There Is A New Future

Prepared for ACCU 2018

Felix Petriconi

2018-04-14

Felix Petriconi

- Started with C++ 1994
- Programmer and development manager since 2003 at MeVis Medical Solutions AG, Bremen, Germany
  - Development of medical devices in the area of mammography and breast cancer therapy (C++, Ruby)
- Programming activities:
  - Blog editor of ISO C++ website
  - Active member of C++ User Group Bremen
  - Contributor to stlab's concurrency library
  - Member of ACCU conference committee
- Married with Nicole, having three children, living near Bremen, Germany
- Other interests: Classic film scores, composition

The [C++] language is too large for *anyone* to master
So *everyone* lives within a subset

Sean Parent, C++Now, 2012

Why I am here?

I saw how we used different ways to delegate work to different CPU cores
I saw how easy it is to make mistakes
I saw and still see the difficulties in maintaining the code

I listened 2015 to the CppCast with Sean Parent about Concurrency
I was impressed
I wanted to learn more

I started collaborating in his open source project for a new concurrency library
I'm having fun in learning there a lot
I care about sharing my knowledge

Why are you here?

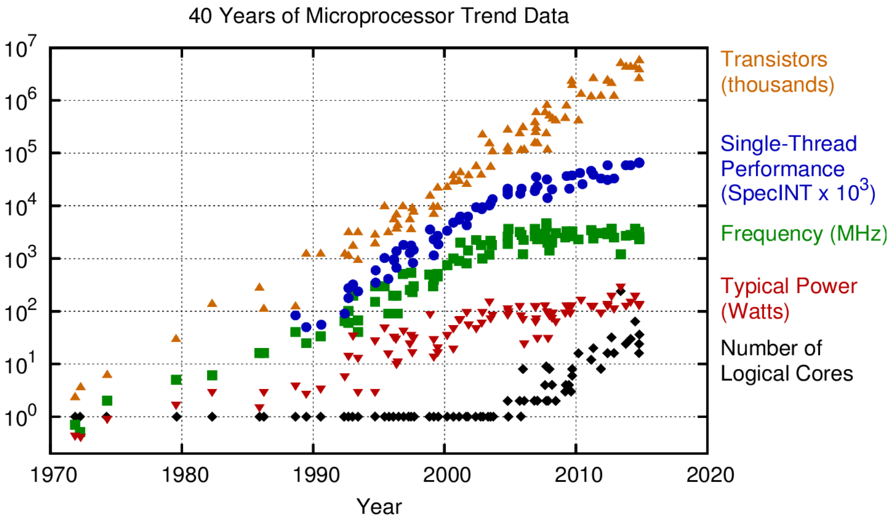
Why do we have to talk about concurrency?

The free lunch is over!

Herb Sutter, 2005[1]

[1] The Free Lunch Is Over: A Fundamental Turn Toward Concurrency in Software
http://www.gotw.ca/publications/concurrency-ddj.htm

The free lunch is over



Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2015 by K. Rupp

Amdahl's Law

Amdahl's Law[2]

$$S(N) = \frac{1}{(1-P)+\frac{P}{N}}$$

$S:$ Speed up
$P:$ Synchronization $[0 - 1]$
$N:$ Number of Cores

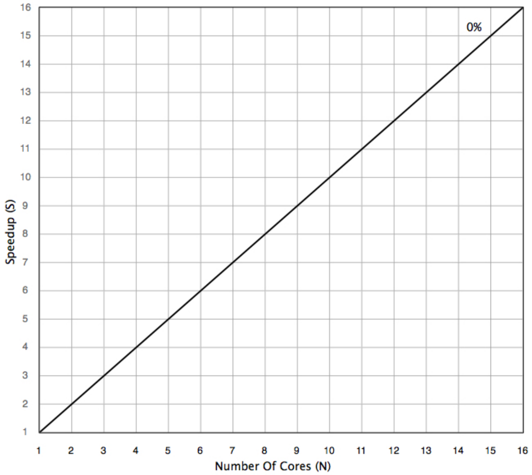
[2] Presented 1967 by Gene Myron Amdahl (1922-2015)

Amdahl's Law

0% Synchronization

$$S(N) = \frac{1}{(1-P)+\frac{P}{N}}$$

$$P = 0$$

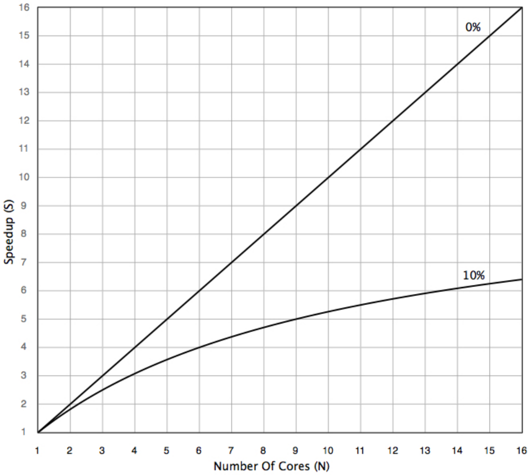


Amdahl's Law

10% Synchronization

$$S(N) = \frac{1}{(1-P)+\frac{P}{N}}$$

$$P = 0.1$$

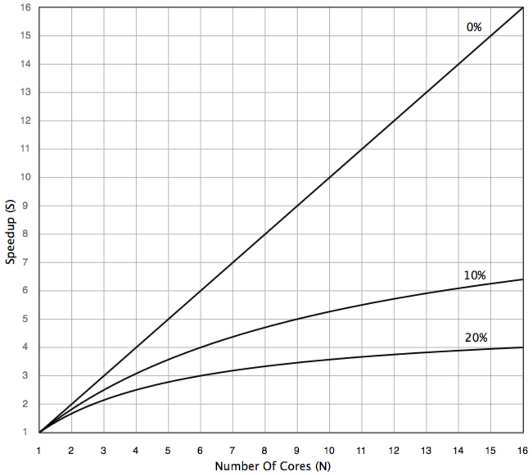


Amdahl's Law

20% Synchronization

$$S(N) = \frac{1}{(1-P)+\frac{P}{N}}$$

$$P = 0.2$$

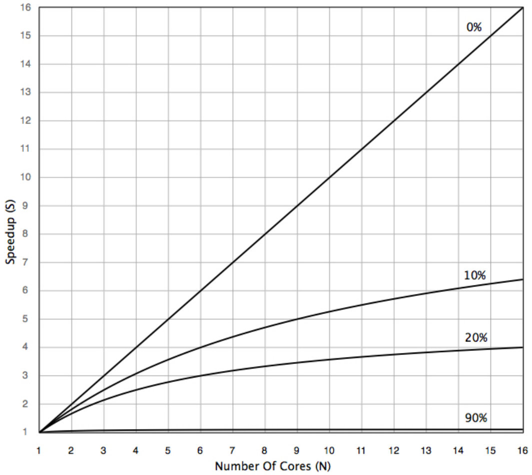


Amdahl's Law

90% Synchronization

$$S(N) = \frac{1}{(1-P)+\frac{P}{N}}$$

$$P = 0.9$$



How to use multiple cores?

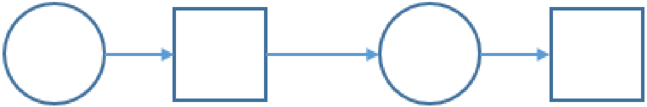
- Individual single threaded processes
- Multi threaded process without synchronization
- Multi threaded process with synchronization
  - Mutex
  - Atomic
  - Semaphore
  - Memory Fence
  - Transactional Memory

  } Low level synchronization primitives
- Multi threaded process with higher level abstractions
  - Future
  - Channel
  - Actor
  - ...

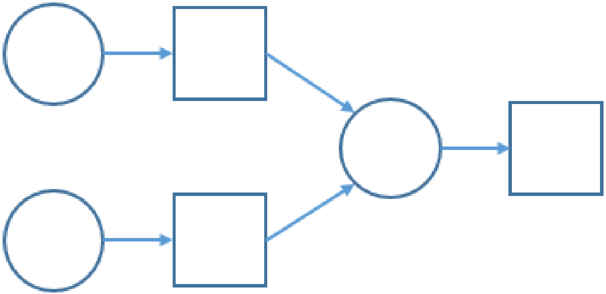
Future Introduction

- Futures provide a mechanism to separate a function $f(...)$ from its result r
- After the function is called the result appears "magically" later in the future
- Futures, resp. promises where invented 1977/1978 by Daniel P. Friedman, David Wise, Henry Baker and Carl Hewitt

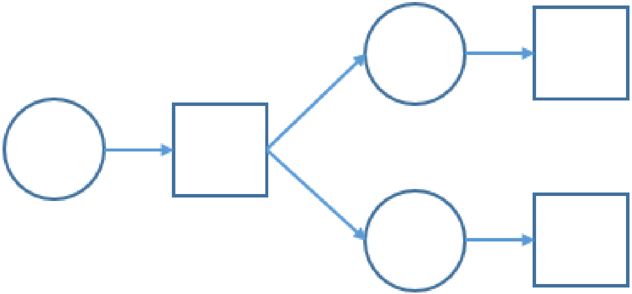
Future Introduction - Continuation



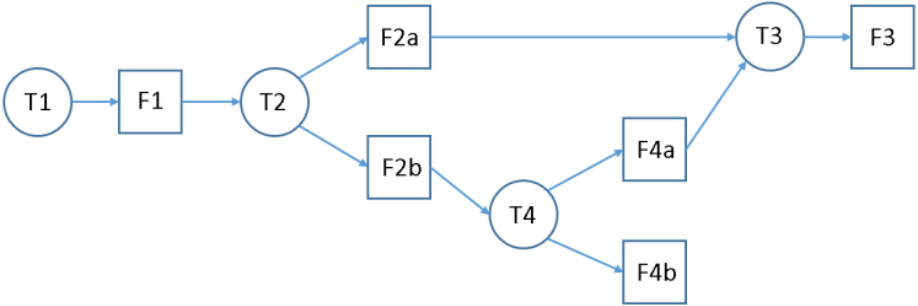
Future Introduction - Join



Future Introduction - Split

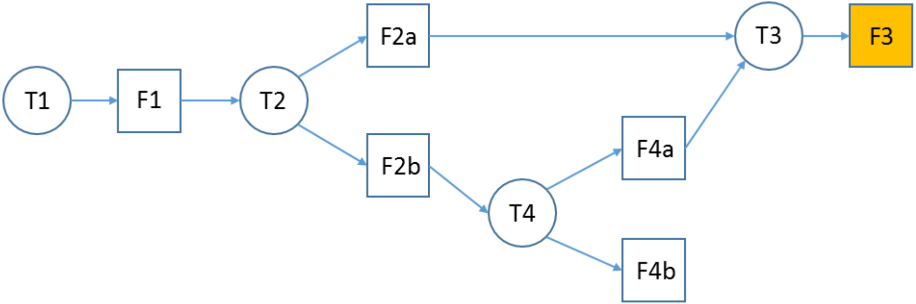


Future Introduction - Cancellation



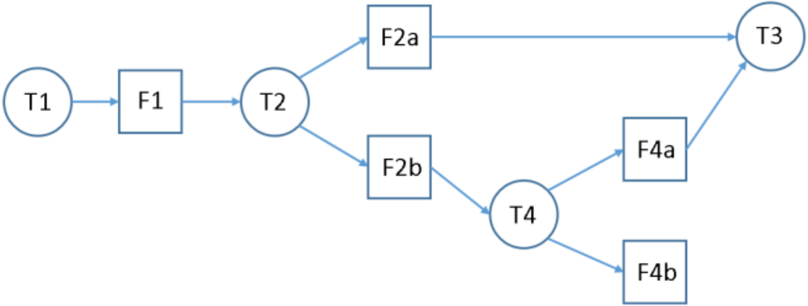
▶

Future Introduction - Cancellation



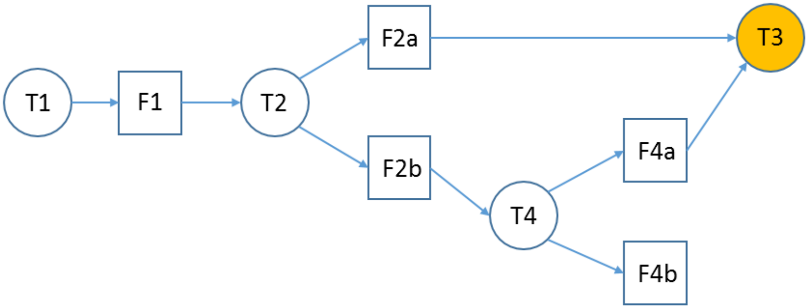
- Future F3 is not needed any more (e.g. the user has canceled an operation)

Future Introduction - Cancellation



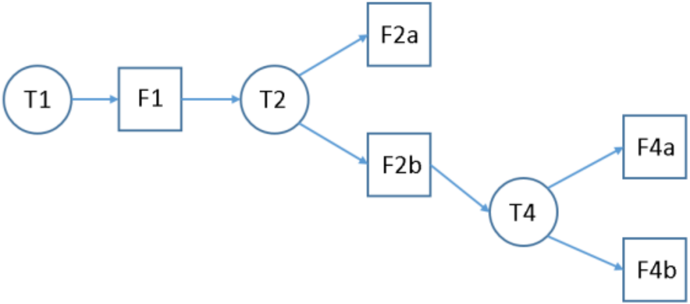
▶

Future Introduction - Cancellation



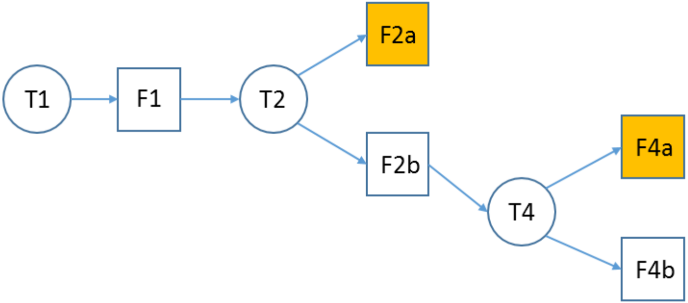
- There is no need to execute task T3

Future Introduction - Cancellation



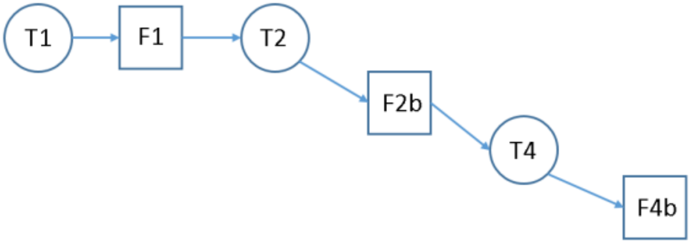
▶

Future Introduction - Cancellation



- Then the futures F2a and F4a are not needed any more

Future Introduction - Cancellation



- The graph collapses to its minimum

C++11 Standard - Futures

- boost::futures were added in boost 1.41, 2009
- std::future are mostly based on boost::futures
- Where added with C++11

C++11 Standard - Futures Overview

C++ Standard - Futures

```cpp
#include <future>
#include <iostream>

using namespace std;

int main() {
  auto answer = [] {
    return 42;
  };

  future<int> f = async(launch::async, answer);

  // Do other stuff, getting the answer may take longer
  cout << f.get() << '\n';         // access the value
}
```

Output

```
42
```

C++ Standard - Futures - packaged_task

```cpp
#include <future>
#include <iostream>
#include <string>

using namespace std;

int main() {
  auto answer = [](string) { return 42; };
  packaged_task<int(string)> task(answer);

  future<int> f = task.get_future();
  task("What is the answer ...?");

  // Do other stuff, getting the answer may take longer
  cout << f.get() << '\n';         // access the value
}
```

Output

42

C++ Standard - Futures - Exceptions

```cpp
int main() {
  auto answer = [] {
    throw runtime_error("Bad things happened: Vogons appeared!");
    return 42;
  };

  future<int> f = async(launch::async, answer);

  // Do other stuff, getting the answer may take longer
  try {
    cout << f.get() << '\n';  // try accessing the value
                              // re-throws the stored exception
  }
  catch (const runtime_error& ex) {
    cout << ex.what() << '\n';
  }
}
```

Output

```
Bad things happened:  Vogons appeared!
```

C++ Standard - Futures - Problem

```cpp
#include <future>
#include <iostream>

using namespace std;

int main() {
  auto answer = [] {
    return 42;
  };

  future<int> f = async(launch::async, answer);

  // Do other stuff, getting the answer may take longer
  cout << f.get() << '\n';          // access the value
}
```

What is the biggest problem within this code when our goal is best CPU utilization?

`future<T>.get()` is a blocking call! There is no direct way of checking if the future is ready! Only indirect with `.wait_for()` with zero timeout.

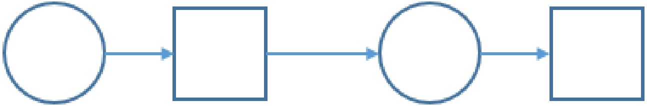
C++11/14/17 Future Capabilities

- No continuation — `future<T>.then()` ✗
- No join — `when_all()` and `when_any()` ✗
- No split — continuation in different directions ✗
- No cancellation (but can be modelled[3]) ✗
- No automatic reduction (`future<future<T>>`⇒`future<T>`) ✗
- No progress monitoring (except ready) ✗
- No custom executor ✗
- Blocks on destruction (may even blocks until termination of used thread) ✗
- Usage of `future<T>.get()` has two problems:
  1. One thread resource is consumed which increases contention and possibly causing a deadlock ✗
  2. Any subsequent non-dependent calculations on the task are also blocked ✗
- Don't behave as a regular type[4] ✗

[3] https://gist.github.com/sean-parent/24df3eefd51068ba34c482f6e71da2c2
[4] Elements of Programming; Stepanov, McJones; Addison-Wesley 2009

boost Futures Overview

Future - Continuation



- A Continuation on an existing future is realized through `future<T>.then()` which returns itself a future

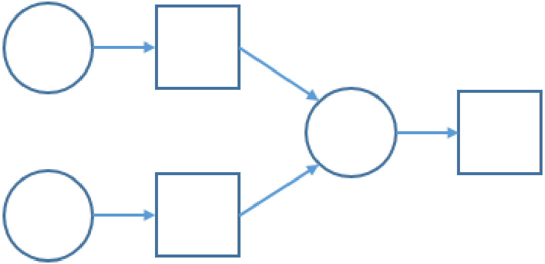
boost Futures - Continuation

```
#include <iostream>
#include <boost/thread/future.hpp>

using namespace std;

int main() {
  auto answer = []{ return 42; };
  auto report_answer = [](auto a) { cout << a.get() << '\n'; }

  boost::future<int> get_answer = boost::async(answer);

  boost::future<void> done = get_answer.then( report_answer );

  // do something else
  done.wait();       // waits until future done is fulfilled
}
```

Output

```
42
```

Futures - Join



- `when_all()` Returns a future that becomes ready when all future arguments are ready
- `when_any()` Returns a future that becomes ready when the first future argument is ready

boost Futures - Join

```cpp
int main() {
  auto answer_a = []{ return 40; };
  auto answer_b = []{ return 2; };

  auto f_a = boost::async(answer_a);
  auto f_b = boost::async(answer_b);

  auto answer = boost::when_all(std::move(f_a), std::move(f_b))
    .then([](auto f) {
        auto t = f.get();
        return get<0>(t).get() + get<1>(t).get();
      });

  // do something else
  cout << answer.get() << '\n';
}
```

Output

42

boost Futures - Join

```cpp
int main() {
  auto answer_a = []{ return 40; };
  auto answer_b = []{ return 2; };

  auto f_a = boost::async(answer_a);
  auto f_b = boost::async(answer_b);

  auto answer = boost::when_all(std::move(f_a), std::move(f_b))
    .then([](auto f) {
        auto t = f.get();
        return get<0>(t).get() + get<1>(t).get();
      });

  // do something else
  cout << answer.get() << '\n';
}
```

What is the type of f?

f is a future tuple of futures: `future<tuple<future<int>, future<int>>>`

C++17 TS / boost - Futures Capabilities

- Continuation — `future<T>.then()` ✓
- Join — `when_all()` and `when_any()` ✓
- No *real* split — continuations into different directions ✗
- No cancellation (but can be modelled) ✗
- No automatic reduction (`future<future<T>>` ⇒ `future<T>`) ✗
- No progress monitoring (except ready) ✗
- Custom executor ✓
- Blocks on destruction (may even blocks until termination of used thread) ✗
- Using `future<T>.get()` has two problems:
  1. One thread resource is consumed which increases contention and possibly causing a deadlock ✗
  2. Any subsequent non-dependent calculations on the task are also blocked ✗
- Don't behave as a regular type ✗
- (C++17 TS is in namespace experimental and there is no interoperation between between std::experimental::future and std::future)

There Is A New Future

stlab Futures

stlab::future

Source: `https://github.com/stlab/libraries`

Documentation: `http://www.stlab.cc/libraries`

stlab - Futures Capabilities

- Continuation — `future<T>.then()` ✓
- Join — `when_all()` and `when_any()` ✓
- Split — continuation in different directions ✓
- Cancellation ✓
- Automatic reduction (`future<future<T>>` ⇒ `future<T>`) ✓
- No progress monitoring (except ready), more planned ✗
- Custom executor ✓
- Do not block on destruction ✓
- Behave as a regular type ✓
- Additional dependencies:
  - C++14: boost.optional
  - C++17: none

stlab Futures

```
#include <iostream>
#include <stlab/concurrency/default_executor.hpp>
#include <stlab/concurrency/future.hpp>
#include <stlab/concurrency/utility.hpp>

using namespace std;

int main() {
  auto answer = [] { return 42; };

  stlab::future<int> f =
    stlab::async(
      stlab::default_executor,// uses platform thread pool on Win/OSX
                              // uses stlab task stealing
                              // thread pool on other OS, e.g. Linux
      answer
    );
```

stlab Futures

```cpp
int main() {
  auto answer = [] { return 42; };

  stlab::future<int> f =
    stlab::async(
      stlab::default_executor,// uses platform thread pool on Win/OSX
                              // uses stlab task stealing
                              // thread pool on other OS,  e.g. Linux
      answer
    );

  while (!f.get_try()) {}   // do something meaningfull while waiting
                            // Don't do busy waiting!
  std::cout << f.get_try().value() << '\n';
}
```

Output

42

stlab Futures - blocking_get()

```cpp
int main() {
  auto answer = [] { return 42; };

  stlab::future<int> f =
    stlab::async(
      stlab::default_executor,// uses platform thread pool on Win/OSX
                              // uses stlab task stealing
                              // thread pool on other OS,  e.g. Linux
      answer
    );

  // access the value in a blocking way
  // try to avoid this whenever it is possible!
  cout << stlab::blocking_get(std::move(f)) << '\n';
}
```

stlab Futures - Exceptions

```cpp
int main() {
  auto answer = [] {
    throw std::runtime_error("Bad thing happened: Vogons appeared!");
    return 42;
  };
  auto f = stlab::async(stlab::default_executor, answer);

  try {
    std::cout << stlab::blocking_get(std::move(f)) << '\n';
  }
  catch (std::runtime_error const& ex) {
    std::cout << ex.what() << '\n';
  }
}
```

Output

```
Bad things happened:  Vogons appeared!
```

stlab Futures - Continuation

```cpp
using namespace stlab;

int main() {
  auto answer = []{ return 42; };

  auto report_answer = [](int a) { std::cout << a << '\n'; };

  future<void> done = async(default_executor, answer)
    .then(report_answer);      // Call by value and not by future

  int quit; std::cin >> quit;
}
```

Output

```
42
```

stlab Futures - Reduction

```
int main() {
  future<int> result =
    async(default_executor, [] { return 42; })
      .then(
        [](int x) {
          return async(default_executor,
                       [](int y) { return y + 42; },
                       x);
        }
      );

  future<void> done = result.then(
    [](int v) { std::cout << v << '\n'; }
  );

  int quit; std::cin >> quit;
```

Output

84

stlab Futures - Error Recovery

```
int main() {
  auto answer = [] {
    throw std::runtime_error("Vogons appeared!");
    return 42;
  };

  auto handleTheAnswer = [](int v) {
    if (v == 0) std::cout << "Oh! We have a problem!\n";
    else std::cout << "The answer is " << v << '\n';
  };
```

stlab Futures - Error Recovery

```
  auto handleTheAnswer = [](int v) {
    if (v == 0) std::cout << "Oh! We have a problem!\n";
    else std::cout << "The answer is " << v << '\n';
  };

  auto f = stlab::async(stlab::default_executor, answer)
    .recover([](stlab::future<int> result) {
      if (result.error()) {
        std::cout << "Listen to Vogon poetry!\n";
        return 0;
      }
      return result.get_try().value();
  }).then(handleTheAnswer);

  int quit; std::cin >> quit;
}
```

Output

```
Listen to Vogon poetry!
We have a problem!
```

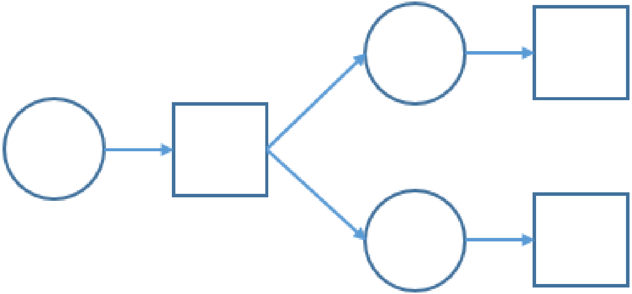
stlab Futures - Join

```
int main() {
  auto a = async(default_executor,[]{ return 40; });
  auto b = async(default_executor,[]{ return 2; });

  auto answer = when_all(
    default_executor,
    [](int x, int y) { return x + y; },
    a, b);                                 // arguments as lvalues

  std::cout << stlab::blocking_get(std::move(answer)) << '\n';
}
```

Output

```
42
```

stlab Futures - Split



- A split is realized by creating multiple continuations on the same future

stlab Futures - Split

```
int main() {
  auto answer = async(default_executor,[]{ return 42; });
  auto report_to_arthur = [](int a) {
    printf("Tell the answer %d Arthur Dent\n", a);
  };
  auto report_to_marvin = [](int a) {
    printf("May the answer %d shear up Marvin\n", a);
  };

  auto dent = answer.then(report_to_arthur);
  auto marvin = answer.then(report_to_marvin);

  blocking_get(dent);
  blocking_get(marvin);
}
```

Output

```
Tell the answer 42 Arthur Dent
May the answer 42 shear up Marvin
```

stlab Futures - Split + Join

```cpp
int main() {
  auto answer = async(default_executor,[]{ return 42; });

  auto report_to_arthur = [](int a) {
    printf("Tell the answer %d Arthur Dent\n", a);
  };
  auto report_to_marvin = [](int a) {
    printf("May the answer %d shear up Marvin\n", a);
  };

  auto dent = answer.then(report_to_arthur);
  auto marvin = answer.then(report_to_marvin);

  auto done = when_all(default_executor, [] {
    std::cout << "All know the answer!\n";
  }, marvin, dent);

  stlab::blocking_get(done);
}
```

Executors

- Executors are needed to customize where the task shall be executed
- Executors can be
  - thread pools
  - serial queues
  - main queues
  - dedicated task groups
  - etc.

stlab Futures - Custom Executor

- std executors are probably/hopefully coming with C++20
- In boost, executors derive from a common base class
- In stlab the executors must only implement the call operator
  `template <typename F> void operator()(F f)`
- stlab currently has
  - `default_executor` (thread pool)
  - `immediate_executor`
  - `main_executor`
  - `system_timer`
- See bonus slides for implementation of an executor for the Qt main-loop

stlab Futures - Continuation with Custom Executor

```cpp
#include <iostream>
#include <QLineEdit>
#include <stlab/concurrency/default_executor.hpp>
#include <stlab/concurrency/future.hpp>
#include "QtExecutor.h"

int main() { // Just illustrational example!
  QLineEdit theAnswerLineEdit;

  auto answer =
    stlab::async(stlab::default_executor, []{ return 42; } );

  stlab::future<void> done = answer.then(
    QtExecutor{},                     // different scheduler
    [&](int a) {
      theAnswerLineEdit.setValue(a); // update in Qt main thread
    });

  int quit; std::cin >> quit;
}
```

stlab Upcomming enhancements

- Coroutine support
- Performance optimization
- Progress monitoring
- Task promotion

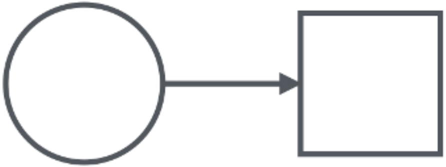
stlab Futures - Conclusion

Futures are a great tool to structure code in a well readable manner so that it runs in parallel with minimal contention.

But the graph can be used for a single execution only.

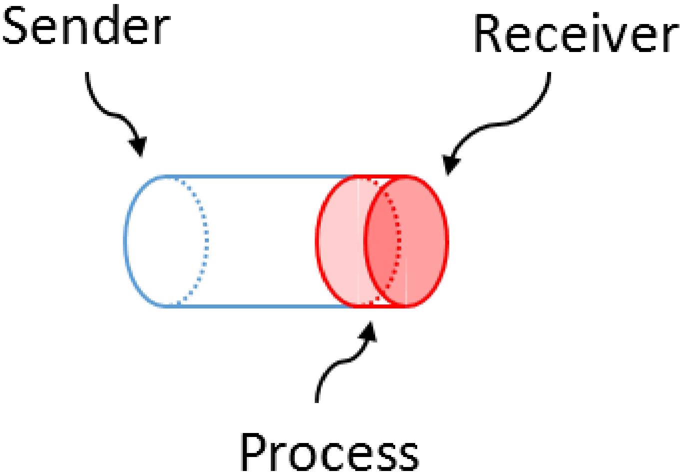
Channels are one concept that supports multiple invocations.

Channel Introduction



- Channels allow the creation of persistent execution graphs
- First published by Tony Hoare 1978

Channel Introduction



Channel - Stateless Process

```
#include <iostream>
#include <stlab/concurrency/channel.hpp>
#include <stlab/concurrency/default_executor.hpp>

int main() {
  stlab::sender<int> send;           // sending part of the channel
  stlab::receiver<int> receiver;  // receiving part of the channel
  std::tie(send, receiver) =       // combining both to a channel
    stlab::channel<int>(stlab::default_executor);

  auto printer =
    [](int x){ std::cout << x << '\n'; }; // stateless process

  auto printer_process =
    receiver | printer;              // attaching process to the receiving
                                     // part
  receiver.set_ready();              // no more processes will be attached
                                     // process starts to work
  send(1); send(2); send(3);         // start sending into the channel

  int end; std::cin >> end;          // simply wait to end application
}
```

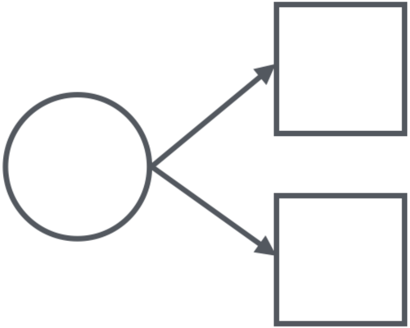
Channel - Stateless Process cont.

```
int main() {
  auto printer =
    [](int x){ std::cout << x << '\n'; }; // stateless process

  auto printer_process =
    receiver | printer;              // attaching process to the receiving
                                     // part
  receiver.set_ready();              // no more processes will be attached
                                     // process starts to work
  send(1); send(2); send(3);         // start sending into the channel

  int end; std::cin >> end;          // simply wait to end application
}
```

Output

1
2
3

Channel - Split



New edges are concatenated with the `operator|()` on the same receiver

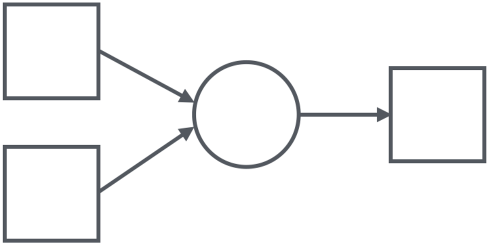
Channel - Split Process

```
int main() {
  auto [send, receiver] = channel<int>(default_executor); // C++17

  auto printerA = [](int x){ printf("Process A %d\n", x); };
  auto printerB = [](int x){ printf("Process B %d\n", x); };

  auto printer_processA = receiver | printerA;
  auto printer_processB = receiver | printerB;

  receiver.set_ready();            // no more processes will be attached
                                   // process may start to work
  send(1); send(2); send(3);
  int end; std::cin >> end;
}
```

Output

```
Process A 1
Process B 1
Process A 2
Process B 2
Process B 3
```

Channel - Join



- `join()` The downstream process is invoked when all arguments are ready.
- `zip()` The downstream process is invoked in round robin manner with the incoming values.
- `merge()` The downstream process is invoked with the next value that is ready

Additional channel options

- With `buffer_size{n}` within the concatenation it is possible to limit the incoming queue to size `n`
- With `executor{T}` within the concatenation it is possible to specify a dedicated executor `T`.

Channel - Stateful Process - Motivation

- Some problems need a processor with state
- Some problems have an $n : m$ relationship from input to output
- The picture becomes more complicated with states:
  - When to proceed?
  - How to handle situations when less than expected values come from upstream?

Channel - Stateful Process Signature

```cpp
#include <stlab/concurrency/channel.hpp>

using process_state_scheduled =
  std::pair<process_state, std::chrono::steady_clock::time_point>;

struct process_signature
{
    void await(T... val);

    U yield();

    process_state_scheduled state() const;

    void close();                          // optional

    void set_error(std::exception_ptr); // optional
};
```

Stateful Process Signature - await

```cpp
#include <stlab/concurrency/channel.hpp>

using process_state_scheduled =
  std::pair<process_state, std::chrono::steady_clock::time_point>;

struct process_signature
{
    void await(T... val);

    U yield();

    process_state_scheduled state() const;

    void close();                        // optional

    void set_error(std::exception_ptr); // optional
};
```

Stateful Process Signature - yield

```cpp
#include <stlab/concurrency/channel.hpp>

using process_state_scheduled =
  std::pair<process_state, std::chrono::steady_clock::time_point>;

struct process_signature
{
    void await(T... val);

    U yield();

    process_state_scheduled state() const;

    void close();                       // optional

    void set_error(std::exception_ptr); // optional
};
```

Stateful Process Signature - state

```cpp
#include <stlab/concurrency/channel.hpp>

using process_state_scheduled =
  std::pair<process_state, std::chrono::steady_clock::time_point>;

struct process_signature
{
    void await(T... val);

    U yield();

    process_state_scheduled state() const;

    void close();                          // optional

    void set_error(std::exception_ptr); // optional
};
```

Stateful Process Signature - close

```cpp
#include <stlab/concurrency/channel.hpp>

using process_state_scheduled =
  std::pair<process_state, std::chrono::steady_clock::time_point>;

struct process_signature
{
    void await(T... val);

    U yield();

    process_state_scheduled state() const;

    void close();                       // optional

    void set_error(std::exception_ptr); // optional
};
```

Stateful Process Signature - set_error

```cpp
#include <stlab/concurrency/channel.hpp>

using process_state_scheduled =
  std::pair<process_state, std::chrono::steady_clock::time_point>;

struct process_signature
{
    void await(T... val);

    U yield();

    process_state_scheduled state() const;

    void close();                      // optional

    void set_error(std::exception_ptr); // optional
};
```

Channel - Stateful Process Example

```
struct adder
{
};

int main() {
  auto [send, receiver] = channel<int>(default_executor);

  auto calculator = receiver | adder{} |
    [](int x) { std::cout << x << '\n'; };

  receiver.set_ready();

  while (true) {
    int x;
    std::cin >> x;
    send(x);
  }
}
```

Channel - Stateful Process Example cont.


```
struct adder
{
  int _sum = 0;
  process_state_scheduled _state = await_forever;

  void await(int x) {
    _sum += x;
    if (x == 0) {
      _state = yield_immediate;
    }
  }

  int yield() {
    int result = _sum;
    _sum = 0;
    _state = await_forever;
    return result;
  }

  auto state() const { return _state; }
};
```

Channel - Conclusion

Channels close the gap of multiple invocations where futures allow just one.

With splits and the different kind of joins it is possible to build graphs of execution.

Take Away

Use high level abstractions like futures, channels or others (actors, etc.) to distribute work on available CPU cores.

Use thread pools from your operating system! Use highly optimized task stealing custom thread pools in case that the operating system does not provide one!

Design your application with the mindset that it can run dead-lock free on an 1-n core hardware!

Don't let your application code be soaked with threads, mutex' and atomics.

Acknowledgement

- My family, who supports me in my work on the concurrency library and this conference.
- Sean Parent, who taught me over time lots about concurrency and abstraction. He gave me the permission to use whatever I needed from his presentations for my own.
- My company MeVis Medical Solutions AG, that released me from work during this conference.
- All contributors to the stlab library.

Reference

- Concurrency library https://github.com/stlab/libraries
- Documentation http://stlab.cc/libraries
- Communicating Sequential Processes by C. A. R. Hoare http://usingcsp.com/cspbook.pdf
- The Theory and Practice of Concurrency by A.W. Roscoe http://www.cs.ox.ac.uk/people/bill.roscoe/publications/68b.pdf
- Towards a Good Future, C++ Standard Proposal by Felix Petriconi, David Sankel and Sean Parent http://open-std.org/JTC1/SC22/WG21/docs/papers/2017/p0676r0.pdf
- Back to std2::future, C++ Standard Proposal by Bryce Adelstein Lelbach http://open-std.org/JTC1/SC22/WG21/docs/papers/2017/p0701r0.html

Further reading I

Software Principles and Algorithms

- Elements of Programming by Alexander Stepanov, Paul McJones, Addison Wesley
- From Mathematics to Generic Programming by Alexander Stepanov, Daniel Rose, Addison Wesley

Further reading II

Concurrency and Parallelism

- HPX `http://stellar-group.org/libraries/hpx/`
- C++CSP `https://www.cs.kent.ac.uk/projects/ofa/c++csp`
- CAF_C++ Actor Framework `http://actor-framework.org/`
- C++ Concurrency In Action by Anthony Williams, Manning

Further listening and viewing

- Goals for better code by Sean Parent: http://sean-parent.stlab.cc/papers-and-presentations
- Goals for better code by Sean Parent: Concurrency: https://youtu.be/au0xX4h8SCI?t=16354
- Future Ruminations by Sean Parent http://sean-parent.stlab.cc/2017/07/10/future-ruminations.html
- CppCast with Sean Parent http://cppcast.com/2015/06/sean-parent/
- Thinking Outside the Synchronization Quadrant by Kevlin Henney: https://vimeo.com/205806162

stlab Futures

stlab::future

Source: `https://github.com/stlab/libraries`

Documentation: `http://www.stlab.cc/libraries`

Thank's for your attention!

- Mail: felix@petriconi.net
- GitHub: `https://github.com/FelixPetriconi`
- Web: `https://petriconi.net`
- Twitter: @FelixPetriconi

Q & A

- Mail: felix@petriconi.net
- GitHub: `https://github.com/FelixPetriconi`
- Web: `https://petriconi.net`
- Twitter: @FelixPetriconi

Feedback is always welcome!

Custom Executor - Qt


```
#include <QApplication>
#include <Event>
#include <stlab/concurrency/task.hpp>

class QtExecutor
{
  using result_type = void;

  class ExecutorEvent : public QEvent

  class EventReceiver : public QObject
public:
  template <typename F>
  void operator()(F f) {
    auto event = std::make_unique<ExecutorEvent>();
    event->set_task(std::move(f))
    QApplication::postEvent(event->receiver(), event.release());
  }
};
```

stlab::future - Custom Executor - Qt cont. I


```cpp
class ExecutorEvent : public QEvent
{
  stlab::task<void()> _f;
  std::unique_ptr<EventReceiver> _receiver;

public:
  ExecutorEvent()
    : QEvent(QEvent::User)
    , _receiver(new EventReceiver()) {
    _receiver()->moveToThread(QApplication::instance()->thread());
  }

  template <typename F>
  void set_task(F&& f) {
    _f = std::forward<F>(f);
  }

  void execute() { _f(); }

  QObject *receiver() const { return _receiver.get(); }
};
```

stlab::future - Custom Executor - Qt cont. II


```
class EventReceiver : public QObject
{
public:
  bool event(QEvent *event) override {
    auto myEvent = dynamic_cast<ExecutorEvent*>(event);
    if (myEvent) {
      myEvent->execute();
      return true;
    }
    return false;
  }
};
```