What's new in Faust

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GRAME
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Brief introduction to FAUST

Main caracteristics

- Faust Stands for *Functional AUdio STream*
- It's a Synchronous, Functional, Domain Specif Language for signal processing
- A Faust program describes a *signal processor*
- It's a compiled language (to C++)
- Various code back-ends (including parallelization)
- It works at sample level
- Constant memory and CPU footprint

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Design Principles

- *Specification Language* : The user gives the DSP specification, the compiler generate the most appropriate implementation
- *Block-Diagram syntax* : A textual block-diagram language based on function composition
- *Strong formal basis* : A language with a simple and well defined formal semantic
- *Functional approach* : A purely functional programming language for real-time signal processing
- *Efficient compiled code* : It should be an alternative to C. The generated C++ code should compete with hand-written code
- *Easy deployment* : Multiple native implementations from a single Faust program

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Demo 1 : Simple Sound Generator

Block-Diagram Algebra

Faust syntax is based on a *block diagram algebra*

5 Composition Operators

- `(A,B)` parallel composition
- `(A:B)` sequential composition
- `(A<:B)` split composition
- `(A:>B)` merge composition
- `(A~B)` recursive composition

2 Constants

- `!` cut
- `_` wire

Block-Diagram Algebra

Parallel Composition

The *parallel composition* (A, B) is probably the simplest one. It places the two block-diagrams one on top of the other, without connections.

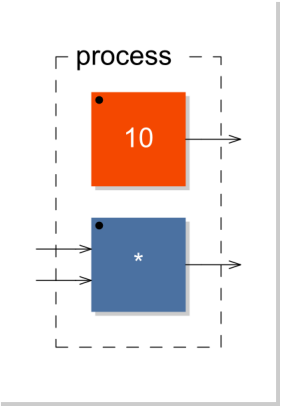

Figure: Example of parallel composition `(10,*)`

Block-Diagram Algebra

Sequential Composition

The *sequential composition* $(A : B)$ connects the outputs of A to the inputs of B. $A[0]$ is connected to $[0]B$, $A[1]$ is connected to $[1]B$, and so on.

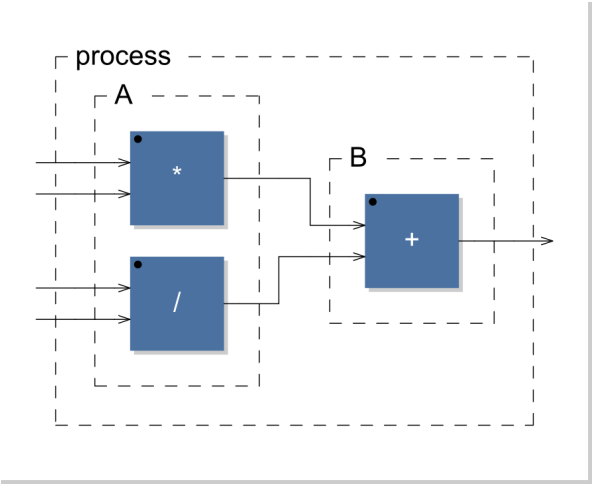

Figure: Example of sequential composition `((*,/):+)`

Block-Diagram Algebra

Split Composition

The *split composition* ($A <: B$) operator is used to distribute the outputs of A to the inputs of B

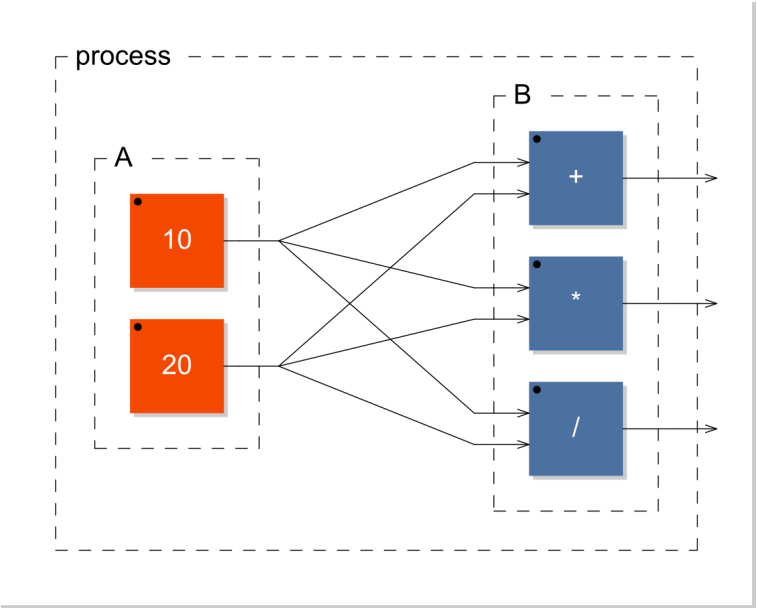

Figure: example of split composition `((10,20) <: (+,*,/))`

Block-Diagram Algebra

Merge Composition

The *merge composition* ($A :> B$) is used to connect several outputs of A to the same inputs of B.

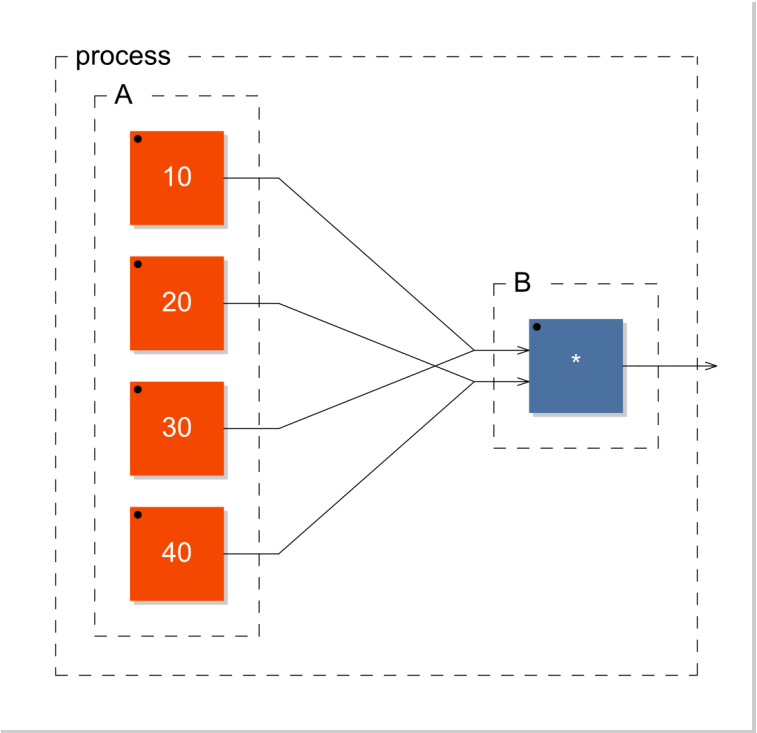

Figure: example of merge composition `((10,20,30,40) :> *)`

Block-Diagram Algebra

Recursive Composition

The *recursive composition* `(A~B)` is used to create cycles in the block-diagram in order to express recursive computations.

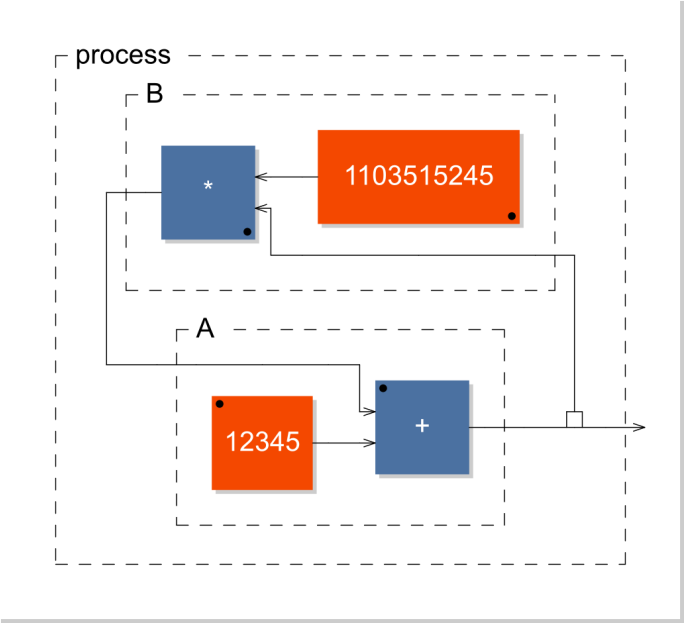

Figure: example of recursive composition `+(12345) ~ *(1103515245)`

Block-Diagram Algebra

Same expression in Lambda-Calculus, FP and Faust

Lambda-Calculus

```
\x.\y.(x+y,x*y) 2 3
```

FP/FL (John Backus)

```
[+,*]:<2,3>
```

Faust

```
2,3 <: +,*
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Figure: block-diagram of `2,3 <: +,*`

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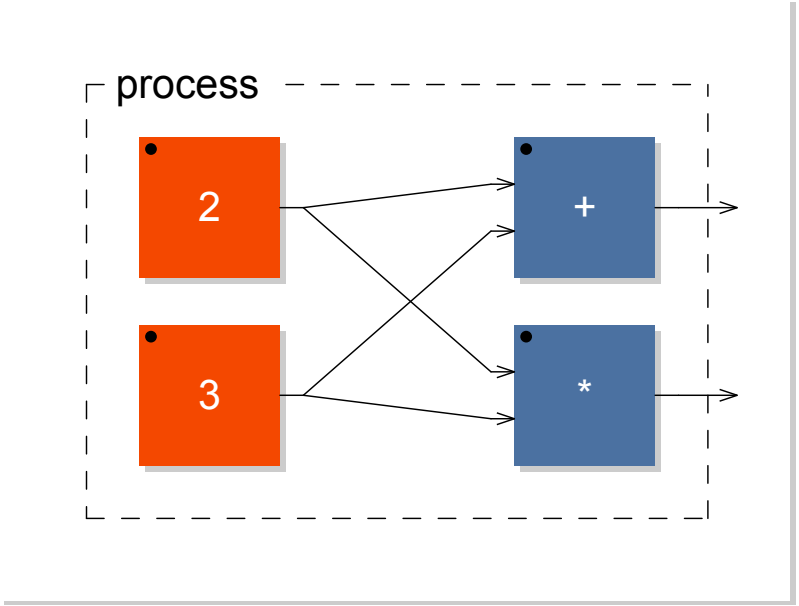

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Demo 2 : Parallelization

So, What's new ?

- Modular architecture files
- Automatic Documentation

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Faust Modular Architecture Files

Motivations

- Easy deployment (one Faust code, multiple audio targets) is an essential feature of the Faust project
- This is why Faust programs say nothing about audio drivers or GUI toolkits to be used.
- There is a *separation of concerns* between the audio computation itself, and its usage.
- It is the role of the *architecture file* to describe how to connect the audio computation to the external world.
- Monolithic architectures, as used so far, works very well but have reached their limits in terms of flexibility and maintainability
- A new approach was needed : *modular architecture files* easier to develop, to combine and to maintain

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Faust Modular Architecture Files

Easy Deployement

Faust can be used to write:

- Audio plugins :
  - LADSPA
  - DSSI
  - Max/MSP
  - VST
  - PD
  - CSound
  - Supercollider
  - Pure
  - Chuck
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As well as:

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Faust Modular Architecture Files

Easy Deployement

Faust can be used to write:

- Audio plugins :
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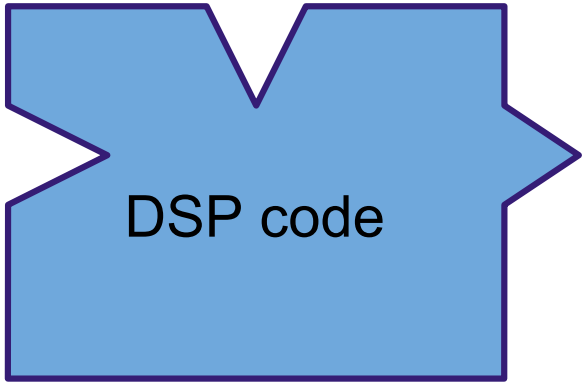
Demo 3 : Easy Deployment

Faust Modular Architecture Files

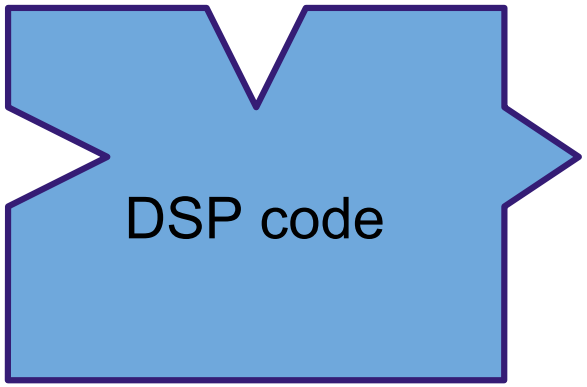
DSP code



To provide easy deployement, the DSP code generated by compiling a Faust program should be pure audio computation, abstracted from any audio drivers or GUI toolkit.

Faust Modular Architecture Files

DSP class

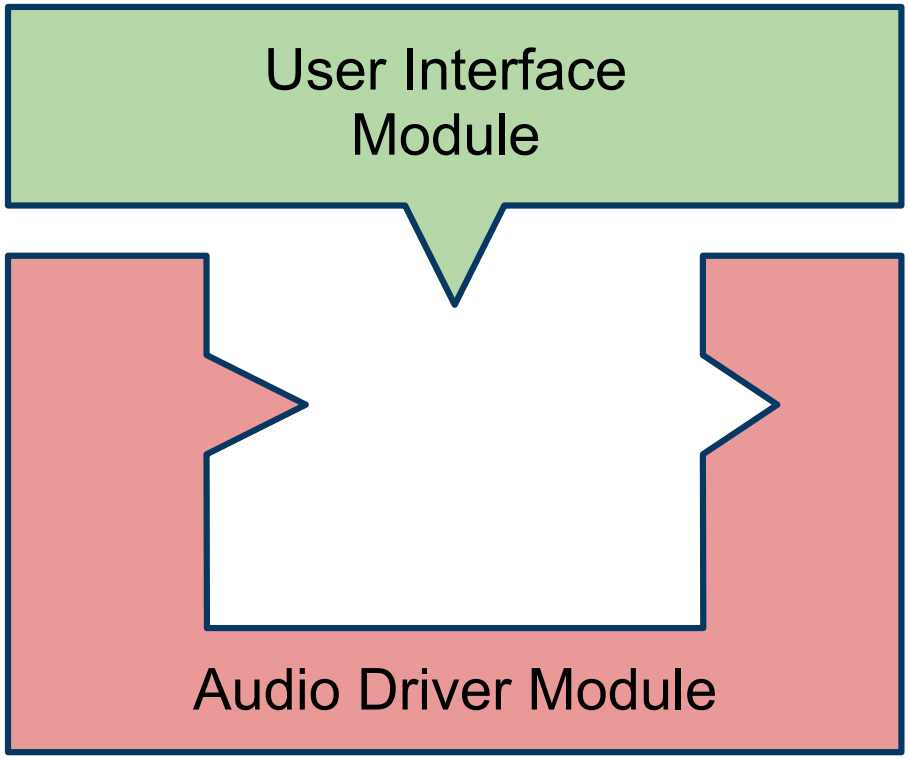



```
class dsp {
  protected:
    int fSamplingFreq;
  public:
    dsp() {}
    virtual ~dsp() {}

    virtual int  getNumInputs()                                    = 0;
    virtual int  getNumOutputs()                                   = 0;
    virtual void buildUserInterface(UI* interface)                 = 0;
    virtual void init(int samplingRate)                            = 0;
    virtual void compute(int len, float** inputs, float** outputs) = 0;
};
```

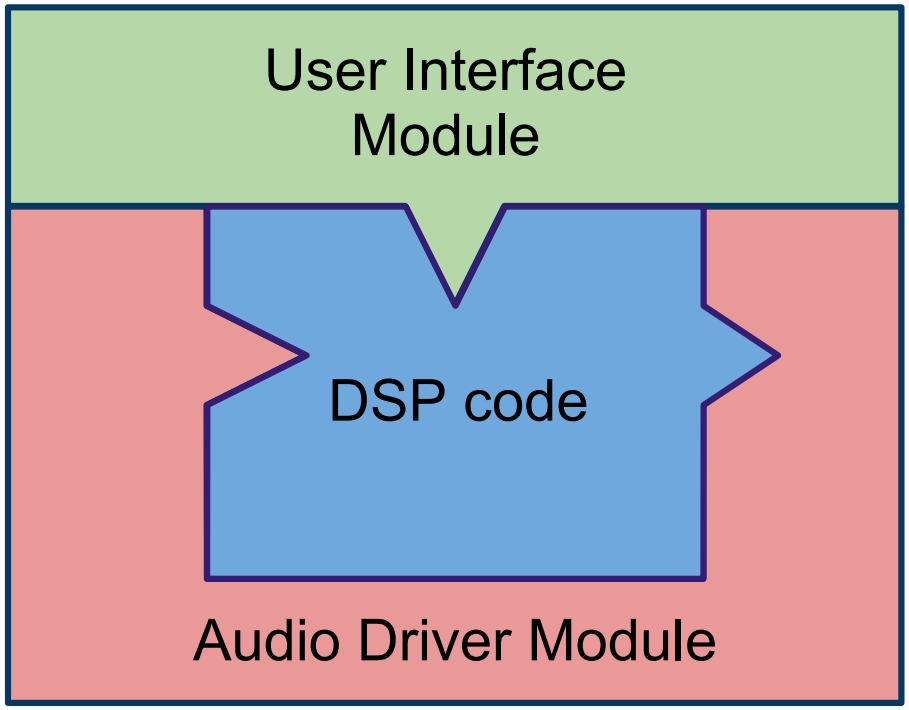
Faust Modular Architecture Files

Audio driver and User Interface modules



The role of the architecture file is to provide the missing information: the audio drivers and the user interface. The new modular architecture file combines an Audio driver module and one or more User Interface modules.

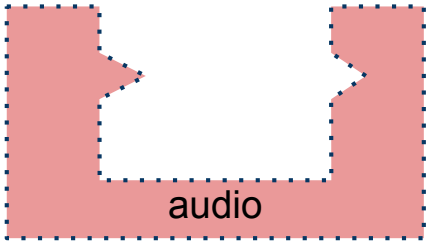
Faust Modular Architecture Files



The Faust compiler wraps the DSP code into the selected architecture file. For examples `faust -a jack-gtk.cpp noise.dsp` will wrap the dsp code of a noise generator into the architecture of jack-gtk standalone application.

Faust Modular Architecture Files

The Audio Class




```
class audio {
 public:
            audio() {}
  virtual ~audio() {}
  virtual bool init(const char*, dsp*) = 0;
  virtual bool start()                 = 0;
  virtual void stop()                  = 0;
};
```

Faust Modular Architecture Files

The User Interface Class

```
class UI
{
 public:

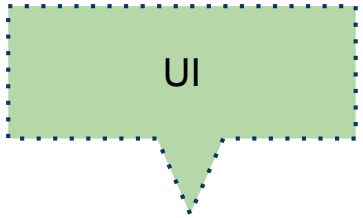
    UI() { }
    virtual ~UI() { }

    virtual void openFrameBox(const char* label) = 0;
    virtual void openTabBox(const char* label) = 0;
    virtual void openHorizontalBox(const char* label) = 0;
    virtual void openVerticalBox(const char* label) = 0;
    virtual void closeBox() = 0;

    virtual void addButton(const char* label, float* zone) = 0;
    virtual void addToggleButton(const char* label, float* zone) = 0;
    virtual void addCheckButton(const char* label, float* zone) = 0;
    virtual void addVerticalSlider(const char* label, float* zone, ...) = 0;
    virtual void addHorizontalSlider(const char* label, float* zone, ...) = 0;
    virtual void addNumEntry(const char* label, float* zone, ...) = 0;

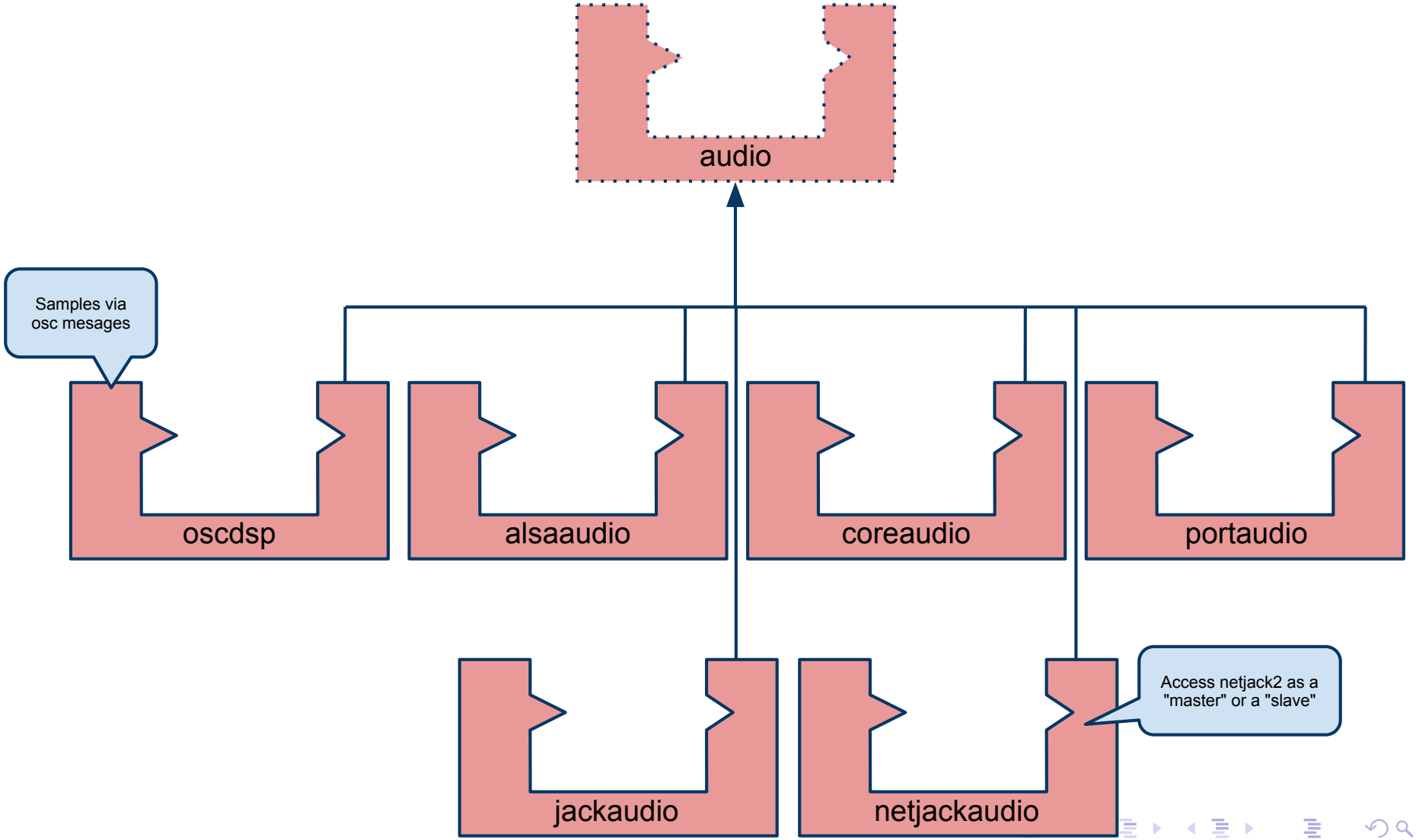
    virtual void addNumDisplay(const char* label, float* zone, int precision) = 0;
    virtual void addTextDisplay(const char* label, float* zone, const char* names[], ...) = 0;
    virtual void addHorizontalBargraph(const char* label, float* zone, ...) = 0;
    virtual void addVerticalBargraph(const char* label, float* zone, ...) = 0;

    virtual void declare(float* , const char* , const char* ) {}
};
```



Faust Modular Architecture Files

Audio modules Hierarchy



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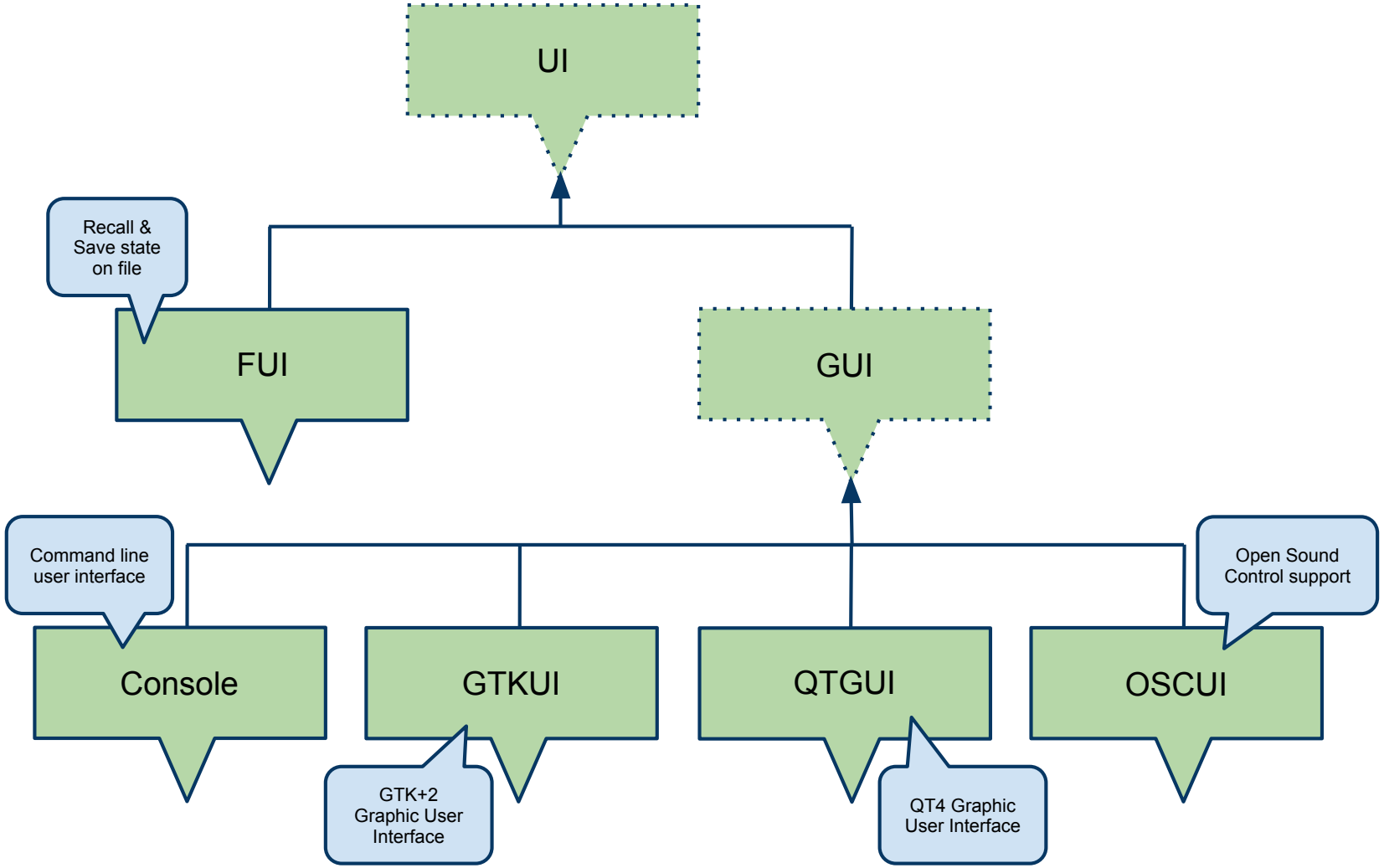

Faust Modular Architecture Files

The jack-gtk architecture

```
int main(int argc, char *argv[])
{
    char    appname[256];
    char    rcfilename[256];
    char*   home = getenv("HOME");

    snprintf(appname, 255, "%s", basename(argv[0]));
    snprintf(rcfilename, 255, "%s/.%src", home, appname);

    DSP = new mydsp();
    if (DSP==0) {
        cerr << "Unable␣to␣allocate␣Faust␣DSP␣object" << endl; exit(1);
    }
    GUI* interface  = new GTKUI (appname, &argc, &argv);
    FUI* finterface = new FUI();
    GUI* oscinterface = new OSCUI(appname, argc, argv);

    DSP->buildUserInterface(interface);
    DSP->buildUserInterface(finterface);
    DSP->buildUserInterface(oscinterface);

    jackaudio audio;
    audio.init(appname, DSP);
    finterface->recallState(rcfilename);
    audio.start();
    oscinterface->run();
    interface->run();
    audio.stop();
    finterface->saveState(rcfilename);
    delete DSP;
    return 0;
}
```

Demo 4 : OSC support

Automatic Mathematical Documentation

Motivations et Principles

- Binary and source code preservation of programs is not enough : quick obsolescence of languages, systems and hardware.
- We need to preserve the mathematical meaning of these programs independetly of any programming language.
- The solution is to generate automatically the mathematical description of any Faust program

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Tools provided

- The easiest way to generate the complete mathematical documentation is to call the `faust2mathdoc` script on a Faust file.
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Automatic Mathematical Documentation

Files generated by `Faust2mathdoc noise.dsp`

- ▼ noise-mdoc/
  - ▼ cpp/
    - ◇ noise.cpp
  - ▼ pdf/
    - ◇ noise.pdf
  - ▼ src/
    - ◇ math.lib
    - ◇ music.lib
    - ◇ noise.dsp
  - ▼ svg/
    - ◇ process.pdf
    - ◇ process.svg
  - ▼ tex/
    - ◇ noise.pdf
    - ◇ noise.tex

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Tags

- The documentation can be generated fully automatically from a regular Faust program.
- It can also be controled by embedding *documentation statements* in Faust programs.
- A *documentation statements* starts with an opening `<mdoc>` tag and ends with a closing `</mdoc>` tag.
- It contains arbitraty text, typically in LaTeX format, as well as five sub-tags :
  - `<diagram>`
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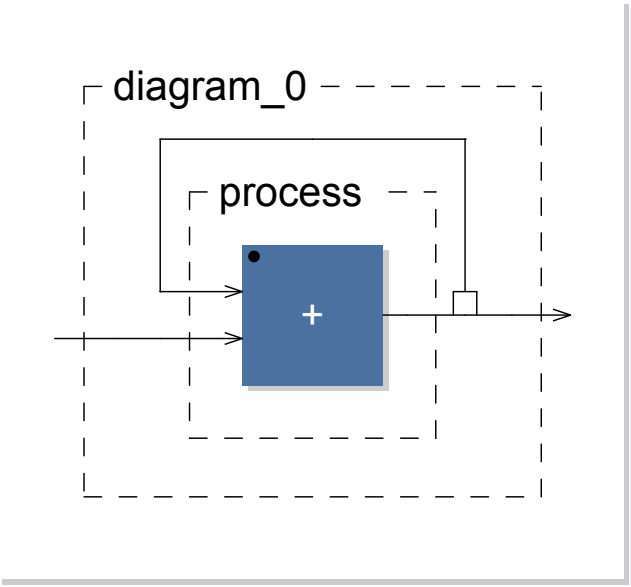
Diagram tags

- The generation of the graphical block-diagram of a Faust expression can be requested using `<diagram>...</diagram>` tags.
- For example: `<diagram> +~_ </diagram>` will produce the embedded diagram:

Expression diagram



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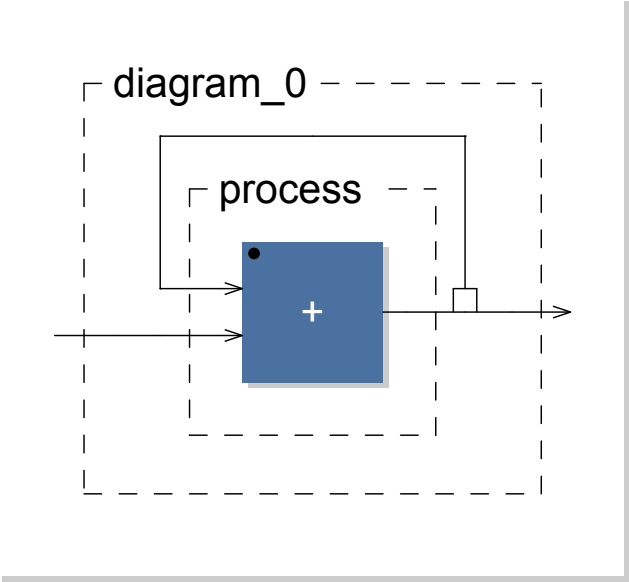

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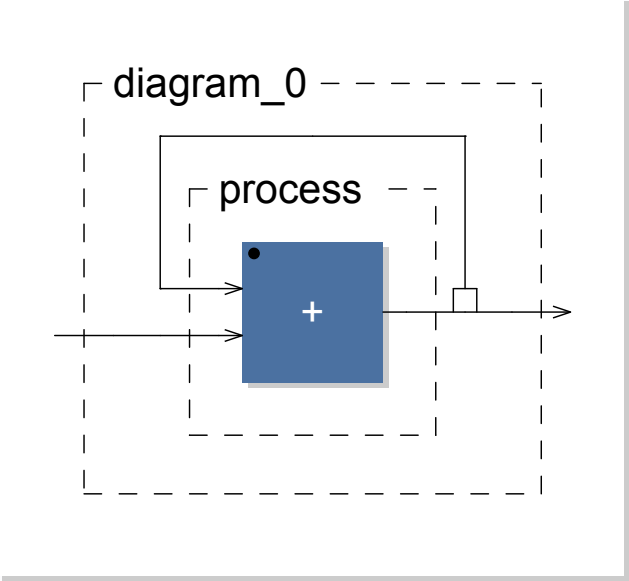

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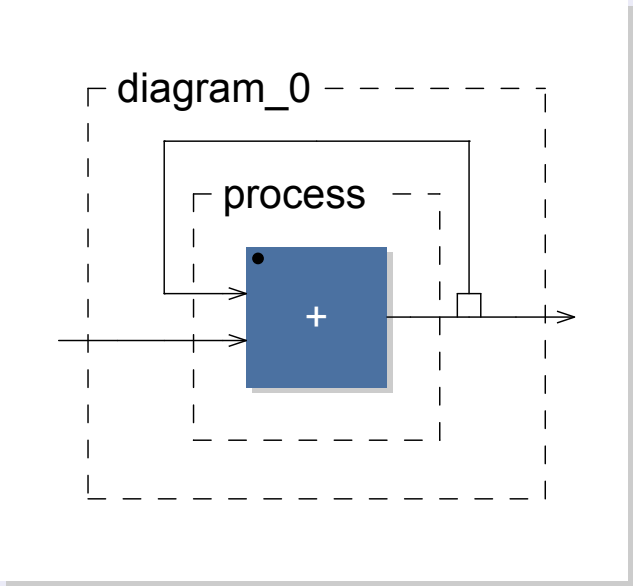

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Expression equations

- Output signal y such that

$$y(t) = r_1(t)$$

- Input signal x
- Intermediate signal r_1 such that

$$r_1(t) = x(t) + r_1(t-1)$$

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- The `<metadata>...</metadata>` tags allow to refer Faust metadatas declarations
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declare author "Albert";
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- The `<listing/>` tag is used to generate the listing of the Faust program.
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         distributed="false" />
```

Automatic Mathematical Documentation

Listing tag

- The `<listing/>` tag is used to generate the listing of the Faust program.
- It can be customized with three boolean attributes that can take the value `true` or `false`:
  - `mdoctags` when true (the default) indicates to include the mdoc comments into the listing.
  - `dependencies` when true (the default) indicates to include the code of the imported libraries into the listing.
  - `distributed` when true (the default) indicates to respect the distribution of faust code and mdoc tags.

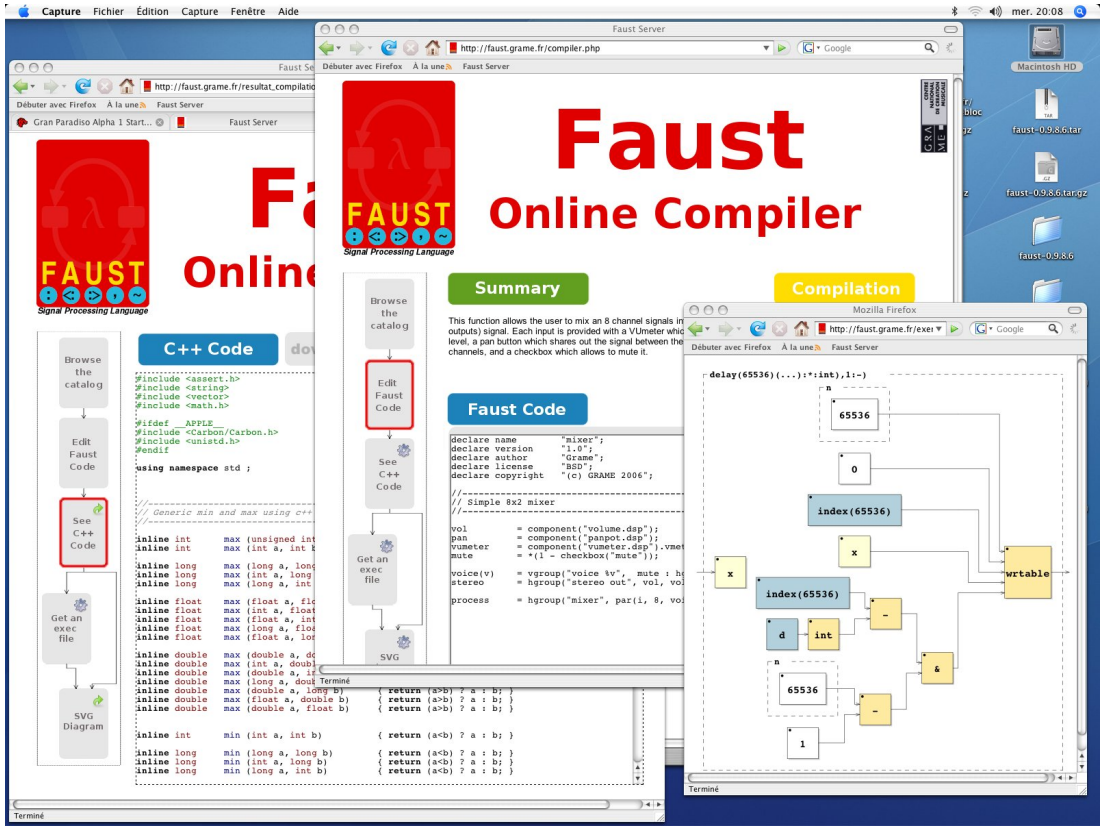
Example

```
<listing mdoctags="true"
         dependencies="false"
         distributed="false" />
```

Demo 5 : Documentation

Resources

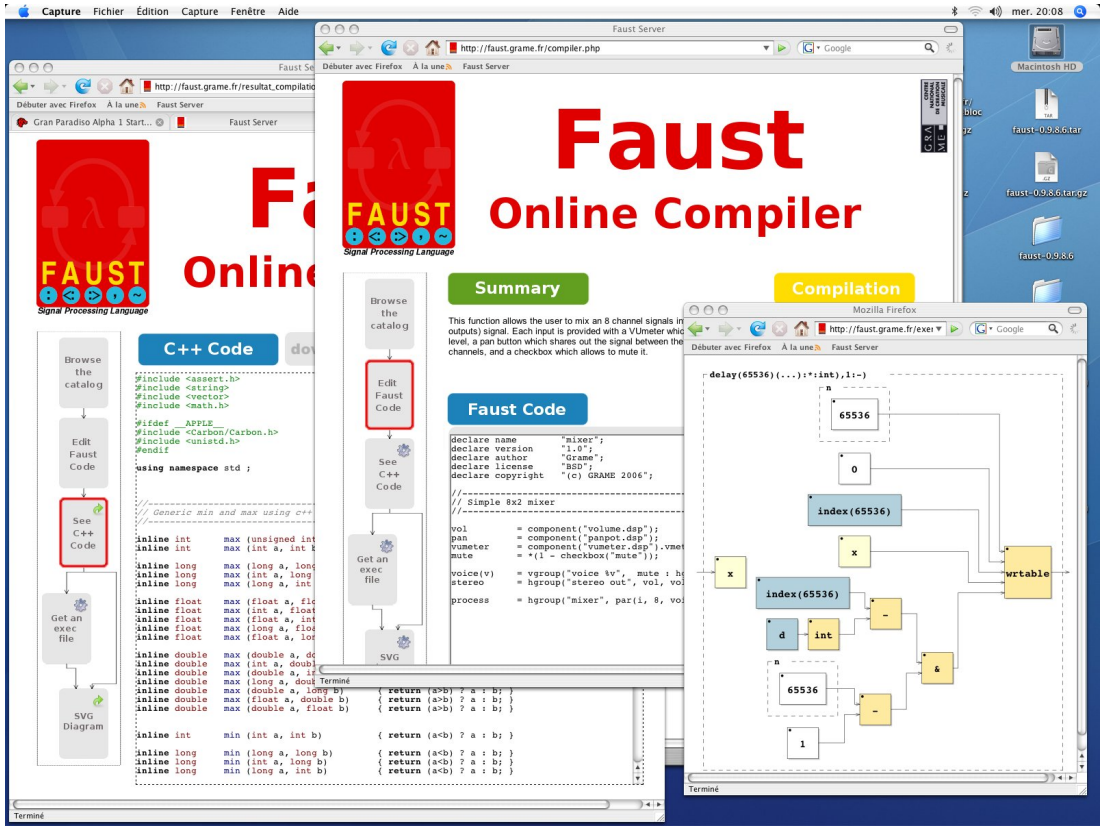
Using FAUST Online Compiler



- http://faust.grame.fr
- No installation required
- Compile to C++ as well as binary (for Linux and Windows)

Resources

Using FAUST Online Compiler



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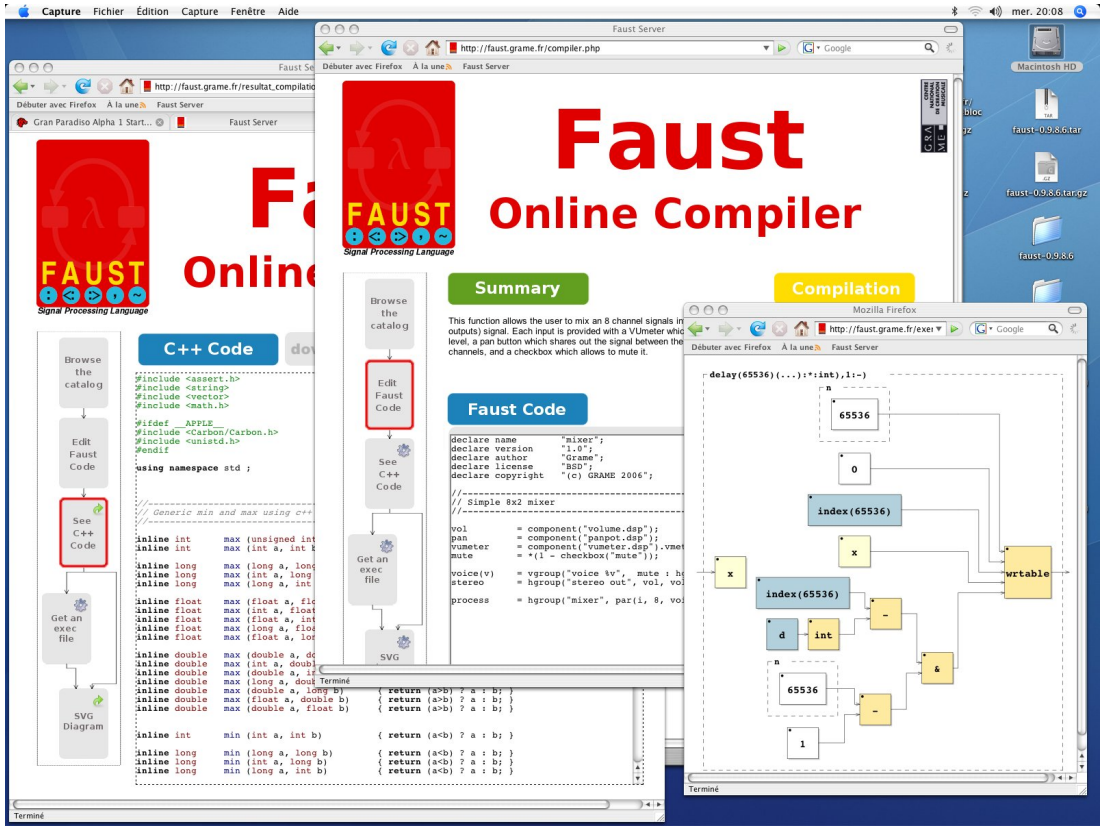

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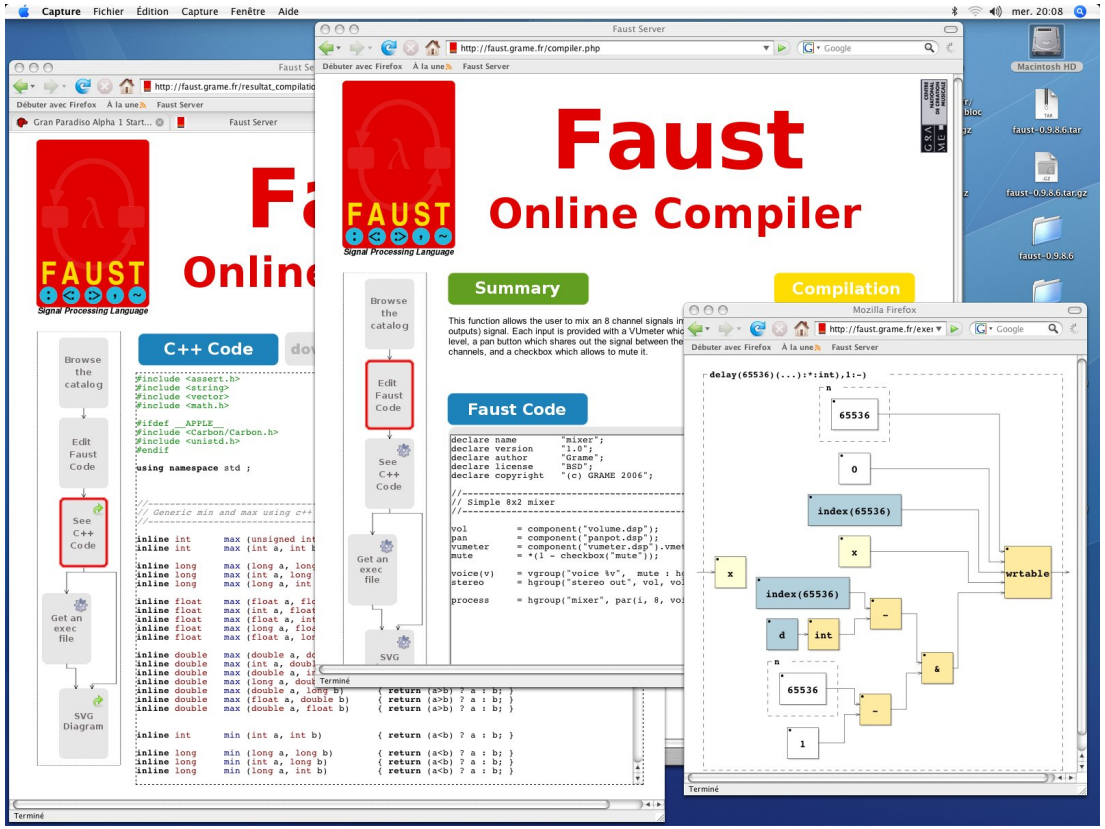
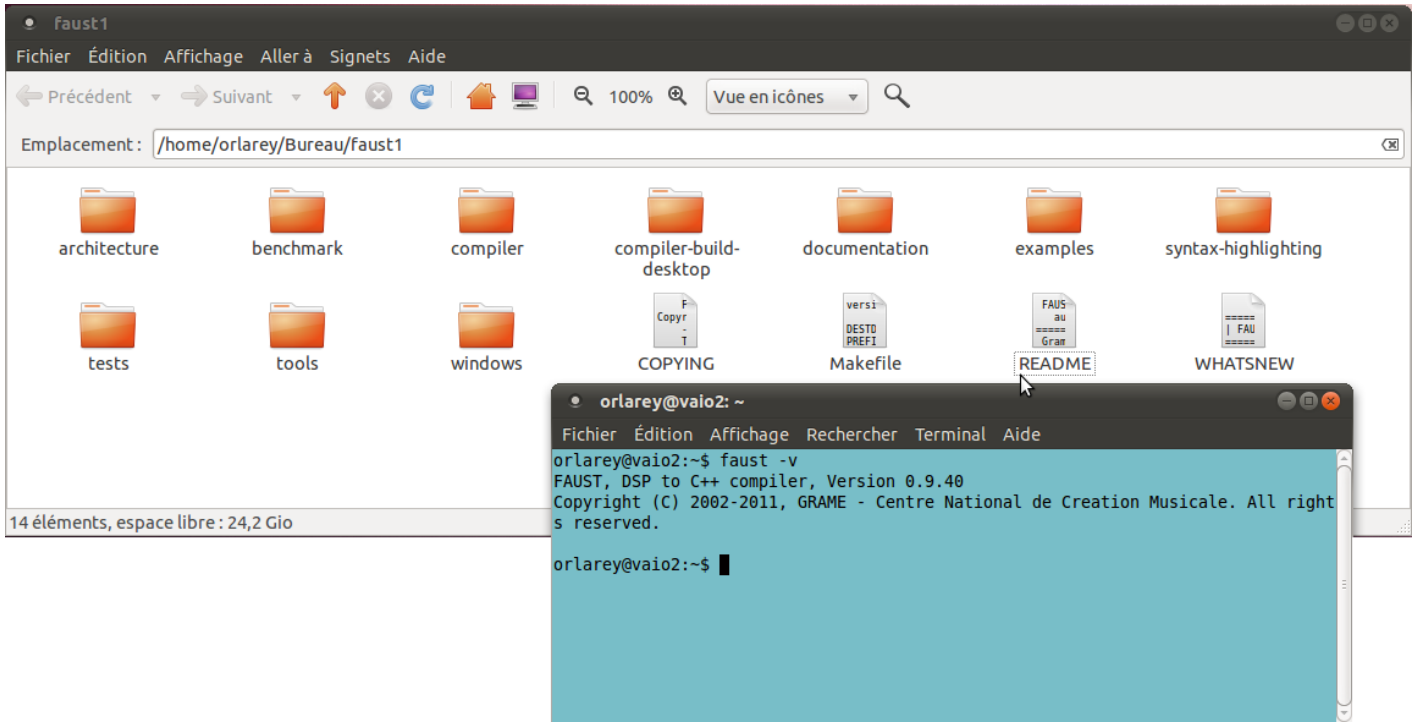


- http://faust.grame.fr
- No installation required
- Compile to C++ as well as binary (for Linux and Windows)

Resources

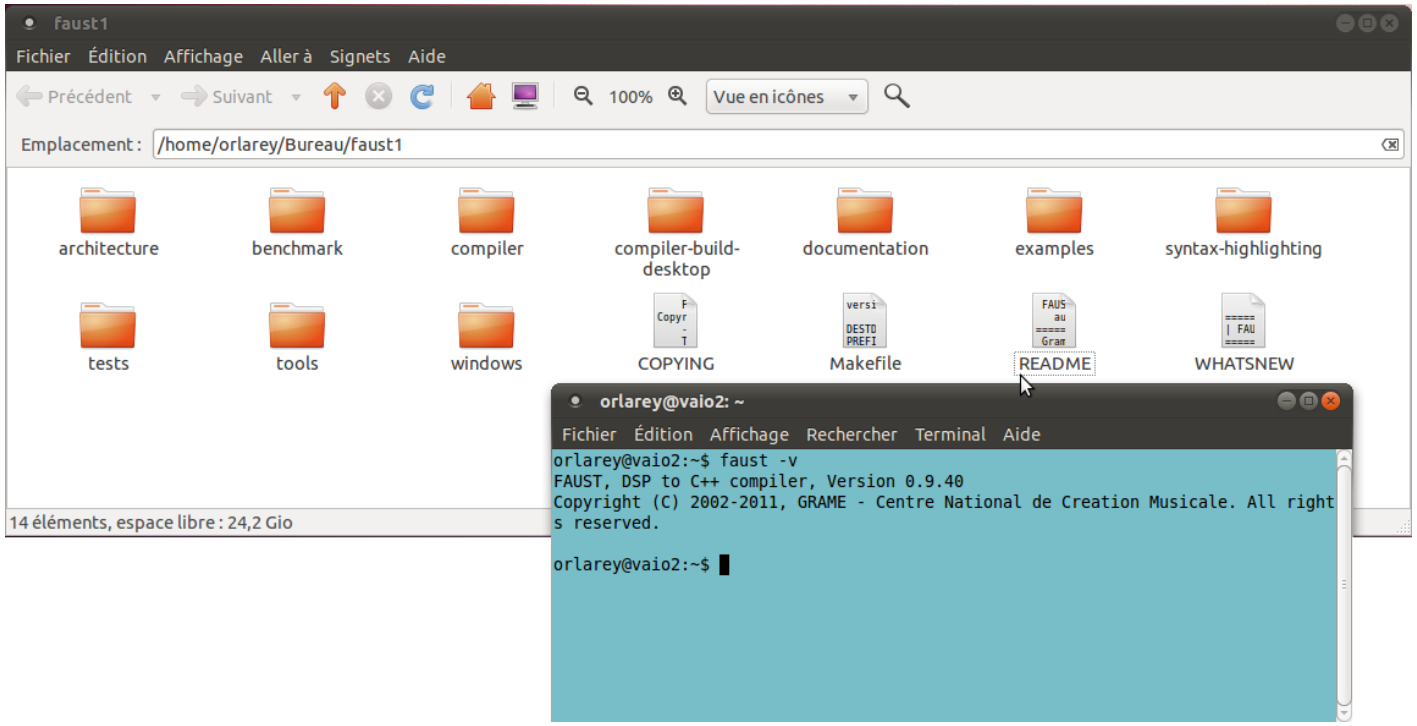
Using FAUST Distribution on Source Forge



- git clone git://faudiostream.git.sourceforge.net/gitroot/faudiostream/faudiostream faust
- cd faust; make; sudo make install

Resources

Using FAUST Distribution on Source Forge



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Resources

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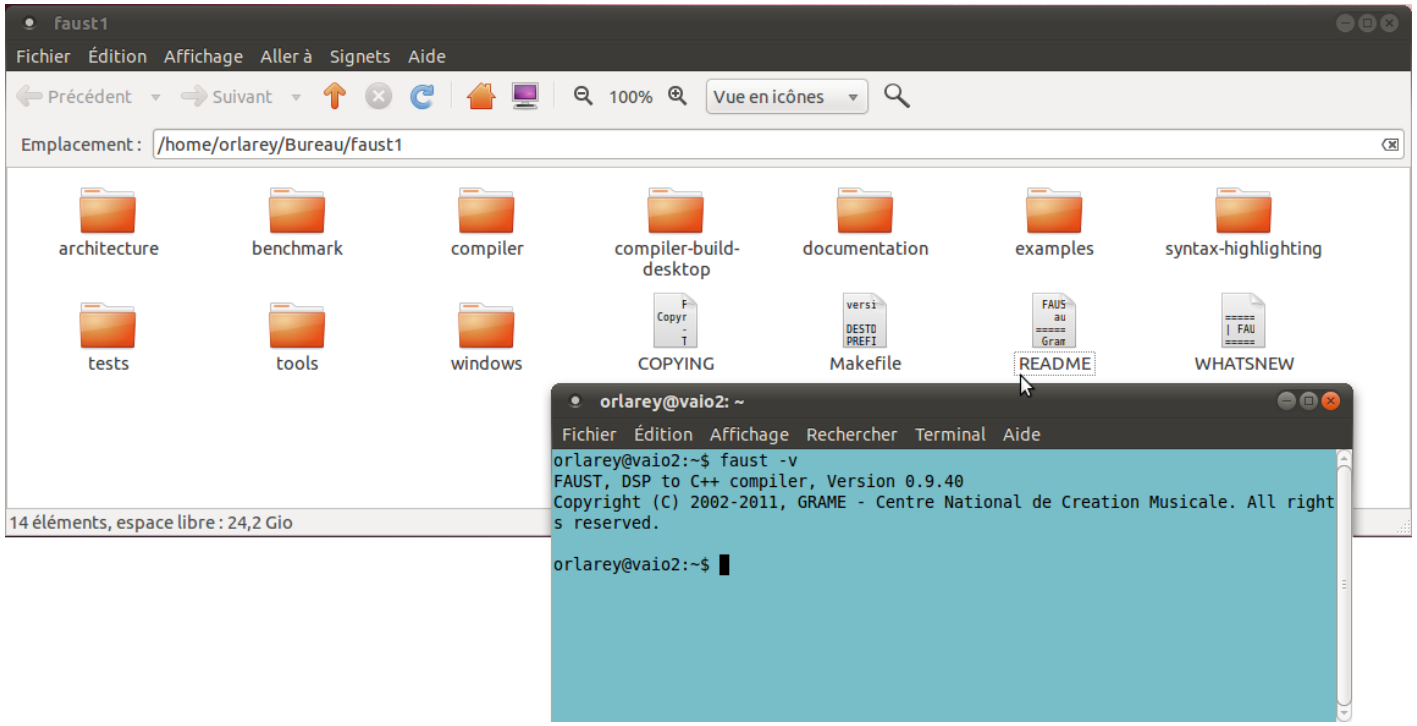

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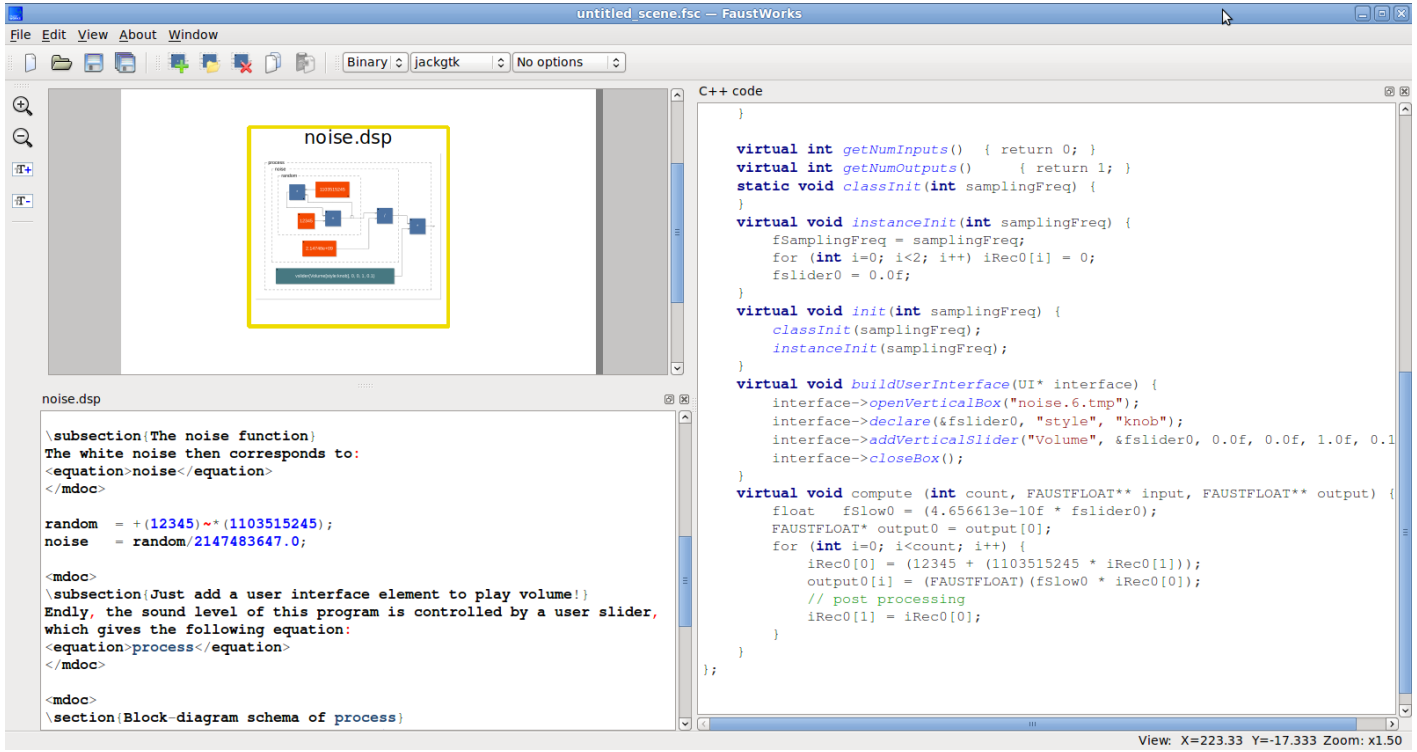
- cd faust; make; sudo make install

Resources

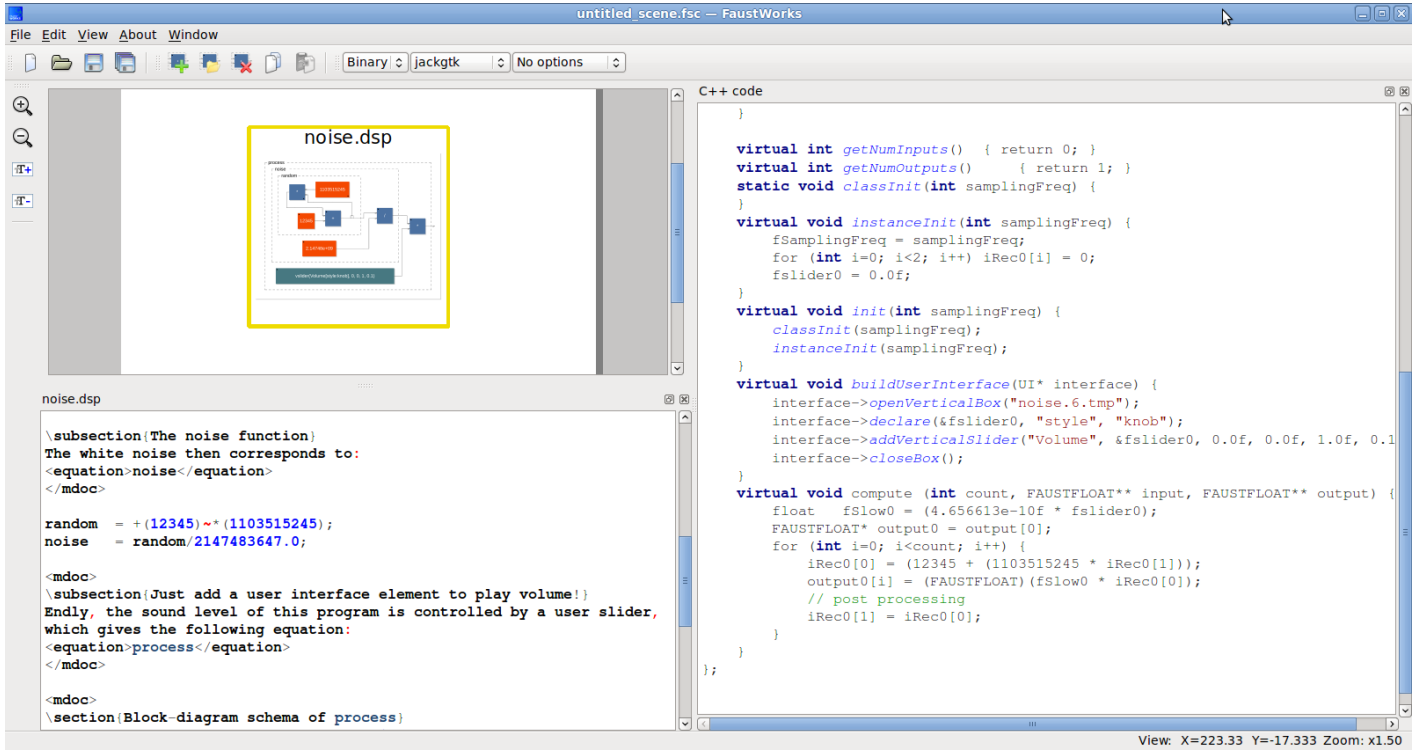
Using FaustWorks IDE



- git clone
  git://faudiostream.git.sourceforge.net/gitroot/faudiostream/FaustWorks
- cd FaustWorks; qmake; make

Resources

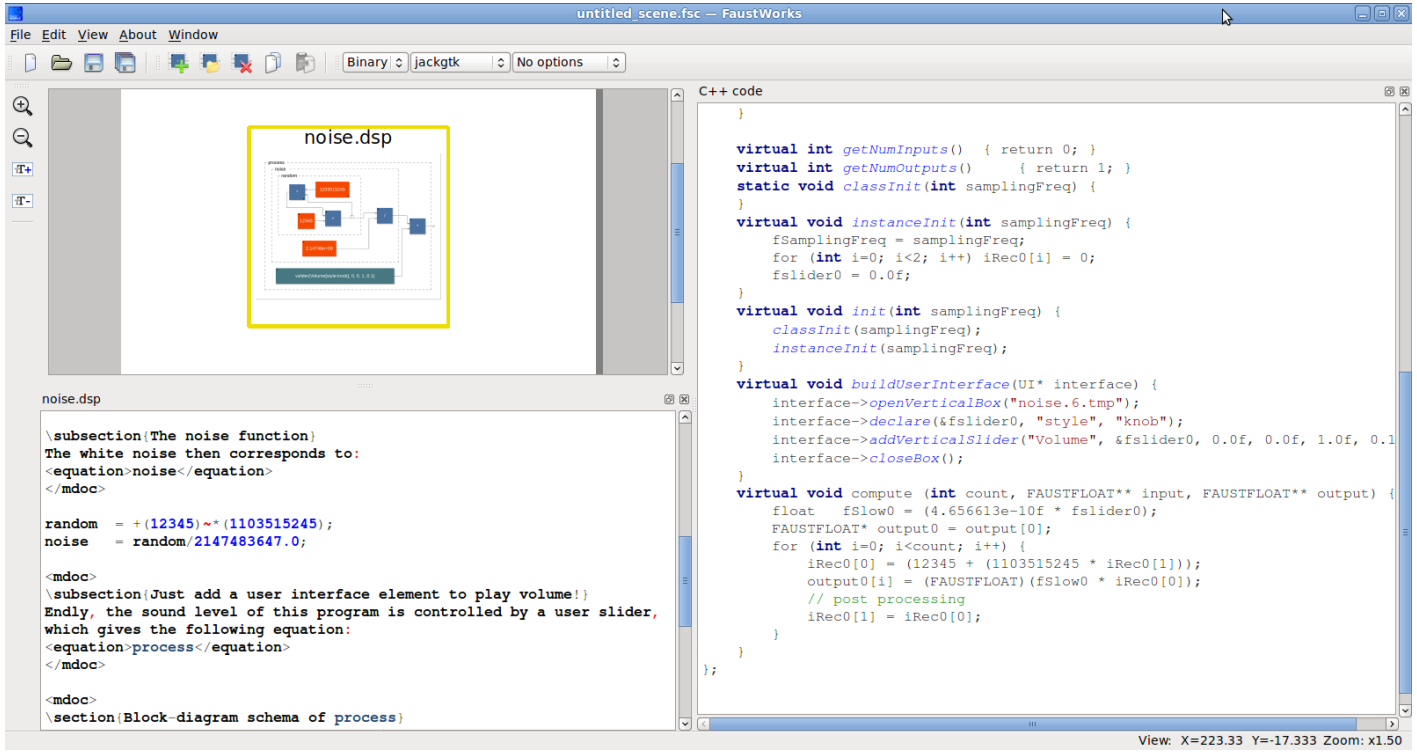
Using FaustWorks IDE



- git clone
  git://faudiostream.git.sourceforge.net/gitroot/faudiostream/FaustWorks
- cd FaustWorks; qmake; make

Resources

Using FaustWorks IDE



- git clone
  git://faudiostream.git.sourceforge.net/gitroot/faudiostream/FaustWorks
- cd FaustWorks; qmake; make

Resources

Books with a FAUST related content

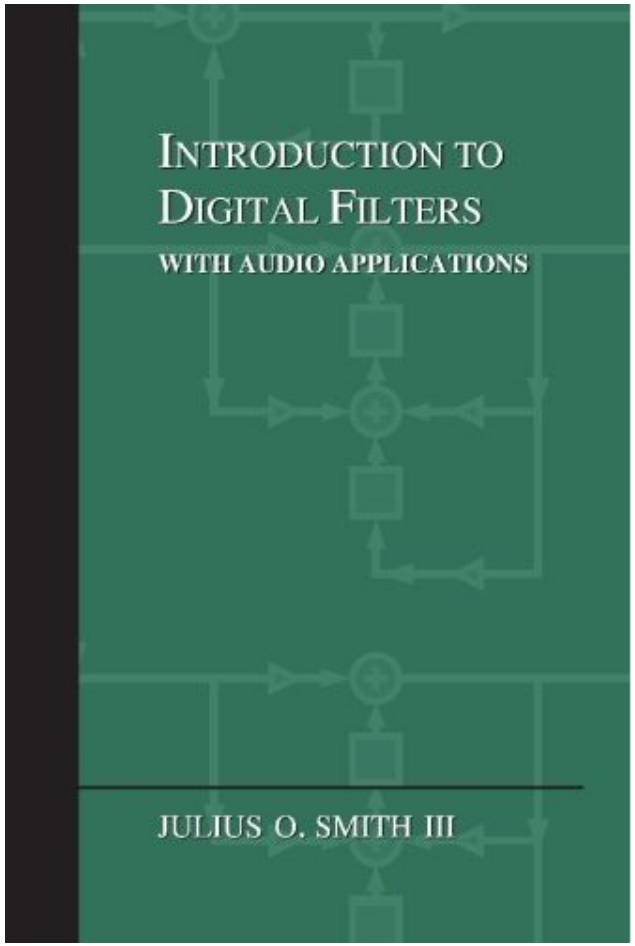


Figure: «*Introduction To Digital Filters with Audio Applications*», prof. Julius O. Smith III, W3K publishing

Resources

FAUST Introduction

Audio Signal Processing in FAUST*

JULIUS O. SMITH III

Center for Computer Research in Music and Acoustics (CCRMA)
Department of Music, Stanford University, Stanford, California 94305 USA

Abstract

FAUST is a high-level programming language for digital signal processing, with special support for real-time audio applications and plugins on various software platforms including Linux, Mac-OS-X, iOS, Windows, and embedded computing environments. Audio plugin formats supported include VST, LADSPA, Pd, Max/MSP, SuperCollider, and more. This tutorial provides an introduction focusing on a simple example of white noise filtered by a variable resonator.

Contents

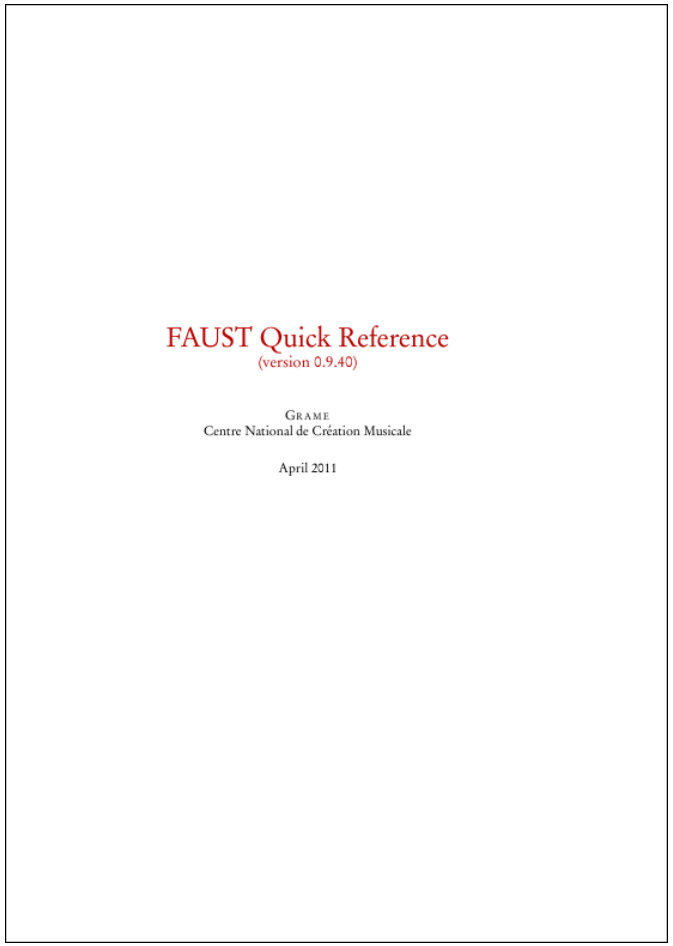
*This document is an extended subset of `http://ccrma.stanford.edu/realsimple/faust/`.

1

Figure: «*Audio Signal Processing in Faust*», Julius O. Smith III, CCRMA, Stanford

Resources

FAUST Quick Reference


FAUST Quick Reference
(version 0.9.40)

GRAME
Centre National de Création Musicale

April 2011

Figure: «*Faust Quick Reference*», Grame