from the free world of
KDE

For a brighter QFuture

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About me

- KDE development
- Talks and teaching
- Functional programming enthusiast, but not a purist

Disclaimer

> Make your code readable. Pretend the next person who looks at your code is a psychopath and they know where you live.
>
> Philip Wadler

Disclaimer

The code snippets are optimized for presentation, it is not production-ready code.

`std` namespace is omitted, value arguments used instead of const-refs or forwarding refs, etc.

FUTURES

Introduction

Concurrency

Futures

Value


```
T value = function();
```

Blocking

What if the call takes too long to complete?

```
T value = function();
```

execution is blocked until function finishes

Blocking

- I/O
- User input
- Network communication

```
T value = function();
```

execution is blocked until function finishes

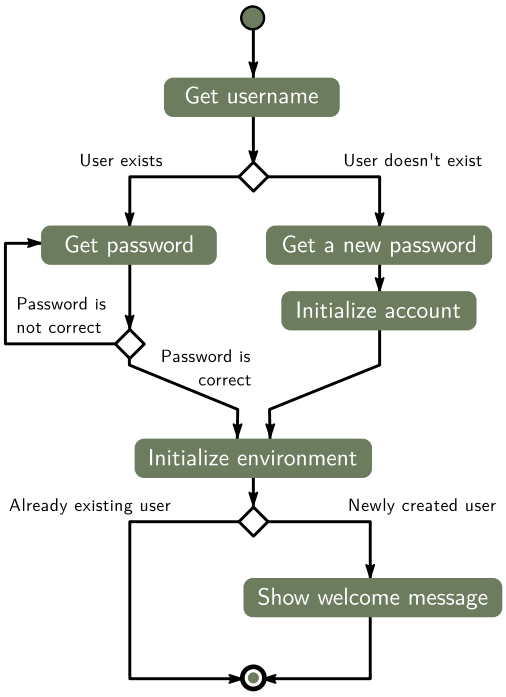
Blocking

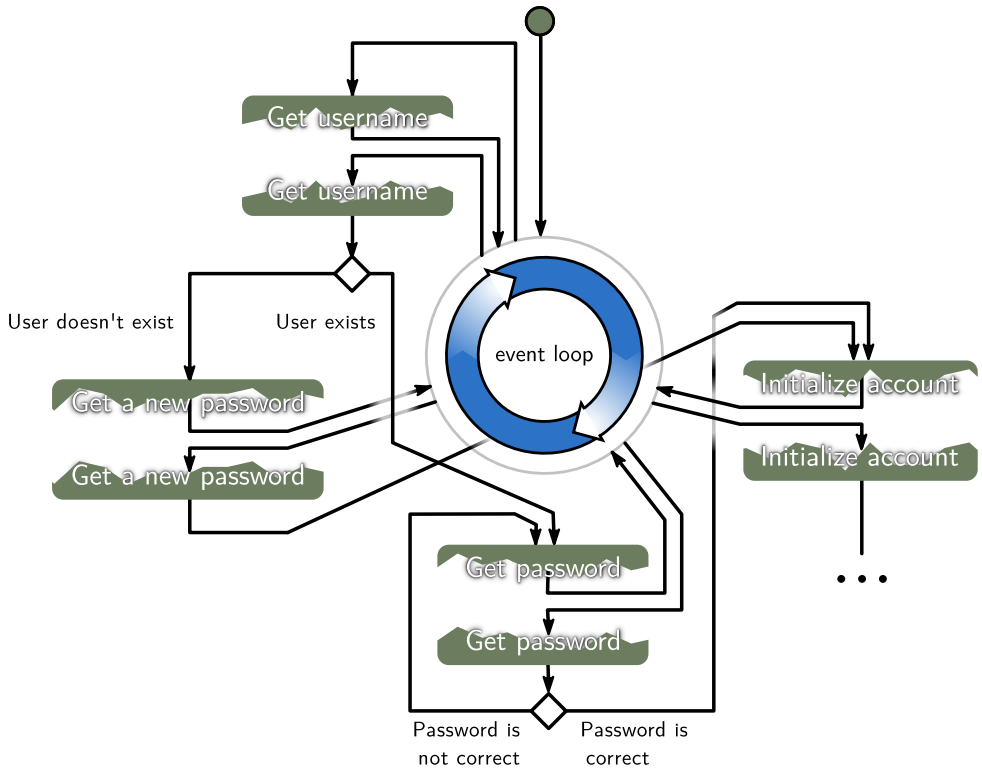
- Callbacks?
- Signals and slots?
- Spin off threads, and wait in the thread?

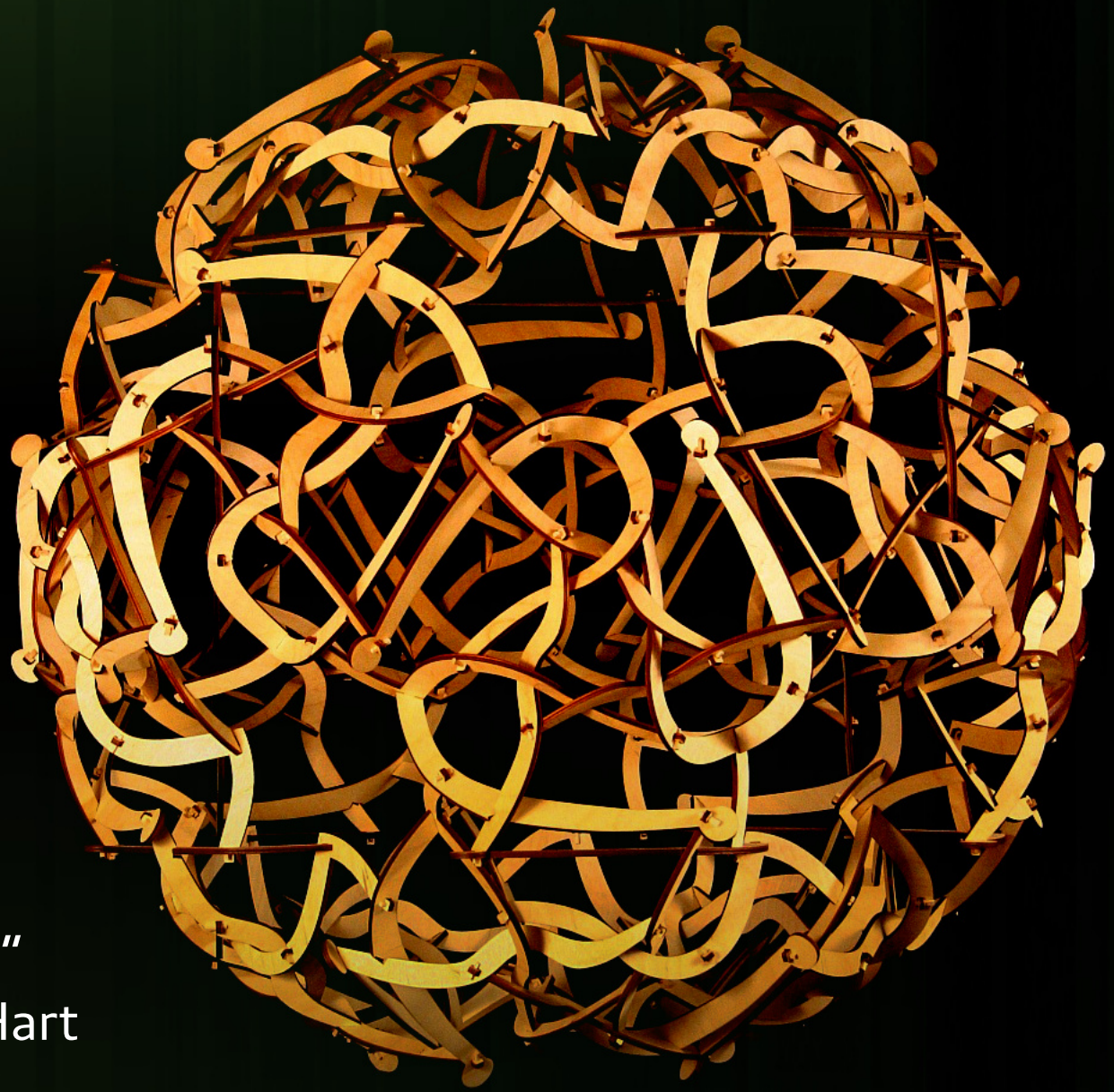
```
T value = function();
```

execution is blocked until function finishes

Inversion of Control

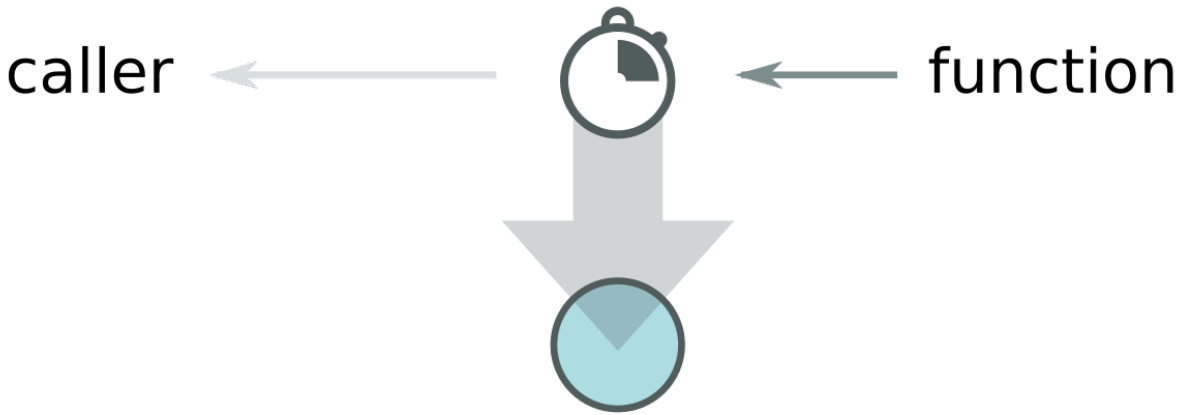






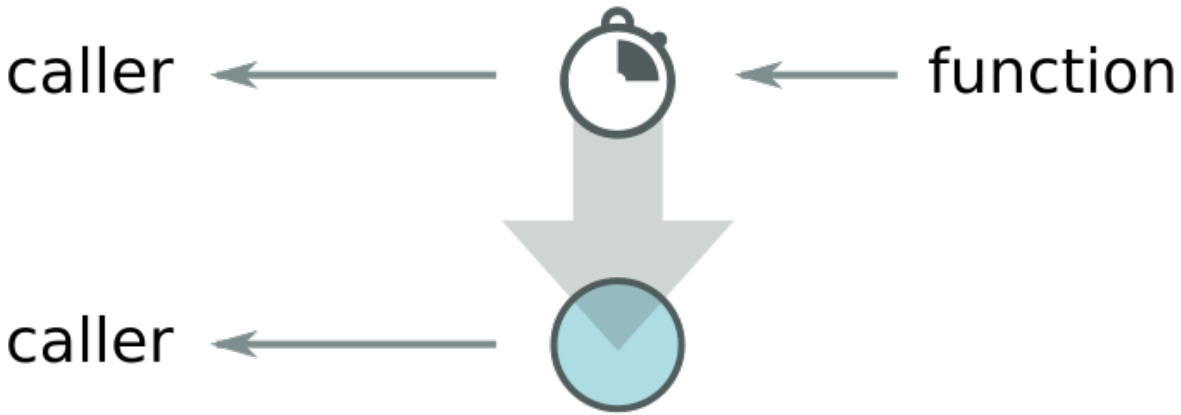
"Spaghetti code"
by George W. Hart

Future



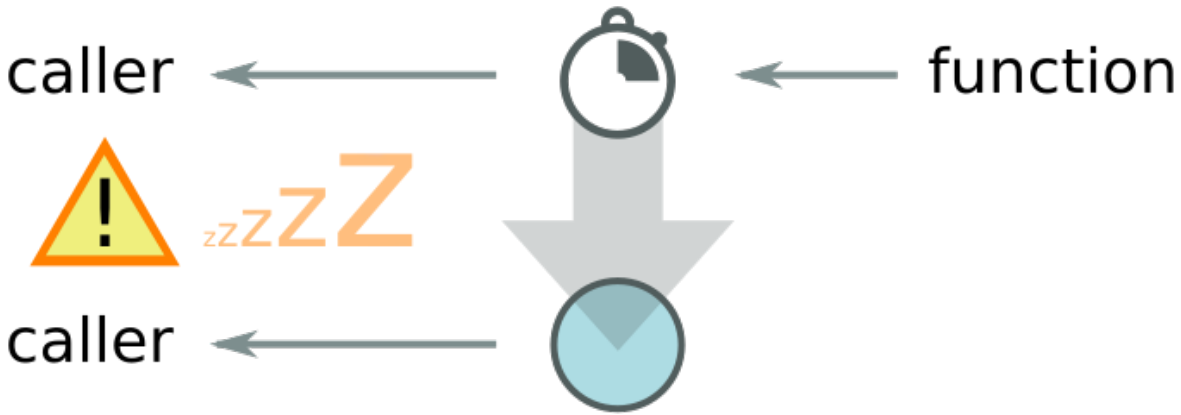

```
future<T> handler = function();
```

Future



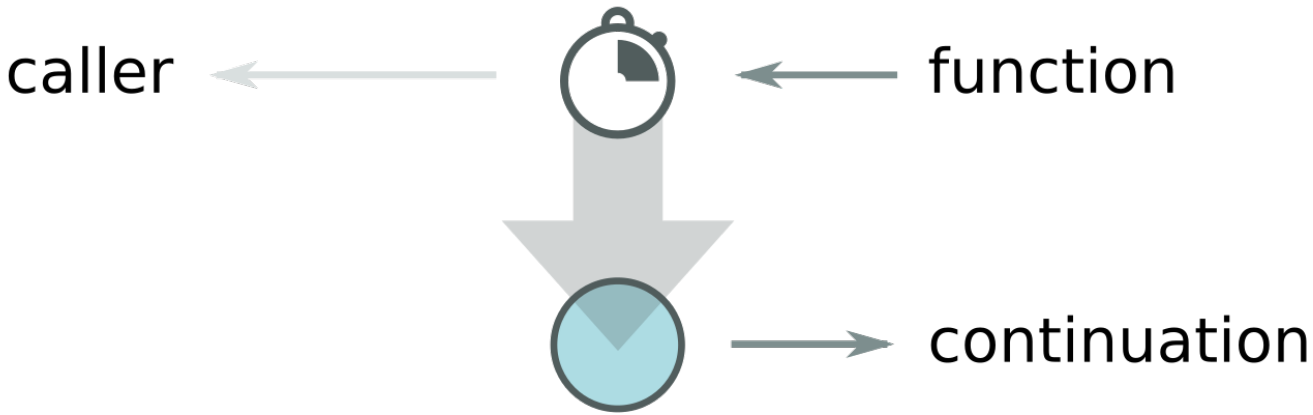

```
future<T> handler = function();
...
T value = handler.get();
```

Future



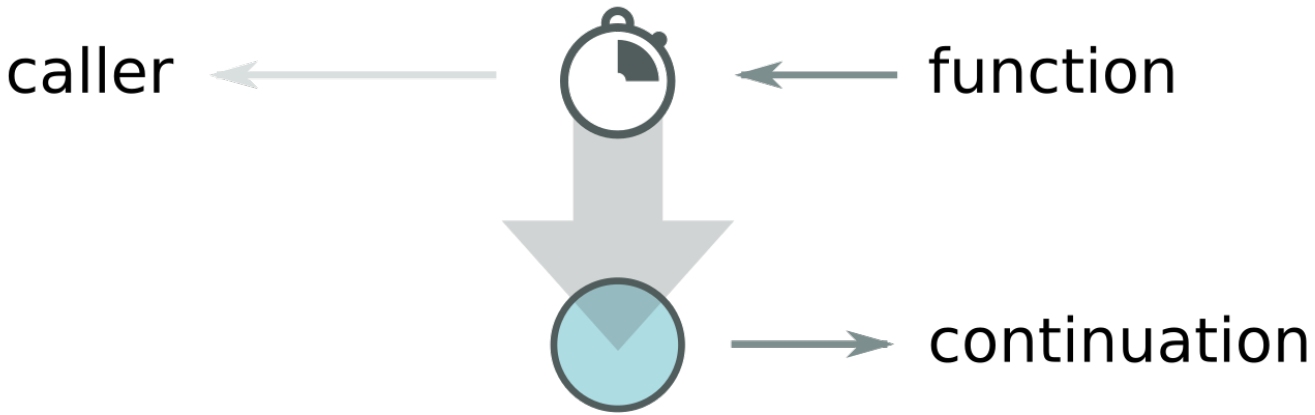

```
future<T> handler = function();
...
T value = handler.get(); !
```

Future




```
future<T> handler = function();
...
handler →
    [] (T value) { ... }
```

Future




```
future<T> handler = function();

handler.then([] (T value) { ... });

auto value = await handler();
```

Concurrency problems

A large fraction of the flaws in software development are due to programmers not fully understanding all the **possible states** their code may execute in. In a multithreaded environment, the lack of understanding and the resulting problems are **greatly amplified**, almost to the point of panic if you are paying attention.

John Carmack
In-depth: Functional programming in C++

Futures

```
std::future
boost::future
QFuture
Folly Future
```

QFUTURE

History

Problems

Under the wraps

A bit of history

Qt4

Born in **QtConcurrent** – for collecting the results of asynchronous operations

Operations like filtering, mapping, reduction etc. or for simply executing a function on another thread.

The main use-case was the fork-join pattern – do stuff in multiple threads, and get the result.

A bit of history

Road to Qt5

Moving **QFuture** from QtConcurrent **to QtCore**

When QtConcurrent was been moved out of QtCore, some of it stayed behind in QtCore: QThreadPool, but not QFuture. I'm arguing here that QFuture should stay in QtCore, or else be renamed to QtConcurrent::Future, to not impede development in that area until Qt 6.

[...]

– Mark Mutz

Today

Qt5

QFuture is a part of QtCore and is no more tied to QtConcurrent.

But is it really?

- Still meant only for multi-threading
- It can not really be constructed outside of QtConcurrent
- API tailored exactly for QtConcurrent uses

...

Threading

Qt5

Used to model thread-based concurrent invocations. What about all other asynchronous computations?

- **QMetaObject::invokeMethod** and QueuedInvocation
  "If the invocation is asynchronous, the return value cannot be evaluated";
- **QDBusPendingReply<T>** is a thing.
  It is a value that will be avilable in the future;
- **QNetworkReply** is a complex structure which will initialize its data some time in the future;
- **KJob** is again a process that can yield a result when the asynchronous job is completed;

  ...

Threading

Qt5

Many future-like things, none of them are **QFuture**.

No ability to compose several calls. Require a lot of boiler-plate to deal with all of them.

```
void processResult(QFuture<Smth> future)
  how awesome would it be not to care
  about which future-like object it is
```

Construction

Qt5

So, how do I **create** a QFuture?

It has only the default constructor which creates an empty, canceled future, and a copy constructor.

```
QFuture();
QFuture(const QFuture &other);
```

Construction

Qt5

So, how do I **create** a QFuture?

From the docs: "To start a computation, use one of the APIs in the **Qt Concurrent** framework."

```
QtConcurrent::run(...);
QtConcurrent::filter(...);
QtConcurrent::mappedReduced(...);
```

Getting the value

Qt5

So, how do I **get the value** from a QFuture?

We can use .get(), but then there is no point in using the futures in the first place.

```
future.get();
```

but get blocks

Getting the value

Qt5

So, how do I **get the value** from a QFuture?

Instead of trying to get the value, consider the future is a black box, and we can only tell it to whom to send the result.

```
future →
    continuation
```

Getting the value

Qt5

So, how do I **get the value** from a QFuture?

Instead of trying to get the value, consider the future is a black box, and we can only tell it to whom to send the result.

```
auto watcher = new QFutureWatcher<int>();
QObject::connect(watcher,
    &QFutureWatcherBase::finished, [=] {
        continuation(watcher->result());
        watcher->deleteLater();
    });
watcher->setFuture(qfuture);
```

Other fun things

Qt5

- Not only one value – QFuture<T> is essentially a future of a list of Ts
- It can store an exception (an error in the asynchronous computation), but the exception can not be accessed via the API without calling .get() which rethrows the exception.
- Job control – setPaused(bool), cancel()

...

Under the wraps

QFuture is very limited as far as the public API is concerned, and we (will pretend) we can not access the private API of a class template.

But, the interesting things are not in the QFuture, but in the **QFutureInterface<T>**.

```
template <typename T>
class QFutureInterface: ... {
public:
    QFuture<T> future();
};
```

Construction

So, how do I create a QFuture?

Creating a future that already holds **a value** is trivial, just create the interface instance, and set the value.

```
QFutureInterface<T> interface;
auto future = interface.future();

interface.reportStarted();
interface.reportResult(value);
interface.reportFinished();
return future;
```

Construction

So, how do I create a QFuture?

To create a future that contains **an error** – just create the interface instance, and set the error.

```
QFutureInterface<T> interface;
auto future = interface.future();

interface.reportStarted();
interface.reportException(exception);
interface.reportFinished();
return future;
```

Construction

So, how do I create a QFuture?

To create a future that will contain a value **after a few seconds** you'll have to do a bit more. Create your own future interface class.

```
template <typename T>
class DelayedFutureInterface : public QObject
                             , public QFutureInterface<T>
{
    ...
};
```

Construction

And make its start member function complete the future after a given number of milliseconds.

```
QFuture<T> start()
{
    auto future = this->future();
    this->reportStarted();

    QTimer::singleShot(milliseconds, [this] {
        this->reportResult(value);
        this->reportFinished();
        deleteLater();
    });

    return future;
}
```

ASYNQT

Usage

Construction

AsynQt

So, how do I create a QFuture?

```
makeReadyFuture(6);

makeCanceledFuture<void>();

makeDelayedFuture(42, 1h + 30min); // C++14
```

Construction

AsynQt

So, how do I create a QFuture?

Wrappers can be written once, and then everything becomes a QFuture.

```
DBus::asyncCall(...);

Process::getOutput("ls");
        ↖ collects process output

Process::exec("ls", [] (auto p) { return p->exitCode(); });
        ↖ the future will contain the process exit code
```

Getting the value

AsynQt

So, how do I **get the value** from a QFuture?

You simply **don't**.

But you can pass the value on, once it is available.

```
QFuture<QString> input = getUserInput();

input | [] (QString) { do something with the value };
```

we can not create a .then for the QFuture

also returns a future

Transforming the value

AsynQt

```
QFuture<QString> input = getUserInput();

QFuture<int> length = input | transform(&QString::length);
```

future that will be initialized as soon as the input becomes available

```
QFuture<QString> valid = input | filter(&inputValidation);
```

future that will hold only valid input strings (remember, QFuture can hold a list of items)

Transforming the value

AsynQt

```
QFuture<QByteArray> future =
    Process::getOutput("echo", { "Hello KDE" });

                          we got a future of QByteArray
                          but we wanted QFuture<QString>
QFuture<QString> castFuture =
    qfuture_cast<QString>(future);

QFuture<QString> castFuture = future | cast<QString>();
            or just simply pipe it
```

Getting the value

AsynQt

What if we want to send the value to another function that will return us a QFuture, will we get a **QFuture<QFuture<T>>**?

```
QFuture<QString> input = getUserInput();

QFuture<int> length =          creates a nested future
    flatten(input | transform( ... ));
          converts a nested future into a normal one

QFuture<int> length =
    input | [] (QString value) {
              shorthand for transform-and-flatten
        // server returns us a future of the HTTP status
        return server.send(value);
    };
```

More composing

AsynQt

And the usual...

```
collect: collection<QFuture<T>> -> QFuture<collection<T>>

collect:
    (QFuture<T1>, QFuture<T2>, ...)
            -> QFuture<tuple<T1, T2, ...>>

anyOf: collection<QFuture<T>> -> QFuture<T>

anyOf:
    (QFuture<T1>, QFuture<T2>, ...)
            -> QFuture<variant<T1, T2, ...>>

...
```

Limitations of QFuture

- Either single values, or multiple values stored in memory – not suitable for data streams;
- Custom QFutures are not first-class citizens;
- Big overhead (both API and runtime) for a concept that could have been much simpler if only it weren't born as a part of Qt Concurrent;
- AsynQt – useful or a fun, but futile experiment?

Answers? Questions! Questions? Answers!

Kudos:

- Friends at KDE
- Saša Malkov
- Zoltán Porkolab

Worth reading and watching:

- Systematic Error Handling in C++, Andrei Alexandrescu
- Await 2.0, Gor Nishanov
- Ranges proposal, Eric Niebler