Structure: Syntax and Name Resolution

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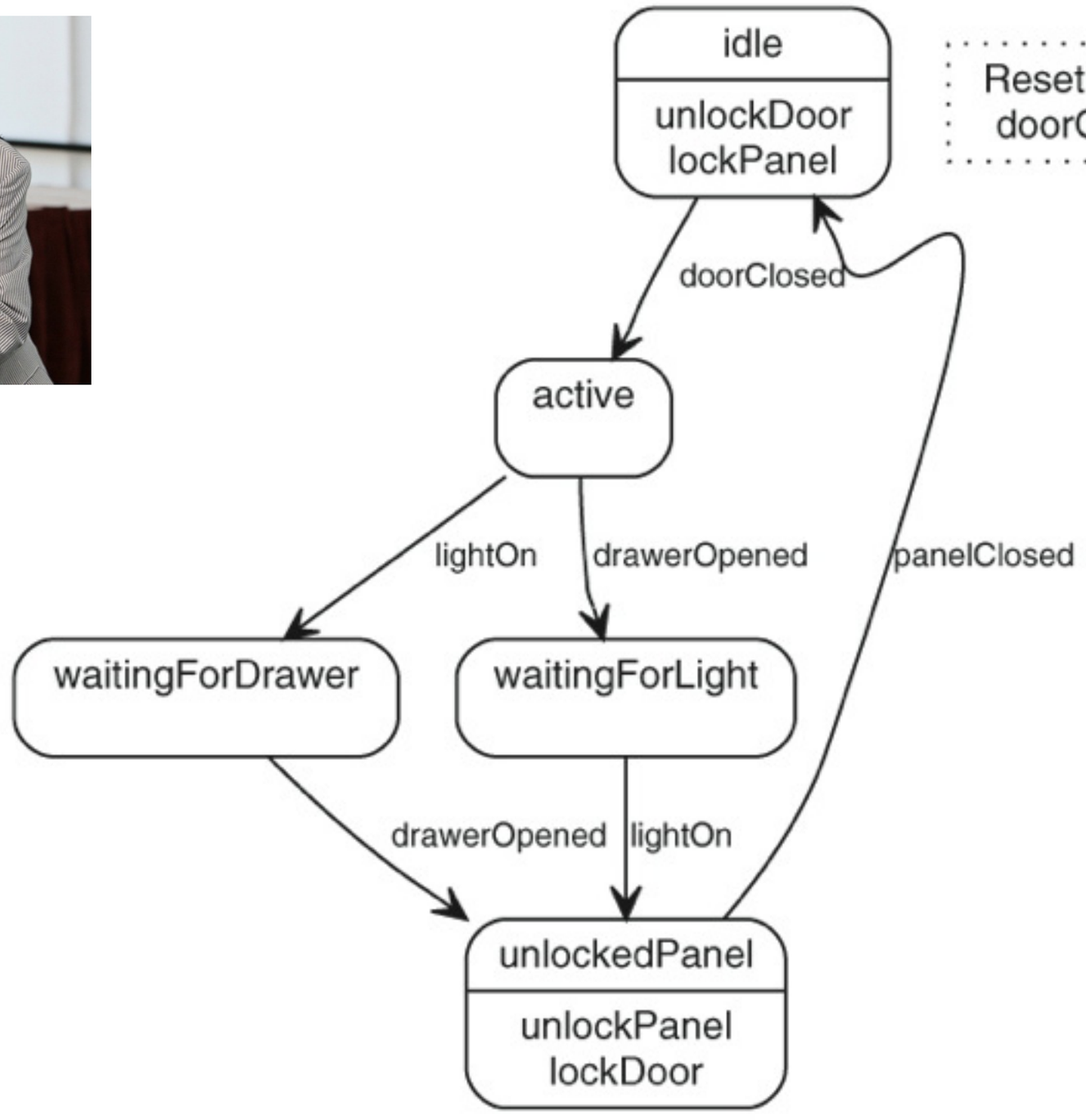
Example: state machines



```
events
 doorClosed D1CL
 drawerOpened D2OP
 lightOn L1ON
 doorOpened D1OP
 panelClosed PNCL
end

resetEvents
 doorOpened
end

commands
 unlockPanel PNUL
 lockPanel PNLK
 lockDoor D1LK
 unlockDoor D1UL
end

state idle
 actions {unlockDoor lockPanel}
 doorClosed => active
end
```

```
state active
 drawerOpened => waitingForLight
 lightOn => waitingForDrawer
end

state waitingForLight
 lightOn => unlockedPanel
end

state waitingForDrawer
 drawerOpened => unlockedPanel
end


state unlockedPanel
 actions {unlockPanel lockDoor}
 panelClosed => idle
end
```

Grammars

```
module Syntax
extend lang::std::Layout;

start syntax Controller =
    controller:
        Events events
        ResetEvents? resets
        Commands? commands
        State+ states;

syntax Events
  = @Foldable "events" Event* "end";
syntax ResetEvents
  = @Foldable "resetEvents" Id* "end";
syntax Commands
  = @Foldable "commands" Command* "end";
```

standard Layout

start symbol

production label

subelement labels

enable folding

Lexical syntax

lexicals don't get layout

follow restriction

character class

```
lexical Id
  = ([a-zA-Z][a-zA-Z0-9_]* !>> [a-zA-Z0-9_])
  \ Reserved ;

keyword Reserved
  = "events"
  | "end"
  | "resetEvents"
  | "state"
  | "actions" ;
```

keyword reservation

keyword class

parse roos

follow(\char-class([range(48,57),range(65,90),range(95,95),range(97,122)]))})]),[char(68),appl(regular(\iter-star(\char-
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[appl(regular(\iter-star(sort("WhitespaceOrComment"))),[appl(prod(label("whitespace",sort("WhitespaceOrComment")),[lex("Whitespace")],{}),
[appl(prod(lex("Whitespace"),[\char-class([range(9,10),range(12,13),range(32,32)])],{}),[char(10)])[@loc=|project://MissGrant/input/
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project://MissGrant/input/missgrant.ctl|(56,2,<4,13>,<5,1>)],appl(prod(label("event",sort("Event")),
[label("name",lex("Id")),layouts("Standard"),label("token",lex("Id"))],{}),[appl(prod(lex("Id"),[conditional(seq([\char-
class([range(65,90),range(97,122)]),conditional(\iter-star(\char-class([range(48,57),range(65,90),range(95,95),range(97,122)])),{\not-
follow(\char-class([range(48,57),range(65,90),range(95,95),range(97,122)]))})]),{delete(keywords("Reserved"))})],{}),
[appl(regular(seq([\char-class([range(65,90),range(97,122)]),conditional(\iter-star(\char-
class([range(48,57),range(65,90),range(95,95),range(97,122)])),{\not-follow(\char-
class([range(48,57),range(65,90),range(95,95),range(97,122)]))})])),[char(100),appl(regular(\iter-star(\char-

Abstract syntax

non-terminals map to data type

productions to constructors

regulars (+/*/?) map to lists

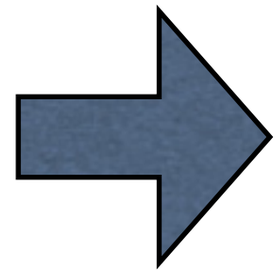
lexicals to str/ int/real/bool

```
data Controller
  = controller(list[Event] events,
               list[str] resets,
               list[Command] commands,
               list[State] states);

data State
  = state(str name,
          list[str] actions,
          list[Transition] transitions);

data Command    = command(str name, str token);
data Event      = event(str name, str token);
data Transition = transition(str event, str state);
```

“Implode”

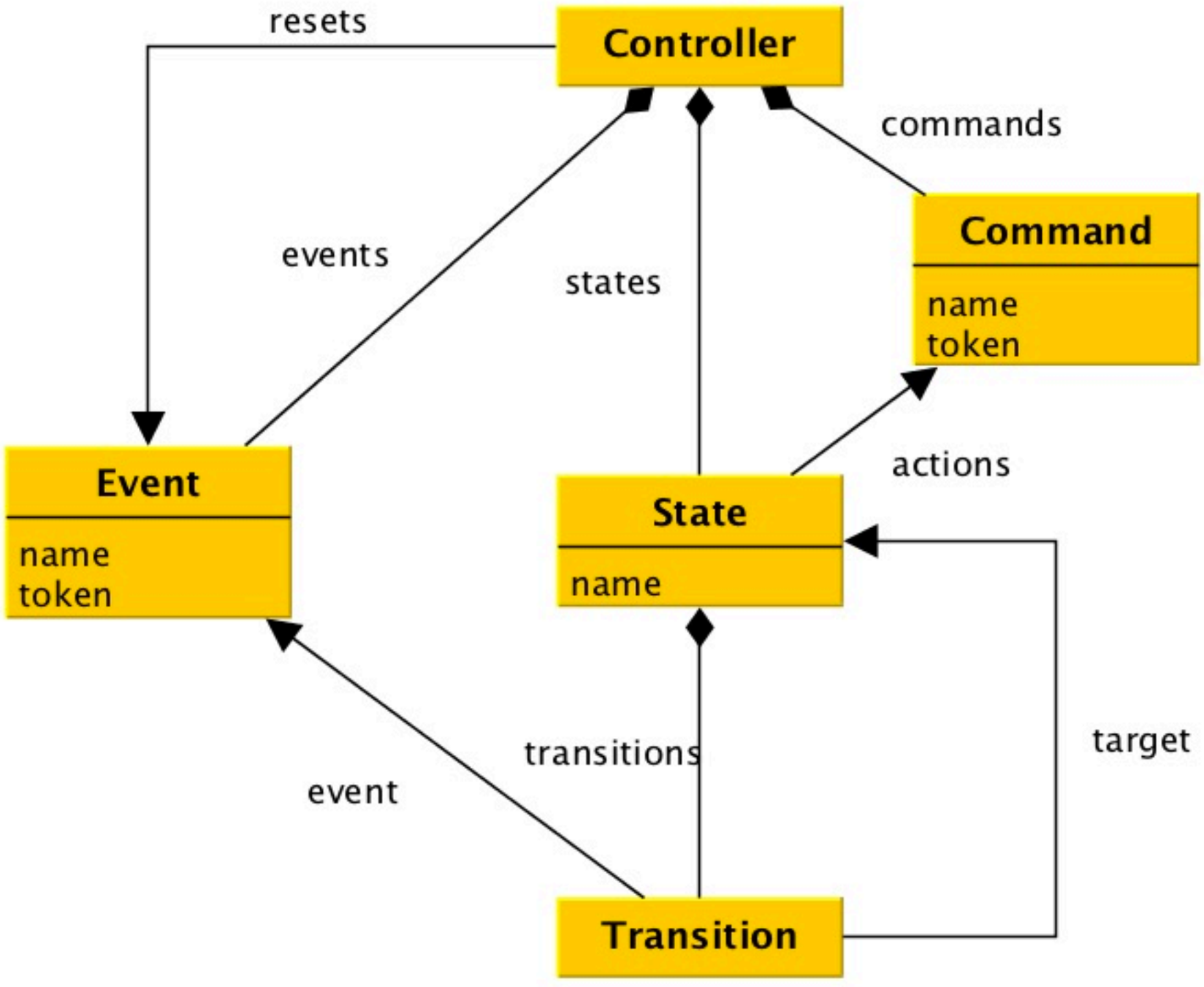


```
controller(
  [
    event("doorClosed","D1CL"),
    event("drawerOpened","D2OP"),
    event("lightOn","L1ON"),
    event("doorOpened","D1OP"),
    event("panelClosed","PNCL")
  ],
  ["doorOpened"],
  [
    command("unlockPanel","PNUL"),
    command("lockPanel","PNLK"),
    command("lockDoor","D1LK"),
    command("unlockDoor","D1UL")
  ],
  [
    state(
      "idle",
      ["unlockDoor","lockPanel"],
      [transition("doorClosed","active")]),
    state(
      "active",
      [],
      [
        transition("drawerOpened","waitingForLight"),
        transition("lightOn","waitingForDrawer")
      ]),
    state(
      "waitingForLight",
      [],
      [transition("lightOn","unlockedPanel")]),
    state(
      "waitingForDrawer",
      [],
      [transition("drawerOpened","unlockedPanel")]),
    state(
      "unlockedPanel",
      ["unlockPanel","lockDoor"],
      [transition("panelClosed","idle")])
  ])
```

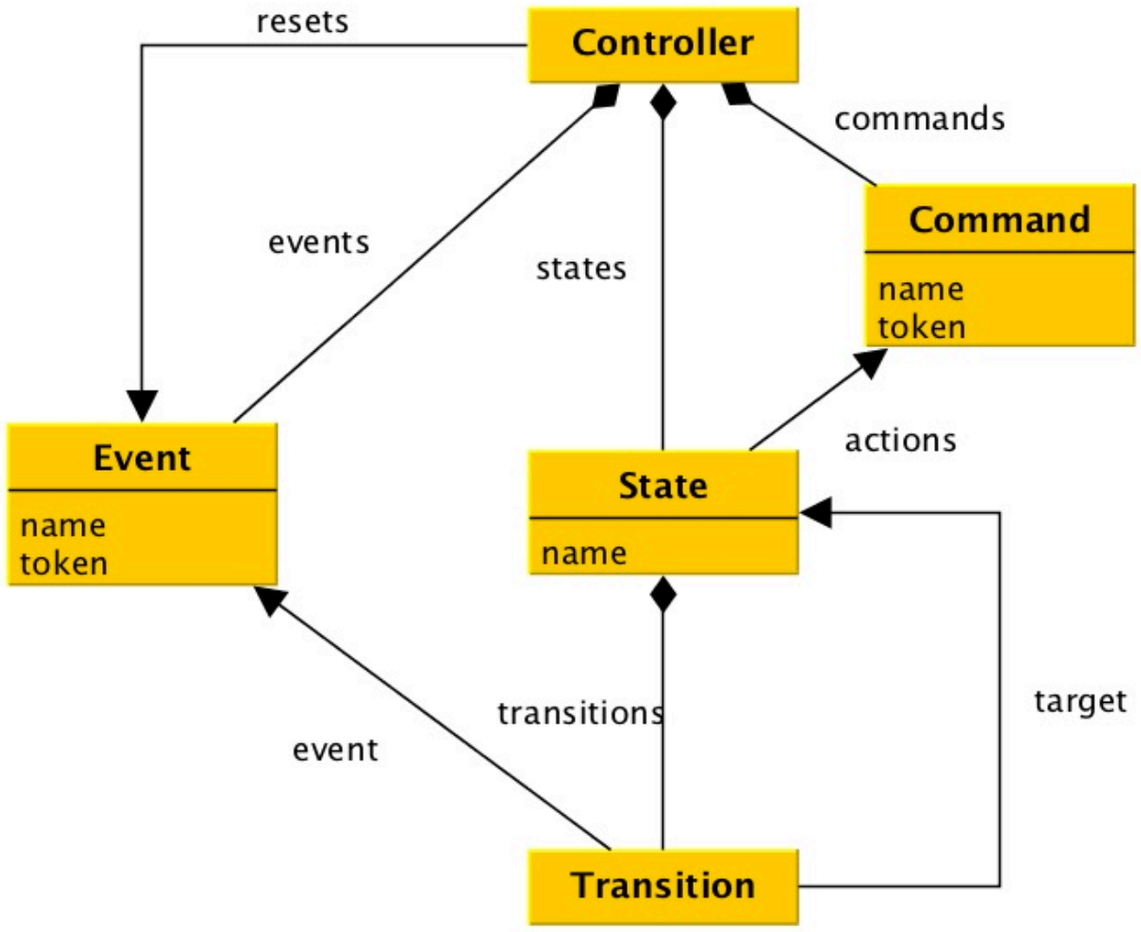
Meta Models

- Algebraic data types (“`data Expr = …`”)
  - Define type of abstract syntax *trees*
- Meta Models are UML-style class diagrams
  - Define type of of object *models*
- Both have benefits and disadvantages
- => Technological space (grammarware, modelware)

State machine meta model



References: explicit or using symbolic names




```
data Controller
  = controller(list[Event] events,
               list[str] resets,
               list[Command] commands,
               list[State] states);

data State
  = state(str name,
      list[str] actions,
      list[Transition] transitions);

data Command
  = command(str name, str token);

data Event
  = event(str name, str token);

data Transition
  = transition(str event, str state);
```

```
events
 doorClosed D1CL
 drawerOpened D2OP
 lightOn L1ON
 doorOpened D1OP
 panelClosed PNCL
end

resetEvents
 doorOpened
end

commands
 unlockPanel PNUL
 lockPanel PNLK
 lockDoor D1LK
 unlockDoor D1UL
end

state idle
 actions {unlockDoor lockPanel}
 doorClosed => active
end
```

```
state active
 drawerOpened => waitingForLight
 lightOn => waitingForDrawer
end

state waitingForLight
 lightOn => unlockedPanel
end

state waitingForDrawer
 drawerOpened => unlockedPanel
end


state unlockedPanel
 actions {unlockPanel lockDoor}
 panelClosed => idle
end
```

Names

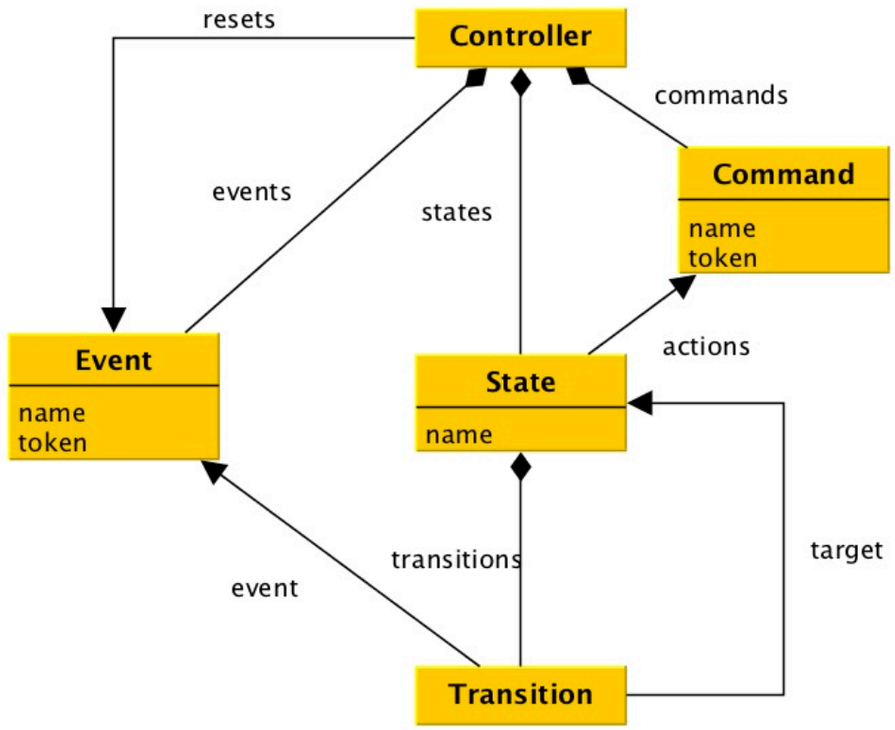
- **defining occurrence**: declaration, or entity, introduction of a name
  - Example: states, events, commands
- **use occurrence**: reference, variable use, etc.
  - Example: reference to event/target state in transition, reference to commands in states

Name resolution

- Finding which use occurrences refer to which defining occurrences

- Recovering the referential structure represented in meta models (roughly)

- IOW: defining the **scoping** rules of a language



Name resolution in Rascal

- Name occurrences (both defining and using) can be identified by **source locations**

- Source locations are unique: no two name occurrences can overlap.

- So we can use source locations as **identities** to represent the referential structure of a program.

Source locations

Scheme | Authority | Path | Offset | Length

```
|project://mutyphonql/src/example.mutql|(45,8,<6,2>,<6,10>)
```

Start line and column

End line and column

NB: clicking on a source location jumps to exact location in an editor

Reference graphs

- Using source locations as identities of concepts in a language, the referential structure is typically represented as **reference graph**
- In Rascal: `"rel[loc, loc]"`
- This can be used to:
  - find naming errors and warnings
  - provide jump-to-definition IDE support
  - use in a compiler to find the declaration of an identifier
  - visualization, etc.

Next up

- Live coding a simpler state machine example
    - abstract syntax, implode, name analysis
- Providing an introduction to the lab assignment skeleton code for this week.