Alloy Analyzer 4 Tutorial

Session 3: Static Modeling

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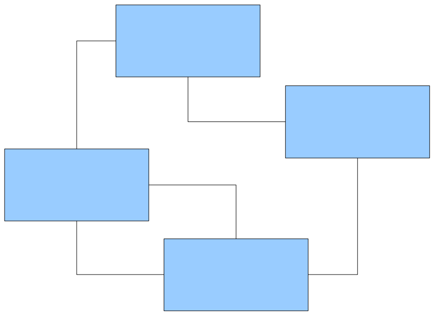
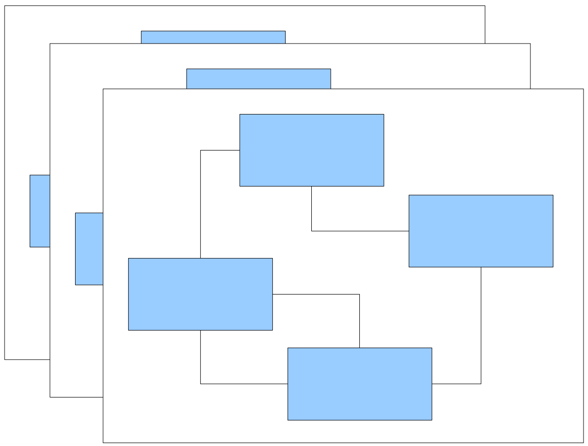
static vs. dynamic models

- static models
  - describes states, not behaviors
  - properties are *invariants*
  - e.g. that a list is sorted



- dynamic models
  - describe transitions between states
  - properties are *operations*
  - e.g. how a sorting algorithm works



modeling academic records

- course catalog and graduation requirements

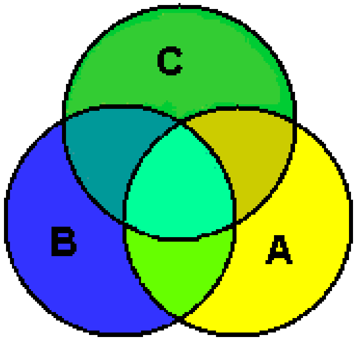
- ➢ create a new file in the Alloy Analyzer

- ➢ save it as *courses.als*

- ➢ write the appropriate module header

set declarations

- declare signatures for the following
  - our system has *courses*, *students*, and *departments*
  - all courses are either *introductory* or *advanced*
  - courses of either type can be *electives*
  - students are *freshmen*, *sophomores*, *juniors*, *seniors*



classification

- first step of building a model
  - consider what things are relevant
  - structure them hierarchically
  - subsets for orthogonal classification

- why *not* include in your classification . . . ?
  - the registrar — *meaning unclear*
  - course prerequisites — *relationship, not entity*
  - rooms where courses meet — *irrelevant*

modeling the relationships

- create fields for the following
  - course belongs to a single department
  - department has courses required to graduate
  - advanced course has one or more prerequisites
  - student has at most one major department
  - student has courses they have taken

pattern: definition

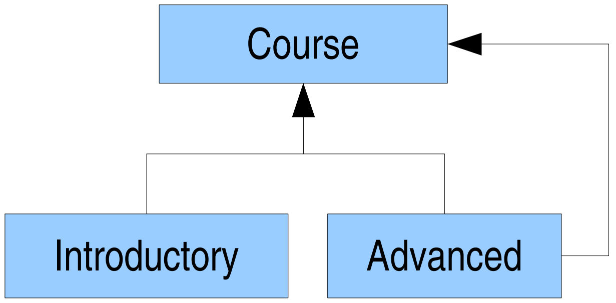
- define a new term using existing terms
  - declare new relation and constrain to existing relations
  - constraint often written as equality, e.g.

```
sig Person {
  spouse: lone Person,
  parents: set Person,
  inlaws: set Person
}
fact { inlaws = spouse.parents }
```

- ➢ define a term for all the courses in a department
  - differs from courses required by a department

pattern: composite

- prerequisites establish *composite* hierarchy
  - advanced courses are composites
  - introductory courses are leafs
  - another example: file system directories and files
- composites typically must be acyclic
  - e.g. directory cannot contain itself



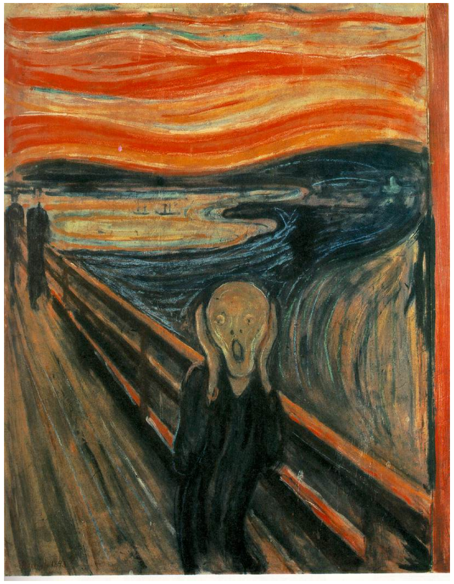
➢ constrain prerequisite relation to be acyclic
  - course cannot be its own prerequisite

pattern: sanity check

- write simple assertions while building models

- you'll be surprised how many fail

➢ check that every advanced course has an introductory course that precedes it



functions and predicates

- create predicates or functions for the following
  - condition that a student can take a course
    - student has taken prereqs but not course itself
  - for a set of courses, expression for complete prereqs
    - prereqs of prereqs, prereqs of prereqs of prereqs, etc
  - condition that a student can graduate
    - student is a senior with a major
    - has taken all course's required by dept
    - one or more of student's courses are electives

pattern: guided simulation

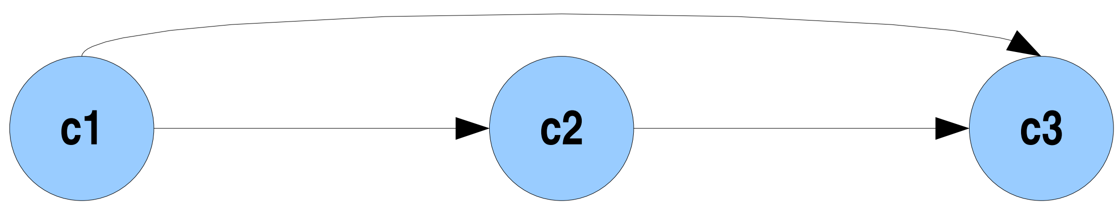
- simulates model to check consistency
  - does the model admit any instances?
  - explore typical & interesting configurations

➢ create predicates with desired configurations
  - run predicates to ensure they exist

- example configuration:
  - every department has at least one advanced course
  - at least one student can graduate

compact prerequisites

- possible redundancy in prerequisite relation
  - transitive prerequisites can be direct prerequisites
  - over-complicates solutions and visualizations



➢ with constraint, eliminate redundant prereqs
  - try it with and without quantifiers

pattern: multirelation

- use higher-arity relation to model relationship between more than two entities
- address book example:

```
sig Book {
  addrs: Name -> Addr
}
```

- create a set of grades
- student has a grade in each course taken

pattern: singleton

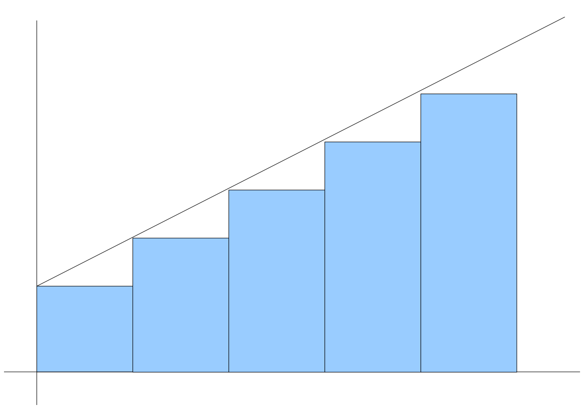
- particular elements of set play important roles
- use **one** multiplicity to make a singleton sig

```
one sig Root extends Directory {}
```

- ➢ divide grades into exactly A, B, C, D, and F
- ➢ change graduation condition so student must pass (C or better) in each required course

pattern: approximation

- omit/loosen constraints present in reality
  - don't need to model everything!
- looser model often good enough
  - if abstraction, property preservation is sound
- important to keep approximations in mind
- ➢ what approximations are in our course model?



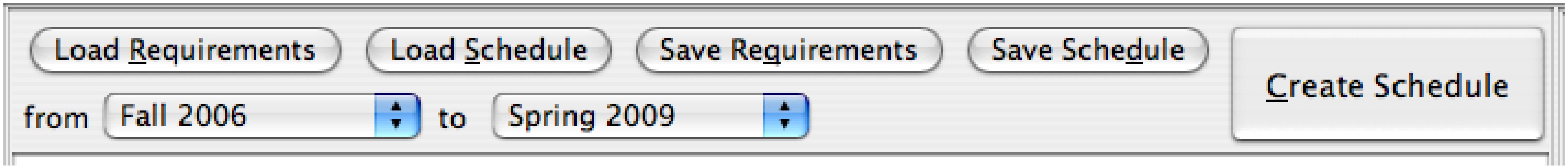
Monet

check and visualize

- write assertion that if a student can graduate, they must have passed all required courses as well as transitive prerequisites of required courses
- check assertion
- create intuitive visualization for counterexample
  - turn on and off sets and relations
  - change colors, shapes, names
  - turn relations into attributes
  - use defined variables
- add sensible constraints to ensure assertion passes

demo: declarative course scheduler

- designed and built by Vincent Yeung
- web application backed by Alloy engine
- generate a course schedule to satisfy MIT degree requirements given past courses
- http://sdg.csail.mit.edu/projects/scheduler.html



pattern: set object

- all relations in Alloy are first order
- *but* some relationships are higher-order
  - relate sets of elements, not individuals

- solution: represent sets themselves as objects
  - single field relating set to its elements
  - often canonicalized: no two sets have same elements

- ➢ allow departments multiple sets of required courses
  - student can fulfill anyone of those sets
  - (optional) canonicalize required sets