On reflecting on runtime or, *"Program know thyself"*

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Part I *of V*

Navel gazing

Part II of V

Navel gazing

Existential C++

Part III of V

Navel gazing
Existential C++
Genesis of Intent

Part IV of V

Navel gazing
Existential C++
Genesis of Intent
Archaeology

Part V of V

Navel gazing
Existential C++
Genesis of Intent
Archaeology
Agent Provocateur

Part Zero

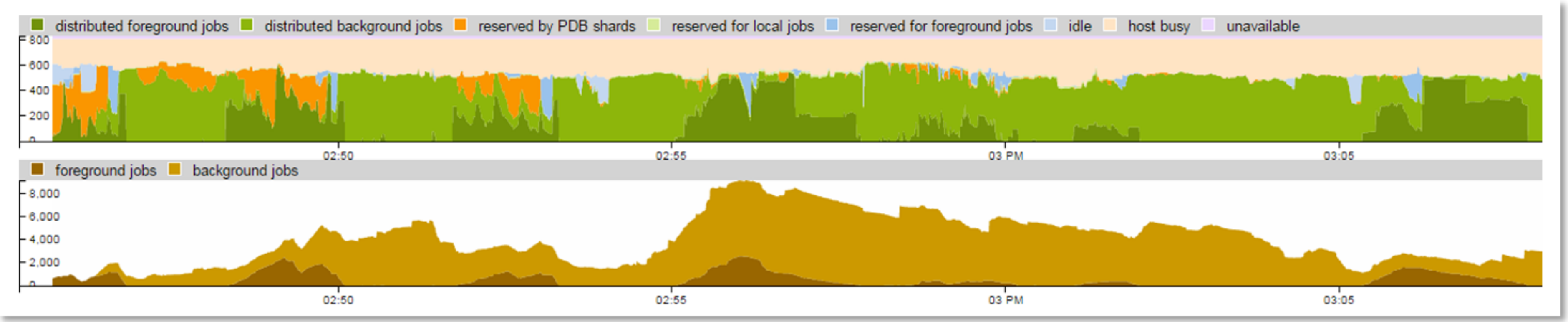
Context

What do I do?

- A distributed build accelerator
- Written in C++ in the style of Erlang
- Runs on tens to hundreds of machines
- Big enough to fail in *interesting* ways

What does it do?

- It distributes compilation and data processing
- Here it is keeping 600 cores busy on up to 8,000 simultaneous jobs for 30 minutes



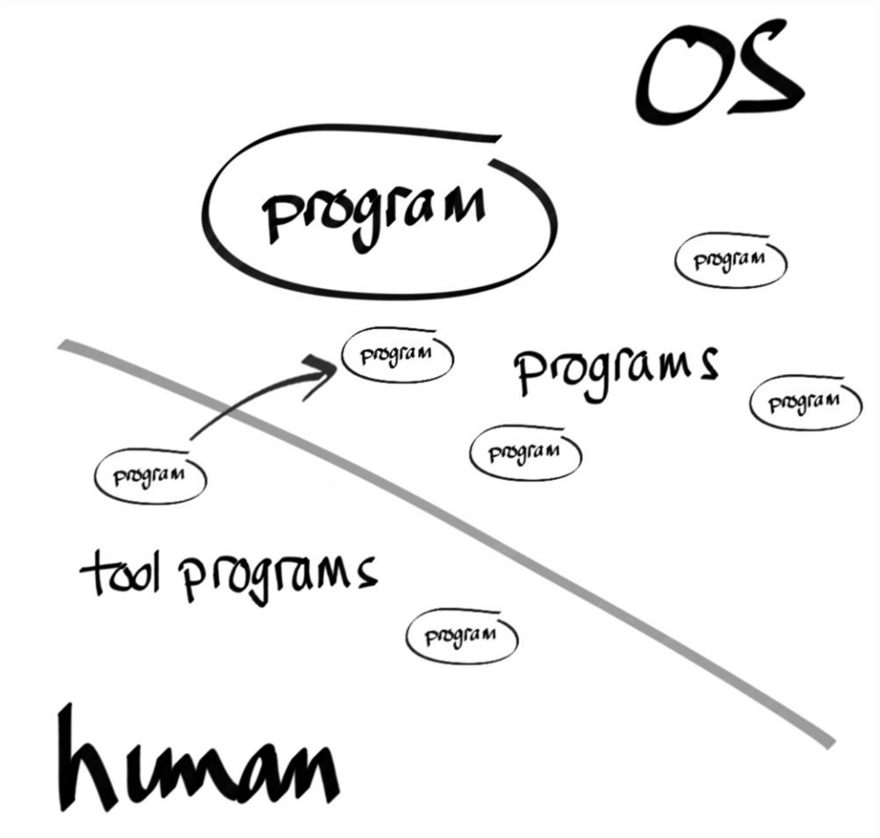
Part I

Navel gazing

- What is the "self"?
- What is "runtime"?
- What is "reflection"?

Navel gazing

What is
the self?



What is
the self?

What is runtime?

The Seven Ages of Code

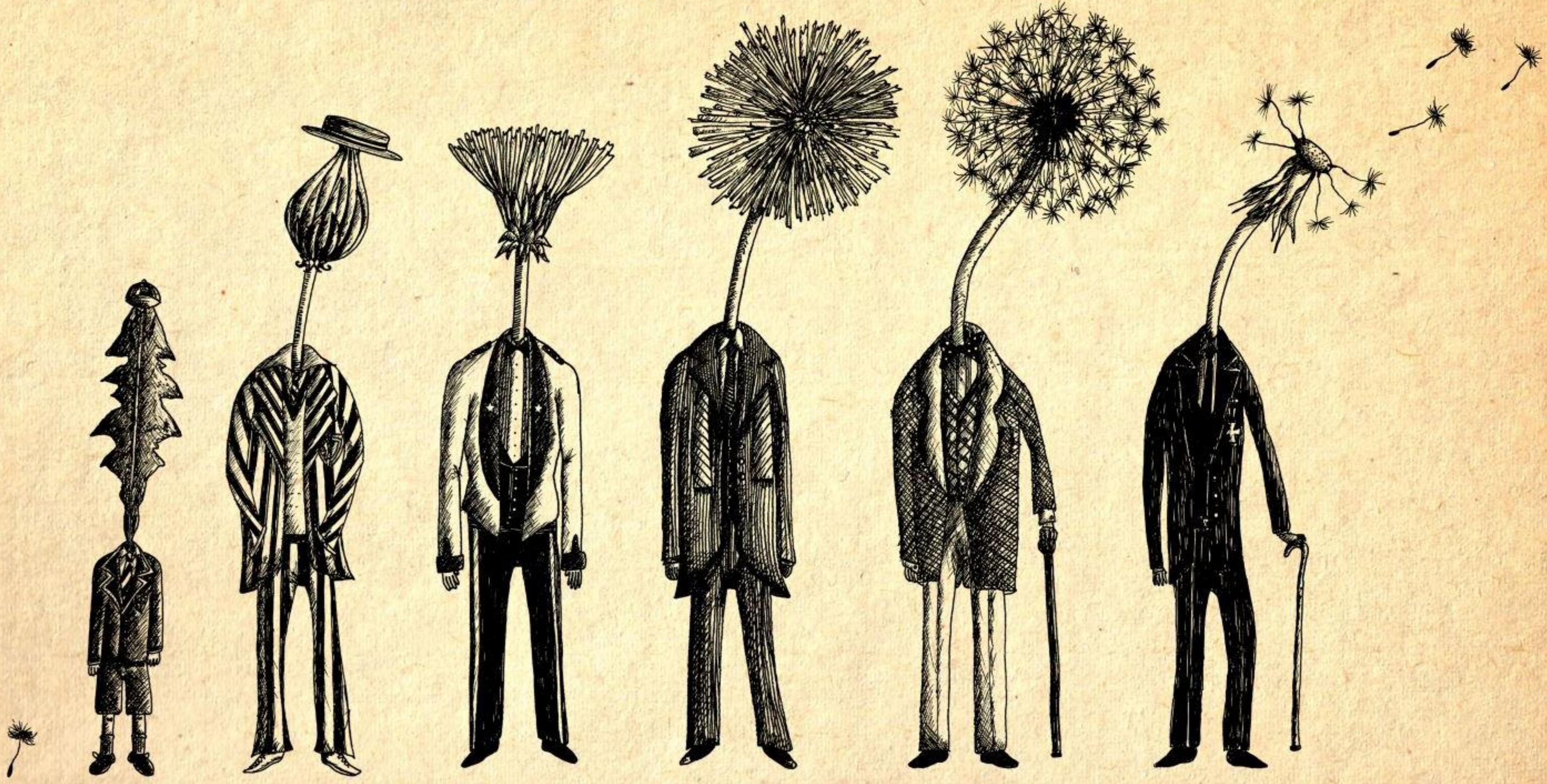
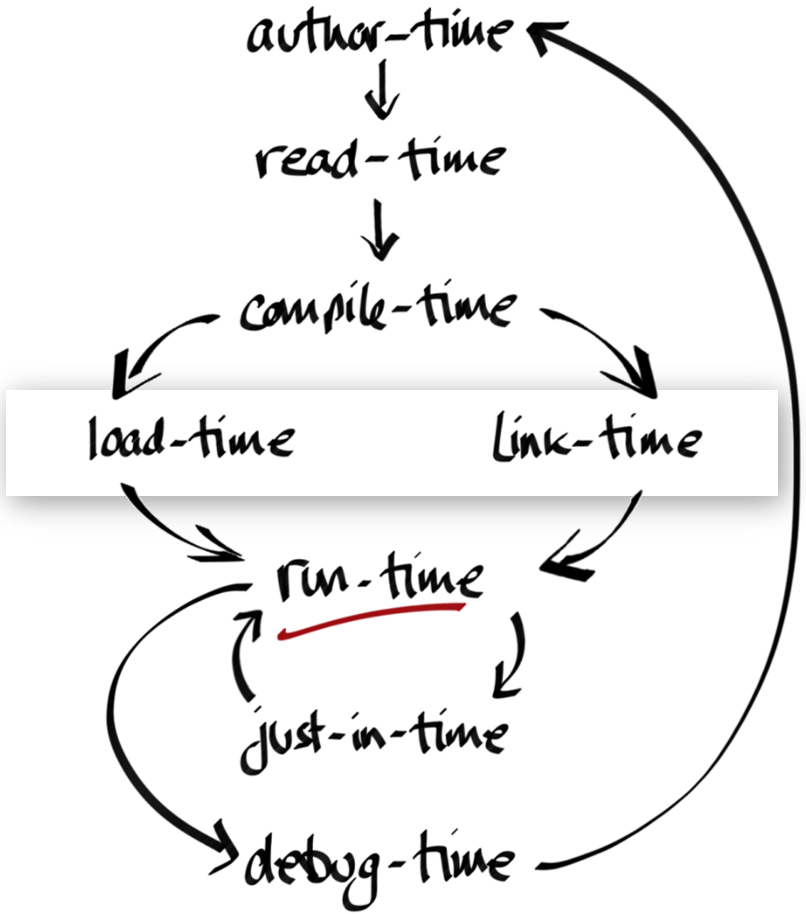
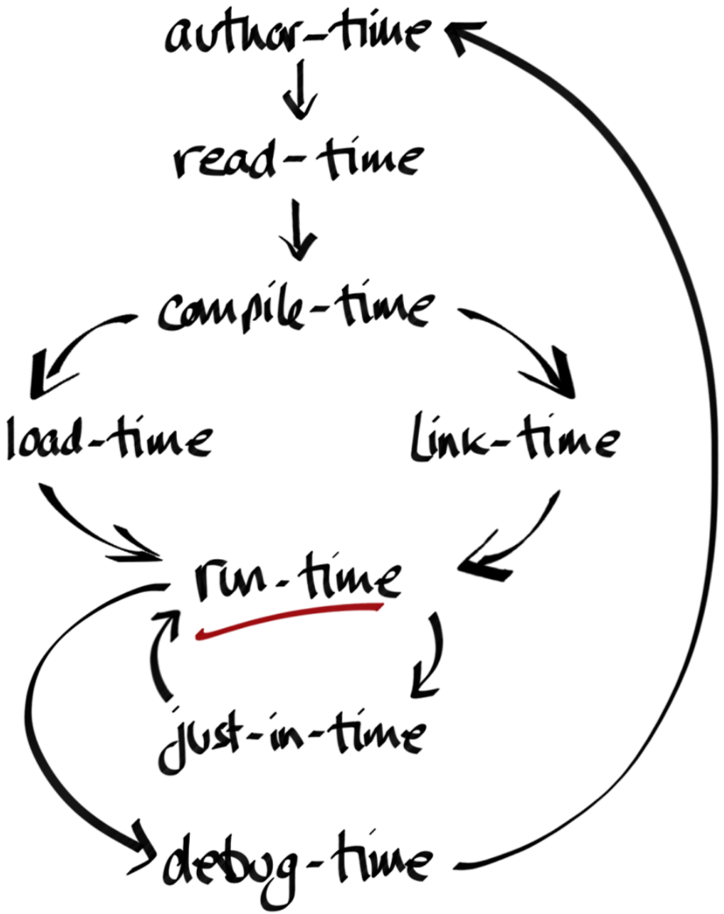


fig. 3: The Seven Ages of Mandelion

By kind permission of Jon Turner, http://www.thisisjonturner.com

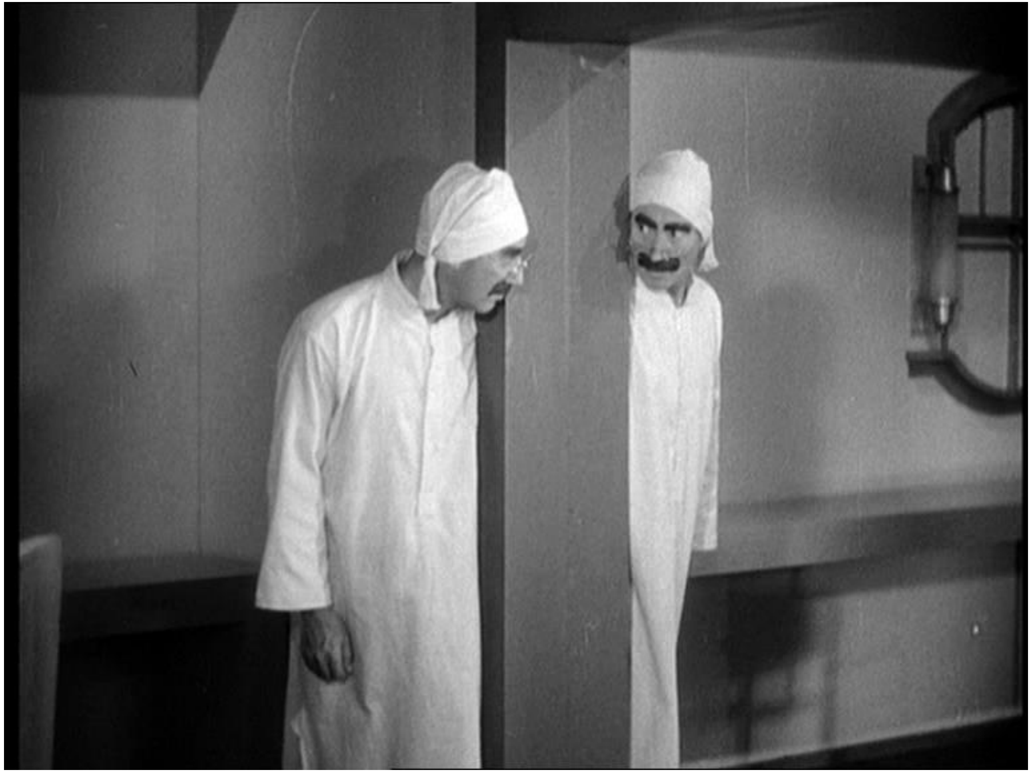


The Seven Ages of Code



The Eight Ages of Code

What is reflection?



What is reflection?

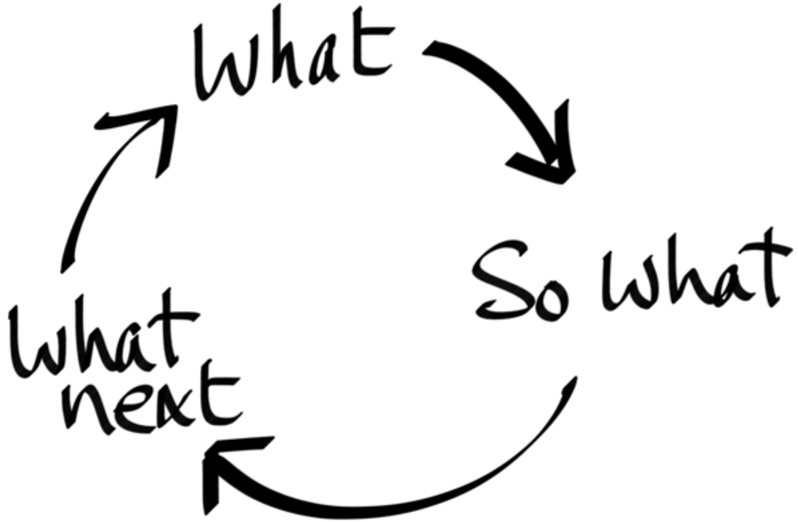
What is reflection?

- Reification :
  - making the implicit visible
  - to convert into or regard as a concrete thing

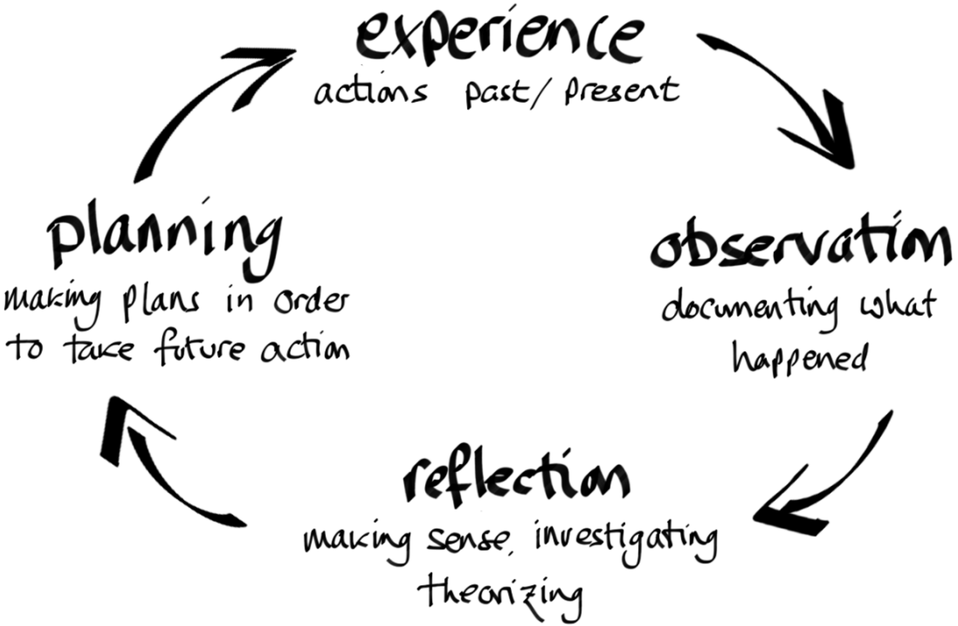
What is reflection?

- Is that it?

Reflective Practice



Reflective
Practice



Reflective Practice

Do programs
practice
reflective
practice?

- **Through a glass darkly :** Shedding light on reflective practice and autonomous learning

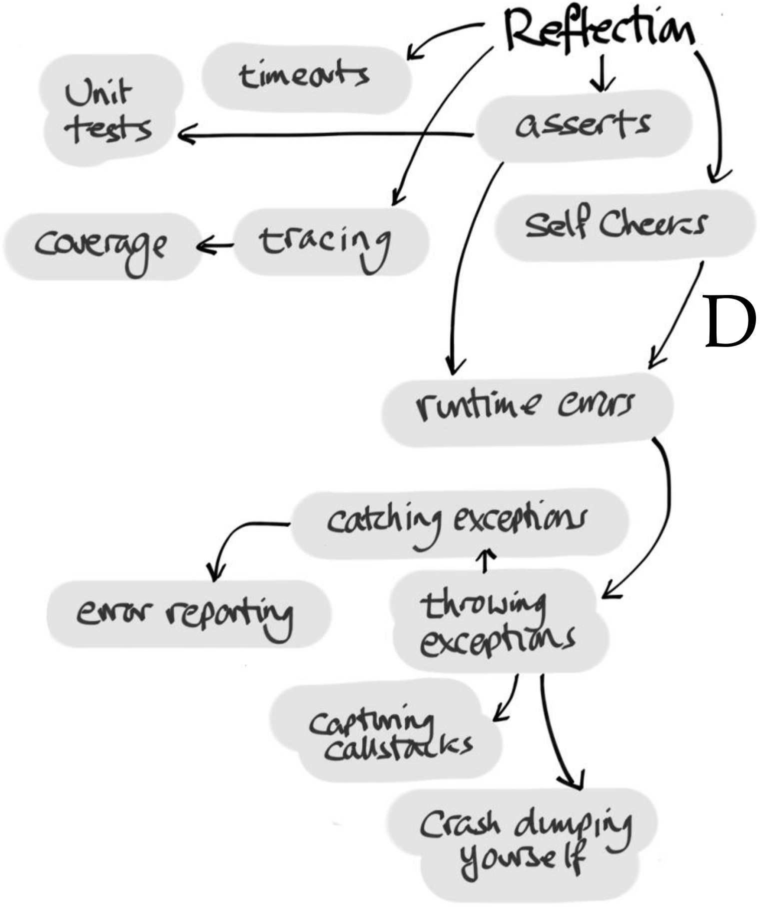
Reflective Practice

Reflective Practice

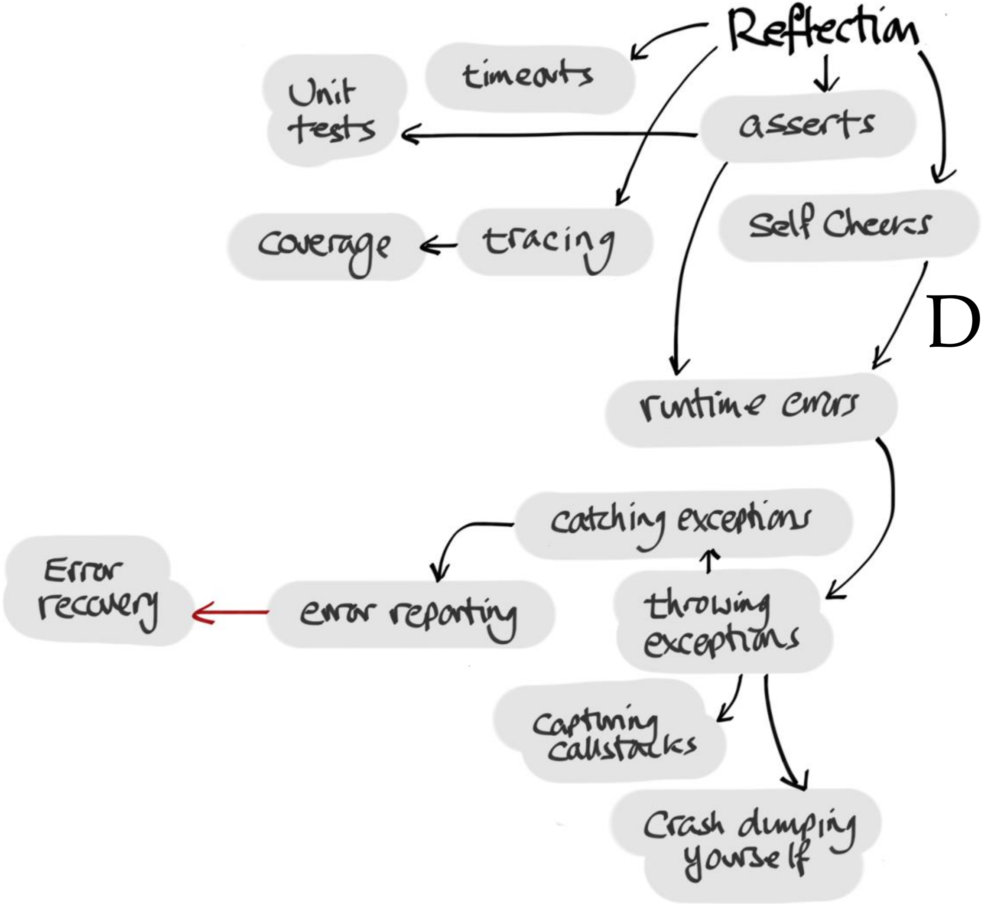
- **Through a glass darkly :** Shedding light on reflective practice and autonomous learning

- *"Reflection may not be enjoyable but it is recorded as a non-threatening process, which can include a balance of positive and negative experiences and has a significant value for students especially in learning from their mistakes."*

- Susan M Taylor and Mary A Dyer, University of Huddersfield, 2010 (unpublished)
- http://eprints.hud.ac.uk/8408



Do programs practice reflective practice?



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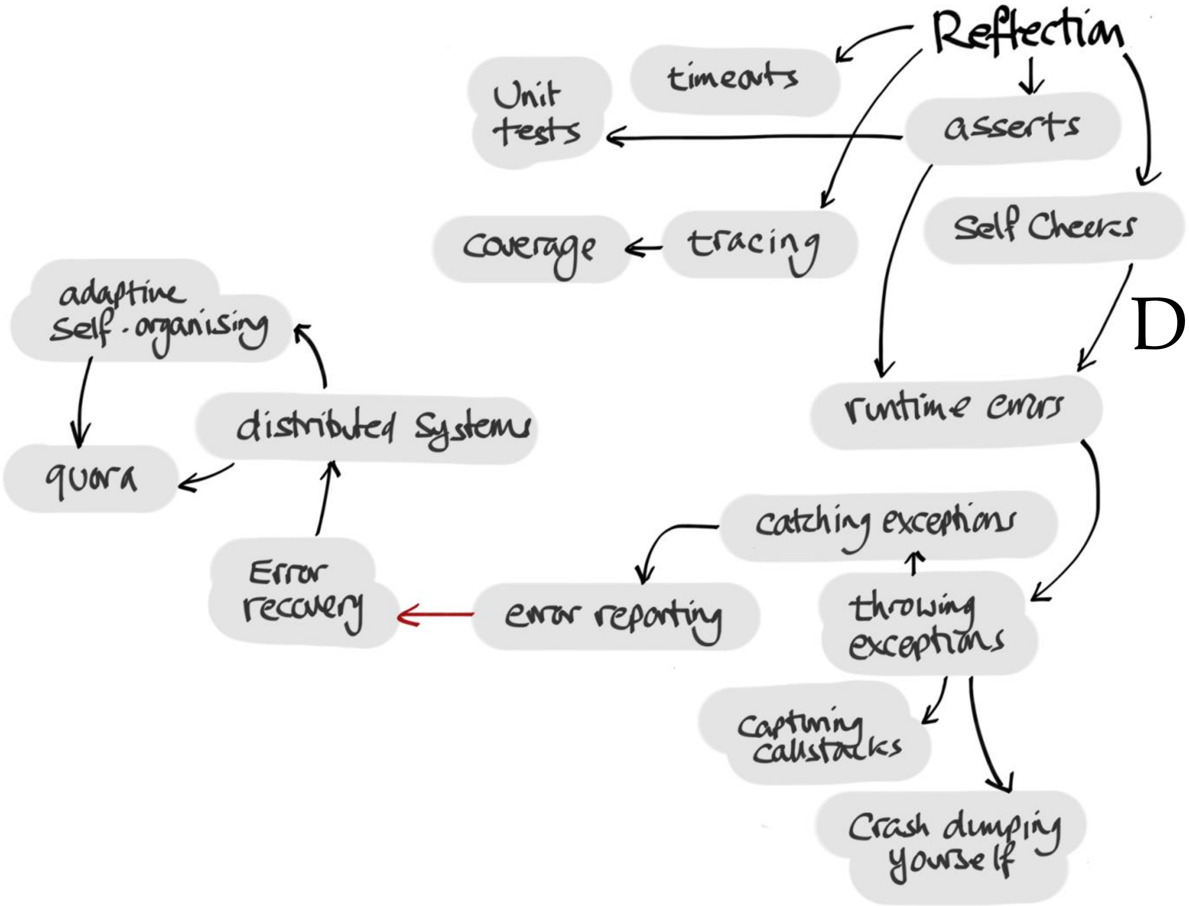

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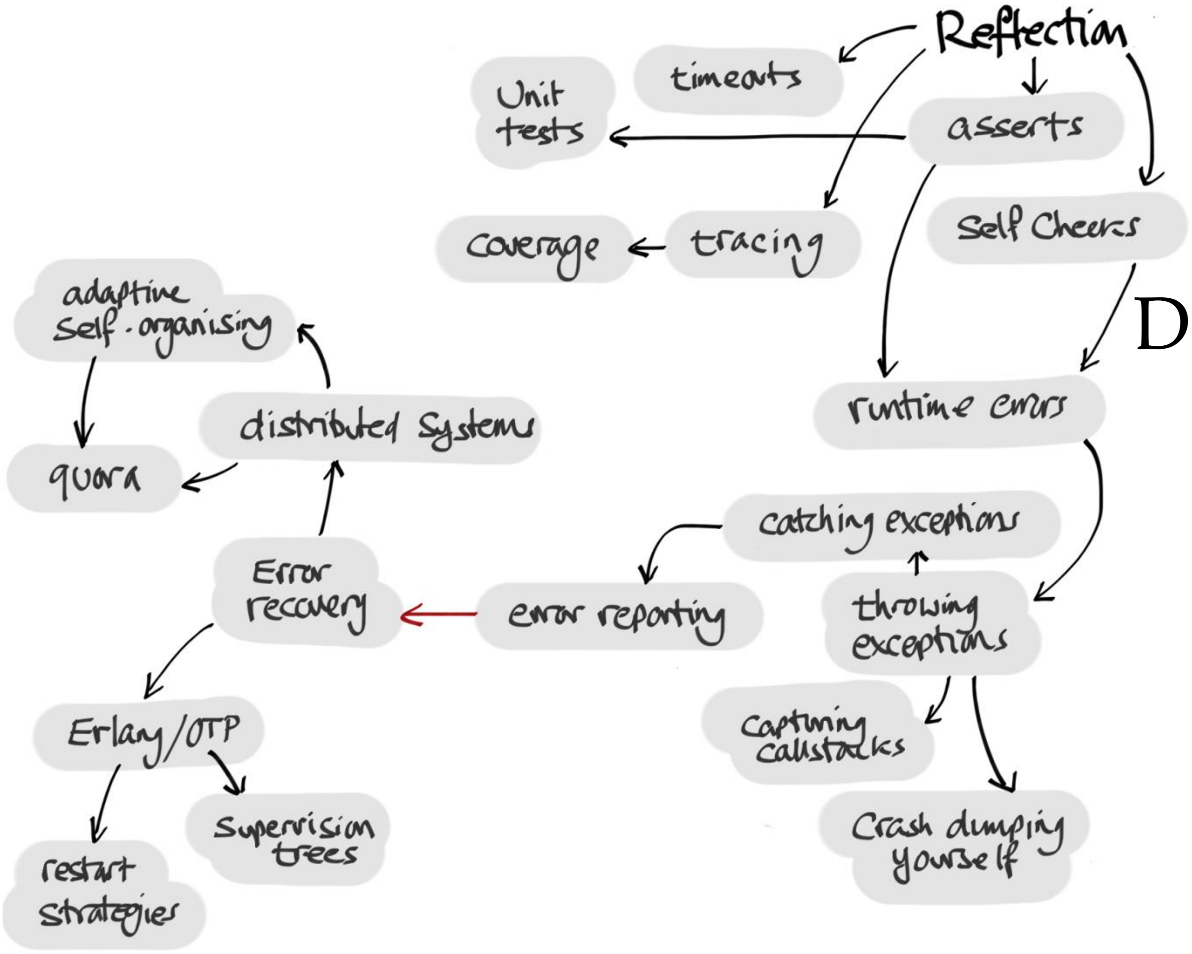

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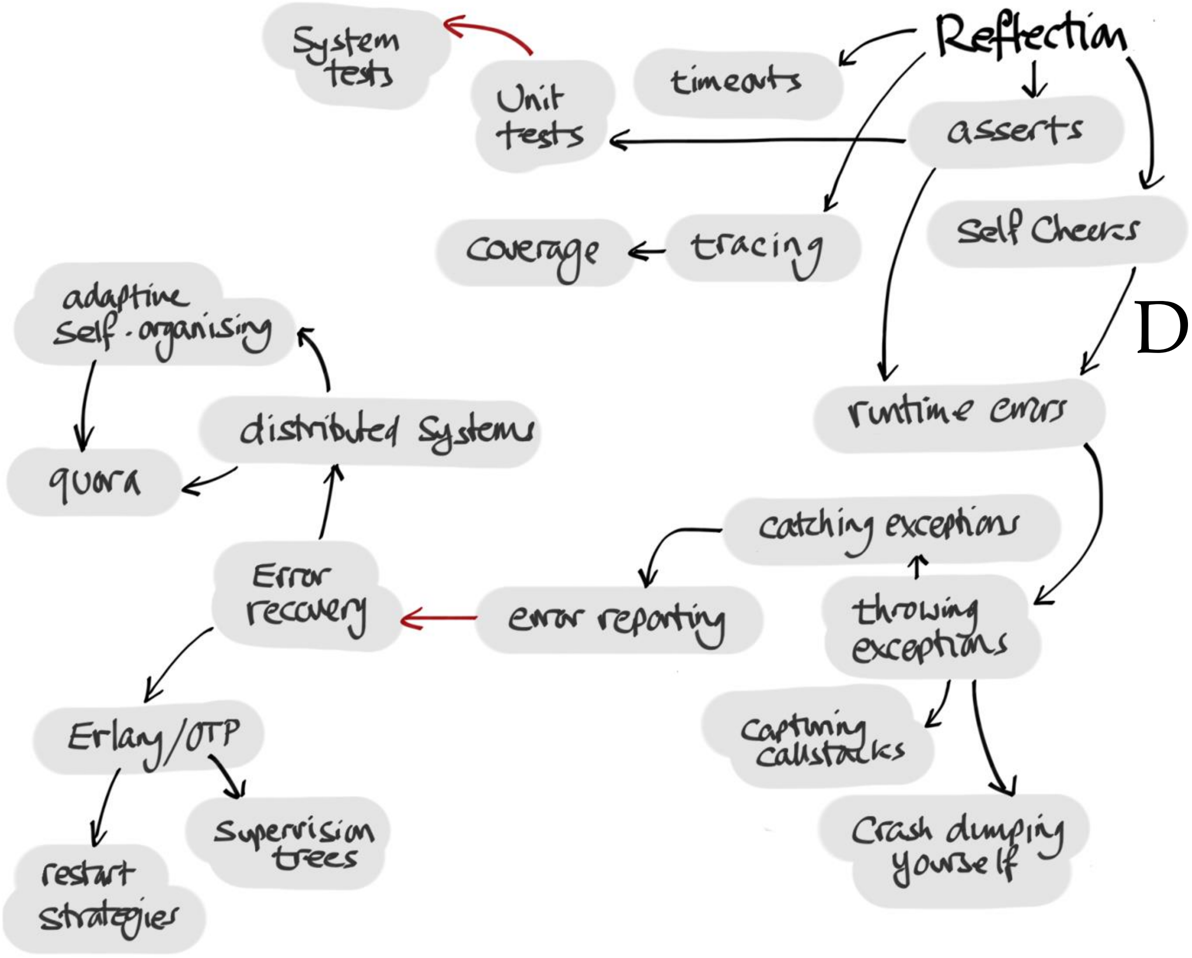

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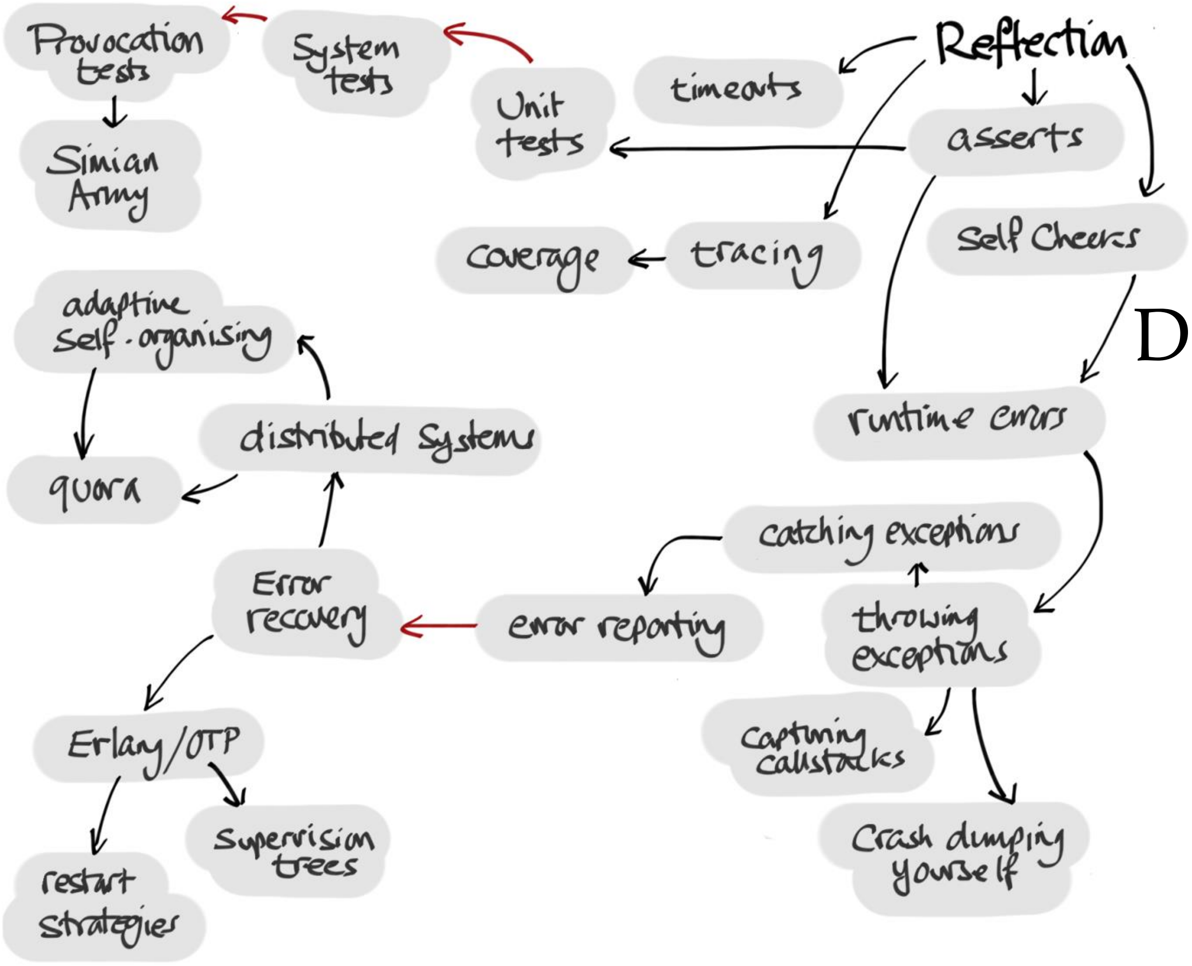

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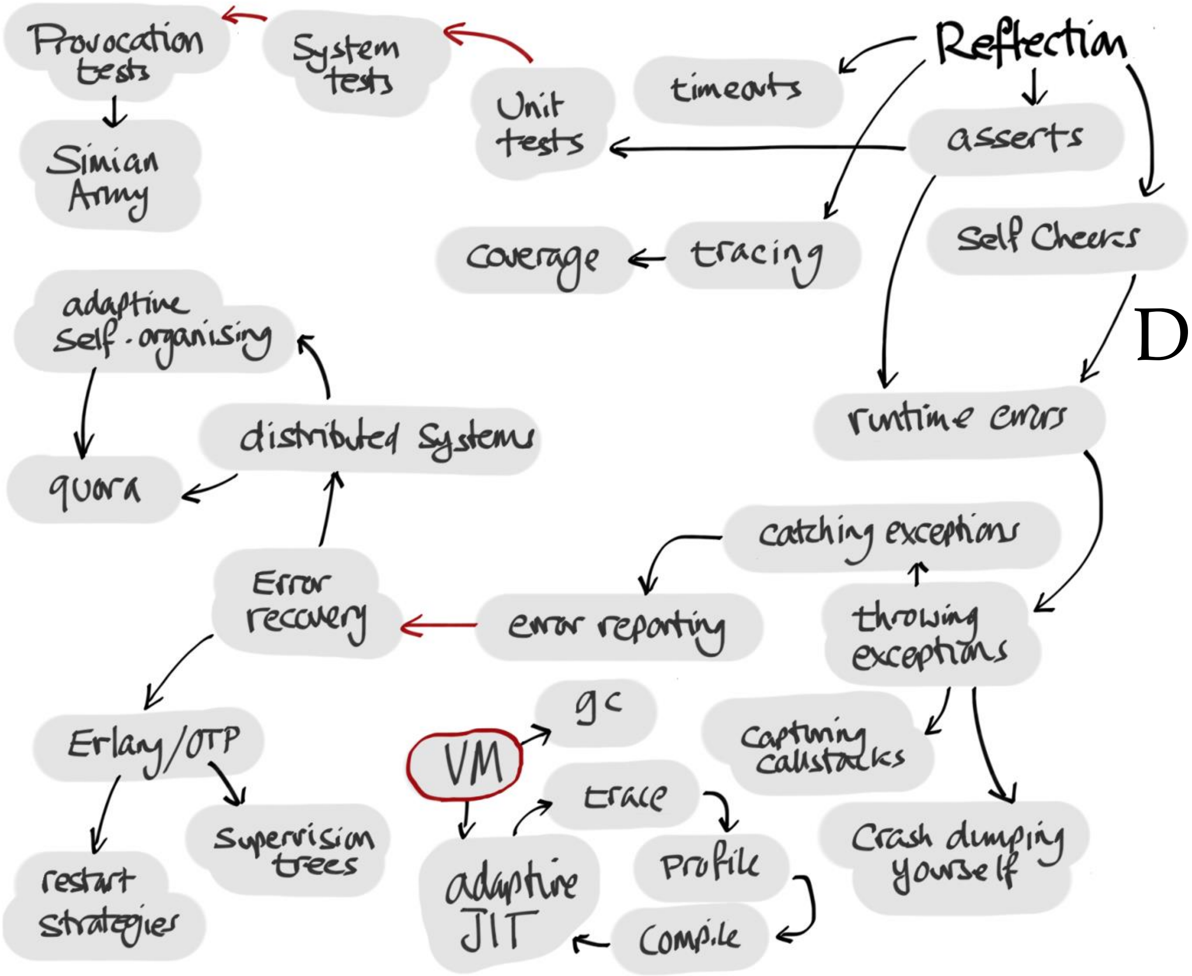


Do programs practice reflective practice?

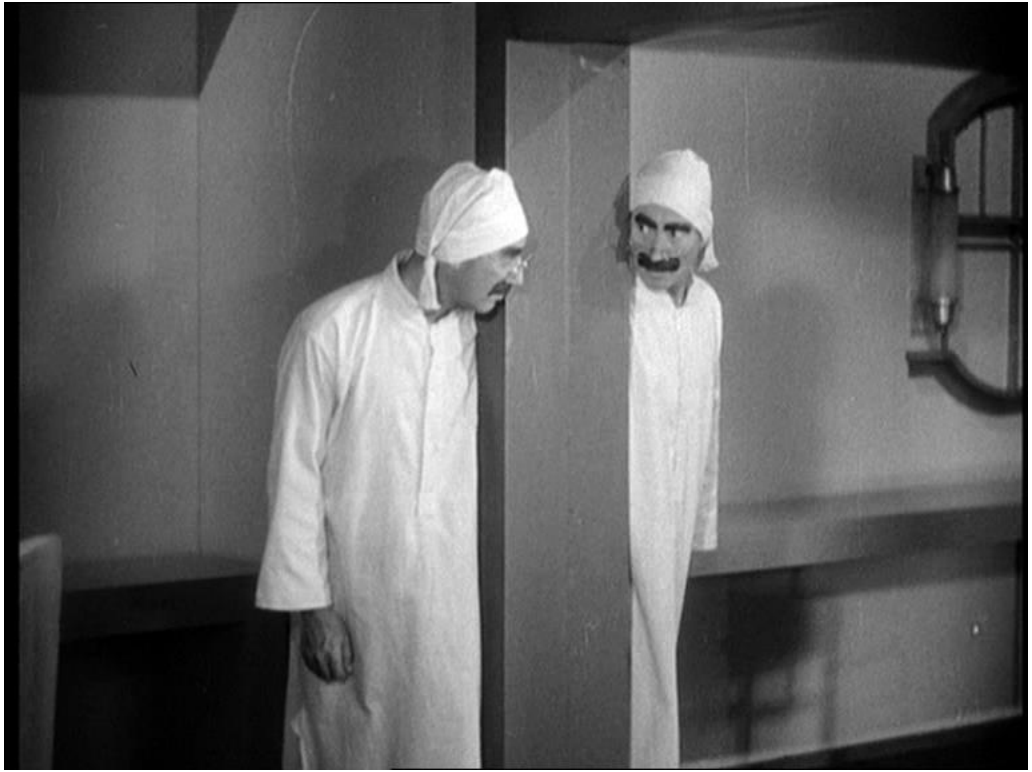
So, what about
C++?

Part II

Existential C++

- A C++ program’s experience of execution

Existential C++



What is reflected?

Shadow puppets

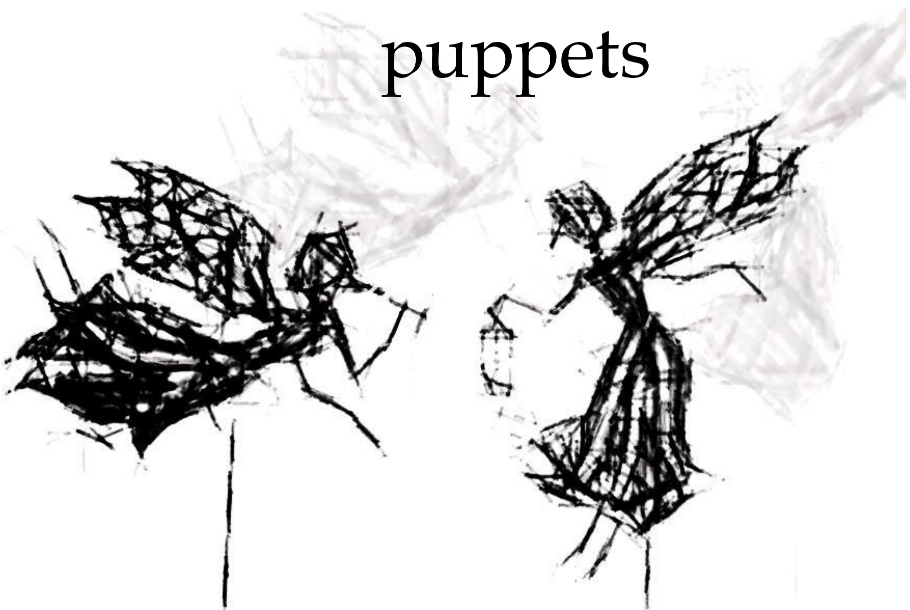
- The semantics of C++ are projected onto the hardware execution model.

- They are implemented behind the screen by representation artefacts.

- *http://papertales.deviantart.com/art/Two-Angels-Shadow-Puppets-174367145*

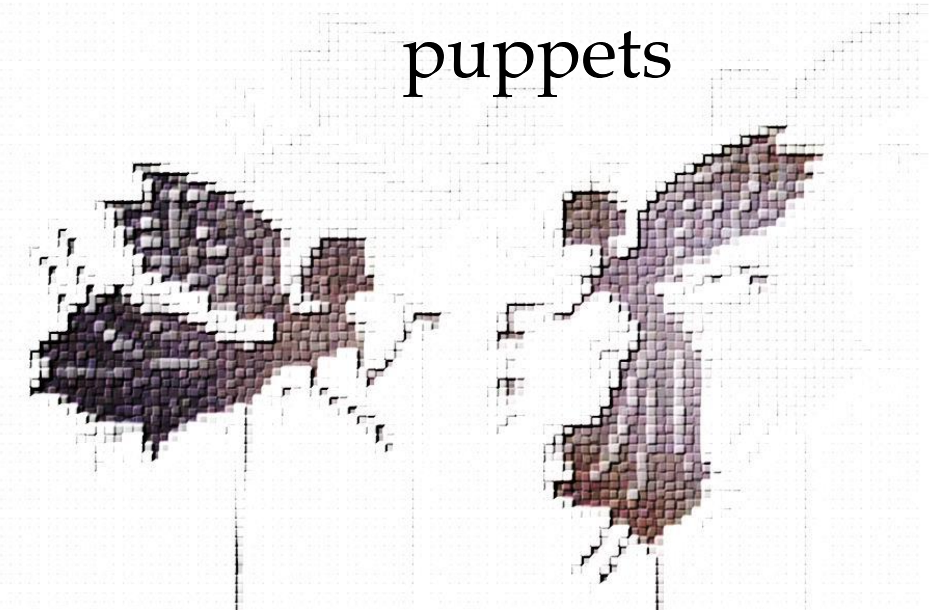
- The semantics of C++ are projected onto the hardware execution model.
- They are implemented behind the screen by representation artefacts.
- Intel doesn't want you to know that in most cases these are wood and string.

Shadow puppets



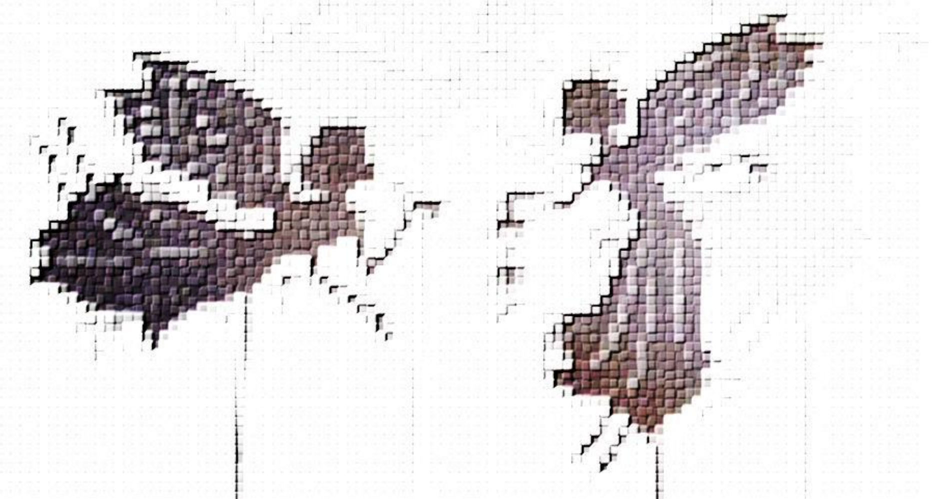
- What can we see?
  - Inspect values that are in scope
  - Inspect memory, perhaps interpret it by heap walking
    - Memory leaks
    - Memory corruption
  - Inspect objects using a MOP
  - Inspect objects using a DWARF

Shadow puppets



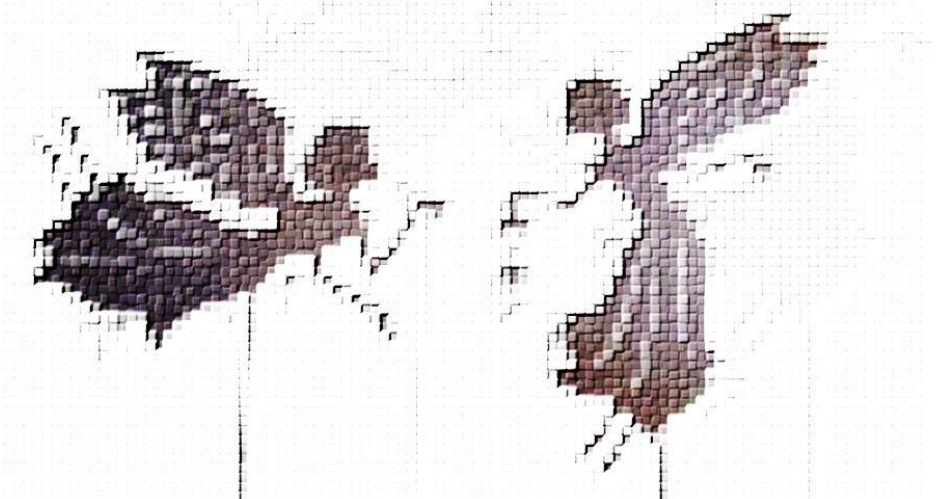
Shadow puppets

- What can we measure?
  - Resource usage
  - Work done against time
    - Timeouts
    - Profiling
    - QOS guarantees



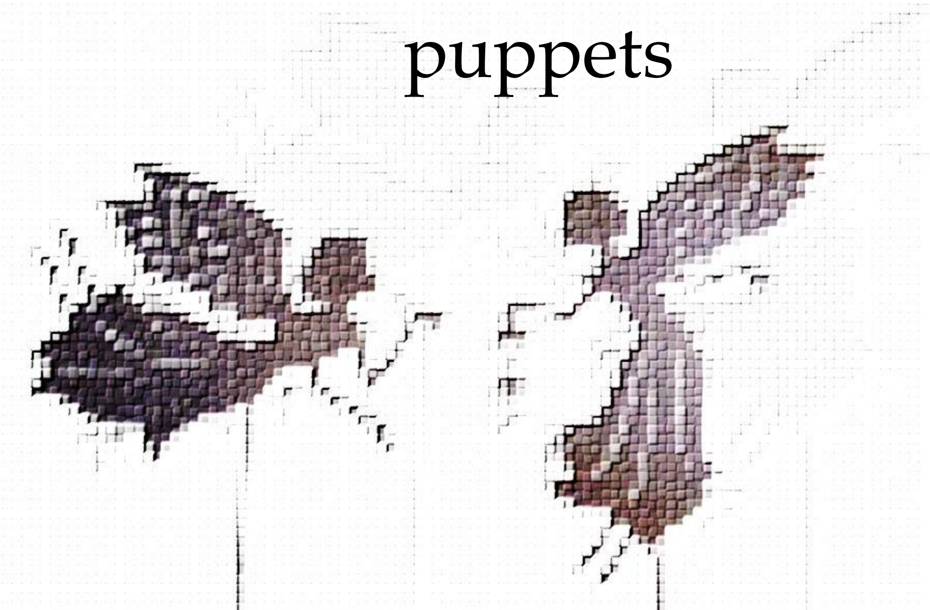
- What can we capture?
  - History
    - Execution history using logs and traces (`printf`)
    - Call stacks (requiring debug data to decipher)
    - Exceptions
    - Core dumps to snapshot state

Shadow puppets



- What is least well represented, or taken for granted?

Shadow puppets



Execution flow

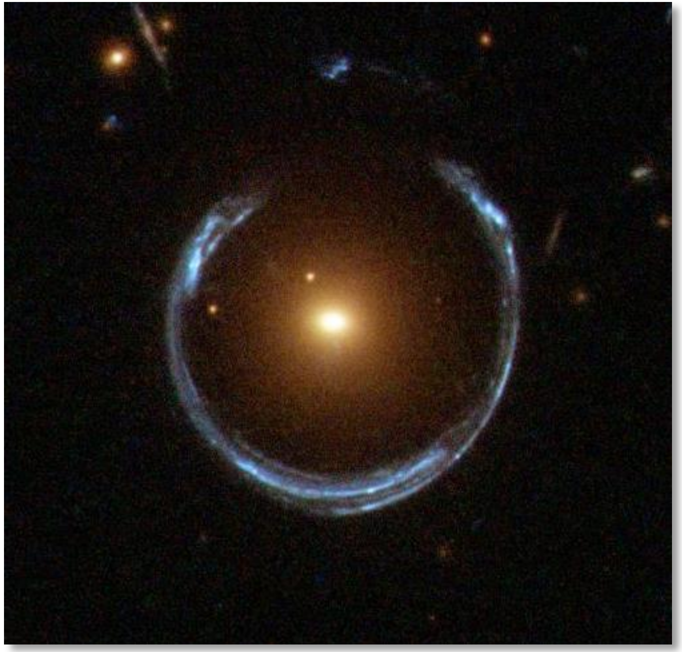
What is
The Standard
Model?

Execution flow

- Stack based model
  - Lexical scopes
  - Call and return
  - Exceptions and unwinding

Concurrent Execution flow

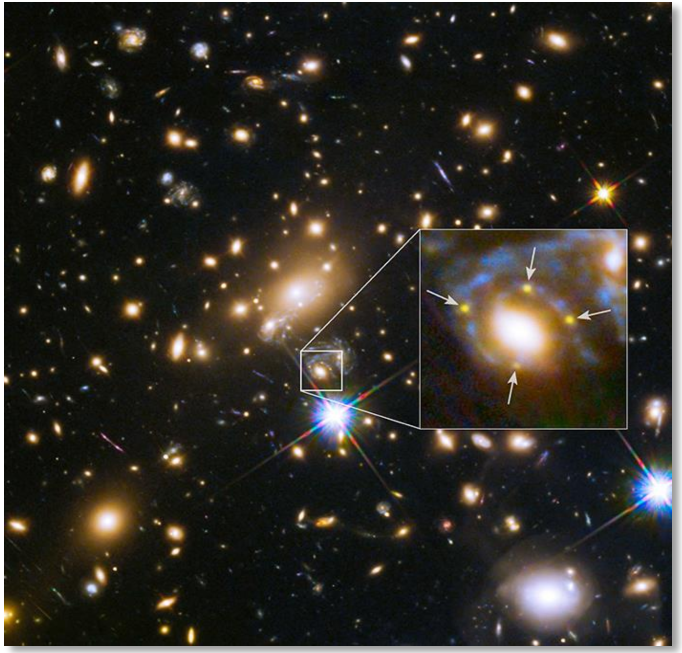
- As parallelism and concurrency become more prevalent, the execution of work related to a domain thing may no longer follow the familiar call stack model.
- Work queues, thread pools, co-routines, message passing, actors, and distributed systems all cause work fragments to be scattered, becoming disconnected.



A metaphor…

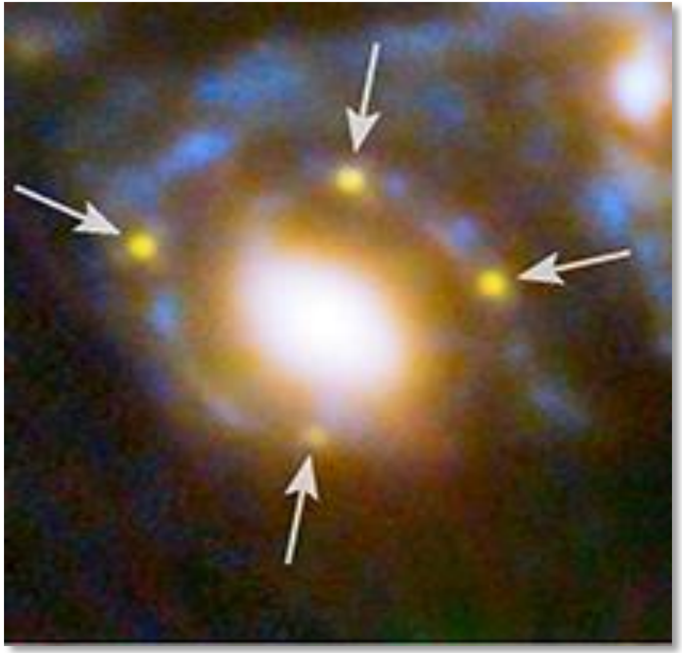
Einstein's Gravity Lens

- http://upload.wikimedia.org/wikipedia/commons/1/11/A_Horseshoe_Einstein_Ring_from_Hubble.JPG



Einstein Cross

- http://physicsworld.com/cws/article/news/2015/mar/05/gravitational-lensing-creates-einsteins-cross-of-distant-supernova



- http://physicsworld.com/cws/article/news/2015/mar/05/gravitational-lensing-creates-einsteins-cross-of-distant-supernova

Einstein Cross

- Conventional control flow is becoming less well correlated with domain work.

Execution flow

The Fabric of
Space and Time
is under threat!

`call/cc`

The Fabric of
Space and Time
is under threat!

A glimmer of hope

- C++ 11’s transportable exceptions are a reaction to new execution flow models.
- Exceptions are becoming first class objects.
- Exception flow can be manipulated.
- Errors can be captured and propagated across between execution fragments to maintain their association with work items.
- Applications have to work at this.

- More generally…

Causality

Causality

- *the relationship between something that happens or exists and the thing that causes it*

- *cause* and *effect*

Causality

- If execution flow is what enacts *cause* and *effect,* how is this made manifest?

Effect

- Programs do work to compute values.
- Doing **work** gives rise to *values* or *exceptions*.

- *effect* = *values* **or** *exceptions*

Effect

- *Systematic Error Handling in C++ 11*

- Andrei Alexandrescu describes the use of **Expect<T>** to unify the handling of results or the exceptions incurred whilst attempting to compute them.

- Expect<T> encodes a *value* or an *exception*.

- What Expect<T> encodes is *effect*.

- *C++ and Beyond 2012 http://channel9.msdn.com/Shows/Going+Deep/C-and-Beyond-2012-Andrei-Alexandrescu-Systematic-Error-Handling-in-C*

❖ `Expect` is *effect* made manifest:

```
template <class T> class Expect {
  union {
    T ham;
    std::exception_ptr spam;
  };
  bool gotHam;
  ...
}
```

Expect

Promises

- C++ 11 Promises go a step further by promising to represent the results (values or exceptions) of computation that may not yet have completed.
- *future effect*

Promises, promises

- The ability to represent the future results of work is a step towards *execution flow meta-programming*.
- But, C++11’s promises are missing the composability that would enable programs to construct, observe and manipulate their execution own flow.

- *See, for example the Promises/A+ spec from the javascript world:*
  https://promisesaplus.com
  and:
  http://bartoszmilewski.com/2009/03/03/broken-promises-c0x-futures/

- What then of *cause*?

Causality

- It must be manifest in the **work**.

- Programs perform the **work** by calling functions that return values or throw exceptions.

- But functions are complex implementation artifacts. They are too unconstrained to be readily reflected upon and understood.

Cause

- Let's look for *inspiration*…

Cause

Insight

- Andrei Alexandrescu identified a key insight:

  "Error codes are limited, exceptions are arbitrarily rich.

  Make exceptions be the error codes."

- *C++ and Beyond 2012 http://channel9.msdn.com/Shows/Going+Deep/C-and-Beyond-2012-Andrei-Alexandrescu-Systematic-Error-Handling-in-C, slide 12.*

Insight

- … but I think there was something on the previous slide:

  “Exceptions are associated only with root reasons, not goals.

  '*I/O error*' *doesn’t describe* '*saving weight file*'.*”*

- *C++ and Beyond 2012 http://channel9.msdn.com/Shows/Going+Deep/C-and-Beyond-2012-Andrei-Alexandrescu-Systematic-Error-Handling-in-C, slide 11.*

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Insight

- *C++ and Beyond 2012 http://channel9.msdn.com/Shows/Going+Deep/C-and-Beyond-2012-Andrei-Alexandrescu-Systematic-Error-Handling-in-C, slide 11.*

Exceptions re-examined

Exceptions re-examined

- Exception handling is also execution flow control, albeit backwards.
- It has fewer degrees of freedom.
- Scary documents extol narrow best practice: *don't, no really don't,* ***or else****...*
- http://www.boost.org/community/error_handling.html

- In other words:

  "When an exception is thrown I shall smite thee back to the dark ages."

Taking exception

- In other words:

  "When an exception is thrown I shall smite thee back to the dark ages."

  "Thou shalt not use std::string."

Taking exception

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  “When an exception is thrown I shall smite thee back to the dark ages.”

  “Thou shalt not use std::string.”

  “Thou shalt pre-allocate buffers for text and use strcpy.”

Taking exception

Taking exception

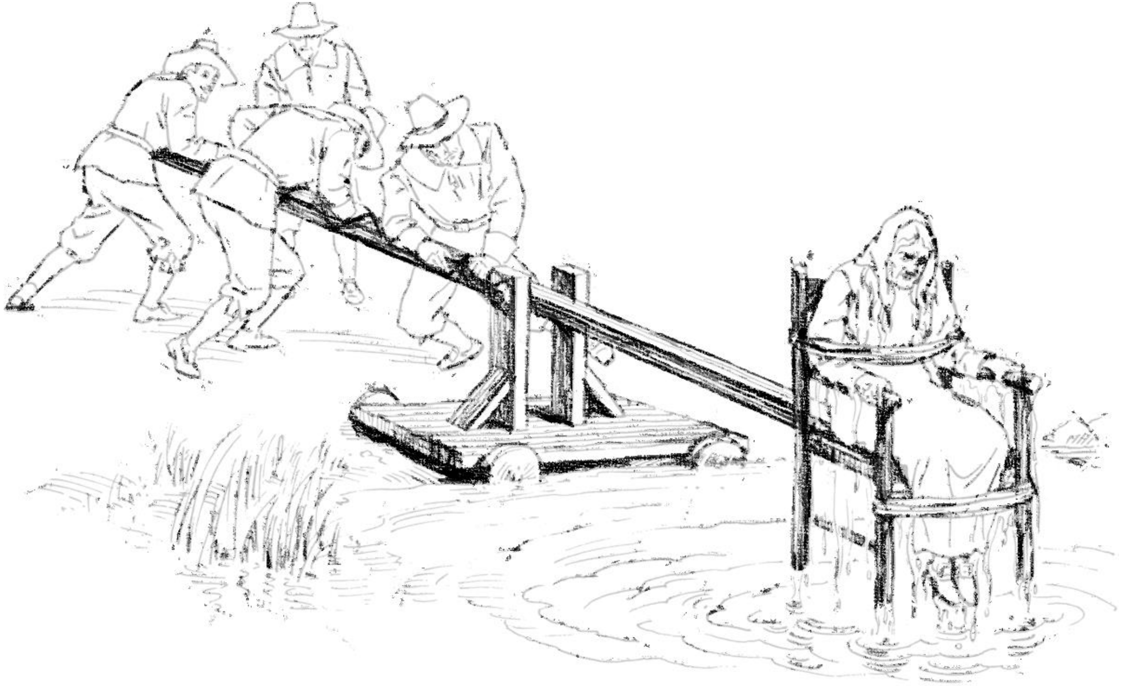
- In other words:

  "When an exception is thrown I shall smite thee back to the dark ages."

  "Thou shalt not use std::string."

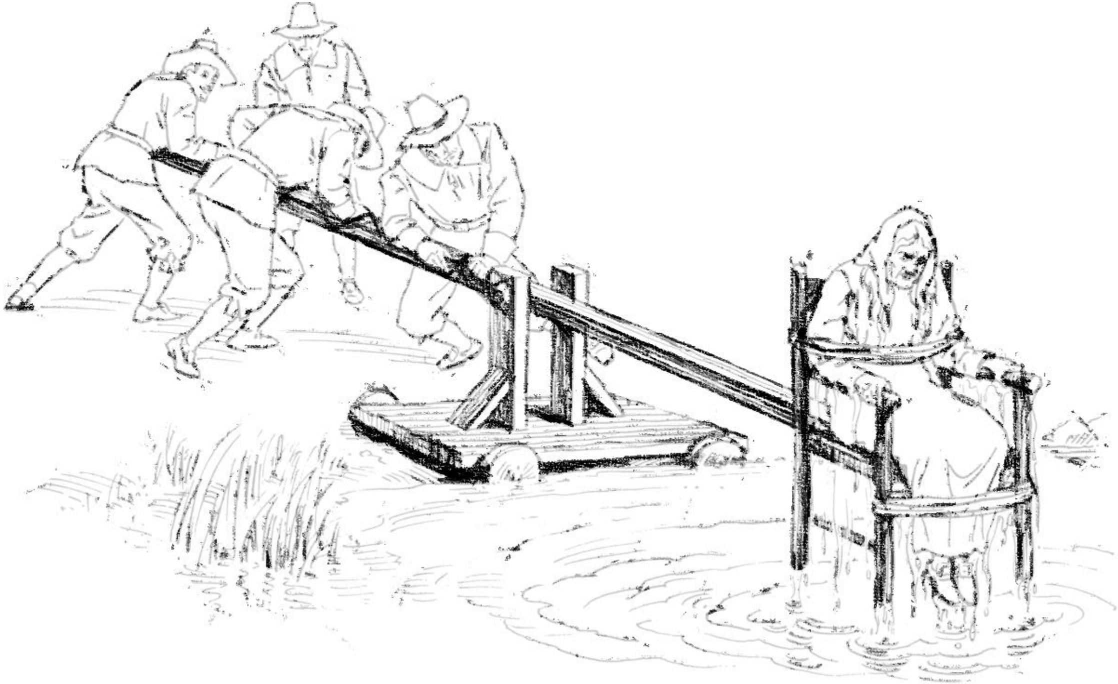
  "Thou shalt pre-allocate buffers for text and use strcpy."

  "Thou shalt not be tempted by opportunities for exotic flow control."



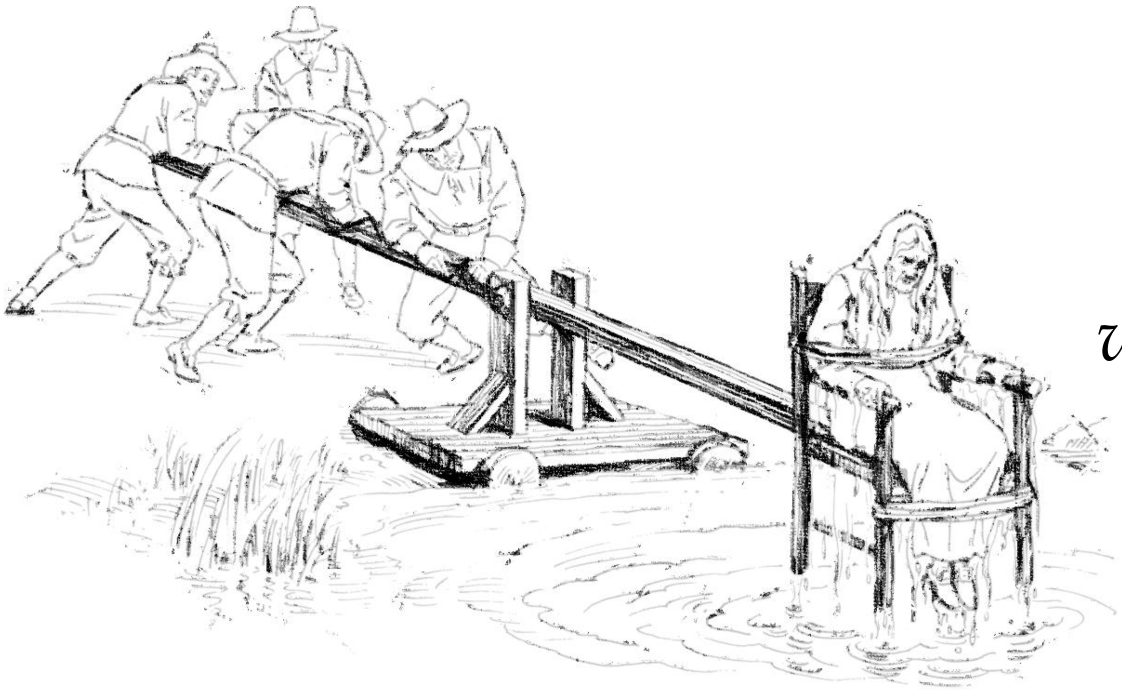
Or else…

- *Adapted from http://en.wikipedia.org/wiki/Cucking_stool#/media/File:Ducking-Stool_1_(PSF).png*



relax…

- *Adapted from http://en.wikipedia.org/wiki/Cucking_stool#/media/File:Ducking-Stool_1_(PSF).png*



because
we're made of
sterner stuff

Exceptions re-examined

- Exceptions are *out of band*, invisible to intervening code.
- We talk about code being *transparent to exceptions*.

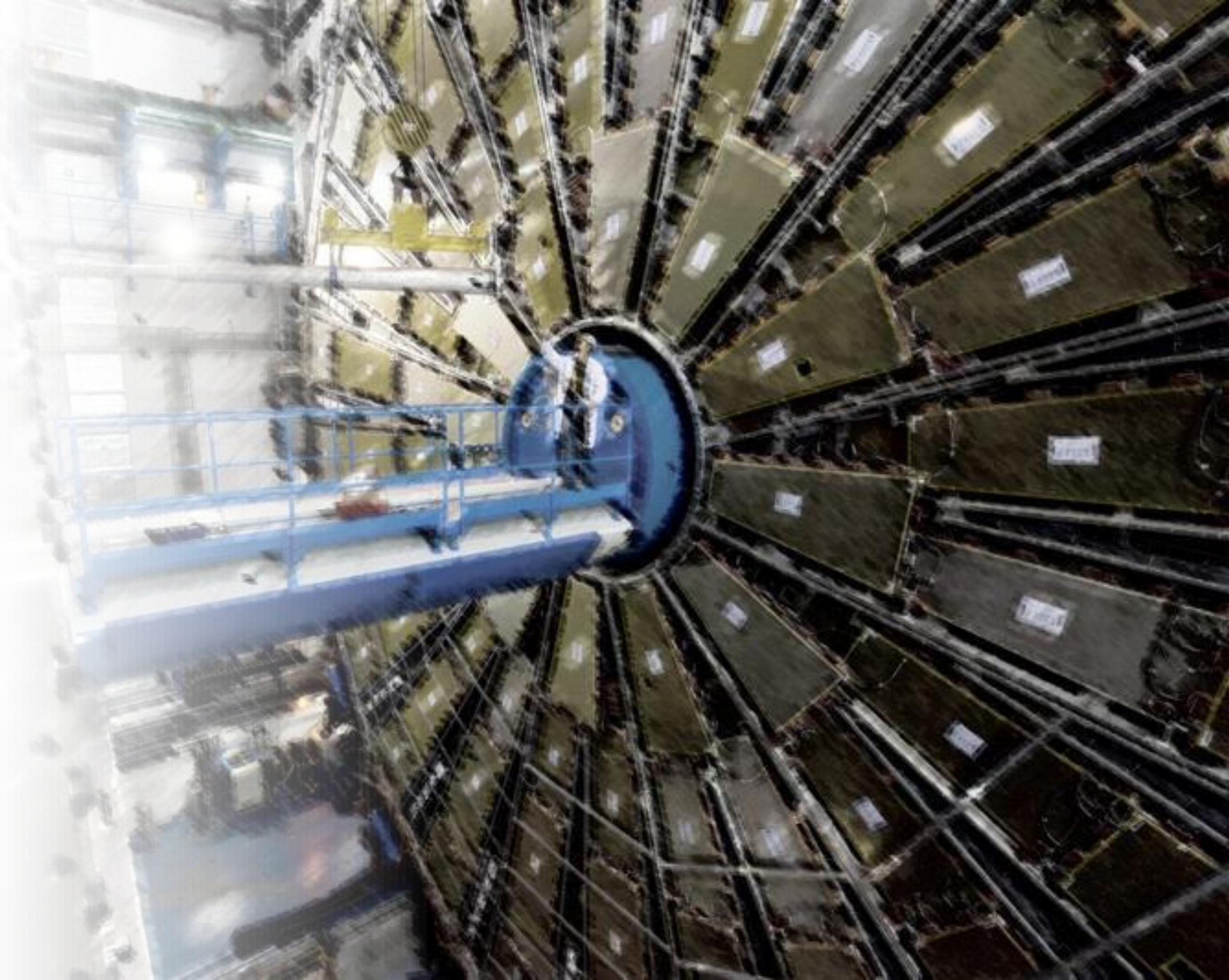
Exceptions re-examined

- Yet the resulting execution flow **can** be observed by suitably constructed detector.

Exceptions re-examined

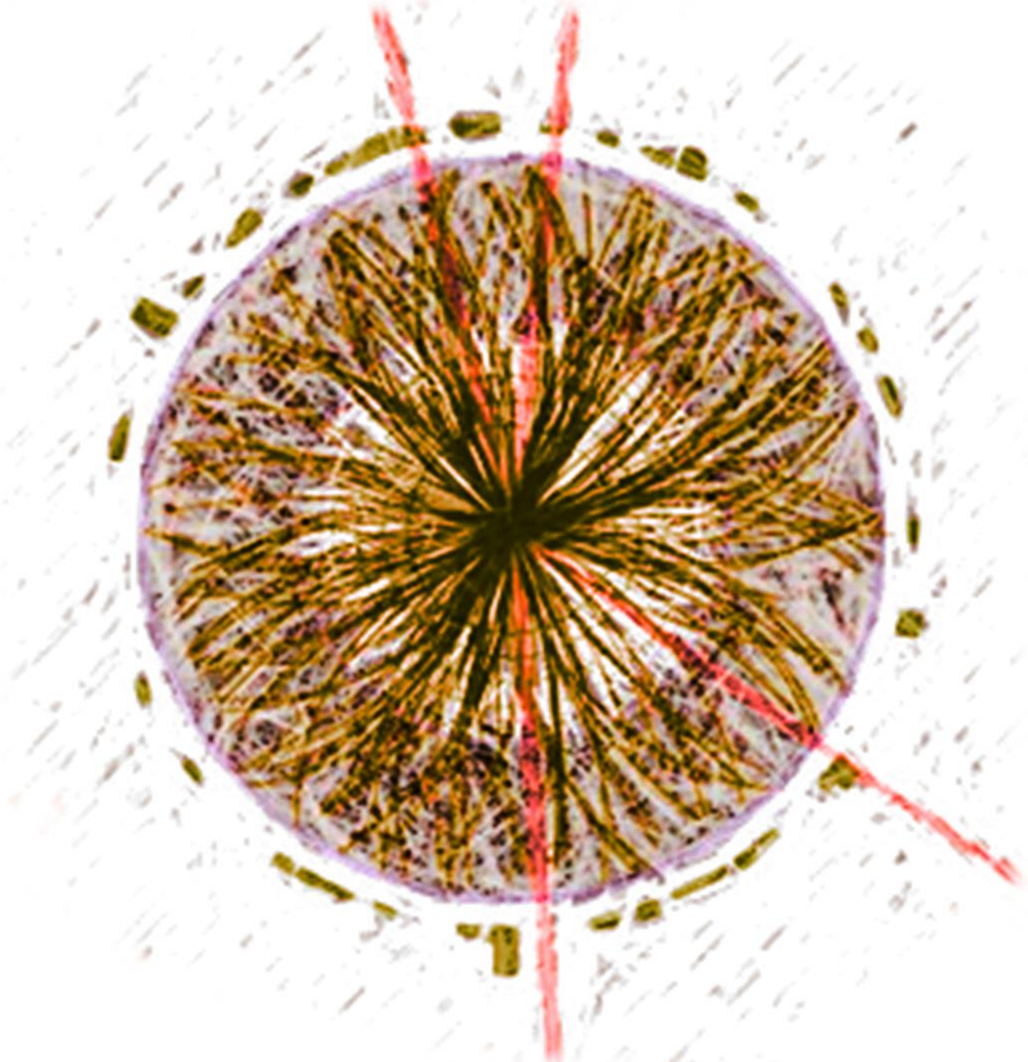
- Luckily Axel Naumann from CERN was here yesterday…

❖ And lent me some spare parts



❖ *Adapted from photo: © CERN*

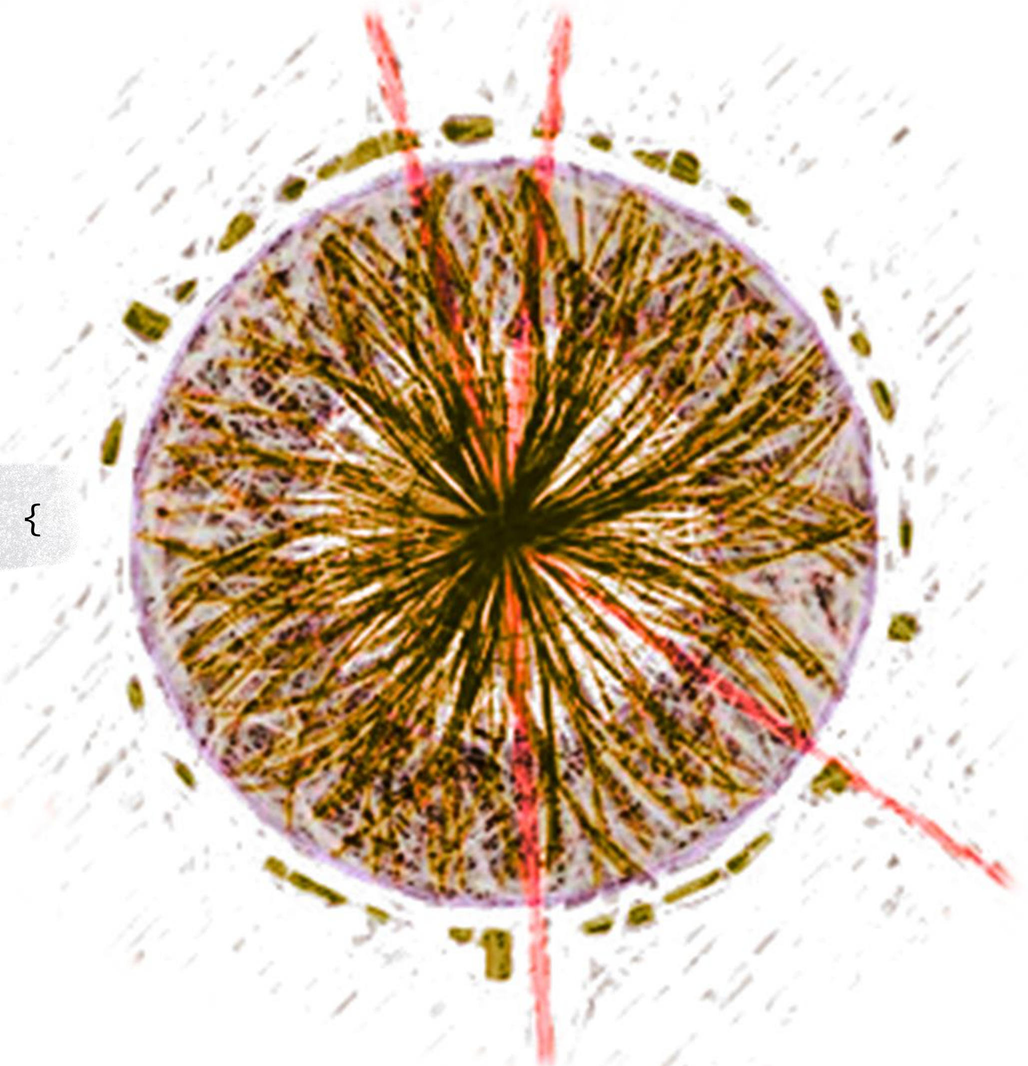
- Exception detector



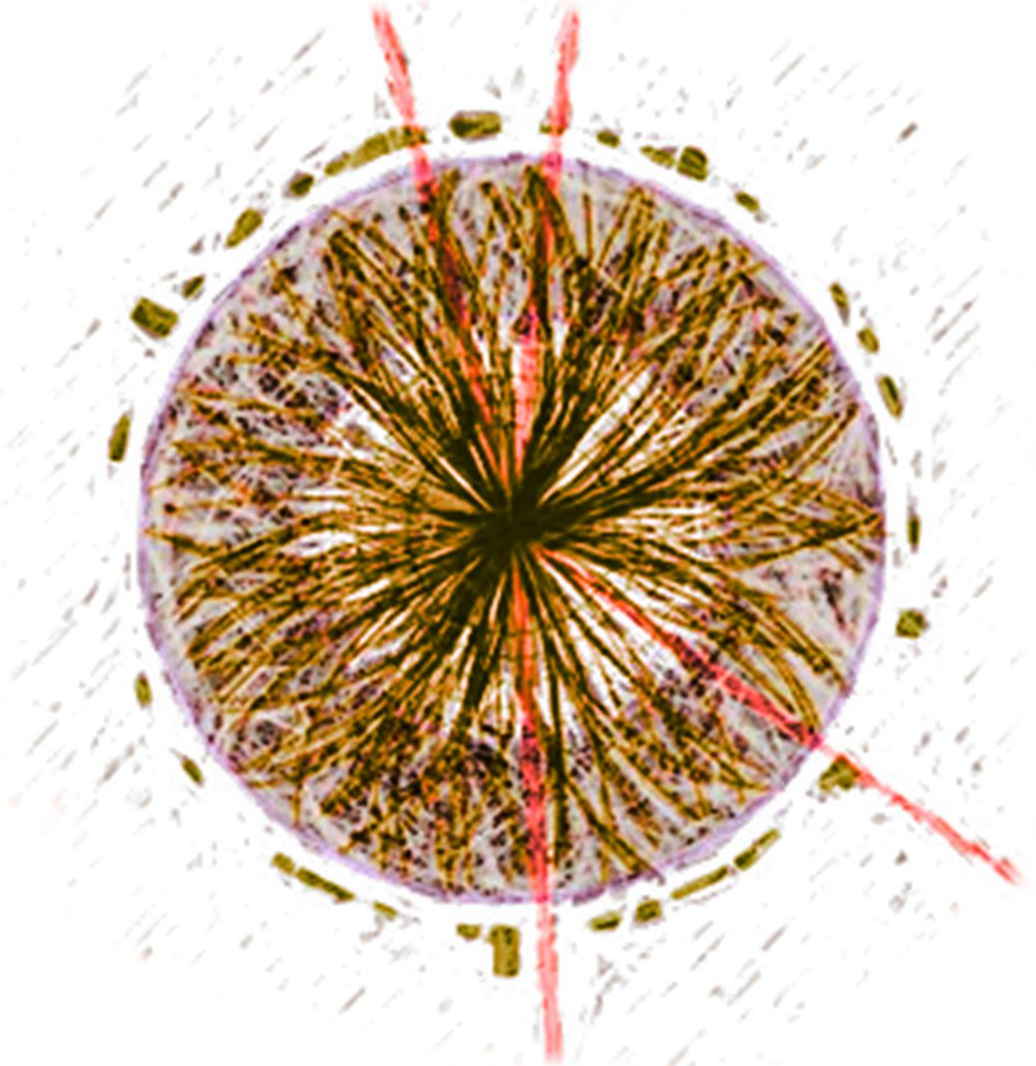
- *Adapted from ATLAS Experiment © 2012 CERN*

```
detector() {
  entering a scope
};

~detector() {
  leaving a scope
  if (std::uncaught_exception()) {
    exceptionally
  } else {
    normally
  }
};
```



- Is this detector safe?



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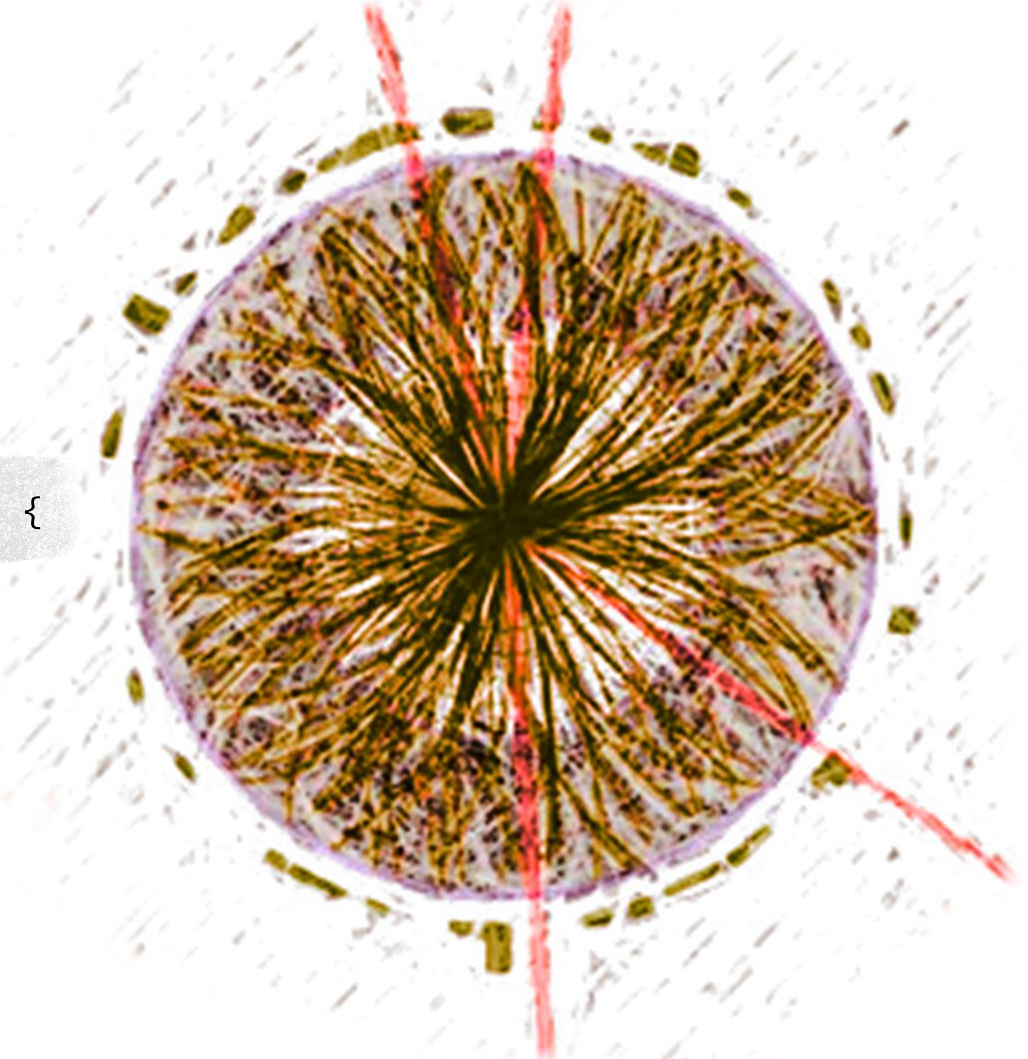
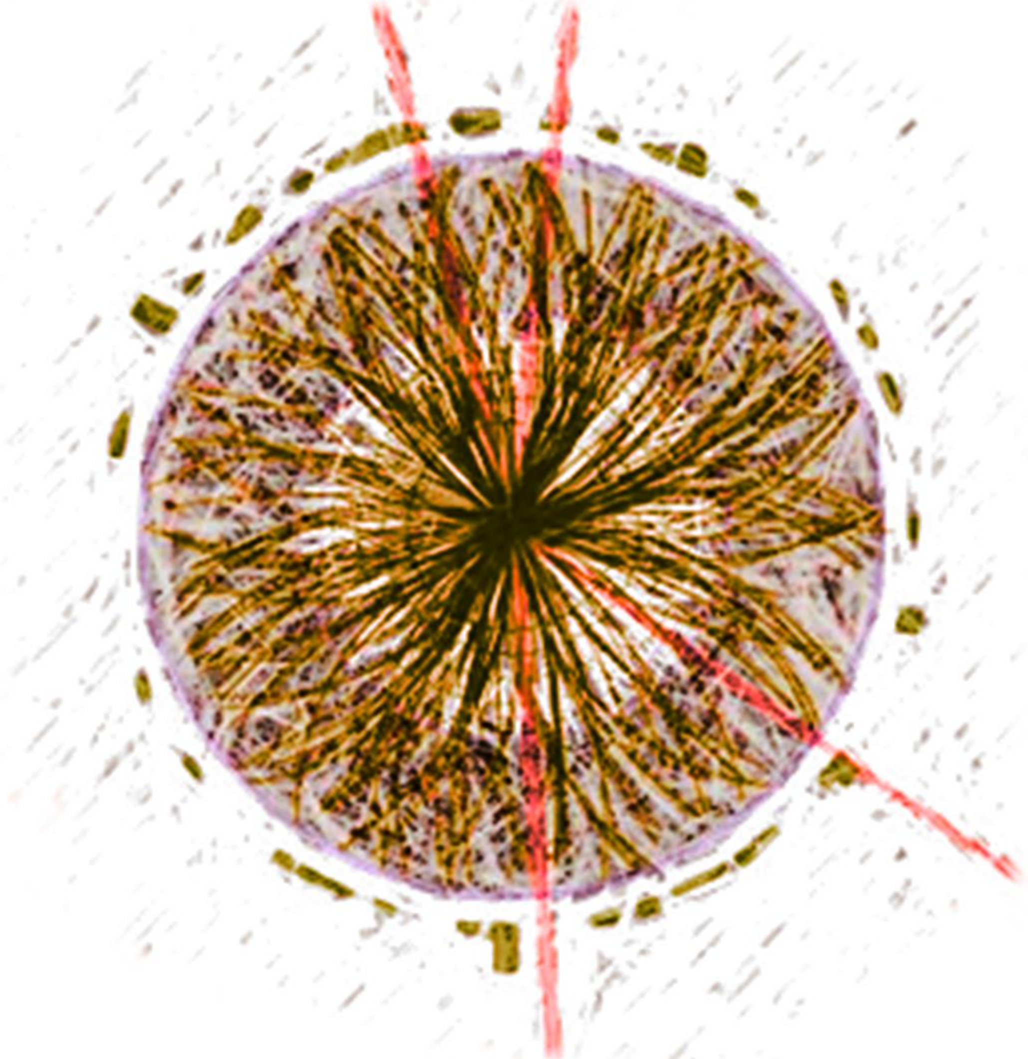
(see: `ScopeGuard ↓`)



- *C++ and Beyond 2012 http://channel9.msdn.com/Shows/Going+Deep/C-and-Beyond-2012-Andrei-Alexandrescu-Systematic-Error-Handling-in-C*

- Don't worry…

  Andrei Alexandrescu says that this is perfectly fine!



The nature of Exceptions

The nature of Exceptions

- The standard has a hierarchy of exception types.
- Whilst some have questioned the utility of the hierarchy, this codification of the **reason** for the exception flow is interesting.
- There is no current analog of this for the forward flow of execution in functions.

- What would a forward equivalent of exceptions look like?

- Like exceptions:
  - Out of band (*not a parameter to every function*)
  - Inspectable
  - Capturable
  - Transportable

- But what()?

Norms?

- If functions are too complex, could *Norms* capture something about functions that we could reflect on?

Norms?

Intentions

- What we want to reify is the *intent* of programs.
- Intentions provide the context in which exceptions make sense.
- Exceptions express "*what went wrong*" in the context of "*what I was trying to do*".

- *cause* = *functions implementing* *intent*
- *effect* = *values* **or** *exceptions*

Part III

Genesis of Intent

Genesis of Intent

- Simplifying error message creation.

- The problem…

Error messages

Breakfast

```
void main() {
  try {
    breakfast(bacon_and_eggs);
  } catch(...) {
    error(std::current_exception());
  }
}
```

```
void breakfast(recipe &fav) {
  prepare(fav);
}
```

Breakfast

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```
void breakfast(recipe &fav) {
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}

void prepare(recipe &r) {
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}
```

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void prepare(recipe &r) {
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  }
}

void fetch(ingredient &i) {
  cupboard.get(i);
}
```

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}

void fetch(ingredient &i) {
  cupboard.get(i);
}

void cupboard::get(ingredient &i) {
  if (empty()) {
    throw std::runtime_exception("the cupboard was bare");
  }
}
```

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void main() {
  try {
    breakfast(bacon_and_eggs);
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“ **the cupboard was bare** ”

```
void main() {
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```

- *“Exceptions are associated only with root reasons, not goals.*

  'I/O error' doesn’t describe 'saving weight file'.”

  Andrei Alexandrescu

“ `the cupboard was bare` ”

- Trying again, with nested exceptions…

Error messages

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  try {
    cupboard.get( i );
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not fetch ingredient: " + i));
  }
}
```

```
void breakfast(recipe &fav) {
  prepare(fav);
}
```

```
void prepare(recipe &r) {
  try {
    for(const auto &i : r.ingredients()) {
      fetch(i);
    }
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not prepare recipe: " + r));
  }
}
```

```
void fetch(ingredient &i) {
  try {
    cupboard.get( i );
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not fetch ingredient: " + i));
  }
}
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```
void breakfast(recipe &fav) {
  try {
    prepare(fav);
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not have breakfast”));
  }
}

void prepare(recipe &r) {
  try {
    for(const auto &i : r.ingredients()) {
      fetch(i);
    }
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not prepare recipe: " + r));
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    cupboard.get( i );
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  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not have breakfast”));
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  try {
    for(const auto &i : r.ingredients()) {
      fetch(i);
    }
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not prepare recipe: " + r));
  }
}
```

the cupboard was bare

```
void fetch(ingredient &i) {
  try {
    cupboard.get( i );
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not fetch ingredient: " + i));
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  try {
    prepare(fav);
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    std::throw_with_nested(std::runtime_error("could not have breakfast”));
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    for(const auto &i : r.ingredients()) {
      fetch(i);
    }
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    std::throw_with_nested(std::runtime_error("could not prepare recipe: " + r));
  }
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  try {
    cupboard.get( i );
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not fetch ingredient: " + i));
  }
}
```

the cupboard was bare

```cpp
void breakfast(recipe &fav) {
  try {
    prepare(fav);
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not have breakfast”));
  }
}

void prepare(recipe &r) {
  try {
    for(const auto &i : r.ingredients()) {
      fetch(i);
    }
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not prepare recipe: " + r));
  }
}

void fetch(ingredient &i) {
  try {
    cupboard.get( i );
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not fetch ingredient: " + i));
  }
}
```

the cupboard was bare

```
void breakfast(recipe &fav) {
  try {
    prepare(fav);
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not have breakfast”));
  }
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  try {
    for(const auto &i : r.ingredients()) {
      fetch(i);
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  } catch(...) {
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  }
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void fetch(ingredient &i) {
  try {
    cupboard.get( i );
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not fetch ingredient: " + i));
  }
}
```

the cupboard was bare

```
void breakfast(recipe &fav) {
  try {
    prepare(fav);
  } catch(...) {
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void prepare(recipe &r) {
  try {
    for(const auto &i : r.ingredients()) {
      fetch(i);
    }
  } catch(...) {
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  }
}

void fetch(ingredient &i) {
  try {
    cupboard.get( i );
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not fetch ingredient: " + i));
  }
}
```

“
```
could not have breakfast
 could not prepare recipe: bacon and eggs
  could not fetch ingredient: eggs
   the cupboard was bare
```
”

the cupboard was bare

```
void breakfast(recipe &fav) {
  try {
    prepare(fav);
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not have breakfast"));
  }
}

void prepare(recipe &r) {
  try {
    for(const auto &i : r.ingredients()) {
      fetch(i);
    }
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not prepare recipe: " + r));
  }
}

void fetch(ingredient &i) {
  try {
    cupboard.get( i );
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    std::throw_with_nested(std::runtime_error("could not fetch ingredient: " + i));
  }
}
```

```
void breakfast(recipe &fav) {

    prepare(fav);



}

void prepare(recipe &r) {

    for(const auto &i : r.ingredients()) {
      fetch(i);
    }



}

void fetch(ingredient &i) {

    cupboard.get( i );



}
```

A dog’s breakfast

```
void breakfast(recipe &fav) {
  try {
    prepare(fav);
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not have breakfast”));
  }
}

void prepare(recipe &r) {
  try {
    for(const auto &i : r.ingredients()) {
      fetch(i);
    }
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not prepare recipe: " + r));
  }
}

void fetch(ingredient &i) {
  try {
    cupboard.get( i );
  } catch(...) {
    std::throw_with_nested(std::runtime_error("could not fetch ingredient: " + i));
  }
}
```

- A gedanken experiment…

Error messages

```
void breakfast(recipe &fav) {
  prepare(fav);
}

void prepare(recipe &r) {
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  cupboard.get(i);
}
```

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

the cupboard was bare

```
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  whilst("having breakfast");
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void prepare(recipe &r) {
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  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

the cupboard was bare

```
void main() {
  try {
    breakfast(bacon_and_eggs);
  } catch(...) {
    error(std::current_exception(),
          current_intentions());
  }
}
```

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

“ **whilst** having breakfast
whilst preparing ***bacon and eggs***
whilst fetching ***eggs***
the cupboard was bare ”


```
void main() {
  try {
    breakfast(bacon_and_eggs);
  } catch(...) {
    error(std::current_exception(),
          current_intentions());
  }
}
```

```cpp
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

“ **whilst** having breakfast
 whilst preparing ***bacon and eggs***
  whilst fetching ***eggs***
   the cupboard was bare ”

We expressed intent

```cpp
void main() {
  try {
    breakfast(bacon_and_eggs);
  } catch(...) {
    error(std::current_exception(),
          current_intentions());
  }
}
```

- *“Exceptions are associated only with root reasons, not **goals**.*

  'I/O error' doesn’t describe 'saving weight file'.”

  Andrei Alexandrescu

“
```
whilst having breakfast
 whilst preparing bacon and eggs
  whilst fetching eggs
   the cupboard was bare
```
”

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

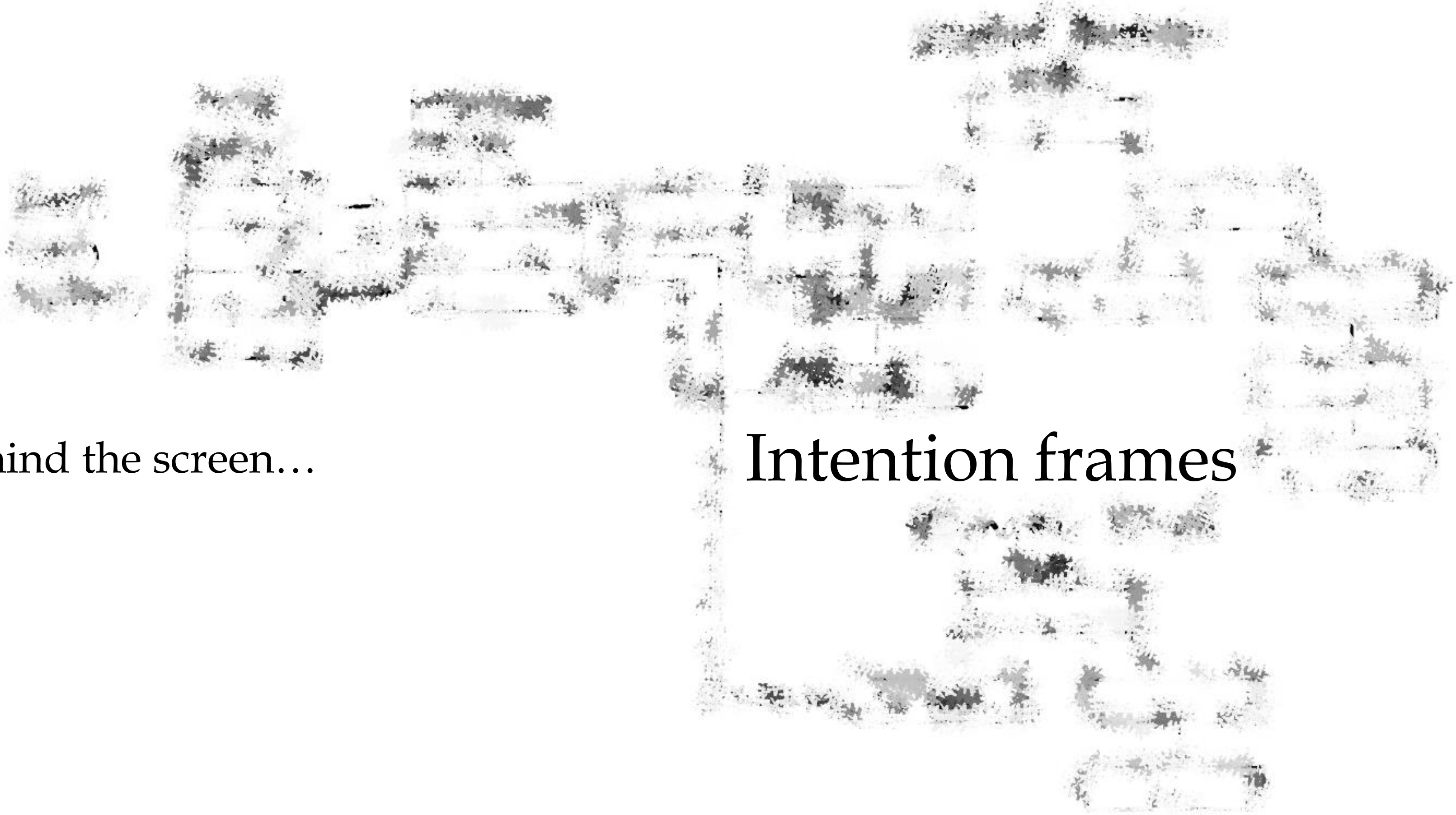
void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

“**whilst** having breakfast
whilst preparing ***bacon and eggs***
whilst fetching ***eggs***
the cupboard was bare”

Expressing intent

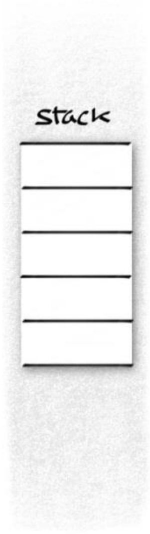
```
void main() {
  try {
    breakfast(bacon_and_eggs);
  } catch(...) {
    error(std::current_exception(),
          current_intentions());
  }
}
```

Intention frames

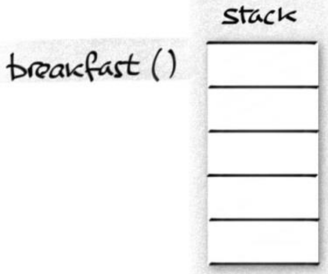


- Behind the screen…

An unintentional breakfast

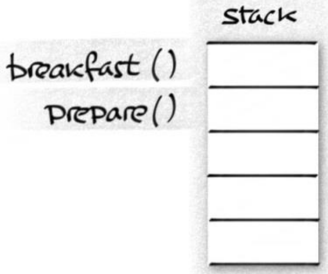


breakfast



breakfast

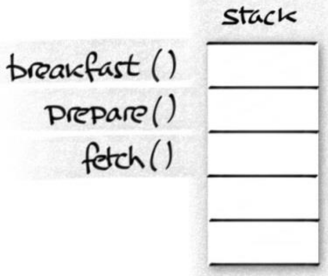
```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}
```



breakfast

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}
```

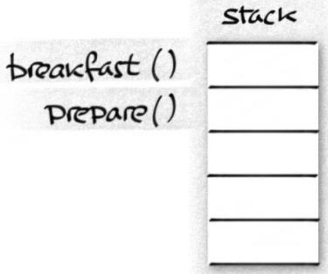


breakfast

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```



breakfast

```
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  for(const auto &i : r.ingredients()) {
    fetch(i);
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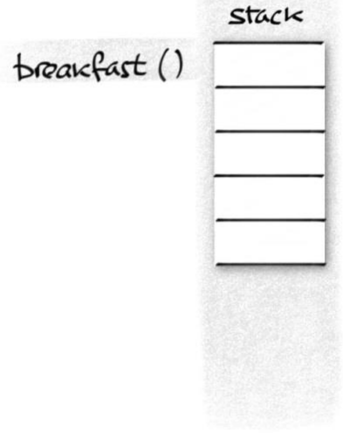
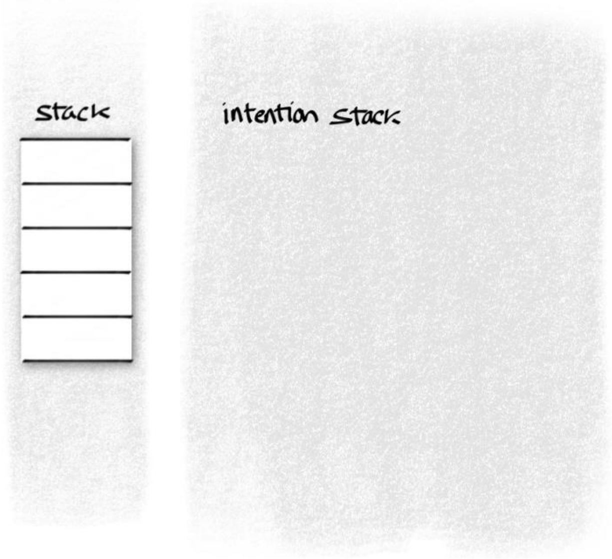


breakfast

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}
```

breakfast

An
intentional
breakfast



breakfast

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  whilst("preparing {recipe}", r);
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}

void fetch(ingredient &i) {
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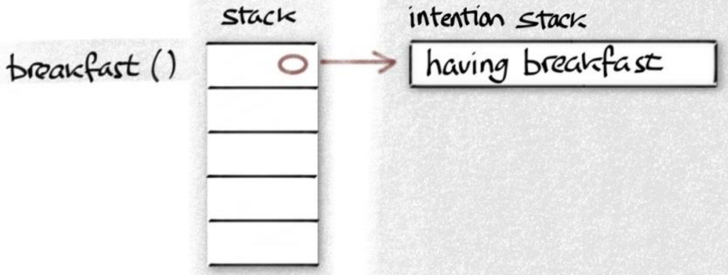

breakfast

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  whilst("preparing {recipe}", r);
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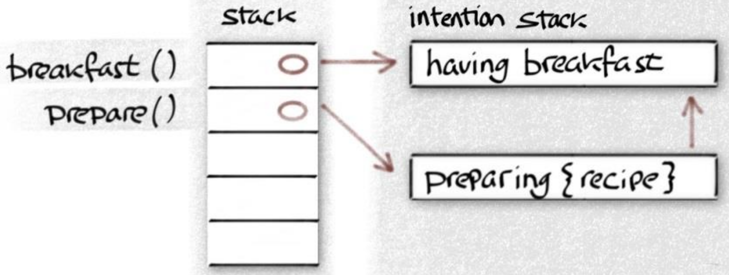

breakfast

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  whilst("preparing {recipe}", r);
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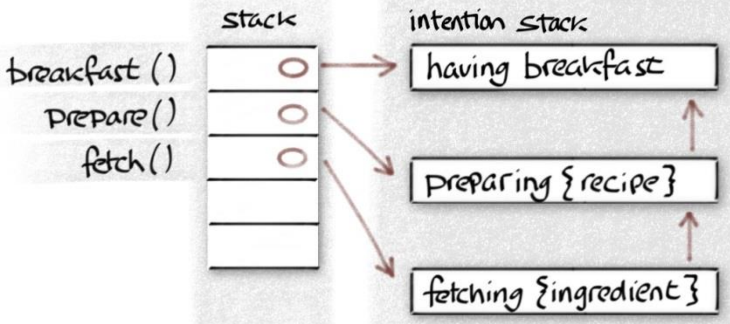

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  whilst("preparing {recipe}", r);
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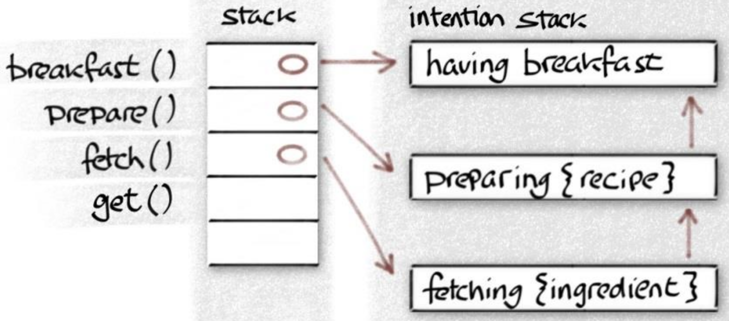
breakfast

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  whilst("preparing {recipe}", r);
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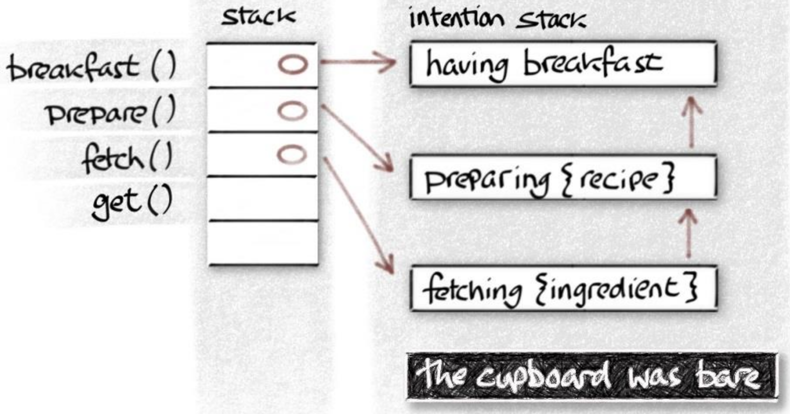
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

```
void cupboard::get(ingredient &i) {
  if (empty()) {
    throw std::runtime_exception("the cupboard was bare");
  }
}
```

breakfast

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  whilst("fetching {ingredient}", i);
  cupboard.get(i);
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void cupboard::get(ingredient &i) {
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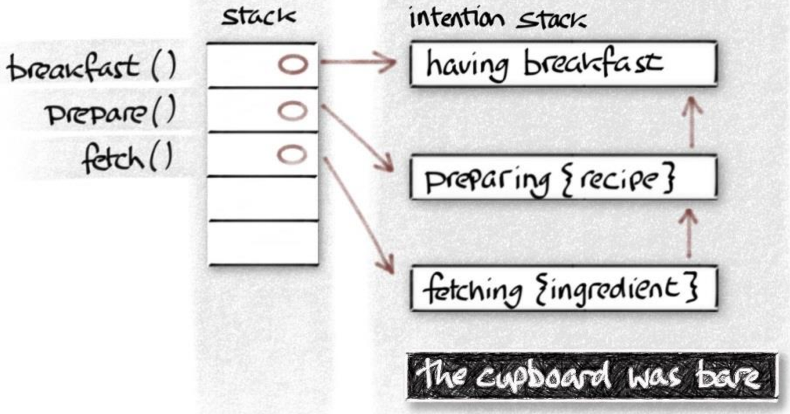

breakfast

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  whilst("preparing {recipe}", r);
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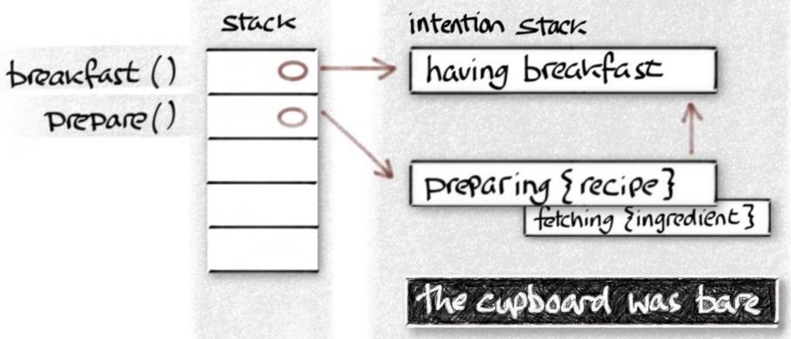
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

breakfast




```
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  whilst("having breakfast");
  prepare(fav);
}

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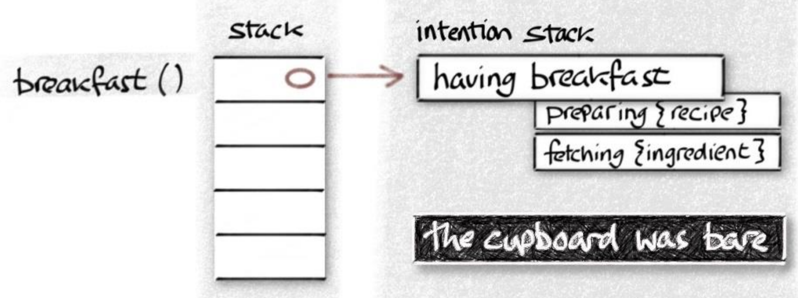
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}
```



breakfast

```
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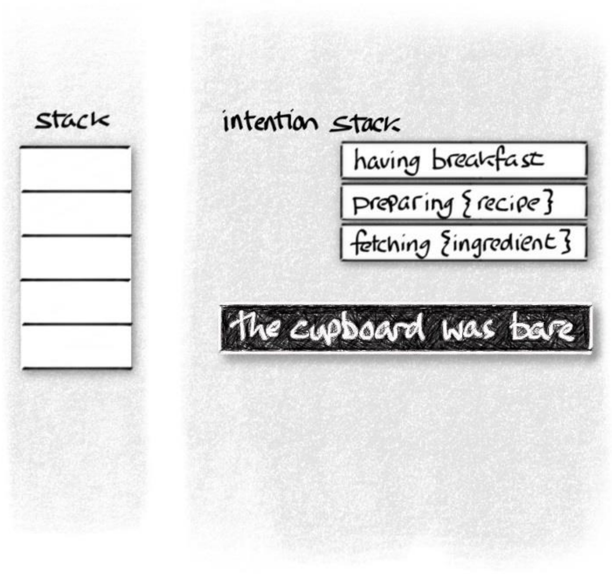
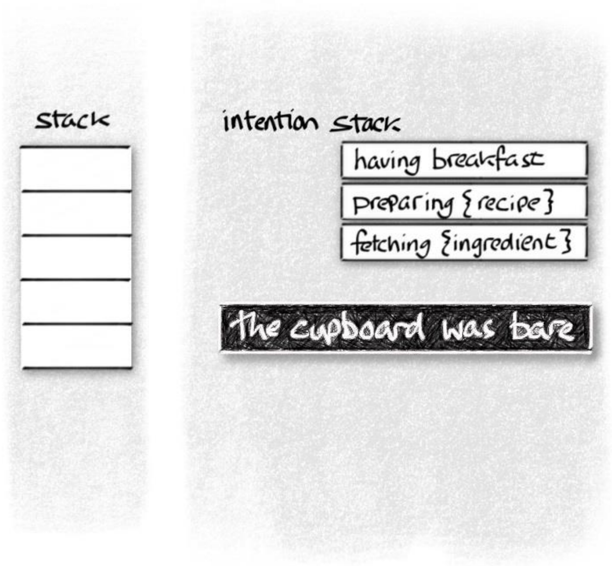
```

breakfast




```
void main() {
  try {
    breakfast(bacon_and_eggs);
  } catch(...) {
    error(std::current_exception(),
          current_intentions());
  }
}
```

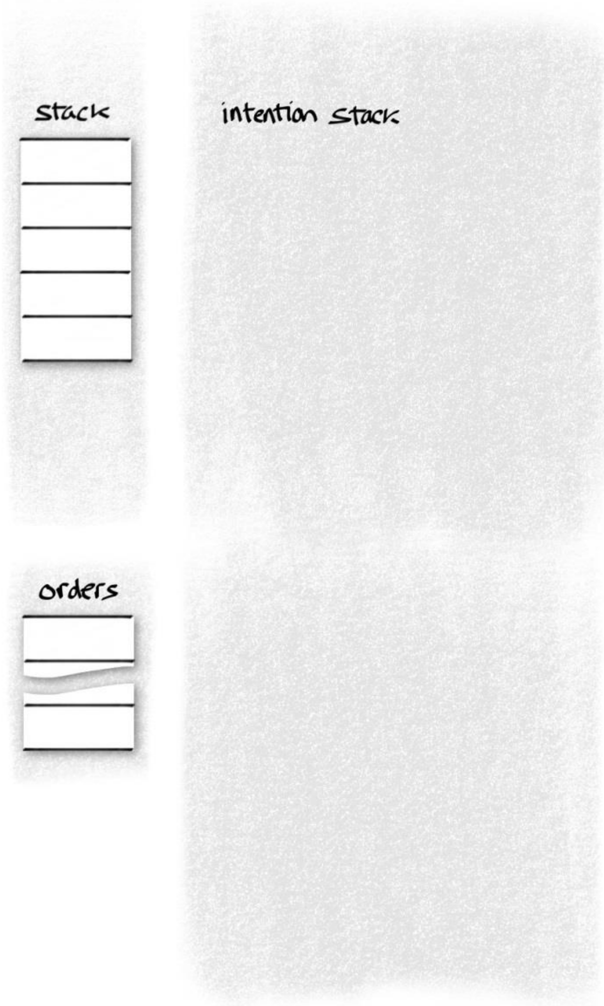


understanding our disappointment

“ **whilst** having breakfast
 whilst preparing ***bacon and eggs***
  whilst fetching ***eggs***
   <u>*the cupboard was bare*</u> ”

```
void main() {
  try {
    breakfast(bacon_and_eggs);
  } catch(...) {
    error(std::current_exception(),
          current_intentions());
  }
}
```

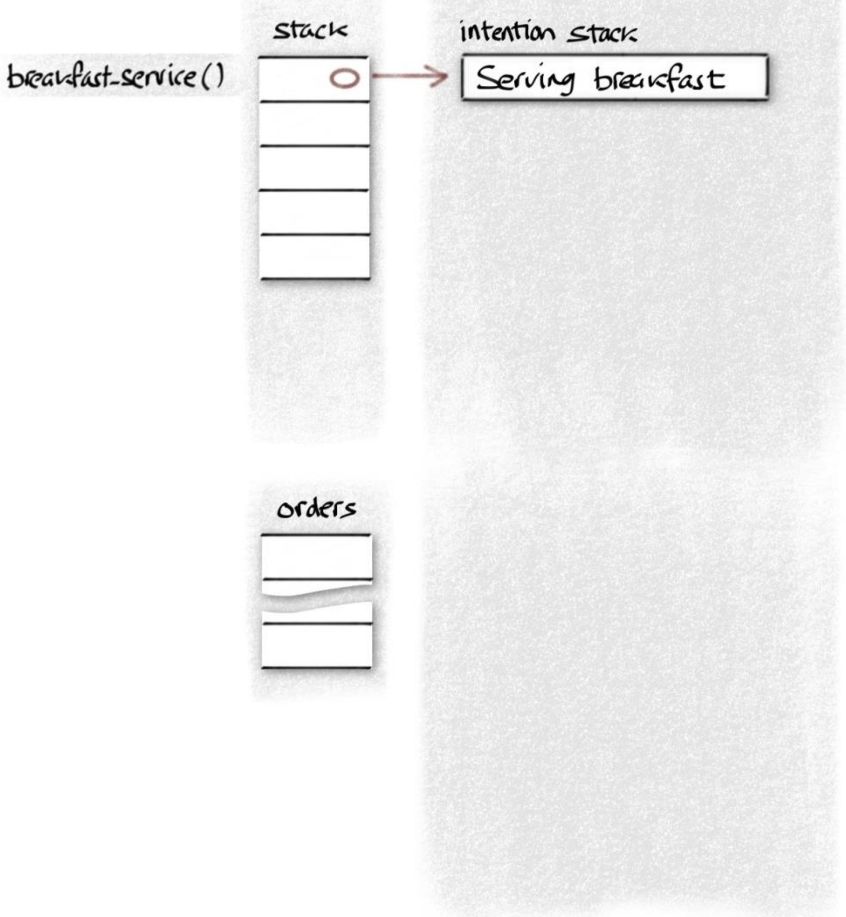
An
exceptional
Cafe



the cafe

```
void breakfast_service() {
  whilst("serving breakfast");
  while (customers.waiting())
    take_order(customers.dequeue());
  }
}

void take_order(customer c) {
  whilst("serving {customer}", c);
  orders.queue(order(c,
                     c.choice(),
                     current_intentions()));
}
```



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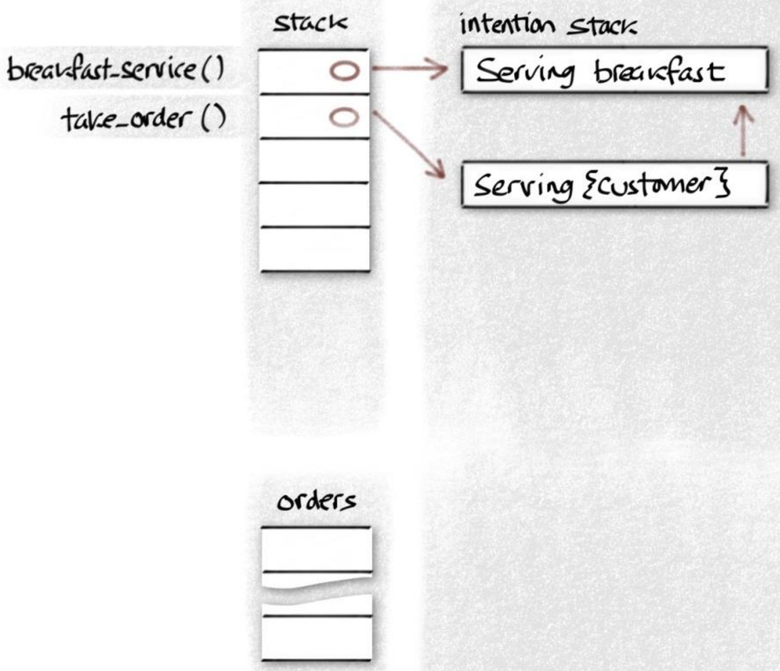

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  whilst("serving {customer}", c);
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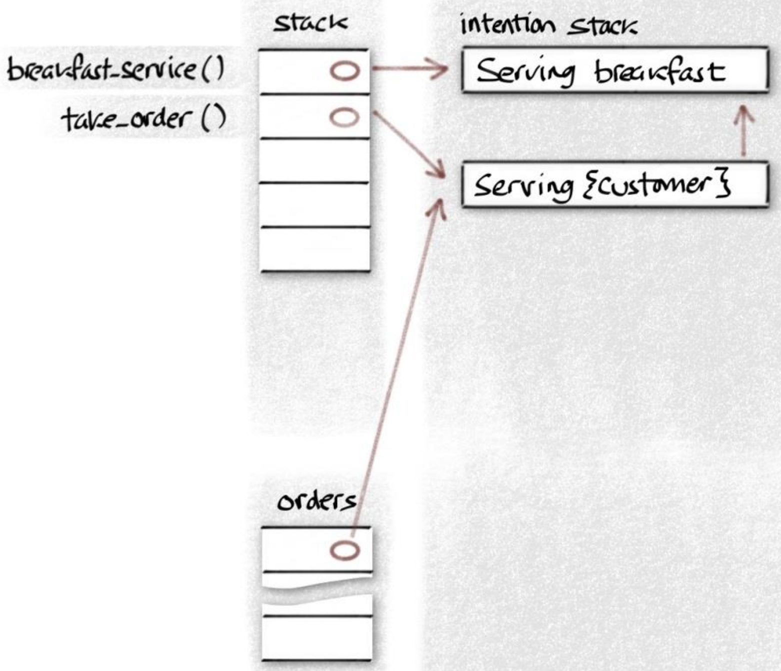

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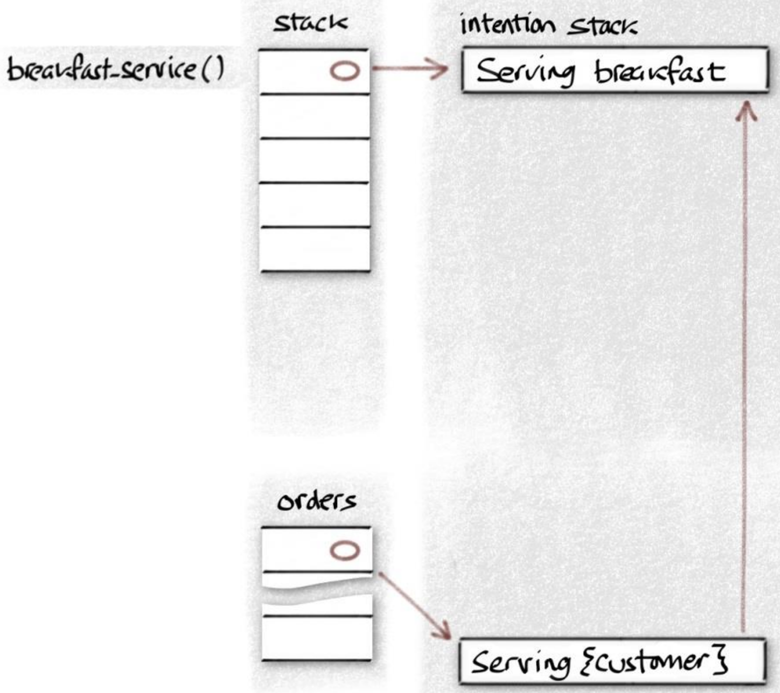
}
```

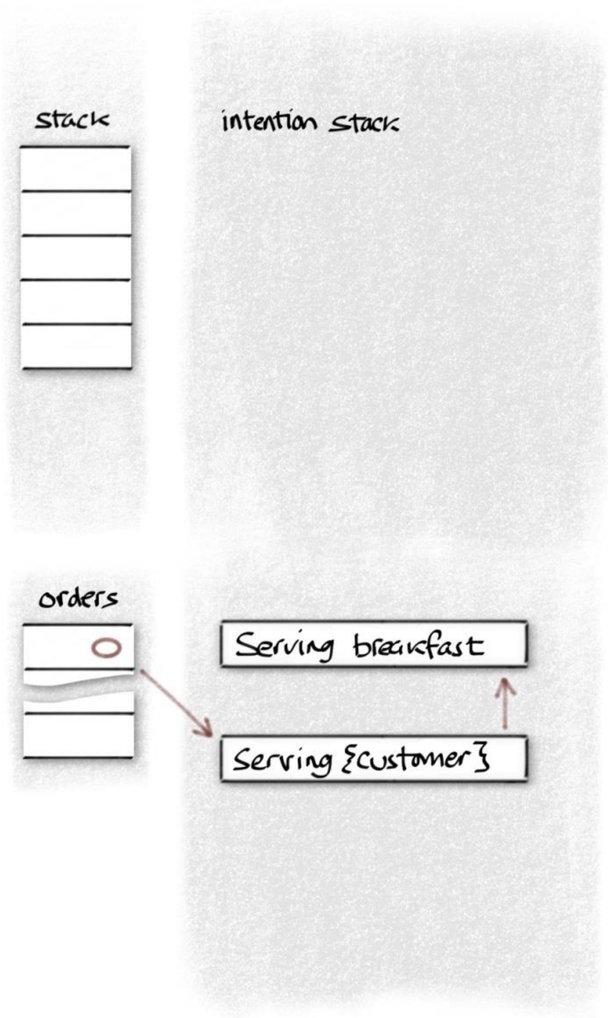


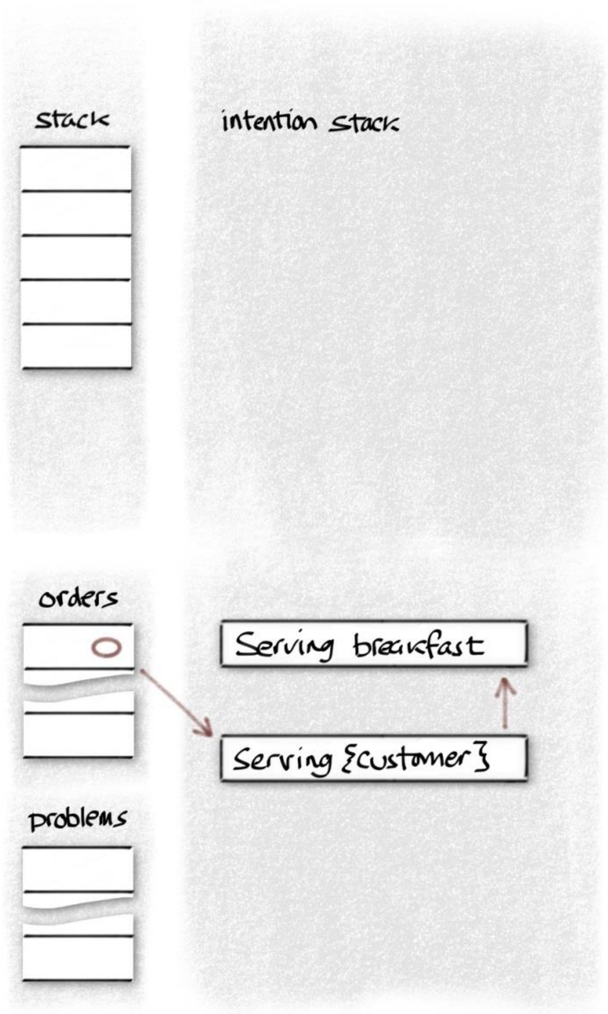
the cafe

```
void breakfast_service() {
  whilst("serving breakfast");
  while (customers.waiting())
    take_order(customers.dequeue());
  }
}

void take_order(customer c) {
  whilst("serving {customer}", c);
  orders.queue(order(c,
                     c.choice(),
                     current_intentions()));
}
```

the kitchen


stack
intention stack
orders
Serving breakfast
Serving {customer}

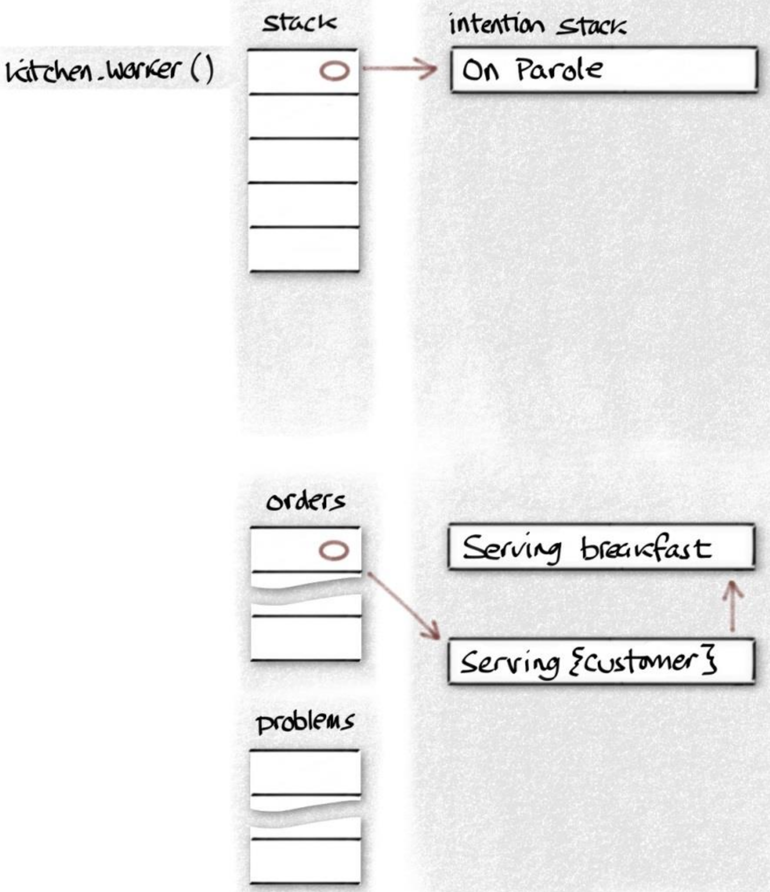


the kitchen

```
void kitchen_worker() {
  whilst("on parole");
  while (orders.waiting()) {
    prepare_order(orders.dequeue());
  }
}

void prepare_order(order o) {
  with_intent(o.intent());
  try {
    prepare(o.recipe());
  } catch(...) {
    problems.queue(problem(o,
                           std::current_exception(),
                           current_intentions()));
  }
}
```

the kitchen

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  try {
    prepare(o.recipe());
  } catch(...) {
    problems.queue(problem(o,
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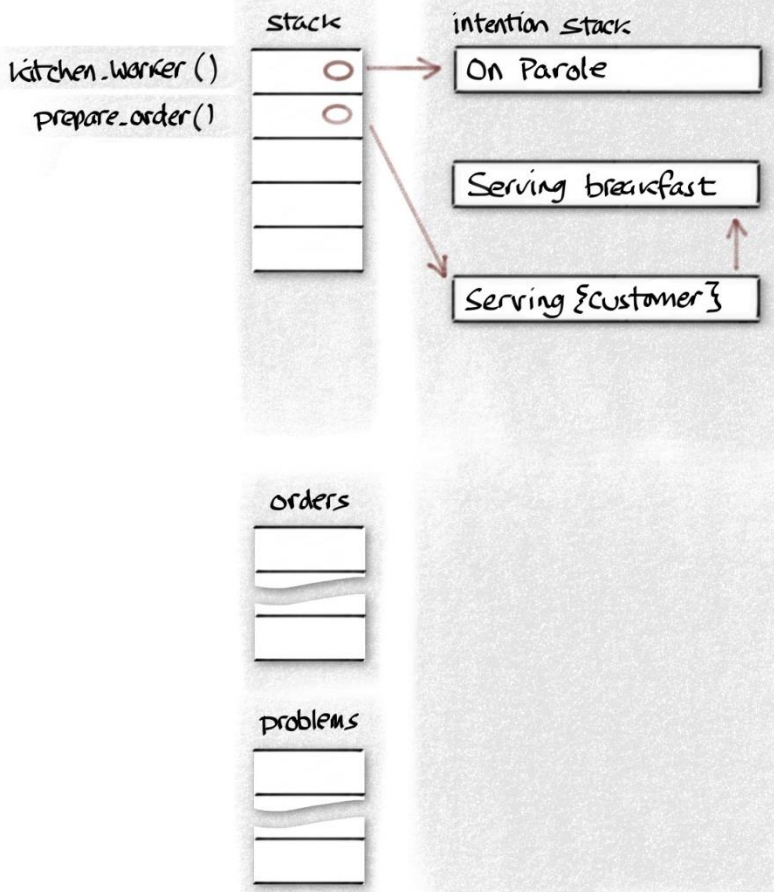
  }
}
```



the kitchen

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void kitchen_worker() {
  whilst("on parole");
  while (orders.waiting()) {
    prepare_order(orders.dequeue());
  }
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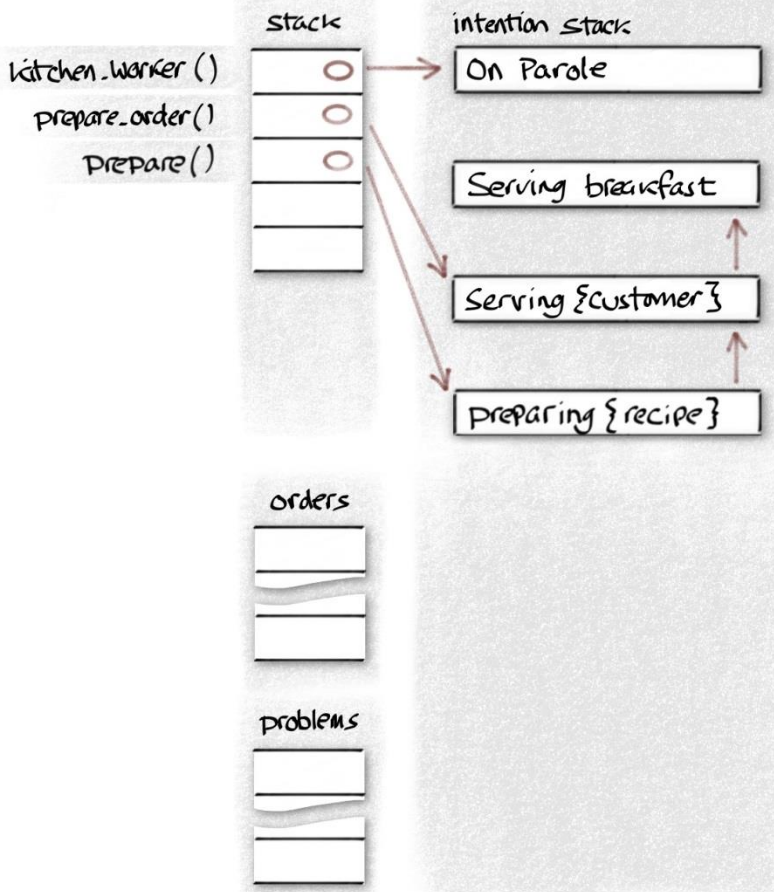
}
```



the kitchen

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  try {
    prepare(o.recipe());
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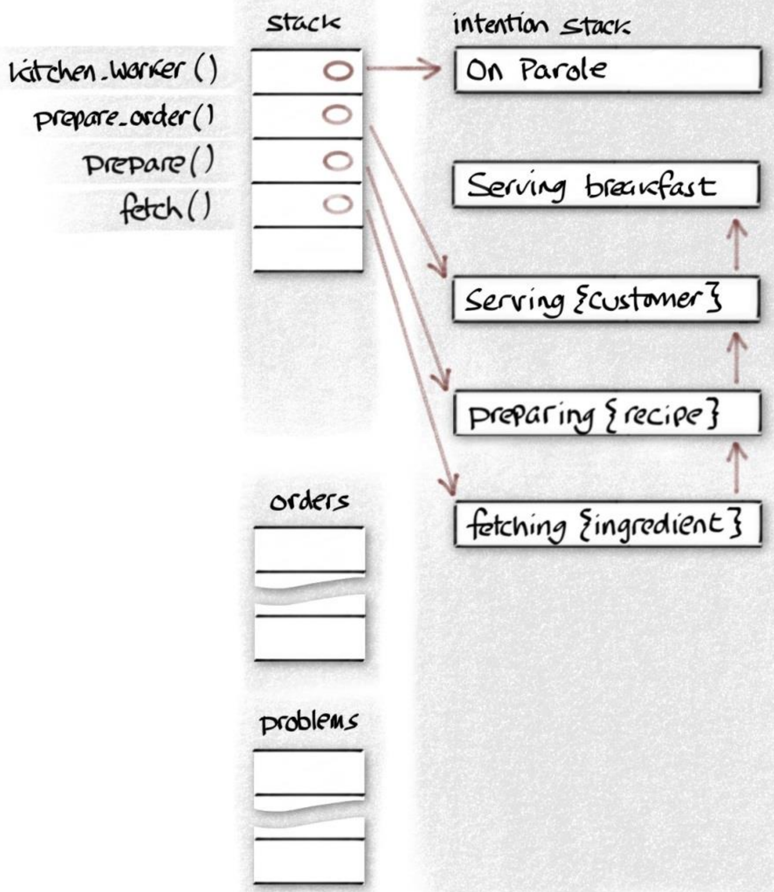
  }
}
```

the kitchen

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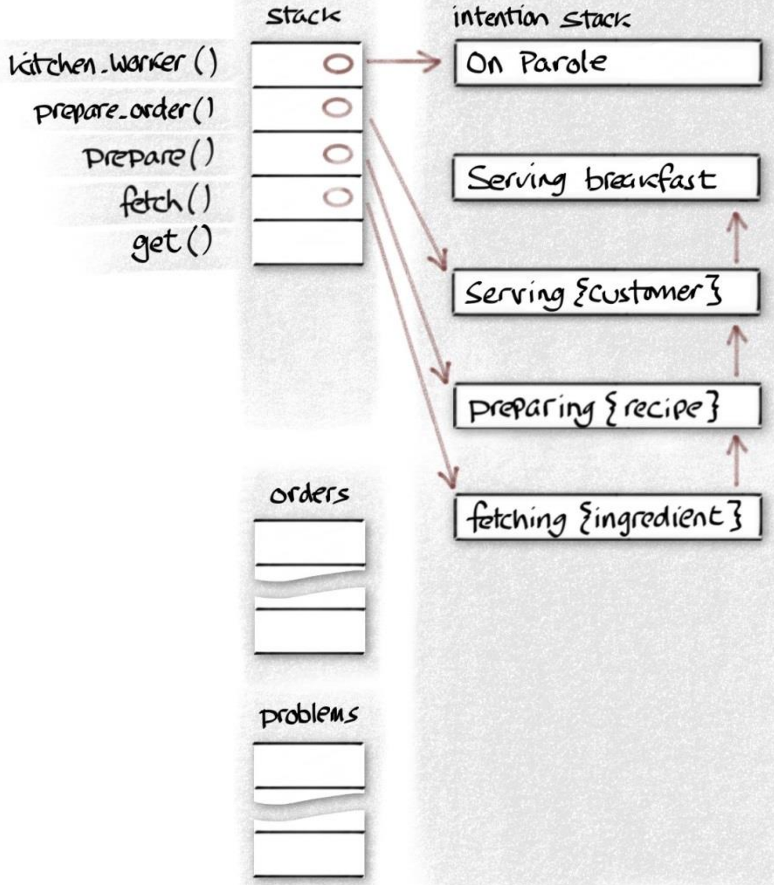
```

the kitchen

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    prepare_order(orders.dequeue());
  }
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  with_intent(o.intent());
  try {
    prepare(o.recipe());
  } catch(...) {
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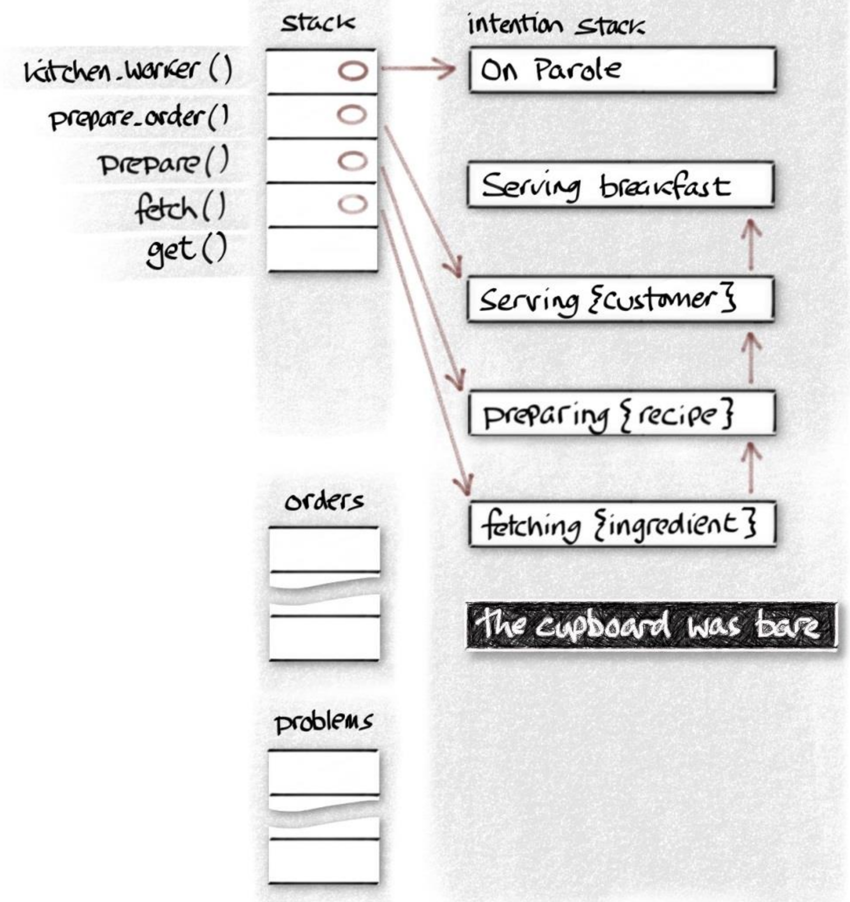
}
```

the kitchen




```
void kitchen_worker() {
  whilst("on parole");
  while (orders.waiting()) {
    prepare_order(orders.dequeue());
  }
}

void prepare_order(order o) {
  with_intent(o.intent());
  try {
    prepare(o.recipe());
  } catch(...) {
    problems.queue(problem(o,
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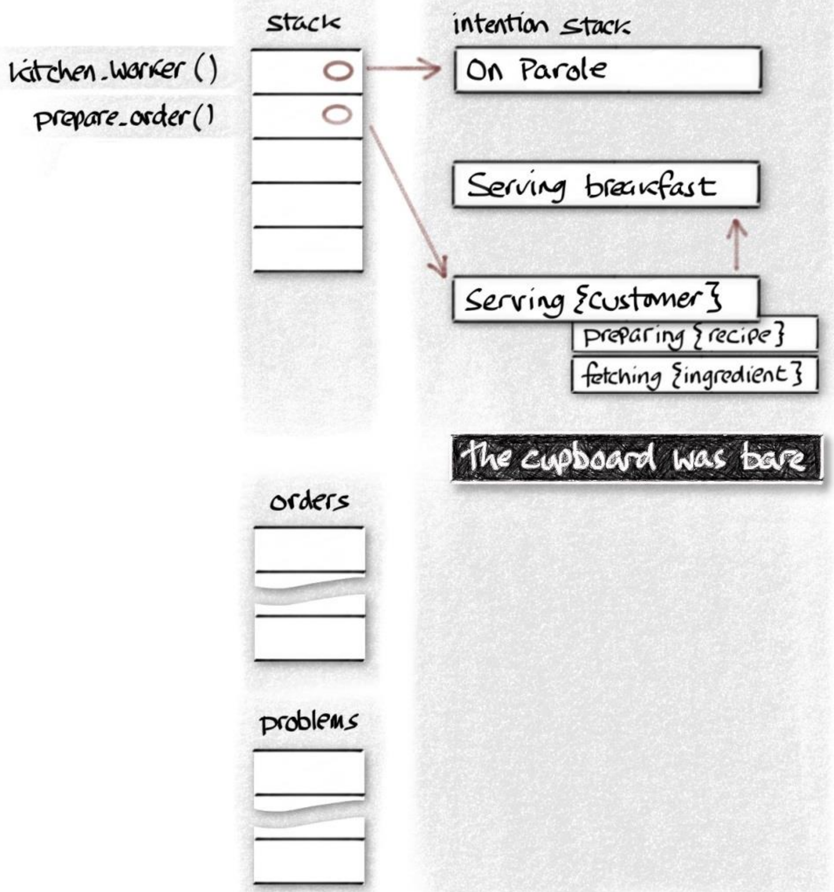
  }
}
```



the kitchen

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  while (orders.waiting()) {
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  } catch(...) {
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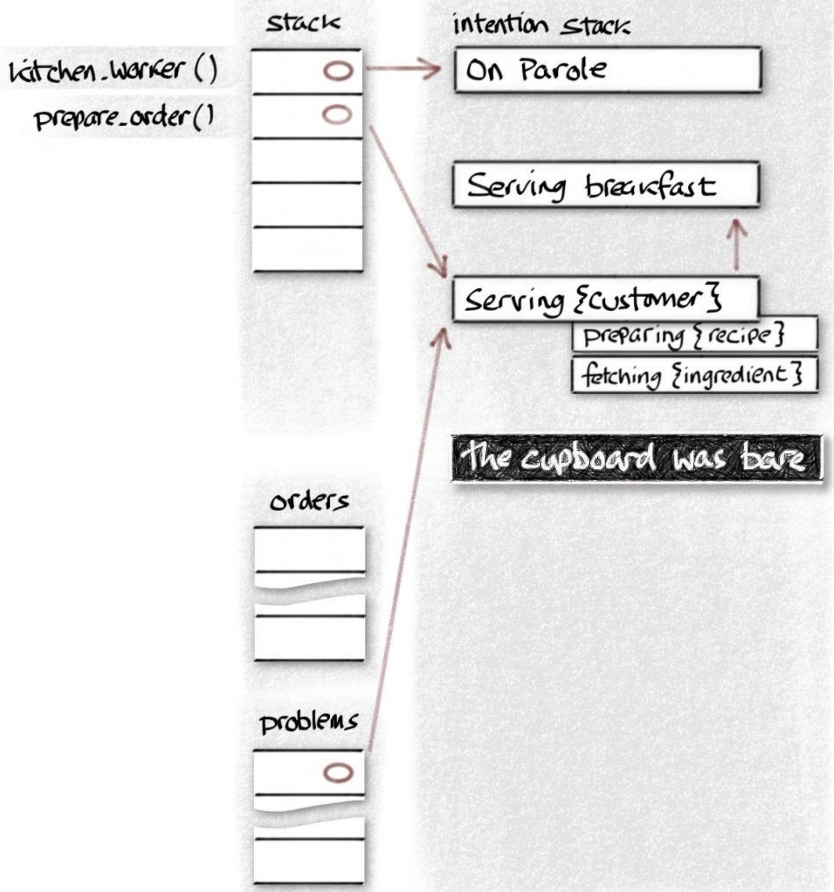
                           std::current_exception(),
                           current_intentions()));
  }
}
```

the kitchen

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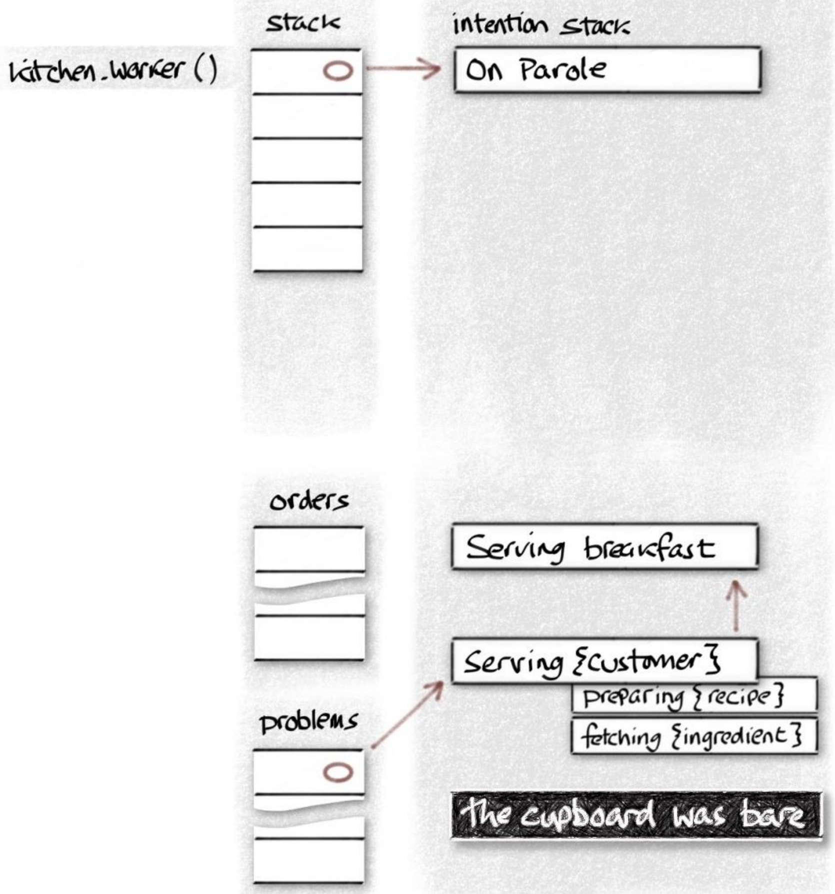
void kitchen_worker() {
  whilst("on parole");
  while (orders.waiting()) {
    prepare_order(orders.dequeue());
  }
}

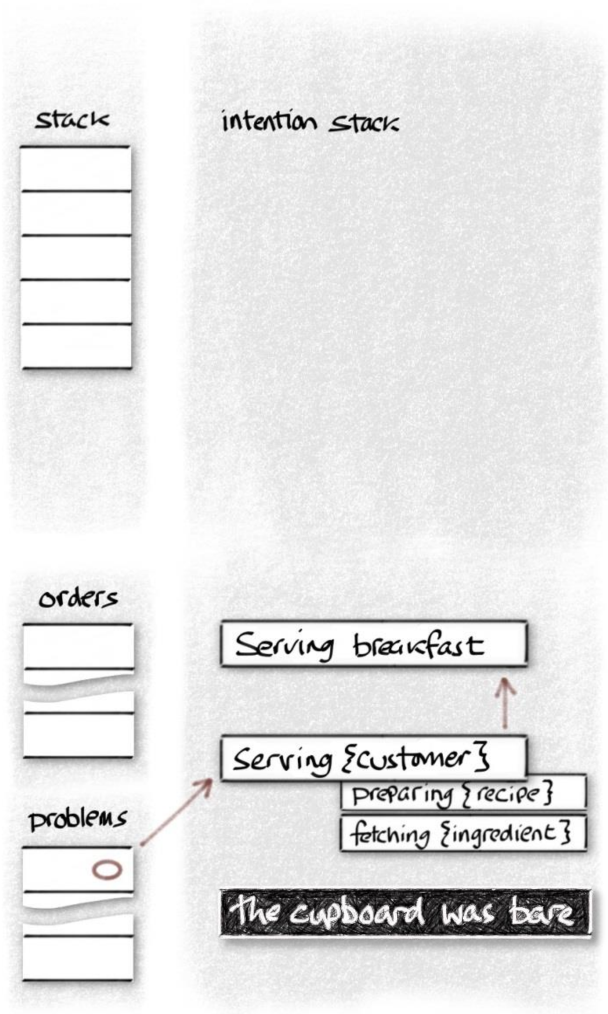
void prepare_order(order o) {
  with_intent(o.intent());
  try {
    prepare(o.recipe());
  } catch(...) {
    problems.queue(problem(o,
                          std::current_exception(),
                          current_intentions()));
  }
}
```

the kitchen



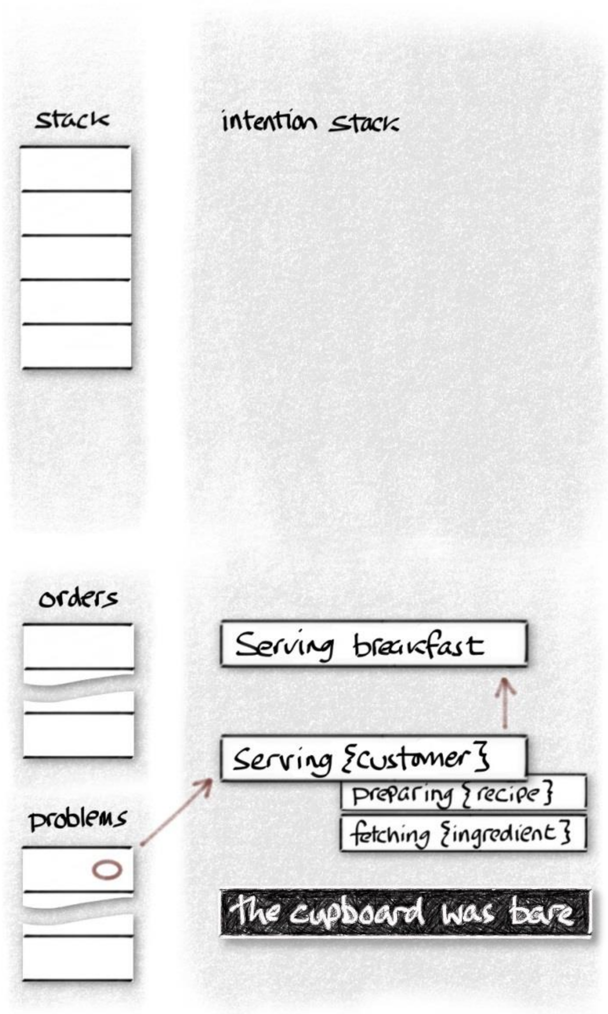

```
void kitchen_worker() {
  whilst("on parole");
  while (orders.waiting()) {
    prepare_order(orders.dequeue());
  }
}

void prepare_order(order o) {
  with_intent(o.intent());
  try {
    prepare(o.recipe());
  } catch(...) {
    problems.queue(problem(o,
                           std::current_exception(),
                           current_intentions()));
  }
}
```



complaints dept.

?



complaints dept.

?

“ **whilst** serving breakfast
 whilst serving **{CUSTOMER}**
  whilst preparing **{RECIPE}**
   whilst fetching **{INGREDIENT}**
    {EXCEPTION}

 whilst explaining that **{ISSUE}**
  {EXCEPTION} ”

Declarative

- Declarative expression of intent
  - is more succinct
  - has fewer execution paths to test
  - is executable documentation
- … but at what cost?

What would an implementation involve?

What's in a **`whilst`**?

```
#define _PASTE_(A, B) A ## B
#define _NAME_(PREFIX, N) _PASTE_(PREFIX, N)

#define INTENTION_ID _NAME_(_intention_, __LINE__)
#define SCOPE_NAME _NAME_(_scope_, __LINE__)

#define whilst(DESC, ...) \
  static intention *INTENTION_ID = runtime::inter(__FILE__, __LINE__, DESC); \
  scope SCOPE_NAME(INTENTION_ID, values(__VA_ARGS__));
```

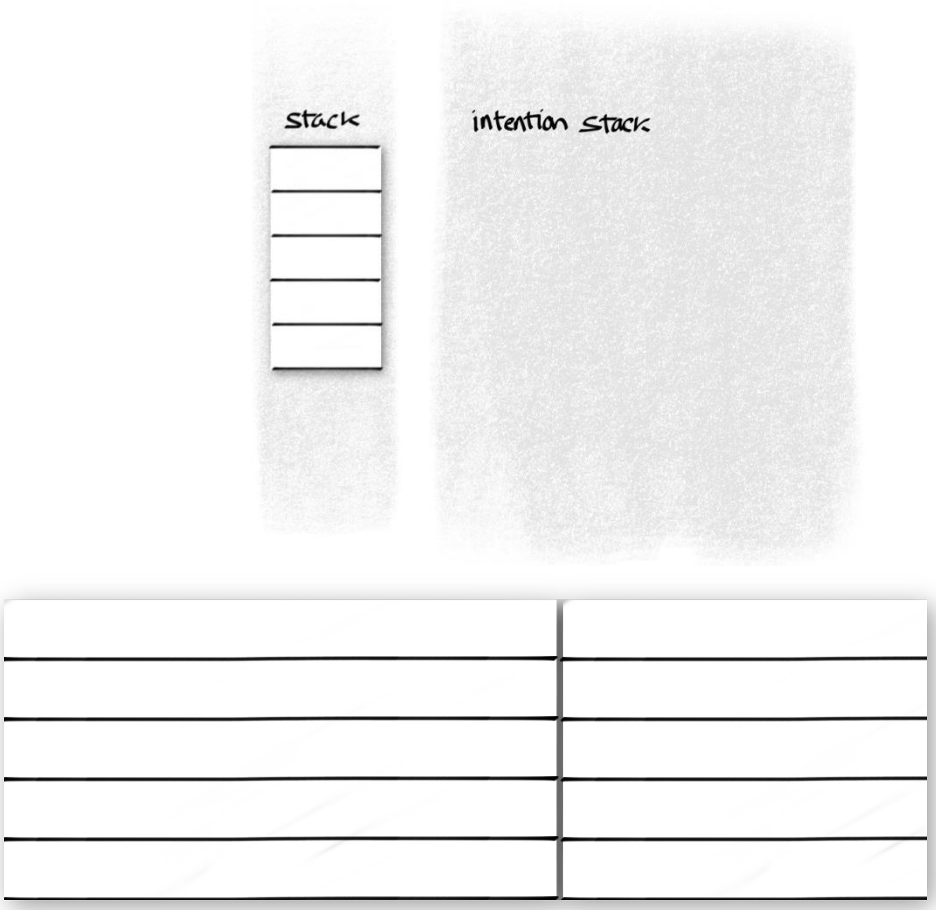
What's in a **`whilst`**?

```
whilst("preparing {recipe}", "bacon and eggs")
```

```
static intention *_intention_101 = runtime::inter("cooking.cpp", 101, "preparing {recipe}");
scope _scope_101(_intention_101, values("bacon and eggs"));
```

Interring intentions

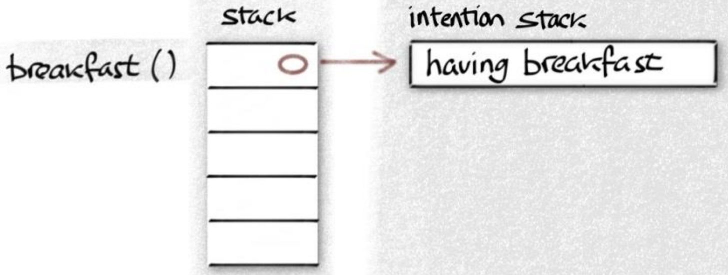
```
static intention *_intention_101 = runtime::inter(“cooking.cpp", 101, "preparing {recipe}");
```




```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

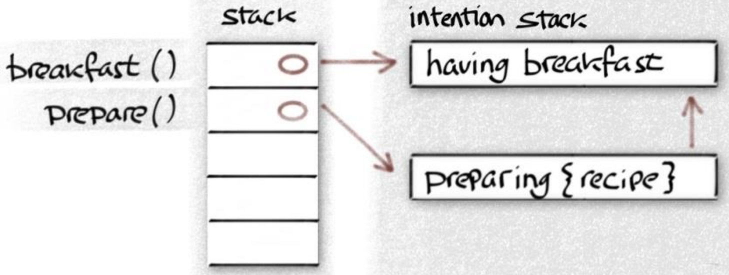


1	*having breakfast*	home.cpp	100

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

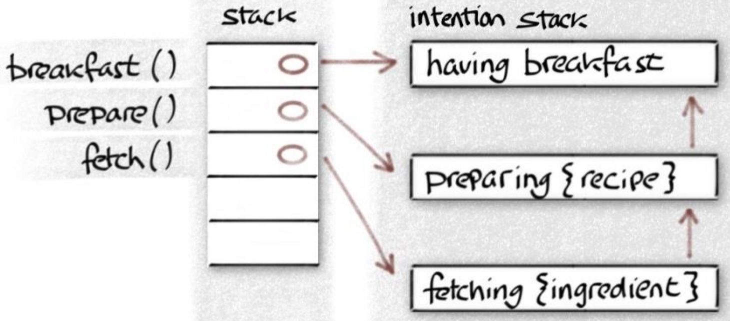


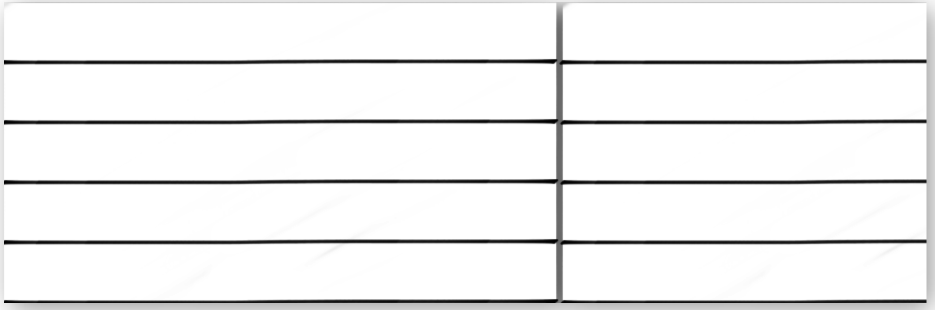
1	*having breakfast*	home.cpp	100
2	*preparing {recipe}*	cooking.cpp	101

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```





```
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  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

Intention scopes

```
static intention *_intention_101 = runtime::inter(“cooking.cpp", 101, "preparing {recipe}");
scope _scope_101(_intention_101, values(“bacon and eggs"));
```

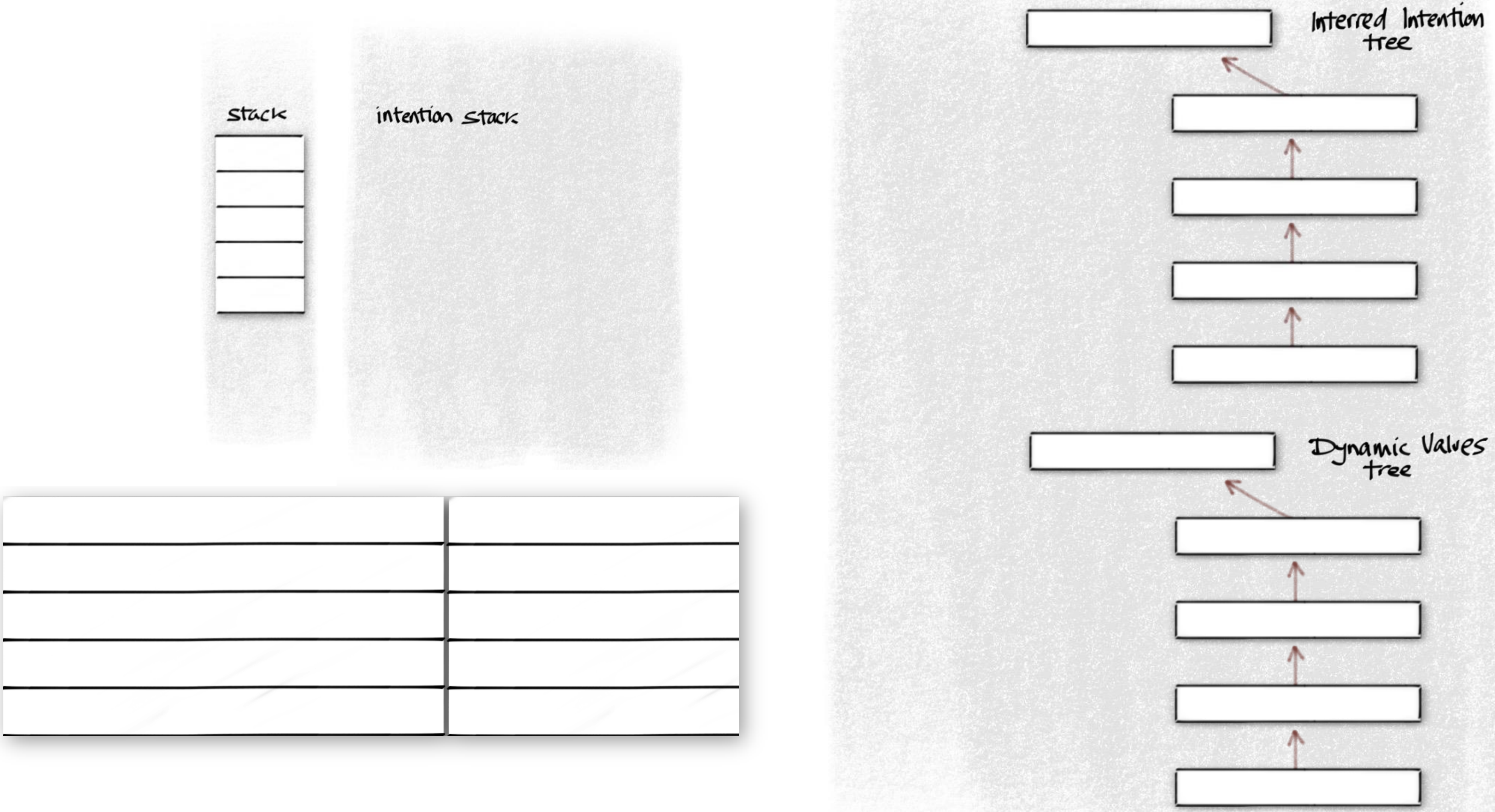
Intention scopes

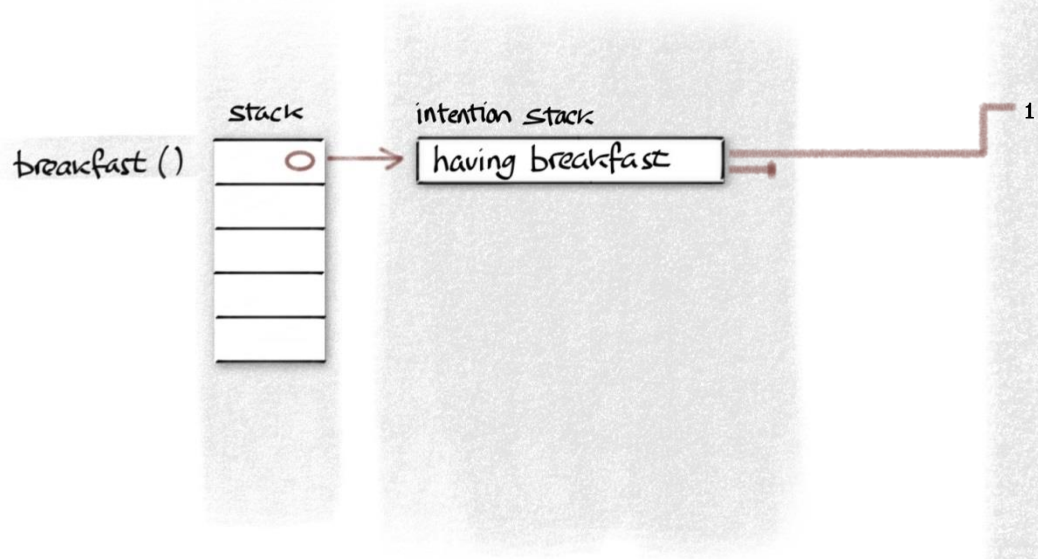
```
struct scope {
  int uncaught_;

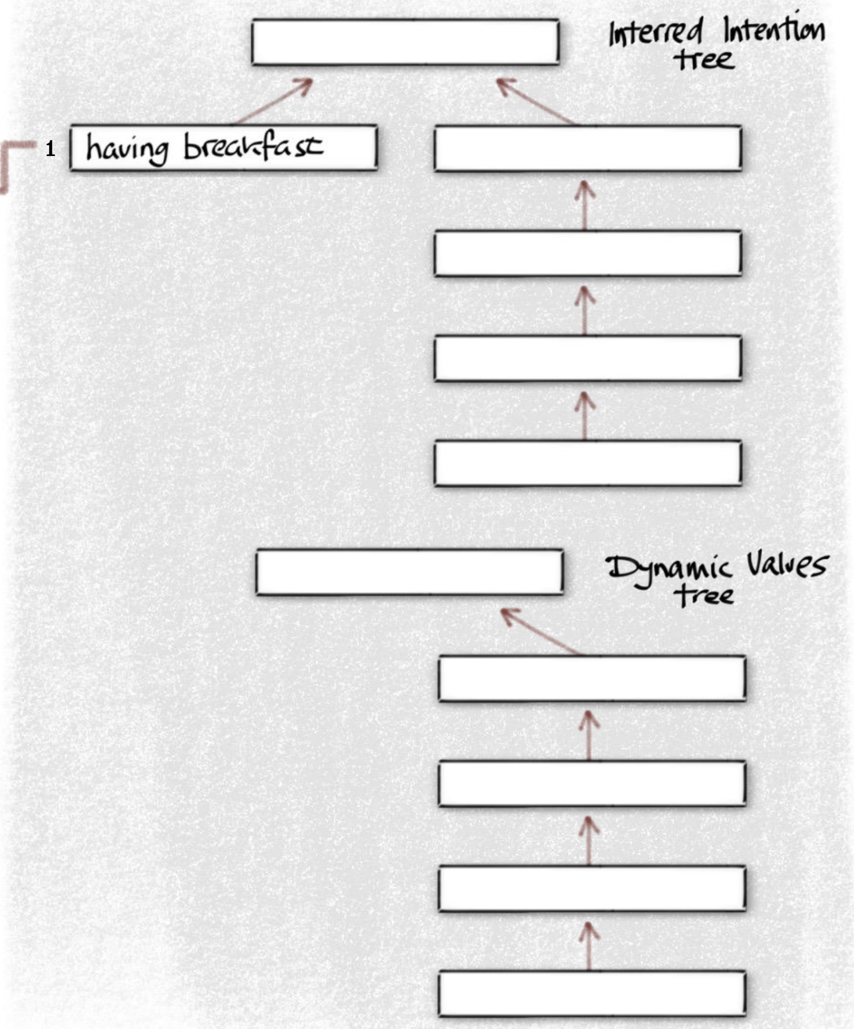
  scope(intention *i, values &v) {
    uncaught_ = uncaught_exceptions();
    runtime.enter(i,v);
  }
  ~scope() {
    runtime.leave(uncaught_);
  }
}

void runtime::enter(intention *i, values &v) {
  push(id, v);
}

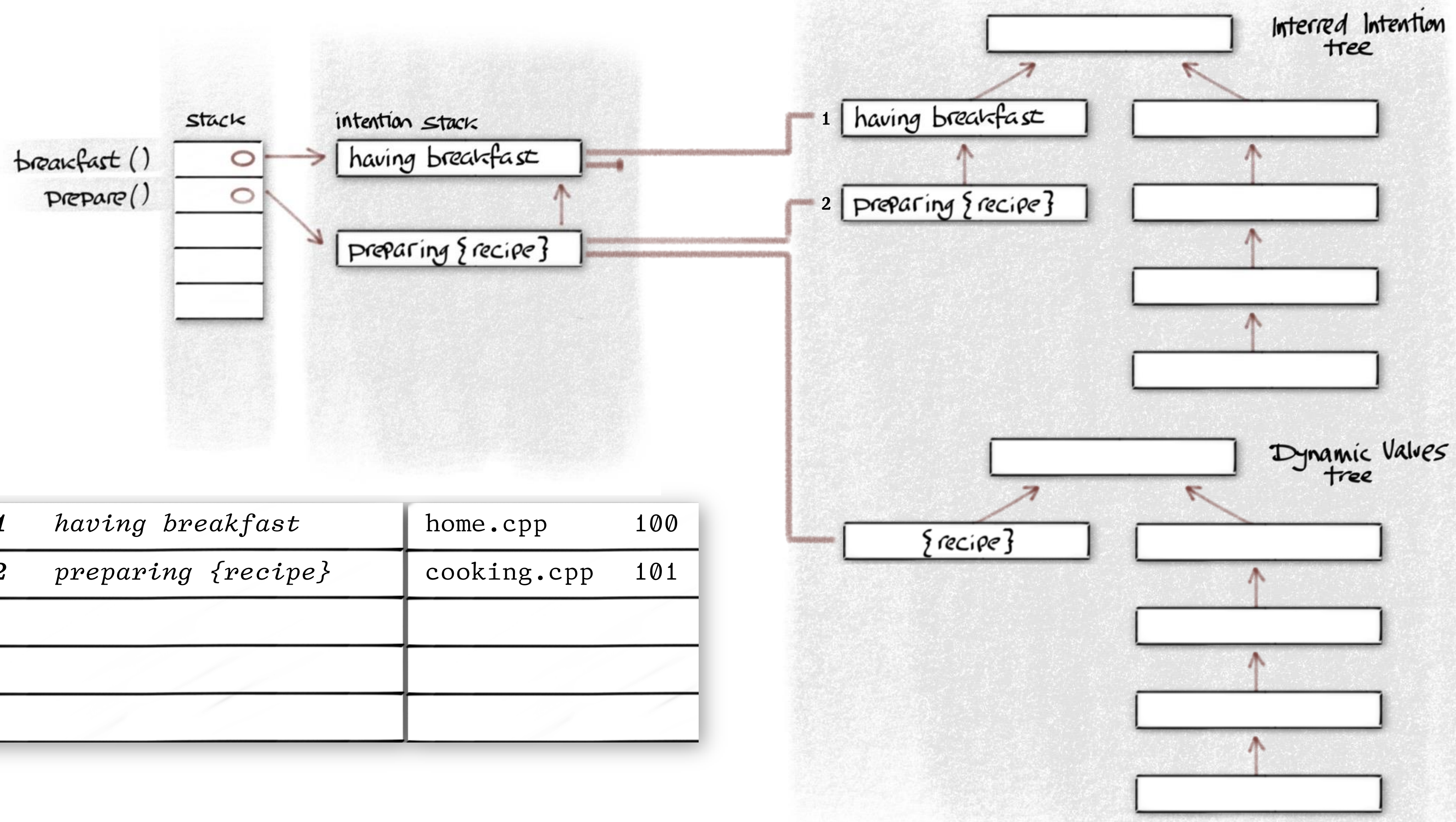
void runtime::leave(int uncaught) {
  if (uncaught_exceptions() != uncaught)
    throwing();
  pop();
}
```


stack
intention stack
Interred Intention tree
Dynamic Values tree

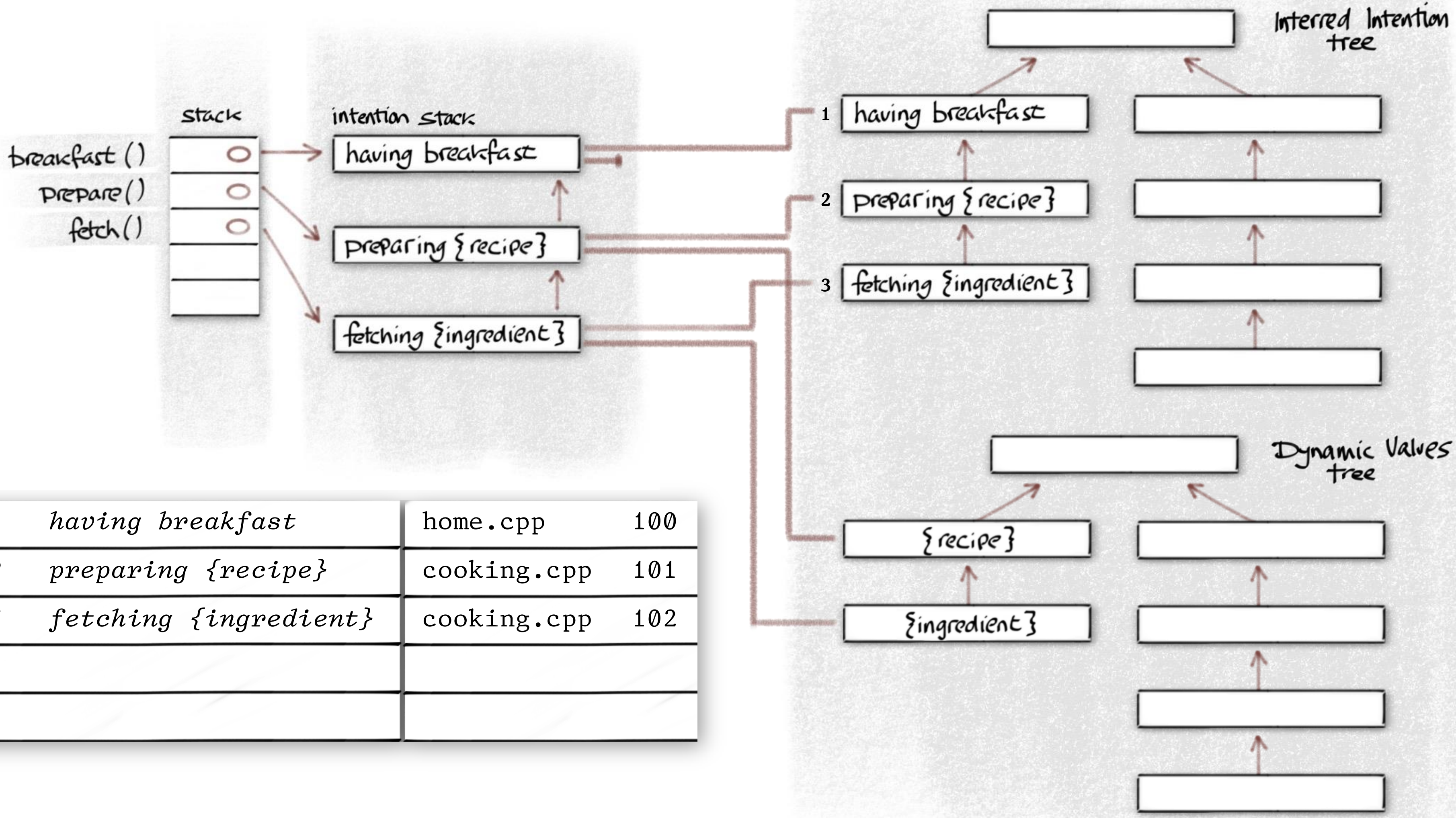




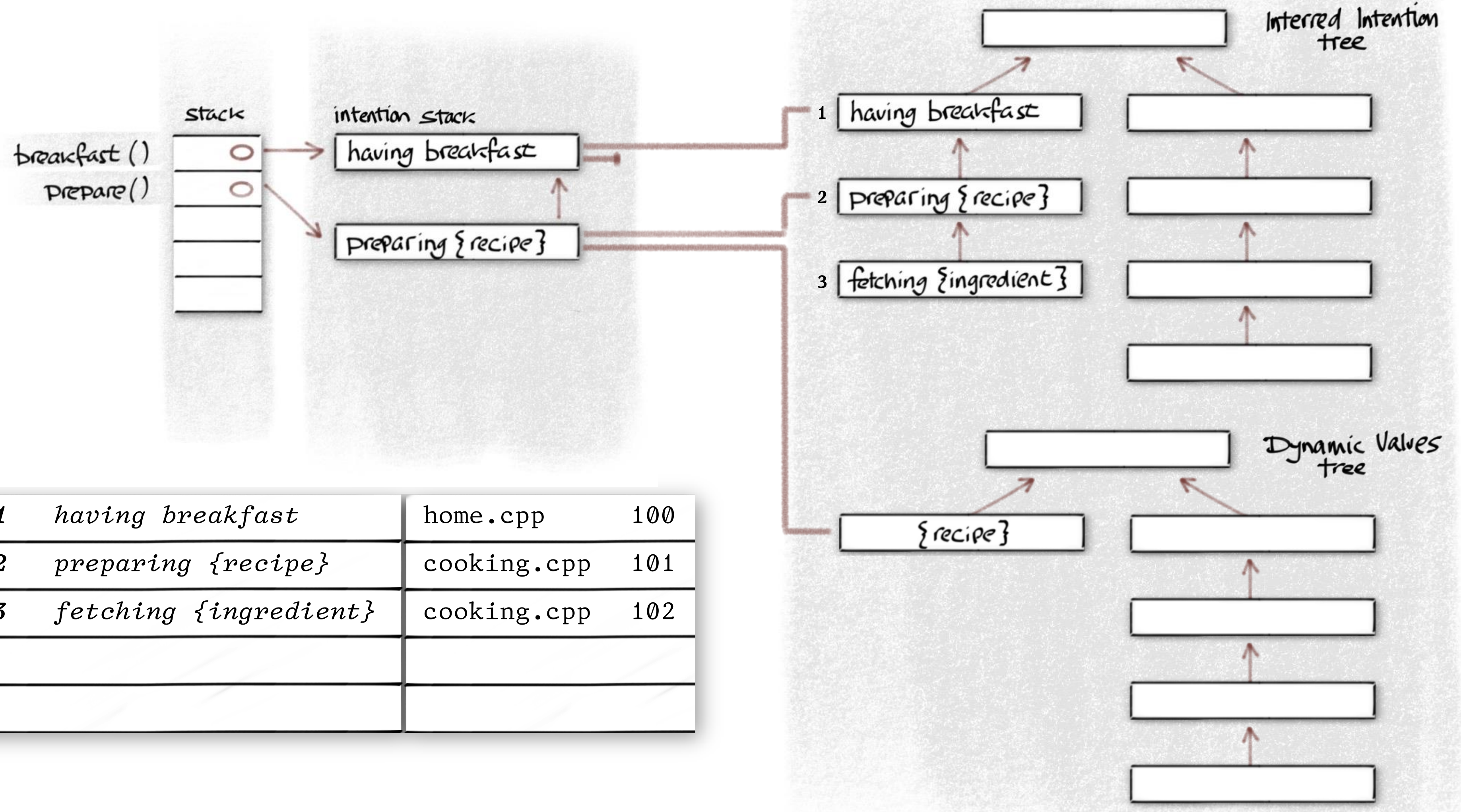
1	*having breakfast*	home.cpp	100



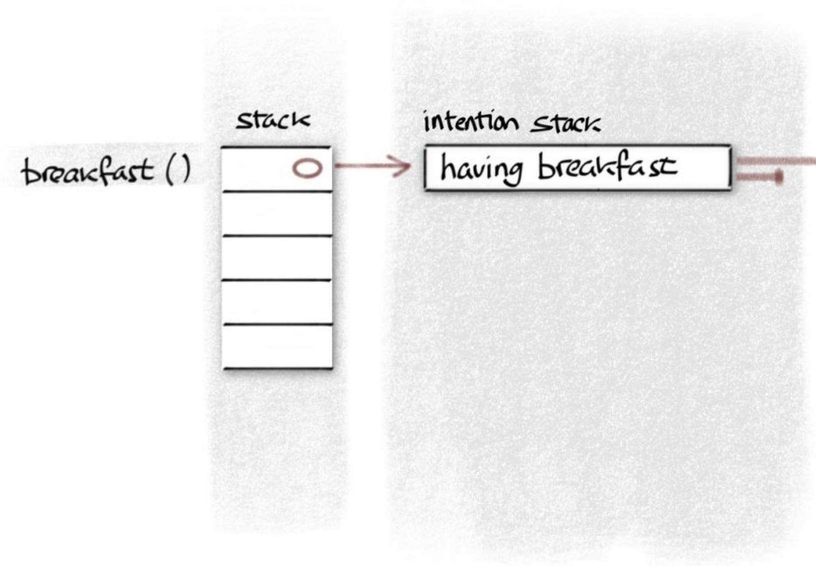
1	*having breakfast*	home.cpp	100
2	*preparing {recipe}*	cooking.cpp	101

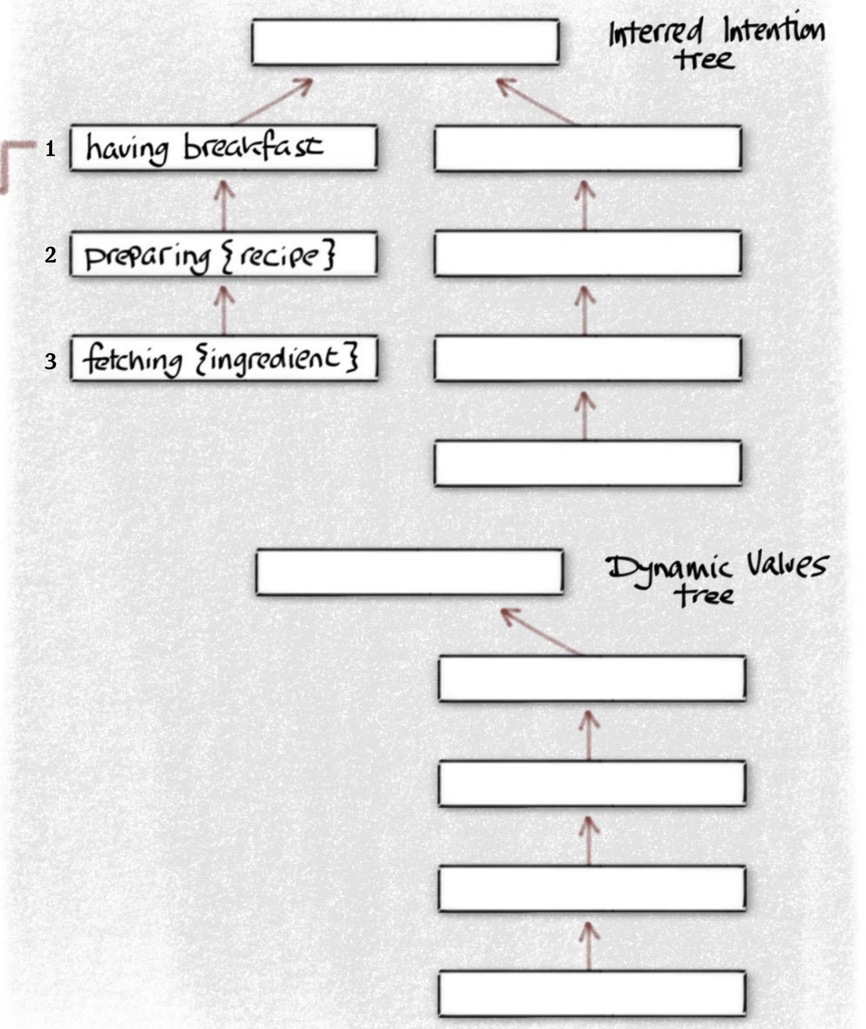


1	*having breakfast*	home.cpp	100
2	*preparing {recipe}*	cooking.cpp	101
3	*fetching {ingredient}*	cooking.cpp	102



1	*having breakfast*		home.cpp	100
2	*preparing {recipe}*		cooking.cpp	101
3	*fetching {ingredient}*		cooking.cpp	102





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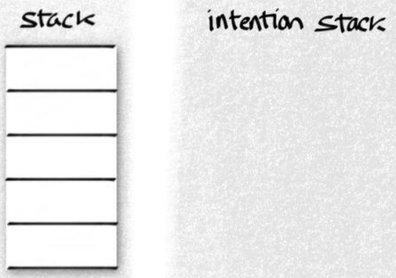
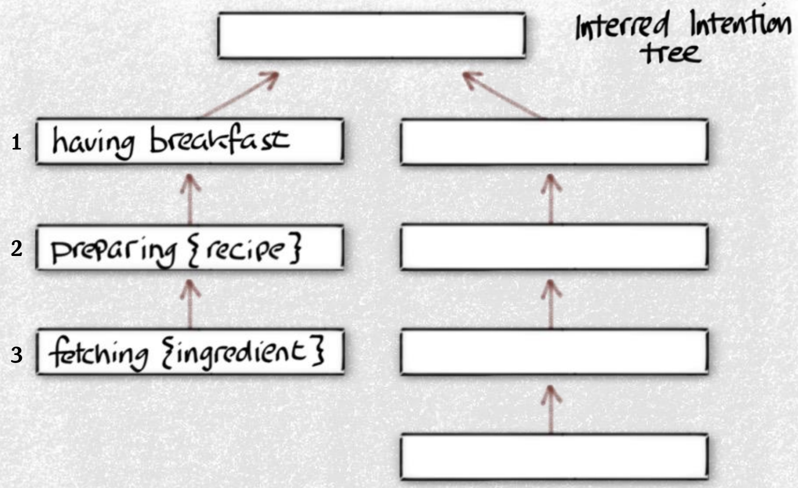
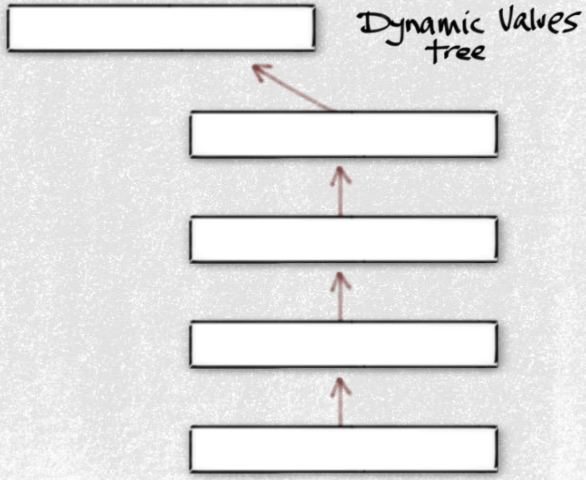
2	*preparing {recipe}*	cooking.cpp	101
3	*fetching {ingredient}*	cooking.cpp	102

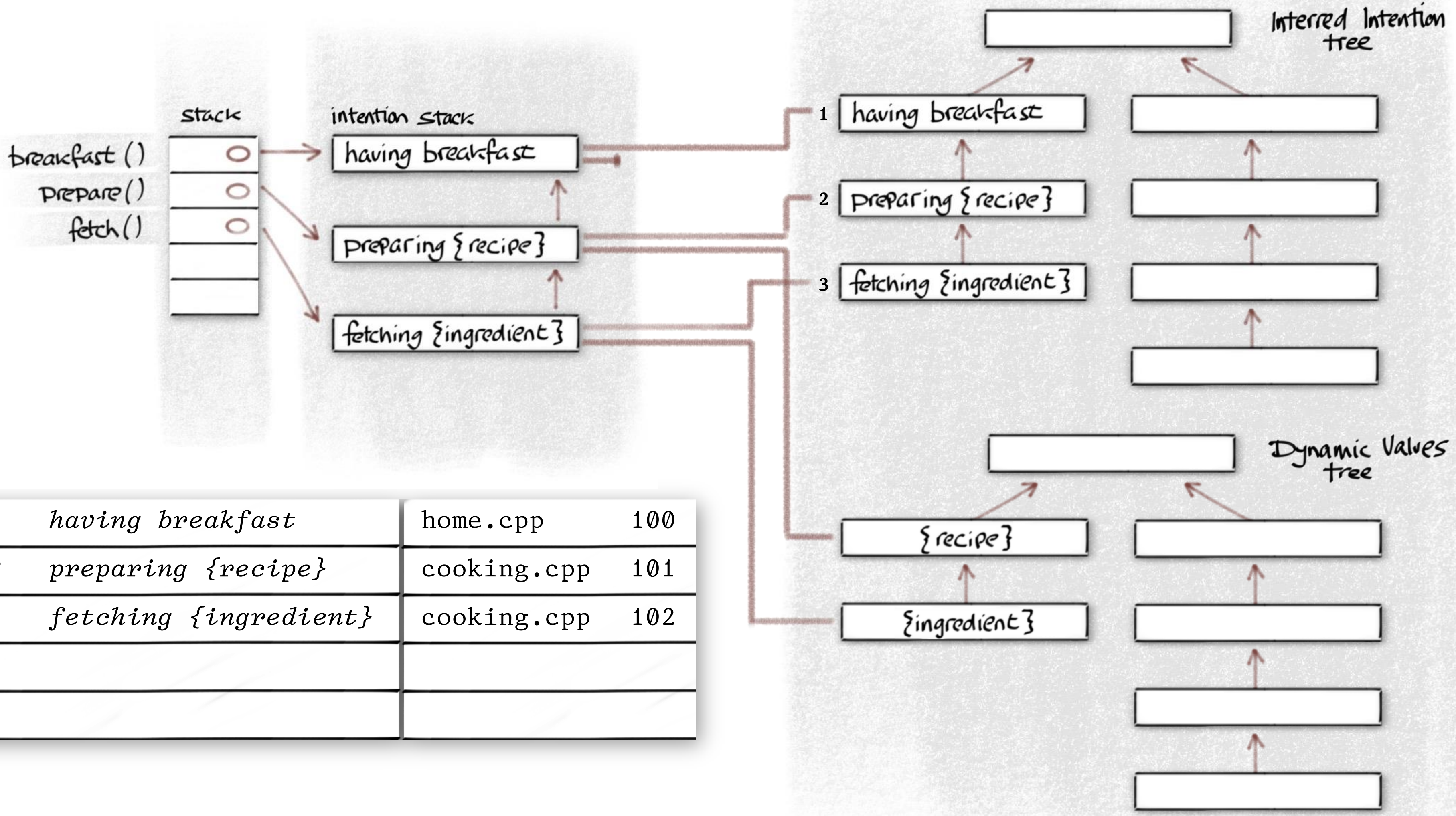


1	*having breakfast*	home.cpp	100
2	*preparing {recipe}*	cooking.cpp	101
3	*fetching {ingredient}*	cooking.cpp	102

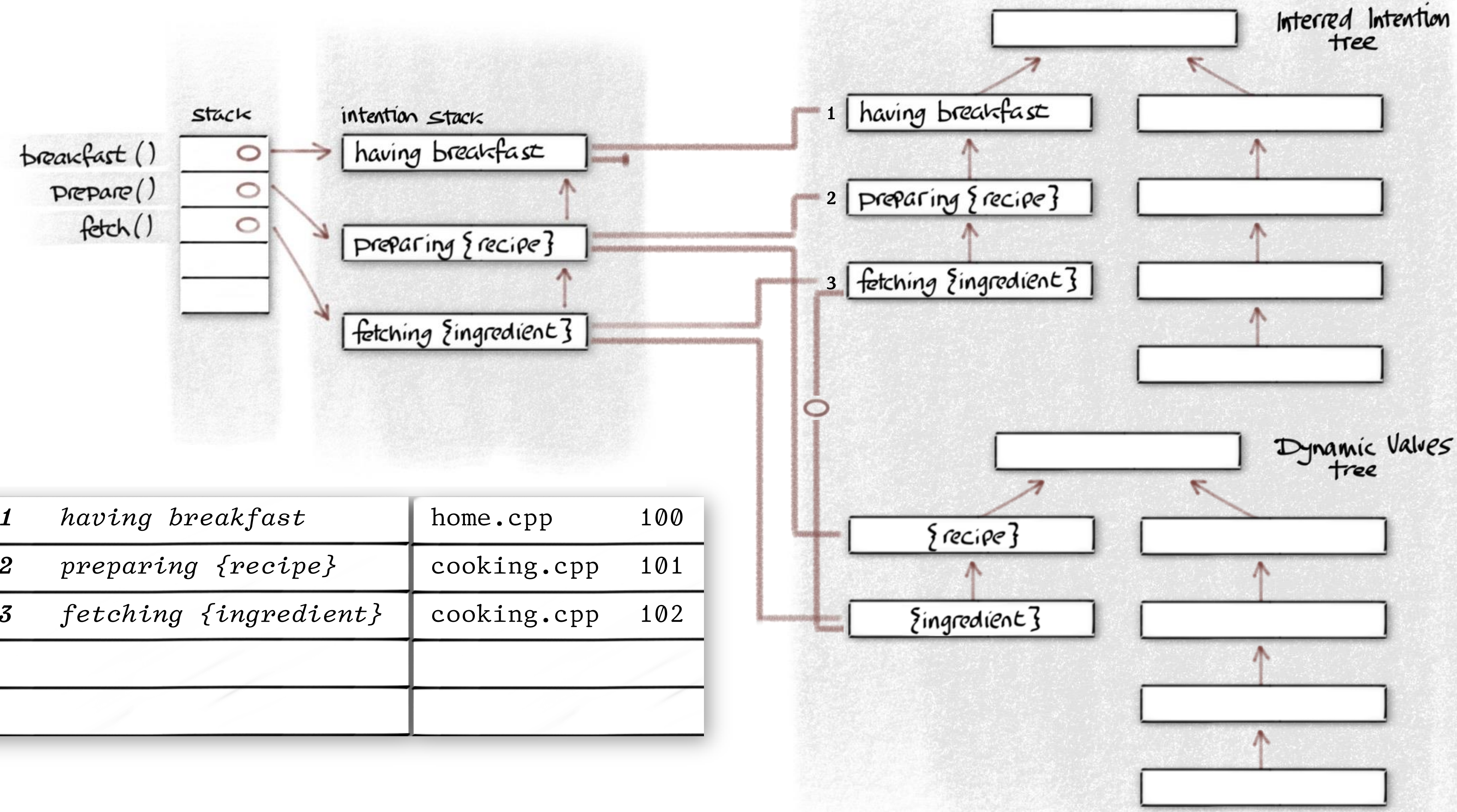




Capture



1	*having breakfast*	home.cpp	100
2	*preparing {recipe}*	cooking.cpp	101
3	*fetching {ingredient}*	cooking.cpp	102



1	*having breakfast*	home.cpp	100
2	*preparing {recipe}*	cooking.cpp	101
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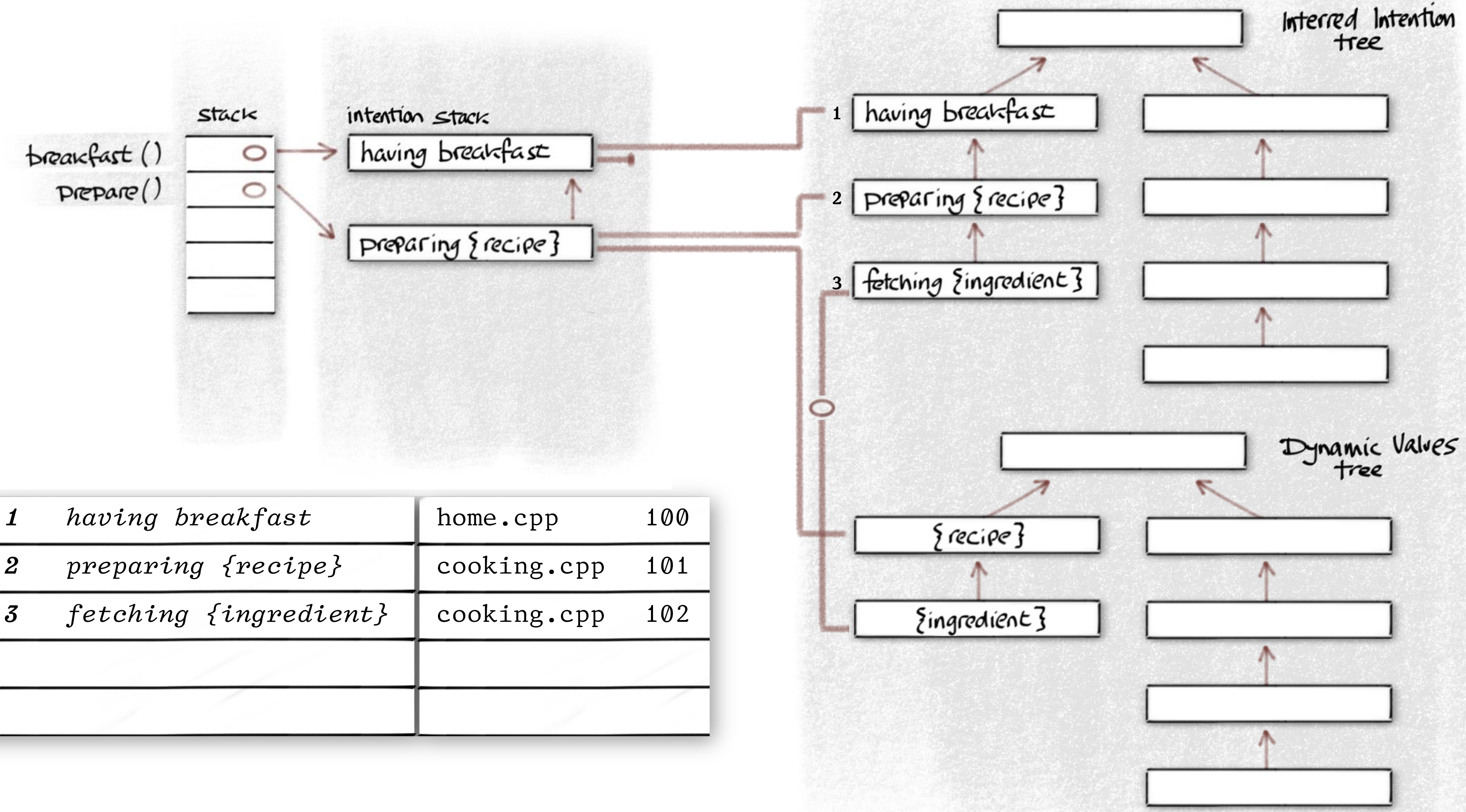

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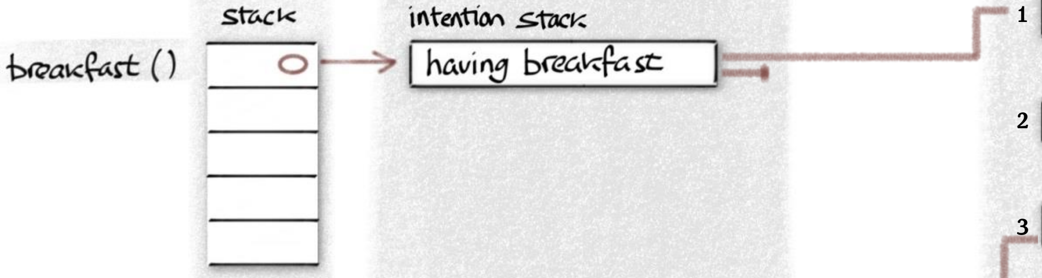

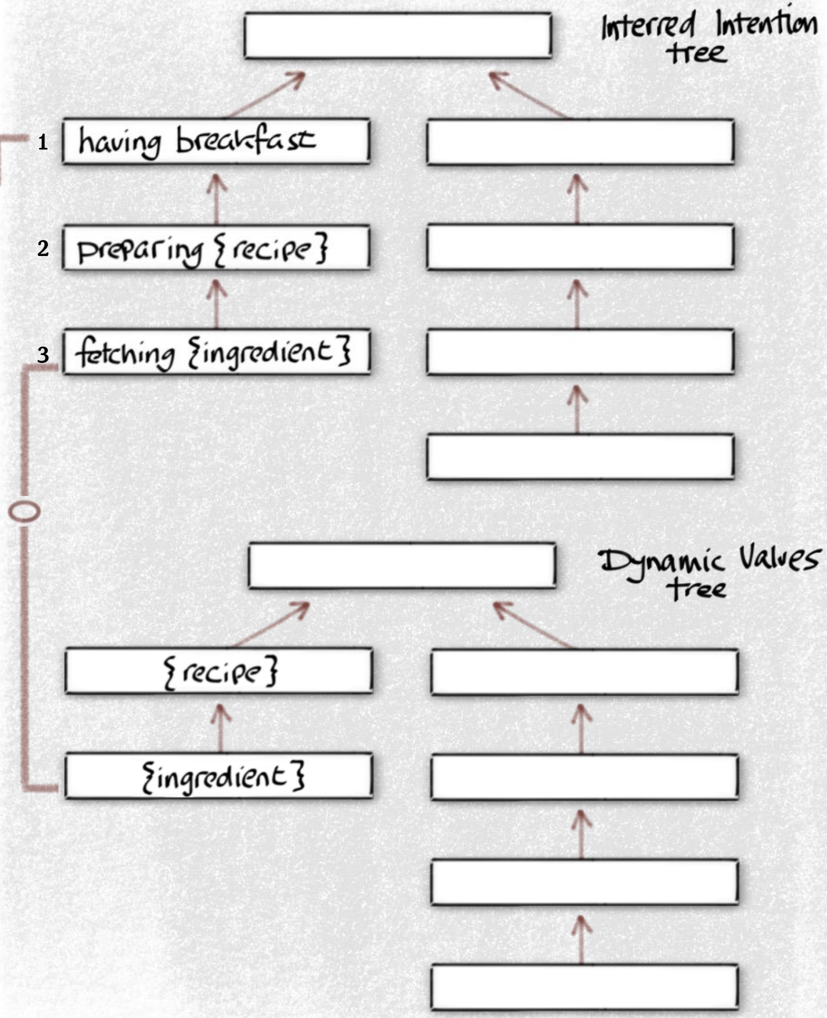

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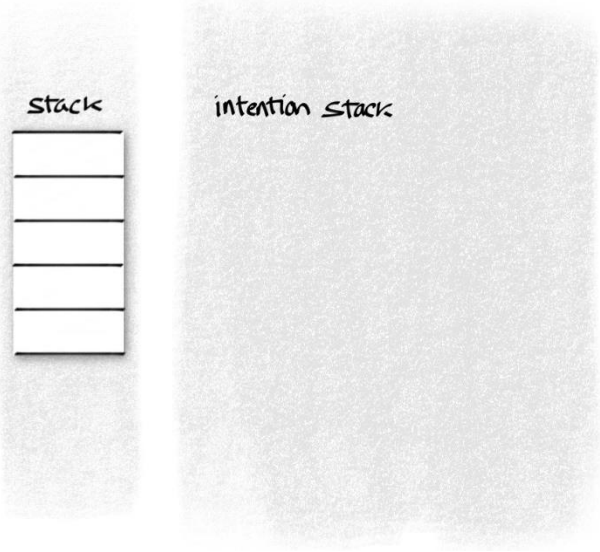

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2	*preparing {recipe}*	cooking.cpp	101
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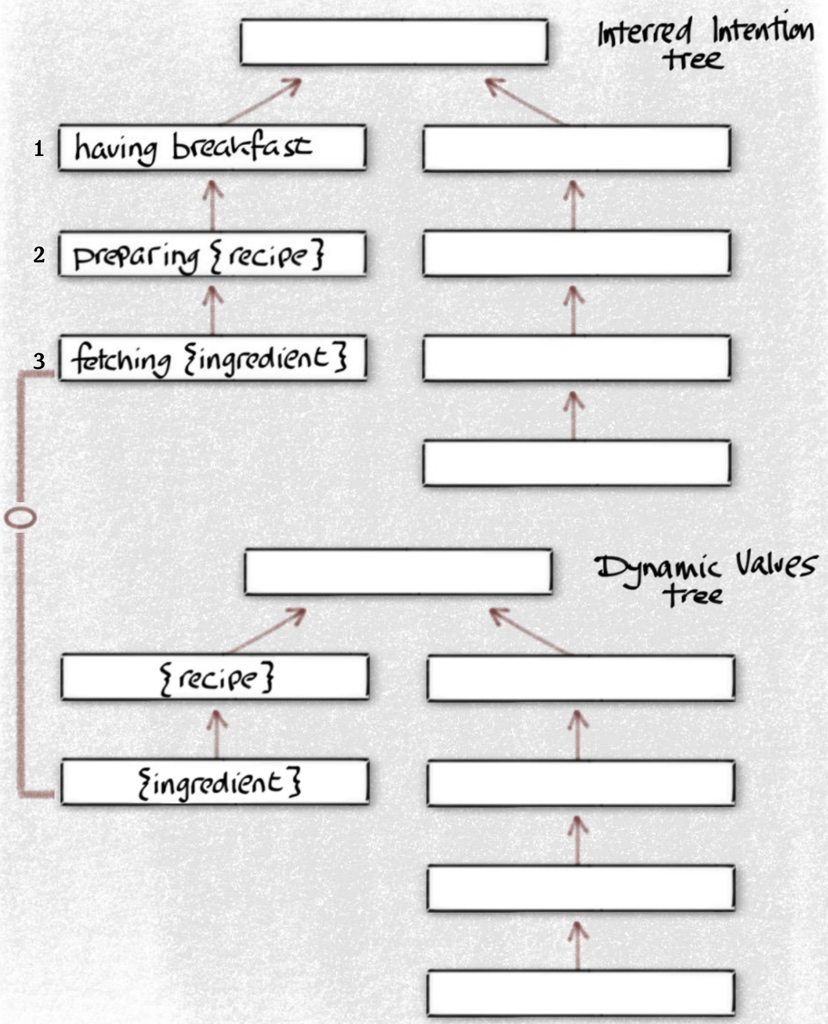
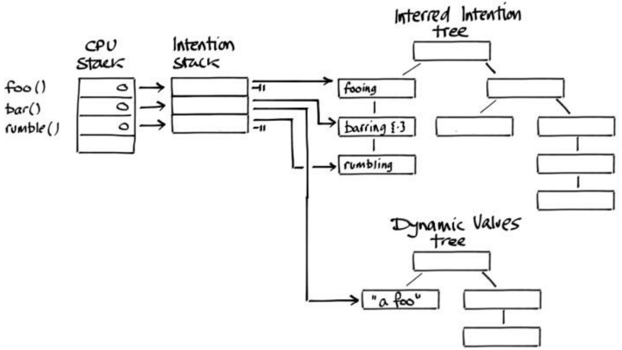


Efficiency

Efficiency

- Intention values (if used) are added to an immutable value tree that may be shared after intention capture. Nodes are reference counted and deleted when no longer required.



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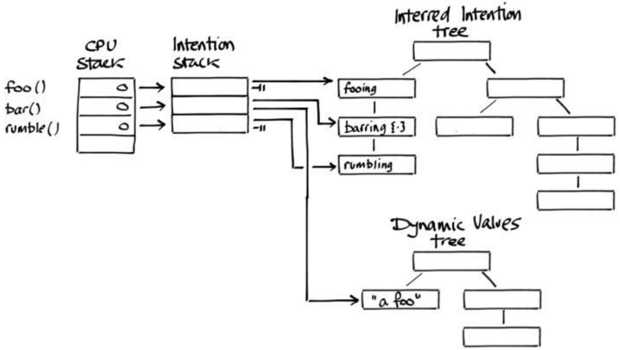
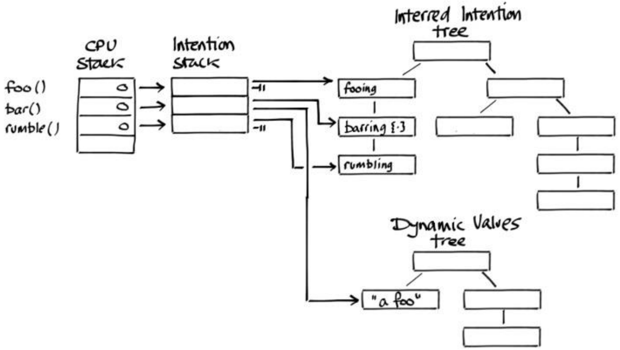


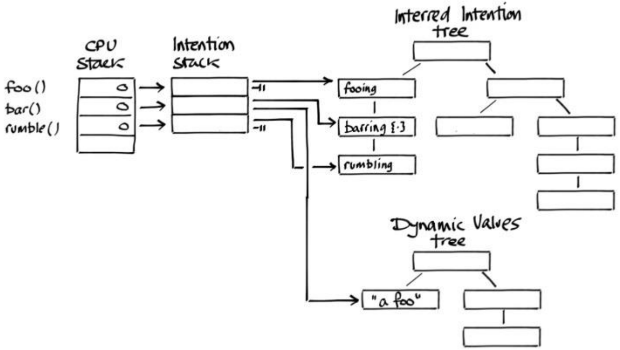
Efficiency

- Overheads are only incurred when intention frames are used.

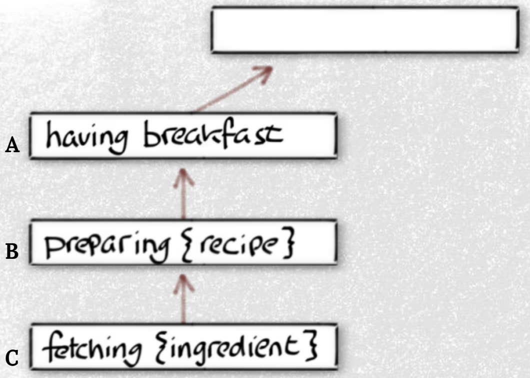


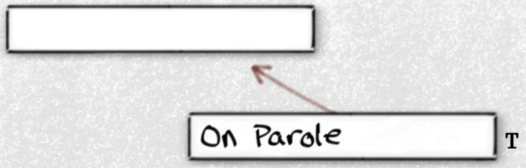
Efficiency in a distributed system

- The interred intention tree can be replicated incrementally when intentions are serialised into messages sent between processes or hosts.



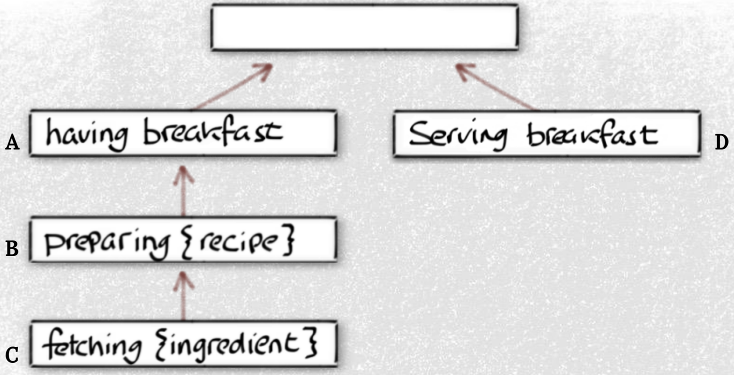
Replication

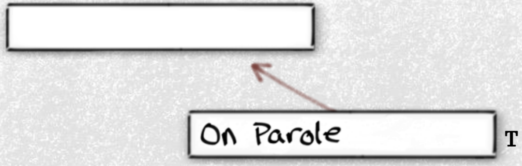




1	*having breakfast*
2	*preparing {recipe}*
3	*fetching {ingredient}*

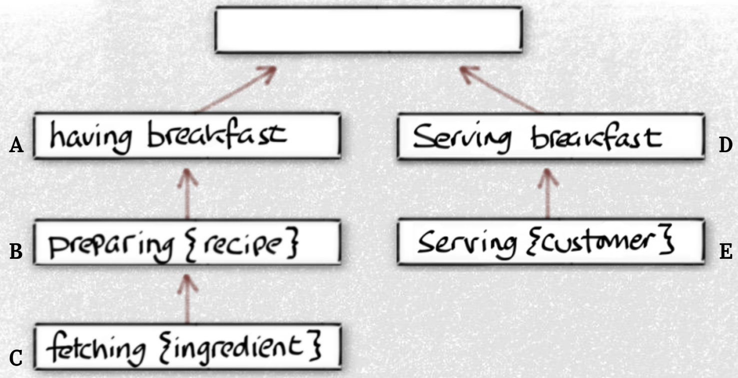
on parole	1

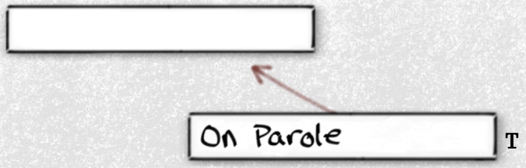




1	*having breakfast*
2	*preparing {recipe}*
3	*fetching {ingredient}*
4	*serving breakfast*

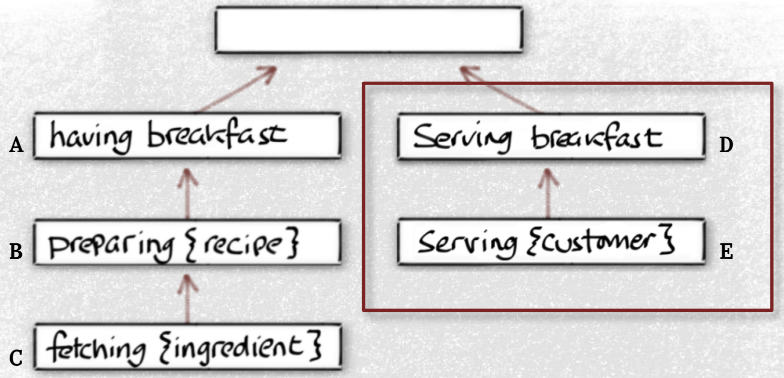
on parole	1

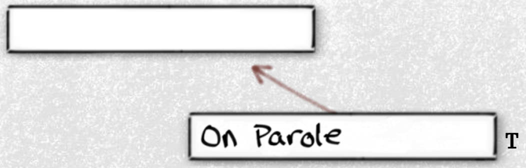




1	*having breakfast*
2	*preparing {recipe}*
3	*fetching {ingredient}*
4	*serving breakfast*
5	*serving {customer}*

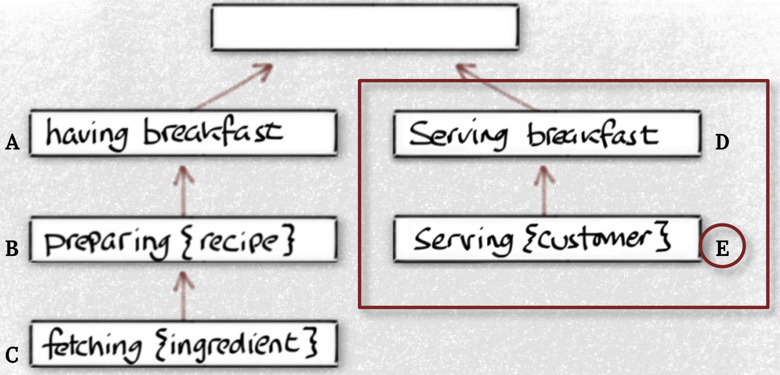
on parole	1



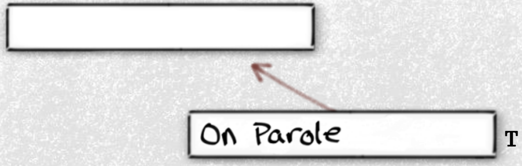


1	*having breakfast*
2	*preparing {recipe}*
3	*fetching {ingredient}*
4	*serving breakfast*
5	*serving {customer}*

on parole	1

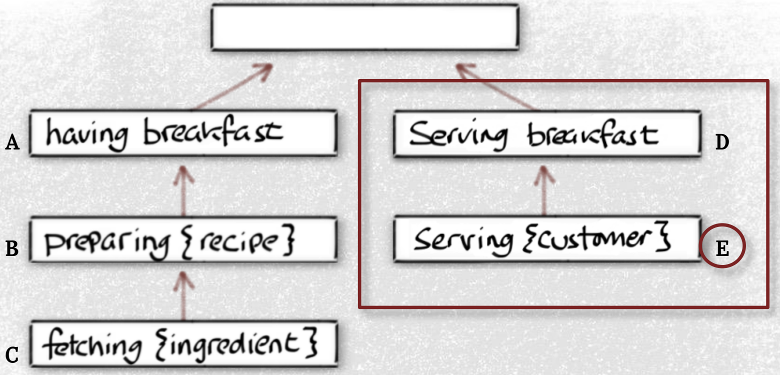


4, 5, E(#4,#5) →

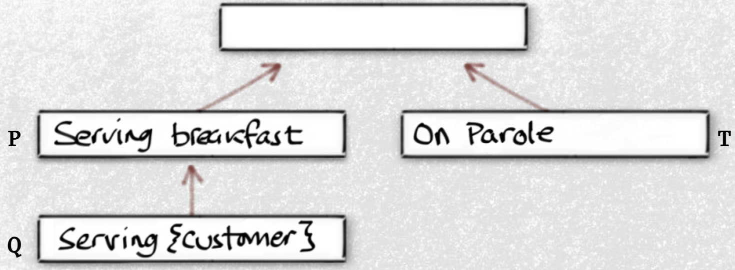


1	*having breakfast*
2	*preparing {recipe}*
3	*fetching {ingredient}*
4	*serving breakfast*
5	*serving {customer}*

on parole	1



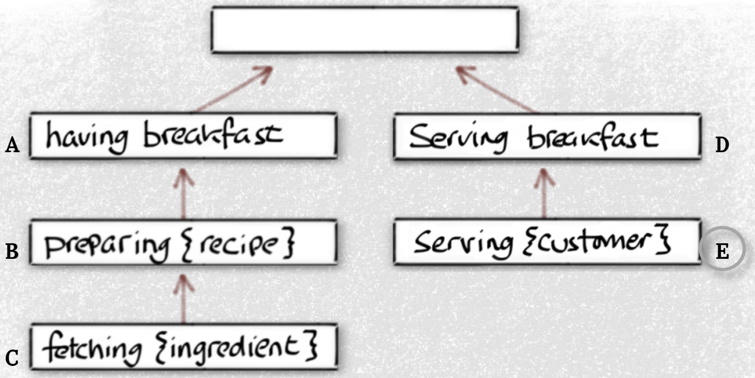
4, 5, E(#4,#5) →

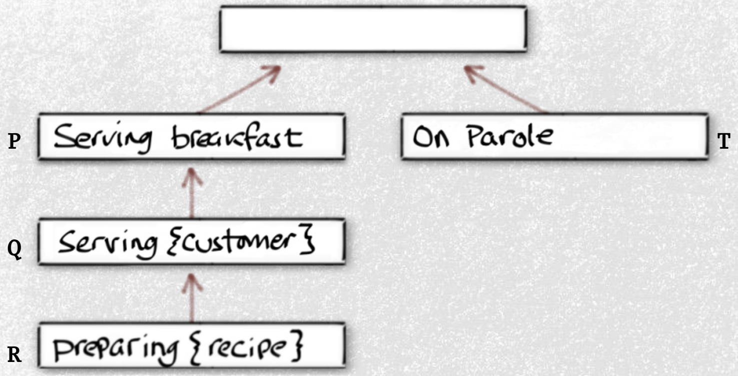


1	*having breakfast*
2	*preparing {recipe}*
3	*fetching {ingredient}*
4	*serving breakfast*
5	*serving {customer}*

	on parole	1
4 → 2	***serving breakfast***	2
5 → 3	***serving {customer}***	3

E → Q

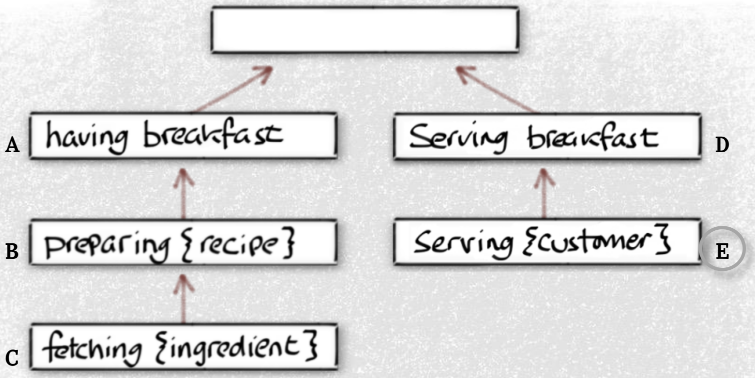


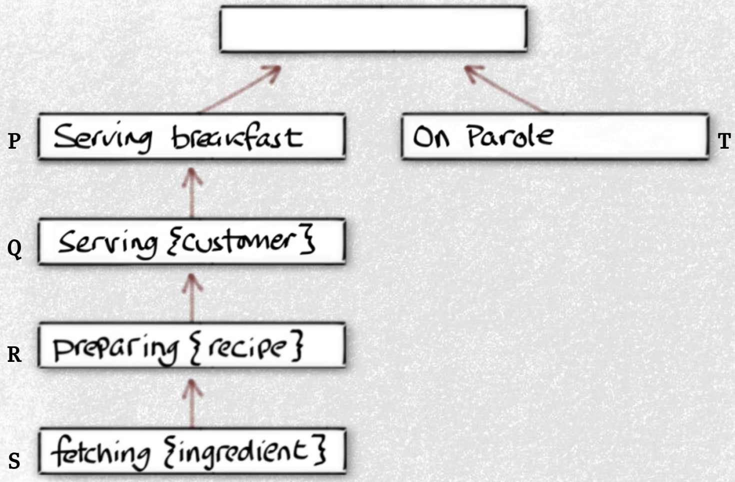


1	*having breakfast*
2	*preparing {recipe}*
3	*fetching {ingredient}*
4	*serving breakfast*
5	*serving {customer}*

	on parole	1
4 → 2	*serving breakfast*	2
5 → 3	*serving {customer}*	3
	preparing {recipe}	4

E → Q

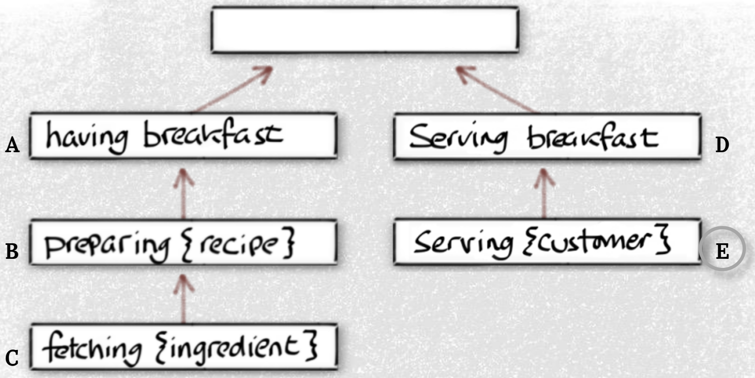


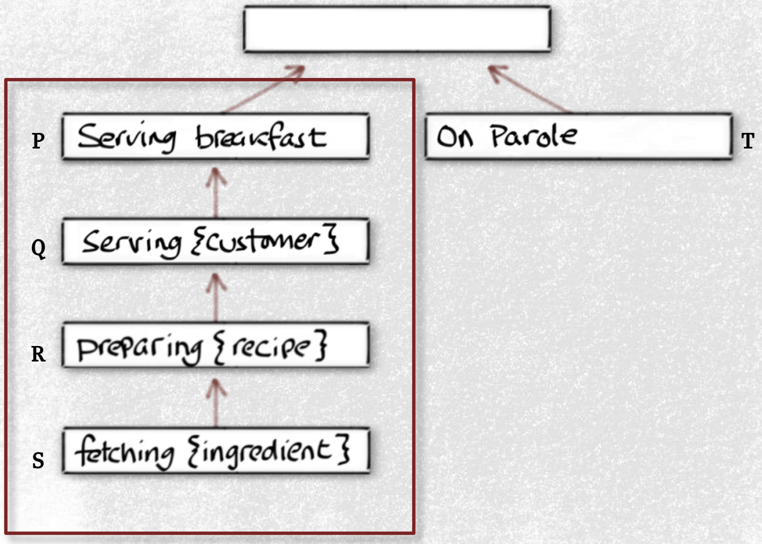


1	*having breakfast*
2	*preparing {recipe}*
3	*fetching {ingredient}*
4	*serving breakfast*
5	*serving {customer}*

	on parole	1
4 → 2	*serving breakfast*	2
5 → 3	*serving {customer}*	3
	preparing {recipe}	4
	fetching {ingredient}	5

E → Q



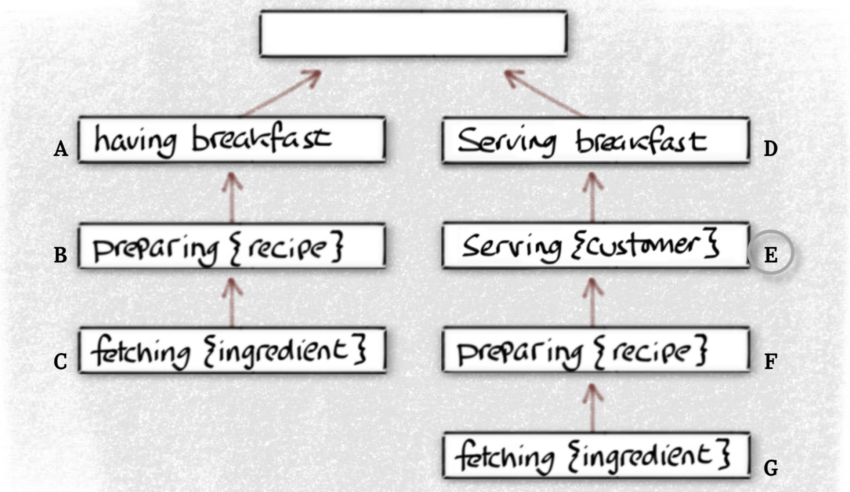


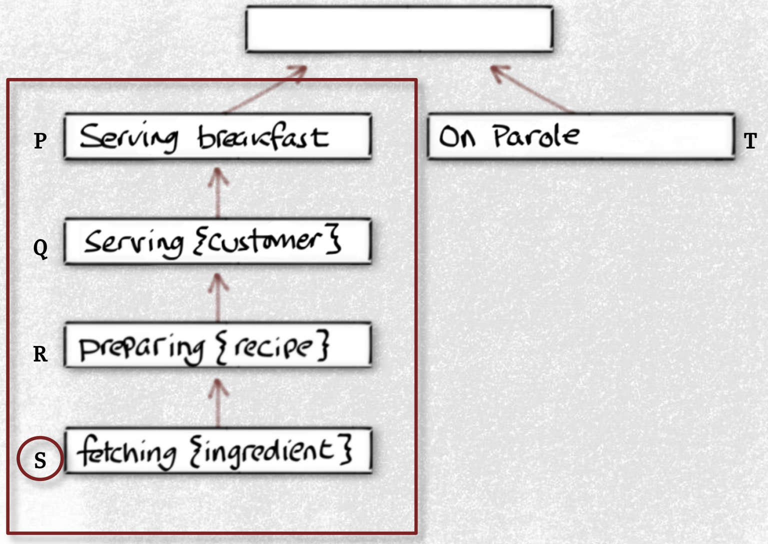
← 2, 3, 4, 5, S(#2,#3,#4,#5)

1	*having breakfast*
2	*preparing {recipe}*
3	*fetching {ingredient}*
4	*serving breakfast*
5	*serving {customer}*

	on parole	1
4 → 2	*serving breakfast*	2
5 → 3	*serving {customer}*	3
	preparing {recipe}	4
	fetching {ingredient}	5

E → Q





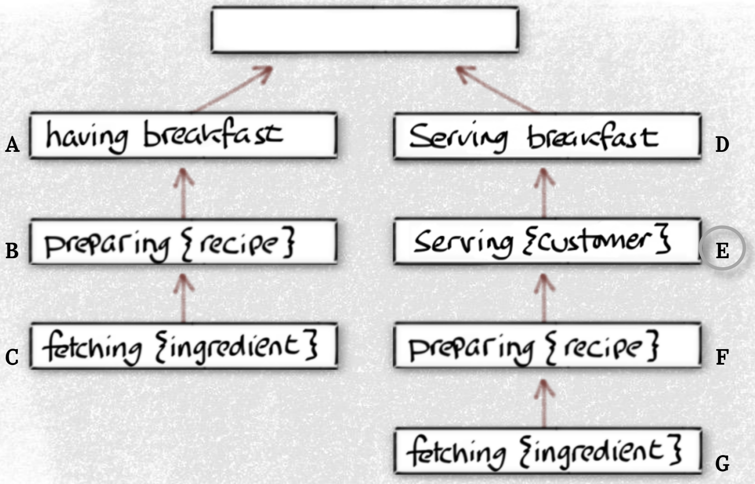
← 2, 3, 4, 5, S(#2,#3,#4,#5)

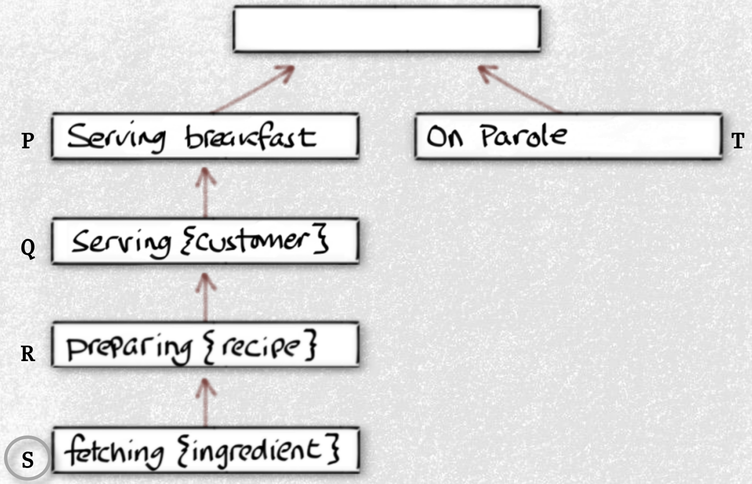
1	*having breakfast*
2	*preparing {recipe}*
3	*fetching {ingredient}*
4	*serving breakfast*
5	*serving {customer}*

2 ← 4
3 ← 5
4 ← 2
5 ← 3
G ← S

4 → 2
5 → 3
E → Q

on parole	1
serving breakfast	2
serving {customer}	3
preparing {recipe}	4
fetching {ingredient}	5



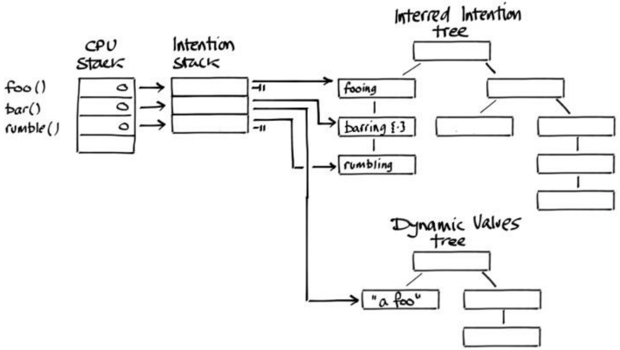


1	*having breakfast*	
2	*preparing {recipe}*	*2* ← 4
3	*fetching {ingredient}*	*3* ← 5
4	*serving breakfast*	*4* ← 2
5	*serving {customer}*	*5* ← 3
		G ← S

	on parole	1
4 → 2	*serving breakfast*	2
5 → 3	*serving {customer}*	3
	preparing {recipe}	4
	fetching {ingredient}	5
E → Q		

Efficiency in a distributed system

- The representation of an intention is only ever transferred once between any two nodes.
- Values must still be transferred each time (but may themselves share their representation).



- So what else do we get for our money?

And…?

Part IV

Archaeology

Logging

Logging

- Intention frames and exceptions can be logged in a compact form.

```
   #1  having breakfast (home.cpp : 100)
   →1
   #2  preparing {recipe} (cooking.cpp : 101)
   →2  “bacon and eggs”
   #3  fetching {ingredient} (cooking.cpp : 102)
   →3  “bacon”
    ←
   →3  “eggs”
    !
    !
    !
    e  the cupboard was bare
    ←
   #4  serving breakfast (cafe.cpp 103)
   →4
   #5  serving {customer} (cafe.cpp 104)
   →5  “dominic”
+λ[n]
    ←
   #6  on parole (kitchen.cpp 100)
   →6
→λ[n]
   →2  “bacon and eggs”
   →3  “bacon”
    ←
   →3  “eggs”
    ←
    ←
```

Hypothetical Format

breakfast

```
 #1  having breakfast (home.cpp : 100)
 →1
 #2  preparing {recipe} (cooking.cpp : 101)
 →2  "bacon and eggs"
 #3  fetching {ingredient} (cooking.cpp : 102)
 →3  "bacon"
  ←
 →3  "eggs"
  !
  !
  !
  e  the cupboard was bare
  ←
 #4  serving breakfast (cafe.cpp 103)
 →4
 #5  serving {customer} (cafe.cpp 104)
 →5  "dominic"
+λ[n]
  ←
 #6  on parole (kitchen.cpp 100)
 →6
→λ[n]
 →2  "bacon and eggs"
 →3  "bacon"
  ←
 →3  "eggs"
  ←
  ←
```

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

breakfast

```
#1  having breakfast (home.cpp : 100)
→1
#2  preparing {recipe} (cooking.cpp : 101)
→2  "bacon and eggs"
#3  fetching {ingredient} (cooking.cpp : 102)
→3  "bacon"
 ←
→3  "eggs"
 !
 !
 !
 e  the cupboard was bare
 ←
#4  serving breakfast (cafe.cpp 103)
→4
#5  serving {customer} (cafe.cpp 104)
→5  "dominic"
+λ[n]
 ←
#6  on parole (kitchen.cpp 100)
→6
→λ[n]
→2  "bacon and eggs"
→3  "bacon"
 ←
→3  "eggs"
 ←
 ←
```

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  prepare(fav);
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

```
#1  having breakfast (home.cpp : 100)
→1
#2  preparing {recipe} (cooking.cpp : 101)
→2  "bacon and eggs"
#3  fetching {ingredient} (cooking.cpp : 102)
→3  "bacon"
 ←
→3  "eggs"
 !
 !
 !
 e  the cupboard was bare
 ←
#4  serving breakfast (cafe.cpp 103)
→4
#5  serving {customer} (cafe.cpp 104)
→5  "dominic"
→λ[n]
 ←
#6  on parole (kitchen.cpp 100)
→6
→λ[n]
→2  "bacon and eggs"
→3  "bacon"
 ←
→3  "eggs"
 ←
 ←
```

the cafe

```
void breakfast_service() {
  whilst("serving breakfast");
  while (customers.waiting())
    take_order(customers.dequeue());
  }
}

void take_order(customer c) {
  whilst("serving {customer}", c);
  orders.queue(order(c,
                     c.choice(),
                     current_intentions()));
}
```

→4 →5
"dominic"

the kitchen

```
#1  having breakfast (home.cpp : 100)
→1
#2  preparing {recipe} (cooking.cpp : 101)
→2  "bacon and eggs"
#3  fetching {ingredient} (cooking.cpp : 102)
→3  "bacon"
 ←
→3  "eggs"
 !
 !
 !
 e  the cupboard was bare
 ←
#4  serving breakfast (cafe.cpp 103)
→4
#5  serving {customer} (cafe.cpp 104)
→5  "dominic"
+λ[n]
 ←
#6  on parole (kitchen.cpp 100)
→6
→λ[n]
→2  "bacon and eggs"
→3  "bacon"
 ←
→3  "eggs"
 ←
 ←
```

```
void kitchen_worker() {
  whilst("on parole");
  while (orders.waiting()) {
    prepare_order(orders.dequeue());
  }
}

void prepare_order(order o) {
  with_intent(o.intent());
  try {
    prepare(o.recipe());
  } catch(...) {
    problems.queue(problem(o,
                           std::current_exception(),
                           current_intentions()));
  }
}
```

the kitchen

```
#2  preparing {recipe} (cooking.cpp : 101)
→2  "bacon and eggs"
#3  fetching {ingredient} (cooking.cpp : 102)
→3  "bacon"
 ←
→3  "eggs"
 !
 !
 !
 e  the cupboard was bare
 ←
#4  serving breakfast (cafe.cpp 103)
→4
#5  serving {customer} (cafe.cpp 104)
→5  "dominic"
+λ[n]
 ←
#6  on parole (kitchen.cpp 100)
→6
→λ[n]
→2  "bacon and eggs"
→3  "bacon"
 ←
→3  "eggs"
 ←
 ←
 ←
-λ[n]
```

```
void kitchen_worker() {
  whilst("on parole");
  while (orders.waiting()) {
    prepare_order(orders.dequeue());
  }
}

void prepare_order(order o) {
  with_intent(o.intent());
  try {
    prepare(o.recipe());
  } catch(...) {
    problems.queue(problem(o,
                           std::current_exception(),
                           current_intentions()));
  }
}
```

```
#2  preparing {recipe} (cooking.cpp : 101)
→2  "bacon and eggs"
#3  fetching {ingredient} (cooking.cpp : 102)
→3  "bacon"
 ←
→3  "eggs"
 !
 !
 !
 e  the cupboard was bare
 ←
#4  serving breakfast (cafe.cpp 103)
→4
#5  serving {customer} (cafe.cpp 104)
→5  "dominic"
+λ[n]
 ←
#6  on parole (kitchen.cpp 100)
→6
→λ[n]
→2  "bacon and eggs"
→3  "bacon"
 ←
→3  "eggs"
 ←
 ←
 ←
-λ[n]
```

the kitchen

```
void kitchen_worker() {
  whilst("on parole");
  while (orders.waiting()) {
    prepare_order(orders.dequeue());
  }
}

void prepare_order(order o) {
  with_intent(o.intent());
  try {
    prepare(o.recipe());
  } catch(...) {
    problems.queue(problem(o,
                           std::current_exception(),
                           current_intentions()));
  }
}
```

→4 →5
"dominic"

the kitchen

```
#2  preparing {recipe} (cooking.cpp : 101)
→2  "bacon and eggs"
#3  fetching {ingredient} (cooking.cpp : 102)
→3  "bacon"
 ←
→3  "eggs"
 !
 !
 !
 e  the cupboard was bare
 ←
#4  serving breakfast (cafe.cpp 103)
→4
#5  serving {customer} (cafe.cpp 104)
→5  "dominic"
+λ[n]
 ←
#6  on parole (kitchen.cpp 100)
→6
→λ[n]
→2  "bacon and eggs"
→3  "bacon"
 ←
→3  "eggs"
 ←
 ←
 ←
-λ[n]
```

```
void kitchen_worker() {
  whilst("on parole");
  while (orders.waiting()) {
    prepare_order(orders.dequeue());
  }
}

void prepare_order(order o) {
  with_intent(o.intent());
  try {
    prepare(o.recipe());
  } catch(...) {
    problems.queue(problem(o,
                   std::current_exception(),
                   current_intentions()));
  }
}
```

Part V

Agent Provocateur

- But first, a tip…

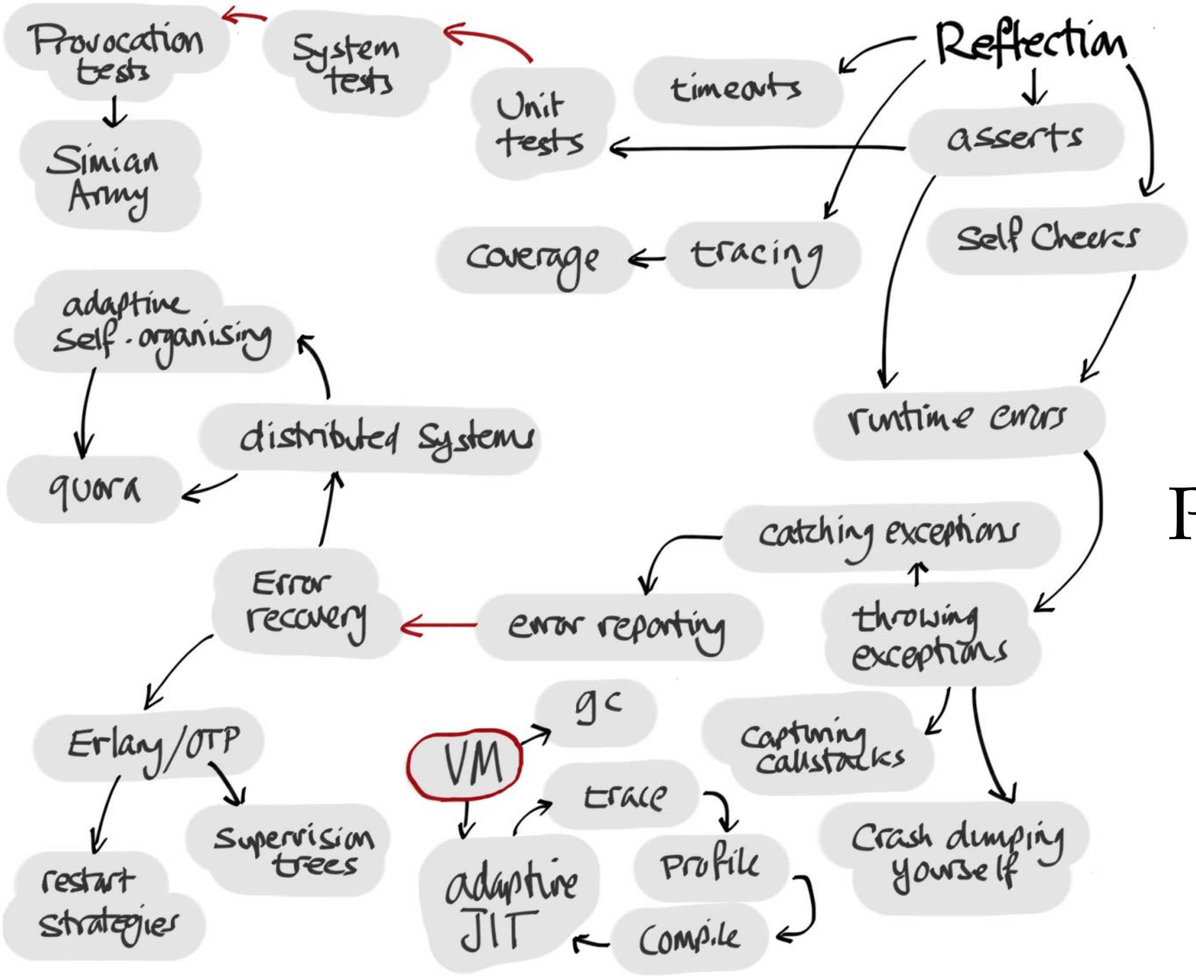
Agent Provocateur

Agent Provocateur

- … don’t Google this at work looking for images to enliven your title slide.

Agent Provocateur

- … don't Google this at work looking for images to enliven your title slide.
- here is one I drew instead…



Agent Provocateur

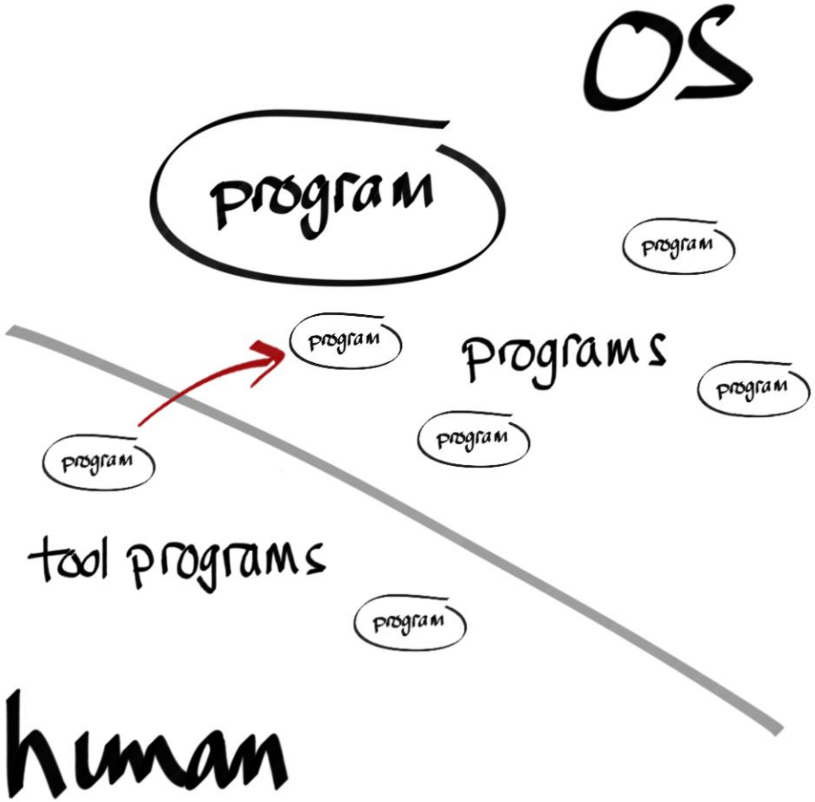
- Intention frames mark scopes in the code where domain relevant activity happens.

- There is an implicit expectation that the activity may fail.

Provocation

Provocation

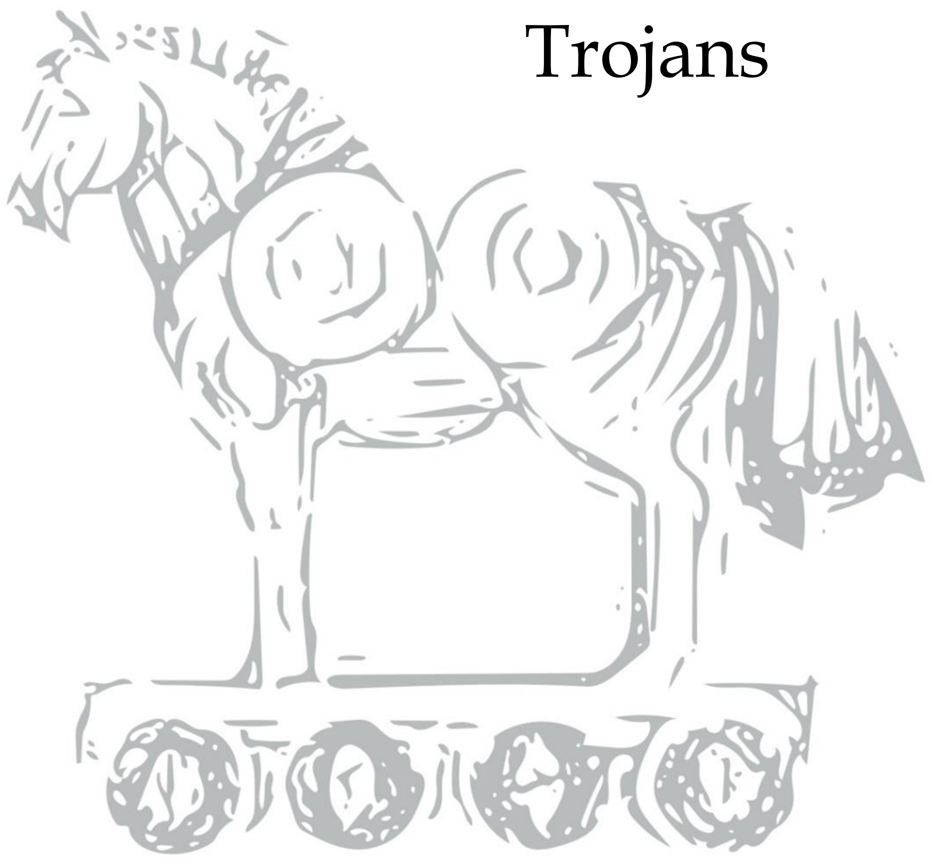
- Intention frames mark scopes in the code where domain relevant activity happens.
- There is an implicit expectation that the activity may fail.
- So… we could test an application's resilience in a controlled way by deliberately provoking errors at these points.



Agent
Provocateur

Trojans

- Inside the horse…



Trojans

- The intention runtime has access to the application as it starts its intended activity.
- It can inspect the application's intentions and selectively inject exceptions to manipulate *effect*.
- It can monitor the application's reaction by observing intention flow in response to it.

Specificity

- By matching specific values in the intention stack, provocations can target and monitor execution flow of specific work items.

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  try {
    whilst("hoping for {favourite}", fav);
    prepare(fav);
  } catch(...) {
    shelve(std::current_exception(),
           current_intentions());
    whilst("making do with {fallback}", toast);
    prepare(toast);
  }
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

“ **whilst** having breakfast

whilst hoping for ***bacon and eggs***
whilst preparing ***bacon and eggs***
whilst fetching ***eggs***
the cupboard was bare

whilst making do with ***toast***
whilst preparing ***toast***
whilst fetching ***bread***
the cupboard was bare ”

```
void breakfast(recipe &fav) {
  whilst("having breakfast");
  try {
    whilst("hoping for {favourite}", fav);
    prepare(fav);
  } catch(...) {
    shelve(std::current_exception(),
           current_intentions());
    whilst("making do with {fallback}", toast);
    prepare(toast);
  }
}

void prepare(recipe &r) {
  whilst("preparing {recipe}", r);
  for(const auto &i : r.ingredients()) {
    fetch(i);
  }
}

void fetch(ingredient &i) {
  whilst("fetching {ingredient}", i);
  cupboard.get(i);
}
```

“ **whilst** having breakfast

whilst hoping for **{FAVOURITE}**
 whilst preparing **{RECIPE}**
  whilst fetching **{INGREDIENT}**
   {EXCEPTION}

whilst making do with **{FALLBACK}**
 whilst preparing **{RECIPE}**
  whilst fetching **{INGREDIENT}**
   {EXCEPTION} ”

Synchronicity

- Trojans can communicate with their controller to coordinate provocation of parallel and distributed systems.
- Waiting until multiple flows have reached specific points by blocking each until conditions are met to release or interrupt them.
- Testing response to:
  - Simultaneous failures.
  - Repeated failures.
  - Induced timeouts.
  - Dropping connections at specific states in a protocol.

- Provided intentions are expressed in terms of domain work rather than implementation details, intention matching patterns used in tests ought to be resilient to implementation change.

Resilience

Harvesting

- Intention descriptions can be harvested statically from source code both to validate patterns used in tests and to generate provocation attack patterns.

- Intention flows can be harvested dynamically via the runtime to collect coverage and to generate context specific provocation patterns.

Command and control

- The intention runtime provides an external command and control interface.
  - Load and unload trojans.
  - Observe intention flow.
  - Coordinate actions at trigger points:
    - Delay.
    - Block until released.
    - Inject exception.

Tests

- Custom test controllers to observe intentions and orchestrate provocations must be succinct and easy to write.
- Use a **declarative** intention matching DSL to target trigger points.
- Employ **actors** and **composable promises** to:
  - Represent and observe triggers.
  - Capture sequences of events.
  - Express expected sequences of events.
  - Hide (some of) the complexities of dealing with asynchronous events.

Caveat

- This doesn’t exist yet…
- … but all the pieces do.

In future

- In a target system implemented with ***intentions*** and ***composable promises*** to reify the forward flow of values, a test system could manipulate both aspects of *effect*:

- *values* and *exceptions*.

Cautions

- Don’t ship builds with the C&C interface.

In conclusion

- *Intentions* are a mechanism for programs to annotate their own execution flow with domain intent.
- They provide a context for exceptions when generating error descriptions.
- They enable a succinct logging mechanism.
- They offer possibilities for program monitoring and provocation testing.

Questions and feedback

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