Ensō

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CWI

Prevent Bad

Enable Good

Bug Finding
Race Detection
Type Checking
etc.

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Prevent Bad

Enable Good

New languages?
New features?
For what?

Bug Finding
Race Detection
Type Checking
etc.

Prevent Bad

Advantages:
Measurable
Domain-free

Enable Good

New languages?
New features?
For what?

Kolmogorov Complexity

Shortest program that generates information

Best

~~Shortest~~ program

that

generates ~~information~~

behavior

Best

~~Shortest~~ program

that

generates ~~information~~

behavior

Qualitative Kolmogorov

Program Complexity

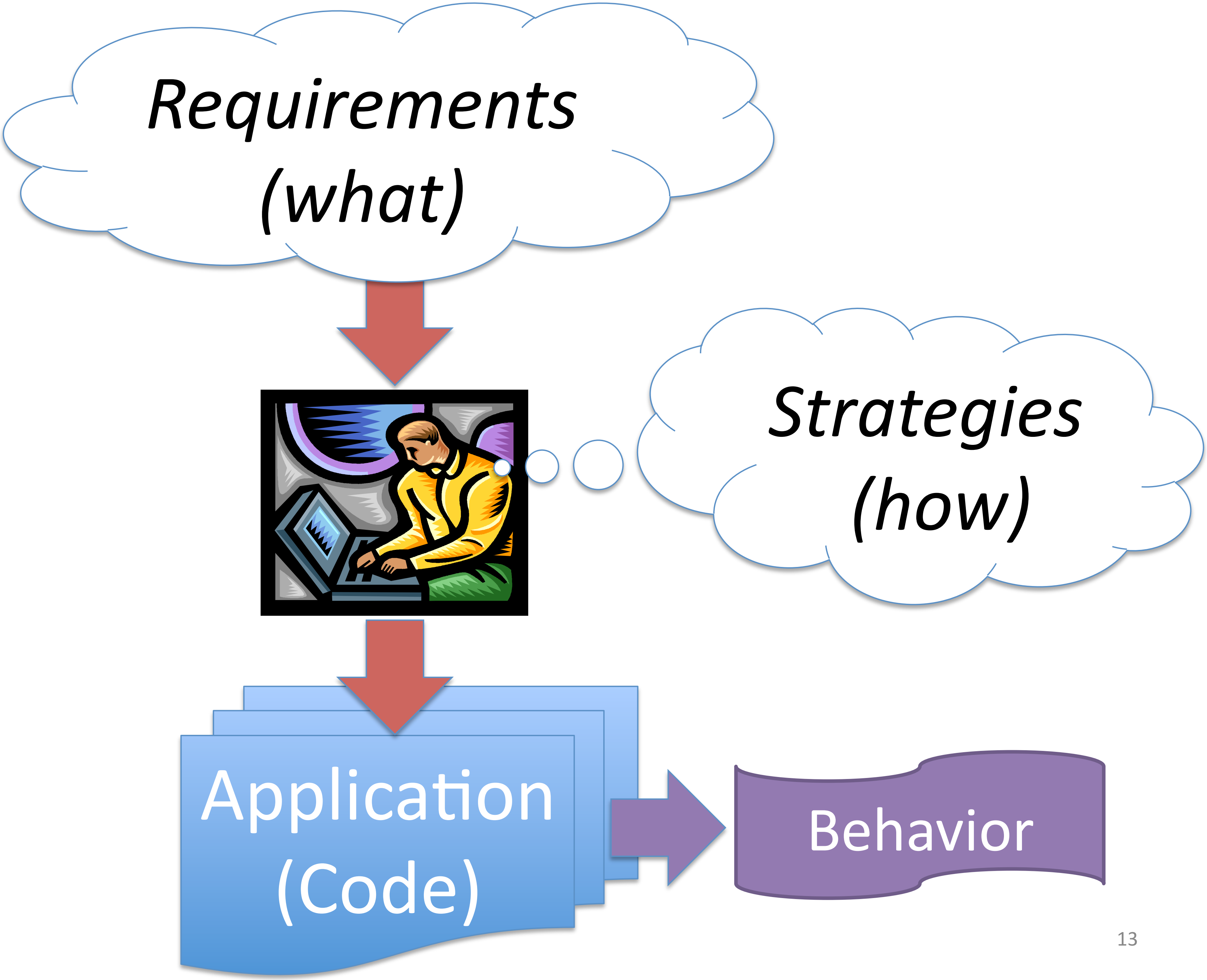
I don't know how

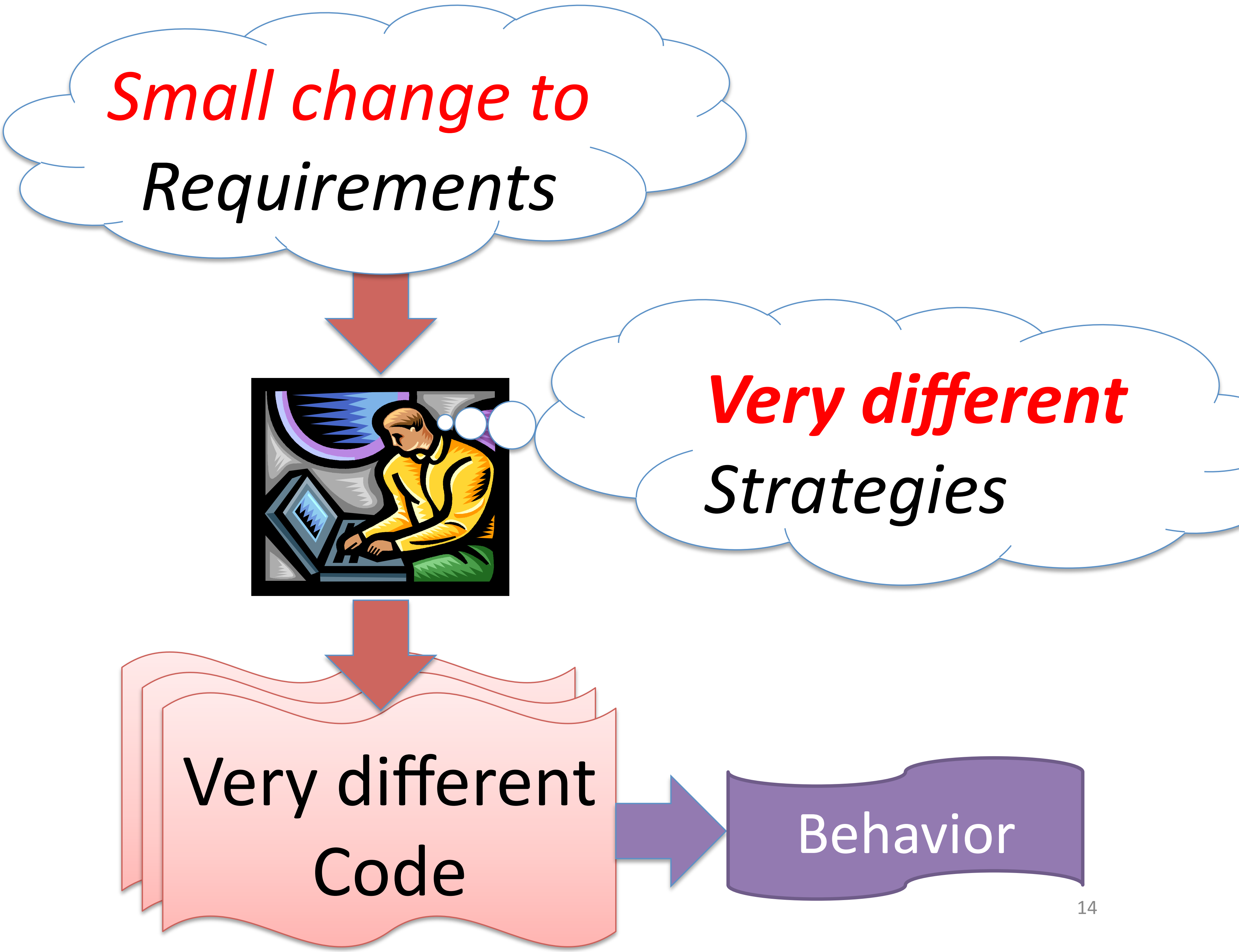
but it’s a good goal

A Problem

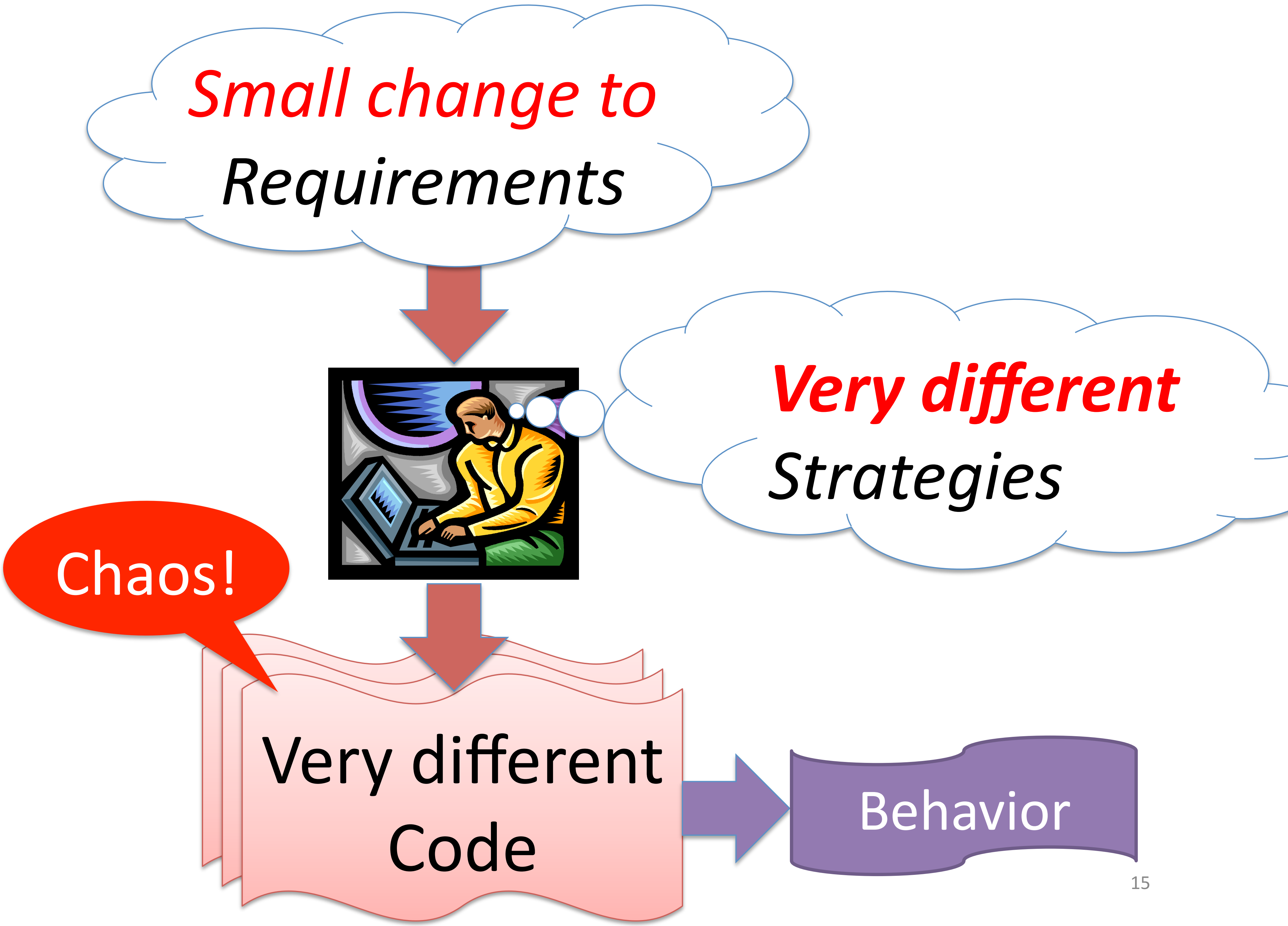
1. Many (many!) repeated instances of *similar* code

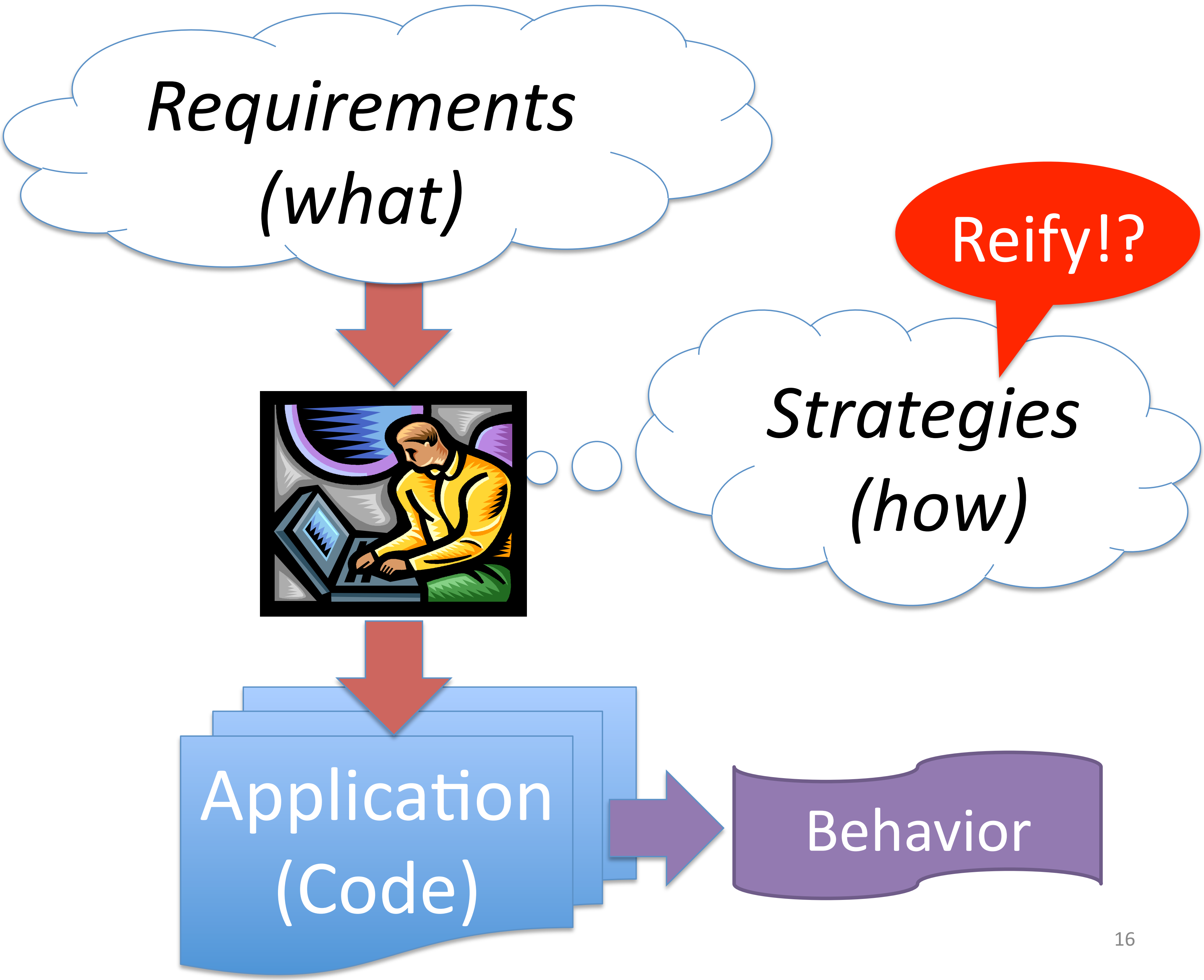
2. Unique *details* and *names* prevent generalization


Requirements
(what)
Strategies
(how)
Application
(Code)
Behavior

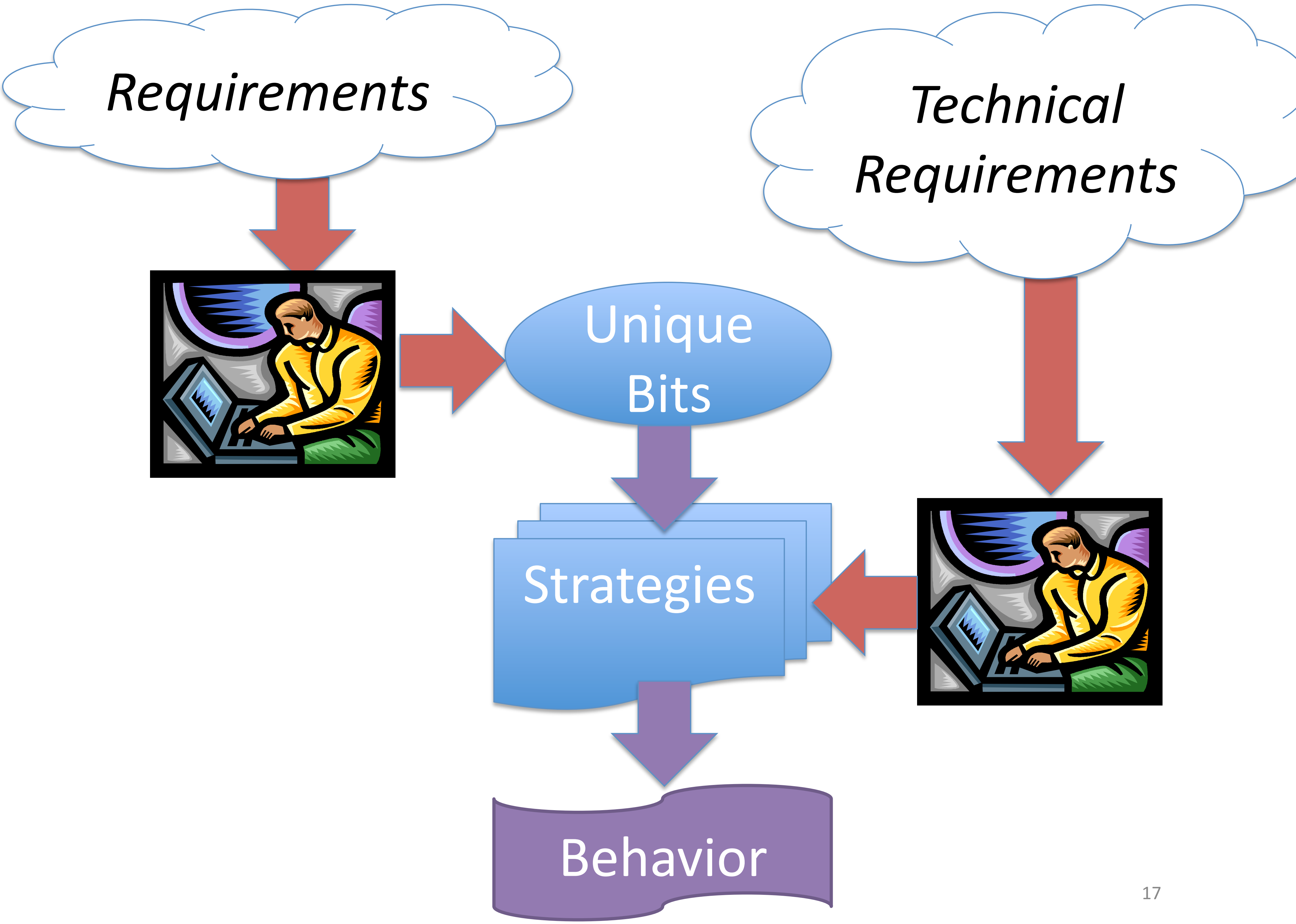


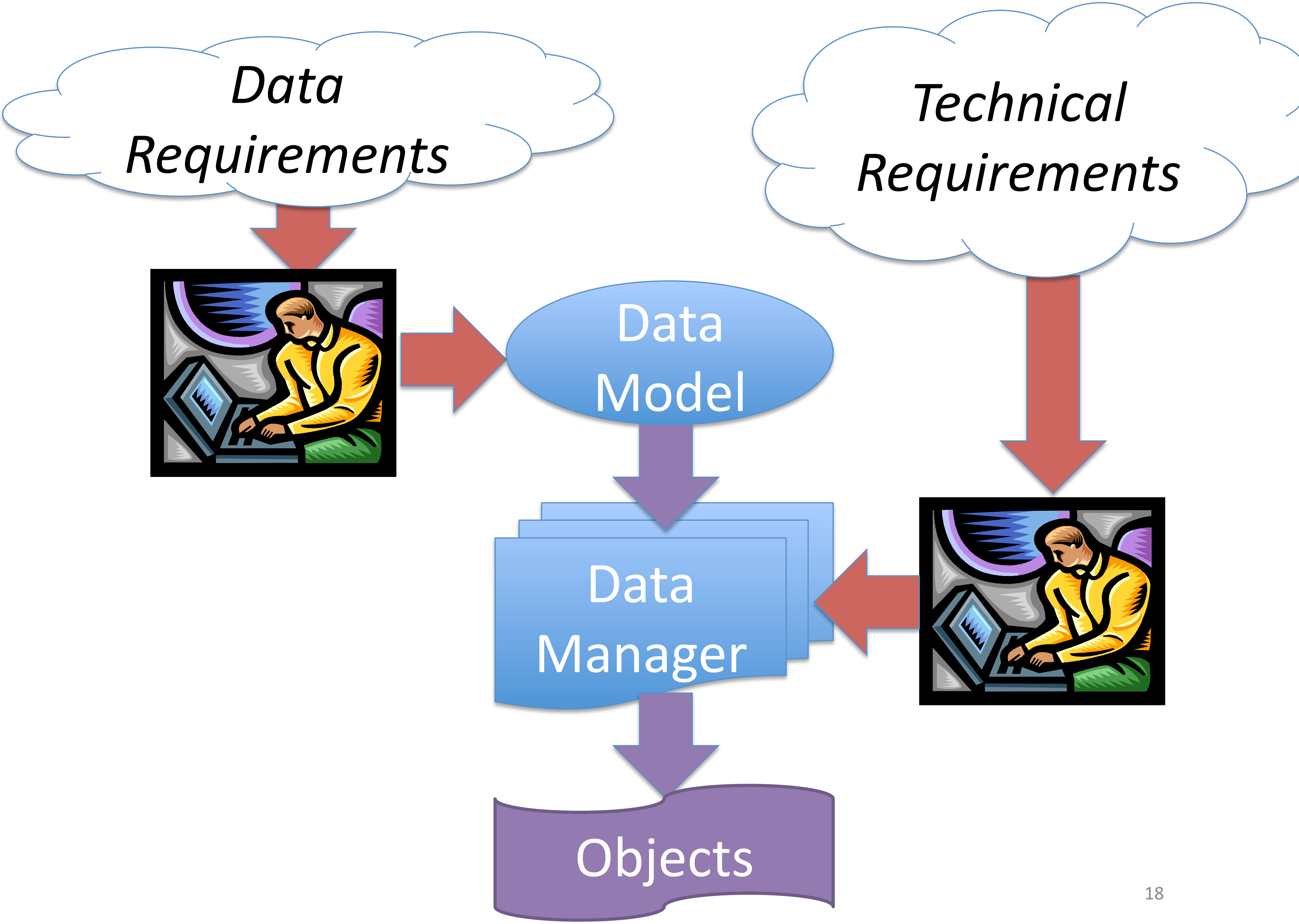
Small change to Requirements
Very different Strategies
Very different Code
Behavior


Small change to
Requirements
Very different
Strategies
Chaos!
Very different
Code
Behavior



Requirements (what)
Reify!?
Strategies (how)
Application (Code)
Behavior


Requirements
Technical Requirements
Unique Bits
Strategies
Behavior


Data Requirements
Technical Requirements
Data Model
Data Manager
Objects

Using Managed Data (Ruby)

- Description of data to be managed

```
Point = { x: Integer, y: Integer }
```

- Dynamic creation based on metadata

```
p = BasicRecord.new Point
p.x = 3
p.y = -10
print p.x + p.y
p.z = 3  # error!
```

- *Factory* BasicRecord: Descrption<T> → T

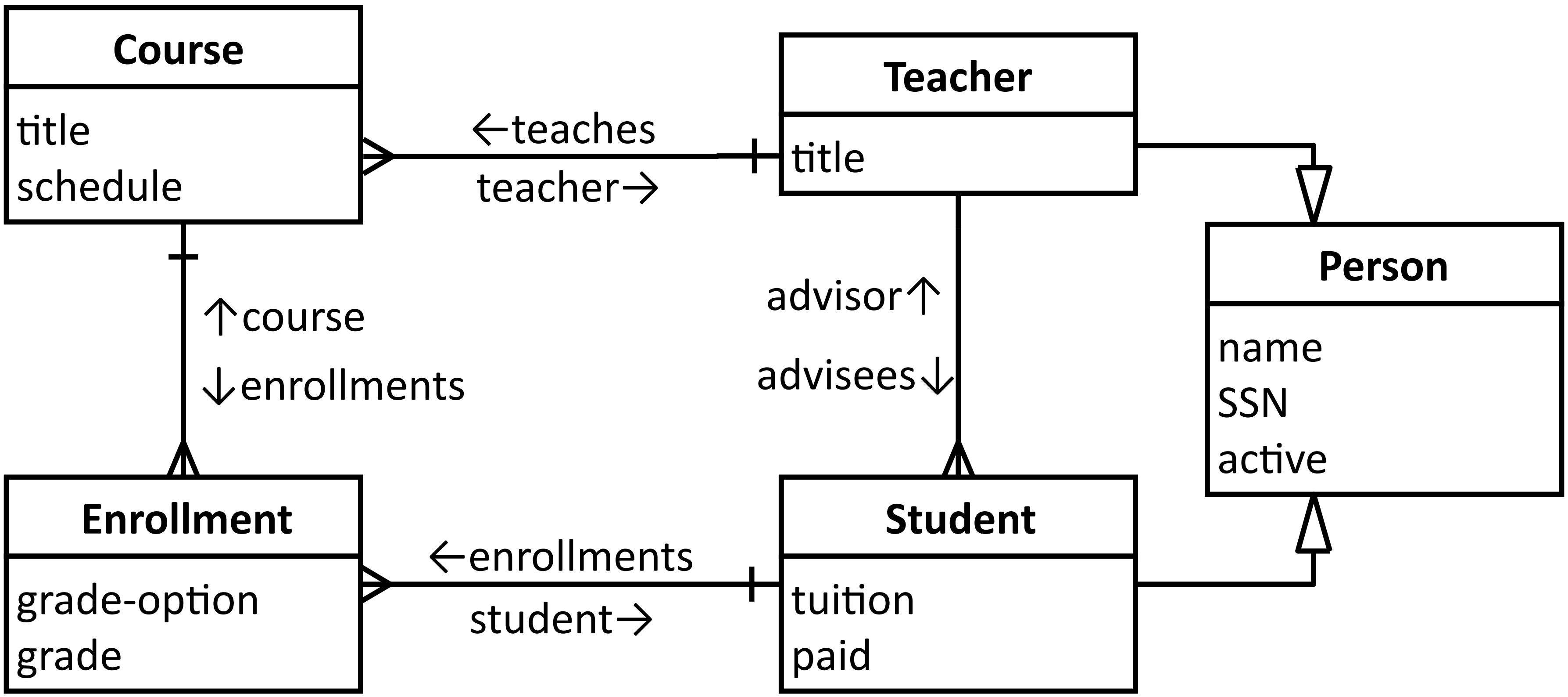
Implementing Managed Data

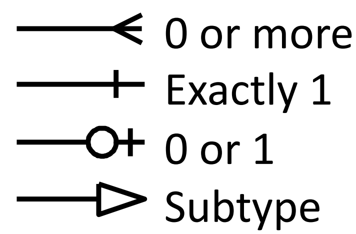
- Override the "dot operator" (p.x)
- Reflective handling of unknown methods
  - Ruby method_missing
  - Smalltalk: doesNotUnderstand
  - Also IDispatch, Python, Objective-C, Lua, CLOS
  - Martin Fowler calls it "Dynamic Reception"
- Programmatic method creation
  - E.g. Ruby define_method
- Partial evaluation

Other Data Managers

- Mutability: control whether changes allowed
- Observable: posts notifications
- Constrained: checks multi-field invariants
- Derived: computed fields (reactive)
- Secure: checks authorization rules
- Graph: inverse fields (bidirectional)
- Persistence: store to database/external format
- General strategy for all accesses/updates
- Combine them for *modular strategies*

Graphs, Invariants, Computed



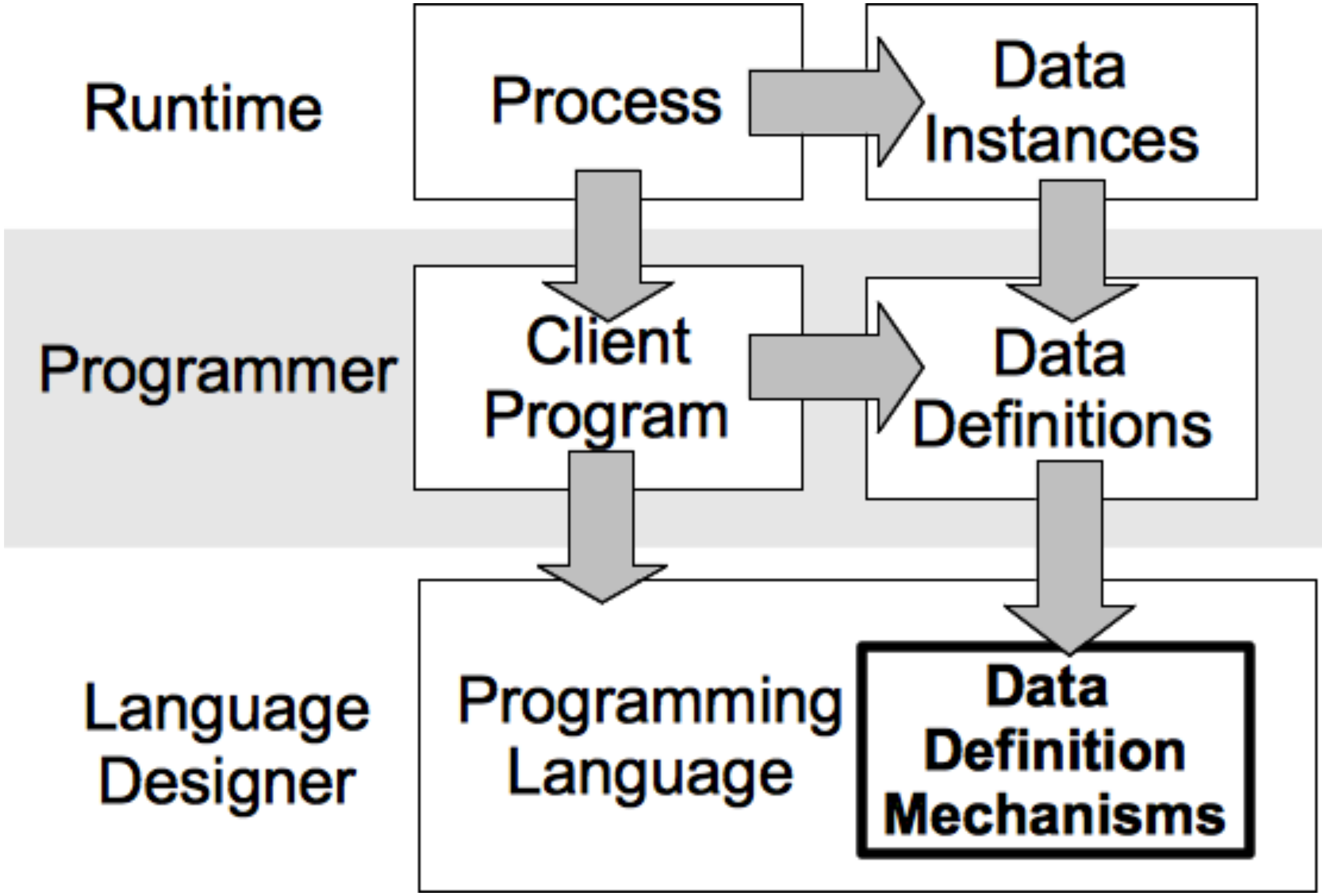


Constraints: for all student s

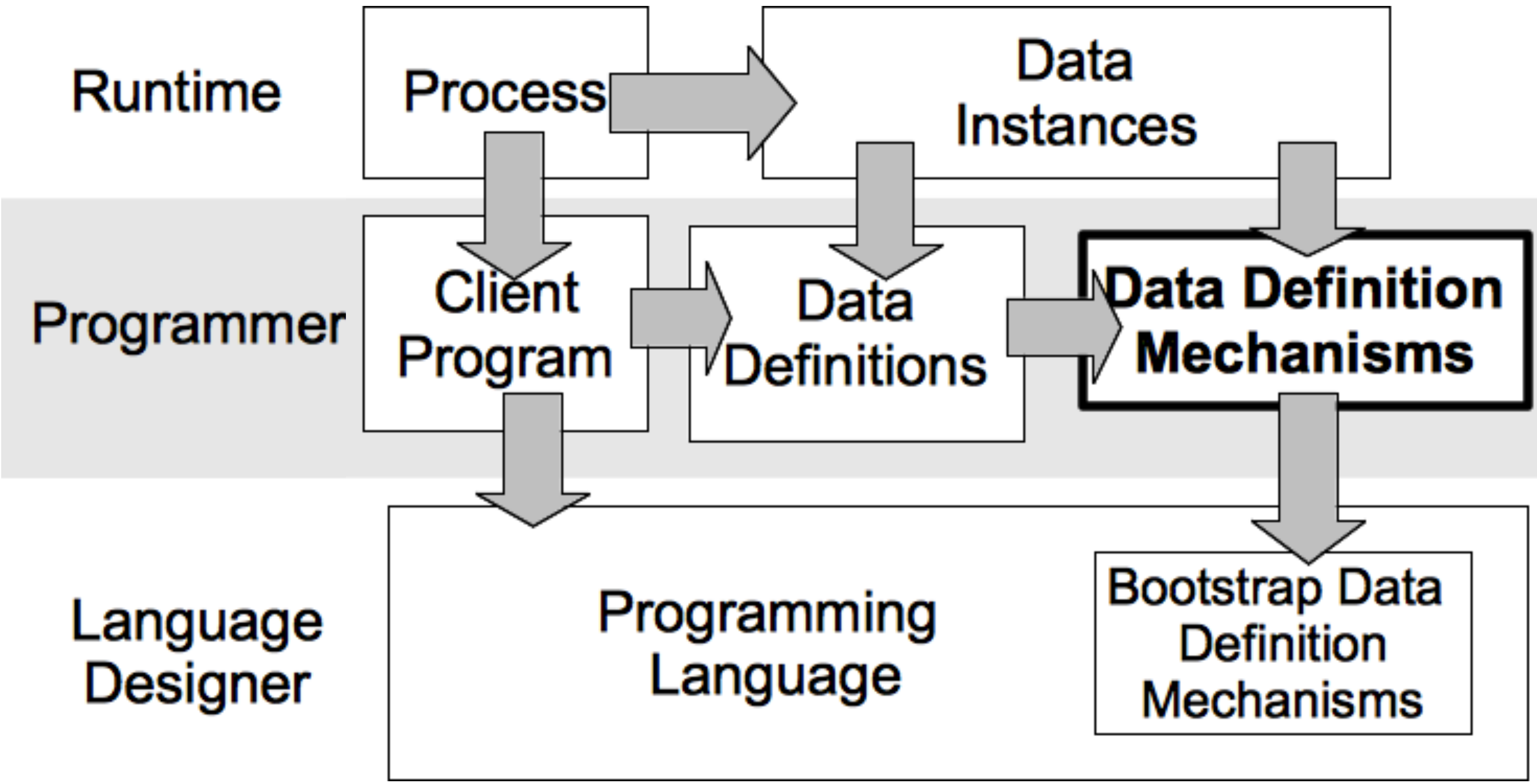
s.dept = s.advisor.dept

Computed values/attribute grammars

Traditional Data Mechanisms



Managed Data



Grammars

- Mapping between *text* and *object graph*
- A *point* is written as (x, y)

Individual	***Grammar***
(3, 4)	P ::= [Point] "(" x:int "," y:int ")"

class

fields

- Notes:
  - Direct reading, no abstract syntax tree (AST)
  - Bidirectional: can parse and pretty-print
  - GLL parsing, *interpreted!*

State Machine Example

Door StateMachine

```
start Opened

state Opened
  on close go Closed

state Closed
  on open go Opened
  on lock go Locked

state Locked
  on unlock go
Closed
```

StateMachine Grammar

```
M::= [Machine] "start" \start:</states[it]> states:S*
S ::= [State] "state" name:sym   out:T*
T ::= [Trans] "on" event:sym "go" to:</states[it]>
```

A StateMachine Interpreter

```
def run_state_machine(m)
  current = m.start
  while gets
    puts "#{current.name}"
    input = $_.strip
    current.out.each do |trans|
      if trans.event == input
        current = trans.to
        break
      end
    end
  end
end
```

StateMachine Schema

```
class Machine
  start  : State
  states! State*

class State
  machine: Machine
  name #   str
  out    !   Trans*
  in     :   Trans*

class Trans
  event :  str
  from   :  State / out
  to      :  State / in
```

Expression Example

Sample Expression

3*(5+6)

Expression Grammar

```
E   ::= [Add] left:E "+" right:M  | M
M ::= [Mul] left:M "*" right:P   | P
P   ::= [Num] val:int             | "(" E ")"
```

Expression Schema

```
class Exp

class Num
  val : int

class Add
  left   : Exp
  right : Exp

class Mul
  left   : Exp
  right : Exp
```

An *Expression* Interpreter

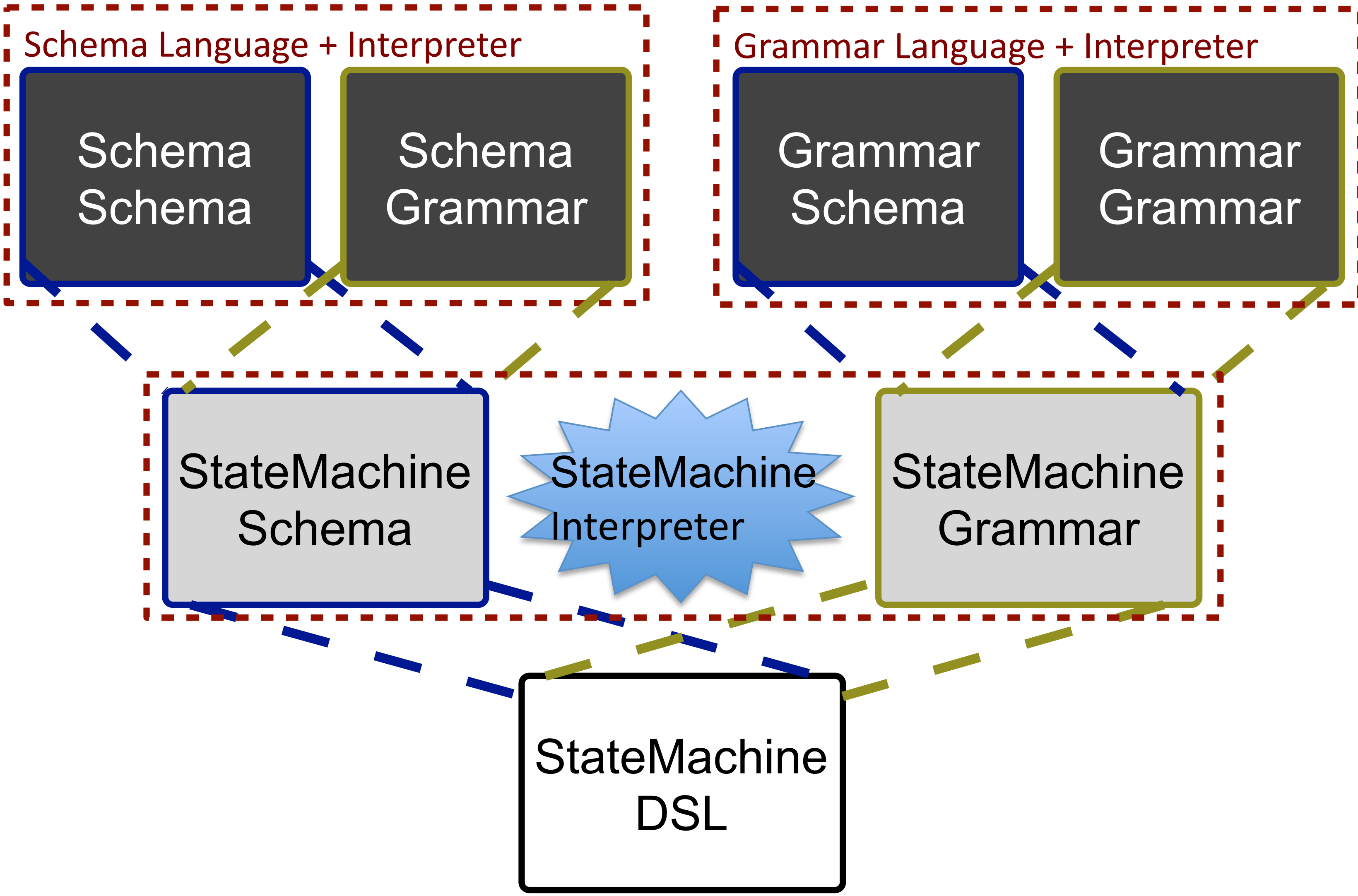
```
module Eval
  operation :eval

  def eval_Num(val)
    val
  end

  def eval_Add(left, right)
    left.eval + right.eval
  end

  def eval_Mul(left, right)
    left.eval * right.eval
  end
end
```

Grammar Grammar

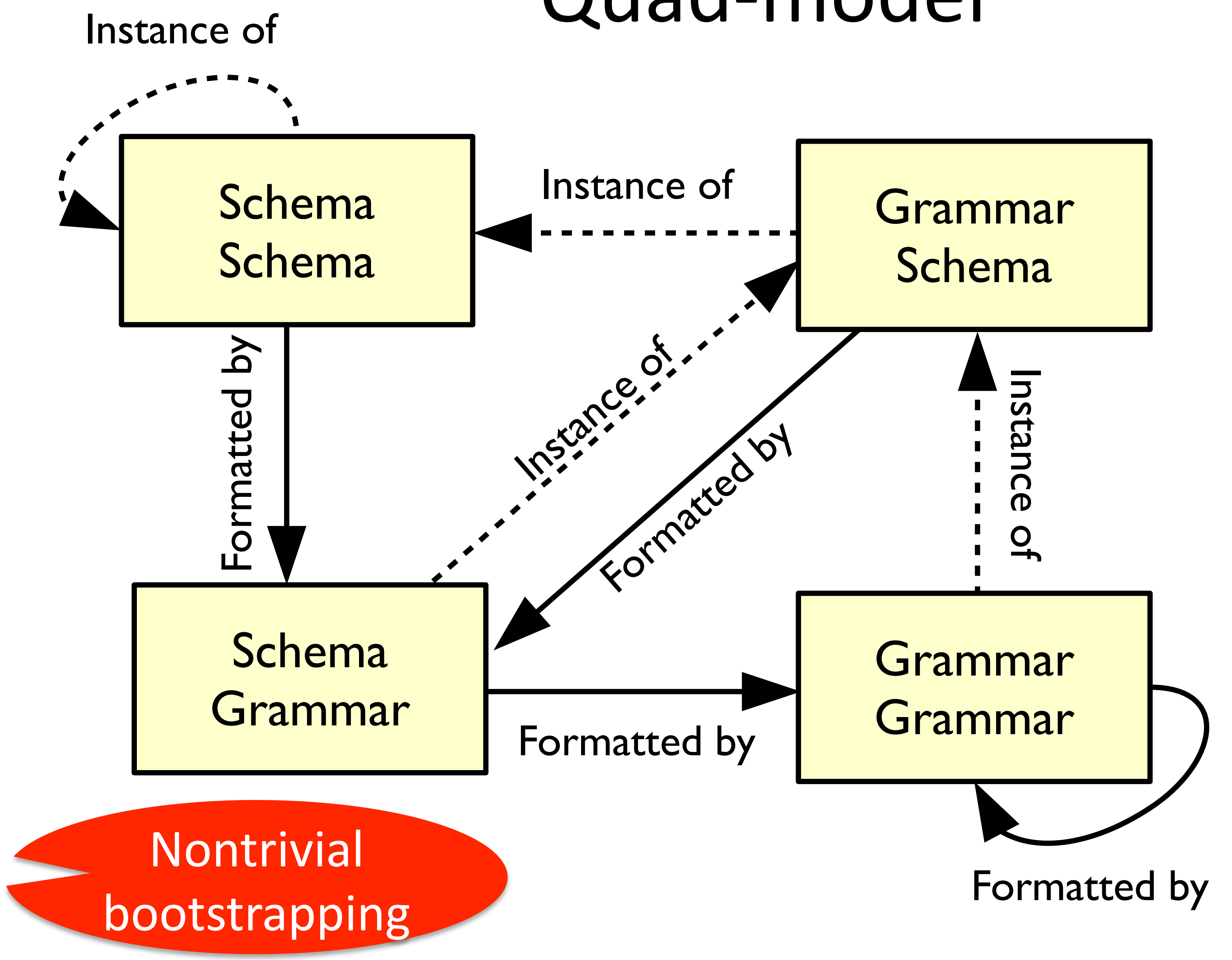
```
start G
G   ::= [Grammar] "start"  start:</rules[it]> rules:R*
R   ::= [Rule]       name:sym "::=" arg:A
A   ::= [Alt]        alts:C+ @"|"
C   ::= [Create]     "[" name:sym "]" arg:S  |  S
S   ::= [Sequence] elements:F*
F   ::= [Field]      name:sym ":" arg:P        |  P
P   ::= [Lit]        value:str
      |  [Value] kind:("int" | "str" | "real" | "sym")
      |  [Ref]    "<" path:Path ">"
      |  [Call]   rule:</rules[it]>
      |  [Code] "{" code:Expr "}"
      |  [Regular] arg:P "*" Sep?      { optional && many }
      |  [Regular] arg:P "?"           { optional }
      |  "(" A ")"
Sep     ::= "@" sep:P
```

non-terminal name
➔ reference to rule

Everything is a language



Quad-model



Instance of
Schema Schema
Instance of
Grammar Schema
Formatted by
Instance of
Formatted by
Instance of
Schema Grammar
Formatted by
Grammar Grammar
Formatted by
Nontrivial bootstrapping

Schema Schema

class Schema
    types: Type*
class Type
    name: string
class Primitive < Type
class Class < Type
    fields: Field*
    super: Type?

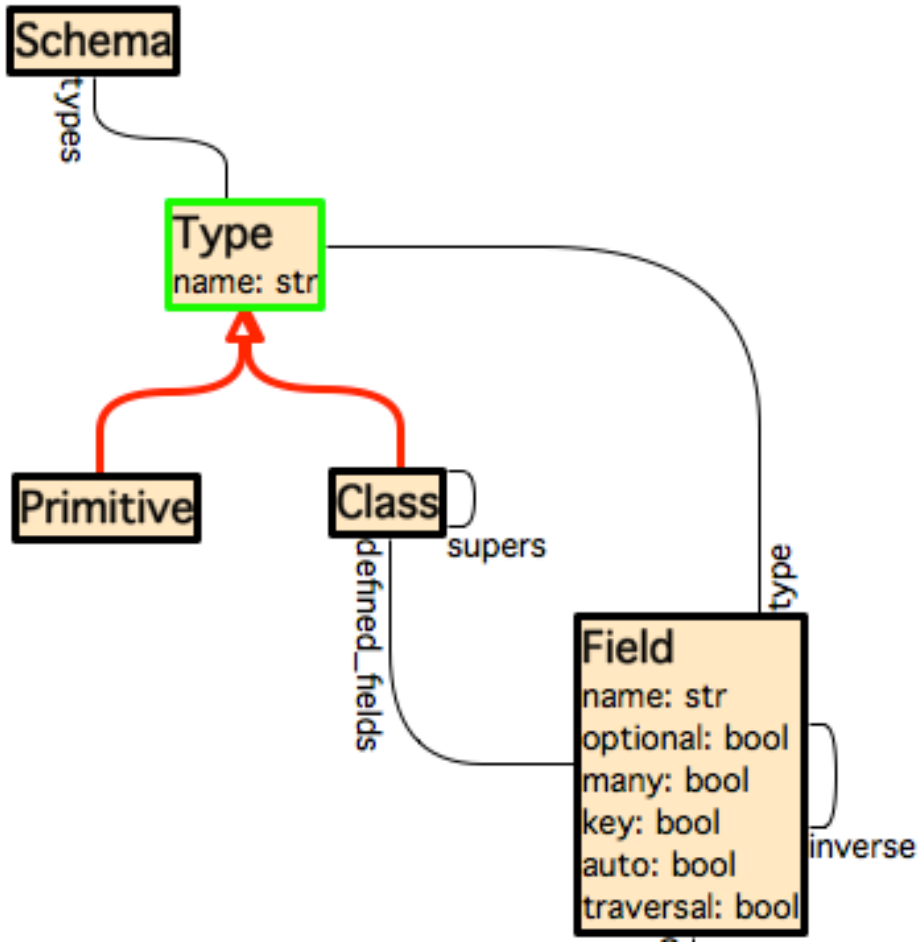
class Field
    name: string
    type: Type
    many: bool
    optional: bool
primitive string
primitive bool

(Self-Description)

Diagrams

- Model
  - Shapes and connectors
- Interpreter
  - Diagram render/edit application
  - Basic constraint solver

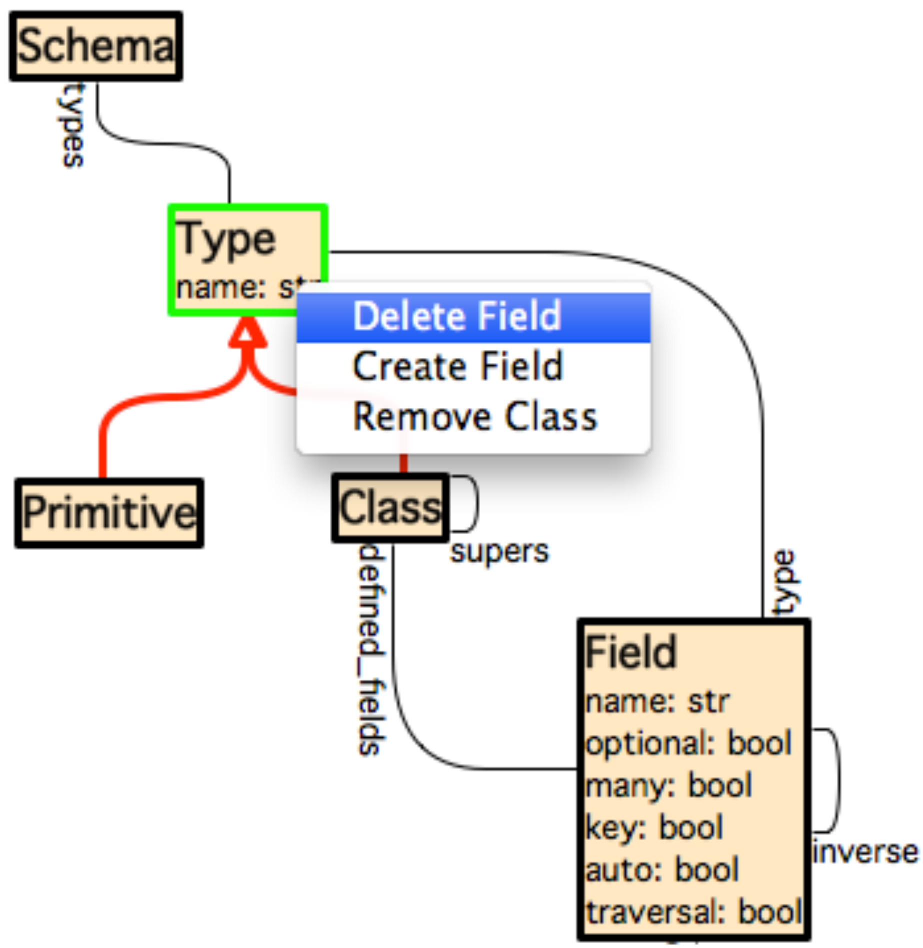
Schema Diagram



Stencils

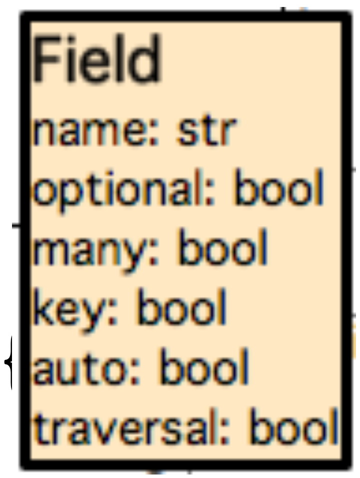
- Model: mapping object graph → diagram
- Interpreter
  - Inherits functionality of Diagram editor
  - Maps object graph to diagram
    - Update projection if objects change
  - Maps diagram *changes* back to object graph
  - Binding for data and collections
    - Strategy uses schema information
    - Relationships get drop-downs, etc
    - Collections get add/remove menus

Schema Diagram Editor



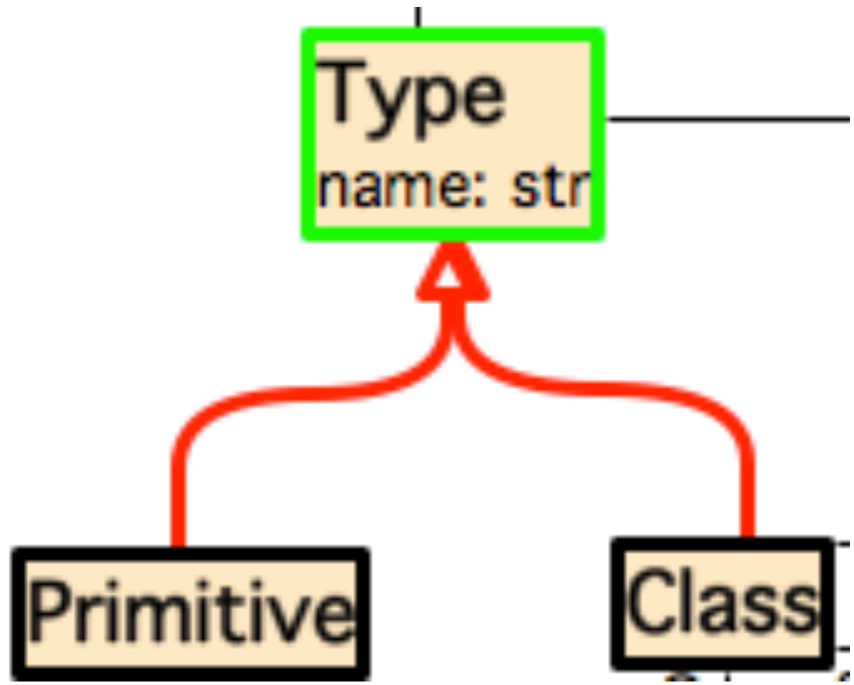
Schema Stencil

```
diagram(schema)
graph [font.size=12,fill.color=(255,255,255)] {
for "Class" class : schema.classes
  label class
   box [line.width=3, fill.color=(255,228,181)] {
    vertical {
      text [font.size=16,font.weight=700] class.name
      for "Field" field : class.defined_fields
       if (field.type is Primitive)
         horizontal {
          text field.name // editable field name
          text ": "
          text field.type.name // drop-down for type
         }}}}
```



Schema Stencil: Connectors

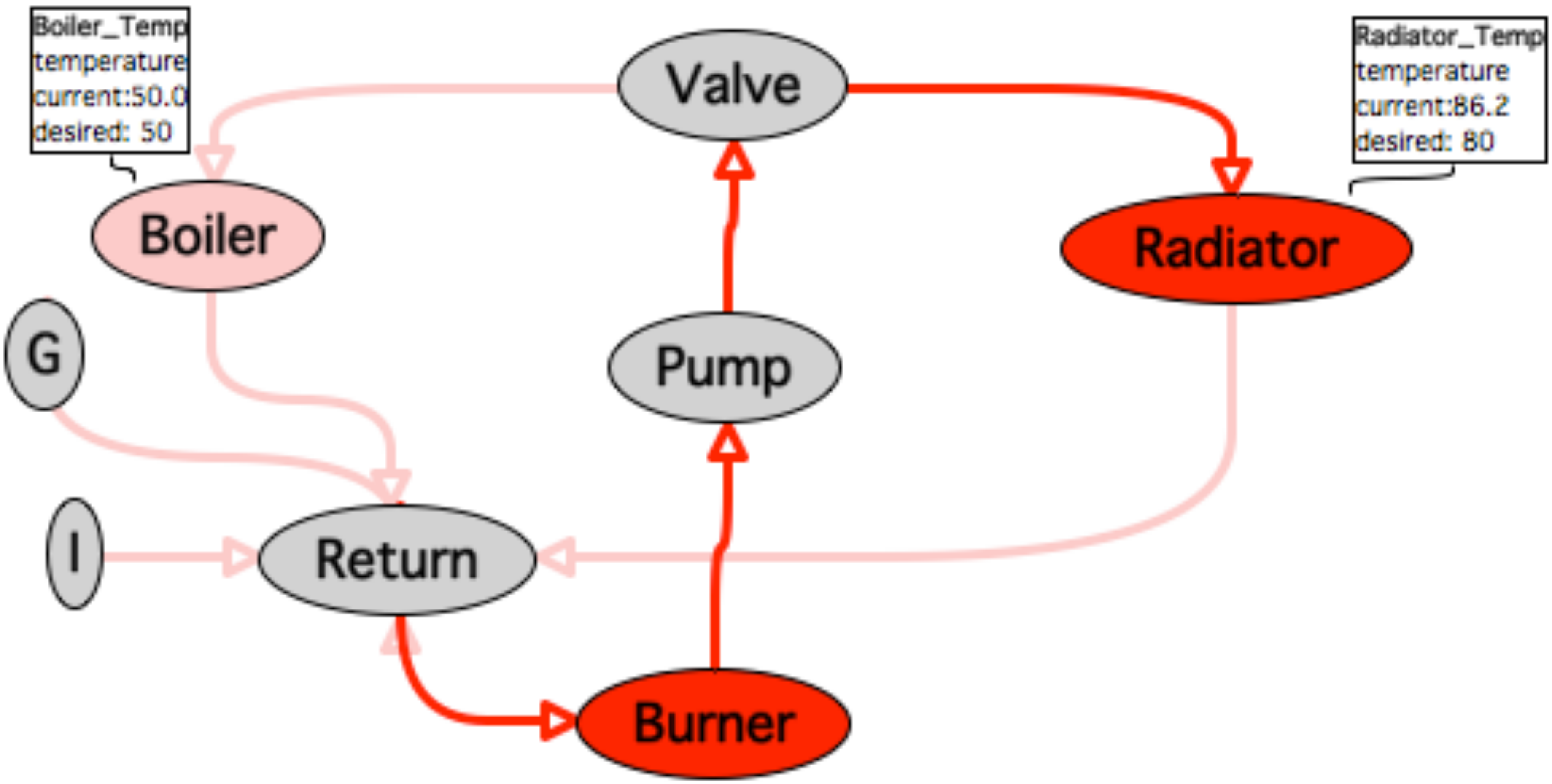
```
 …
// create the subclass links
  for class : schema.classes
    for "Parent" super : class.supers
      connector [line.width=3, line.color=(255,0,0)]
          (class --> super)
…
[also for relationships]
```



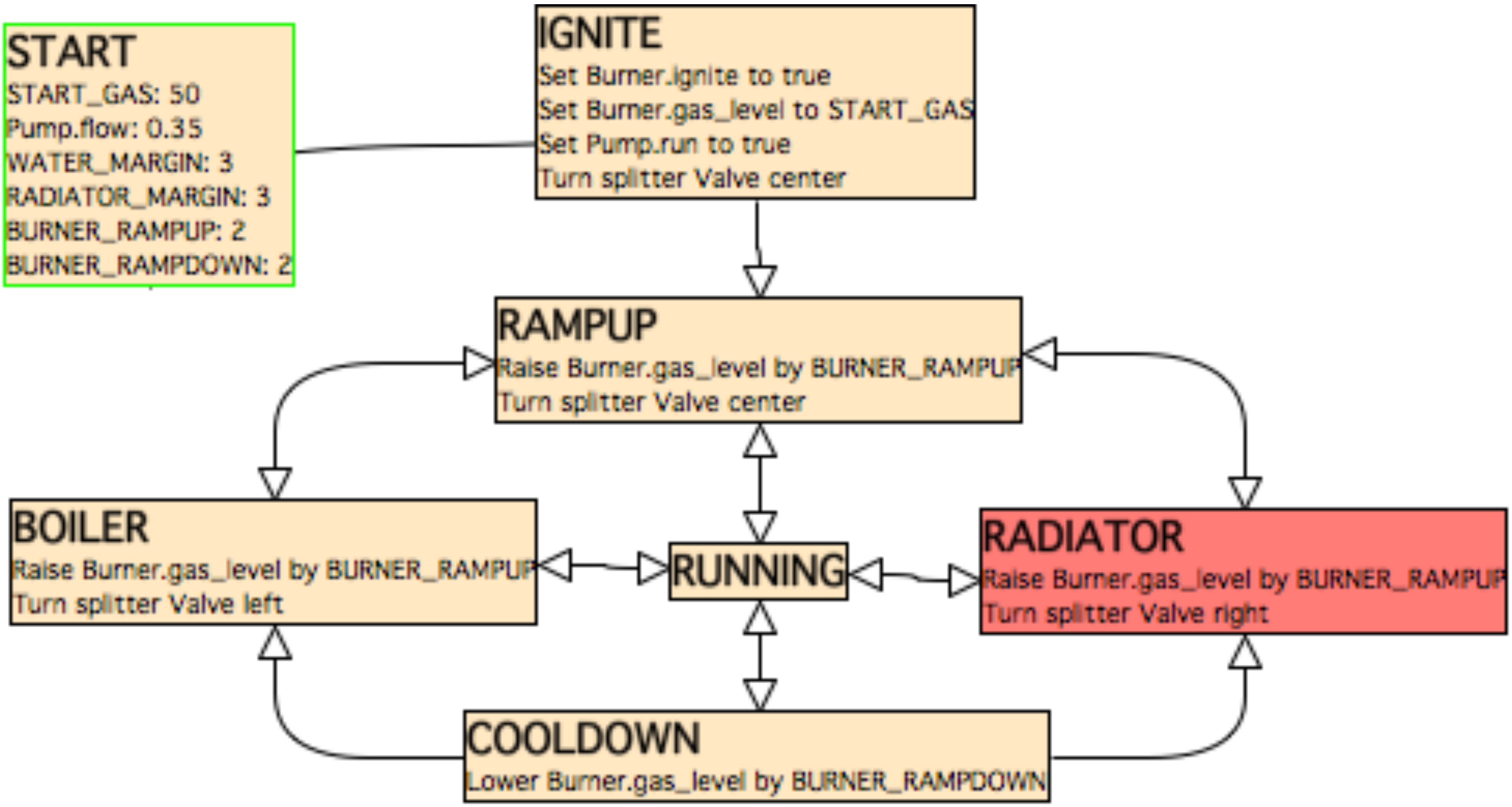
Language Workbench Challenge

- Models
  - Physical heating system
    - furnace, radiator, thermostat, etc
  - Controller for heating system
- Interpreter
  - Simulator for heating system
    - pressure, temperature
  - State machine interpreter
    - Events and actions

Physical Heating System Model



Piping Controller



Piping Details

- Simulation updates physical model
  - Change to physical model causes update to view
  - Observable Data Manager -> Presentation update
- State machine interpreter changes states
  - Presentation shows current state
- User can interact with physical model
  - Change thermostat
- User can edit diagram

Performance

- Ensō is currently slow but usable
  - Accessing a field involves two levels of meta-interpretation
  - My job is to give compiler people something to do
- Partial Evaluation of model interpreters

```
web(UI, Schema, db, request) : HTML
web[UI, Schema](db, request) : HTML
```

static *dynamic*

Aspect	Code SLOC	Model SLOC
Bootstrap	387	—
Utilities	256	—
Schemas	691	51
Grammar/Parse	885	106
Render	318	17
Web	932	305
Security	276	46
Diagram/Stencil	1389	176
Expressions	448	144
Core	5582	844
Piping	527	268

Ensō Summary

- Executable Specification Languages
  - Data, grammar, GUI, Web, Security, Queries, etc.
- External DSLs (not embeded)
- Interpreters (not compilers/model transform)
  - Multiple interpreters for each languages
- Composition of Languages/Interpreters
  - Reuse, extension, derivation (inheritance)
- Self-implemented (Ruby for base/interpreters)
  - Partial evaluation for speed

Related Work

- Aspects: a fundamental idea
  - Current solutions are terrible (AspectJ)
- DSLs and Models: Feeling same elephant
  - external vs. internal
  - graphical vs. textual

Language	Meta-Model
Program	**Model**

- F# Type Providers
- Scheme macros (defstruct)
- Metaprogramming
  - But without manipulating 'code'

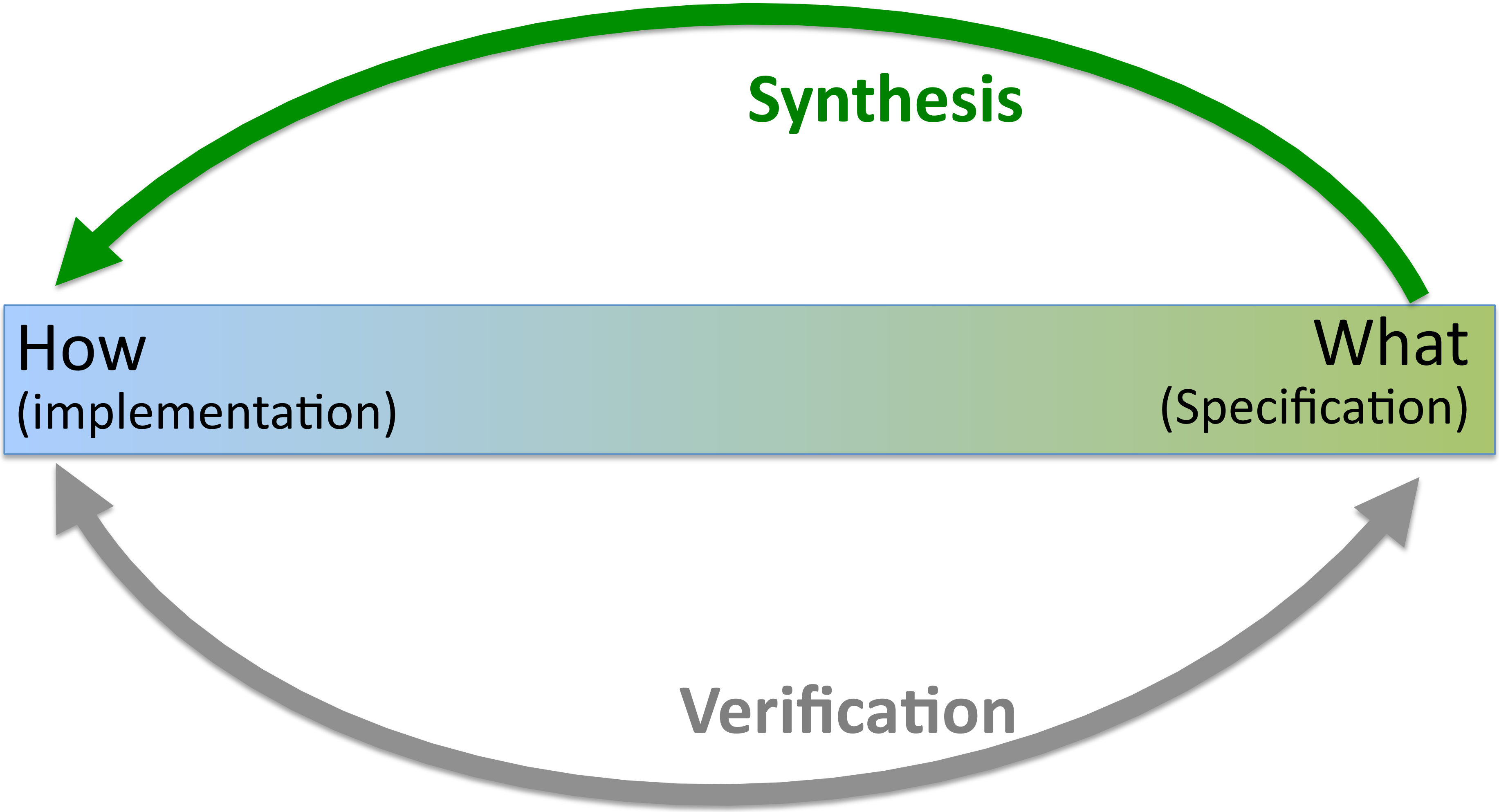
More..

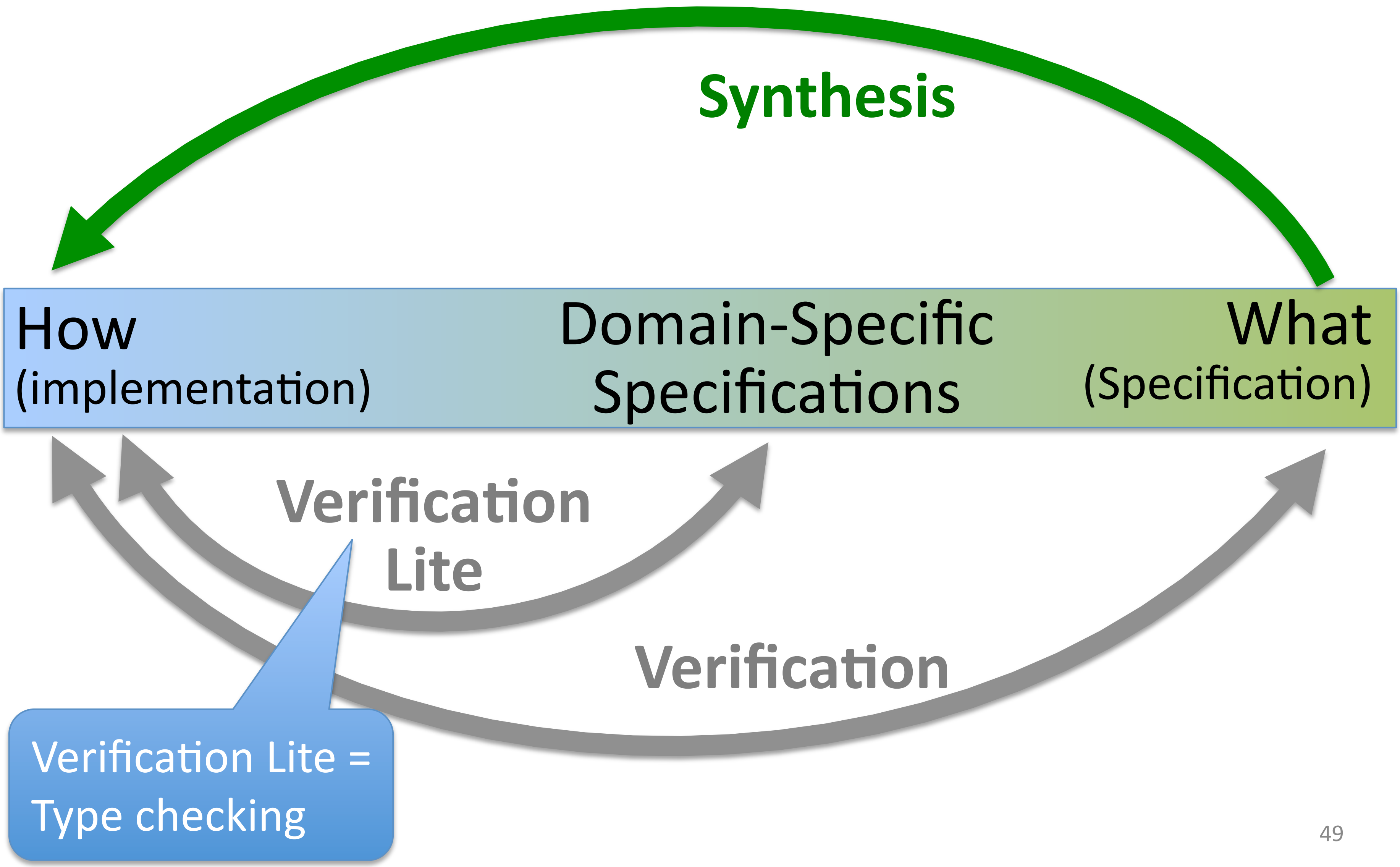
Spectrum of programming

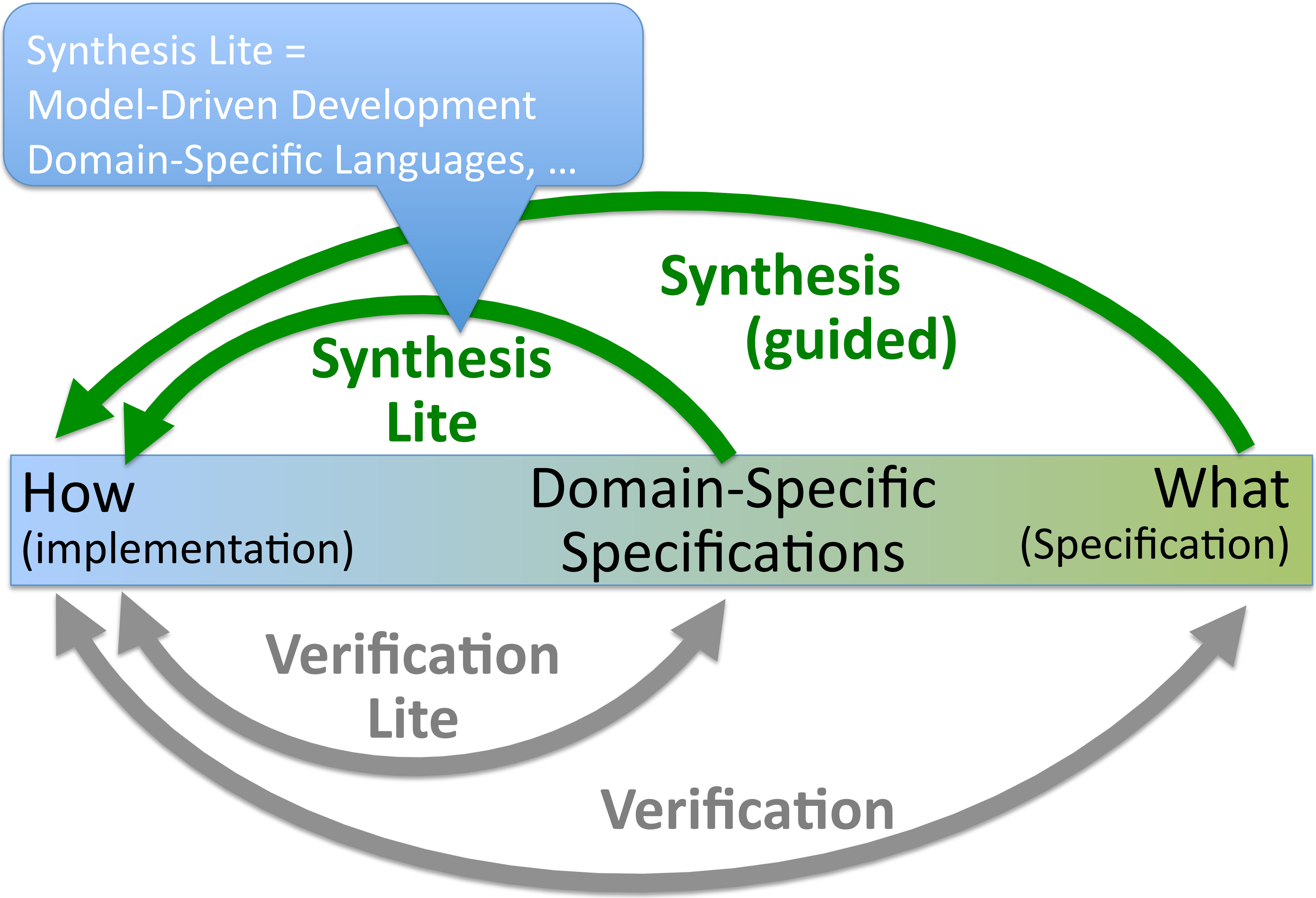
How
(implementation)

What
(Specification)


How
(implementation)
What
(Specification)
Verification


Synthesis
How
(implementation)
What
(Specification)
Verification


Synthesis
How
(implementation)
Domain-Specific
Specifications
What
(Specification)
Verification
Lite
Verification
Verification Lite =
Type checking


Synthesis Lite =
Model-Driven Development
Domain-Specific Languages, …
Synthesis
(guided)
Synthesis
Lite
How
(implementation)
Domain-Specific
Specifications
What
(Specification)
Verification
Lite
Verification

Don't Design
Your Programs

Program
Your Designs

Ensō
enso-lang.org