6.005 Elements of Software Construction
Fall 2008

how to design a photo catalog

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topics for today

a problem

- conceptual design of a photo organizer

a new paradigm

- computation over relational structures
- today, the abstract design level: object modelling
- determines, in particular, model part of MVC (see last lecture)

object modelling

- snapshot semantics
- basic notation: domain/range, multiplicity, classification
- some classic patterns

the problem

problem

Screenshot of Adobe Photoshop Lightroom removed due to copyright restrictions.
In the Library view, you can select images to add or remove.
The left-hand sidebar includes Collections that you can define.

design a photo cataloguing application

- Lightroom, iView MediaPro, iPhoto, Aperture, Picasa, etc

what kind of problem is this?

mostly about conceptual design

- what are the key concepts?
- how are they related to one another?
- what kinds of structures?

good conceptual design leads to

- straightforward path to implementation
- simplicity and flexibility in final product

why a new model?

why not use datatype productions?

- tree-like structures only: no sharing
- immutable types only

why not state machines?

- our catalog is a state machine
- but the problem lies in the structure of the state
- our state machine notation assumed simple states

a new approach: object models

- structure is a labelled graph
- put another way: sets of objects + relations

the relational paradigm

computation is about

- actions, states, transitions
- functions, expressions, values
- and now: **updates and queries on relations**

why is this useful?

- conceptual modeling
- relational databases
- object-oriented programming*
- semantic web, document object models, etc

*for proposals to make relations explicit in object-oriented programming, see this survey: James Noble, Roles and Relationships, ECOOP 2007 Workshop on Roles and Relationships in Object-Oriented Programming, Multiagent Systems, and Ontologies; http://iv.tu-berlin.de/TechnBerichte/2007/2007-09.pdf

basic OM notation

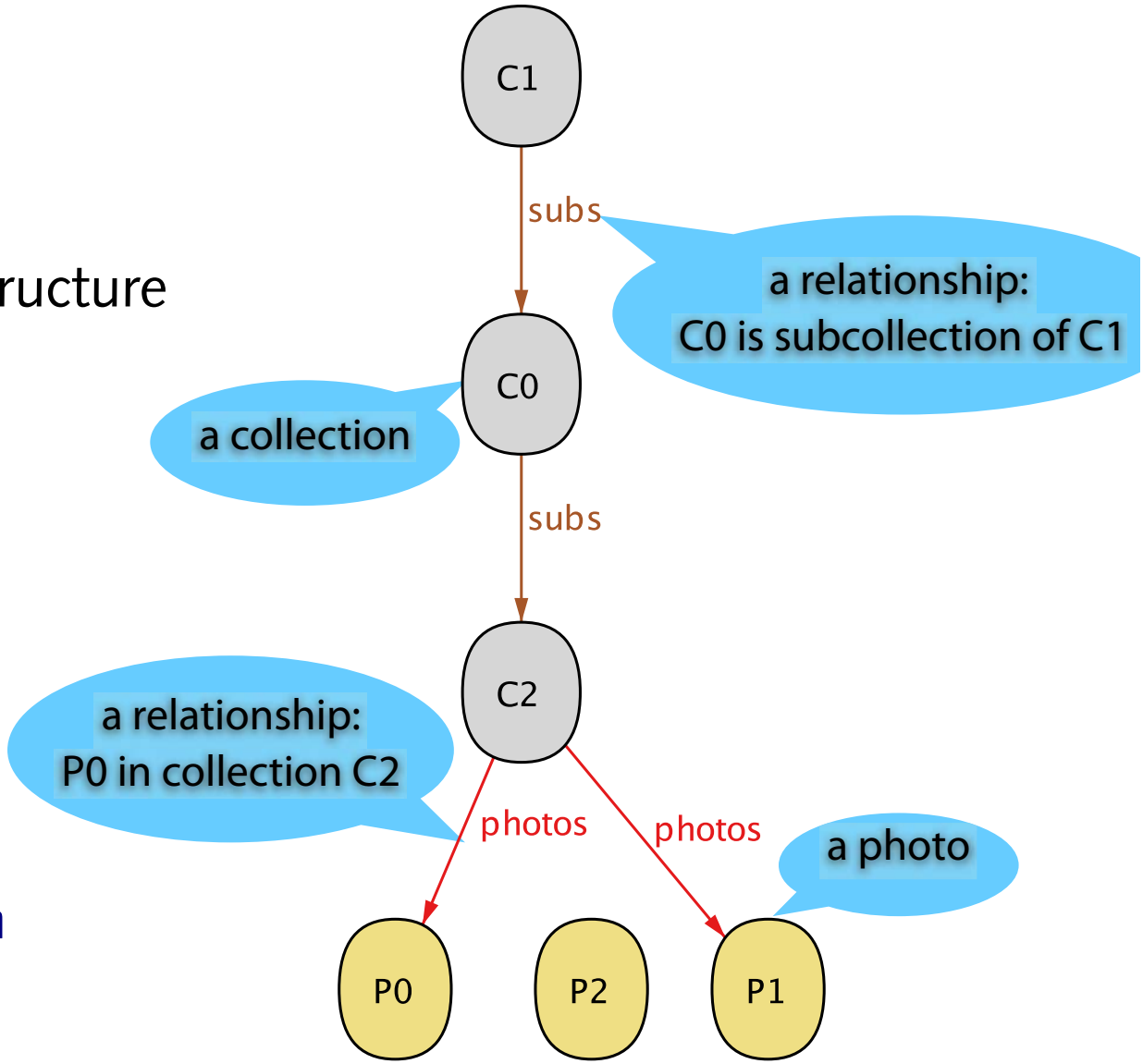
snapshots

a snapshot or object diagram

- shows a single instance of a structure

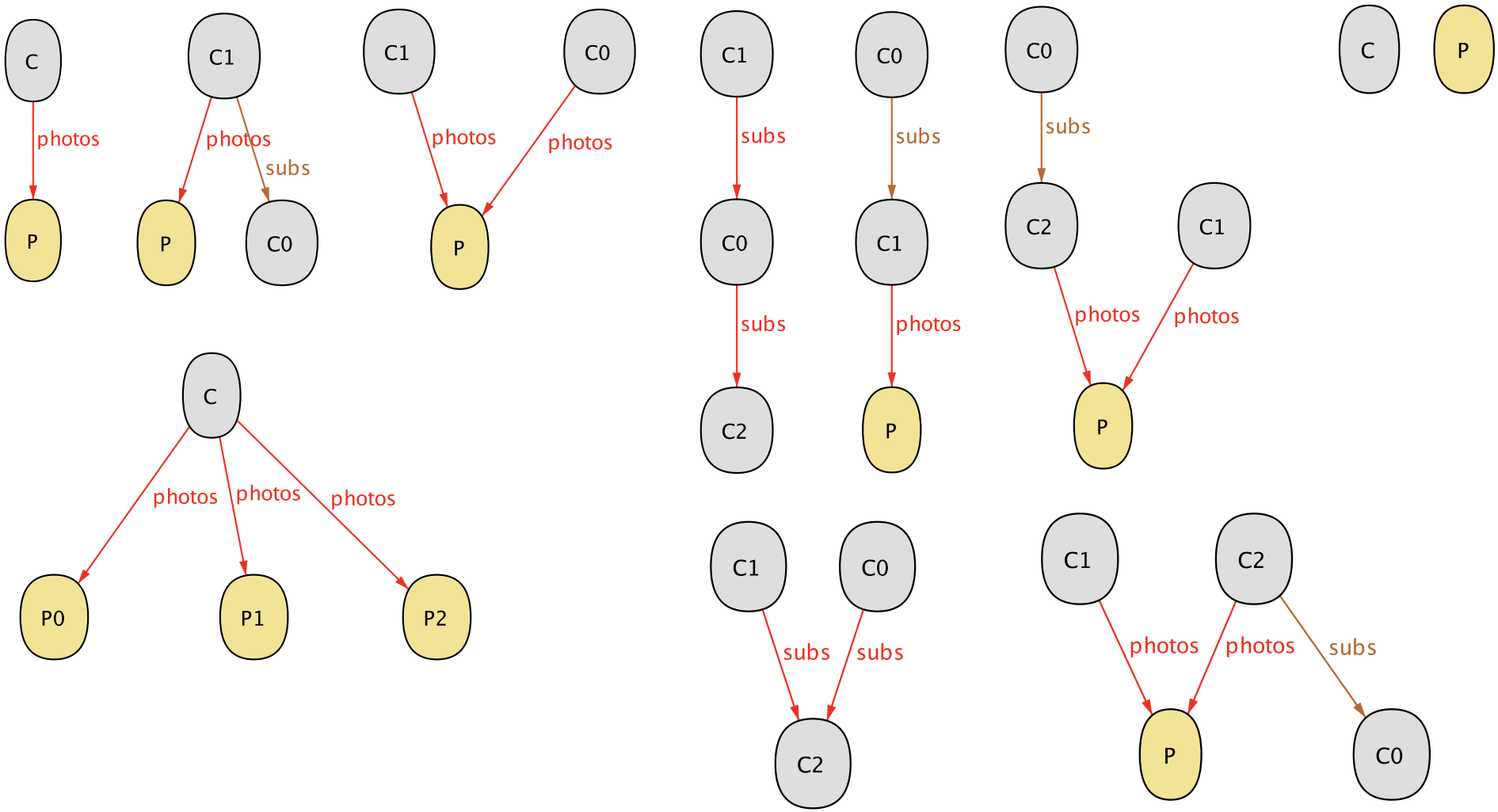
example for photo organizer

- in this case, two sets
  - Photo (shown in beige)
  - Collection (in grey)
- and two relations
  - photos: Collection -> Photo
  - subs: Collection -> Collection



more snapshots

how can we summarize this infinite set?



an object model

each box

- denotes a (maybe empty) set of objects

each arc

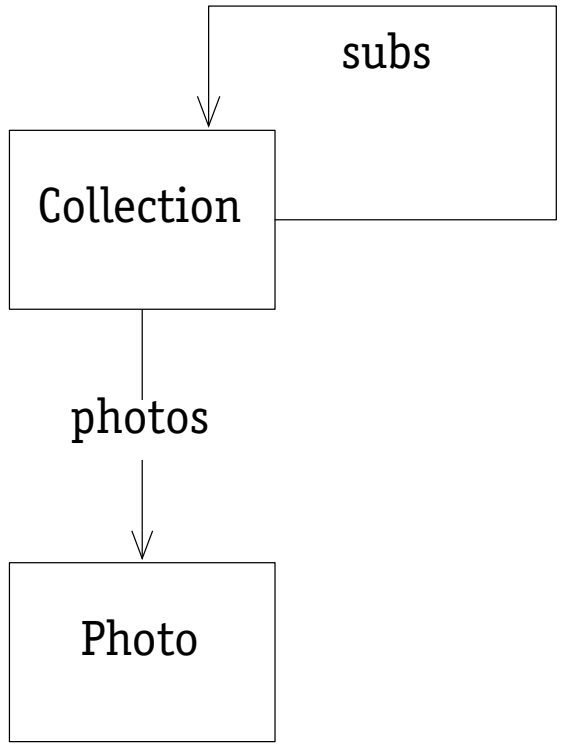
- denotes a relation, ie. set of links between objects

note

- objects have no internal structure!
- all structure is in the relations

exercise

- draw a snapshot that the OM rules out



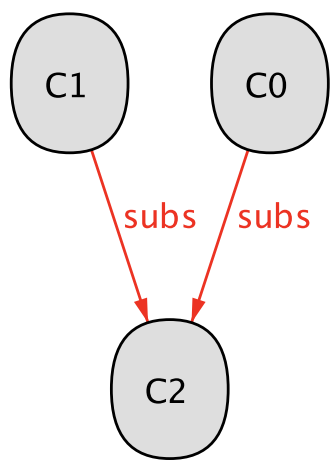
enriching the notation

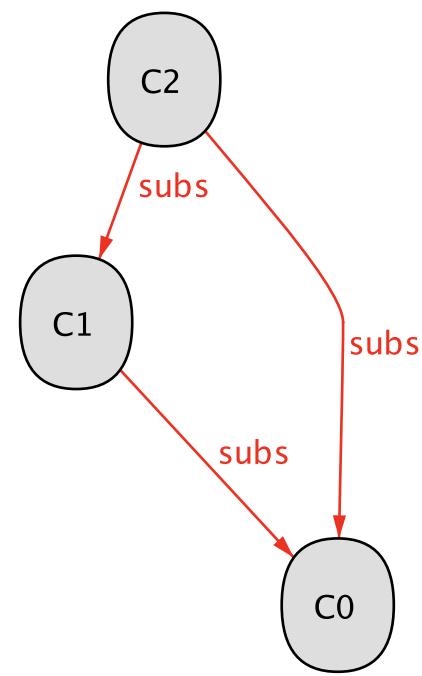
what's wrong with these snapshots?

- how would we rule them out?

key idea: multiplicity

- measure the in-degree and out-degree of each relation

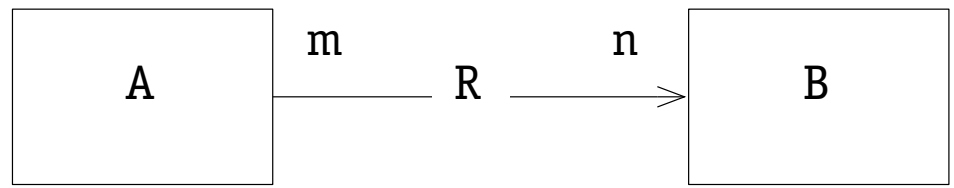




multiplicity

multiplicity markings

- on ends of relation arc
- show relative counts



interpretation

- R maps **m** A's to each B
- R maps each A to **n** B's

marking/meaning

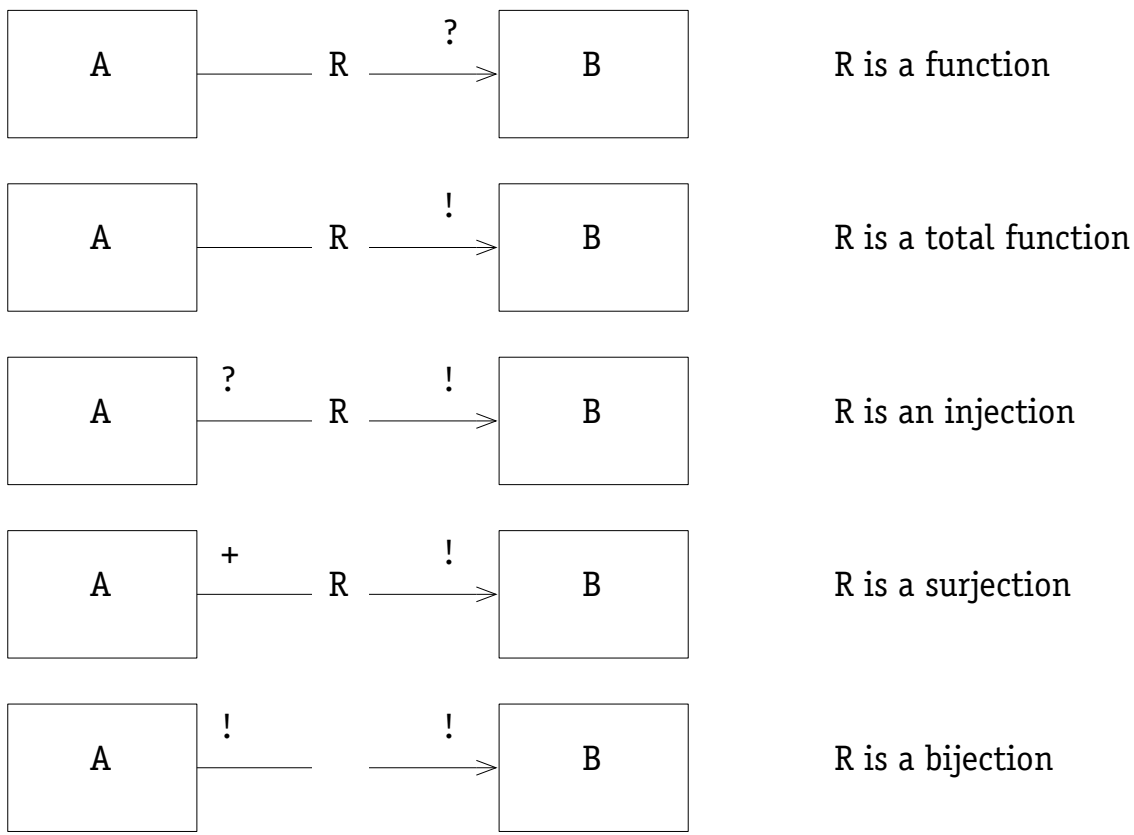
+	one or more
*	zero or more
!	exactly one
?	at most one

omitted marking equivalent to *

kinds of function

standard kinds of function

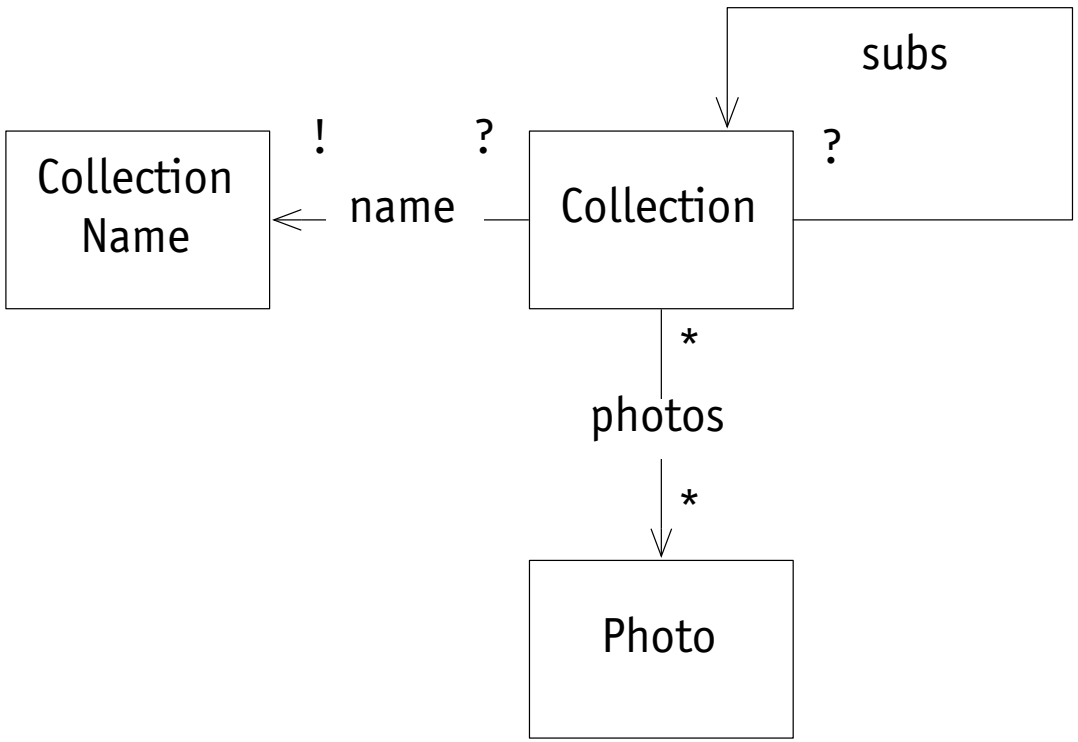
- easily expressed with multiplicities



multiplicity example

we've added naming

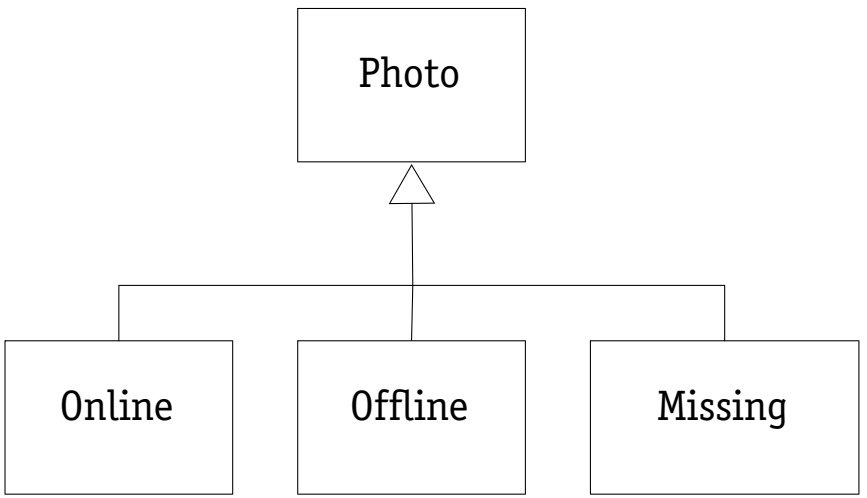
- always an important and subtle issue
- is the multiplicity constraint desirable? necessary?

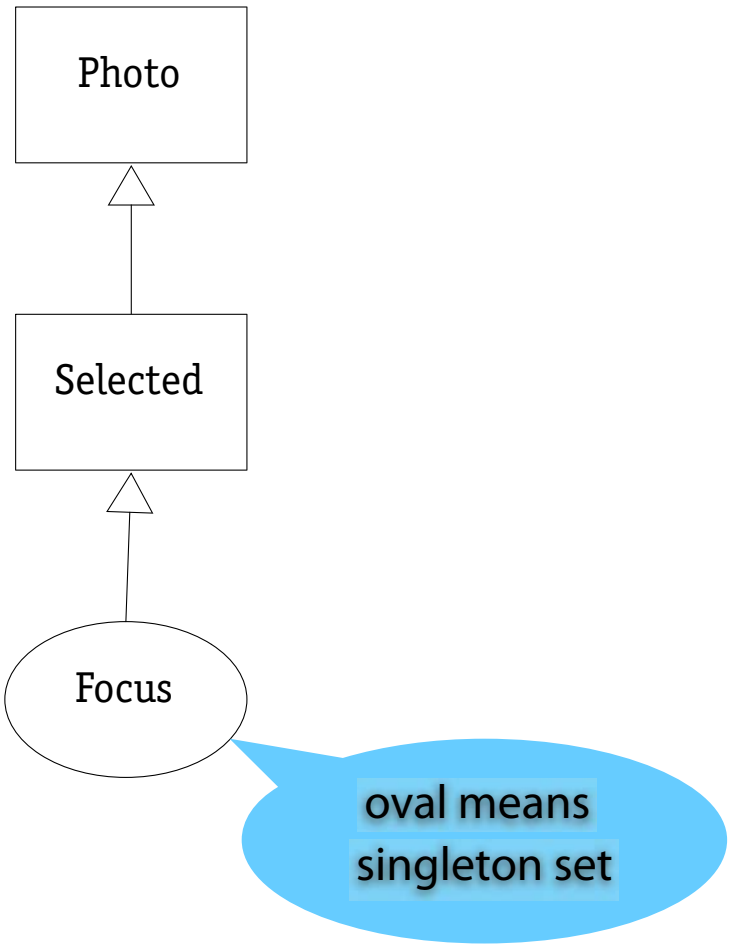


classifying objects

suppose we to classify photos

- by file location: online, offline, missing
- by selection: selected, focus

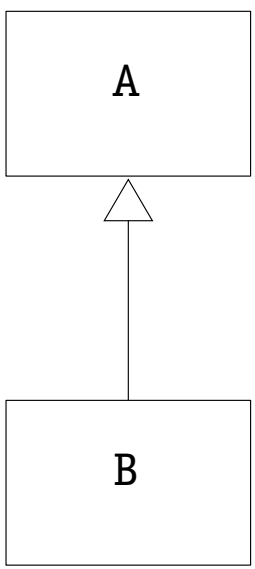




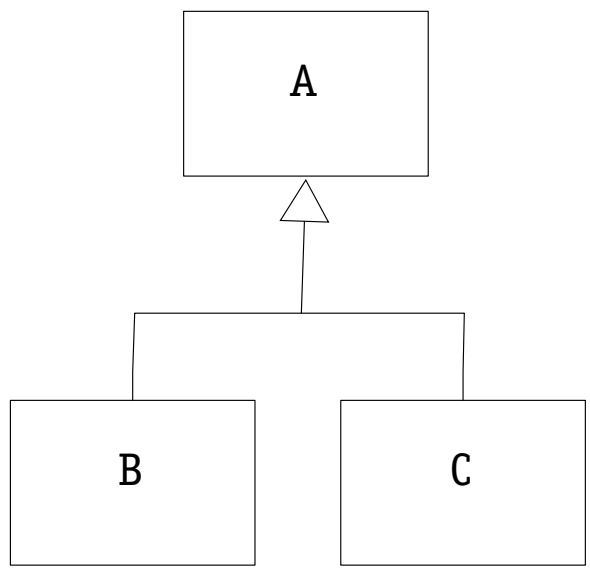
classification syntax

can build a taxonomy of objects

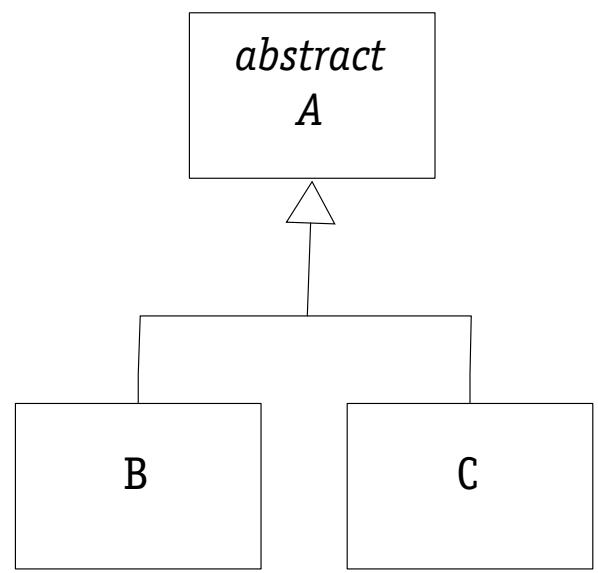
- introduce subsets
- indicate which are disjoint
- and which exhaust the superset



$B \subseteq$



$B \cap C = \varnothing$

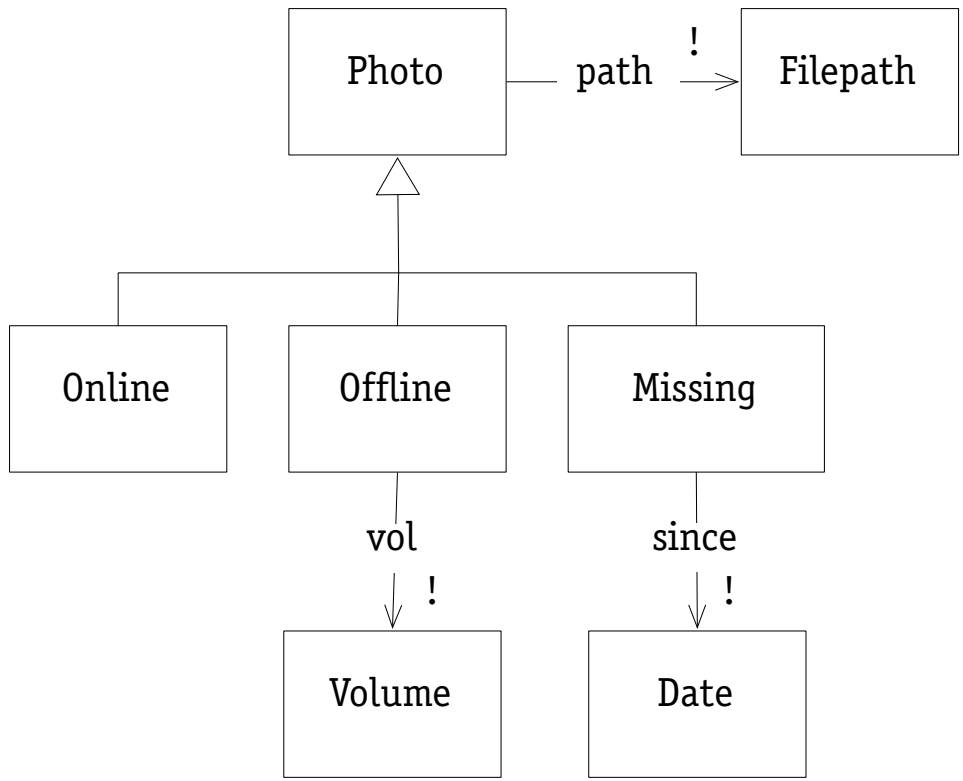


$B \cup C = A$

relations on subsets

when placing a relation

- can place on subset
- loose multiplicity is a hint



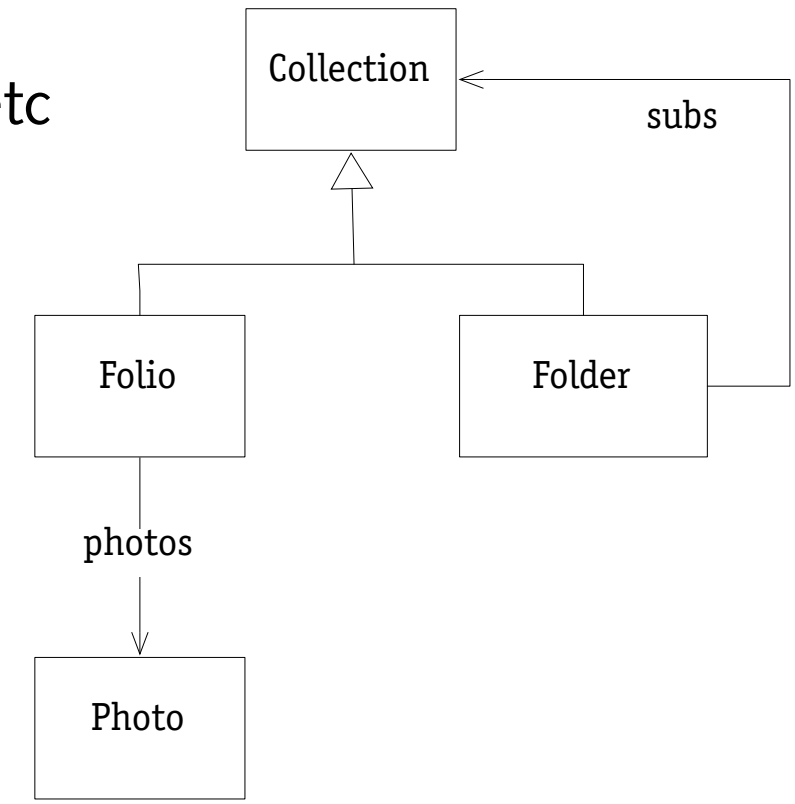
composite

a classic pattern

- hierarchical containment
- file systems, org charts, network domains, etc

you've seen this with datatypes

- technical differences though
- OM allows cycles (but often rule out)
- OM can say just one root



hotel locking

example: hotel locking

modelling physical, distributed state

state in OM need not represent

- a centralized store
- data stored in a computer

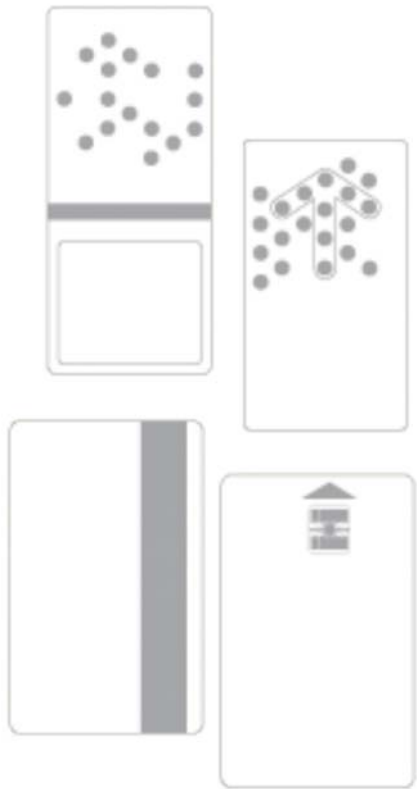
hotel locking

recodable locks (since 1980)

- new guest gets a different key
- lock is ‘recoded’ to new key
- last guest can no longer enter

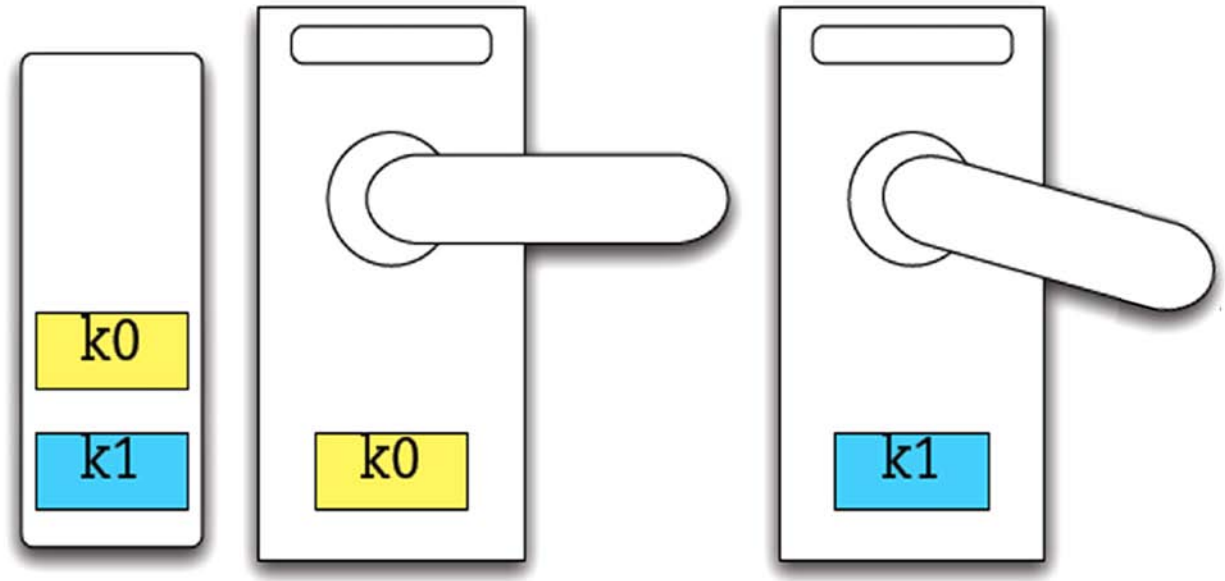
how does it work?

- locks are standalone, not wired

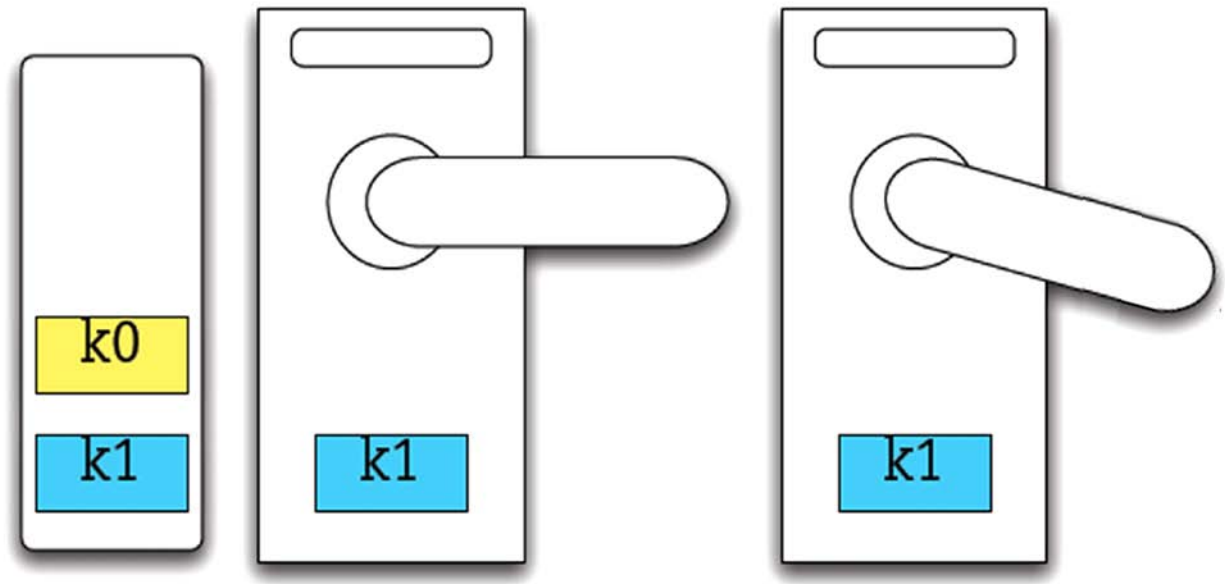


a recodable locking scheme

card has two keys
if first matches lock,
recode with second



if second matches,
just open



exercise

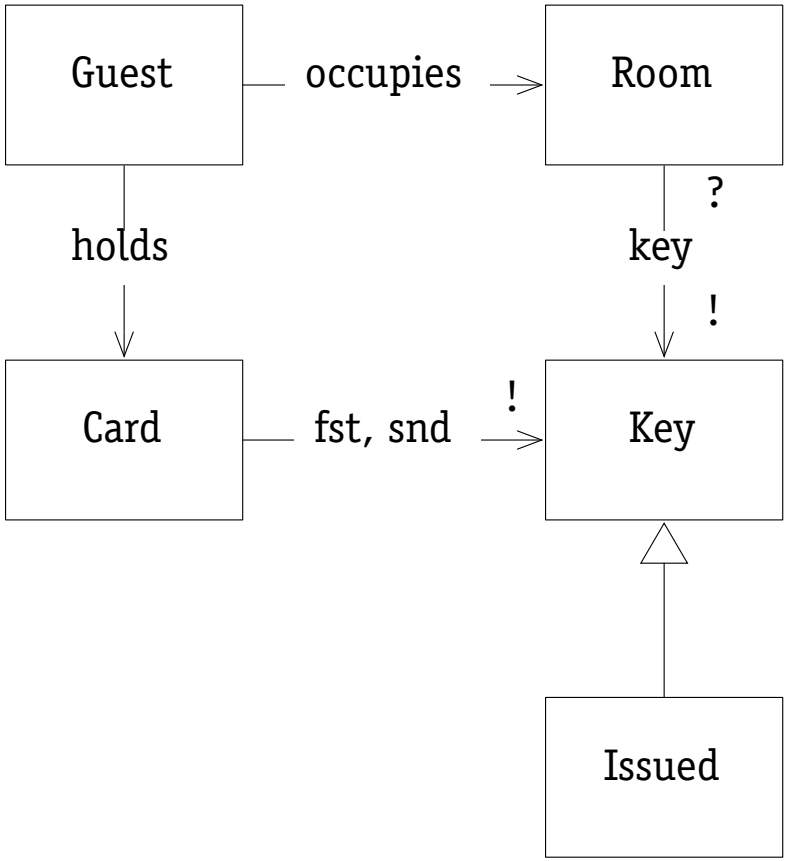
draw an object model

- showing the essential state of hotel locking
- state includes front desk, locks, keys held by guests

review

- did you exploit multiplicities? keys are all about uniqueness
- did you include only the sets and relations that are needed?
- are your sets really sets, or are some of them ‘singleton placeholders’?
- do all your sets and relations have a clear interpretation?
- where are the various parts of the state stored physically?
- which relations are modifiable?

a solution



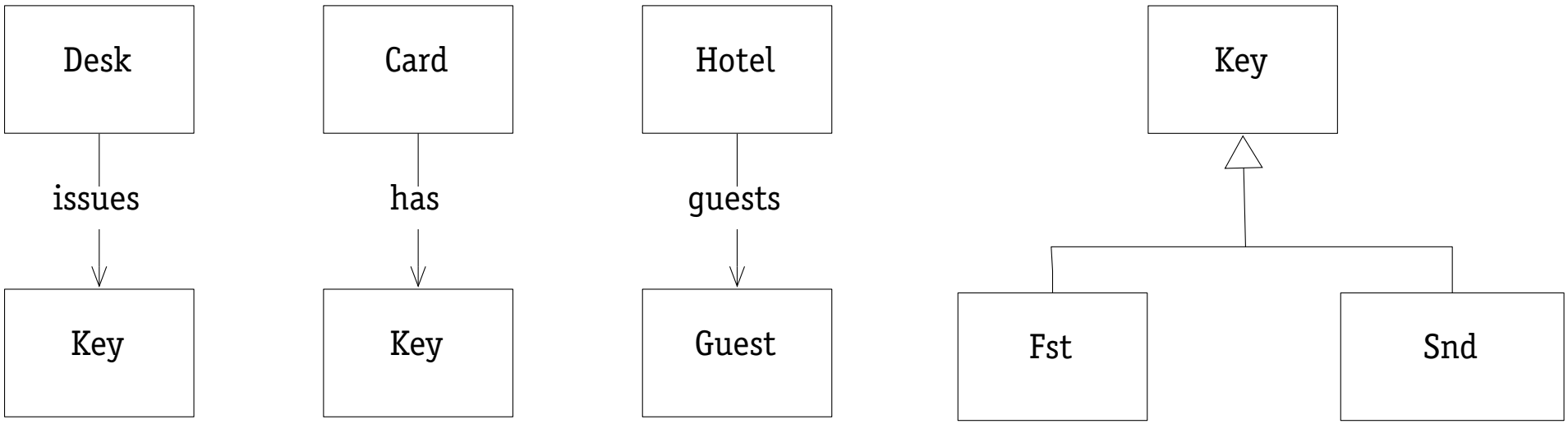
g->r in **occupies**: guest g has checked in for room r but has not yet checked out

k in **Issued**: key k has already been issued by front desk on some card: used to ensure that locks are always recoded with fresh keys

some subtleties

- guest may occupy more than one room
- family members may have identical cards

common errors



be wary of top-level singleton

- Desk and Hotel not needed

relations represent state, not actions

- so issues is suspect

need enough information in state to support application

- has is not enough: need to know which key is first, second

scope of classification

- classification of keys into first and second, is by card, not global
- so need relation, not subsets to indicate the distinction

colour palettes

example: colour palettes

modelling the state of an application

- how colours are organized

essential idea

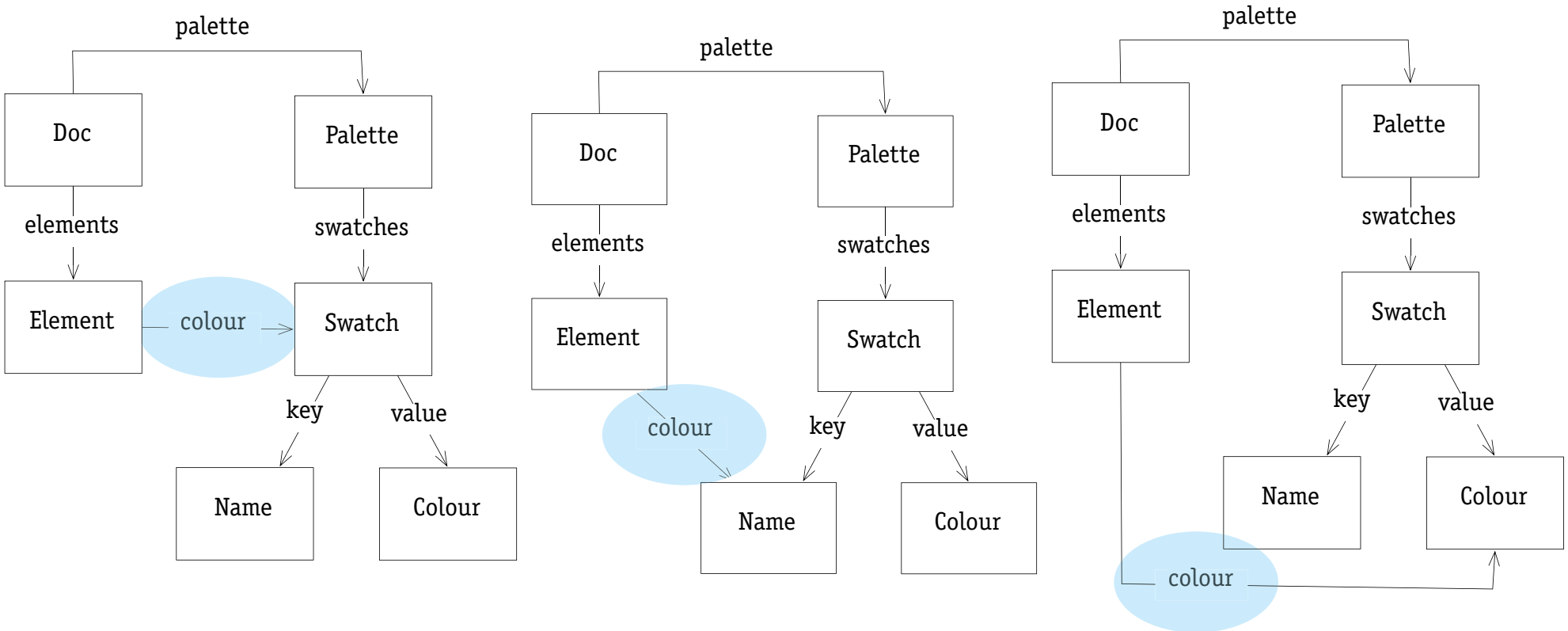
- elements are coloured
- can assign colour from palette
- gives consistent appearance

Screenshots of color schemes in the Keynote and PowerPoint presentation programs removed due to copyright restrictions.

palette object models

three subtly different approaches

- think what happens when palette is modified
- hard vs. soft links: as in Unix



"Every problem in computer science can be solved by introducing another level of indirection"
-- David Wheeler

completing the organizer

issues to resolve

can collections hold photos and subcollections?

- decision: yes, so not Composite pattern

how are "all photos" in catalog represented?

- decision: introduce non-visible root collection

unique collection names?

- decision: file system style, so siblings have distinct names

do parents hold children's photos?

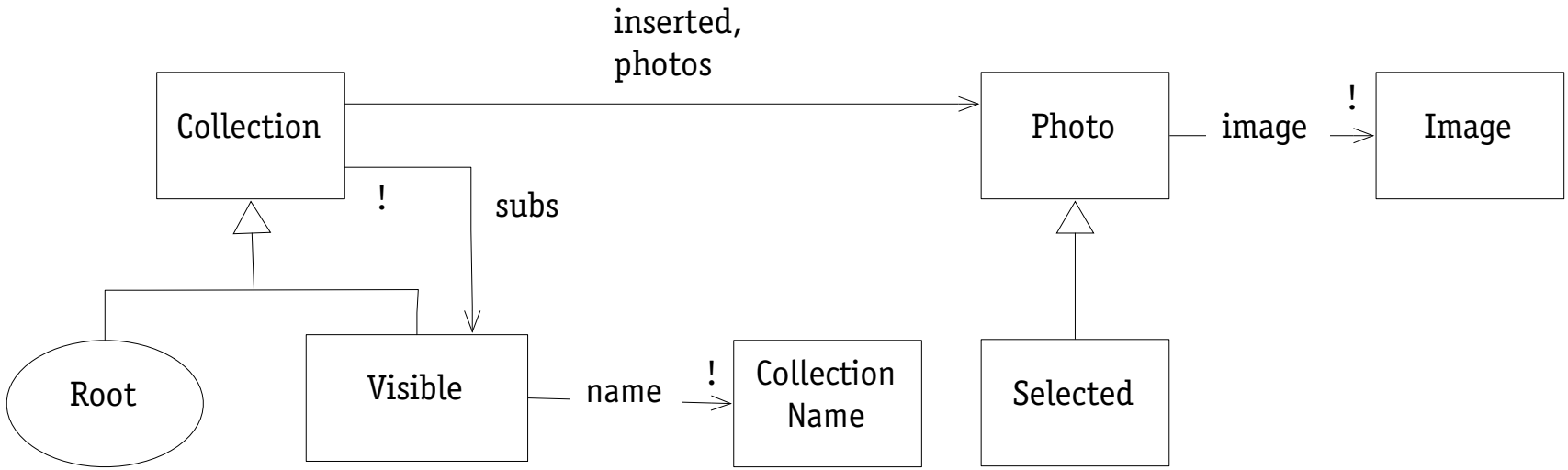
- in logic: `all c: Collection | c.subs.photos in c.photos` ?
- decision: use two relations instead

  `c.inserted`: the photos explicitly inserted into collection `c`

  `c.photos`: the photos in collection `c` implicitly and explicitly

  invariant relates these: `c.photos = c.inserted + c.subs.photos`

final object model



additional constraints

- all collections reachable from root (implies acyclic)

  Collection in Root.*subs

- implicit photos are inserted photos plus photos in subcollections

  all c: Collection | c.photos = c.inserted + c.subs.photos

- names unique within parent

  all c: Collection | no c1, c2: c.subs | c1 != c2 and c1.name = c2.name

modeling hints

hints

how to pick sets

- be as abstract as possible (thus Name, not String; SSN, not Number)
- but values to be compared must have same type (so Date, not Birthday)
- beware of singletons -- often a sign of code thinking

how to pick relations

- represent state, not actions (so atFloor: Elevator->Floor, not arrives)
- direction is semantic; doesn't constrain 'navigation'

choosing names

- choose names that make interpretation clear
- include a glossary explaining what relations and sets mean

summary

principles

data before function

- before thinking about system function, think about data

an object model is an invariant

- meaning is set of structured states
- declared sets + subset relationships + relations between sets + multiplicities
- augment diagram with textual constraints (in Alloy, as above, or just English)

model objects are immutable

- all state kept in subsets and relations
- model objects have no 'contents'
- important to keep coding options open