Abstract Syntax and Name Resolution

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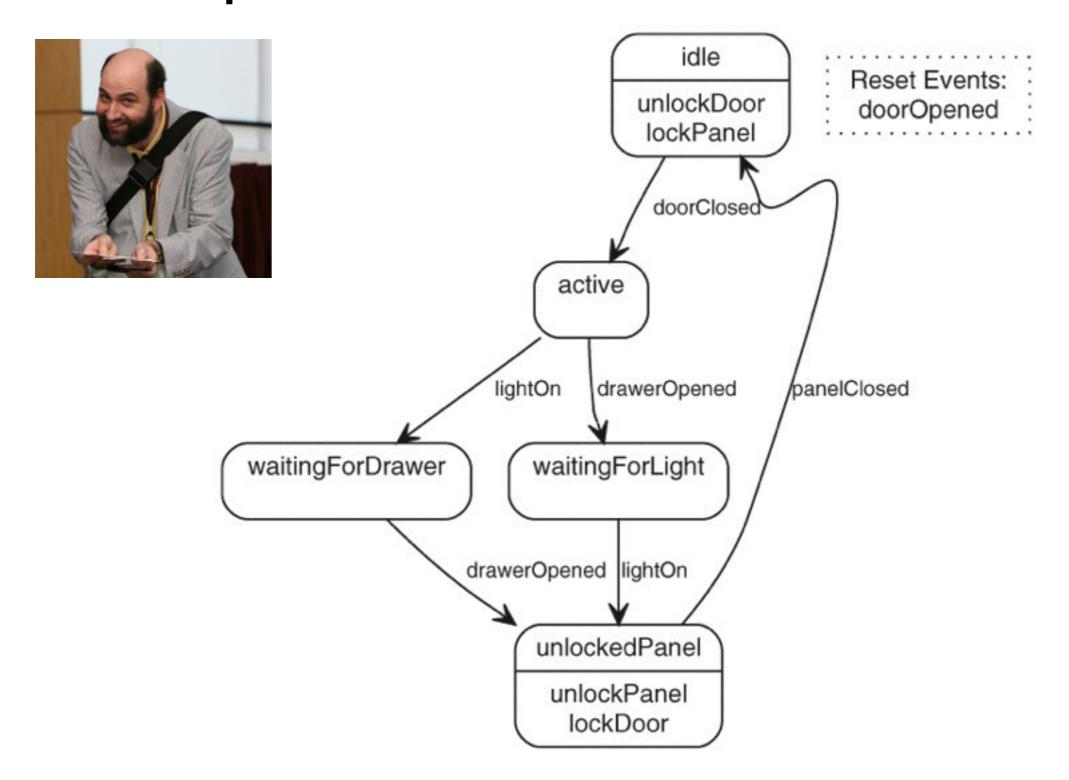




Recap

- Context-free grammars to define syntax
- Parser generator: Grammar -> Parser
- Parser: Text -> Concrete syntax tree
- Today:
 - abstract syntax representations
 - name resolution

Example: state machines



```
events
 doorClosed D1CL
 drawerOpened D2OP
 lightOn L10N
 doorOpened D1OP
 panelClosed PNCL
end
resetEvents
 door0pened
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

```
standard
              module Syntax
              extend lang::std::Layout;
                                                   Layout
  start
              start syntax Controller =
symbol
                 controller:
                    Events events
                                            subelement
                    ResetEvents? resets
production
                                               labels
                    Commands? commands
   label
                    State+ states;
              syntax Events
                = @Foldable "events" Event* "end";
              syntax ResetEvents
enable
                = @Foldable "resetEvents" Id* "end";
folding
              syntax Commands
                = @Foldable "commands" Command* "end";
```

Lexical syntax

lexicals don't get layout

```
follow
restriction
```

character class

```
= ([a-zA-Z][a-zA-Z0-9_]* !>> [a-zA-Z0-9_])

Reserved;
```

keyword reservation

```
keyword Reserved
```

- = "events"
- I "end"

lexical Id

- l "resetEvents"
- l "state"
- l "actions";

keyword class

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ctart (1(38,12,4,12), 3-3,125), only (prod (lotter (7, 10, 10, 10)),
ctart (1(38,12,4,12), 3-3,4,8,1), only (prod (lotter (3, 10, 10, 10)),
ctart (1(38,12,4,12), 3-3,4,8,1), only (prod (lobe) (254,13,14), 3-3,4,14),
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[appl(regular(\iter-star(sort("WhitespaceOrComment"))), [appl(prod(label("whitespace", sort("WhitespaceOrComment")), [lex("Whitespace")], {}),
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[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([\cline{c}]),conditional(\cline{c})),conditional(\cline{c})
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(108), appl(regular(\iter-star(\char-
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star(sort("WhitespaceOrComment")), {\not-follow(\char-class([range(9,10), range(12,13), range(32,32)])), \not-follow(lit("//"))})], {}),
[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(32)])[@loc=|project://MissGrant/input/
missgrant.ctl[(51,1,<4,8>,<4,9>)]])[@loc=|project://MissGrant/input/missgrant.ctl|(51,1,<4,8>,<4,9>)]])[@loc=|project://MissGrant/input/missgrant.ctl|(51,1,<4,8>,<4,9>)]])[@loc=|project://MissGrant/input/missgrant.ctl|(51,1,<4,8>,<4,9>)]])
missgrant.ctl(51,1,<4,8>,<4,9>)])[@loc=|project://MissGrant/input/missgrant.ctl(51,1,<4,8>,<4,9>)],appl(prod(lex("Id"),
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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-
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(52,4,4,9),4,13)])[@loc=|project://MissGrant/input/missgrant.ctl|(44,12,4,1>,4,13>)],appl(prod(layouts("Standard"),[conditional(\iter-layouts("Standard"),[conditional(\ite
star(sort("WhitespaceOrComment")), {\not-follow(\char-class([range(9,10), range(12,13), range(32,32)])), \not-follow([it("//"))], {}),
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project://MissGrant/input/missgrant.ctll(56,2,<4,13>,<5,1>)],appl(prod(label("event",sort("Event")),
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[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-
```

non-terminals map to data type

bstract syntax

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

$\label{eq:miscond} \begin{tabular}{ll} $$ (miscond) $$$

x mix teppoe 1, (tom - class)(range(s) - range(s) 2, 3) range(s) 2, 3) (range(s) 2, 3) (range(

[])][[@loc_|project://Missform/input/missgramt.ctl(25,12, a), a, 3,13-3)], app[proof(layouts("Standard"), [conditional(\text{\text{term}}, a), a, 3, a), a, 3, a)], app[proof(layouts("Standard"), [conditional(\text{\text{\text{term}}, a), a, 3, a, 3, a, 3, a)], [][@loc_|project://Missform/input/missgramt.ctl] range(5,9), range(9,122))], [@loc_|project://Missform/input/missgramt.ctl] range(5,9), range(9,122))], [world-follow[ind] range(5,9), range(9,122))], range(9,122))], [world-follow[ind] range(1,9), range(5,12))], range(1,9), range(2,12))], [world-follow[ind] range(1,9), [world-foll

ce*), (char-class([range(3,18), range(12,13), range(23,32)]), [d), [dnar(32)])@[loc-lproject:/Missformirinput/missgramt.ctl]
titional(liter-study-char-class([range(3,8), range(3,8), rang

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(27, b.)]])[@loc-iproject://MissGrant/input/missgrant.cell(188, 2, 46, 18-, 47, 1-3)], appl(grod(label*['command''), sort-'command'')), § 5, 80), range(97, 122)]), and it to moliticities-star(victor-class([range4,67], range(58, 98), range(97, 122)])), {molitical(victor-follow(char-follow(char-follow(char-follow)), range(58, 98), range(97, 122)]), {molitical(victor-follow(char-follow), range(58, 98), range(97, 122)]), {molitical(victor-star(sort-(mintespocedricomment')), range(97, 122)]), conditional(victor-star(victor-class([range(68, 57), range(58, 98), range(97, 122))), {molitical(victor-star(victor-class([range(68, 57), range(58, 98), range(58, 98), range(97, 122)))), {molitical(victor-star(victor-class([range(68, 57), range(58, 98), range(58, 98), range(97, 122)))), {molitical(victor-star(victor-class([range(68, 57), range(58, 98), range(58, 98), range(97, 122)))), {molitical(victor-star(victor-class([range(68, 57), range(58, 98), ra

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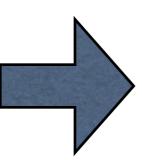
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"Implode"

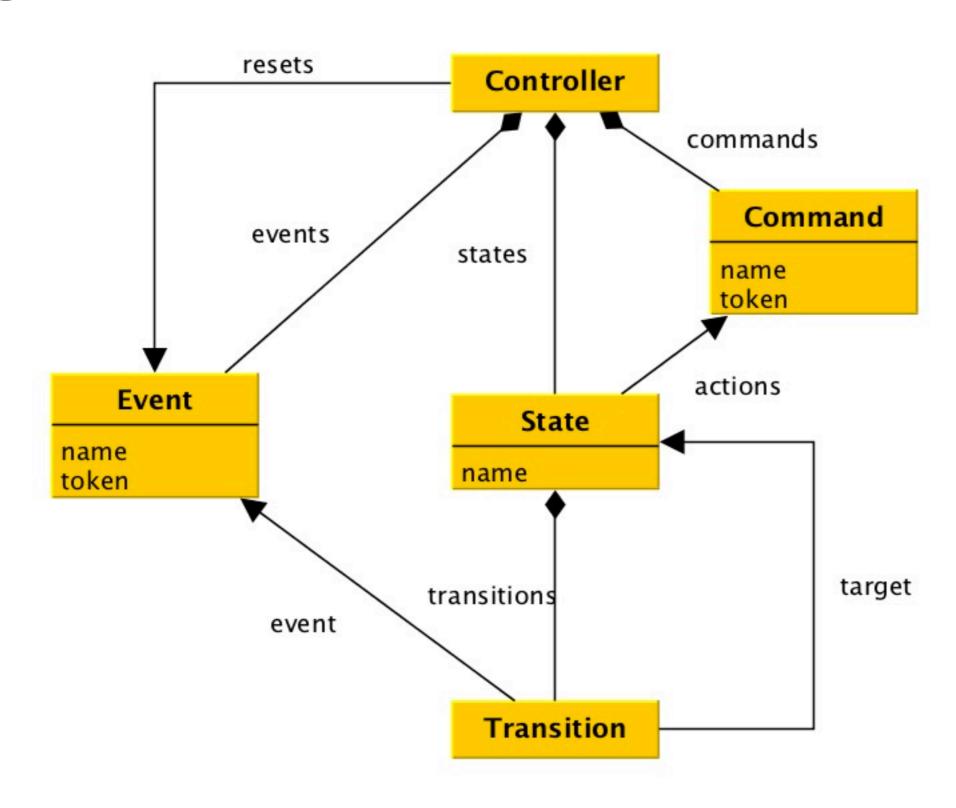


```
controller(
    event("doorClosed","D1CL"),
    event("drawer0pened","D20P"),
    event("lightOn","L10N"),
    event("door0pened", "D10P"),
    event("panelClosed","PNCL")
  ["door0pened"],
    command("unlockPanel", "PNUL"),
    command("lockPanel", "PNLK"),
    command("lockDoor","D1LK"),
    command("unlockDoor", "D1UL")
    state(
      "idle",
      ["unlockDoor","lockPanel"],
      [transition("doorClosed", "active")]),
    state(
      "active",
      []
        transition("drawerOpened", "waitingForLight"),
        transition("lightOn", "waitingForDrawer")
    state(
      "waitingForLight",
      [transition("lightOn", "unlockedPanel")]),
      "waitingForDrawer",
      [transition("drawerOpened", "unlockedPanel")]),
    state(
      "unlockedPanel",
      ["unlockPanel", "lockDoor"],
      [transition("panelClosed","idle")])
  ])
```

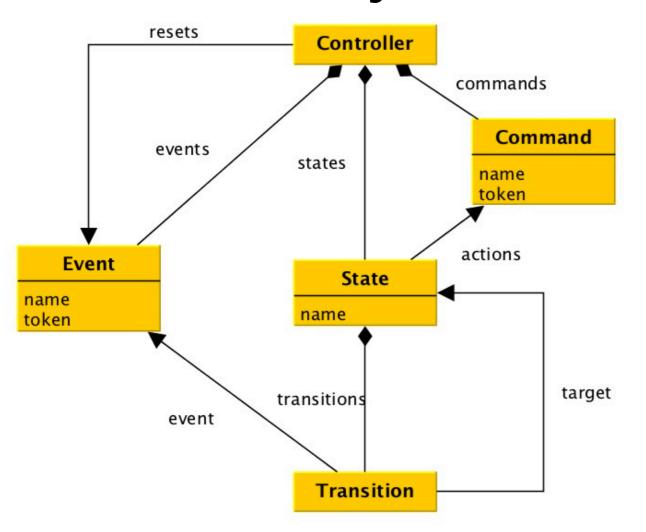
Meta Models

- 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)

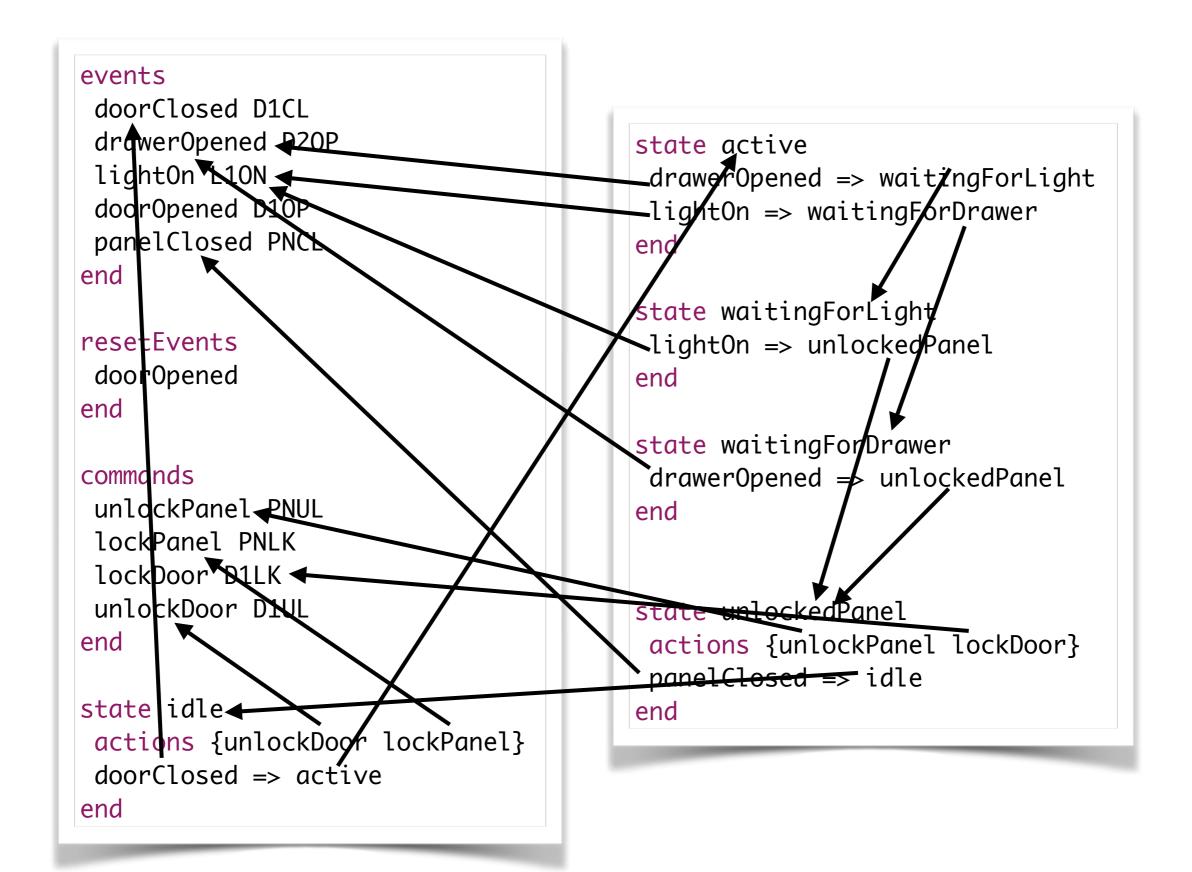
State machine meta model



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);
```

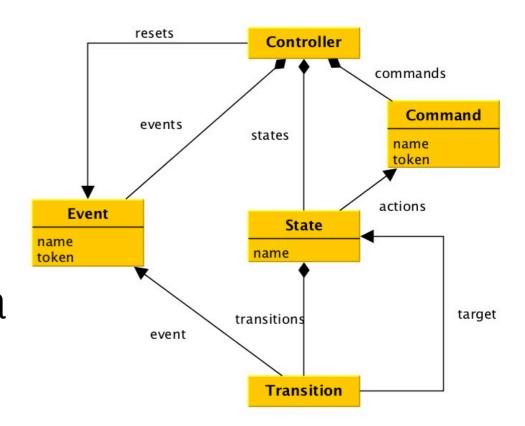


Names

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

Name resolution

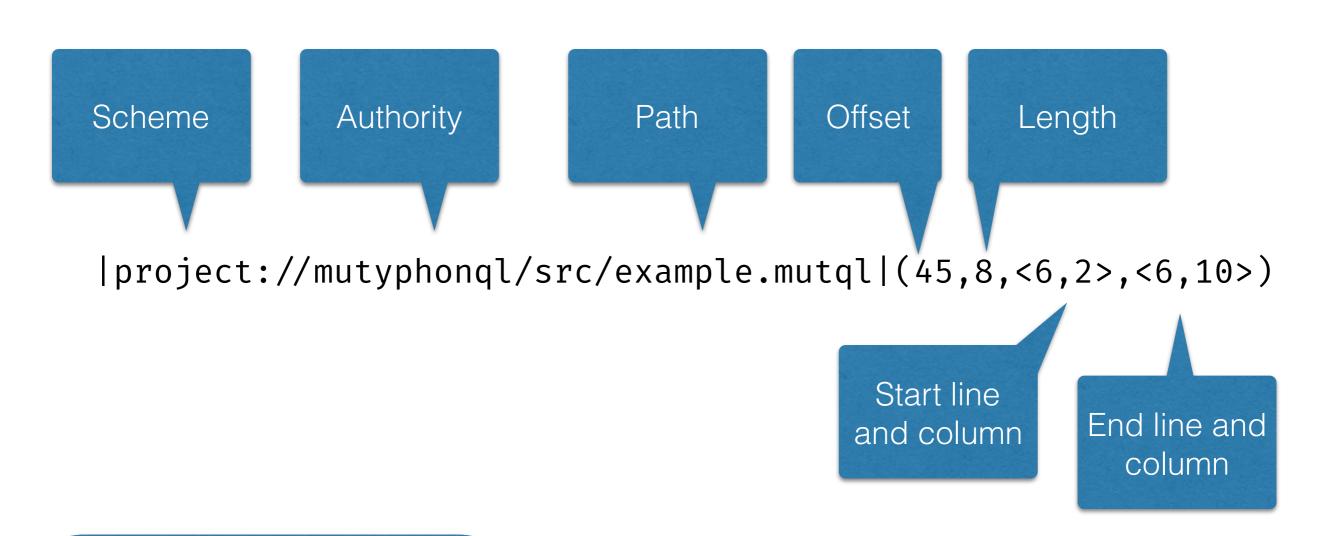
- Finding which use occurrences refer to which defining occurrences
- Recovering the referential structure represented in meta models (roughly)
- IOW: defining the scoping rules of a language



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



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.