</title>
   <desc>Activity description ...</desc>
   <icon>Bundles/media_0-1/icons/icon-3D.png</icon>
   <requirements>
        <requirement name="param1" type="::fwData::Image" /> <!-- defaults :␣
↪minOccurs = 1, maxOccurs = 1-->
        <requirement name="param2" type="::fwData::Mesh" maxOccurs="3" >
            <key>Item1</key>
            <key>Item2</key>
            <key>Item3</key>
        </requirement>
        <requirement name="param3" type="::fwData::Mesh" maxOccurs="*" container=
↪"vector" />
        <requirement name="imageSeries" type="::fwMedData::ImageSeries" minOccurs="0"␣
↪maxOccurs="2" />
        <requirement name="modelSeries" type="::fwMedData::ModelSeries" minOccurs="1"␣
↪maxOccurs="1">
             <desc>Description of the required data....</desc>
             <validator>::fwActivities::validator::ImageProperties</validator>
        </requirement>
        <requirement name="transformationMatrix" type=
↪"::fwData::TransformationMatrix3D" minOccurs="0" maxOccurs="1" create="true" />
       <!-- ...-->
   </requirements>
   <builder>::fwActivities::builder::ActivitySeries</builder>
   <validator>::fwActivities::validator::ImageProperties</validator><!-- pour fw4spl_
↪0.9.2 -->
   <appConfig id="myAppConfigId">
       <parameters>
           <parameter replace="registeredImageUid" by="@values.param1" />
           <parameter replace="orientation" by="frontal" />
           <!-- ...-->
       </parameters>
   </appConfig>
</extension>
```

The activity parameters are (in the following order):

id

The activity unique identifier.

title

The activity title that will be displayed on the tab.

desc

The description of the activity. It is displayed by the SActivityLauncher when several activity can be launched with the selected data.

icon

The path to the activity icon. It is displayed by the SActivityLauncher when several activity can be launched with the selected data.

requirements

The list of the data required to launch the activity. This data must be selected in the vector (`::fwData::Vector`).

requirement: A required data.

- **name:** Key used to add the data in the activity Composite.
- **type:** The data type (ex: `::fwMedData::ImageSeries`).
- **minOccurs (optional, "1" by default):** The minimum number of occurrences of this type of object in the vector.
- **maxOccurs (optional, "1" by default):** The maximum number of occurrences of this type of object in the vector.
- **container (optional, "vector" or "composite", default: composite):** Container used to contain the data if minOccurs or maxOccurs are not "1". If the container is "composite", you need to specify the "key" of each object in the composite.
- **create (optional, default "false"):** If true and (minOccurrs == 0 && maxOccurs == 1), the data will be automatically created if it is not present.
- **desc (optional):** description of the parameter
- **validator (optional):** validator to check if the associated data is well formed (inherited of ::fwAtivities::IObjectValidator)

builder

The builder is only used when the activity series is created from a selection of Series. Implementation of the activity builder. The default builder is `::fwActivities::builder::ActivitySeries` : it creates the `::fwMedData::ActivitySeries` and adds the required data in its composite with de defined key.

The builder `::fwActivities::builder::ActivitySeriesInitData` allows, in addition to what the default builder does, to create data when minOccurs == 0 and maxOccurs == 0.

validators (optional)

It defines the list of validators. If you need only one validator, you don't need the "validators" tag (only "validator").

validator (optional): It allows to validate if the selected required objects are correct for the activity.

For example, the validator `::fwActivities::validator::ImageProperties` checks that all the selected images have the same size, spacing and origin.

appConfig

It defines the AppConfig to launch and its parameters

id: Identifier of the AppConfig

parameters: List of the parameters required by the AppConfig

parameter: Defines a parameter

replace: Name of the parameter as defined in the AppConfig

by: Defines the string that will replace the parameter name. It should be a simple string (ex. frontal) or define a sesh@ path (ex. @values.myImage). The root object of the sesh@ path is the composite contained in the ActivitySeries.

8.5.3 Validators

There is three types of validator :

Pre-build validator

This type of validator is only used when the activity series is created from a selection of Series. This type of validators checks if the current selection of data is correct to build the activity. It inherits of ::fwActivities::IValidator and must implement the methods:

```
ValidationType validate(
       const ::fwActivities::registry::ActivityInfo& activityInfo,
       SPTR(::fwData::Vector) currentSelection ) const;
```

Activity validator

This type of validator checks if the ::fwMedData::ActivitySeries is correct to launch its associated activity. It inherits of ::fwActivities::IActivityValidator and must implement the method:

```
ValidationType validate(const CSPTR(::fwMedData::ActivitySeries) &activity ) const;
```

The validator ::fwActivities::validator::DefaultActivity is applied if no other validator is defined. It checks if all the required objets are present in the series and if all the parameters delivered to the AppConfig are present.

It provides some method useful to implement your own validator.

Object validator

This type of validator checks if the required object is well formed. It can check a single object or a Vector or a Composite containing one type of object. It inherits of ::fwActivities::IObjectValidator and must implement the method:

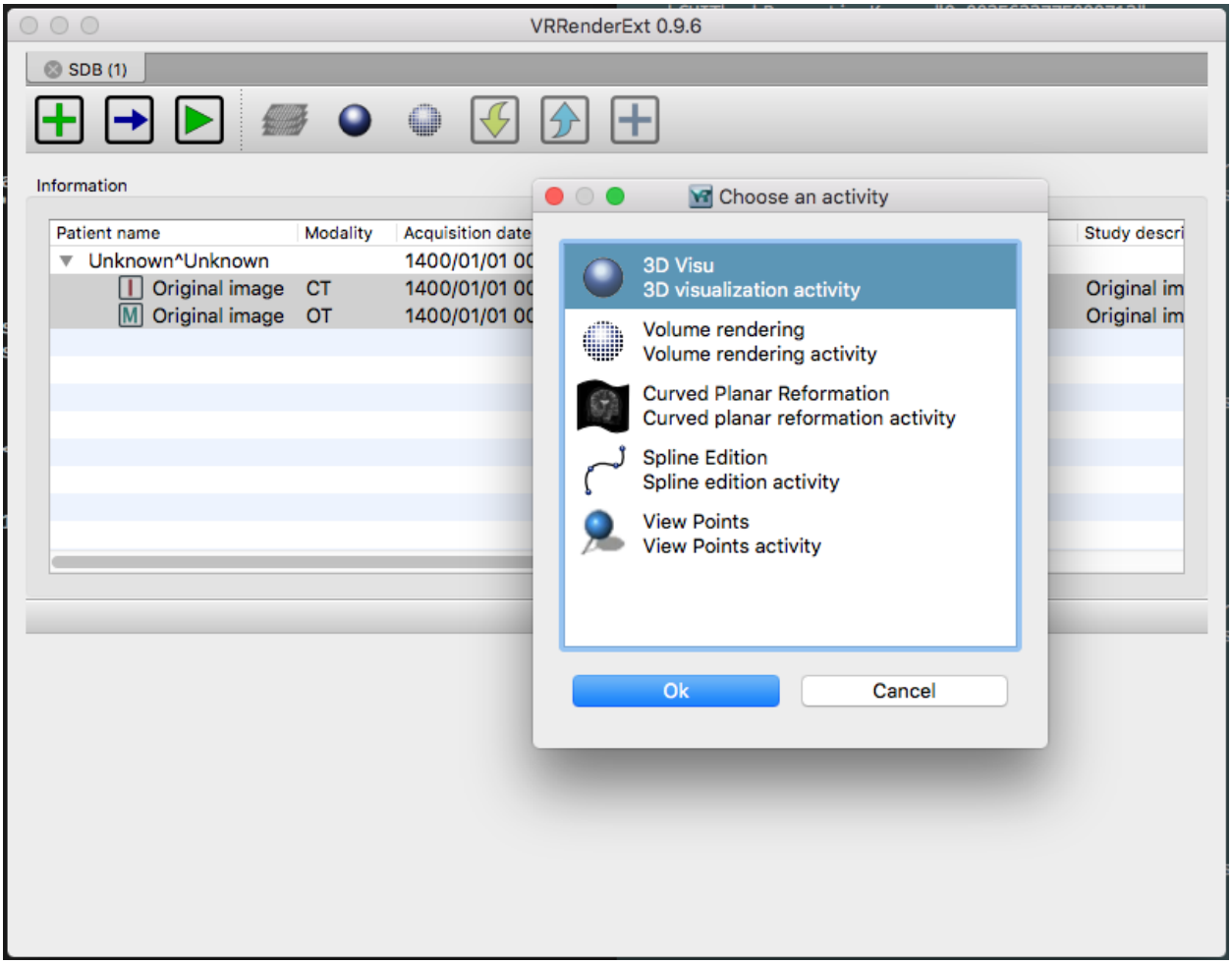
```
ValidationType validate(const CSPTR(::fwData::Object) &currentData ) const;
```

8.5.4 Wizard

Services are available to create/launch activities :

SActivityLauncher

This action allows to launch an activity according to the selected data.



SCreateActivity

There is an action or an editor (`::activities::action::SCreateActivity` or `::activities::editor::SCreateActivity`). This services display the available activities according to the configuration.

When the activity is selected, the service sends a signal with the activity identifier. It should works with the ::uiMedData::editor::SActivityWizard that creates or updates the activitySeries.

```
<service uid="action_newActivity" type="::activities::action::SCreateActivity">
    <!-- Filter mode 'include' allows all given activity id-s.
         Filter mode 'exclude' allows all activity id-s excepted given ones. -->
    <filter>
        <mode>include</mode>
        <id>2DVisualizationActivity</id>
        <id>3DVisualizationActivity</id>
        <id>VolumeRenderingActivity</id>
    </filter>
</service>
```

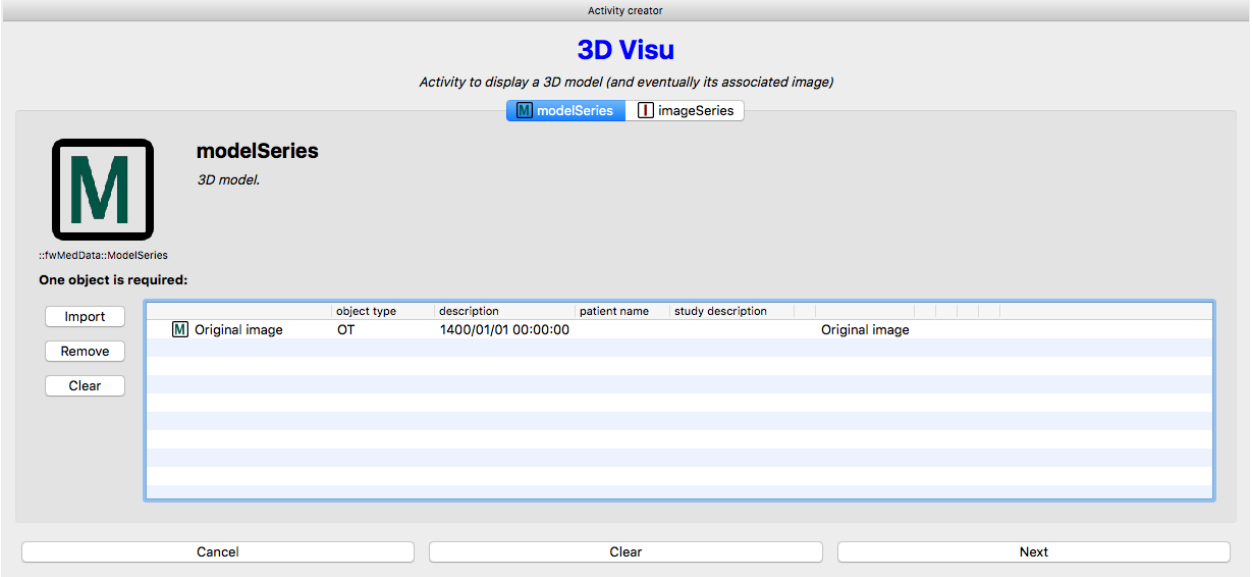
filter (optional): it allows to filter the activity that can be proposed.

mode: 'include' or 'exclude'. Defines if the activity in the following list are proposed (include) or not (exclude).

id: id of the activity

SActivityWizard

This editor allows to select the data required by an activity in order to create the ActivitySeries. This editor displays a tab widget (one tab by data). It works on a ::fwMedData::SeriesDB and adds the created activity series into the seriesDB.



Example

To launch the activity, you will need to connect the services in you AppConfig:

```
<extension implements="::fwServices::registry::AppConfig">
    <id>myExample</id>
    <config>

        <object uid="seriesDB" type="::fwMedData::SeriesDB" />
```

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```
        <!-- ... -- >

        <!-- Editor to select an activity. -->
        <service uid="activitySelector" type="::activities::editor::SCreateActivity" /
↪>

        <service uid="activityCreator" type="::uiMedDataQt::editor::SActivityWizard" >
            <inout key="seriesDB" uid="seriesDB" />
            <ioSelectorConfig>SDBReaderIOSelectorConfig</ioSelectorConfig>
        </service>

        <service uid="dynamicView" type="::guiQt::editor::SDynamicView" autoConnect=
↪"yes">
            <mainActivity id="myMainActivity" closable="false" />
            <inout key="SERIESDB" uid="seriesDB" />
            <parameters>
                <parameter replace="ICON_PATH" by="${appIconPath}" />
            </parameters>
        </service>

        <!-- Display the gui allowing to create a ::fwMedData::ActivitySeries with␣
↪the required data for
             the selected activity. -->
        <connect>
            <signal>selector/activityIDSelected</signal>
            <slot>activityCreator/createActivity</slot>
        </connect>

        <!-- Launch the activity when it is created. -->
        <connect>
            signal>activityCreator/activityCreated</signal>
            <slot>dynamicView/launchActivity</slot>
        </connect>

    </config>
</extension>
```

8.6 Multithreading

8.6.1 Overview

The multithreading paradigm has become more popular as efforts to further exploit instruction level parallelism have stalled since the late 1990s. This allowed the concept of throughput computing to re-emerge to prominence from the more specialized field of transaction processing:

- Even though it is very difficult to further speed up a single thread or single program, most computer systems are actually multi-tasking among multiple threads or programs.
- Techniques that would allow speedup of the overall system throughput of all tasks would be a meaningful performance gain.

Some advantages include:

- If a thread gets a lot of cache misses, the other thread(s) can continue, taking advantage of the unused computing resources, which thus can lead to faster overall execution, as these resources would have been idle if only a single

thread was executed.

- If a thread cannot use all the computing resources of the CPU (because instructions depend on each other's result), running another thread can avoid leaving these idle.
- If several threads work on the same set of data, they can actually share their cache, leading to better cache usage or synchronization of its values.

Some criticisms of multithreading include:

- Multiple threads can interfere with each other when sharing hardware resources such as caches or translation look aside buffers (TLBs).
- Execution times of a single thread are not improved but can be degraded, even when only one thread is executing. This is due to slower frequencies and/or additional pipeline stages that are necessary to accommodate thread-switching hardware.
- Hardware support for multithreading is more visible to software, thus requiring more changes to both application programs and operating systems than multiprocessing.
- Thread scheduling is also a major problem in multithreading.

Michael K. Gschwind, et al.[1]

8.6.2 Worker and Timer

In the FW4SPL architecture, the library `fwThread` provides few tools to execute asynchronous tasks on different threads.

In this library, the class `Worker` creates and manages a task loop. The default implementation creates a loop in a new thread. Some tasks can be posted on the worker and will be executed on the managed thread. When the worker is stopped, it waits for the last task to be processed and stops the loop.

```
::fwThread::Worker::sptr worker = ::fwThread::Worker::New();

::boost::packaged_task<void> task( ::boost::bind( &myFunction ) );
::boost::future< void > future = task.get_future();
::boost::function< void () > f = moveTaskIntoFunction(task);

worker->post(f);

future.wait();
worker->stop();
```

The Timer class provides single-shot or repetitive timers. A Timer triggers a function once after a delay, or periodically, inside the worker loop. The delay or the period is defined by the duration attribute.

```
::fwThread::Worker::sptr worker = ::fwThread::Worker::New();

::fwThread::Timer::sptr timer = worker->createTimer();

timer->setFunction(  ::boost::bind( &myFunction)  );

::boost::chrono::milliseconds duration
        = ::boost::chrono::milliseconds(100) ;
timer->setDuration(duration);
```

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[1] Michael K. Gschwind, Valentina Salapura. 2011. Using Register Last Use Infomation to Perform Decode-Time Computer Instruction Optimization US 20130086368 A1 [Patent]. http://www.google.com/patents/US20130086368

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```
timer->start();
//...
timer->stop();

worker->stop();
```

8.6.3 Mutex

The namespace `fwCore::mt` provides common foundations for multithreading in FW4SPL, especially tools to manage mutual exclusions. In computer science, mutual exclusion refers to the requirement of ensuring that two concurrent threads are not in a critical section at the same time, it is a basic requirement in concurrency control, to prevent race conditions. Here, a critical section refers to a period when the process accesses a shared resource, such as shared memory. A lock system is designed to enforce a mutual exclusion concurrency control policy.

Currently, FW4SPL uses Boost Thread library which allows the use of multiple execution threads with shared data, keeping the C++ code portable. `fwCore::mt` defines a few typedef over Boost:

```
namespace fwCore
{
namespace mt
{

typedef ::boost::mutex Mutex;
typedef ::boost::unique_lock< Mutex > ScopedLock;

typedef ::boost::recursive_mutex RecursiveMutex;
typedef ::boost::unique_lock< RecursiveMutex > RecursiveScopedLock;

/// Defines a single writer, multiple readers mutex.
typedef ::boost::shared_mutex ReadWriteMutex;
/**
* @brief Defines a lock of read type for read/write mutex.
* @note Multiple read lock can be done.
*/
typedef ::boost::shared_lock< ReadWriteMutex > ReadLock;
/**
* @brief Defines a lock of write type for read/write mutex.
* @note Only one write lock can be done at once.
*/
typedef ::boost::unique_lock< ReadWriteMutex > WriteLock;
/**
* @brief Defines an upgradable lock type for read/write mutex.
* @note Only one upgradable lock can be done at once but there
        may be multiple read lock.
*/
typedef ::boost::upgrade_lock< ReadWriteMutex > ReadToWriteLock;
/**
* @brief Defines a write lock upgraded from ReadToWriteLock.
* @note Only one upgradable lock can be done at once but there
        may be multiple read lock.
*/
typedef ::boost::upgrade_to_unique_lock< ReadWriteMutex >
            UpgradeToWriteLock;
```

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```
} //namespace mt
} //namespace fwCore
```

8.6.4 Multithreading and communication

Asynchronous call

Slots are able to work with `fwThread::Worker`. If a Slot has a Worker, each asynchronous execution request will be run in its worker, otherwise asynchronous requests can not be satisfied without specifying a worker.

Setting worker example:

```
::fwCom::Slot< int (int, int) >::sptr slotSum
        = ::fwCom::newSlot( &sum );
::fwCom::Slot< void () >::sptr slotStart
        = ::fwCom::newSlot( &A::start, &a );

::fwThread::Worker::sptr w = ::fwThread::Worker::New();
slotSum->setWorker(w);
slotStart->setWorker(w);
```

`asyncRun` method returns a boost::shared_future< void >, that makes it possible to wait for end-of-execution.

```
::boost::future< void > future = slotStart->asyncRun();
// do something else ...
future.wait(); //ensures slotStart is finished before continuing
```

`asyncCall` method returns a `boost::shared_future< R >` where R is the return type. This allows facilitates waiting for end-of-execution and retrieval of the computed value.

```
::boost::future< int > future = slotSum->asyncCall();
// do something else ...
future.wait(); //ensures slotStart is finished before continuing
int result = future.get();
```

In this case, the slots asynchronous execution has been *weakened*. For an async call/run pending in a worker queue, it means that :

- if the slot is detroyed before the execution of this call, it will be canceled.
- if slot's worker is changed before the execution of this call, it will also be canceled.

Asynchronous emit

As slots can work asynchronously, triggering a Signal with asyncEmit results in the execution of connected slots in their worker :

```
sig2->asyncEmit(21, 42);
```

The instruction above has the consequence of running each connected slot in its own worker.

Note: Each connected slot must have a worker set to use asyncEmit.

8.6.5 Object-Service and Multithreading

Object

The architecture allows the writing of thread safe functions which manipulate objects easily. Objects have their own mutex (inherited from `fwData::Object`) to control concurrent access from different threads. This mutex is available using the following method:

```
::fwCore::mt::ReadWriteMutex & getMutex();
```

The namespace `fwData::mt` contains several helpers to lock objects for multithreading:

- `ObjectReadLock`: locks an object mutex on read mode.
- `ObjectReadToWriteLock`: locks an object mutex on upgradable mode.
- `ObjectWriteLock`: locks an object mutex on exclusive mode.

The following example illustrates how to use these helpers:

```
::fwData::String::sptr m_data = ::fwData::String::New();
{
    // lock data to write
    ::fwData::mt::ObjectReadLock readLock(m_data);
} // helper destruction, data is no longer locked


{
    // lock data to write
    ::fwData::mt::ObjectWriteLock writeLock(m_data);

    // unlock data
    writeLock.unlock();

    // lock data to read
    ::fwData::mt::ObjectReadToWriteLock updrageLock(m_data);

    // unlock data
    updrageLock.unlock();

    // lock again data to read
    updrageLock.lock();

    // lock data to write
    updrageLock.upgrade();

    // lock data to read
    updrageLock.downgrade();

} // helper destruction, data is no longer locked
```

Services

The service architecture allows the writing of a thread-safe service by avoiding the requirement of explicit synchronization. Each service has an associated worker in which service methods are intended to be executed.

Specifically, all inherited `IService` methods (`start`, `stop`, `update`, `receive`, `swap`) are slots. Thus, the whole service life cycle can be managed in a separate thread.

Since services are designed to be managed in an associated worker, the worker can be set/updated by using the inherited method :

```
// Initializes m_associatedWorker and associates
// this worker to all service slots
void setWorker( ::fwThread::Worker::sptr worker );

// Returns associate worker
::fwThread::Worker::sptr getWorker() const;
```

Since the signal-slot communication is thread-safe and `IService::receive(msg)` method is a slot, it is possible to attach a service to a thread and send notifications to execute parallel tasks.

Note: Some services use or require GUI backend elements. Thus, they can't be used in a separate thread. All GUI elements must be created and managed in the application main thread/worker.

8.7 Serialization

8.7.1 Overview

Serialization is the process to save plain C++ structures from memory to hard drive. In fw4spl, `fwAtoms` library provides tools to serialize all data (and especially Object that extend `::fwData::Object`) to a JSON format[1]. Of course, this process is also available for loading data from JSON format to plain C++ structures.

To achieve this serialization, `fwAtoms` provides basic structures (which extend `::fwAtoms::Base`) to manage better plain C++ structure evolution. Thus, there are two main steps in the serialization process:

- Converting a `::fwData::Object` into a `::fwAtoms::Object`
- Serializing a `::fwAtoms::Base` in a JSON format

8.7.2 Atom objects

The basic structures provided by `fwAtoms` library are a set of restricted C++ type. All these structures extend `::fwAtoms::Base` and cover all basic types and containers:

type	brief
::fwAtoms::Base	Base class of all atoms
::fwAtoms::String	Atom to represent string types
::fwAtoms::Numeric	Atom to represent numeric types (floating number or integer)
::fwAtoms::Boolean	Atom to represent a boolean value
::fwAtoms::Map	Atom to represent an associative container (std::string to ::fwAtoms::Base)
::fwAtoms::Sequence	Atom to represent a sequence of object like vector or list
::fwAtoms::Object	Atom to represent a C++ object with attributes
::fwAtoms::Blob	Atom to represent binary information like buffers

For instance, consider the following C++ class:

[1] Introducing JSON. http://json.org/

```
class SimpleClass
{
    bool m_myBoolean;
};

class ComplexClass
{
    std::string m_myString;
    float m_myFloat;
    SimpleClass* m_mySimpleClass;
};
```

It's Atom equivalent is (simplified code):

```
fwAtoms::Object
{
    metaInfos
    {
        "CLASSNAME_METAINFO" : "SimpleClass"
        "ID_METAINFO" : "<ID of the object>"
    }

    attributes
    {
        "myBoolean" : ::fwAtoms::Boolean
    }
}


fwAtoms::Object
{
    metaInfos
    {
        "CLASSNAME_METAINFO" : "ComplexClass"
        "ID_METAINFO" ; "<ID of the object>"
    }

    attributes
    {
        "myString" : ::fwAtoms::String
        "myFloat" : ::fwAtoms::Numeric
        "mySimpleClass" : ::fwAtoms::Object("SimpleClass")
    }
}
```

The main advantage of this representation is the ability to change easily the form of a class. In fact, all plain C++ objects are represented as `Atoms::Object` with a map of attributes. Thus, adding, removing or changing the content of an attribute is easy. Moreover, because of these restricted types, atom parsing is also made easier. The main difficulty is how to convert plain C++ object using this set of restricted types.

8.7.3 Convert a `fwData::Object`

As explained earlier, all objects in fw4spl inherit from the `::fwData::Object` class. To convert a C++ object in Atom, it must inherit from this class. To allow this conversion, some work must be done.

The first thing is to update the header file of the structure and add these lines :

```
// Before all namespace
fwCampAutoDeclareDataMacro((<namespace elem>)
        (<namespace elem>)(<class name>), <method export macro>);

// In the public class part
fwCampMakeFriendDataMacro((<namespace elem>)
        (<namespace elem>)(<class name>));
```

These two functions allow the declaration of the class to the conversion process.

Next, the conversion systems must know the class information including attributes, base class, library location and data version. This is achieved by creating a class which defines these properties.

Example

This can be illustrated by taking the previous class and creating these two files:

Header file of the newly created class: ComplexClass.hpp

```
// Reference class

fwCampAutoDeclareDataMacro((fwData)(ComplexClass), FWDATA_API);

namespace fwData
{
class ComplexClass : public ::fwData::Object
{
    fwCampMakeFriendDataMacro((fwData)(ComplexClass));

    std::string m_myString;
    float m_myFloat;
    ::fwData::SimpleClass* m_mySimpleClass;
};
}
```

Header file of serialization class :

```
// hpp binding file
#include <fwCamp/macros.hpp>
#include <fwData/ComplexClass.hpp>
#include "fwDataCamp/config.hpp"

fwCampDeclareAccessor((fwData)(ComplexClass), (fwData)(SimpleClass));
```

Source file of serialization class :

```
// cpp binding file
// include previous cpp file

#include <fwCamp/UserObject.hpp>

fwCampImplementDataMacro((fwData)(ComplexClass))
{
    builder
        .tag("object_version", "1")
        .tag("lib_name", "fwData")
        .base< ::fwData::Object>()
```

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```
        .property("myString" , &::fwData::ComplexClass::m_myString)
        .property("myFloat" , &::fwData::ComplexClass::m_myFloat)
        .property("mySimpleClass" , &::fwData::ComplexClass::m_mySimpleClass)
        ;
}
```

In a header file, the method fwCampDeclareAccessor is necessary when an object has a pointer or a smart pointer to another object.

In a source file, fwCampImplementDataMacro declares the properties of the bound object with an object called a builder: it provides several methods to describe the object to bind.

method	brief
tag(key, value)	Register a tag in the atom meta information.
base<BaseClass>()	Identify the base class of the bound object
property(arg1, arg2)	Set property of the object and how to access it

Most of the work is completed when the header file of the relevant class has been updated and a binding class created. The last step is to register the binding class in the conversion system using the following line in the library containing binding classes:

```
localDeclarefwDataComplexClass();
```

In fw4spl, data are located in `fwData` library whereas data binding classes are located in `fwDataCamp` library. The above line registering a binding class can be found in `fwDataCamp` autoload.hpp files.

Serialization file example

For more information about serialization see:

location	brief
Srclib/core/fwData/include/	fwData header files with serialization macros
Srclib/core/fwDataCamp	Serialization description of all fw4spl data
Srclib/core/fwDataCamp/include/fwDataCamp/autoload.hpp	Auto loading data bindings in the system

`fwData::Object` to `fwAtoms::Object` conversion

The requirements to convert an `fwData::Object` into an `fwAtoms::Object` are in the `fwAtomConversion` library.

Two functions are necessary to achieve this conversion:

```
//Convert a fwData::Object into fwAtoms::Object
SPTR(::fwAtoms::Object) convert( const SPTR(::fwData::Object) &data );

//Convert a fwAtoms::Object into fwData::Object
SPTR(::fwData::Object) convert( const SPTR(::fwAtoms::Object) &atom );
```

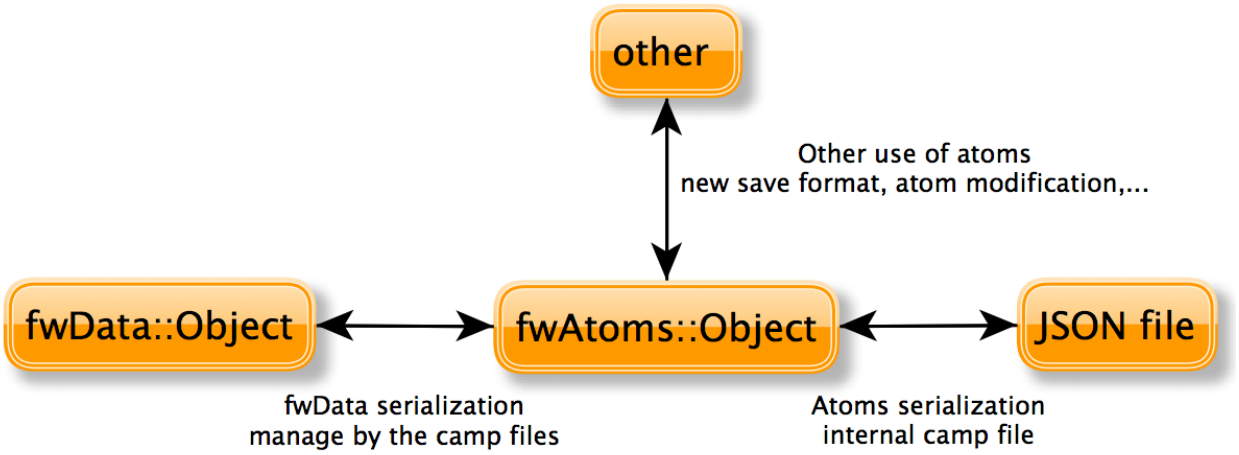
8.7.4 Serialize an Atoms object to JSON format

When a fw4spl data is converted into Atoms, it can be saved in JSON format. Both an Atom reader and Atom writer are available in the `fwAtomsBoostIO` fw4spl library: simply instantiate one of these classes with an Atom object and call the read or write method.

To serialize atoms into JSON, a visitor pattern is used. An example can be found in the `fwAtomsBoostIO/Reader.cpp` file.

8.7.5 Conclusion

Accordingly, you have now the requirements to serialize data in the framework and a basic knowledge about the mechanism behind it. To conclude, this is a diagram of the serialization mechanism:



8.8 Medical patient folder

> DICOM is a software integration standard that is used in Medical Imaging. All modern medical imaging systems (aka Imaging Modalities) equipment like X-Rays, Ultrasounds, CT (Computed Tomography), and MRI (Magnetic Resonance Imaging) support DICOM and use it extensively. The core of DICOM is a file format and a networking protocol.
>
> All Medical Images are saved in DICOM format. Medical Imaging Equipment creates DICOM files. Doctors use DICOM Viewers, computer software applications that can display DICOM images.
>
> DICOM files contain more than just images. Every DICOM file holds patient information (name, ID, sex and birth date), important acquisition data (e.g., type of equipment used and its settings), and the context of the imaging study that is used to link the image to the medical treatment it was part of.

Roni Z. 2011. Introduction to DICOM[1]:

The objects representing the medical patient data In FW4SPL are aligned with the DICOM standard. In the library `fwMedData` several structures and values have been retrieved:

[1] Roni Z. 2011. Introduction to DICOM. Introduction. http://dicomiseasy.blogspot.fr/2011/10/introduction-to-dicom-chapter-1.html

- `Patient`: name, primary hospital identification number, birth date and sex.
- `Study`: unique identifier of the study, study date and time, referring physician, institution-generated description, age of the patient.
- `Equipment`: institution where the equipment that produced the composite instances is located.
- `Series`: unique identifier of the series, type of equipment that originally acquired the data used to create this series, series date and time, series description, name of the physician(s) administering the series.

In FW4SPL, the class `Series` is the main structure and contains pointers to Patient, Study and Equipment structure. The class `SeriesDB` is a container holding several instances of the `Series` class.

To specify an object of type `Series`, the library `fwMedData` holds the following classes inherited from `Series`:

- `ImageSeries` which corresponds to the image series of DICOM (CT images, MRI images, etc).
- `ModelSeries` which corresponds to the meshes series of DICOM and also represents 3D patient models.

The `fwMedData` library also provides a custom series called `ActivitySeries`. An `ActivitySeries` is a `Series` linked to an activity (sub part an application). Hence it is possible to save the state of all the objects used in the activity. Further application specific parameters which are not referred to an object can also be saved in an `ActivitySeries`. Application parameters in relation to the patient can be the view point on an organ, landmarks, calculated distances between organ points, etc.

8.9 Component-based software

The FW4SPL is also a component-based architecture.

Component-based software engineering (CBSE) (also known as component-based development (CBD)) is a branch of software engineering that emphasizes the separation of concerns in respect of the wide-ranging functionality available throughout a given software system. It is a reuse-based approach to defining, implementing and composing loosely coupled independent components into systems. This practice aims to bring about an equally wide-ranging degree of benefits in both the short-term and the long-term for the software itself and for organizations that sponsor such software. Excerpt from "Component-based software engineering"[1] on Wikipedia

8.9.1 Definitions and characteristics

An individual software component is a software package that encapsulates a set of related code: resources, objects, services, XML configuration, etc.

All the architecture is placed into separate components so that all of the data and functions inside each component are semantically related. Because of this principle, it is often said that components are modular and cohesive.

Components communicate with each other via interfaces. When a component offers services to the rest of the system, it adopts a provided interface which specifies services that other components can use. The generic architecture provided by classes Object/IService and the factory system make this interfacing easier.

Re-usability is an important characteristic of a high-quality software component. Programmers should design and implement software components in such a way that many different programs can reuse them.

8.9.2 Component-based implementation

Implementation requires a dynamic structure which represents the component and a software launcher which loads and manages these components. A component, called a bundle, is just a simple folder that contains :

[1] Component-based software engineering http://en.wikipedia.org/wiki/Component-based_software_engineering

- the component description file (plugin.xml) to describe the content of the dynamic library
- the dynamic library, the type of which (.so, .dll, .dylib) differs between operating systems
- other shared resources (icons, XSD file, media files, . . .)

The software launcher uses the library `fwRuntime` to parse the software description file (profile.xml) and load required dynamic libraries:

```
./fwlauncher.exe mySoftware/profile.xml
```

The component description file (plugin.xml) is used to describe the content of the dynamic library. This file reveals which concepts and concept implementations are proposed by the component. These terms are identified in the file by keywords:

- Extension point: the concept
- Extension: a concept implementation (there can be many implementations one of a single concept)

In some cases, the Extension point is represented by an abstract class in a component, and the Extension by the class that it inherits from the abstract class of another component.

One example is the service concept. The component description file of servicesReg introduces the concept of service and incorporates the class IService into the dynamic library:

```
<plugin id="serviceReg">

  <library name="servicesReg" />

  <extension-point id="::fwServices::registry::ServiceFactory" />

</plugin>
```

And in another component, a new service is proposed in the dynamic library and the information is shared in the description file.

```
<plugin id="myBundle">

   <library name ="myBundle" />

   <! -- myBundle requires the bundle servicesReg to run -->
   <requirement id="servicesReg" />

   <! -- Need code related to ::io::IReader -->
   <requirement id="io" />

   <extension implements =" ::fwServices::registry::ServiceFactory ">
       <! -- service type -->
       <type>::io::IReader</type>
       <! -- the service name available in this component library -->
       <service>::myBundle::myReader</service>
       <! -- the object type associated to the service -->
       <object>::fwData::myData</object>
       <desc>Description of my reader</desc>
   </extension>

</plugin>
```

Even if it is often the case, concepts are not limited to class level. A lot a concepts can be defined : service configurations, operator parameters, etc.

8.10 Manager and updater services

In the FW4SPL architecture, there are container objects like `::fwData::Composite`, `::fwData::Vector` and `::fwMedData::SeriesDB`. The `::fwData::Composite` is also an Object and represents a map which associates a string with an Object. The architecture provides a service to manage these objects `::ctrlSelection::SManage`.

We also need services to extract the sub-objects from the containers and add the object in the application configuration (AppConfig)

8.10.1 SManage

This service manages an object (add/swap/remove) into a container object (composite, vector, seriesDB) or into any object's fields.

Available operations on composite are:

- Adding an object
- Swapping an object
- Removing an object
- Removing an object if present
- Adding or swapping an object

```
<object uid="composite" type="::fwData::Composite" />
<object uid="image" type="::fwData::Image" />

<service uid="manager" type="::ctrlSelection::SManage">
    <inout key="object" uid="image" />
    <inout key="composite" uid="composite" />
    <compositeKey>myImage</compositeKey>
</service>

<!-- Add the image in the composite when it is modified -->
<connect>
    <signal>image/modified</signal>
    <slot>manager/addOrSwap</slot>
</connect>

<start uid="manager" />
```

8.10.2 SObjFromSlots

This service allows to add or remove an object in the *Object-Service registry (OSR)* when calling the slots.

```
<object uid="modelSeries" type="::fwMedData::ModelSeries" />
<object uid="reconstruction" type="::fwData::Reconstruction" src="deferred" />

<service uid="listOrganEditor" type="::uiMedDataQt::editor::SModelSeriesList"␣
↪autoConnect="yes">
    <inout key="modelSeries" uid="modelSeries" />
</service>
```

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```
 <service uid="myUpdater" type="::ctrlSelection::updater::SObjFromSlot">
     <out key="object" uid="reconstruction" />
 </service>

<!-- Add the selected reconstruction -->
<connect>
    <signal>listOrganEditor/reconstructionSelected</signal>
    <slot>myUpdater/add</slot>
</connect>

<!-- Remove the reconstruction -->
<connect>
    <signal>listOrganEditor/emptiedSelection</signal>
    <slot>myUpdater/remove</slot>
</connect>

<start uid="listOrganEditor" />
<start uid="myUpdater" />
```

8.10.3 SExtractObj

This service get objects from a source object and expose them as new objects. It uses "camp path" to extract the object (see *What is a camp path ?*).

```
<object uid="composite" type="::fwData::Composite" />

<object uid="image" type="::fwData::Image" src="deferred" />
<object uid="mesh" type="::fwData::Mesh" src="deferred" />

<service uid="extractor" type="::ctrlCamp::SExtractObj" >
   <inout key="source" uid="composite">
       <extract from="@values.myImage" />
       <extract from="@values.myMesh" />
   </inout>
   <out group="target">
       <key uid="image"/>
       <key uid="mesh"/>
   </out>
</service>

<start uid="extractor" />
<update uid="extractor" />
```

8.11 Graphical User Interface

8.11.1 Overview

Graphical User Interface (GUI) is the process of displaying the graphical components of an application. In fw4spl, the `fwGui` library provides abstract tools to display components like windows, buttons, textfield, aso.

The software architecture provides a way of selecting different backends in order to manage the GUI components. As a result, the `fwGuiQt` library has been created to display components created using the Qt soup. Presently, this

backend is the only one supported by the applications.

8.11.2 Backend

When creating an application, we need to specify which gui backend we want to use. To do so, the chosen gui bundle must be activated and started in the profile.xml of the application. The main gui bundle for any application is `guiQt`. The `gui` bundle must be activated regardless of the chosen backend.

```
<activate id="gui" version="0-1" />
<activate id="guiQt" version="0-1" />

<!-- ... -->

<start id="guiQt" />
```

Warning : The gui backend bundle must be started before any other bundle in the profile.xml.

8.11.3 Configuration

Frames

The frame is the main component of a GUI. The main service used to represent a general frame is `::fwGui::IFrameSrv`. The service `::gui::frame::DefaultFrame` is the default implementation for the main application frame. Every backend must provide its own implementation of this service.

The DefaultFrame service is configurable with different parameters :

- Application name
- Application icon
- Minimum window size
- GUI elements (toolbar, menubar, aso.)

```
<service uid="mainFrame" type="::gui::frame::SDefaultFrame">
    <gui>
        <frame>
            <name>Application name</name>
            <icon>path_to_application_icon</icon>
            <minSize width="800" height="600"/>
        </frame>
        <menuBar />
        <toolBar >
            <toolBitmapSize height= "32" width="32" />
        </toolBar>
    </gui>
    <registry>
        <menuBar sid="menuBar" start="yes" />
        <toolBar sid="toolBar" start="yes" />
        <view sid="view" start="yes" />
    </registry>
</service>
```

Menus and actions

The menu bar is used to organize application action groups. The main service used to display that kind of bar is `::fwGui::IMenuBarSrv`. The service `::gui::aspect::SDefaultMenuBar` is the default implementation. Every backend must provide its own implementation of this service.

The configuration is used to associate a menu label with the service representing the menu.

```
<service uid="menuBar" type="::gui::aspect::SDefaultMenuBar">
    <gui>
        <layout>
            <menu name="First Menu"/>
            <menu name="Second Menu"/>
        </layout>
    </gui>
    <registry>
        <menu sid="firstMenu" start="yes" />
        <menu sid="secondMenu" start="yes" />
    </registry>
</service>
```

The main service used to display a menu is `::fwGui::IMenuSrv`. The service `::gui::aspect::SDefaultMenu` is the default implementation. Every backend must provide its own implementation of this service.

The configuration is used to associate an action name and the service performing the action. An action can be configured with a shortcut, a style (default, check, radio) and/or an icon. Several special actions can also be specified (QUIT, ABOUT, aso.).

```
<service uid="myMenu" type="::gui::aspect::SDefaultMenu">
    <gui>
        <layout>
            <menuItem name="First Item" icon="icon_path" />
            <menuItem name="Checked Item" style="check" />
            <separator />
            <menuItem name="Quit" shortcut="Ctrl+Q" specialAction="QUIT" />
        </layout>
    </gui>
    <registry>
        <menuItem sid="actionFirstItem" start="no" />
        <menuItem sid="actionCheckedItem" start="no" />
        <menuItem sid="actionQuit" start="no" />
    </registry>
</service>
```

A menu can also be displayed using a tool bar. The main service used to display a tool bar is `::fwGui::IToolBarSrv`. The service `::gui::aspect::SDefaultToolBar` is the default implementation. Every backend must provide its own implementation of this service.

The configuration of a tool bar is the same as the one used to describe a menu.

Layouts

The layouts are used to organize the different parts of a GUI. The main service used to manage layouts is `::fwGui::IGuiContainerSrv`. The service `::gui::view::SDefaultView` is the default implementation. Every backend must provide its own implementation of this service.

Several types of layout can be used :

- Line layout
- Cardinal layout
- Tab layout

Every layout can be configured with a set of parameters (orientation, alignment, aso.).

```
<service uid="subView" type="::gui::view::SDefaultView">
    <gui>
        <layout type="::fwGui::LineLayoutManager" >
            <orientation value="horizontal" />
            <view caption="view1" />
            <view caption="view2" />
        </layout>
    </gui>
    <registry>
        <view sid="subView1" start="yes" />
        <view sid="subView2" start="yes" />
    </registry>
</service>
```

8.11.4 Multi-threading

The `fwGui` library has been designed to support multi-thread application. When a GUI component needs to be accessed, the function call must be encapsulated in a lambda declaration as shown in this example:

```
::fwServices::registry::ActiveWorkers::getDefaultWorker()->postTask<void>(
[&] {
        //TODO Write function calls
}
).wait();
```

This encapsulation is required because all access to GUI components must be performed in the thread containing the GUI. It moves the function calls from the current thread, to the GUI thread.

8.12 Generic Scene

8.12.1 Overview

A generic scene in FW4SPL is a feature to visualize elements like meshes or images in a scene. The scene is based on VTK. The generic scene is universal and therefore applicable for diverse visualization tasks. It can be seen as fusion of a negatoscope and the 3D model visualization.

8.12.2 Manager

The `SRender` is the manager service of the VTK scene. Its main task is to instantiate a VTK context (`vtkRender` and `vtkRenderWindow`). In addition, it configures the rendering properties and describes a list of *adaptors*, which are dedicated services that render FW4SPL data into this rendering context.

```
<service uid="generiSceneUID" type="::fwRenderVTK::SRender" >
    <scene renderMode="auto|timer|none" offScreen="imageKey" width="1920" height="1080
↪">
```

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```
        <renderer id="myRenderer" layer="0" background="0.0" />
        <vtkObject id="transform" class="vtkTransform" />
        <picker id="negatodefault" vtkclass="fwVtkCellPicker" />

        <adaptor uid="meshAdaptor" />
        <adaptor uid="imageAdaptor" />

    </scene>
    <fps>30</fps><!-- used if renderMode=="timer" -->
</service>
```

renderMode (optional, "auto" by default) This attribute is forwarded to all adaptors. For each adaptor, if renderMode="auto", the scene is automatically rendered after doStart, doUpdate, doSwap, doStop and m_vtkPipelineModified=true. If renderMode="timer" the scene is rendered at N frame per seconds (N is defined by **fps** tag). If renderMode="none" you should call 'render' slot to render the scene.

offScreen (optional): Key of the image used for off screen render

width (optional, "1280" by default): Width for off screen render

height (optional, "720" by default): Height for off screen render

renderer Defines a renderer. At least one renderer is mandatory, but there can be multiple renderer on different layers.

- **id** (mandatory): the identifier of the renderer
- **layer** (optional): defines the layer of the vtkRenderer. This is only used if there are layered renderers.
- **background** (optional): the background color of the rendering screen.

The color value can be defined as a grey level value (ex . 1.0 for white) or as a hexadecimal value (ex : #ffffff for white).

vtkObject

Represents a vtk object. It is usually used for vtkTransform or vtkImageBlend.

- **id** (mandatory): the identifier of the vtkObject
- **class** (mandatory): the classname of the vtkObject to create. For example vtkTransform, vtkImageBlend, ...

picker Represents a picker.

- **id** (mandatory): the identifier of the picker
- **vtkclass** (optional, by default vtkCellPicker): the classname of the picker to create.

adaptor Defines the adaptors to display in the scene.

- **uid** (mandatory): the uid of the adaptor service

8.12.3 Adaptor

An adaptor (inherited from `::fwRenderVTK::IAdaptor`) is a service to manipulate or display a FW4SPL data. Services representing an adaptor are managed by a generic scene (`::fwRenderVTK::SRender`). The adaptors are the gateway between FW4SPL objects and VTK objects. To respect the principles of the framework, adaptors are kept as generic as possible. Therefore they are reusable in other applications or even adaptors as sub-services.

As usual, an adaptor needs to implement the methods `configuring`, `starting`, `stopping`, and `updating`.

```
class MyAdaptor : public ::fwRenderVTK::IAdaptor
{

public:

    fwCoreServiceClassDefinitionsMacro ( (MyAdaptor)(::fwRenderVTK::IAdaptor) );

protected:

    /// Parse the adaptor "config" tag
    void configuring() override;

    /// Initialize the vtk pipeline (actor, mapper, ...)
    void starting() override;

    /// Clear the vtk pipeline
    void stopping() override;

    /// Update the pipeline from the current object
    void updating() override;
};
```

To ease the configuration and the link with the `::fwRenderVTK::SRender`, the `configuring` and `starting` should contain this minimal code:

```
void SMesh::configuring()
{
    this->configureParams();
    ...
}

void SMesh::starting()
{
    this->initialize();

    ...

    // Request ::fwRenderVTK::SRender to trigger a rendering when it is ready
    this->requestRender();
}
```

Adaptors are configured and started like other services in the xml since **FW4SPL 12.0.0**.

```
<service uid="meshAdaptor" type="::visuVTKAdaptor::SMesh" autoConnect="yes">
    <in key="mesh" uid="meshUID" />
    <config renderer="default" picker="" uvgen="sphere" />
</service>

...

<start uid="meshAdaptor" />
```

8.13 Data file migration

Contents

8.13.1 Overview

The data migration system consists on converting the data to another version. It allows us to adapt any version of data to any version of software, and thus ensuring compatibility between data and software independently of their version.

Migration process is applied on two independent steps :

- In `::ioAtoms::SReader` while reading data files, previously serialized with `fwAtoms`, right before converting said data to `::fwData::Objects`.
- In `::ioAtoms::SWriter` after data is converted to `fwAtoms::Base`.

8.13.2 Definitions

Context It represents a complex chunk of data. For example, the medical patient folder, the software preference file, etc. Hereafter we will consider a medical patient folder which is called **MedicalData**.

Structural patch This sort of patch affects only one object of the serialized data regardless of the context (ex: add or remove attribute, type, . . .), see *Structural patch*.

Semantic patch This sort of patch is applied on a context to migrate to a given version without changing the data structure. (These patches are sometimes called contextual patches), see *Semantic patch*.

Patcher A patcher defines the methods to parse the data and applies the structural and semantic patches, see *Patcher*.

8.13.3 Data Version

After the conversion from `::fwData::Object` to `::fwAtoms::Object`, each data is assigned a version number. Said number is defined in the camp serialization source files (see Serialization). Each data structure modification causes an incrementation of the data version.

Example of data declaration for introspection (used to convert to `fwAtoms`):

```
#include <fwCamp/UserObject.hpp>

fwCampImplementDataMacro((fwData)(ComplexClass))
{
```

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```
    builder
        .tag("object_version", "1") // data version
        .tag("lib_name", "fwData")
        .base< ::fwData::Object>()
        .property("myString" , &::fwData::ComplexClass::m_myString)
        .property("myFloat" , &::fwData::ComplexClass::m_myFloat)
        .property("mySimpleClass" , &::fwData::ComplexClass::m_mySimpleClass)
        ;
}
```

8.13.4 Context version

The context version must be incremented after a data version modification.

Note:

- If several data versions are modified simultaneously, only one incrementation of the context version is necessary.
- A single context version can contain data with different versions (see the example below).

The `.versions` file contains a detailed description of the context version, and the version of each data.

Example of `V1.versions`:

```
{
    "context": "MedicalData",
    "version_name": "V1",
    "versions":
    {
        "::fwData::Array": "1",
        "::fwData::Boolean": "1",
        "::fwData::Image": "1",
        "::fwData::Integer": "1",
        "::fwData::Material": "1",
        "::fwData::Mesh": "1",
        "::fwData::Patient": "1",
    }
}
```

Example of `V2.versions`:

```
{
    "context": "MedicalData",
    "version_name": "V2",
    "versions":
    {
        "::fwData::Array": "1",
        "::fwData::Boolean": "1",
        "::fwData::Image": "2",
        "::fwData::Integer": "1",
        "::fwData::Material": "1",
        "::fwData::Mesh": "1",
        "::fwMedData::Patient": "1",
    }
}
```

8.13.5 Migration

The migration is applied on a given context. It is described in the `.graphlink` file. It defines how to migrate from a context version to another.

Example of `V1ToV2.graphlink`:

```
{
    "context" : "MedicalData",
    "origin_version" : "V1",
    "target_version" : "V2",
    "patcher" : "DefaultPatcher",
    "links" : [
        {
            "::fwData::Patient" : "1",
            "::fwMedData::Patient" : "1"
        },
        {
            "::fwData::Image" : "1",
            "::fwData::Image" : "2"
        }
    ]
}
```

The `links` tag represents the data version modifications, by doing so, associated patches can be applied.

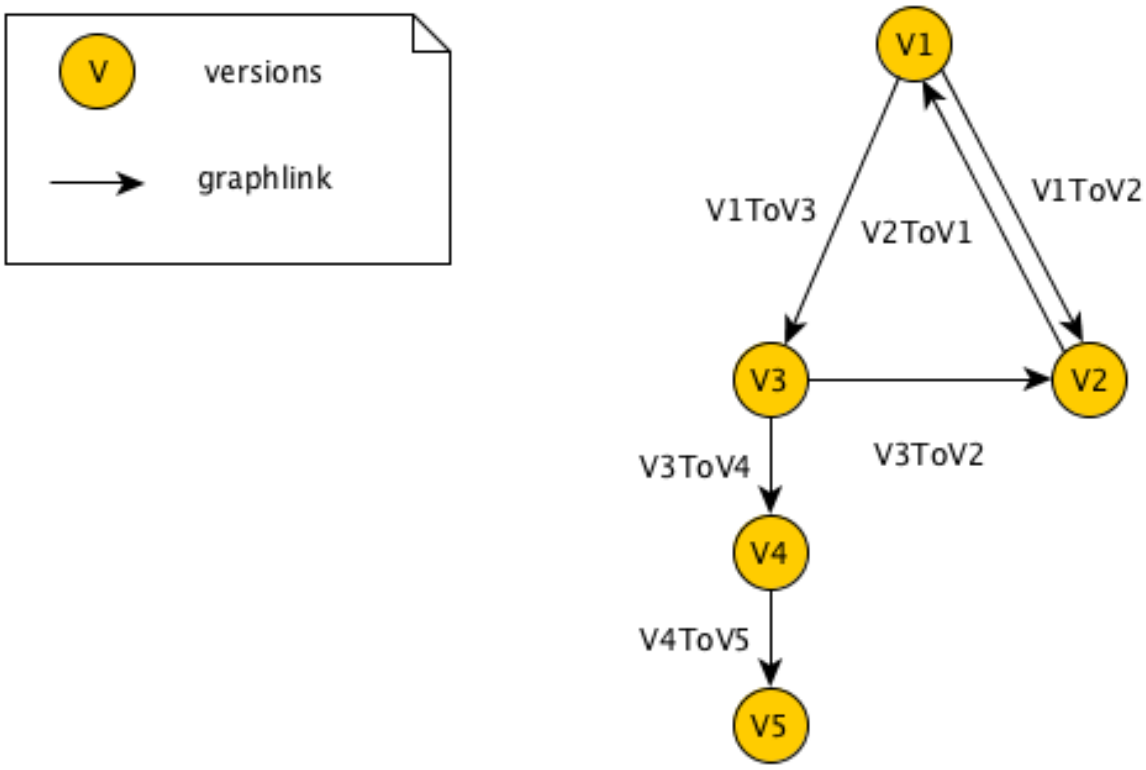
Warning: Two `.versions` files must be defined, one for each version (V1.versions and V2.versions).

Note: It is not necessary to specify a simple data version incrementation on the `links` tag, the patching system establishes this information from the data version defined in the `.versions` files.

8.13.6 Graph

The `.graphlink` and `.versions` files are parsed and the information is stored in the `::fwAtoms::VersionsManager`. Each context defines a graph.

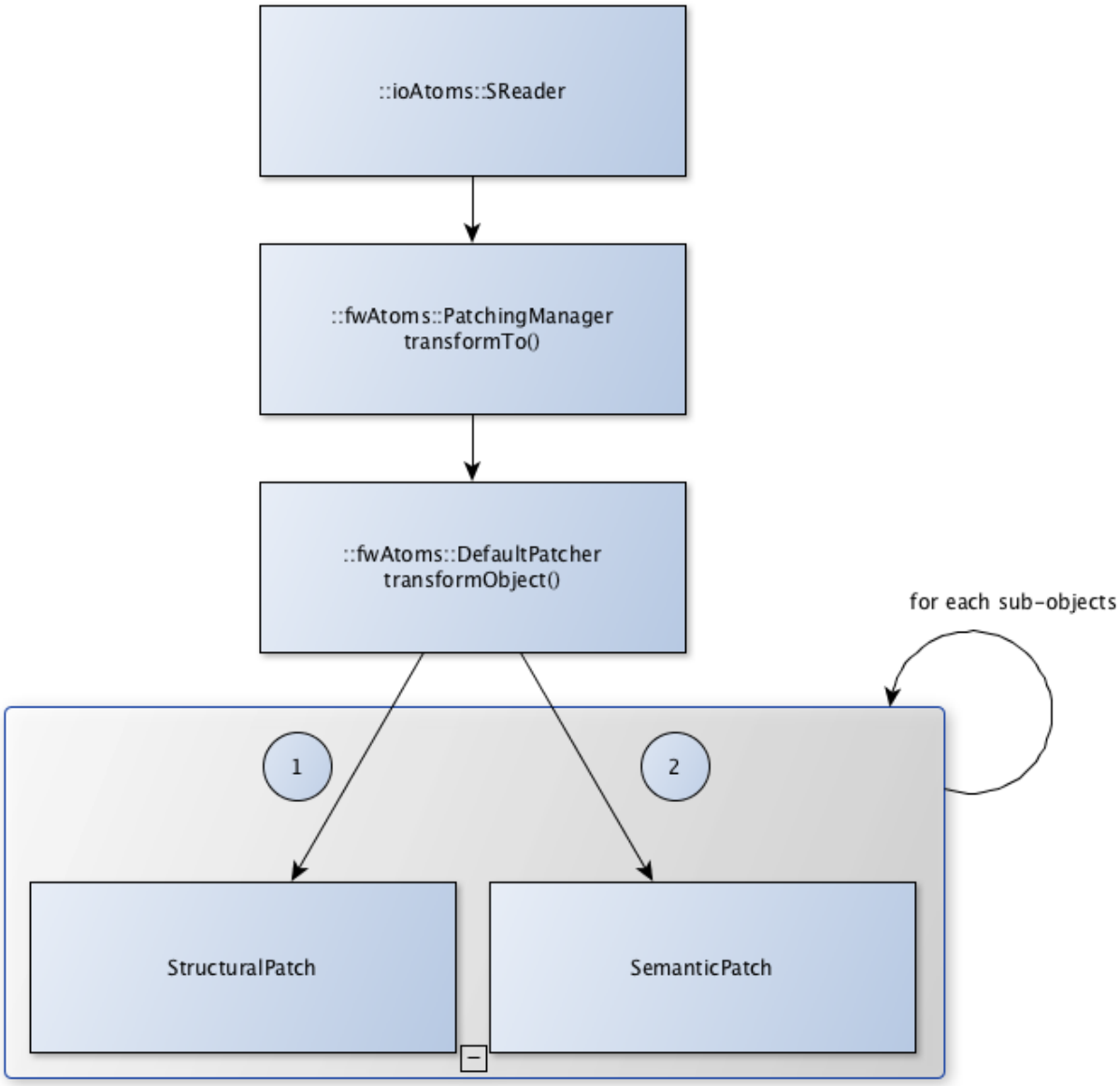
Example of graph:



The graph is used to find the migration path from an initial version to a target version. In our example, it is possible to migrate from V1 to V5, the data is converted to V3, V4 then V5. If several paths are possible, the shortest path is used.

8.13.7 Structure

The `fwAtomsPatch` library contains the base classes to perform the migration.



PatchingManager This class provides the `transformTo()` method used to migrate the data. It uses the graph to apply the patcher on each version.

patcher::IPatcher Base class for patchers.

patcher::DefaultPatcher Patcher used by default. It performs the data migration in two steps: first it applies the structural patches recursively on each sub-object and then applies the semantic patches recursively on each sub-object .

IPatch Base class for structural and semantic patches. It provides an `apply()` method that must be implemented in sub-classes.

ISemanticPatch Base class for semantic patches.

IStructuralPatch Base class for structural patches.

IStructuralCreator Base class for creators. It provides a `create()` method that must be implemented in sub-classes.

SemanticPatchDB Singleton used to register all the semantic patches.

StructuralPatchDB Singleton used to register all the structural patches.

CreatorPatchDB Singleton used to register all the creator patches.

VersionsGraph Registers the migration graphs.

VersionsManager Singleton used to register all the version graph.

The `fwStructuralPatch` library contains the structural patches for `fwData` and `fwMedData` conversion.

The `fwMDSemanticPatch` library contains the semantic patches for `fwData` and `fwMedData` conversion in the `MedicalData` context.

The `patchMedicalData` bundle must be activated in your application to allow migration in `MedicalData` context.

Structural patch

The structural patches are registered in the `::fwAtomsPatch::StructuralPatchDB` singleton. A structural patch provides a method `apply` that performs the structure conversion. The constructor defines the classname and versions of the origin and target objects as described in the `.graphlink` links section.

Example of structural patch to convert the `fwData::Image` from version 1 to 2. We add three attributes related to medical imaging: the number of components `nb_components`, the window center `window_center` and the window width `window_width`.

```
#include "fwStructuralPatch/fwData/Image/V1ToV2.hpp"

#include <fwAtoms/Numeric.hpp>
#include <fwAtoms/Numeric.hxx>

namespace fwStructuralPatch
{

namespace fwData
{

namespace Image
{

V1ToV2::V1ToV2() : ::fwAtomsPatch::IStructuralPatch()
{
    m_originClassname = "::fwData::Image";
    m_targetClassname = "::fwData::Image";
    m_originVersion   = "1";
    m_targetVersion   = "2";

}

// ----------------------------------------------------------------------------

void V1ToV2::apply(
    const ::fwAtoms::Object::sptr& previous, // object in the origin version
    const ::fwAtoms::Object::sptr& current, // clone of the previous object to␣
↪convert in the targer version
    ::fwAtomsPatch::IPatch::NewVersionsType& newVersions) // map < previous object,␣
↪new object > association
```

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```
{
    // Check if the previous and current object version and classname correspond
    IStructuralPatch::apply(previous, current, newVersions);

    // Update object version
    this->updateVersion(current);

    // Create helper
    ::fwAtomsPatch::helper::Object helper(current);

    helper.addAttribute("nb_components", ::fwAtoms::Numeric::New(1));
    helper.addAttribute("window_center", ::fwAtoms::Numeric::New(50));
    helper.addAttribute("window_width", ::fwAtoms::Numeric::New(500));
}

} // namespace Image

} // namespace fwData

} // namespace fwStructuralPatch
```

To register the structural patch:

```
// fwStructuralPatch/autoload.cpp

::fwAtomsPatch::StructuralPatchDB::sptr structuralPatches =␣
↪::fwAtomsPatch::StructuralPatchDB::getDefault();
structuralPatches->registerPatch(::fwStructuralPatch::fwData::Image::V1ToV2::New());
```

Creator

The creator provides a method `create` that allows to create a new object with the default attribute initialization. The creator is used in structural patches to create new sub-objects. Creators are registered in the `::fwAtomsPatch::StructuralCreatorDB` singleton.

Creators are useful for adding an attribute that is a non-null object.

Example of creator for the `::fwMedData::Patient` :

```
#include "fwStructuralPatch/creator/fwMedData/Patient1.hpp"

#include <fwAtoms/String.hpp>

#include <fwAtomsPatch/helper/Object.hpp>

namespace fwStructuralPatch
{
namespace creator
{
namespace fwMedData
{

Patient1::Patient1()
{
    m_classname = "::fwMedData::Patient";
    m_version   = "1";
```

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```
}

// ----------------------------------------------------------------------------

::fwAtoms::Object::sptr Patient1::create()
{
    // Create an empty ::fwAtoms::Object with the classname, version and ID␣
↪informtation
    ::fwAtoms::Object::sptr patient = this->createObjBase();

    ::fwAtomsPatch::helper::Object helper(patient);

    helper.addAttribute("name", ::fwAtoms::String::New(""));
    helper.addAttribute("patient_id", ::fwAtoms::String::New(""));
    helper.addAttribute("birth_date", ::fwAtoms::String::New(""));
    helper.addAttribute("sex", ::fwAtoms::String::New(""));

    return patient;
}

} // namespace fwMedData
} // namespace creator
} // namespace fwStructuralPatch
```

To register the creator:

```
// fwStructuralPatch/creator/autoload.cpp

::fwAtomsPatch::StructuralCreatorDB::sptr creators =␣
↪::fwAtomsPatch::StructuralCreatorDB::getDefault();
creators->registerCreator(::fwStructuralPatch::creator::fwMedData::Equipment1::New());
```

Semantic patch

The semantic patches are registered in the `::fwAtomsPatch::SemanticPatchDB` singleton. The structural patch provides a method `apply` that performs the structure conversion. The constructor defines the origin classname, the origin version of the object, and the origin and the target context version as described in the `.graphlink`.

The semantic patch is used when we need several objects to perform the object migration.

Example of semantic patch :

```
#include "fwMDSemanticPatch/V2/V3/fwData/Image.hpp"

#include <fwAtoms/Object.hpp>
#include <fwAtoms/Object.hxx>
#include <fwAtoms/Numeric.hpp>
#include <fwAtoms/Numeric.hxx>

#include <fwAtomsPatch/helper/functions.hpp>


namespace fwMDSemanticPatch
{
namespace V2
{
```

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```
namespace V3
{
namespace fwData
{

Image::Image() : ::fwAtomsPatch::ISemanticPatch()
{
    m_originClassname = "::fwData::Image";
    m_originVersion   = "1";
    this->addContext("MedicalData", "V2", "V3"); // Context version
}

// ----------------------------------------------------------------------------

void Image::apply(
    const ::fwAtoms::Object::sptr& previous, // object in the origin version
    const ::fwAtoms::Object::sptr& current, // clone of the previous object to␣
↪convert in the targer version
    ::fwAtomsPatch::IPatch::NewVersionsType& newVersions) // map < previous object,␣
↪new object > association
{
    // Check if the previous and current object version and classname correspond
    ISemanticPatch::apply(previous, current, newVersions);

    // Cleans object fields (also creates them if they are missing)
    ::fwAtomsPatch::helper::cleanFields( current );

    ::fwAtomsPatch::helper::Object helper( current );

    ::fwAtoms::Object::sptr array        = ::fwAtoms::Object::dynamicCast(previous->
↪getAttribute("array"));
    ::fwAtoms::Numeric::sptr nbComponent =
             ::fwAtoms::Numeric::dynamicCast(array->getAttribute("nb_of_components"));

    helper.replaceAttribute("nb_components", nbComponent->clone());
}

// ----------------------------------------------------------------------------

} // namespace fwData
} // namespace V3
} // namespace V2
} // namespace fwMDSemanticPatch
```

This patch changed the attribute `nb_components` in the image copied from array `nb_of_components`.

To register the semantic patch:

```
// fwMDSemanticPatch/V1/V2/fwData/autoload.cpp
::fwAtomsPatch::SemanticPatchDB::sptr contextPatchDB =␣
↪::fwAtomsPatch::SemanticPatchDB::getDefault();
contextPatchDB->registerPatch(::fwMDSemanticPatch::V1::V2::fwData::Composite::New());
```

Patcher

The patcher defines the methods to parse the data and applies the structural and semantic patches. It must inherit from `fwAtomsPatch::patcher::IPatcher` and implements the `transformObject()` method.

We usually use the `DefaultPatcher`. The conversion is processed in two steps: first it applies the structural patches recursively on each sub-objects, then it applies the semantic patches recursively on each sub-objects.

Rules

Rule 1 A change in data (fwData, fwMedData, ...) involves the incrementation of the data version and the context version and thus, the creation of structural and/or semantic patch.

Rule 2 The creator patch creates the `fwAtoms::Object` representing the data object. The `::fwAtoms::Object` created must be the same as the data created with a `New()` and converted to `fwAtoms`.

Rule 3 The *buffer object* (converted as BLOB in fwAtoms) is just reused (without copy) during the migration. If its structure is modified, you should clone the buffer before applying the patch.

Rule 4 If an object is contained in the `fwAtoms::Object` to migrate but is not present in the current context version (in the `.versions` file), this object will be erased from the `fwAtoms::Object`.

8.13.8 Usage

If you have to modify data, you don't have to re-implement all the migration system, but there are steps to perform :

step 1 Increment the data version in camp declaration (and update the declaration of the attribute if needed). See *Data Version*.

step 2 Increment the context version: create new `.versions` files (with the associated data version). See *Context version*.

step 3 Create the `.graphlink` file. See *graphlink*.

step 4 (optional) Create the creator if you need to add a new non-null objet. See *Creator*.

step 5 Create the structural patch. See *Structural patch*.

step 6 (optional) Create the semantic patch if you need other objects to update the current one. See *Semantic patch*.

Note: You can create migration patches from V1 to V3 without using the V1 to V2 and V2 to V3.

CHAPTER 9

Contributors

9.1 Contributors

From 2004 to 2006, an advanced modular software for patient modeling (see publication page) has been designed and implemented by Guillaume Brocker, Johan Moreau, Jean-Baptiste Fasquel, Vincent Agnus and Nicolas Papier. This represented the basis of the component management system of FW4SPL, essentially conceived by Guillaume Brocker and Johan Moreau. This framework version (v0.1) was used to create 3 software tools in visualization and medical image processing in the Eureka project Odysseus (3DVPM, 3DDVP and MARNS software).

Throughout 2007, Vincent Agnus and Jean-Baptiste Fasquel conceived and implemented the main core mechanisms of this new version of FW4SPL. Jean-Baptiste Fasquel focused on the notion of roles coupled with the component management system, the inter-role communication system, as well as an appropriate XML formalism for the description of both roles embedded into components and description of software. Many basic software tools have been built to validate the architecture (see publication page). Vincent Agnus also focused on role design, and more specifically on data structures, a generic serialization mechanism and a powerful template dispatching technique. During his internship in 2007, Benjamin Gaillard has improved the communication system in FW4SPL. In parallel with the work on the pure FW4SPL system, Johan Moreau got involved in the construction/compilation system and, together with Arnaud Charnoz, in the management of external dependencies and some specific medical data structures. Their work also led to advanced visualization of medical images (free download). Early 2008, the framework was available in version 0.2.

During the period from mid-2008 to mid-2009, some advanced data structures and functionalities have been developed on the basis of the architecture to further evaluate it and make it more robust. A larger development team has been involved, including Emilie Harquel, Julien Waechter and Nicolas Philipps additionally to Vincent Agnus, Jean-Baptiste Fasquel, Johan Moreau and Arnaud Charnoz. Additional efforts have been made by Johan Moreau and Arnaud Charnoz on the management of external dependencies. Nicolas Philipps, Julien Waechter and Johan Moreau also improved the construction environment Sconspiracy, initially opened as an opensource project YAMS++ in 2007. The version 0.3 of the framework had been achieved by early summer 2009.

From mid-2009 to mid-2010, the main work on FW4SPL included: performing generic scenes for visualization (mainly developed by Nicolas Philipps, Julien Waechter and Vincent Agnus), a new communication system (mainly developed by Nicolas Philipps and Arnaud Charnoz), new UI components (mainly developed by Emilie Harquel and Julien Waechter), better log and assert system (by Arnaud Charnoz), new documentation (mainly done by Pascal Monnier, Alexandre Hostettler).

FW4SPL (version 0.4) has been opened late 2009 and was used to create several software in the European project Passport (VR-Render, VR-Render WLE, AR-Surg, VR-Planning and VR-Probe software). In December, we had switched to version 0.5 (with generic scene). The latest stable version is 0.6 (new communication system) and the current branch development is the 0.6.1 branch.

Version 0.7 adds a limited Qt support during summer 2010 (Hocine Chekatt's internship) and limited support for Python, OpenNI and SOFA (these two last parts had been developed by Altran). During 2011, FW4SPL 0.8 adds a Qt based 2D scene (Ivan MATHIEU's internship), new buffer for meshes and images, new memory dump mechanisms, a new set of applications (Apps/Examples), a new Dicom reader (Jordi ROMERA's internship), new registration functionalities (Marc Schweitzer's internship) an improved image origin management, etc. A new scenegraph design has been developed but not yet integrated (Loïc Velut's internship).

Multithreading (fwThread), signal/slot (fwCom), dump management and data introspection (fwAtoms) mechanisms have been added during 2012 in version 0.9 (co-working between IRCAD and IHU). A new design to manage data and store data (Julien Weinzorn's internship) has been prototyped.

This version supports msvc2010 and has also been used to evaluate the transition to Android and iOS (Adrien Bensaibi's internship). Altran has added a connector towards the management tool of the MIDAS content developed by Kitware. Finally, a version management mechanism has been developed (fwAtomsPatch) (Clément Troesch's internship) and new data has been created (fwMedData). This version has been used by the Visible Patient company within the framework of their ISO 13485 certification. A new repository has also been created (fw4spl-ext) with the aim of welcoming not yet stabilized functionalities or to host PoC. The CMake construction system is also supported.

Version 0.10.0 provides the notion of timeline to manage temporal data (IHU). The SConspiracy construction system has been removed.

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	This project has partly funded by the European Commission via PASS • http://www.passport-liver.eu/ • http://www.vph-noe.eu/vph-repository/doc_download/154-passportppt • newsletter july 2010

9.2 Libraries

9.3 FLOSS projects using FW4SPL

skuld-project	Skuld project work on mobile port (iphone, android, meego/maemo, ...) of FW4SPL