3 Goals for Better Code

Sean Parent | Principal Scientist

No Raw Loops

What is a Raw Loop?

- A raw loop is any loop inside a function where the function serves purpose larger than the algorithm implemented by the loop

What is a Raw Loop?

```
void PanelBar::RepositionExpandedPanels(Panel* fixed_panel) {
  CHECK(fixed_panel);

  // First, find the index of the fixed panel.
  int fixed_index = GetPanelIndex(expanded_panels_, *fixed_panel);
  CHECK_LT(fixed_index, expanded_panels_.size());

  // Next, check if the panel has moved to the other side of another panel.
  const int center_x = fixed_panel->cur_panel_center();
  for (size_t i = 0; i < expanded_panels_.size(); ++i) {
    Panel* panel = expanded_panels_[i].get();
    if (center_x <= panel->cur_panel_center() ||
        i == expanded_panels_.size() - 1) {
      if (panel != fixed_panel) {
        // If it has, then we reorder the panels.
        ref_ptr<Panel> ref = expanded_panels_[fixed_index];
        expanded_panels_.erase(expanded_panels_.begin() + fixed_index);
        if (i < expanded_panels_.size()) {
          expanded_panels_.insert(expanded_panels_.begin() + i, ref);
        } else {
          expanded_panels_.push_back(ref);
        }
      }
      break;
    }
  }

  // Find the total width of the panels to the left of the fixed panel.
  int total_width = 0;
  fixed_index = -1;
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Single function from Chromium OS
First code I reviewed at Google
Not picking on Google (or anyone)- I've certainly written code like this
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        } else {
          expanded_panels_.push_back(ref);
        }
      }
      break;
    }
  }

  // Find the total width of the panels to the left of the fixed panel.
  int total_width = 0;
  fixed_index = -1;
  for (int i = 0; i < static_cast<int>(expanded_panels_.size()); ++i) {
    Panel* panel = expanded_panels_[i].get();
    if (panel == fixed_panel) {
      fixed_index = i;
      break;
    }
    total_width += panel->panel_width();
  }
  CHECK_NE(fixed_index, -1);
  int new_fixed_index = fixed_index;

  // Move panels over to the right of the fixed panel until all of the ones
  // on the left will fit.
  int avail_width = max(fixed_panel->cur_panel_left() - kBarPadding, 0);
  while (total_width > avail_width) {
    new_fixed_index--;
    CHECK_GE(new_fixed_index, 0);
    total_width -= expanded_panels_[new_fixed_index]->panel_width();
  }
```


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for (int i = 0; i < static_cast<int>(expanded_panels_.size()); ++i) {
  Panel* panel = expanded_panels_[i].get();
  if (panel == fixed_panel) {
    fixed_index = i;
    break;
  }
  total_width += panel->panel_width();
}
CHECK_NE(fixed_index, -1);
int new_fixed_index = fixed_index;

// Move panels over to the right of the fixed panel until all of the ones
// on the left will fit.
int avail_width = max(fixed_panel->cur_panel_left() - kBarPadding, 0);
while (total_width > avail_width) {
  new_fixed_index--;
  CHECK_GE(new_fixed_index, 0);
  total_width -= expanded_panels_[new_fixed_index]->panel_width();
}

// Reorder the fixed panel if its index changed.
if (new_fixed_index != fixed_index) {
  Panels::iterator it = expanded_panels_.begin() + fixed_index;
  ref_ptr<Panel> ref = *it;
  expanded_panels_.erase(it);
  expanded_panels_.insert(expanded_panels_.begin() + new_fixed_index, ref);
  fixed_index = new_fixed_index;
}

// Now find the width of the panels to the right, and move them to the
// left as needed.
total_width = 0;
for (Panels::iterator it = expanded_panels_.begin() + fixed_index + 1;
     it != expanded_panels_.end(); ++it) {
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  }
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    fixed_index = new_fixed_index;
  }

  // Now find the width of the panels to the right, and move them to the
  // left as needed.
  total_width = 0;
  for (Panels::iterator it = expanded_panels_.begin() + fixed_index + 1;
       it != expanded_panels_.end(); ++it) {
    total_width += (*it)->panel_width();
  }

  avail_width = max(wm_->width() - (fixed_panel->cur_right() + kBarPadding),
                    0);
  while (total_width > avail_width) {
    new_fixed_index++;
    CHECK_LT(new_fixed_index, expanded_panels_.size());
    total_width -= expanded_panels_[new_fixed_index]->panel_width();
  }

  // Do the reordering again.
  if (new_fixed_index != fixed_index) {
    Panels::iterator it = expanded_panels_.begin() + fixed_index;
    ref_ptr<Panel> ref = *it;
    expanded_panels_.erase(it);
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  while (total_width > avail_width) {
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    CHECK_LT(new_fixed_index, expanded_panels_.size());
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  if (new_fixed_index != fixed_index) {
    Panels::iterator it = expanded_panels_.begin() + fixed_index;
    ref_ptr<Panel> ref = *it;
    expanded_panels_.erase(it);
    expanded_panels_.insert(expanded_panels_.begin() + new_fixed_index, ref);
    fixed_index = new_fixed_index;
  }

  // Finally, push panels to the left and the right so they don't overlap.
  int boundary = expanded_panels_[fixed_index]->cur_panel_left() - kBarPadding;
  for (Panels::reverse_iterator it =
         // Start at the panel to the left of 'new_fixed_index'.
         expanded_panels_.rbegin() +
         (expanded_panels_.size() - new_fixed_index);
       it != expanded_panels_.rend(); ++it) {
    Panel* panel = it->get();
    if (panel->cur_right() > boundary) {
      panel->Move(boundary, kAnimMs);
    } else if (panel->cur_panel_left() < 0) {
      panel->Move(min(boundary, panel->panel_width() + kBarPadding), kAnimMs);
    }
    boundary = panel->cur_panel_left() - kBarPadding;
  }

  boundary = expanded_panels_[fixed_index]->cur_right() + kBarPadding;
  for (Panels::iterator it = expanded_panels_.begin() + new_fixed_index + 1;
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  boundary = expanded_panels_[fixed_index]->cur_right() + kBarPadding;
  for (Panels::iterator it = expanded_panels_.begin() + new_fixed_index + 1;
       it != expanded_panels_.end(); ++it) {
    Panel* panel = it->get();
    if (panel->cur_panel_left() < boundary) {
      panel->Move(boundary + panel->panel_width(), kAnimMs);
    } else if (panel->cur_right() > wm_->width()) {
      panel->Move(max(boundary + panel->panel_width(),
                      wm_->width() - kBarPadding),
                  kAnimMs);
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    boundary = panel->cur_right() + kBarPadding;
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Why No Raw Loops?

- Difficult to reason about and difficult to prove post conditions
- Error prone and likely to fail under non-obvious conditions
- Introduce non-obvious performance problems
- Complicates reasoning about the surrounding code

Alternatives to Raw Loops

The standard algorithms have all been proven correct

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    - Preferably open source

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∅ Patents

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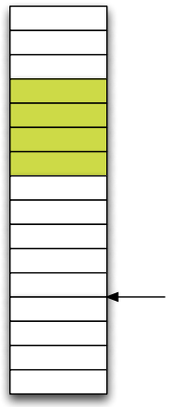
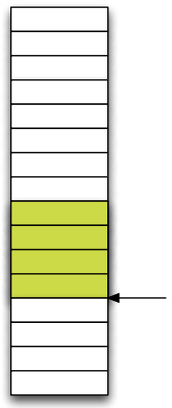
No Raw Loops

Two Beautiful Examples

No Raw Loops



No Raw Loops



No Raw Loops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rotate(f, l, p);
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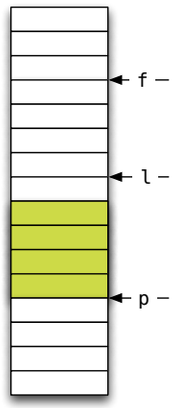


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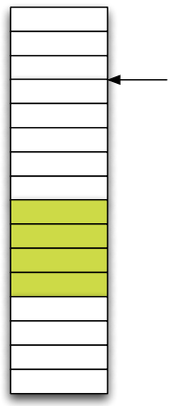

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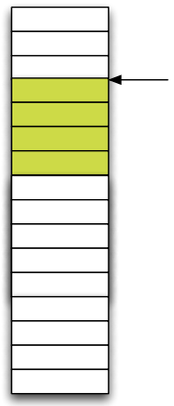

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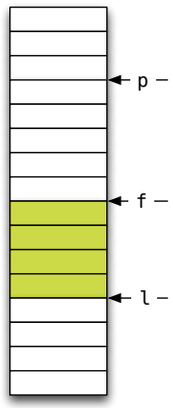


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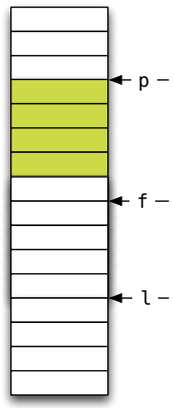


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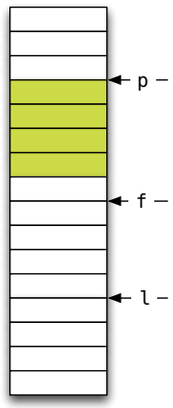


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if (p < f) rotate(p, f, l);
if (l < p) rotate(f, l, p);
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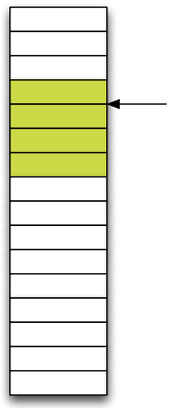

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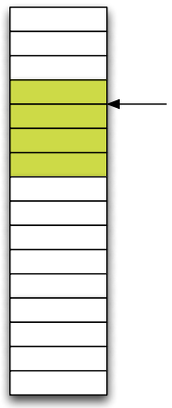

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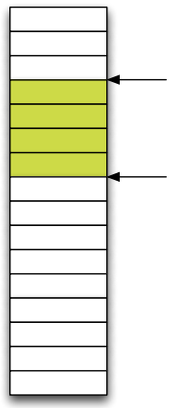

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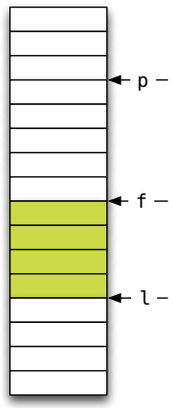


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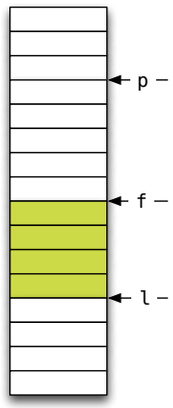


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C++11

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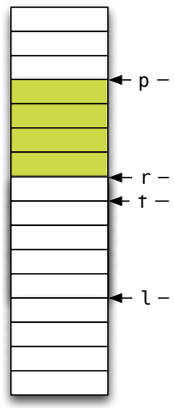


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C++11

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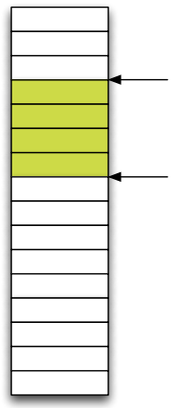
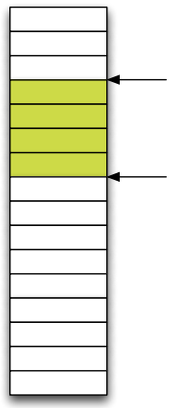


```
if (p < f) return { p, rotate(p, f, l) };
if (l < p) return { rotate(f, l, p), p };
return { f, l };
```

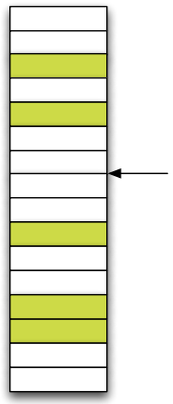
No Raw Loops



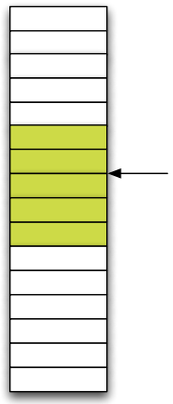
```
template <typename I> // I models RandomAccessIterator
auto slide(I f, I l, I p) -> pair<I, I>
{
    if (p < f) return { p, rotate(p, f, l) };
    if (l < p) return { rotate(f, l, p), p };
    return { f, l };
}
```

[Add a slide after this showing slide(f, l, p)...]

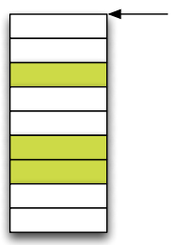
No Raw Loops



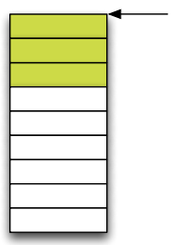
No Raw Loops



No Raw Loops

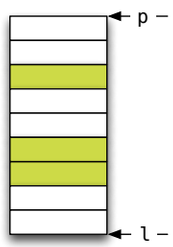


No Raw Loops



No Raw Loops

```
stable_partition(p, l, s)
```



No Raw Loops

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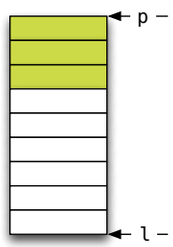
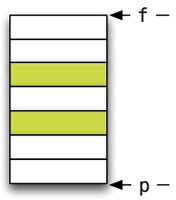
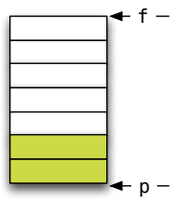


No Raw Loops




```
stable_partition(f, p, not1(s))
```

No Raw Loops

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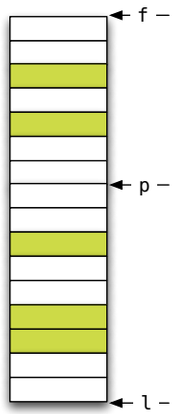
No Raw Loops

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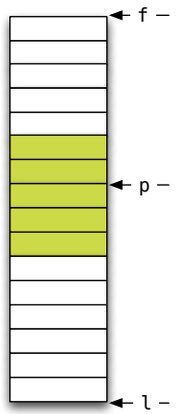
stable_partition(f, p, not1(s))
stable_partition(p, l, s)
```

No Raw Loops

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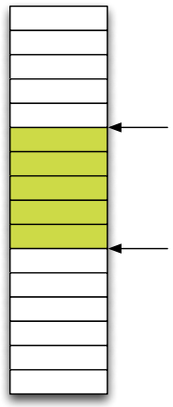

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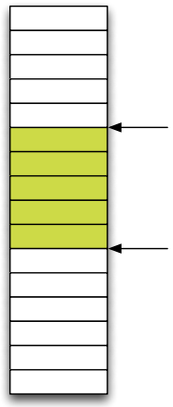
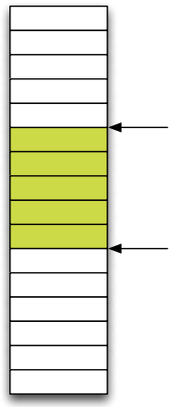


```
return { stable_partition(f, p, not1(s)),
         stable_partition(p, l, s) };
```

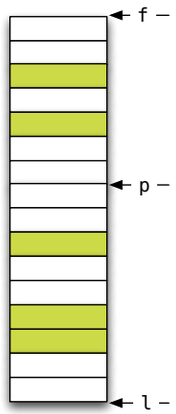
No Raw Loops



```
template <typename I, // I models BidirectionalIterator
          typename S> // S models UnaryPredicate
auto gather(I f, I l, I p, S s) -> pair<I, I>
{
    return { stable_partition(f, p, not1(s)),
             stable_partition(p, l, s) };
}
```

*

No Raw Loops

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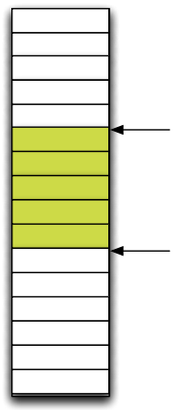
f *
p –
l –

No Raw Loops



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What about that messy loop?

```
// Next, check if the panel has moved to the other side of another panel.

for (size_t i = 0; i < expanded_panels_.size(); ++i) {
  Panel* panel = expanded_panels_[i].get();
  if (center_x <= panel->cur_panel_center() ||
      i == expanded_panels_.size() - 1) {
    if (panel != fixed_panel) {
      // If it has, then we reorder the panels.
      ref_ptr<Panel> ref = expanded_panels_[fixed_index];
      expanded_panels_.erase(expanded_panels_.begin() + fixed_index);
      if (i < expanded_panels_.size()) {
        expanded_panels_.insert(expanded_panels_.begin() + i, ref);
      } else {
        expanded_panels_.push_back(ref);
      }
    }
    break;
  }
}
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// Fix this code - panel is the panel found above.

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This is redundant - we are looking for an element that we _know_ is in the list.

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This is find_if()

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// Next, check if the panel has moved to the other side of another panel.

auto p = find_if(begin(expanded_panels_), end(expanded_panels_),
  [&](const ref_ptr<Panel>& e){ return center_x <= e->cur_panel_center(); });

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if (panel != fixed_panel) {
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   ref_ptr<Panel> ref = expanded_panels_[fixed_index];
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C++11

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if (panel != fixed_panel) {
  // If it has, then we reorder the panels.
  auto f = begin(expanded_panels_) + fixed_index;
  rotate(p, f, f + 1);
}
```

We don’t need this check - we can rotate an empty range!

What about that bad loop?

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// Next, check if the panel has moved to the left side of another panel.

auto f = begin(expanded_panels_) + fixed_index;

auto p = lower_bound(begin(expanded_panels_), f, center_x,
  [](const ref_ptr<Panel>& e, int x){ return e->cur_panel_center() < x; });

// If it has, then we reorder the panels.
rotate(p, f, f + 1);
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- This is 1/2 of a `slide()` that only supports a single element being selected

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- This code is considerably more efficient

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- This is 1/2 of a `slide()` that only supports a single element being selected
  - The other `rotate()` is the `erase()/insert()` further down in the function
- None of the special cases were necessary
- This code is considerably more efficient
- Now we can have the conversation about supporting multiple selections and disjoint selections!

Seasoning

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- Use a range library (Boost or ASL)

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```
auto p = find(begin(a), end(a), x);
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- Have many variants of simple, common algorithms such as find() and copy()

Seasoning

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```
auto p = find(begin(a), end(a), x);
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- Have many variants of simple, common algorithms such as find() and copy()
- Look for interface symmetry

Seasoning

- Use a range library (Boost or ASL)

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- Have many variants of simple, common algorithms such as find() and copy()

- Look for interface symmetry

```
sort(a, [](const employee& x, const employee& y){ return x.last < y.last; });
```

Seasoning

- Use a range library (Boost or ASL)

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auto p = find(begin(a), end(a), x);
auto p = find(a, x);
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auto p = lower_bound(a, "Parent", less(), &employee::last);
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Seasoning

Seasoning

- Range based for loops for for-each and simple transforms

```
for (const auto& e: r) f(e);
for (auto& e: r) e = f(e);
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C++11

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  - Use const auto& for for-each and auto& for transforms

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  - Use const auto& for for-each and auto& for transforms
  - Keep the body **short**
    - A general guideline is no longer than composition of two functions with an operator

```
for (const auto& e: r) f(g(e));
for (const auto& e: r) { f(e); g(e); };
for (auto& e: r) e = f(e) + g(e);
```

Seasoning

- Range based for loops for for-each and simple transforms

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  - If the body is longer, factor it out and give it a name

Seasoning

Seasoning

- Use lambdas for predicates, comparisons, and projections, but keep them **short**

Seasoning

- Use lambdas for predicates, comparisons, and projections, but keep them **short**
- Use function objects with template member function to simulate polymorphic lambda

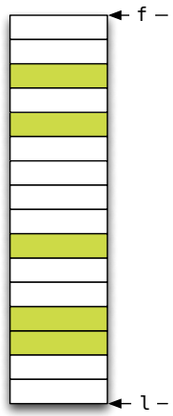
```
struct last_name {
    using result_type = const string&;

    template <typename T>
    const string& operator()(const T& x) const { return x.last; }
};

// ...

auto p = lower_bound(a, "Parent", less(), last_name());
```

Stable Partition



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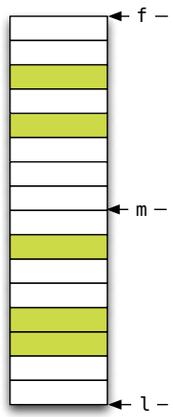
Stable Partition



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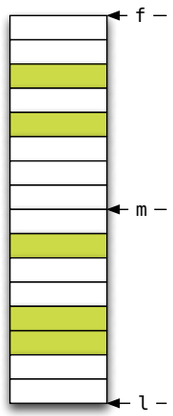

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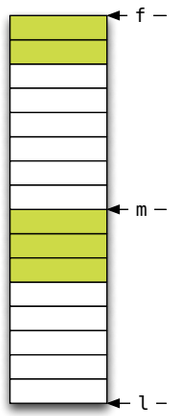

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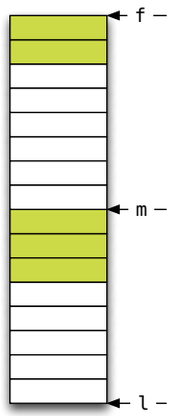
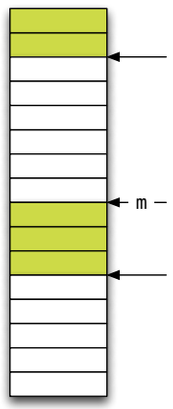



```
stable_partition(f, m, p)

stable_partition(m, l, p)
```

Back

Stable Partition

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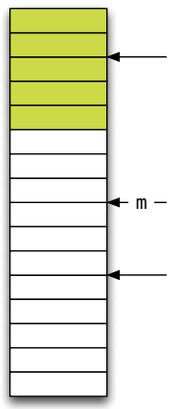


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Back

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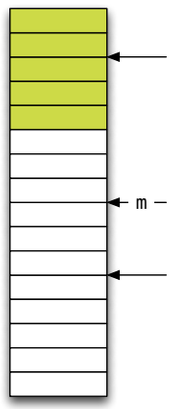
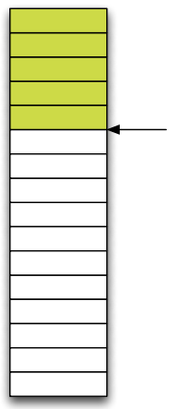



```
rotate(stable_partition(f, m, p),
       m,
       stable_partition(m, l, p));
```

Back

Stable Partition



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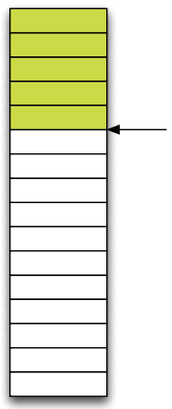

```
return rotate(stable_partition(f, m, p),
              m,
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```
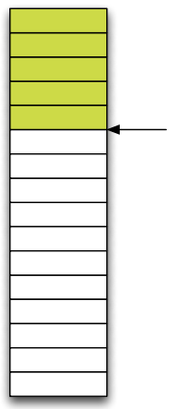

Back

Stable Partition



```
template <typename I,
          typename P>
auto stable_partition(I f, I l, P p) -> I
{
    auto n = l - f;
    if (n == 0) return f;
    if (n == 1) return f + p(*f);

    auto m = f + (n / 2);

    return rotate(stable_partition(f, m, p),
                  m,
                  stable_partition(m, l, p));
}
```

Back

No Raw Synchronization Primitives

What are raw synchronization primitives?

- Synchronization primitives are basic constructs such as:
  - Mutex
  - Atomic
  - Semaphore
  - Memory Fence

You Will Likely Get It Wrong

Emailing Hans Boehm about about how to correctly communicate a bool for cancelation.

Problems with Locks

```
template <typename T>
class bad_cow {
    struct object_t {
        explicit object_t(const T& x) : data_m(x) { ++count_m; }
        atomic<int> count_m;
        T           data_m; };
    object_t* object_m;
 public:
    explicit bad_cow(const T& x) : object_m(new object_t(x)) { }
    ~bad_cow() { if (0 == --object_m->count_m) delete object_m; }
    bad_cow(const bad_cow& x) : object_m(x.object_m) { ++object_m->count_m; }

    bad_cow& operator=(const T& x) {
        if (object_m->count_m == 1) object_m->data_m = x;
        else {
            object_t* tmp = new object_t(x);
            --object_m->count_m;
            object_m = tmp;
        }
        return *this;
    }
};
```


I marked in red each of the atomic operations
There is a subtle bug in this code...

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};
```

- There is a subtle race condition here:
  - if count != 1 then the bad_cow could also is owned by another thread(s)
  - if the other thread(s) releases the bad_cow between these two atomic operations
  - then our count will fall to zero and we will leak the object

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Problems with Locks

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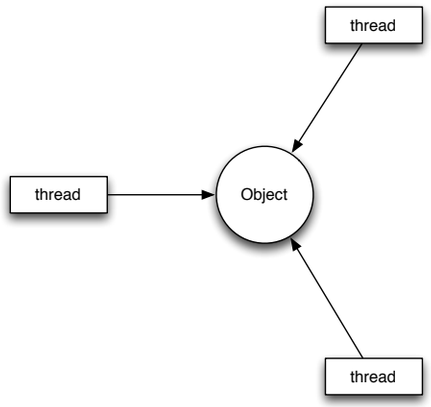
Why No Raw Synchronization Primitives?



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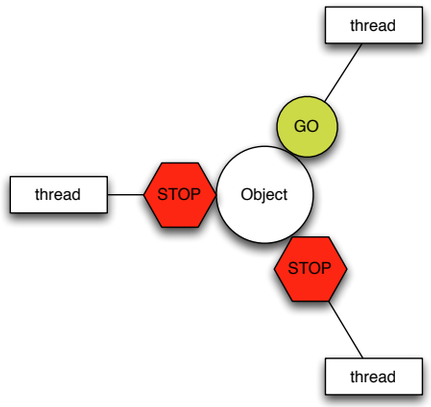

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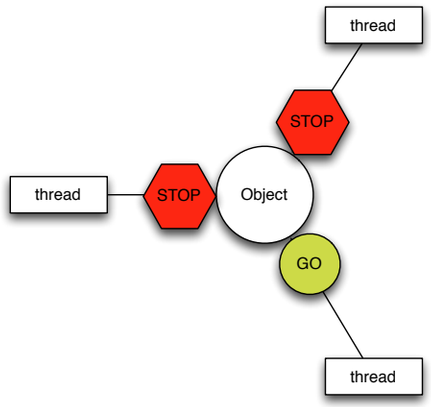

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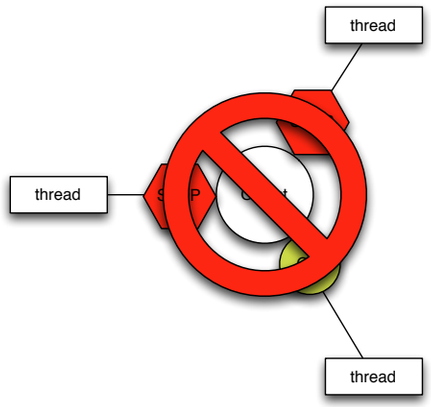
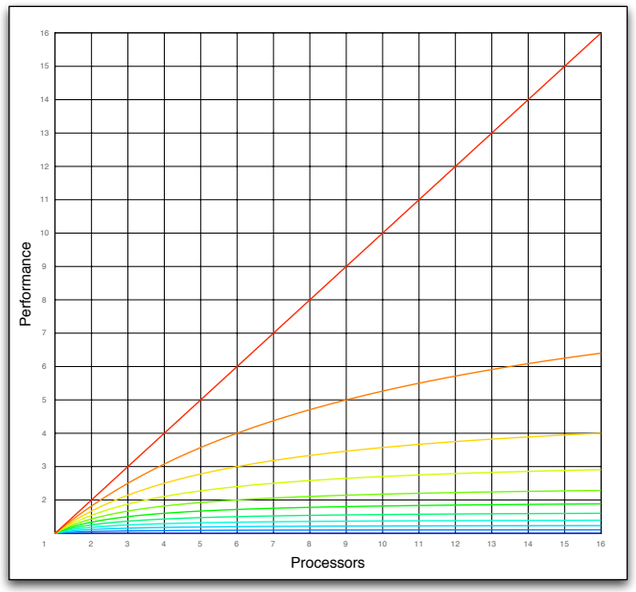


Amdahl's Law

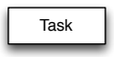


Amount of synchronization - any shared resource causes synchronization

Minimize Locks

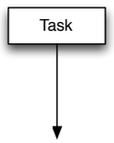
Minimize Locks

No Raw Synchronization Primitives



This is a communicating sequential process model

No Raw Synchronization Primitives



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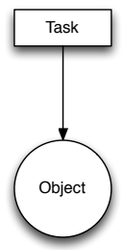

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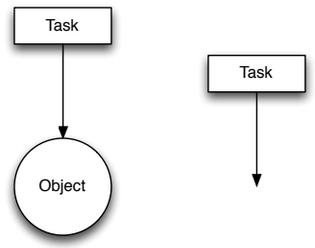

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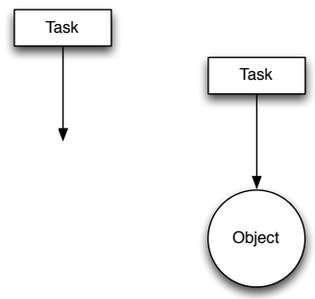

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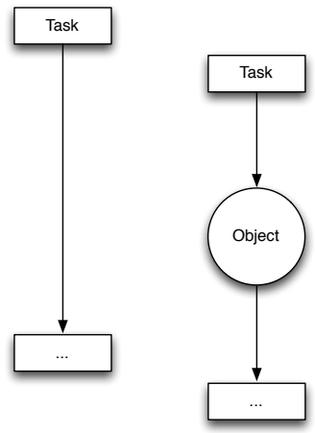

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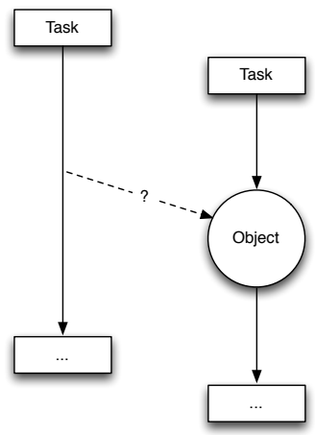


This is a communicating sequential process model

Tasks

- Communicating Sequential Process Model

- A task is a unit of work (a function) which is executed asynchronously
  - Tasks are scheduled on a thread pool to optimize machine utilization

- The arguments to the task and the task results are convenient places to communicate with other tasks
  - Any function can be “packaged” into such a task

Task Systems

- Unfortunately, we don't yet have a standard async task model
  - std::async() is currently defined to be based on threads
    - This may change in C++14 and Visual C++ 2012 already implements std::async() as a task model

- Windows – Window Thread Pool and PPL
- Apple – Grand Central Dispatch (libdispatch)
  - Open sourced, runs on Linux and Android
- Intel TBB – many platform

C++14 compatible async with libdispatch

```
namespace adobe {

template <typename F, typename ...Args>
auto async(F&& f, Args&&... args)
        -> std::future<typename std::result_of<F (Args...)>::type>
{
    using result_type = typename std::result_of<F (Args...)>::type;
    using packaged_type = std::packaged_task<result_type ()>;

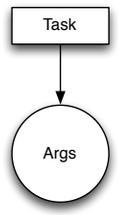
    auto p = new packaged_type(std::forward<F>(f), std::forward<Args>(args)...);
    auto result = p->get_future();

    dispatch_async_f(dispatch_get_global_queue(DISPATCH_QUEUE_PRIORITY_DEFAULT, 0),
            p, [](void* f_) {
                packaged_type* f = static_cast<packaged_type*>(f_);
                (*f)();
                delete f;
            });

    return result;
}

} // namespace adobe
```

No Raw Synchronization Primitives



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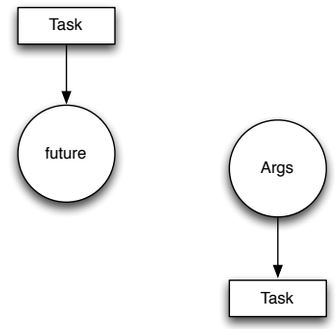

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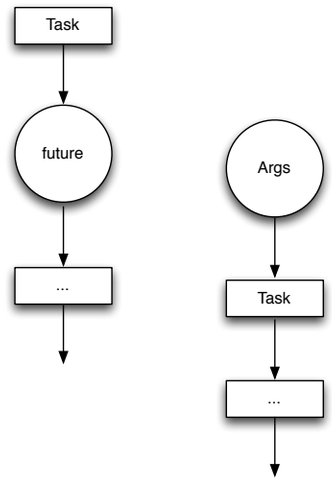

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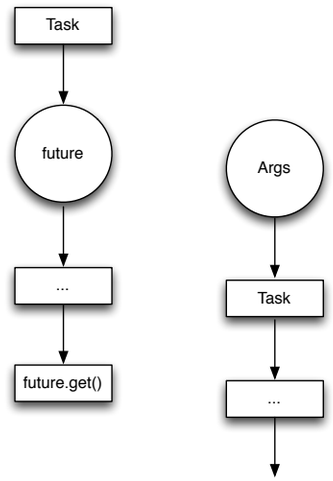

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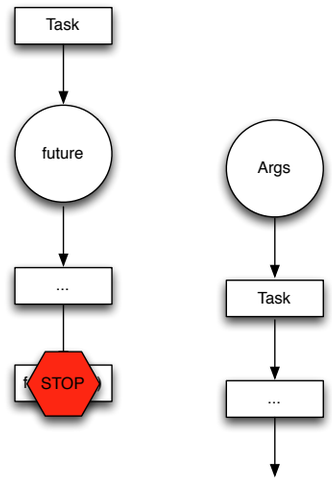

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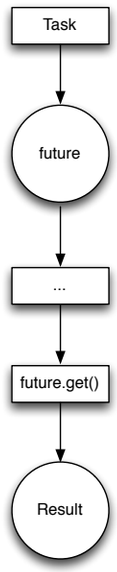
No Raw Synchronization Primitives



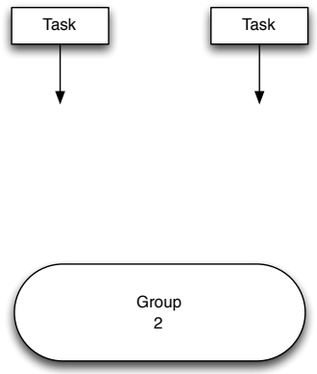
This is a communicating sequential process model

Task Systems

- Blocking on std::future.get() has two problems
  - One thread resource is consumed, increasing contention
  - Any subsequent non-dependent calculations on the task are also blocked

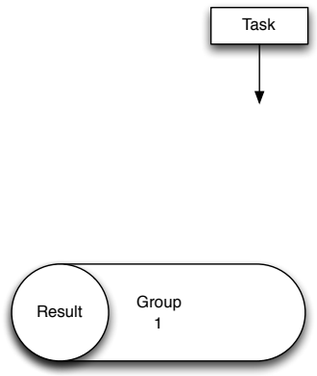
- Unfortunately, C++11 doesn't have dependent tasks
  - GCD has serialized queues and groups
  - PPL has chained tasks
  - TBB has flow graphs
- All are able to specify dependent tasks, including joins

Task Systems



Add seasoning slide with packaged task
LIttle discussion on other items are too complex.

Task Systems



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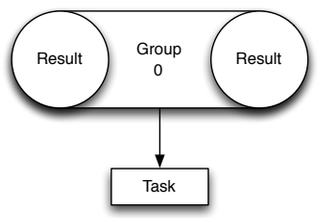

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Seasoning

- std::list can be used in a pinch to create thread safe data structures with splice

```
template <typename T>
class concurrent_queue
{
    mutex   mutex_;
    list<T> q_;
  public:
    void enqueue(T x)
    {
        list<T> tmp;
        tmp.push_back(move(x));
        {
        lock_guard<mutex> lock(mutex);
        q_.splice(end(q_), tmp);
        }
    }

    // ...
};
```

Seasoning

- std::packaged_task can be used to marshall results, including exceptions, from tasks
  - std::packaged_task is also useful to safely bridge C++ code with exceptions to C code
  - see prior async() implementation for an example

No Raw Pointers

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  - unique_ptr<T>
  - shared_ptr<T>

Why pointers (heap allocations)?

- Runtime variable size
  - Runtime polymorphic
  - Container
- Satisfy complexity or stability requirements within a container (list vs. vector)
- Shared storage for asynchronous communication (future, message queue, …)
- Optimization to copy
  - Copy deferral (copy-on-write)
  - Immutable item
  - Elide copy to move
- To separate implementation from interface (PIMPL)

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- See previous section regarding shared storage for asynchronous operations

- Runtime polymorphism

Write a very simple application which consists of a document which contains objects.
Containment is a non-intrusive relationship which relies on particular properties of the objects being placed in the container.

client | library

```
using object_t = int;

void draw(const object_t& x, ostream& out, size_t position)
{ out << string(position, ' ') << x << endl; }

using document_t = vector<object_t>;

void draw(const document_t& x, ostream& out, size_t position)
{
    out << string(position, ' ') << "<document>" << endl;
    for (const auto& e : x) draw(e, out, position + 2);
    out << string(position, ' ') << "</document>" << endl;
}
```

cout | guidelines | defects

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Not much more difficult to use then "Hello World".

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```
int main()
{
    document_t document;

    document.emplace_back(0);
    document.emplace_back(1);
    document.emplace_back(2);
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    draw(document, cout, 0);
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cout

```
<document>
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Polymorphism

- What happens if we want the document to hold any drawable object?

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```
class object_t {
  public:
    virtual ~object_t() { }
    virtual void draw(ostream&, size_t) const = 0;
};

using document_t = vector<shared_ptr<object_t>>;

void draw(const document_t& x, ostream& out, size_t position)
{
    out << string(position, ' ') << "<document>" << endl;
    for (const auto& e : x) e->draw(out, position + 2);
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Note memory leak at new...
Why can’t I put an integer into my document?

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class my_class_t : public object_t
{
  public:
    void draw(ostream& out, size_t position) const
    { out << string(position, ' ') << "my_class_t" << endl; }
    /* ... */
};


int main()
{
    document_t document;

    document.emplace_back(new my_class_t());

    draw(document, cout, 0);
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cout | guidelines | defects

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cout

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```

defects

- An instance of my_class_t will be allocated first
- Then the document will grow to make room
- If growing the document throws an exception, the memory from my_class_t is leaked

Note memory leak at new...
Why can’t I put an integer into my document?

Deep problem

- Changed semantics of copy, assignment, and equality of my document
  - leads to incidental data structures
  - thread safety concerns

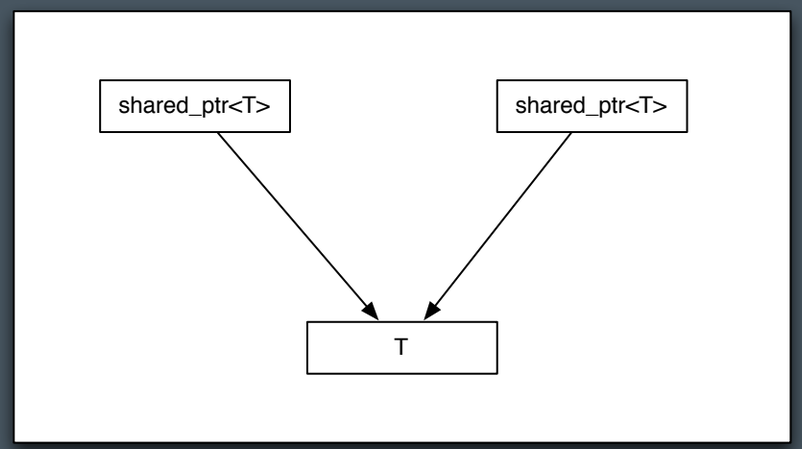
Semantics & Syntax

- We define an operation in terms of the operation's semantics:
  - "Assignment is a procedure taking two objects of the same type that makes the first object equal to the second without modifying the second."

(2) The more problematic case is adapting incomplete types.

(3) With an exception or two. These are operations on regular types so it isn't a coincidence that they are so common.

Semantics & Syntax



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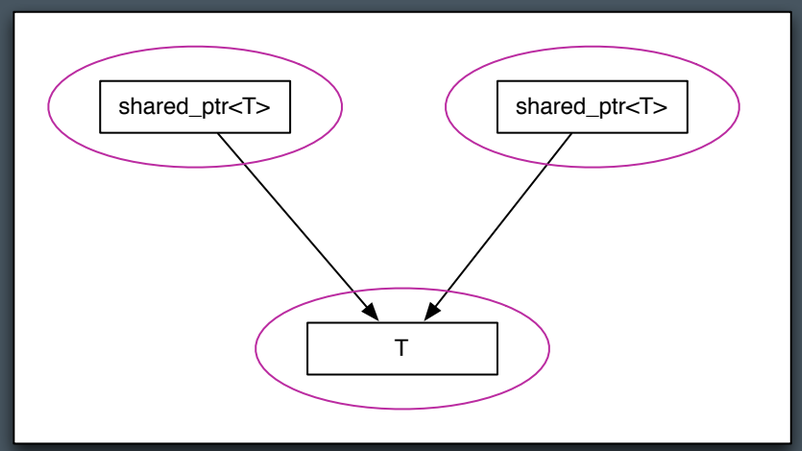
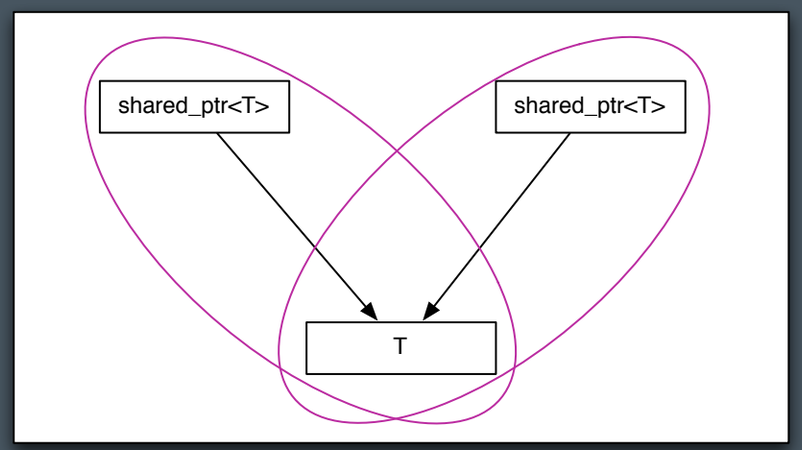


Semantics & Syntax

- Considered as individual types, assignment and copy hold their regular semantic meanings
  - However, this fails to account for the relationships (the arrows) which form an incidental data-structure. You cannot operate on T through one of the shared pointers without considering the effect on the other shared pointer

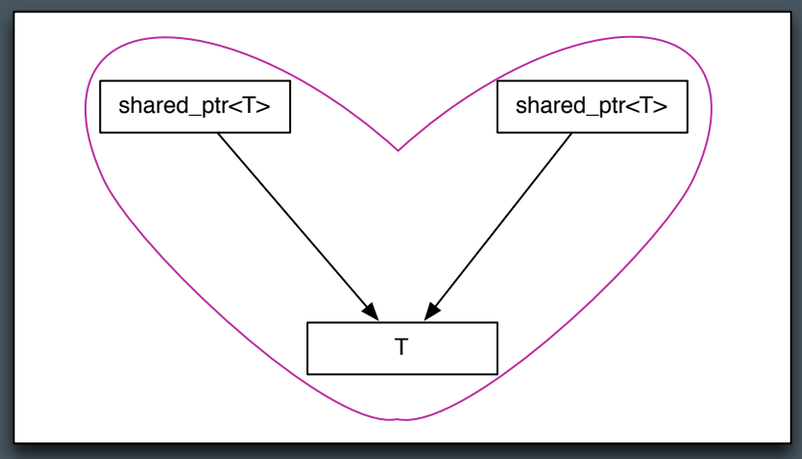
Semantics & Syntax



Semantics & Syntax

- If we extend our notion of object type to include the directly related part then we have intersecting objects which will interfere with each other

Semantics & Syntax



Semantics & Syntax

- When we consider the whole, the standard syntax for copy and assignment no longer have their regular semantics.
  - This structure is still copyable and assignable but these operations must be done through other means
- The shared structure also breaks our ability to reason locally about the code

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> A shared pointer is as good as a global variable

Write a very simple application which consists of a document which contains objects.
Containment is a non-intrusive relationship which relies on particular properties of the objects being placed in the container.

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template <typename T>
void draw(const T& x, ostream& out, size_t position)
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    template <typename T>
    object_t(T x) : self_(make_shared<model<T>>(move(x))) { }

    friend void draw(const object_t& x, ostream& out, size_t position)
    { x.self_->draw_(out, position); }

  private:
    struct concept_t {
        virtual ~concept_t() = default;
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    template <typename T>
    struct model : concept_t {
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```
  private:
    struct concept_t {
        virtual ~concept_t() = default;
        virtual void draw_(ostream&, size_t) const = 0;
    };
    template <typename T>
    struct model : concept_t {
        model(T x) : data_(move(x)) { }
        void draw_(ostream& out, size_t position) const
        { draw(data_, out, position); }

        T data_;
    };

   shared_ptr<const concept_t> self_;
};

using document_t = vector<object_t>;

void draw(const document_t& x, ostream& out, size_t position)
{
    out << string(position, ' ') << "<document>" << endl;
    for (auto& e : x) draw(e, out, position + 2);
    out << string(position, ' ') << "</document>" << endl;
```

cout | guidelines | defects

Write a very simple application which consists of a document which contains objects.
Containment is a non-intrusive relationship which relies on particular properties of the objects being placed in the container.

client | library

```
 private:
   struct concept_t {
       virtual ~concept_t() = default;
       virtual void draw_(ostream&, size_t) const = 0;
   };
   template <typename T>
   struct model : concept_t {
       model(T x) : data_(move(x)) { }
       void draw_(ostream& out, size_t position) const
       { draw(data_, out, position); }

       T data_;
   };

  shared_ptr<const concept_t> self_;
};
```

```
using document_t = vector<object_t>;

void draw(const document_t& x, ostream& out, size_t position)
{
    out << string(position, ' ') << "<document>" << endl;
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}
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cout | guidelines | defects

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client | library

cout | guidelines | defects

client | library

```
class my_class_t {
    /* ... */
};

void draw(const my_class_t&, ostream& out, size_t position)
{ out << string(position, ' ') << "my_class_t" << endl; }

int main()
{
    document_t document;

    document.emplace_back(my_class_t());

    draw(document, cout, 0);
}
```

cout | guidelines | defects

client | library

```
class my_class_t {
    /* ... */
};

void draw(const my_class_t&, ostream& out, size_t position)
{ out << string(position, ' ') << "my_class_t" << endl; }

int main()
{
    document_t document;

    document.emplace_back(my_class_t());

    draw(document, cout, 0);
}
```

cout

```
<document>
 my_class_t
</document>
```

client | library

```
class my_class_t {
    /* ... */
};

void draw(const my_class_t&, ostream& out, size_t position)
{ out << string(position, ' ') << "my_class_t" << endl; }

int main()
{
    document_t document;

    document.emplace_back(my_class_t());
    document.emplace_back(string("Hello World!"));

    draw(document, cout, 0);
}
```

cout | guidelines | defects

client | library

```
class my_class_t {
    /* ... */
};

void draw(const my_class_t&, ostream& out, size_t position)
{ out << string(position, ' ') << "my_class_t" << endl; }

int main()
{
    document_t document;

    document.emplace_back(my_class_t());
    document.emplace_back(string("Hello World!"));

    draw(document, cout, 0);
}
```

cout

```
<document>
  my_class_t
  Hello World!
</document>
```

client | library

```
class my_class_t {
    /* ... */
};

void draw(const my_class_t&, ostream& out, size_t position)
{ out << string(position, ' ') << "my_class_t" << endl; }

int main()
{
    document_t document;

    document.emplace_back(my_class_t());
    document.emplace_back(string("Hello World!"));
    document.emplace_back(document);

    draw(document, cout, 0);
}
```

cout | guidelines | defects

client | library

```
class my_class_t {
    /* ... */
};

void draw(const my_class_t&, ostream& out, size_t position)
{ out << string(position, ' ') << "my_class_t" << endl; }

int main()
{
    document_t document;

    document.emplace_back(my_class_t());
    document.emplace_back(string("Hello World!"));
    document.emplace_back(document);

    draw(document, cout, 0);
}
```

cout

```
<document>
 my_class_t
 Hello World!
 <document>
  my_class_t
  Hello World!
 </document>
</document>
```

client | library

```
class my_class_t {
    /* ... */
};

void draw(const my_class_t&, ostream& out, size_t position)
{ out << string(position, ' ') << "my_class_t" << endl; }

int main()
{
    document_t document;

    document.emplace_back(my_class_t());
    document.emplace_back(string("Hello World!"));

    auto saving = async([=]() {
        this_thread::sleep_for(chrono::seconds(3));
        cout << "-- save --" << endl;
        draw(document, cout, 0);
    });

    document.emplace_back(document);

    draw(document, cout, 0);
    saving.get();
}
```

cout | guidelines | defects

client | library

```
class my_class_t {
    /* ... */
};

void draw(const my_class_t&, ostream& out, size_t position)
{ out << string(position, ' ') << "my_class_t" << endl; }

int main()
{
    document_t document;
    document.insert_at_back(my_class_t());
    document.insert_at_back(string("Hello World!"));
```

cout

```
<document>
 my_class_t
 Hello World!
 <document>
  my_class_t
  Hello World!
 </document>
</document>
-- save --
<document>
 my_class_t
 Hello World!
</document>
```

Seasoning

- Using make_shared<> to create shared_ptrs eliminates an extra heap allocation

```
template <typename T> // T models Drawable
object_t(T x) : self_(make_shared<model<T>>(move(x)))
{ }
```

- Pass sink arguments by value and move into place

Goals Recap

- No Raw Loops
- No Raw Syntonization Primitives
- No Raw Pointers

Locality of Reasoning

- Easier to reason about
- Composable
- General
- Correct
- Efficient

[Before this add a seasoning / tips slide on make_shared and pass-by-value]

One slide recap goals.


Adobe

No Raw Loops

```
template <typename I, // I models BidirectionalIterator
          typename S> // S models UnaryPredicate
auto gather(I f, I l, I p, S s) -> pair<I, I>
{
    using value_type = typename iterator_traits<I>::value_type;

    return { stable_partition(f, p, [&](const value_type& x){ return !s(x); }),
             stable_partition(p, l, s) };
}
```

- `not1` is not lambda friendly because of the `argument_type` requirement
- With C++ 14 we should be able to express this with a `const auto&` argument
  - Perhaps with a fixed `not1` or `!bind`
- The `BidirectionalIterator` requirement should be weakened to `ForwardIterator`
  - See SGI STL for an implementation
- The `gather()` function was developed with Marshall Clow and is in Boost

Back

No Raw Loops

C++11

```
template <typename I, // I models BidirectionalIterator
          typename S> // S models UnaryPredicate
auto gather(I f, I l, I p, S s) -> pair<I, I>
{
    using value_type = typename iterator_traits<I>::value_type;

    return { stable_partition(f, p, [&](const value_type& x){ return !s(x); }),
             stable_partition(p, l, s) };
}
```

- `not1` is not lambda friendly because of the `argument_type` requirement
- With C++ 14 we should be able to express this with a `const auto&` argument
  - Perhaps with a fixed `not1` or `!bind`
- The `BidirectionalIterator` requirement should be weakened to `ForwardIterator`
  - See SGI STL for an implementation
- The `gather()` function was developed with Marshall Clow and is in Boost

Back

Write a very simple application which consists of a document which contains objects.
Containment is a non-intrusive relationship which relies on particular properties of the objects being placed in the container.

client | library

```
// For illustration only
class group {
  public:
    template <typename F>
    void async(F&& f) {
        auto then = then_;
        thread(bind([then](F& f){ f(); }, std::forward<F>(f))).detach();
    }

    template <typename F>
    void then(F&& f) {
        then_->f_ = forward<F>(f);
        then_.reset();
    }

  private:
    struct packaged {
        ~packaged() { thread(bind(move(f_))).detach(); }
        function<void ()> f_;
    };

    shared_ptr<packaged> then_ = make_shared<packaged>();
};
```

cout | guidelines | defects

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client | library

cout | guidelines | defects

client | library

```
int main()
{
    group g;
    g.async([]() {
        this_thread::sleep_for(chrono::seconds(2));
        cout << "task 1" << endl;
    });

    g.async([]() {
        this_thread::sleep_for(chrono::seconds(1));
        cout << "task 2" << endl;
    });

    g.then([=](){
        cout << "done!" << endl;
    });

    this_thread::sleep_for(chrono::seconds(10));
}
```

cout | guidelines | defects

client | library

```
int main()
{
    group g;
    g.async([]() {
        this_thread::sleep_for(chrono::seconds(2));
        cout << "task 1" << endl;
    });

    g.async([]() {
        this_thread::sleep_for(chrono::seconds(1));
        cout << "task 2" << endl;
    });

    g.then([=](){
        cout << "done!" << endl;
    });

    this_thread::sleep_for(chrono::seconds(10));
}
```

cout

```
task 2
task 1
done!
```

Write a very simple application which consists of a document which contains objects.
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client | library

```
// For illustration only
class group {
  public:
    template <typename F, typename ...Args>
    auto async(F&& f, Args&&... args)
        -> future<typename result_of<F (Args...)>::type>
    {
        using result_type = typename std::result_of<F (Args...)>::type;
        using packaged_type = std::packaged_task<result_type ()>;

        auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
        auto result = p.get_future();

        auto then = then_;
        thread(bind([then](packaged_type& p){ p(); }, move(p))).detach();

        return result;
    }

    template <typename F, typename ...Args>
    auto then(F&& f, Args&&... args)
        -> future<typename result_of<F (Args...)>::type>
    {
        using result_type = typename std::result_of<F (Args...)>::type;
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```

cout | guidelines | defects

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cout | guidelines | defects

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      auto result = p.get_future();

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      return result;
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      using packaged_type = std::packaged_task<result_type ()>;

      auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
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cout | guidelines | defects

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cout | guidelines | defects

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    auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
    auto result = p.get_future();

    auto then = then_;
    thread(bind([then](packaged_type& p){ p(); }, move(p))).detach();

    return result;
}

template <typename F, typename ...Args>
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    -> future<typename result_of<F (Args...)>::type>
{
    using result_type = typename std::result_of<F (Args...)>::type;
    using packaged_type = std::packaged_task<result_type ()>;

    auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
    auto result = p.get_future();

    then_->reset(new packaged<packaged_type>(move(p)));
```

cout | guidelines | defects

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client | library

```
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    auto result = p.get_future();

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    auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
    auto result = p.get_future();

    then_->reset(new packaged<packaged_type>(move(p)));
    then_ = nullptr;
```

cout | guidelines | defects

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client | library

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cout | guidelines | defects

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template <typename F, typename ...Args>
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    auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
    auto result = p.get_future();

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```

cout | guidelines | defects

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```

cout | guidelines | defects

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client | library

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    auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
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    return result;
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    then_ = nullptr;

    return result;
}
```

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client | library

```
        auto result = p.get_future();

        auto then = then_;
        thread(bind([then](packaged_type& p){ p(); }, move(p))).detach();

        return result;
    }

    template <typename F, typename ...Args>
    auto then(F&& f, Args&&... args)
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        using result_type = typename std::result_of<F (Args...)>::type;
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        auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
        auto result = p.get_future();

        then_->reset(new packaged<packaged_type>(move(p)));
        then_ = nullptr;

        return result;
    }

private:
```

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Write a very simple application which consists of a document which contains objects.
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client | library

```
        auto then = then_;
        thread(bind([then](packaged_type& p){ p(); }, move(p))).detach();

        return result;
    }

    template <typename F, typename ...Args>
    auto then(F&& f, Args&&... args)
        -> future<typename result_of<F (Args...)>::type>
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        using result_type = typename std::result_of<F (Args...)>::type;
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        auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
        auto result = p.get_future();

        then_->reset(new packaged<packaged_type>(move(p)));
        then_ = nullptr;

        return result;
    }

private:
    struct any_packaged {
```

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client | library

```
        auto then = then_;
        thread(bind([then](packaged_type& p){ p(); }, move(p))).detach();

        return result;
    }

    template <typename F, typename ...Args>
    auto then(F&& f, Args&&... args)
        -> future<typename result_of<F (Args...)>::type>
    {
        using result_type = typename std::result_of<F (Args...)>::type;
        using packaged_type = std::packaged_task<result_type ()>;

        auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
        auto result = p.get_future();

        then_->reset(new packaged<packaged_type>(move(p)));
        then_ = nullptr;

        return result;
    }

  private:
    struct any_packaged {
        virtual ~any_packaged() = default;
```

cout | guidelines | defects

Write a very simple application which consists of a document which contains objects.
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client | library

```
        thread(bind([then](packaged_type& p){ p(); }, move(p))).detach();

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    }

    template <typename F, typename ...Args>
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cout | guidelines | defects

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client | library

```
        return result;
    }

    template <typename F, typename ...Args>
    auto then(F&& f, Args&&... args)
        -> future<typename result_of<F (Args...)>::type>
    {
        using result_type = typename std::result_of<F (Args...)>::type;
        using packaged_type = std::packaged_task<result_type ()>;

        auto p = packaged_type(forward<F>(f), forward<Args>(args)...);
        auto result = p.get_future();

        then_->reset(new packaged<packaged_type>(move(p)));
        then_ = nullptr;

        return result;
    }

  private:
    struct any_packaged {
        virtual ~any_packaged() = default;
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client | library

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    shared_ptr<unique_ptr<any_packaged>> then_ = make_shared<unique_ptr<any_packaged>>();
```

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Back

client | library

```
int main()
{
    group g;

    auto x = g.async([]() {
        this_thread::sleep_for(chrono::seconds(2));
        cout << "task 1" << endl;
        return 10;
    });

    auto y = g.async([]() {
        this_thread::sleep_for(chrono::seconds(1));
        cout << "task 2" << endl;
        return 5;
    });

    auto r = g.then(bind([](future<int>& x, future<int>& y) {
        cout << "done:" << (x.get() + y.get()) << endl;
    }, move(x), move(y)));

    r.get();
}
```

Back

cout | guidelines | defects

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                    ove(y)));
```

cout

```
task 2
task 1
done:15
```

Back