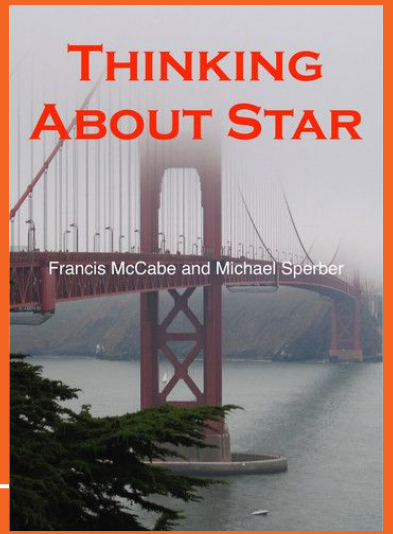
Star - A Modern Programming Language

And a splash of logic



Change is the norm

Real software engineering is about change, and responding to it. However, our main tools for software - programming languages - are not very good at supporting change.

Change is hard:

A typical programmer's lifetime's output is about 500K loc.

A moderately sized system.

Impossible to migrate..

1. Three ‘R’s

- **Re-use**
  New roles for old software
- **Re-purpose**
  React to changing circumstances
- **Refactor**
  Improvement

Huh?

Compilers can generate better code than humans.

So, why do we try to compete?

A tale of three loops

Ok?

Let's start simple.

This looks easy...

```
int total = 0;
for(Integer ix:L)
   total += ix;
```

- we had to fix on the type of the number being totaled;
- we had to know about Java's boxed v.s. unboxed types;
- we had to construct an explicit loop, with the result that we sequentialized the process of adding up the numbers.

Well?

Still better than C-style for loop.

Functional Programming

Mathematical properties of functions

Tractable reasoning

Very expressive

Functions are better?

```
let{
   total(nil) => 0.
   total(cons(E,L)) => total(L)+E
} in total(L)
```

- We had to fix on the type of the collection;
- Explicit about state management; and
- Explicit about order of processing

Huh?

Explicit recursion may be lower level than iteration

Contracts

```
contract arith[e] ::= {
   (+):(e,e)=>e.
   (*):(e,e)=>e.
   ...
   zero:e.
   one:e.
}
```

Wow!

Arithmetic is not special in Star

- Separate specification from implementation
- Can implement contracts for types you do not own.

Stream total

- Abstracted collections and arithmetic
- Order is still explicit

```
let{
   total:all c,e ~~
      arith[e], stream[c->>e] |:
         (c)=>e.
    total([])=>zero.
    total([E,..Ls]) => total(Ls)+E.
} in total(L)
```

Um...

Type annotation optional in most cases

Better by folding

```
leftFold((+),0,L)
```

See!

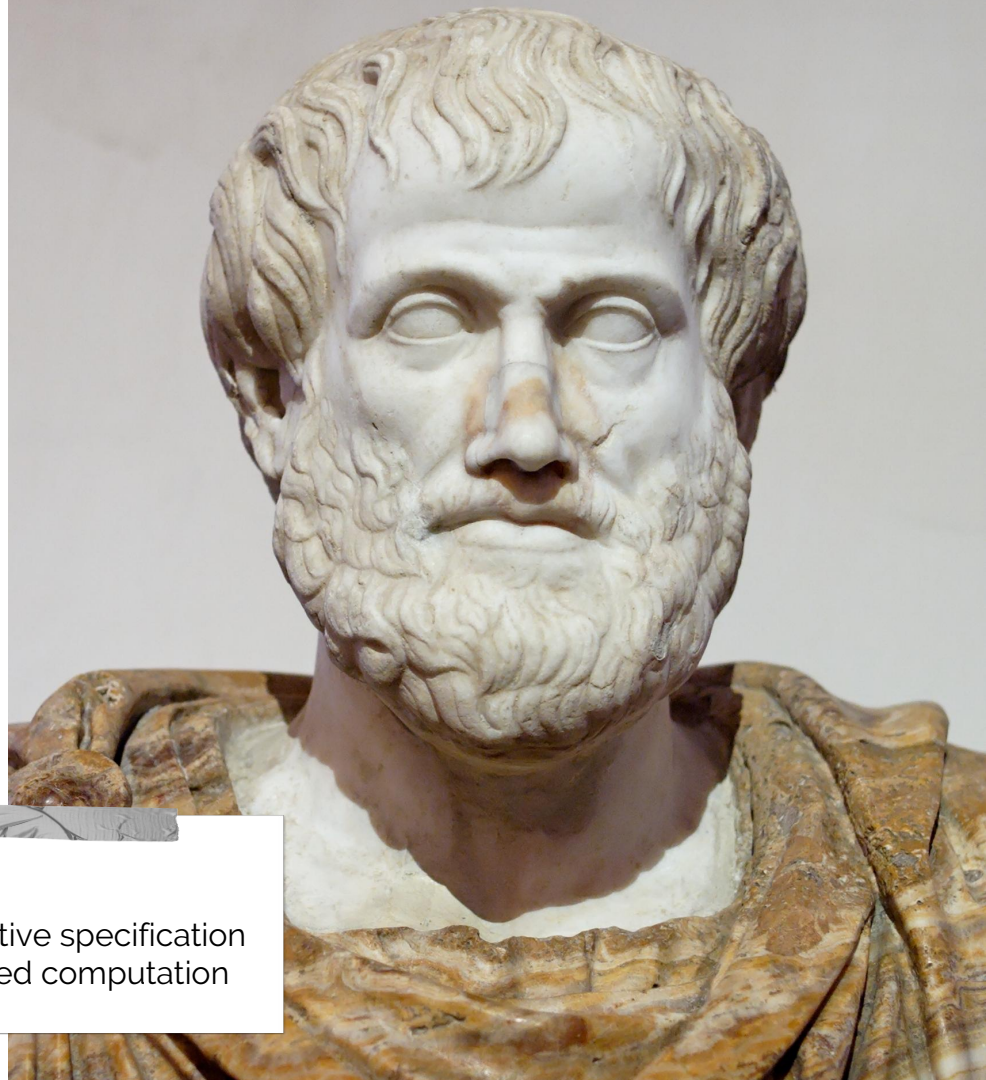
Recursion is buried in standard function

- No explicit iteration
- Still rely on arithmetic and stream abstractions
- Order dependent on implementation of `leftFold`

Even better with Logic

```
{ fold X with (+) | X in L }
```

- No commitment to ordering
- No commitment to types



Deep!

Declarative specification of desired computation

Grandparents

Look:

Java can be verbose

```
for(Pair<Person,Person> P:parents){
  for(Pair<Person,Person> Q:parents){
    if(P.child==Q.parent)
      emit(P.parent,Q.child)
  }
}
```

- Search -> satisfaction semantics
- **`emit`** hides some nastinesses

Folding Grandparents

```
foldLeft(
 (SoFar,(X,Z)) => foldLeft(
   let {
     acc(gp1,(ZZ,Y)) where Z==ZZ => [gp1..,(X,Y)].
     acc(gp1,_) => gp1.
   } in acc,
   SoFar,parents),
   [],
  parents)
```

Wow!

I guess it's declarative!

- Fold expressions have a tendency to explode when there is any complication
- Uses some powerful features:
  a. Tuple patterns
  b. `let` expressions
  c. Conditional equations

Grandparents' Logic

```
{ (GP,GC) |
   (GP,P) in parents && (P,GC) in parents }
```

Wow!

Similar in spirit to list abstractions

- Easy to extend with different connectives
- Easy to integrate 'logic' semantics with more conventional programming

Don’t need rules

Using functions to define queries is a very powerful technique. No need for a separate syntax of ‘logic’ rule.

```
yourGPs(GC) => { GP |
   (GP,P) in parents &&
   (P,GC) in parents }
```

Semantics is not the same as Prolog!

Hmm

Can use a good query planner

2. Modules

We need to be able to program in the large as well as in the small

➔ **What**

A module is simply a record with functions

➔ **But**

Modules often expose types as well as functions

➔ **And so**

We can systematize many engineering patterns

Huh?

Are modules ways of breaking up large programs?

Or are large programs constructed from smaller pieces.

In the large

Modules, packages, libraries

Few languages make much effort into *computing* libraries.

Records of functions

Cool!

FP makes functions 1st class.

```
{ find:all k,v ~~ (dict[k,v],k)=>option[v].
  update:all k,v~~(dict[k,v],k,v)=>dict[k,v].
}
```

- Record contains functions.
- Full power of language available at large scale
- But, ...

Modules export types

Embed types in records

Existentially quantified types

Existential Dictionaries

```
dictModTp ::= exists dict/2 ~~ {
  find:all k,v ~~ (dict[k,v],k)=>option[v].
  update:all k,v~~(dict[k,v],k,v)=>dict[k,v].
  new:all k,v ~~ ()=>dict[k,v].
}
```

Hmm...

`dict/2` is a type variable that must have two type arguments

Dictionary Defined

Wow!

Function returns a module

```
MyDictM:()=> dictModTp.

MyDictM() => {
  dict[k,v] <~ fancyMap[k,v].
  find(D,K) => findInFancyMap(D,K).
  update(D,K,V) => updateFancyMap(D,K,V).
  new() => ...
}
```

- Existentials need evidence
- Can be different inside vs outside

Using modules

See...

The type of D depends on a dynamically computed expression

```
MD = MyDictM()
D:MD.dict[string,integer].
D.find("fred")
```

- Split module import into separate architectural elements
- Can write module-valued functions

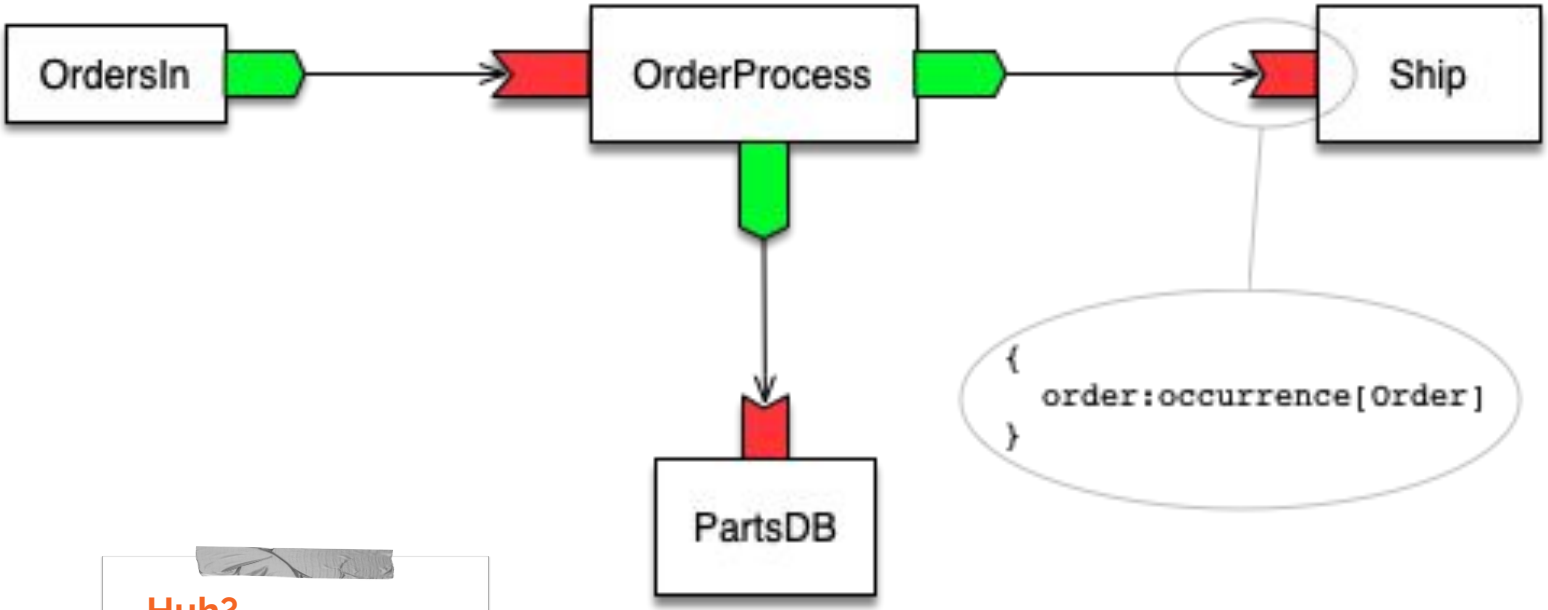

A platform is a foundation where others can develop and promulgate solutions

3. Platforms

A platform needs

- **Construction**
  Bigger structures from smaller pieces, in a type safe way.
- **Marketplace**
  Modules type signature means better reusability
- **Frameworks**
  Testing, deployment, scenarios; sometimes independent of modules being used.

A Simple Application

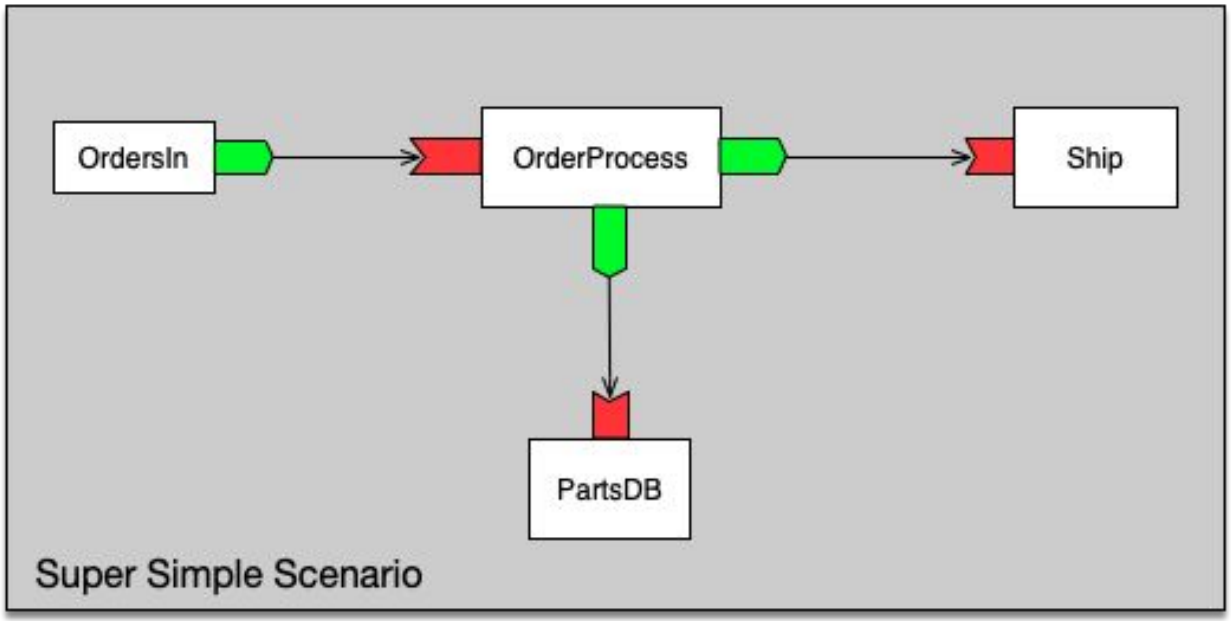


Huh?

Connections are well typed

- Many simple applications look like this

A Complete (Simple) Scenario

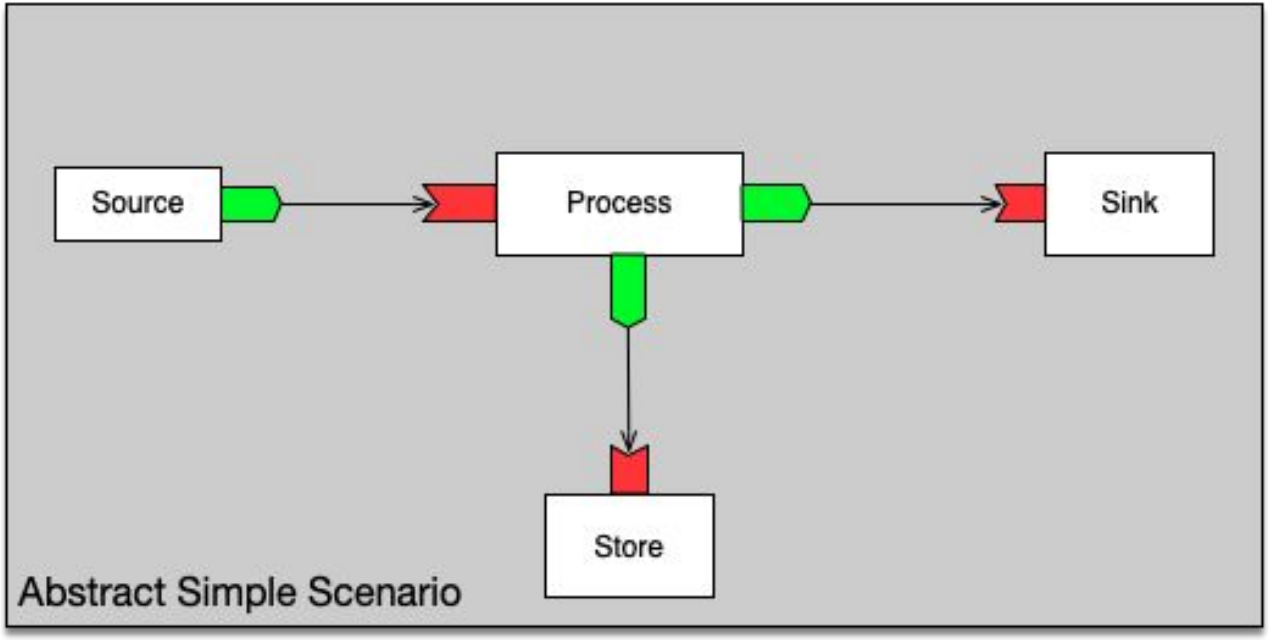


Wow!

The whole application is statically typed

- Create an application from the use case

An Abstract Scenario

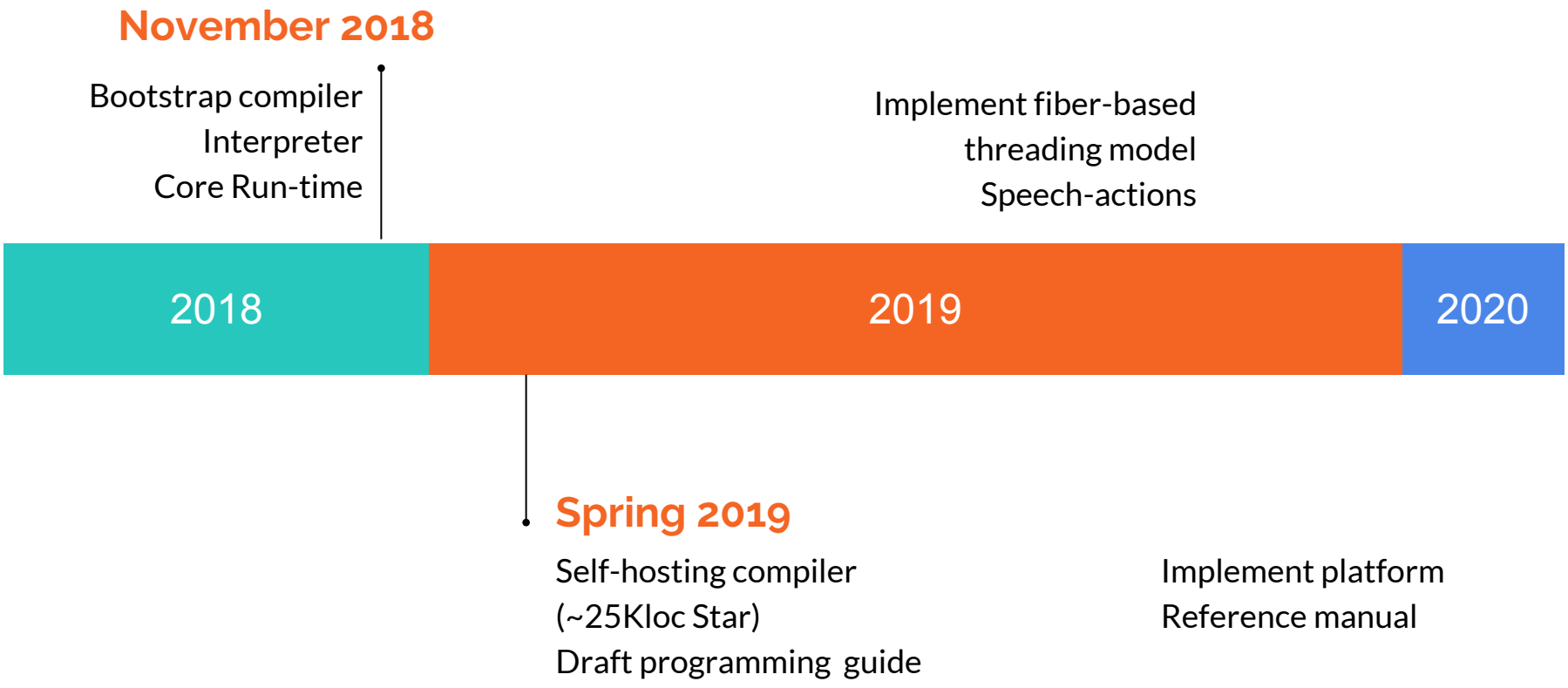


Deep!

We have variables in place of modules

- Can re-use this template by plugging in different modules for different roles
- Existential types respect ownership

Road map


November 2018
Bootstrap compiler
Interpreter
Core Run-time
Implement fiber-based
threading model
Speech-actions
2018
2019
2020
Spring 2019
Self-hosting compiler
(~25Kloc Star)
Draft programming guide
Implement platform
Reference manual

Takeaways

Star has strong foundations to support ‘good’ architecture

Logic can be very expressive, with a small but critical role

Sound semantics for modules leads to a greater role for PLs in large systems

Conclusions for illustration purposes only

Not a solo effort

Michael Sperber, David Frese, Andreas Bernauer, Steve Banauch, Bob Riemenschneider, Chris Gray, Kevin Twidle, Utkarsh Lath, Keith Clark, Michael Weber and … you?

Any more questions?

For more,, go to
https://github.com/fgmccabe/star

In progress...