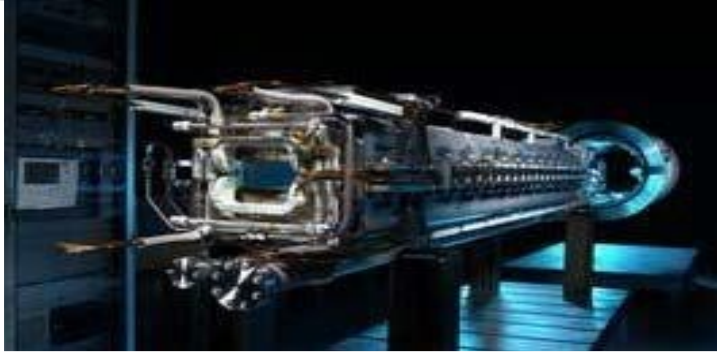




GNU Radio 4.0: Hands-on Session

A guided tour over the construction site

Alexander Krimm[2], Josh Morman[1], Ralph J. Steinhagen[2]

on behalf of: the GR Architecture Team, Ralph Steinhagen[2], Björn Balazs[3], Giulio Camuffo[3], Ilya Doroshenko[3], Semën Lebedev[2], Ivan Čukić[3], Matthias Kretz[2], Frank Osterfeld[3], ...

[1] GNU Radio 4.0 (lead) & Peraton Labs, Basking Ridge, NJ, USA
[2] FAIR – Facility for Anti-Proton and Ion Research & GSI, Darmstadt, Germany
[3] KDAB Berlin, Germany

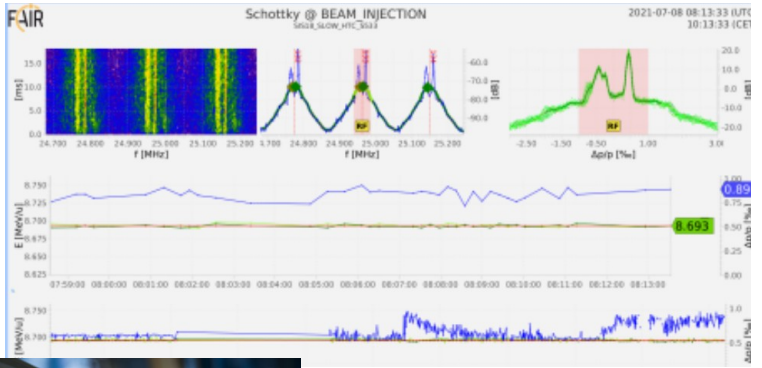
GRCon23
2023-09-07
TEMPE, ARIZONA

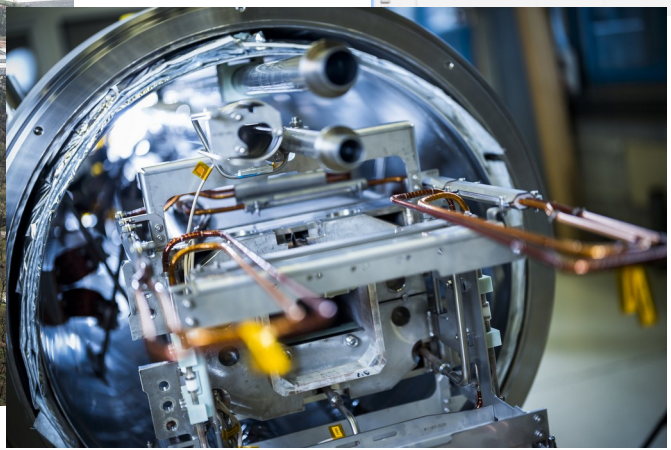
Finland France Germany India Poland Romania Russia Slovenia Sweden UK

GSI HELMHOLTZ ASSOCIATION FAIR

Who I am and where I work

- Software Engineer for Beam Based Feedback Systems at GSI/FAIR particle accelerator facility near Frankfurt, Germany
- Visit us if you’re in the area!





FAIR GSI

Scope and Motivation

- GR4 will include some breaking changes while maintaining continuity to GR3

- For a complete rundown of the changes and the motivations, see yesterday's talk: https://events.gnuradio.org/event/21/contributions/390/

Goals of the workshop

- short recap of changes and features
- assist you as users/gr-devs/oot-devs in getting into the code
- collect feedback and start discussions on
  - things that we have not yet figured out 100%
  - things we missed
  - things that need to be communicated more clearly

Short Recap: Major Differences

- C++ ≥ 20 → concepts, constexpr, NTTPs, std::simd
- codegen → compile-time reflection
  - previously: yaml → boilerplate c++ code, bindings, documentation, ...
  - new: code as single truth → bindings, documentation, ...
- additional prominent `process_one` API
- new features:
  - dataset based bulk processing
  - pmt based settings
  - automatic tag propagation

Entry Point

- currently in external repository
  - https://github.com/fair-acc/graph-prototype.git
  - to be merged into gnuradio’s dev 4.0 branch soon
- Requirements:
  - gcc > 12.2, clang > 15 or emscripten-latest
  - cmake

Getting started

- Pretty much the classic cmake workflow

```
git clone https://github.com/fair-acc/graph-prototype.git
# native linux
cmake -S . -B build && cmake –build build -j
cd build && ctest .
# emscripten
emcmake cmake -S . -B build_wasm && cmake –build build -j
cd build && ctest .
```

- There is some meson support which unfortunately does not work at the moment
- Tried on Ubuntu, SuSe, Fedora, ...

What can you do in the current state

- Write simple blocks: 1:1, n:m
- Compose flow-graphs from either c++ code or load from yaml
- Generate .so library plugins (=OOT) from a set of blocks
- Run flow-graphs using a basic scheduler
- Use a profiler (perfetto) integration to analyse the flow-graph
- Manage node settings
- Add and propagate tags to sample streams

What’s not yet there?

- Python integration
- Implementation of more advanced schedulers
- Handling of message ports
- Dynamic number of ports
- Consistent naming
- https://github.com/fair-acc/graph-prototype/issues/148

Writing a block – Simplest possible example

```
struct MyBlock : public node<MyBlock> {
  IN<double>          in;
  OUT<double>         out;

  T process_one(T in) {
    return in * in;
  }
};

ENABLE_REFLECTION(MyBlock, in, out);
```

Writing a block – adding more features

- Templated types
- SIMD
- process_bulk
- settings
- history_buffer (stateful blocks with process_one)
- sources
- annotations
- dynamic number of ports (not implemented yet)

Writing a block – templated types

```
template<typename T>
requires (std::is_arithmetic<T>())
struct MyBlock : public node<MyBlock<T>> {
  IN<T>        in;
  OUT<T>       out;

  T process_one(T in) {
    return in * in;
  }
};

ENABLE_REFLECTION_FOR_TEMPLATE_FULL((typename T),
                (MyBlock<T>), in, out);
```

Writing a block – SIMD

```
template<typename T>
requires (std::is_arithmetic<T>())
struct MyBlock : public node<MyBlock<T>> {
  IN<T>        in;
  OUT<T>       out;

  template<fair::meta::t_or_simd<T> V>
  constexpr auto process_one(V in) {
    return in * in;
  }
};
ENABLE_REFLECTION_FOR_TEMPLATE_FULL((typename T),
                    (MyBlock<T>), in, out);
```

Writing a block – process_bulk

```
struct MyBlock : public node<MyBlock> {
  IN<float>        in;
  OUT<float>       out;

  void process_bulk(
      std::span<const float> in,
      std::span<float> out
      ) const noexcept {
    for (int i=0; i < in.size(); i++) {
      out[i] = f(in[u]);
    }
  }
};
ENABLE_REFLECTION(MyBlock, in, out);
```

Writing a block – settings

```
struct MyBlock : public node<MyBlock> {
  IN<float>        in;
  OUT<float>       out;

  float factor; // setting

  void settings_changed(const property_map & /*old*/,
                        const property_map &updated) noexcept {
    if (settings_valid(updated)) {
      fmt::print("updated settings successfully: \n {}", updated);
    }
  }

  T process_one(T in) {
    return in * factor;
  }
};
ENABLE_REFLECTION(MyBlock, in, out, factor);
```

Writing a block – history buffer

```
struct MyBlock : public node<MyBlock> {
  IN<float>         in;
  OUT<float>        out;

  history_buffer<float> history{ 8 };

  T process_one(T in) {
    history.push_back(in);
    return std::accumulate(history.begin(), history.end(), 0)/8;
  }
};

ENABLE_REFLECTION(MyBlock, in, out);
```

- just a small circular buffer to keep local node state

Writing a block – sources

```
struct MyBlock : public node<MyBlock> {
  OUT<T>       out;

  int          count = 0;

  std::size_t available_samples() {
    auto result = samples – count;
    return result > 0 ? result : -1; // -1 → DONE
  }

  int process_one() {
    return count++;
  }
};
ENABLE_REFLECTION(MyBlock<T>, out);
```

Writing a block – annotations

```
struct MyBlok : public node<MyBlock,  Doc<R""(
@brief A super cool block doing important processing

Put a more extensive documentation here.
)"">> {
  IN<float>        in;
  OUT<float>       out;

  Annotated<float, "myparam", Visible,
      Doc<"target size">, Unit<"mm">> myparam = 1f;

  T process_one(T in) {
    return f(in, myparam);
  }
};
ENABLE_REFLECTION(MyBlock, in, out, myparam);
```

Writing a block – plugin/OOT blocks

```
GP_PLUGIN("Example Plugin", "A. Krimm", "LGPL3", "v1")

template<typename T>
requires (std::is_arithmetic<T>())
struct MyBlock : public node<MyBlock<T>> {
  IN<T>       in;
  OUT<T>      out;

  T process_one(T in) {
    return in * in;
  }
};
ENABLE_REFLECTION_FOR_TEMPLATE_FULL((typename T),
             (MyBlock<T>), in, out);
GP_PLUGIN_REGISTER_NODE(MyBlock, float, double);
```

FAIR GSI

Creating and running a fixed flowgraph from C++

```
fg::graph graph{};
auto& source graph.make_node<source>();
auto& node   grap.make_node<scale>({{ “factor”, 3.0 }});
auto& sink   graph.make_node<sink>();

graph.connect<”out”>(source).to<”raw”>(scale);
graph.connect<”scaled”>(scale).to<”in”>(sink);

fg::scheduler::simple<> scheduler{std::move(graph)};

scheduler.run();
```

Dynamic flowgraphs

```
fg::graph graph{};

fg::node_registry registry;
fg::plugin_loader loader(&registry,
    std::vector<std::filesystem::path>{ "/share/gr-plugins"});
GP_REGISTER_NODE(registry, MySource, double, float);

// load builtin node
auto &node_source = loader.instantiate_in_graph(graph, “MySource”, "double");
// load from .so file
auto &node_source = loader.instantiate_in_graph(graph, “MyBlock”, "double");

node_source→dynamic_output_port(0)
    .connect(node_myblock(node_multiply->dynamic_input_port(0))

fg::scheduler::simple<> scheduler{std::move(graph)};

scheduler.run();
```

Compile time merging of nodes

```
fg::graph graph{};
auto& source graph.make_node<source>();
auto& sink   graph.make_node<sink>();

auto merged = graph.add_node(fg::merge<”scaled”, “raw”>(
    scale({{ “factor”, 3.0 }}, square));

graph.connect<”out”>(source).to<”raw”>(merged);
graph.connect<”squared”>(merged).to<”in”>(sink);

fg::scheduler::simple scheduler{std::move(graph)};

scheduler.run();
```

Goals of the workshop

- assist you as users/gr-devs/oot-devs in getting into the code
- collect feedback and start discussions on
  - things that we have not yet figured out 100%
  - things we missed
  - things that need to be communicated more clearly
- Slides 

  https://events.gnuradio.org/event/21/contributions/496/
- Repo 

  https://github.com/fair-acc/graph-prototype

FAIR GSI