6170 · laboratory in software engineering

lecture 12 · march 1, 1999 · object models

Daniel Jackson
Lab for Computer Science
MIT

contents

motivation
- why have design notations?
- why object modelling?

elements of an OM
- sets, domains and subsets
- relations & multiplicity
- mutability

from design to code
- how design & code OMs differ

why have design notations?

design stage

- help articulate ideas
- find problems early
- exploit idioms

implementation stage

- clear basis for delegation & division of labour
- touchstone for lower-levels of design

later stages

- hard to debug or maintain without design

what kind of design notations?

criteria

- expressive: can capture essence
- abstract: can suppress irrelevant details
- precise: unambiguous, can analyze
- lightweight: economical & easy to use

two key notations

- object models
  structure of state
- module dependency diagrams
  code organization, coupling

other notations

- state machines
  structure of events & state sequences: good for reactive systems
- architectural sketches
  process structure & communication paths

object models (OMs)

why

- state structure is major source of complexity
- helps bridge gap between problem and solution
  code state can be compared to problem state
- in OO languages, state structure *is* system structure

in industry

- OMs form basis of all current OO development methods
  UML, Catalysis, Fusion, Syntropy, OMT
- UML has been made an industrial standard
  see <http://www.rational.com/uml>

our notation

- Alloy, an OM language developed at MIT
- a clarified version of UML's "static structure notation"
- simpler than UML, but analyzable & more precise

exactly how do OMs help?

in design, OMs help you figure out

- what information system must retain
  - what state components are needed
  - how these fit together
- which constraints you can exploit
  - to simplify implementation

in coding, OMs tell you

- where to use containers
  - sets, tables, etc
- about sharing and mutability
  - when to watch for aliasing & rep exposure

design OM

a design OM is a graph

- nodes are sets of objects
- arcs are relations or subset relationships
- two kinds of markings: multiplicity & mutability

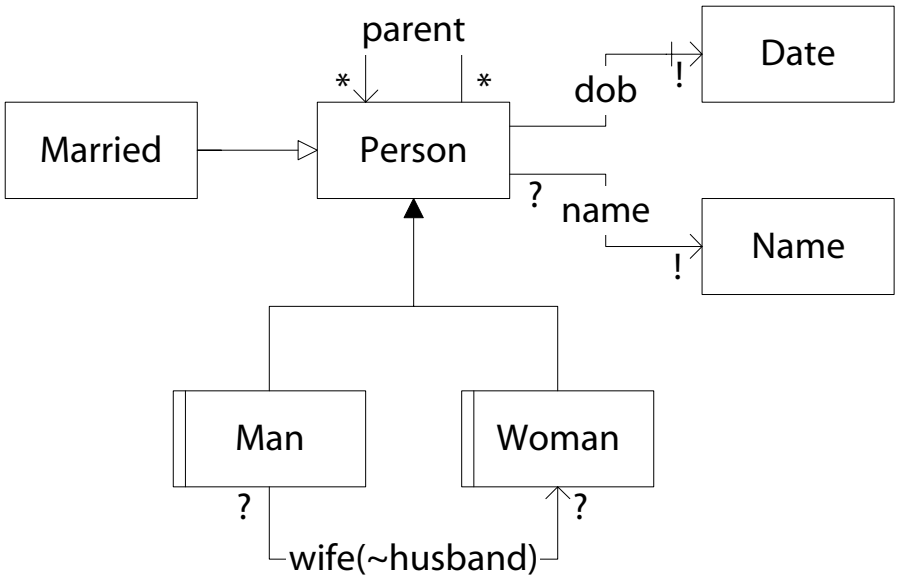
a design OM describes

- what system states are possible
- basic temporal properties (mutability)

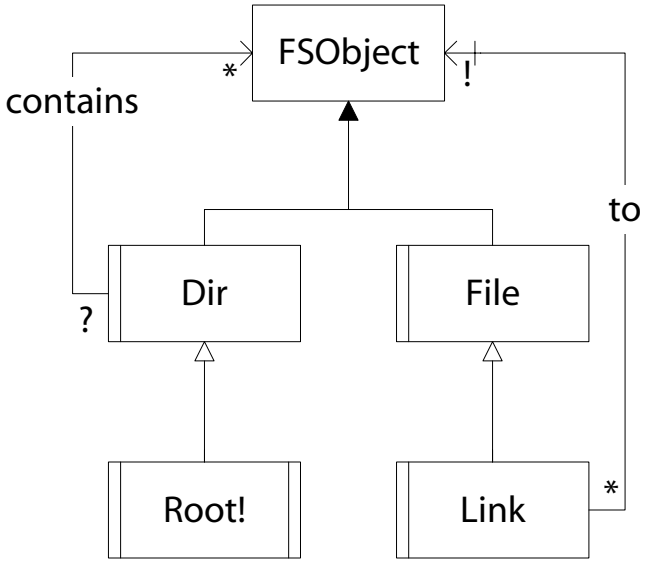
examples

- family tree: state is information about a family
- file system: state is structure of files, dirs & links
- employment database: state is employment & recommendation records

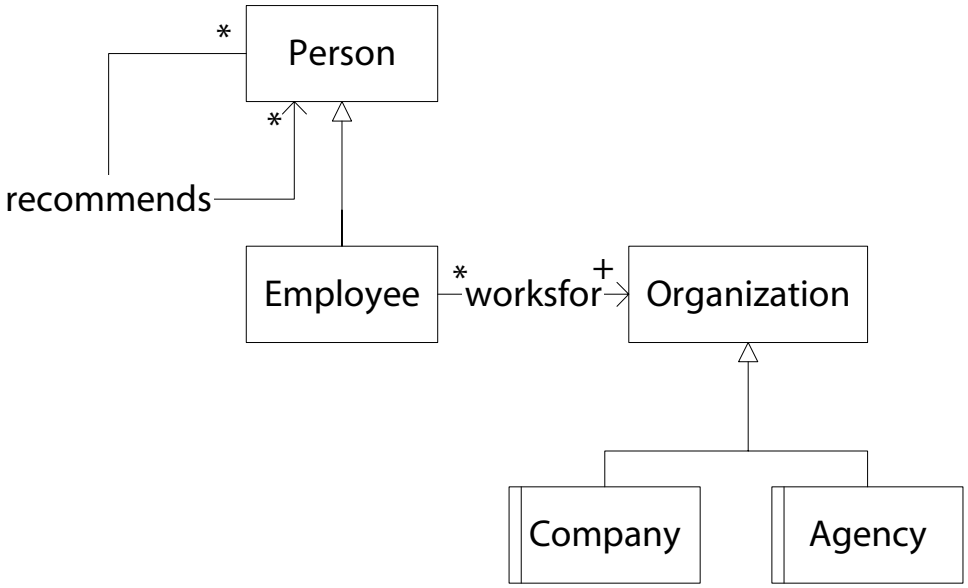
family tree example



file system example



employment database example



sets, domains & subset

sets

- a box represents a set of objects
- objects are structureless entities: no state is "contained"

subset

- closed arrow denotes subset
- can read subset as "is-a": a *Man* is-a *Person*

domains

- sets without supersets are called domains
- domains are disjoint: no object is both a Person and a Date

examples, with domains underlines

- family: Person, Date, Name, Married, Man, Woman
- file system: FSObject, File, Dir, Link, Root
- employment DB: Person, Organization, Employee, Agency, Company

disjoint subsets & partitions

shared subset arrows

- say that subsets are disjoint
  - no Person is both a Man and a Woman
  - no FSObject is both a File and a Dir
  - no Organization is a Company and an Agency
  - but Person may be both Married and a Man
- when arrowhead is filled, subsets are exclusive too
  - every Person is a Man or a Woman
  - every FSObject is a File or a Dir

domains

- are implicitly disjoint

relations

relations

- arc with open arrow denotes a relation
- a relation is a mapping (ie, a set of pairs)
  relation r: S -> T contains pairs (x, y) with x in S and y in T

examples

- *parents* maps x to y when Person x has parent Person y
- *wife* maps x to y when Man x has wife Woman y
- *to* maps x to y when Link x points to the FSObject y
- *recommends* maps x to y when Person x recommends Person y

transpose

- the label p(~q) introduces two relations; second is transpose of first
- wife(~husband): wife maps x to y when husband maps y to x

notes about relations

non-disjoint sets

- relations don't just map elements of sets with arrows
- wife maps objects in Married, even though arrow is from Man to Woman
  since Man and Married are not necessarily disjoint

what relations don't say

- anything about references in objects
- anything about direction of navigation
  direction is just for semantics: a Dir *contains* FSObjects
  but could do other way round: an FSObject *inside* a Dir

multiplicity

how many?

- instances of a set?
- instances mapped by a relation?

multiplicity markings

- \+ means one or more
- * means zero or more
- ! means exactly 1
- ? means zero or 1
- omission equivalent to *

which way round?

- A * -> ! B means
  each A is mapped to one B
  each B is mapped to by zero or more A's

can use for sets too

- Root! is a set of Dirs with one element (ie, there's only one file system root)

multiplicity examples

family

- each Person has zero or more parents
- each Man has zero or one wife

file system

- each Link points to exactly one FSObject
- each Dir contains zero or more FSObjects

employment DB

- each Employee works for one or more Organizations

constraints

some constraints

- can't be expressed graphically
- just express in text, informally

examples

- family
  - a Man with a wife is Married
  - x has wife y -> x.parents and y.parents are disjoint
  - nobody is their own parent
- employment database
  - no Employee works for an Agency and a Company
  - no self-recommendations
  - every Employee has a recommender
- file system
  - no Dir contains Root

snapshot semantics

an OM denotes

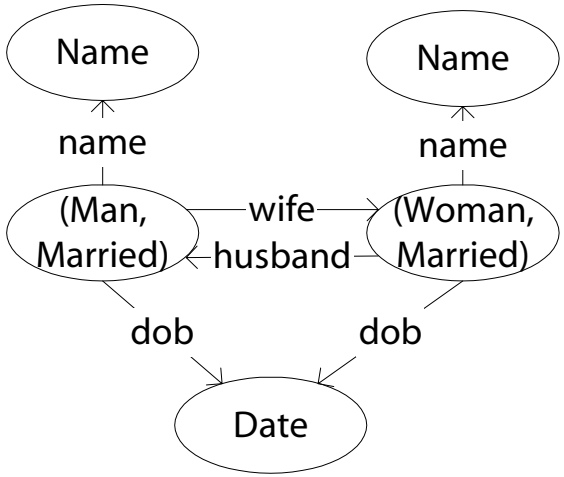
- a set of snapshots, usually infinite

snapshot is graph

- nodes are objects
  - marked with names of sets they belong too
  - (can omit superset when one of its subsets is included)
- arcs are pairs in a relation
  - labelled with name of relation

sample snapshots: family

good



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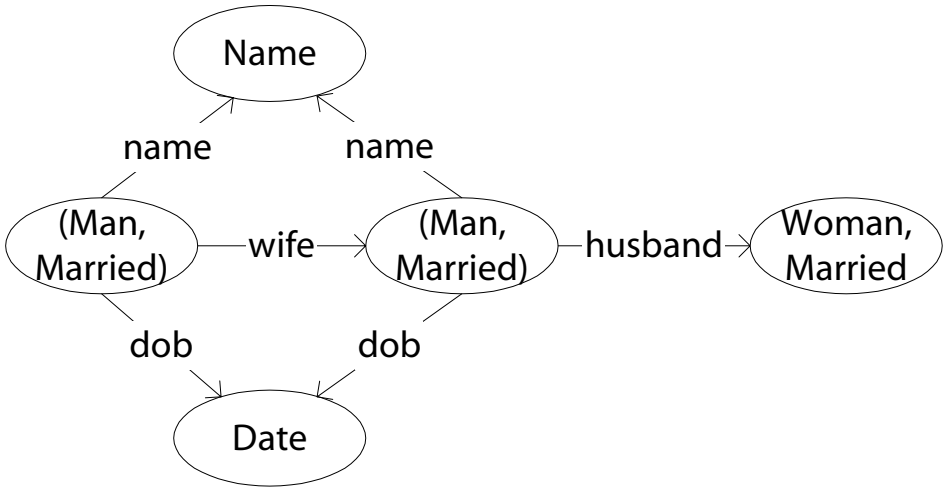
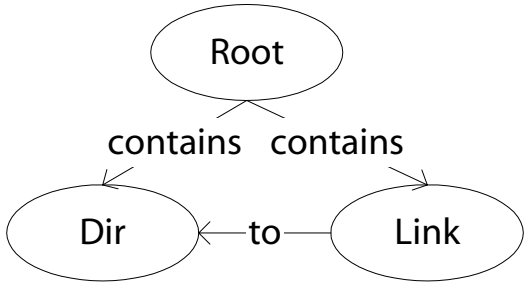


sample snapshots: file system

good



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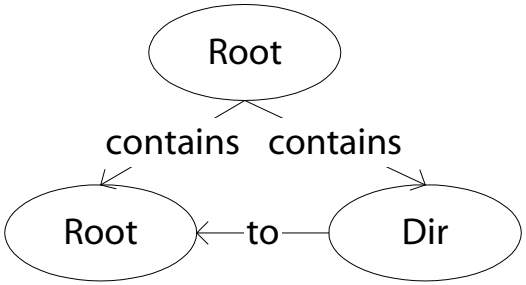
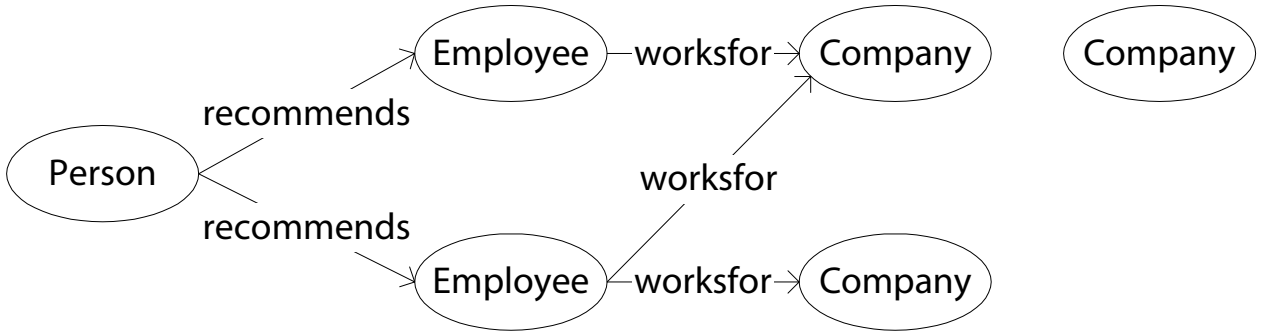


sample snapshots: employment db

good



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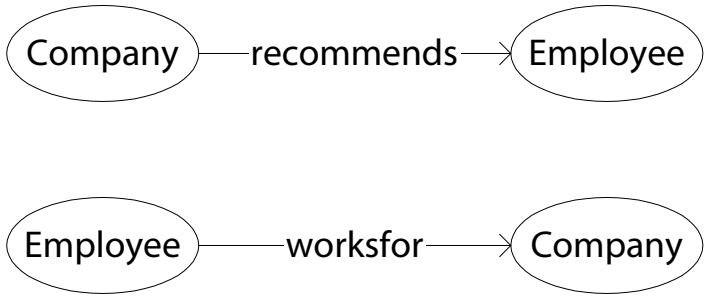


mutability

what it's about

- very useful to say what can change
- rather a subtle notion
  - not often useful to say a set or relation doesn't change
  - this prohibits new objects from coming into existence!

two useful kinds of constraint

- no change to classification of an object
- no change to which objects an object maps to

static sets (shown with vertical stripe)

- a set S is static when
  - an existing object can't move in and out of the set

static relations (shown with hatch on line end)

- for relation r from A to B
- left static (hatch on A end): each B, during its life, is mapped to by same A's
- right static (hatch on B end): each A, during its life, maps to same B's

examples of mutability

family

- Man, Woman static (no sex change)
- Married not static (divorce)
- dob is right-static: can't change your date of birth

file system

- File, Dir, Link are all static (a file can't become a directory)
- to is right-static (what a given link points to is fixed)

employment db

- Employee is not static (can get a job)
- Agency is static (govt agency can't become a Company)

fixed sets

very occasionally

- might want to describe a set that doesn't change
  then it's *fixed*
- shown with vertical stripes on both sides of box

examples

- in file system, *Root* is fixed: can't change which object is the root
- in card game program, *Suit* would be fixed

notes on design OMs

what's abstracted away

- localization of state
  - no instance vars, references etc
  - all state is global, in relations and subsets
- navigation issues
  - direction of relation does not imply navigability
  - no notion of "root" object from which navigations start
- PL notions: subclasses vs. interfaces, methods, etc.

OMs are tricky!

- often embody careful judgments
- family example:
  - *dob* right static? not if system must allow corrections
  - every Married Man has a wife? not if program allows incomplete info
  - at most one parent who's a Man? not if step & adoption handled

code OMs

same syntax, but read more into it

- sets are classes or interfaces
- subset is extends or implements
- relations are references

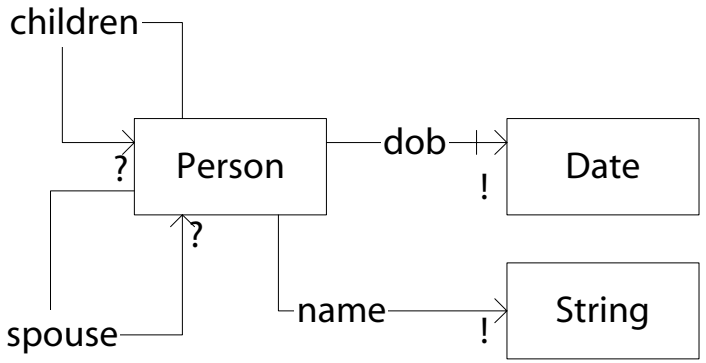
but many choices

- about how state is represented
- affect performance, ease of coding, flexibility

code OM for family (1)

representation choices

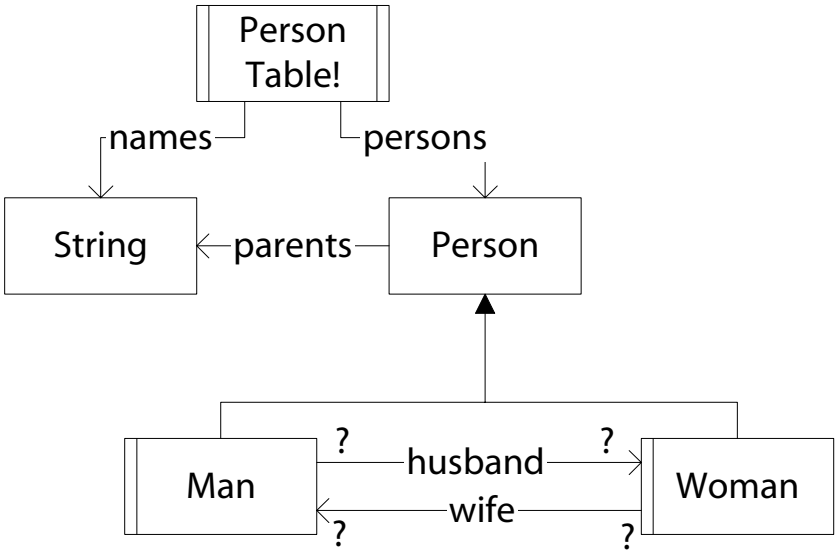
- wife, husband: as one field *spouse*
- parents: in transpose, as vector field *children*
- Married, Man, Woman: as boolean fields of Person
- top-most class has instance variable that holds Person at root of family tree



code OM for family (2)

representation choices

- name: as PersonTable
- dob/Date: as dd/mm/yy int fields
- parents: as array[string] field



from design OM to code OM

ways to represent a relation

- directly or in transpose (ie. reversed), as a field
- as a separate table object

ways to represent a set

- as a concrete or abstract class, or as an interface
- as a boolean field
- as a separate set object

other changes

- adding redundancy for extra paths

consequence of mutability

- a static set can become a *subtype*
- a set whose relations are all right-static can become *immutable*

polymorphism in code OMs

polymorphism

- some classes are polymorphic
- can be used in different ways
- eg, hashtable can be used for different relations
- add clarity to OM by representing with separate boxes

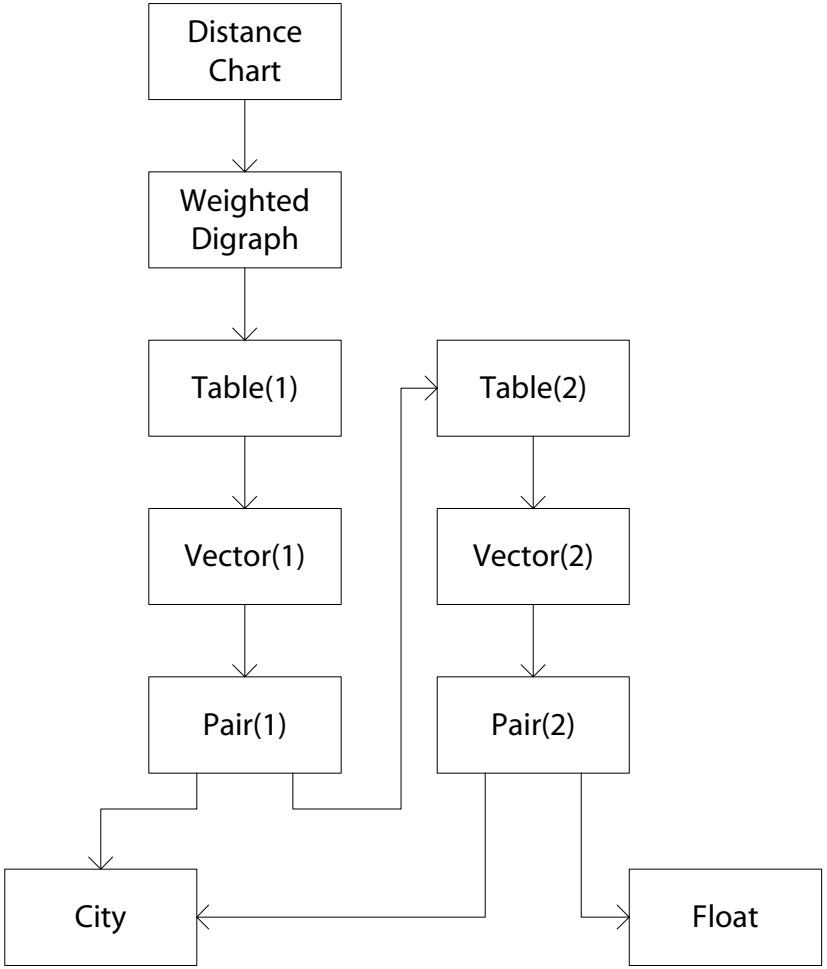
example

- in PS2/3

  Table(1): from City to Table(2)

  Table(2): from City to Float

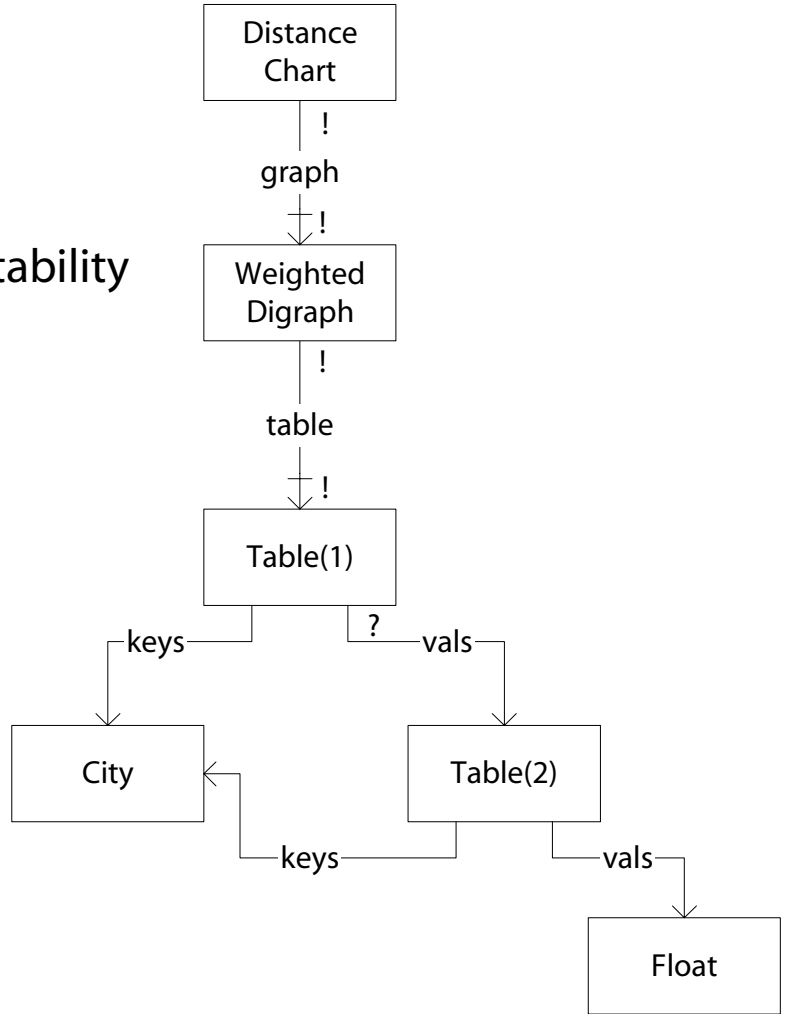
OM for PS2/3


Distance Chart
Weighted Digraph
Table(1)
Table(2)
Vector(1)
Vector(2)
Pair(1)
Pair(2)
City
Float

another OM for PS 2/3

notes

- same rep
- this OM elides some rep details
- also shows multiplicity and mutability



summary

OM gives

- an invariant on the state space
  - which states are permissible
  - state is like a venn diagram with relations
- basic constraints about how state changes
  - mutability markings

OM is

- abstract but precise
- invaluable in early stages of design
- useful later for understanding runtime structures
- programming language independent