rethinking software design by analyzing state

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Workshop Honoring Shmuel Katz · Technion · Dec 19, 2013

three puzzles

why are formal methods not widely used?

› great advances, successful application in specialized domains
› but still a niche, little impact on mainstream development

why is analysis often a second order effect?

› key rationale for formalization: mechanical analysis?
› but in many case studies, most errors found during formalization

why is software so "reliable without proof"?

› better languages & more testing don't explain it
› least usable features are the least reliable?

a hypothesis

one underlying driver

- clarity of the underlying conceptual model

bad concepts affect both

- user: can’t form mental model
- developer: can’t implement clean modules

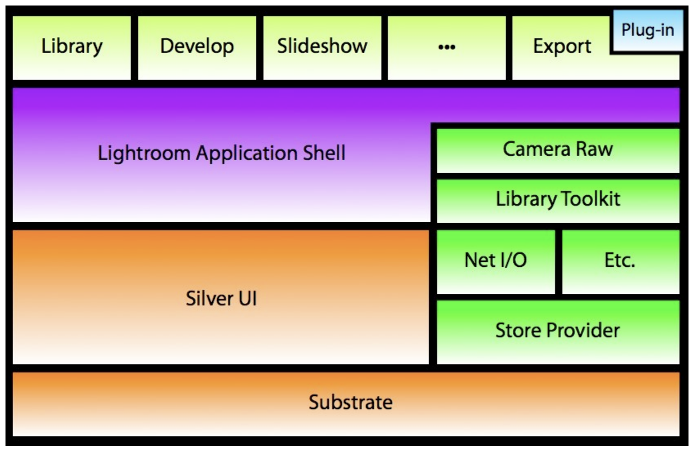
so:

- why don’t formal methods have more influence?

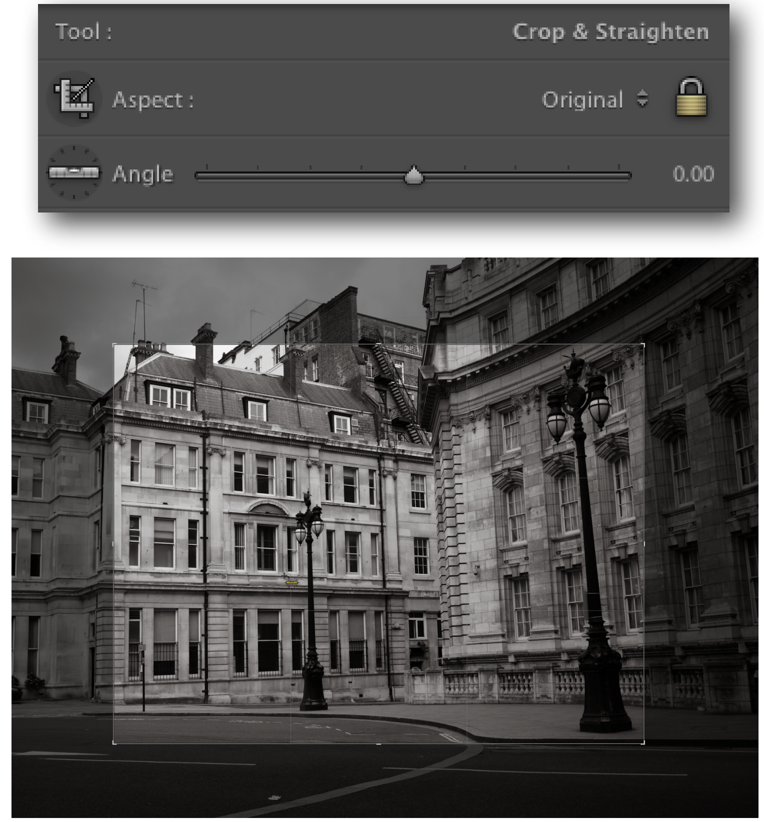
  with good conceptual model, informal reasoning goes far
- why does formalization alone find flaws so effectively?

  it forces you to clarify the concepts
- why do the least usable features have the most bugs?

  because the developers are confused too

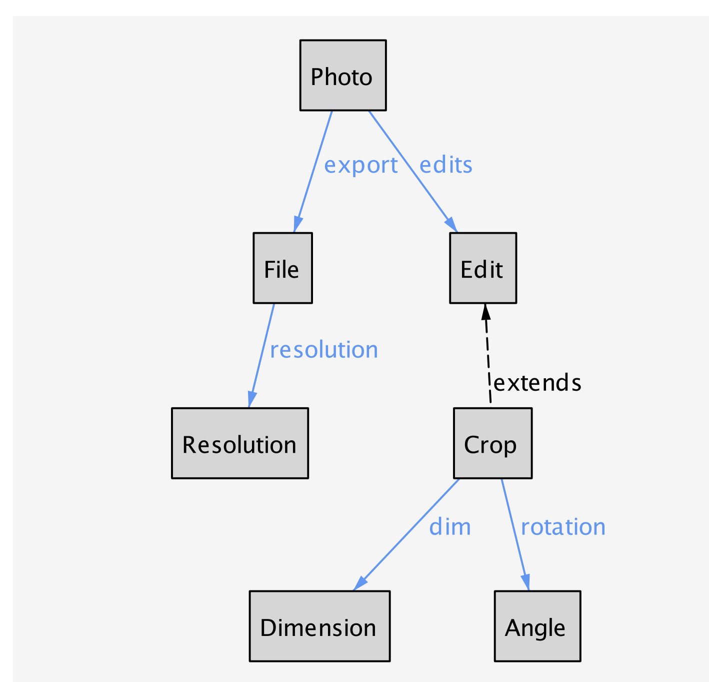


code



interface

user's model



conceptual model

Lightroom architecture diagram from
http://www.troygaul.com/LrExposedC4.html

research program

basic theory

defining concepts
concept dependence
structural design criteria

conceptual redesigns

git, gmail, dropbox, css

concept models

concept idioms
behavioral design criteria

WARNING

evolving research

as the thesis reader said: "There are new and good ideas here"

"But what's new isn't good and what's good isn't new"

concept models


IT WILL
DO YOU GOOD.
Classify
Spread recycling!! To save limited natural
resources for our children's future.
4300 02
SPAPA
TRADE MARK ®
©1991 Produced by Super Planning Company Limited.

classification syntax

atoms are

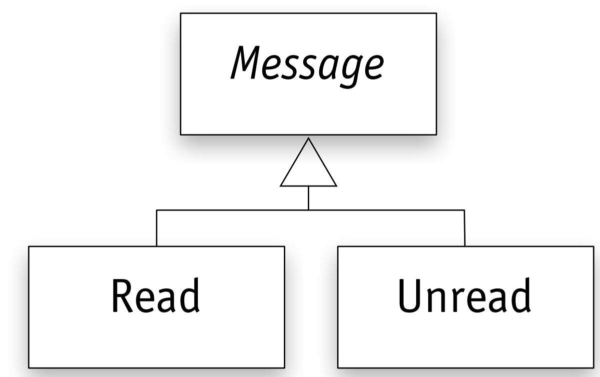
- distinguishable: have an identity
- immutable: don't change
- indivisible: not structured

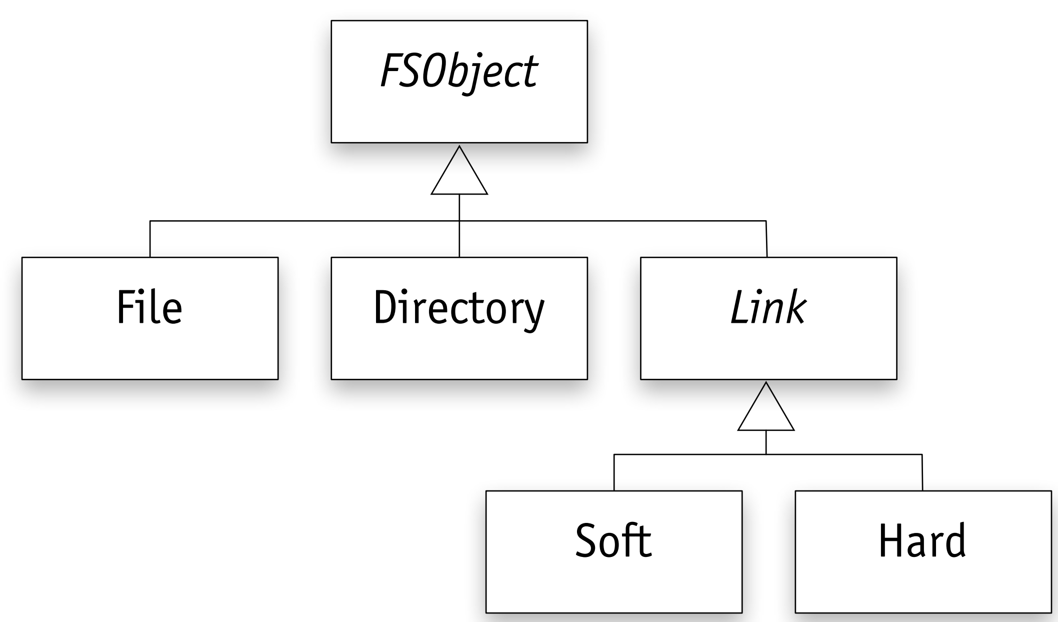
box

- set of atoms (empty, singleton, finite, infinite)
- italic: exhausted by subsets

fat arrow

- subset, not necessarily static
- shared arrow: disjoint subsets

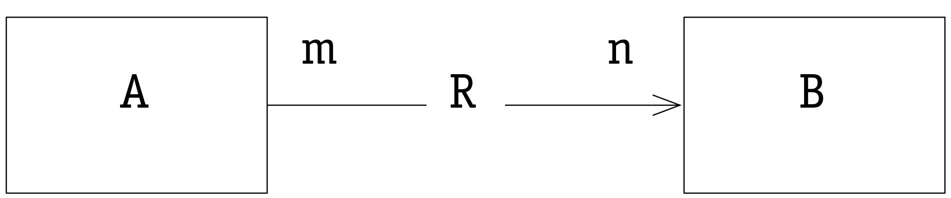




relations syntax & semantics

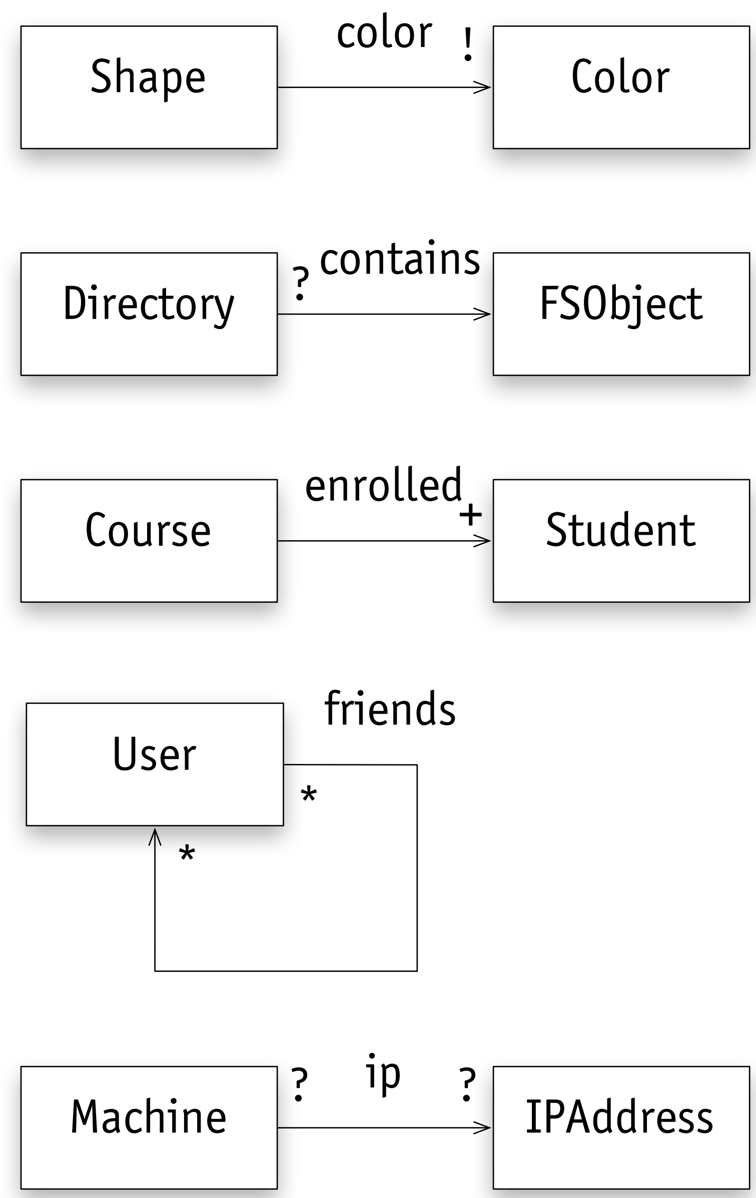
kinds of relation

› property
› containment
› association
› naming

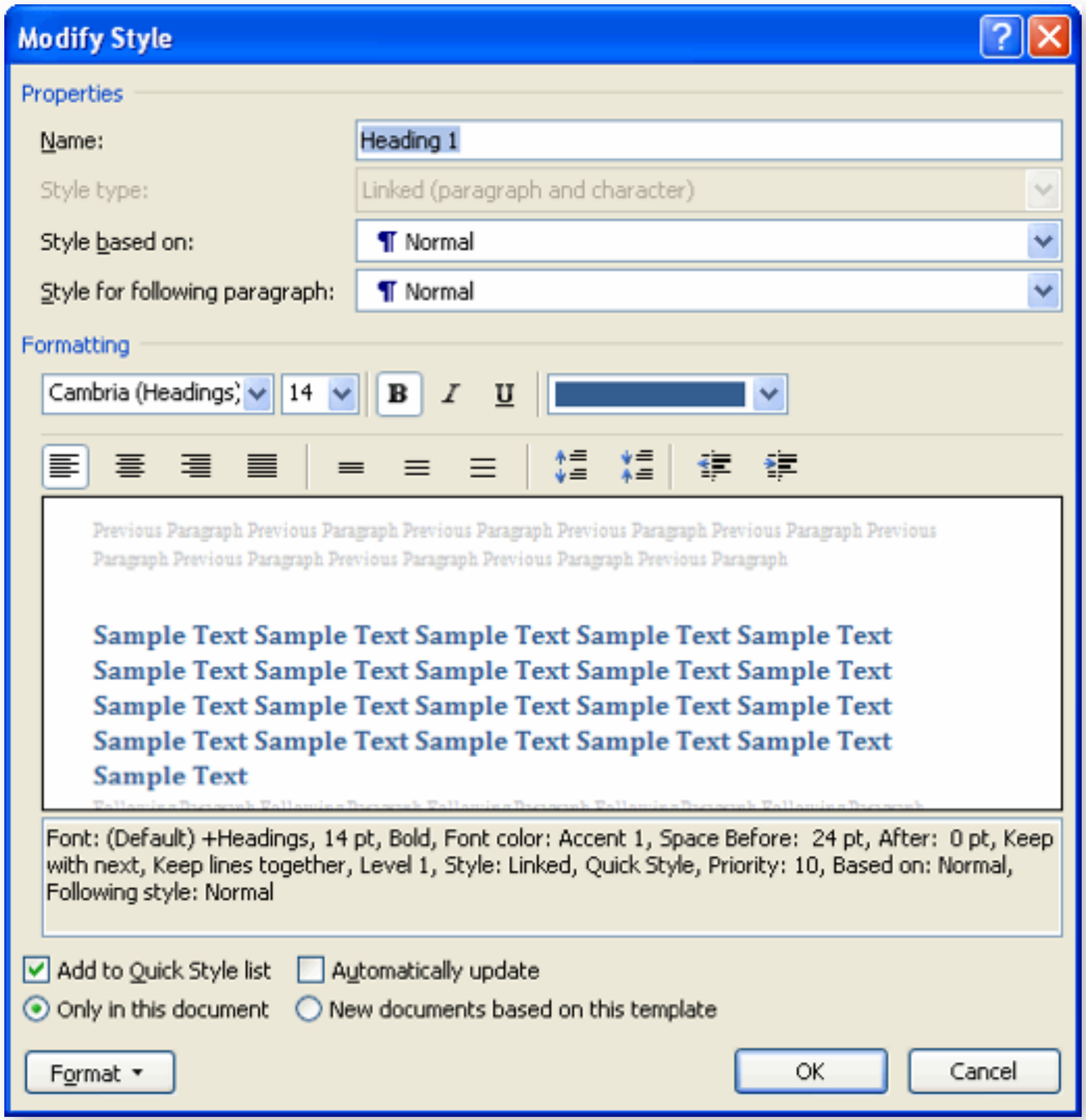


- R maps **m** A's to each B
- R maps each A to **n** B's

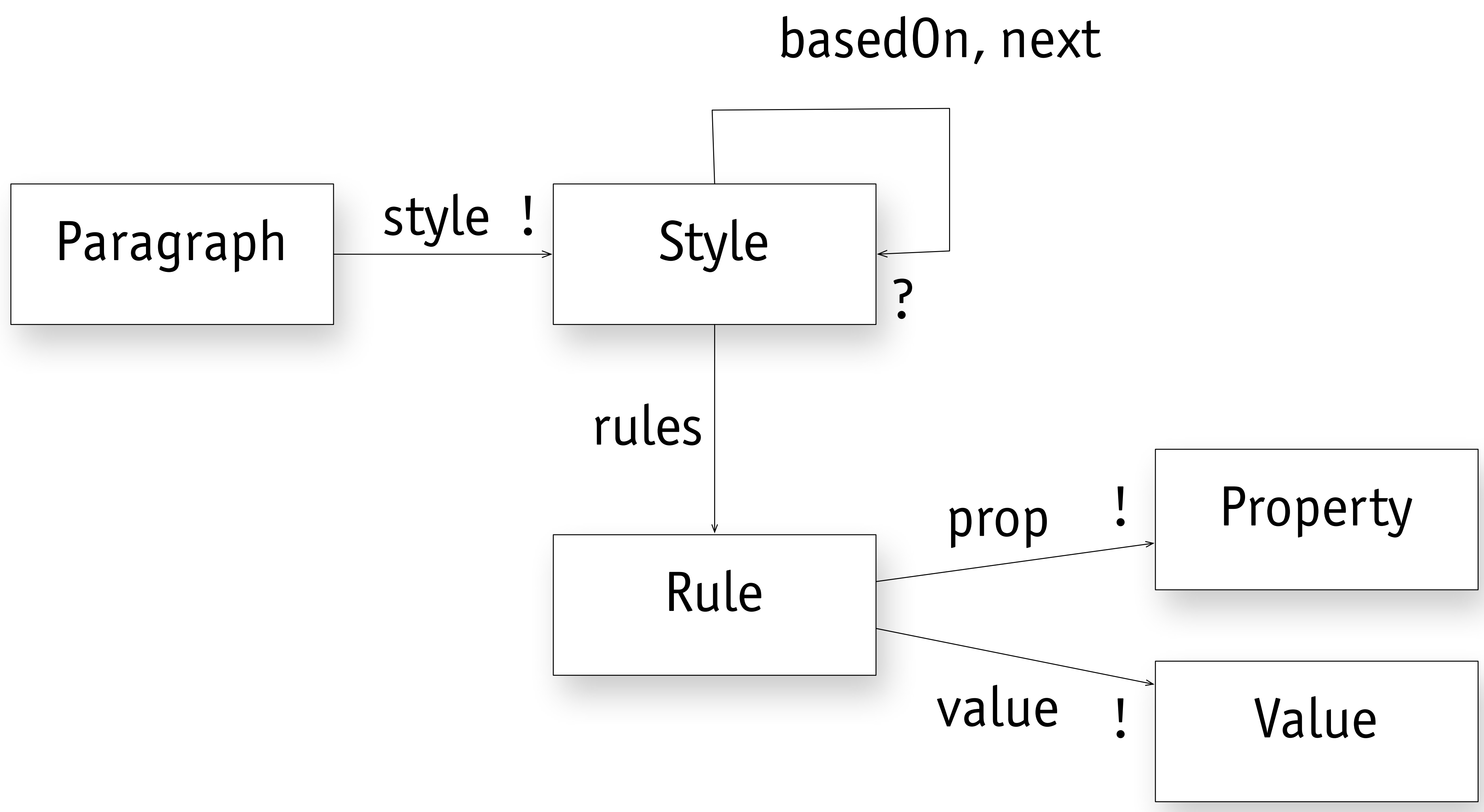
+ one or more
* zero or more
! exactly one
? at most one
omitted = *



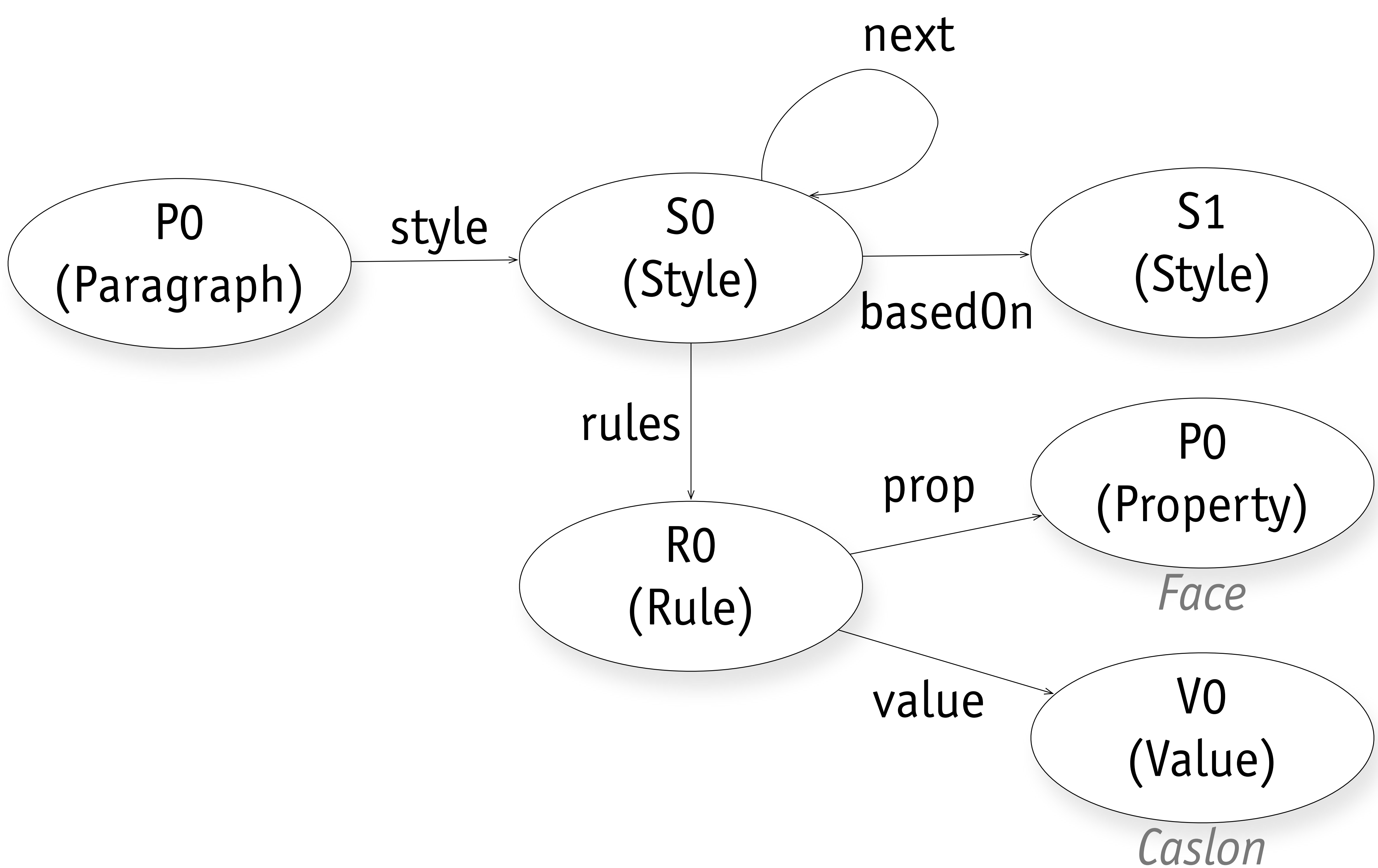
example word styles



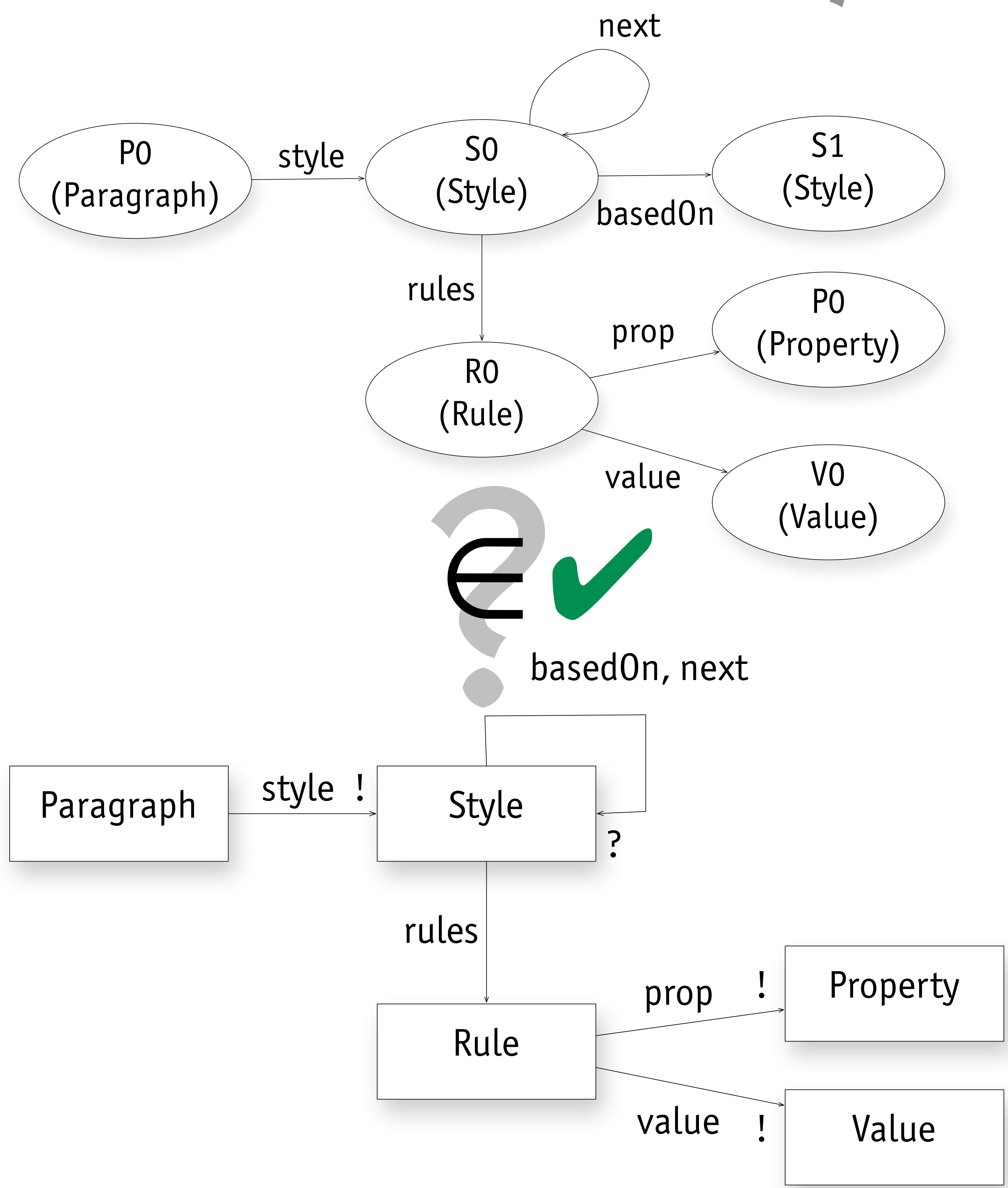
model word styles



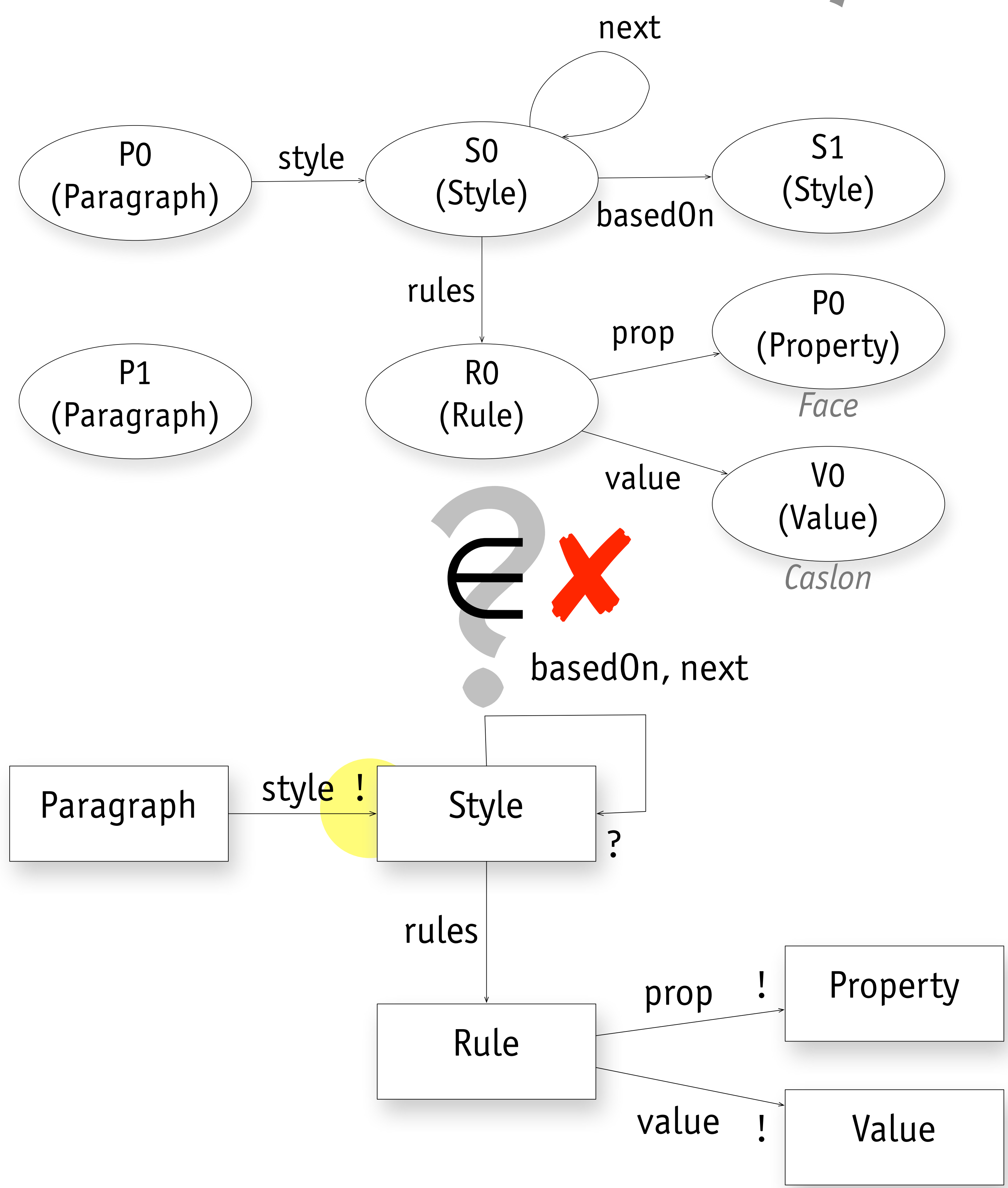
instance word styles



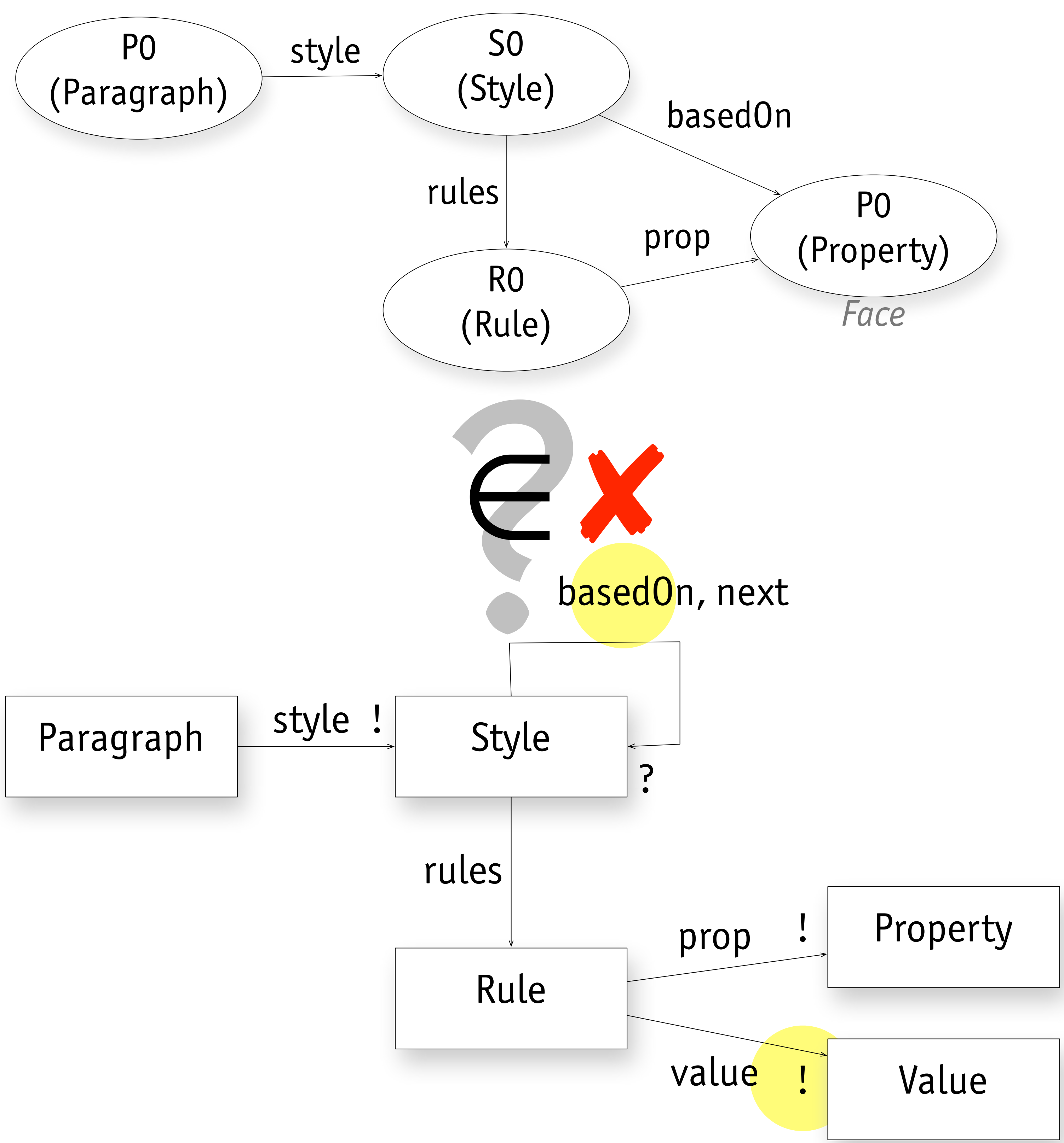
semantics word styles



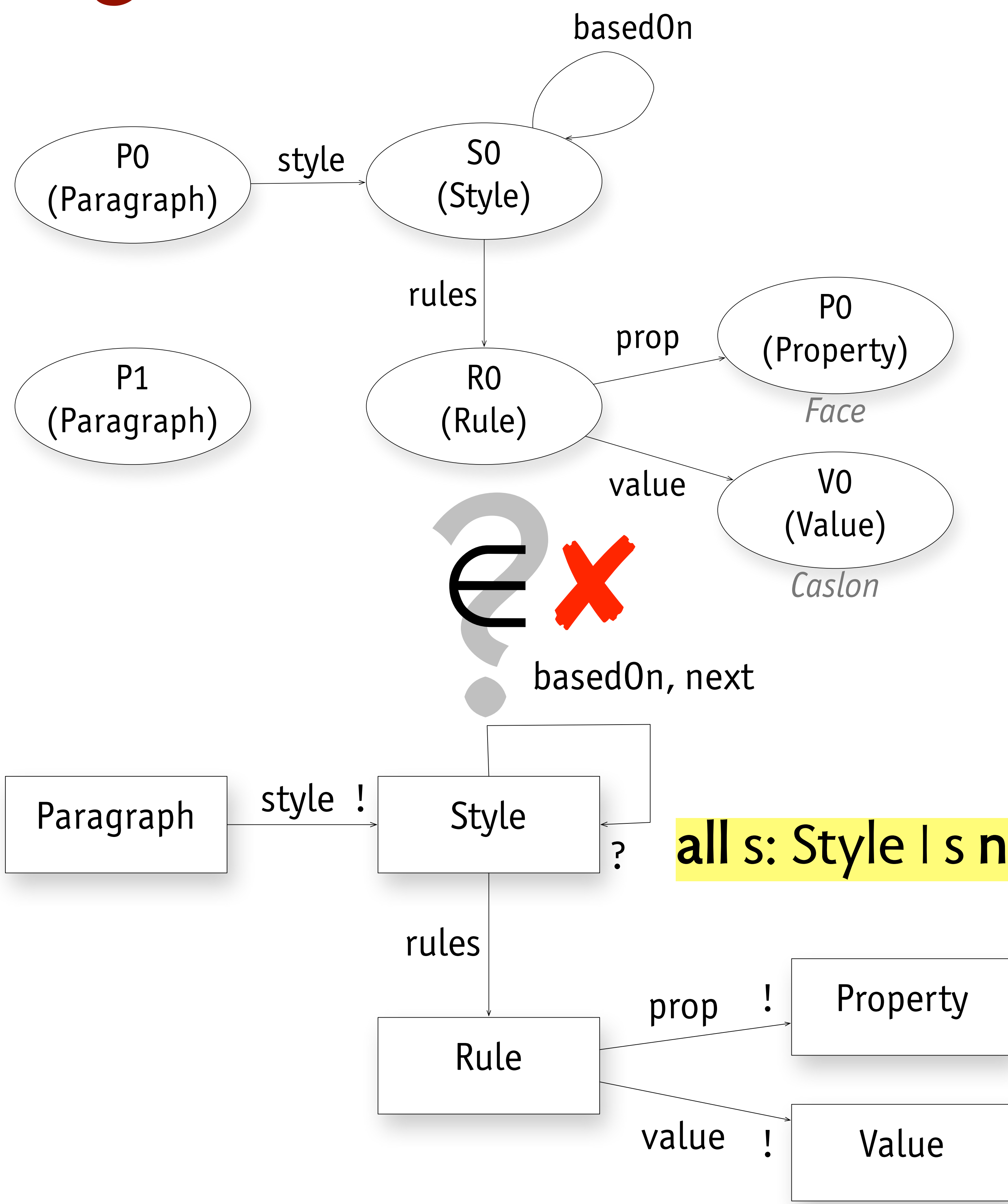
semantics word styles



semantics word styles

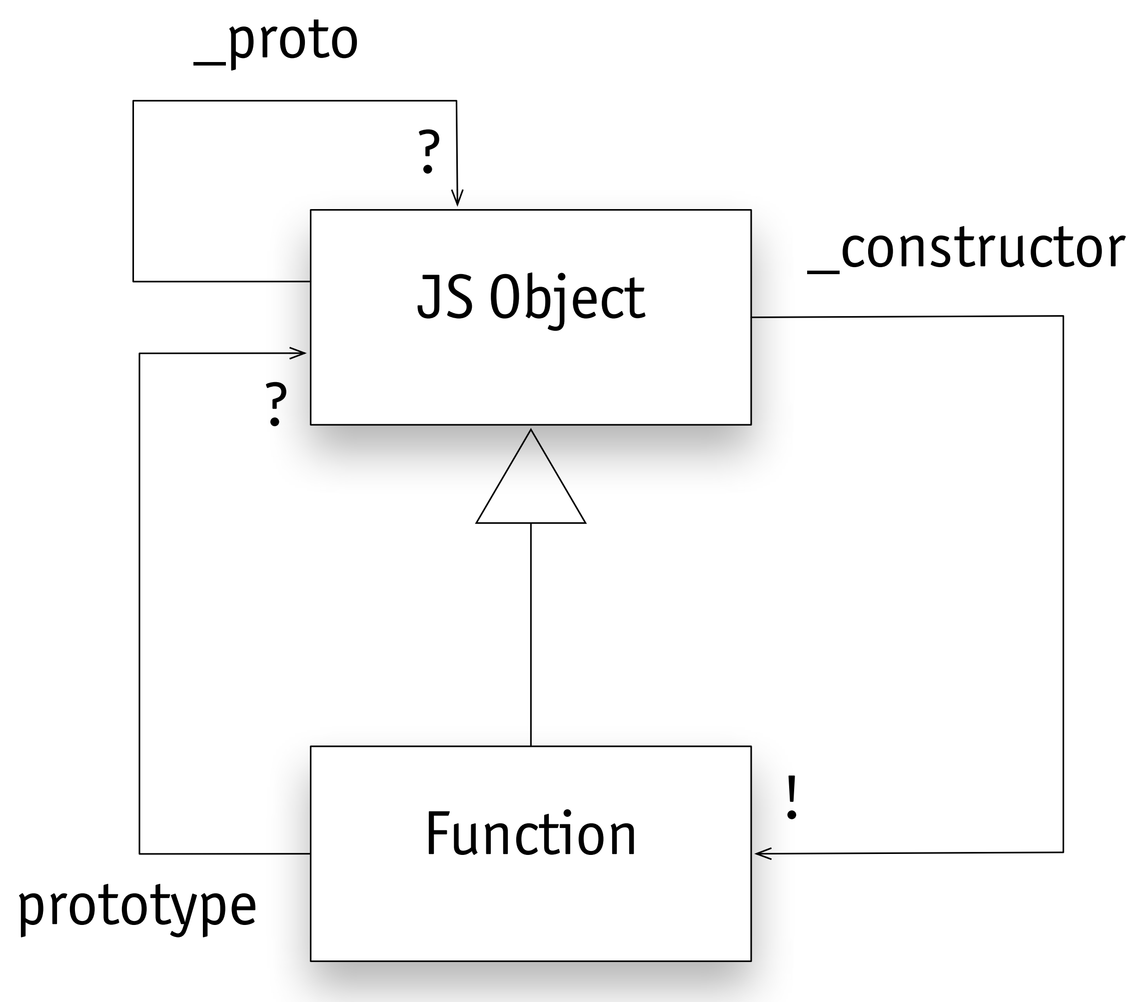


adding constraints word styles



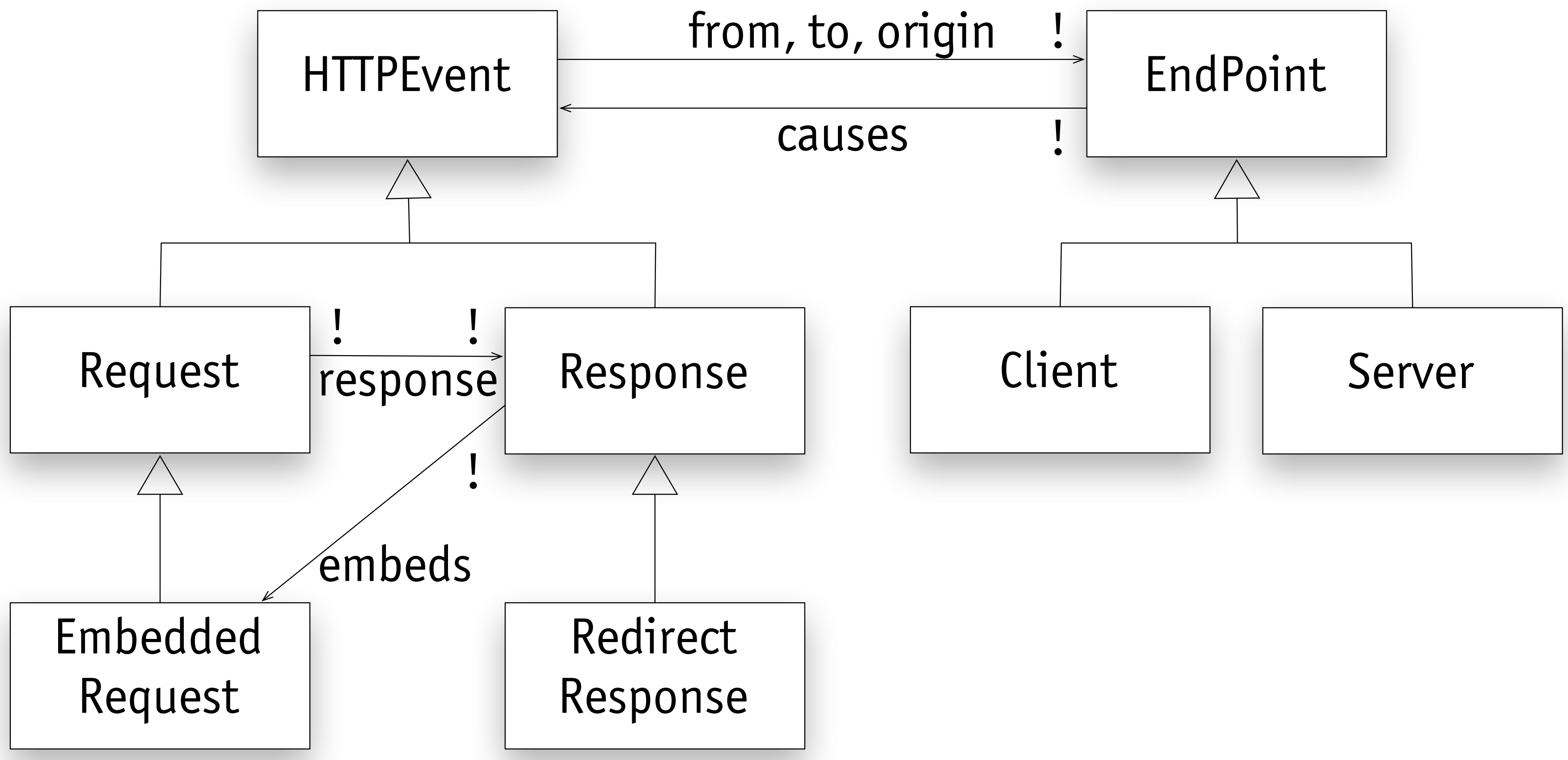
all s: Style | s **not in** s.basedOn not just application state

model javascript



all o: JSObject | o._proto = o._constructor.prototype

model same origin policy



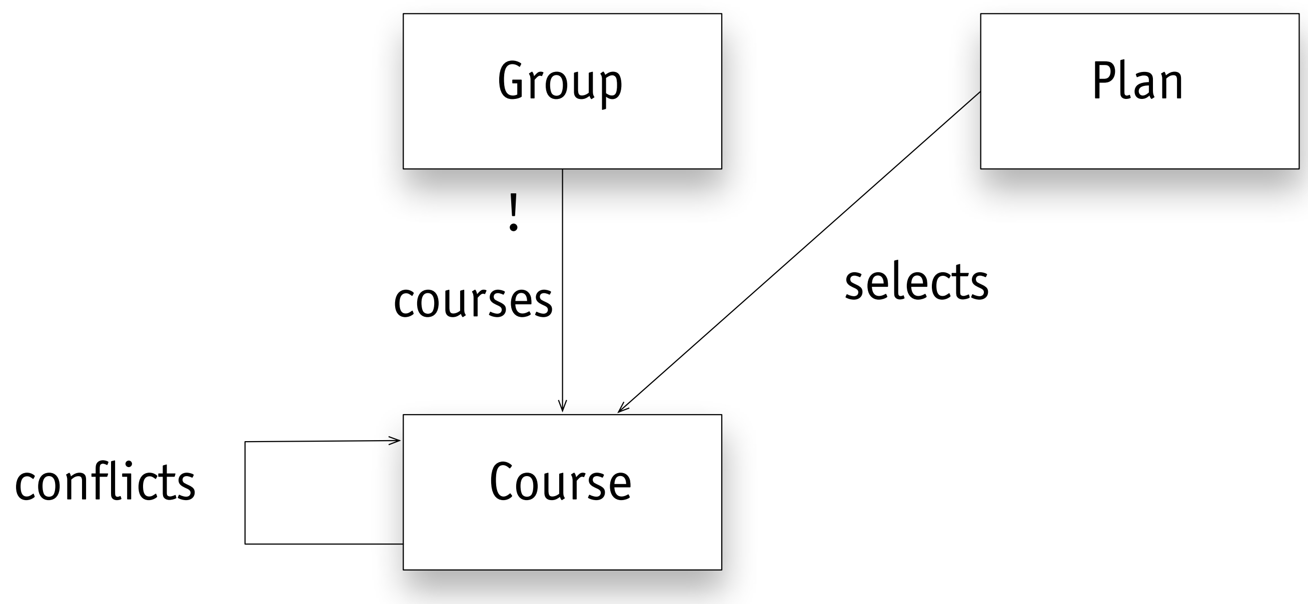
after *Barth et al*

// requests that are not embedded come from the client
all r: Request - Embedded | r.origin = r.from

// embedded requests have the same origin as the response
all r: Response, e: r.embeds | e.origin = r.origin

// request is only accepted if origin is server itself or sender
all s: Server, r: Request | r.to = s **implies** r.origin = r.to **or** r.origin = r.from

model degree rules



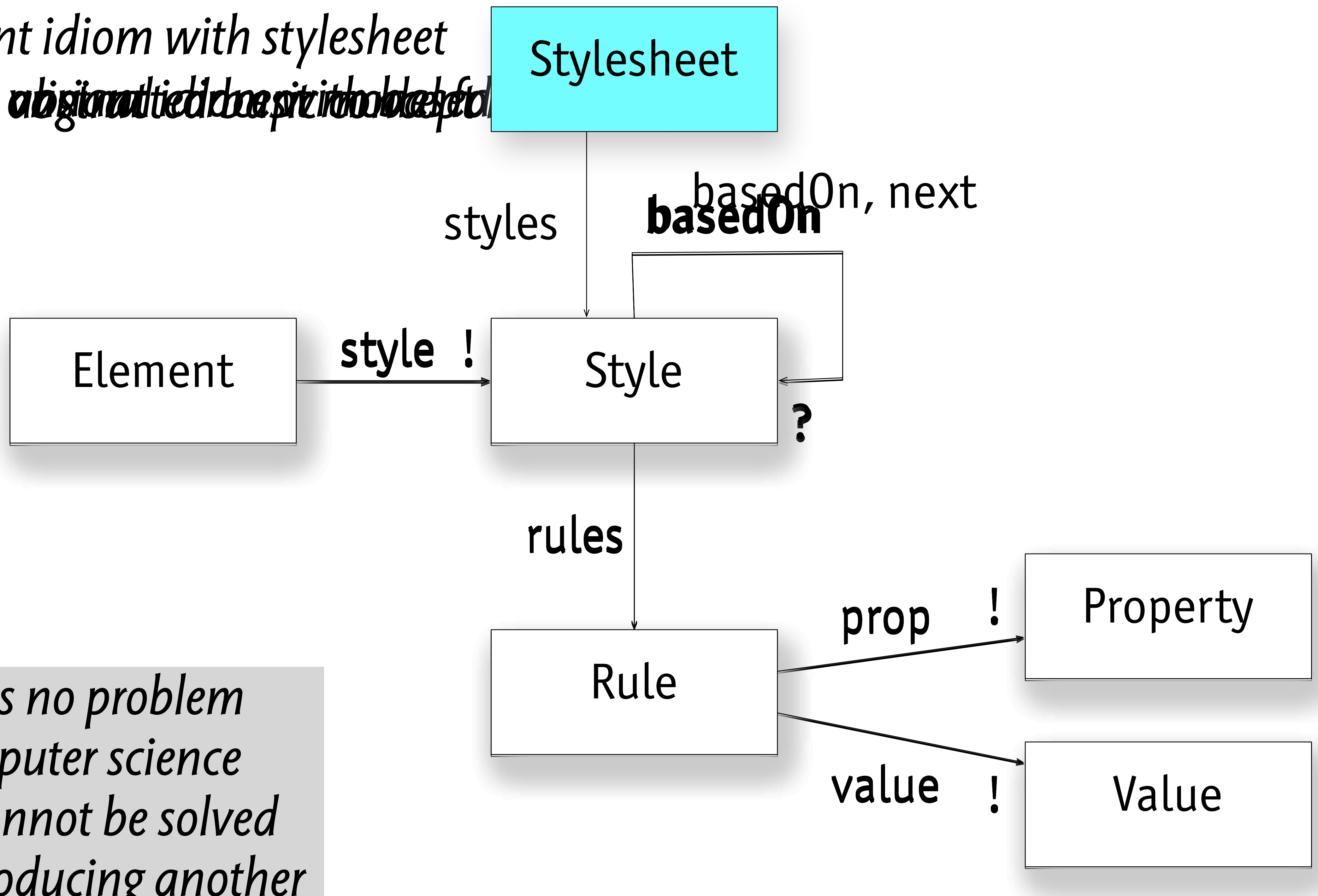
// plan must include one course from each group
all p: Plan, g: Group | **some** c: p.selects | c **in** g.courses

// plan cannot include conflicting courses
all p: Plan | **no** c1, c2: p.selects | c1 **in** c2.conflicts

concept idioms

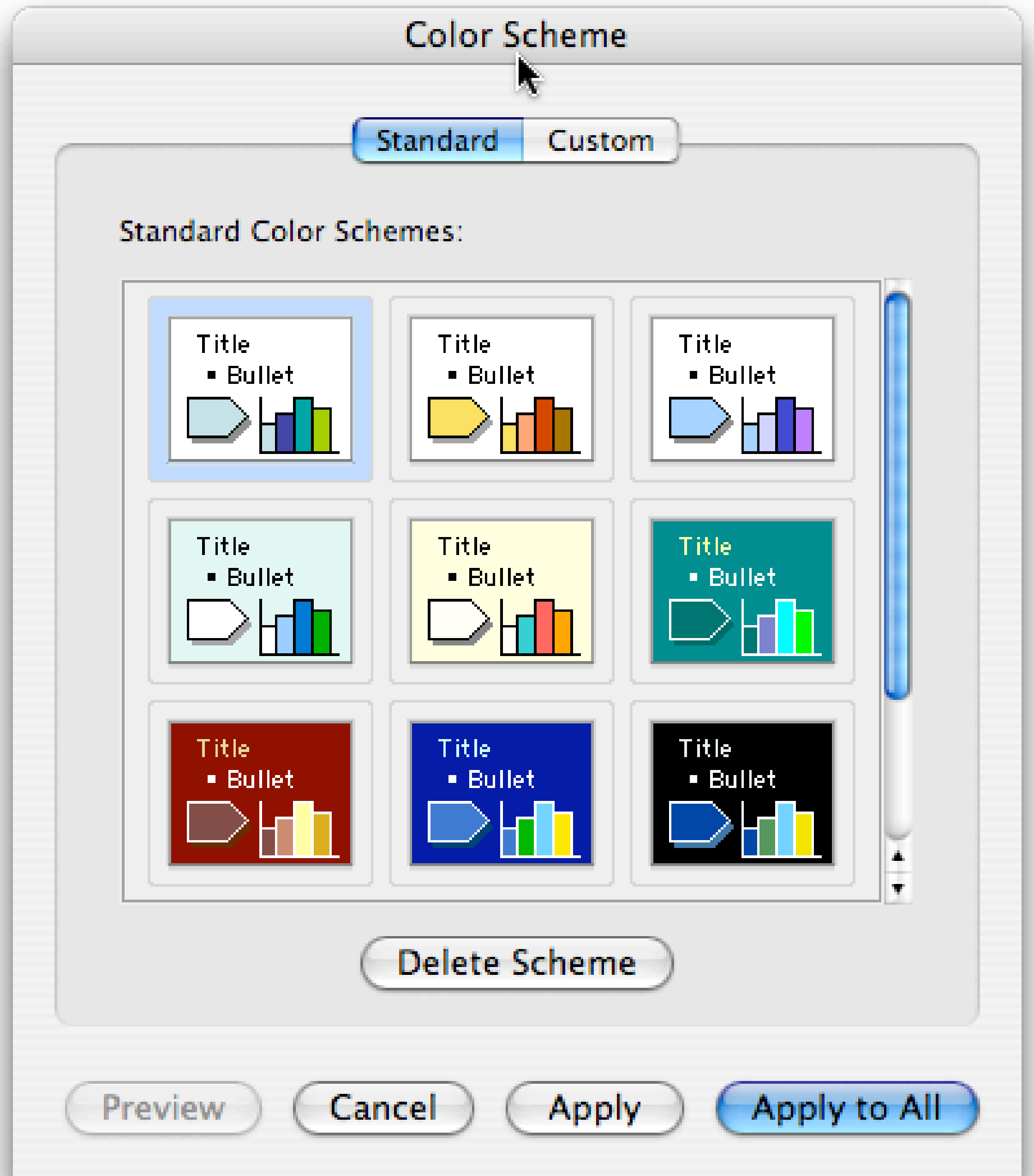
style idiom

variant idiom with stylesheet

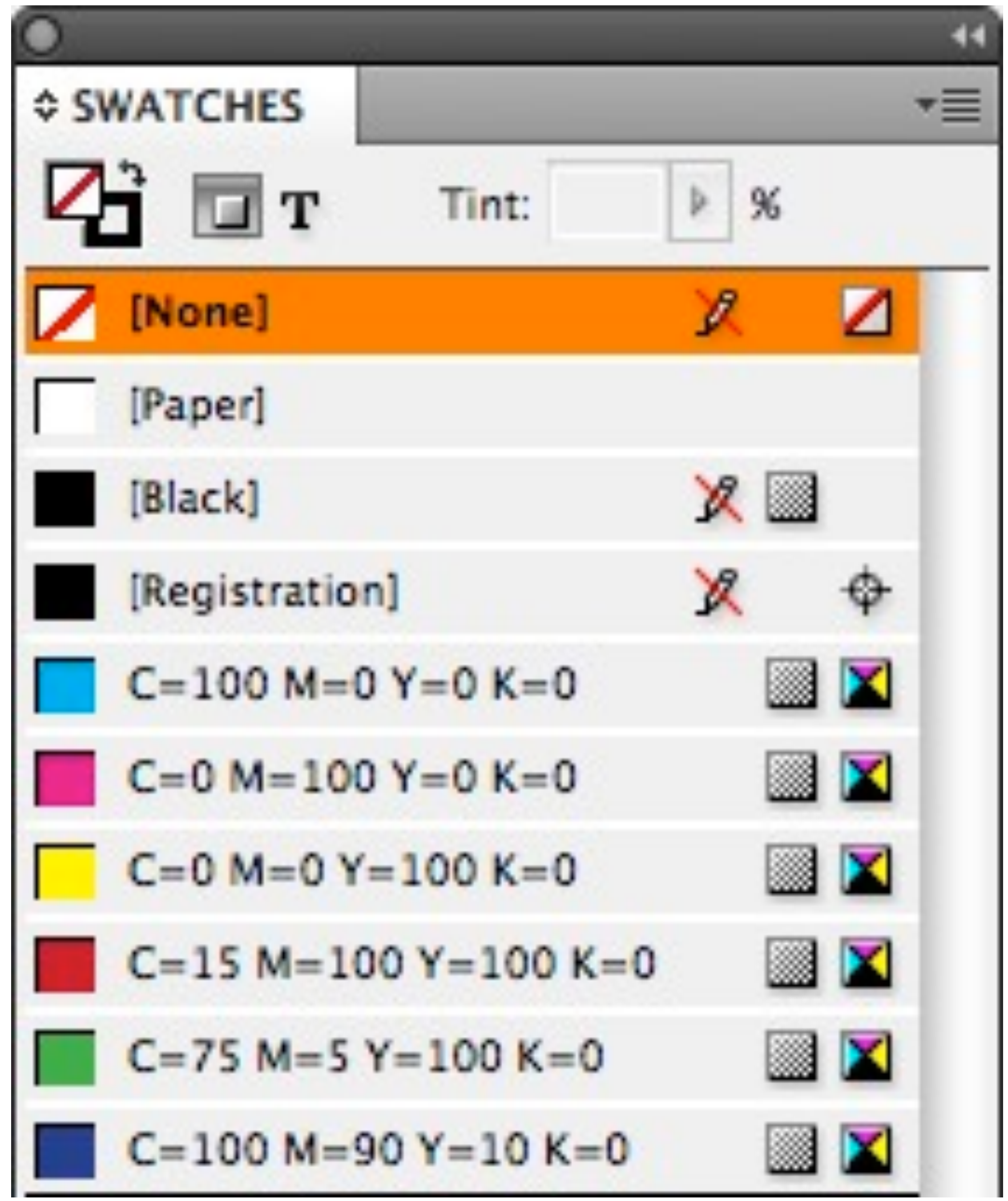


*There is no problem
in computer science
that cannot be solved
by introducing another
level of indirection.
--David Wheeler*

style other instantiations

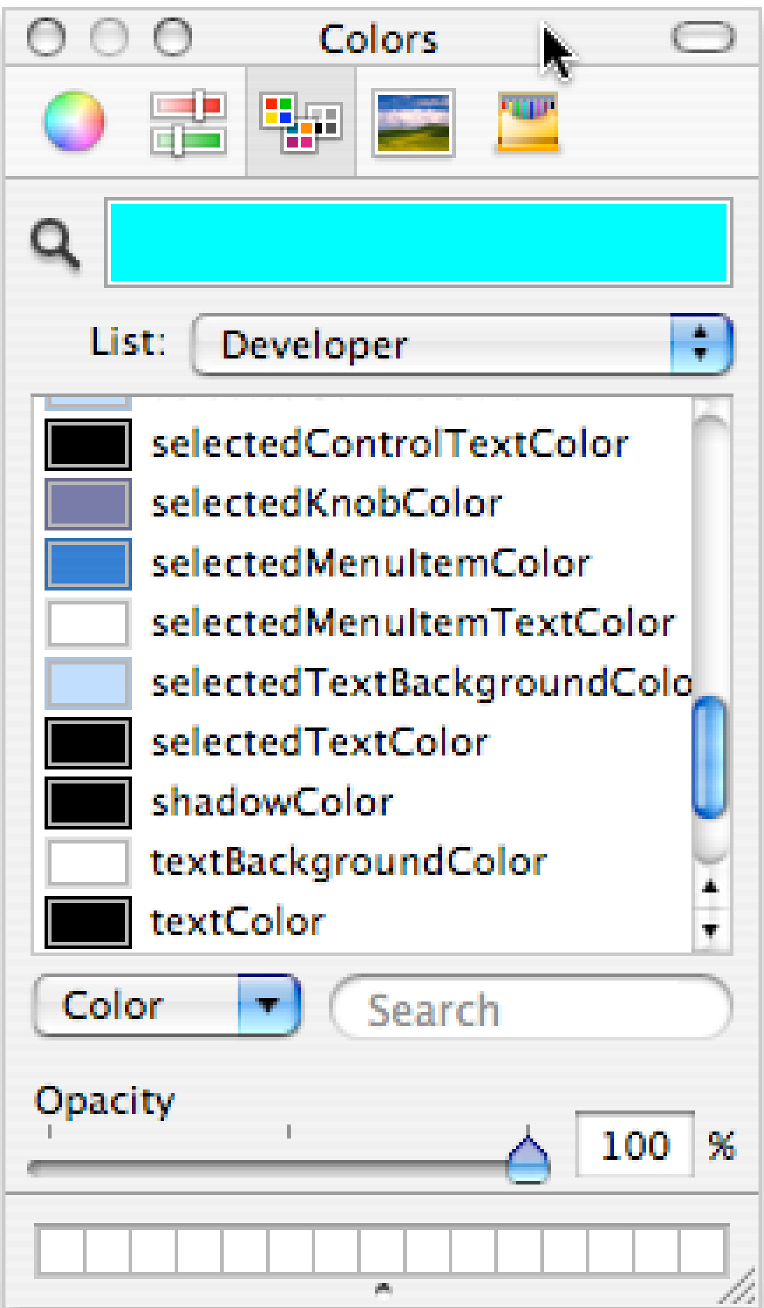


Powerpoint schemes

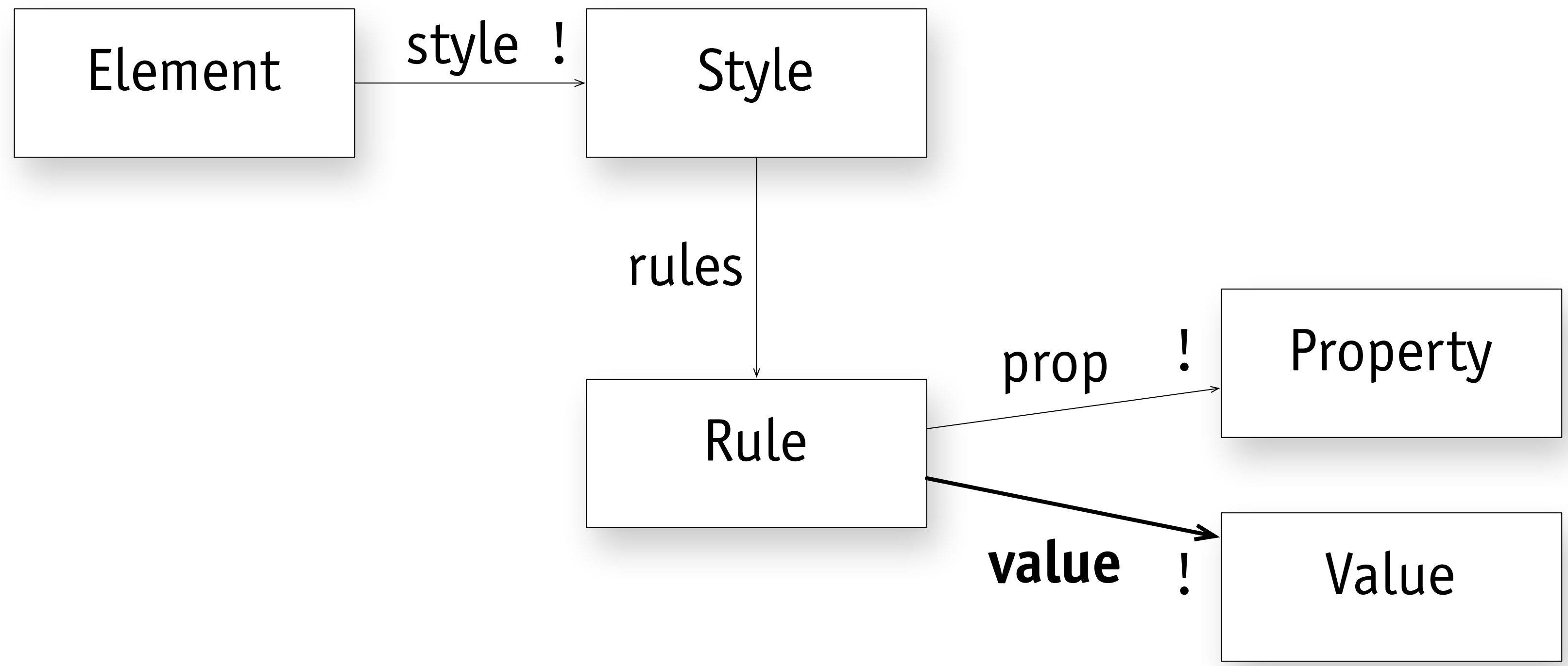


Indesign swatches

style non instantiations



Apple color picker

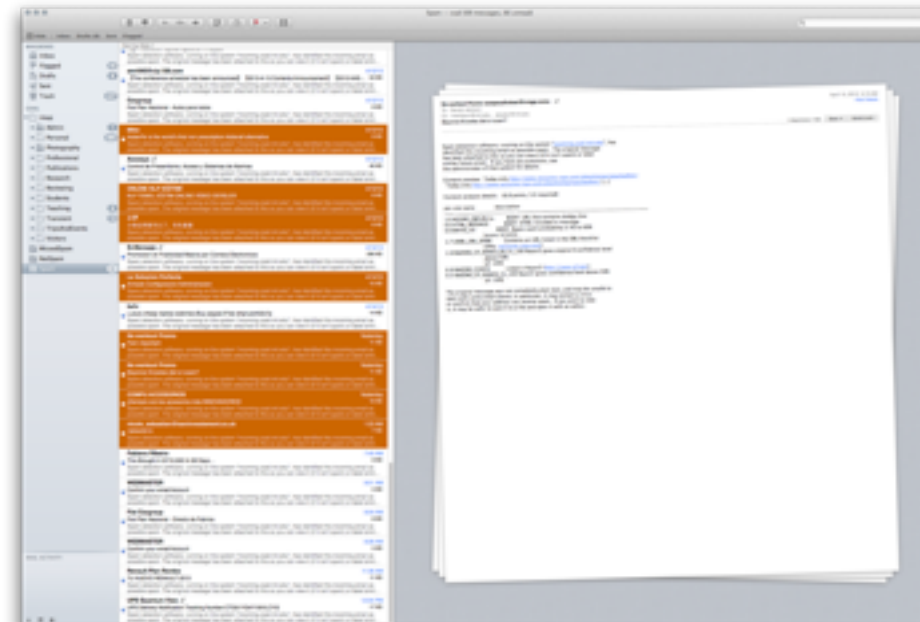


value relation must be **mutable**

idiom selection

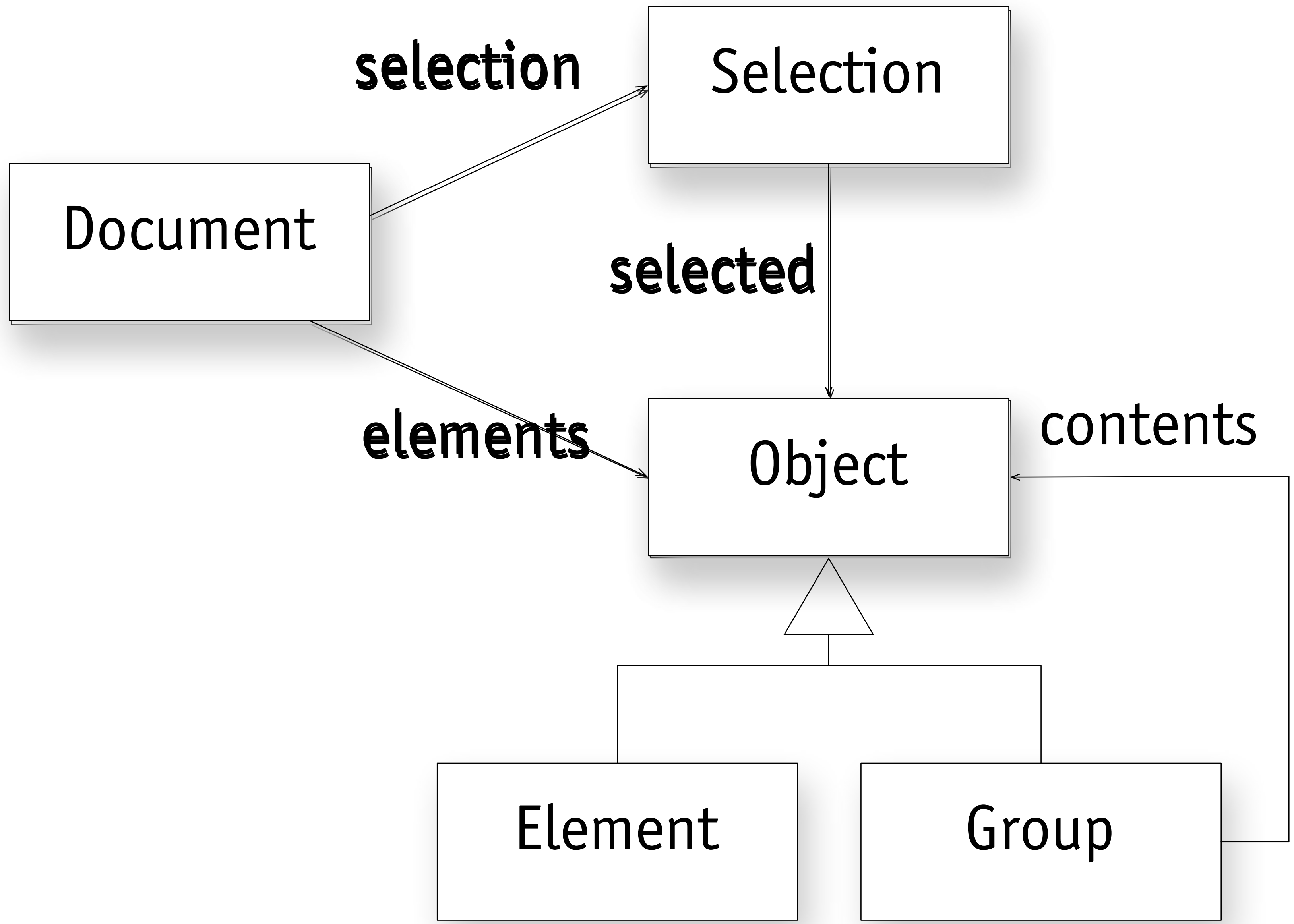
slides in Keynote

photos in Adobe Lightroom



messages in Apple Mail

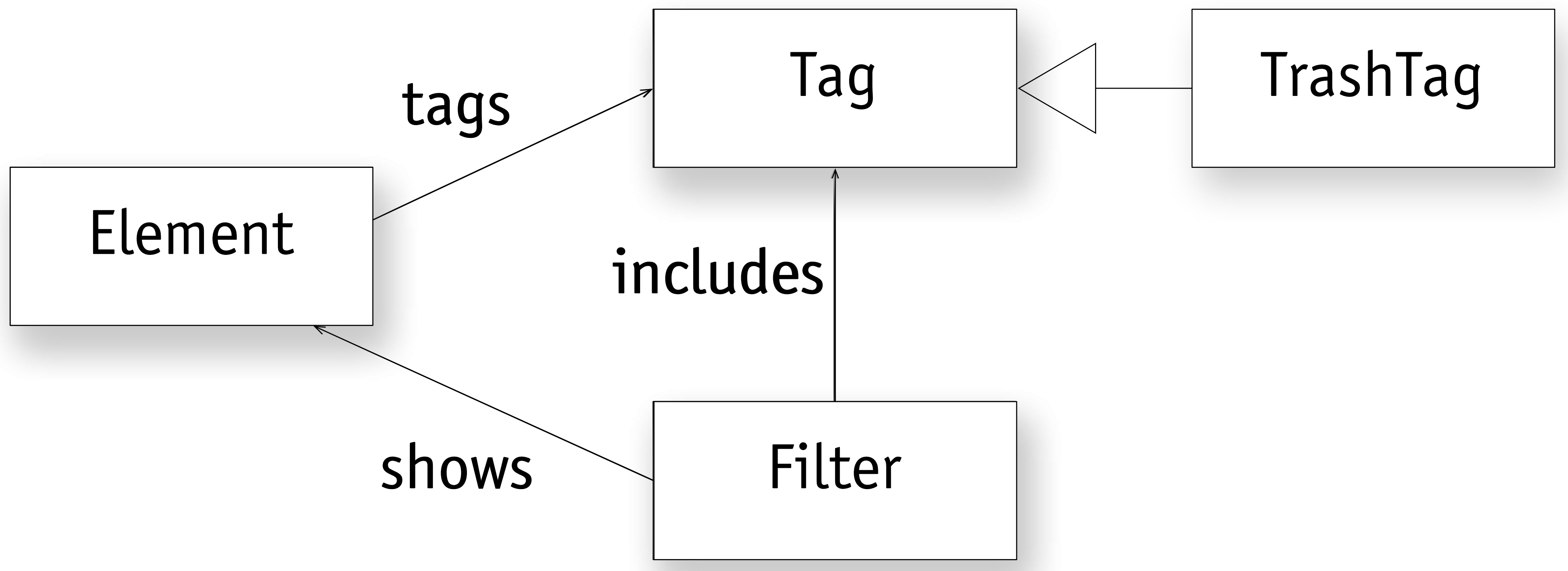
idiom selection



some variants

one or more selections per document?
selected elements and active element?
selection is 0/1 or 0..1?
can select groups too

idiom tagging



some variants

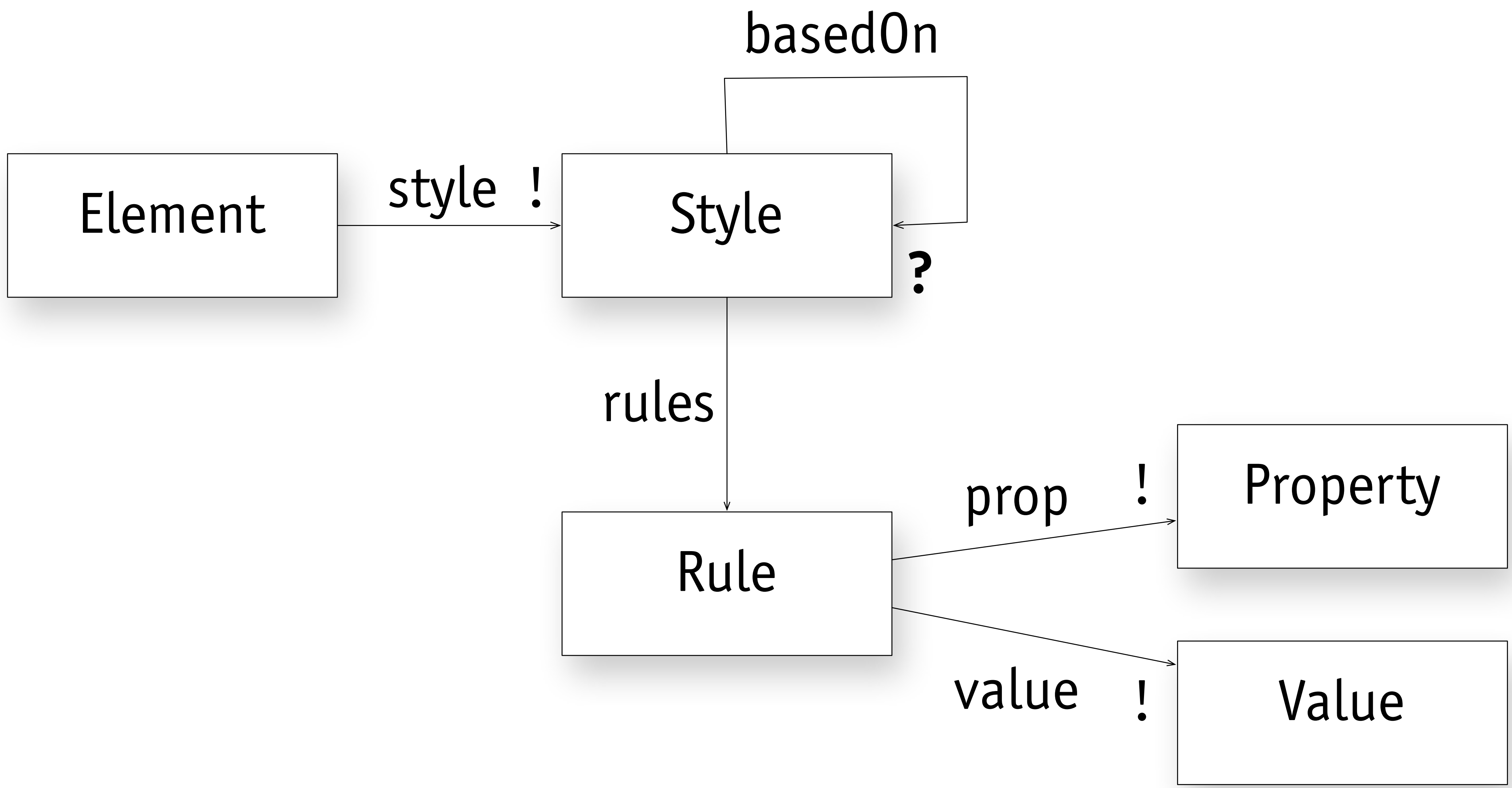
filter has disjuncts/conjuncts
tags are key/value pairs
some tags are system tags
some tags inhibit display

examples

labels in Gmail
keywords in Lightroom
file properties in OS X

idiom invariants

invariant style



every style has a rule for every property

all s: Style, p: Property | **some** r: s.rules | r.prop = p

invariant variants style

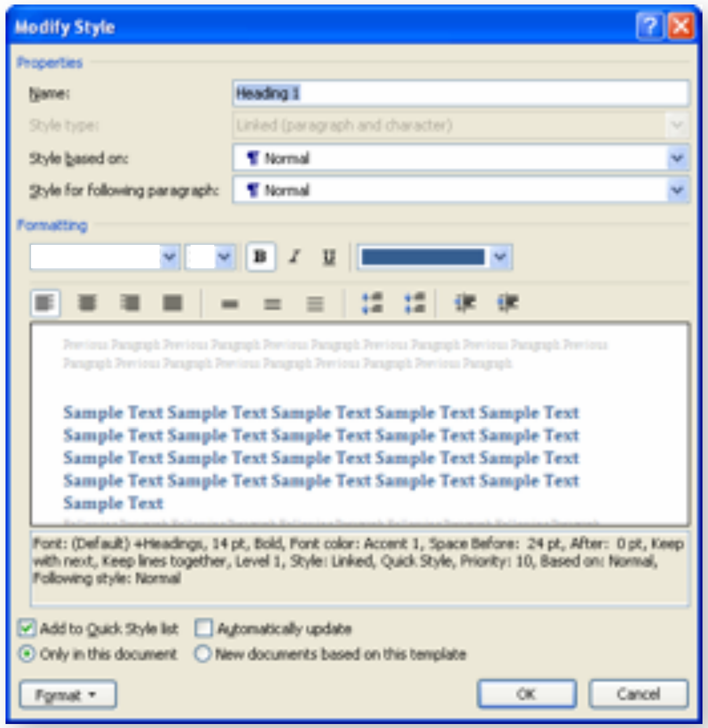
why it matters

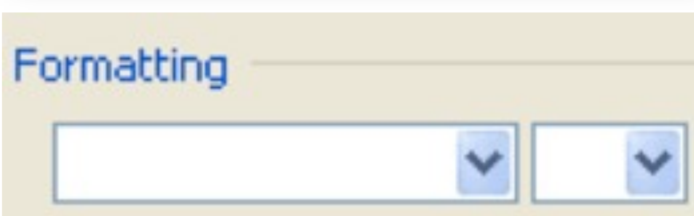
- if a style must include all properties then:
- a style can’t inherit a rule from its parent

but unfortunately

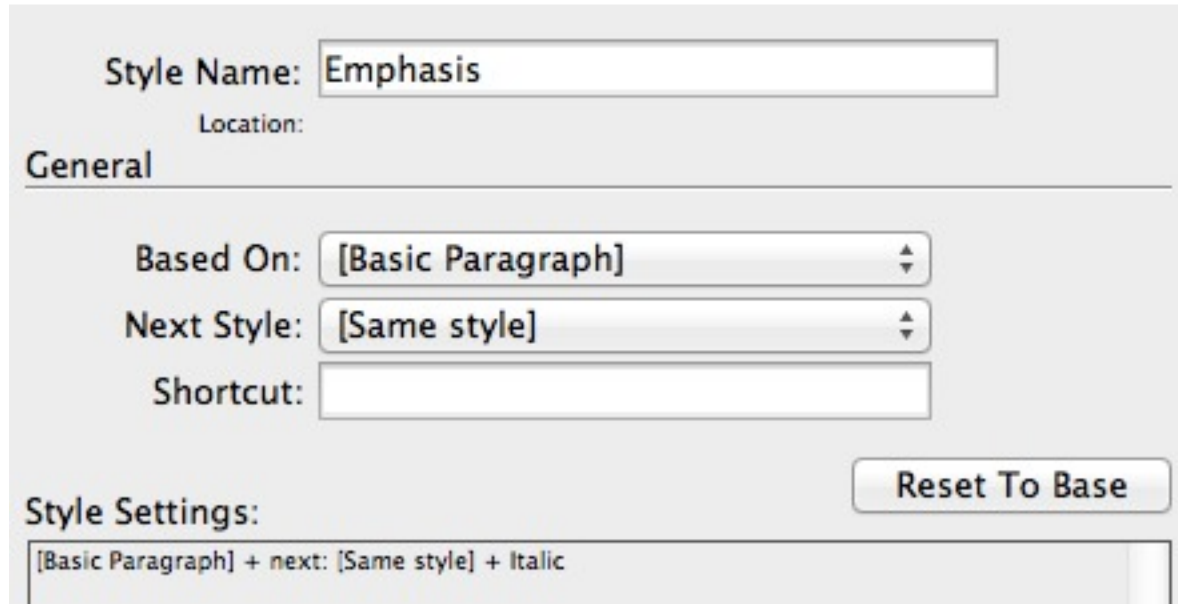
- many designs don’t consider implications fully…

can you inherit a property?





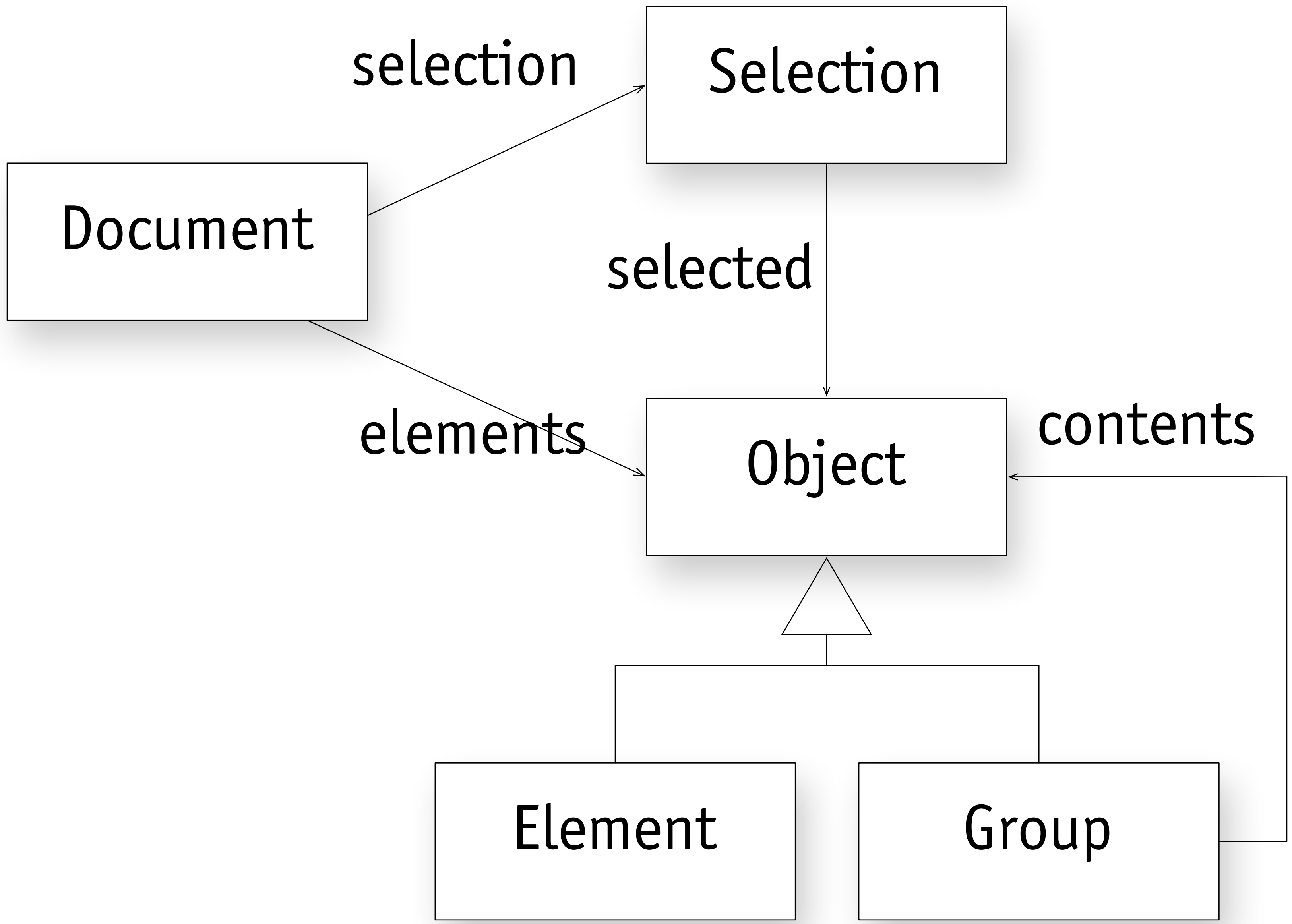
Word: property
absent until entered;
then remove only
in Visual Basic!



Indesign: property
absent until entered;
then remove only
with Reset (since 2007)

Pages: aaah!
properties
are optional

invariant selection



selecting a group selects its elements too

all s: Selection, o: s.selected & Group | o.contents **in** s.selected

invariant variants selection

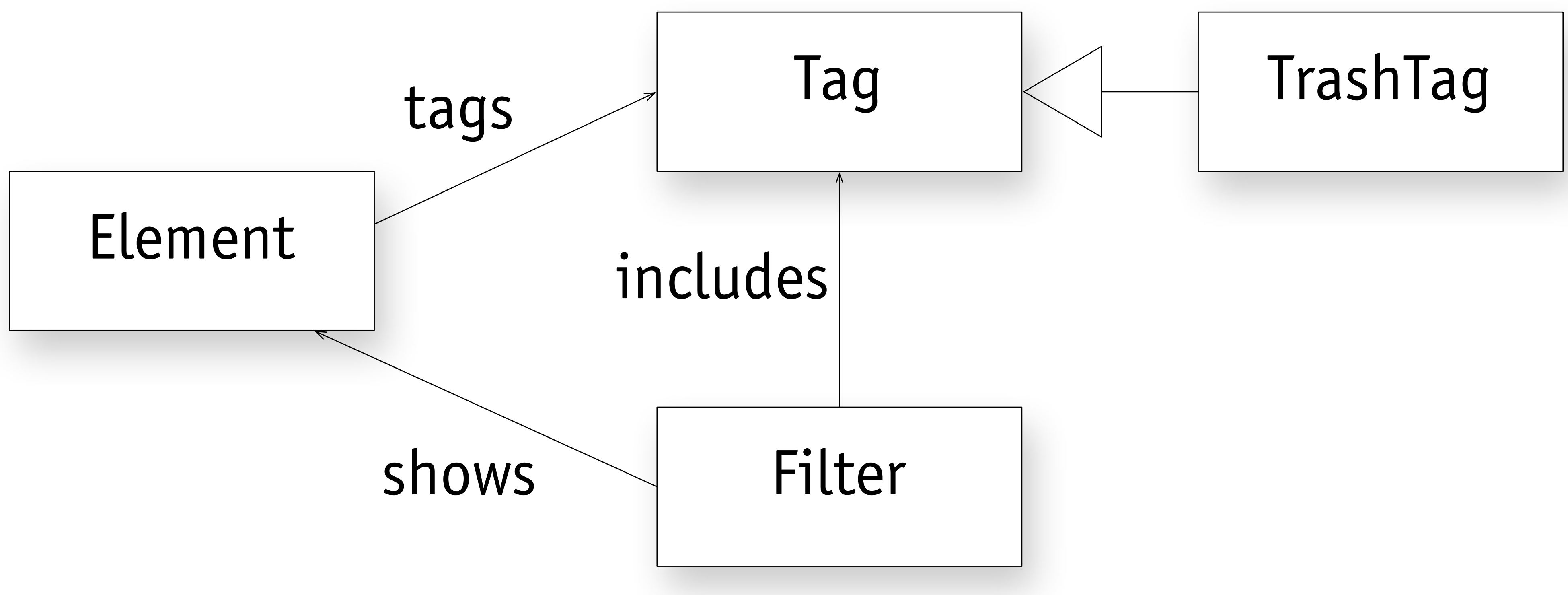
why it matters

- if groups and their members can be selected separately, the design is more flexible for the user

variants

- drawing apps: until recently, grouping prevented separate selection now many apps allow elements of groups to be selected alone
- Apple Mail: selecting an element of a group and an element outside the group causes all elements of the group to be selected
- git: eliminates notion of group by not syncing directories
- CrashPlan: selection of directory has different meaning; sets default for files that will be added later

invariant tagging



a filter shows elements with its included tags

all f: Filter | f.shows = f.includes.~tags

invariant variants tagging

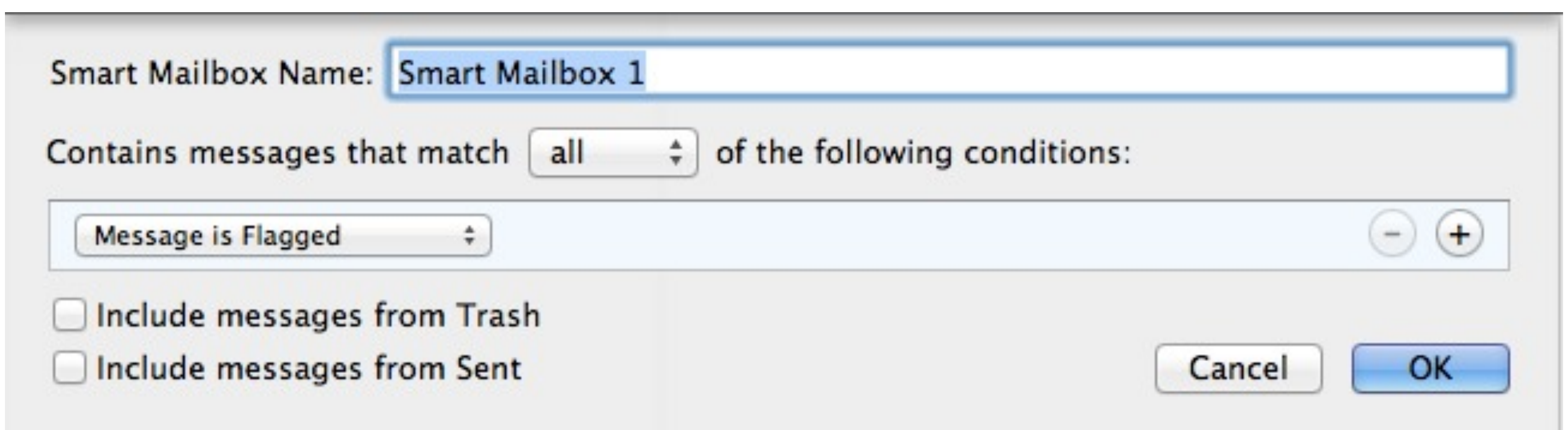
why it matters

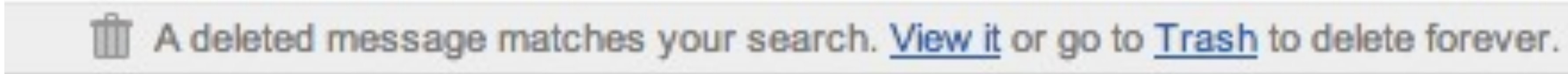
› users get very confused if things they expect to be there are not

variants

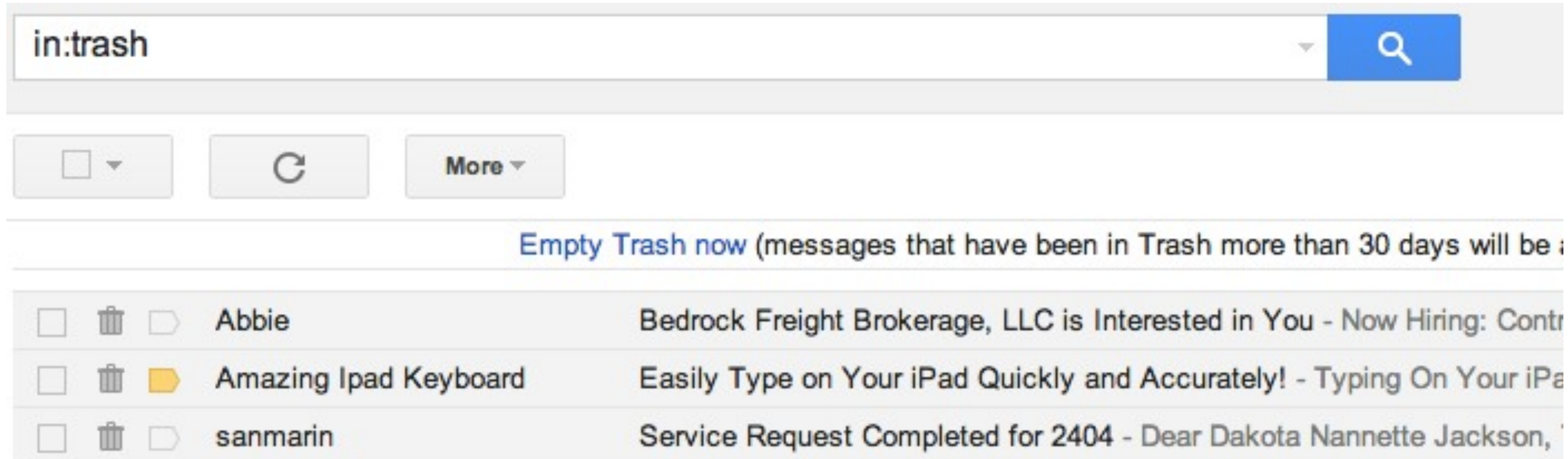
› Lightroom: deleted images are never shown

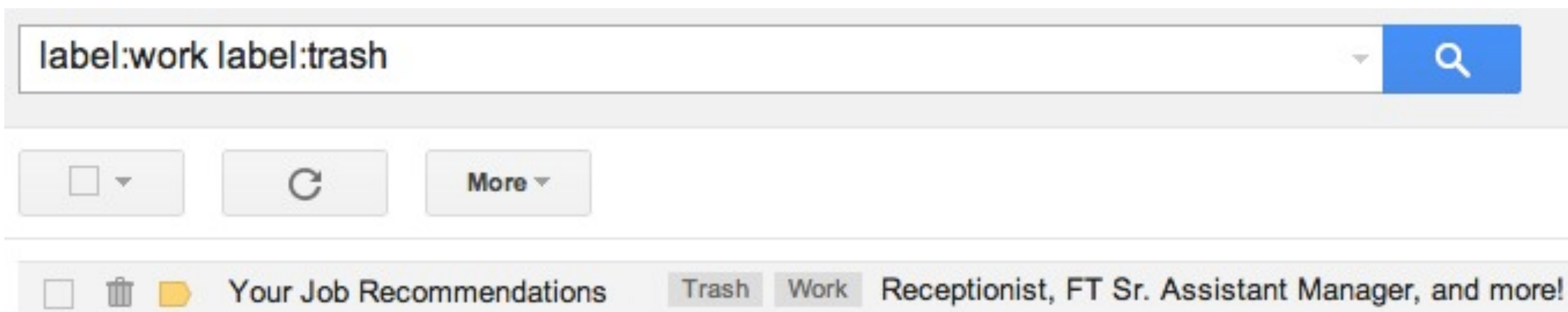
› Apple Finder: “include trash” separated out
(but will create a smart folder that shows files marked as invisible!)



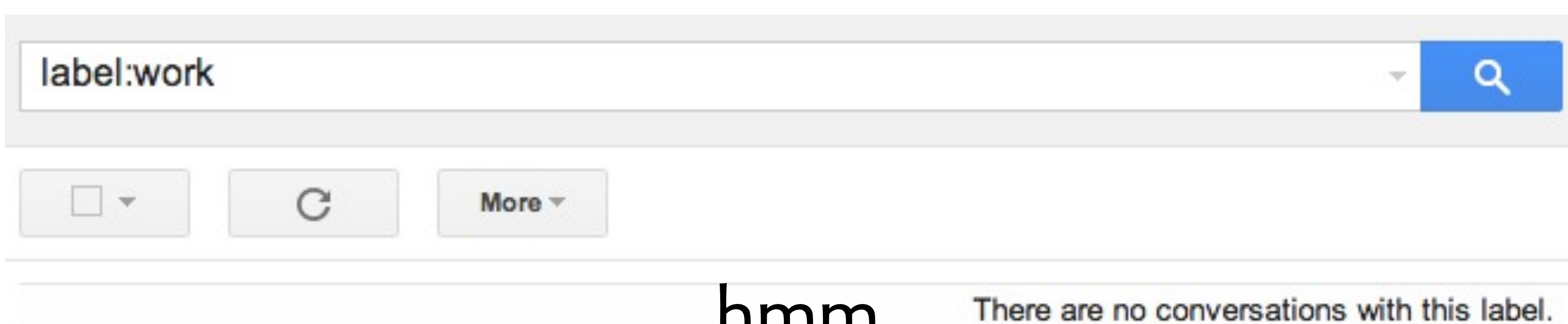


generally won't show trashed messages





if you ask for them explicitly, you'll see *some*



hmm...

analyzing concepts

refactoring concept models

suppose we have a bad concept model

- can we refactor into a better one?
- and show that the two are somehow equivalent?

an example from the “Area 2 web app”

- application that tracks degree requirements for MIT CS students
-

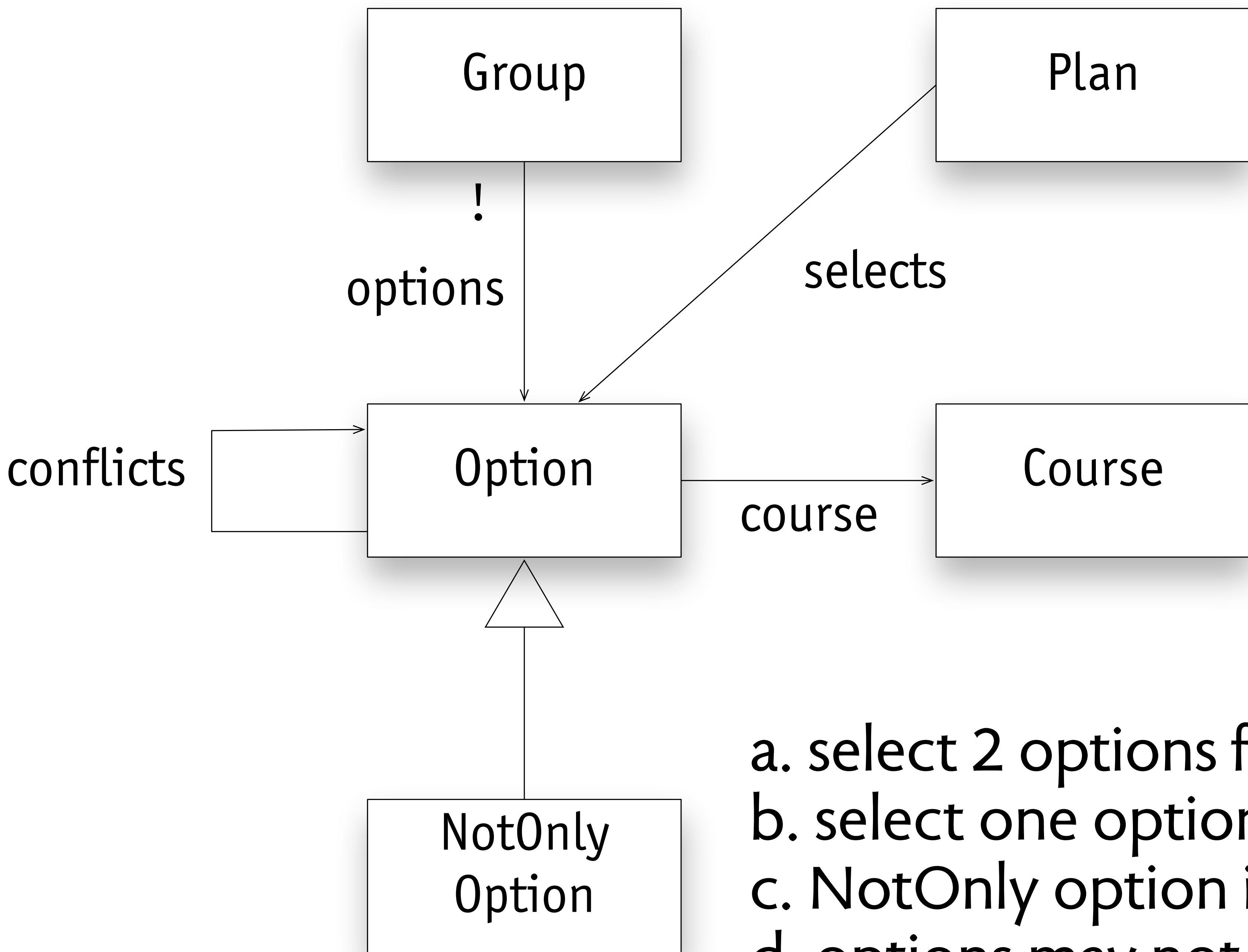
Circle four subject numbers in the table below. Of the 4 subjects, two subjects should be selected from a single group. The remaining two subjects must be selected from two other groups. If you have already received a grade in the subject, please enter the grade in the box. Please enter the term that you completed the subject or plan to take the subject as well (e.g. FT12 is the term starting September 2012 and ST13 is the term starting February 2013). Prior to Drop Date of the Spring term 2013, changes in your choices may be made by submitting a new version of this form; after that date, a petition to the Committee on Graduate Students is required.

Group 1: Systems in CS 6.820, 6.824, 6.829, 6.830, 6.375, 6.823, 6.858, 6.831 (see note below) option	**Group 2: Theoretical CS** 6.840, 6.845, 6.850, 6.852, 6.854, 6.856, 6.875 (Any 1 or 2 subject allowed)	**Group 3: Artificial Intelligence** conflict [6.345 xor 6.863 xor 6.864], [6.866 xor 6.869], [6.437 xor 6.438 xor 6.867], 6.832, option [6.831* xor 6.839*], [6.874 xor 6.878] (*see note below)
Group 4: System Science and Control Engineering 6.241, [6.251 xor 6.255], [6.341 xor 6.344 xor 6.555]	**Group 5: Circuits and Electronic Systems** 6.334, 6.336, 6.374, 6.376, 6.775 (Any 1 or 2 subject allowed)	**Group 6: Information Science and Communication** 6.262, 6.436, [6.437 xor 6.438], 6.450, 6.453
Group 7: Bioelectrical Engineering 6.521, 6.522, 6.551	**Group 8: Electromagnetics** [6.630 xor 6.632], 6.631, 6.634	**Group 9: Physical Science and Engineering** 6.720, 6.728, 6.730, 6.774, 6.777

Note: Students in Area II Computer Science select subjects from Group 1, 2, 3 only (shaded boxes)

- 6.840 or 6. 854 are recommended for students who plan to take only one subject in Group 2.
- 6.839 can be used as the second AI subject, but not the only subject.
- 6.831 can be the second subject in Group 1 or 3, but not the only subject in either group.

implied conceptual model



a. select 2 options from one group
b. select one option from other groups
c. NotOnly option is not only option in group
d. options may not conflict

new design

Edit TQE Plan

Systems in CS

6.375 - Complex Digital Systems Design

Theoretical CS

6.840 - Theory of Computation

Artificial Intelligence

6.345 - Automatic Speech Recognition

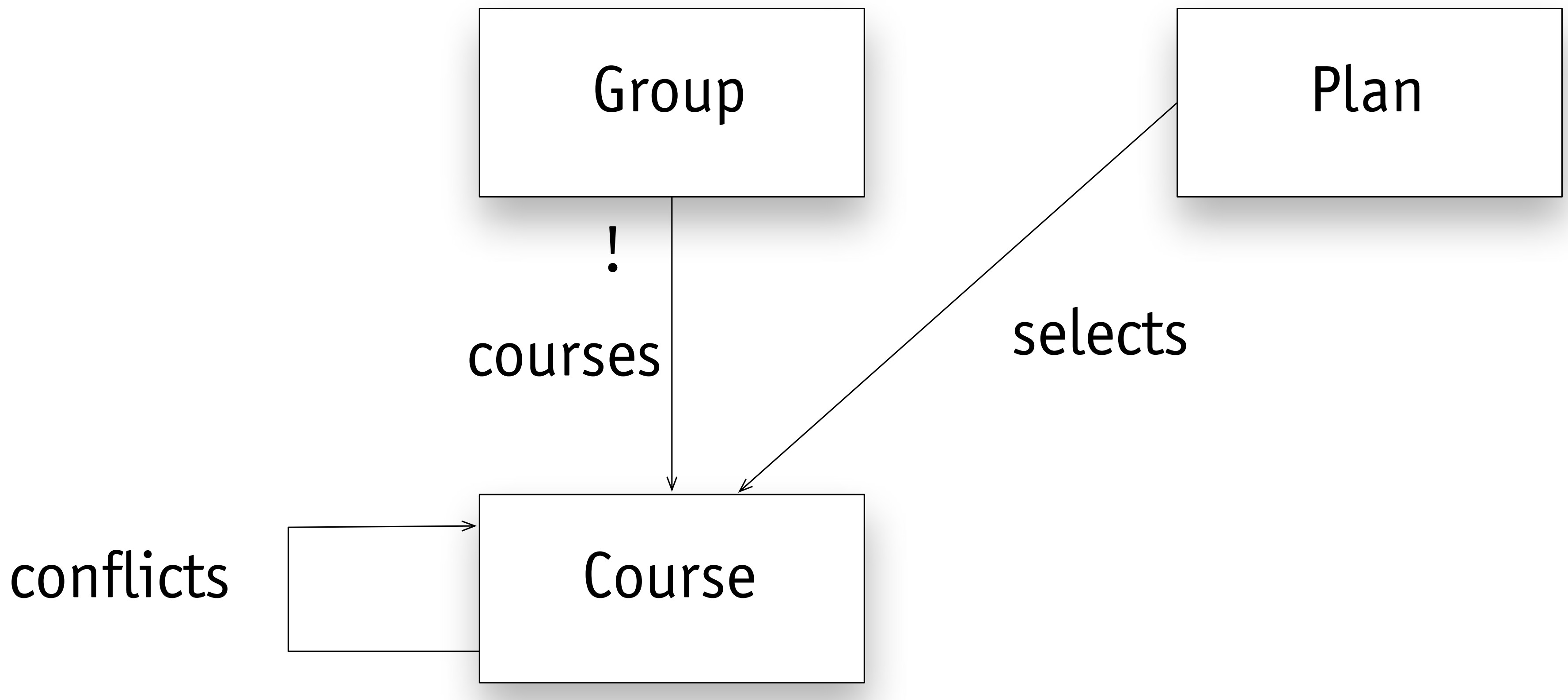
Miscellaneous

6.823 - Computer Systems Architecture

Select one subject from each of the four groups. Note that the following subjects conflict; you may take at most one from each set:

- 6.345, 6.863, and 6.864
- 6.437, 6.438, and 6.867
- 6.831 and 6.839
- 6.840 and 6.841
- 6.866 and 6.869
- 6.874 and 6.878

simplified conceptual model



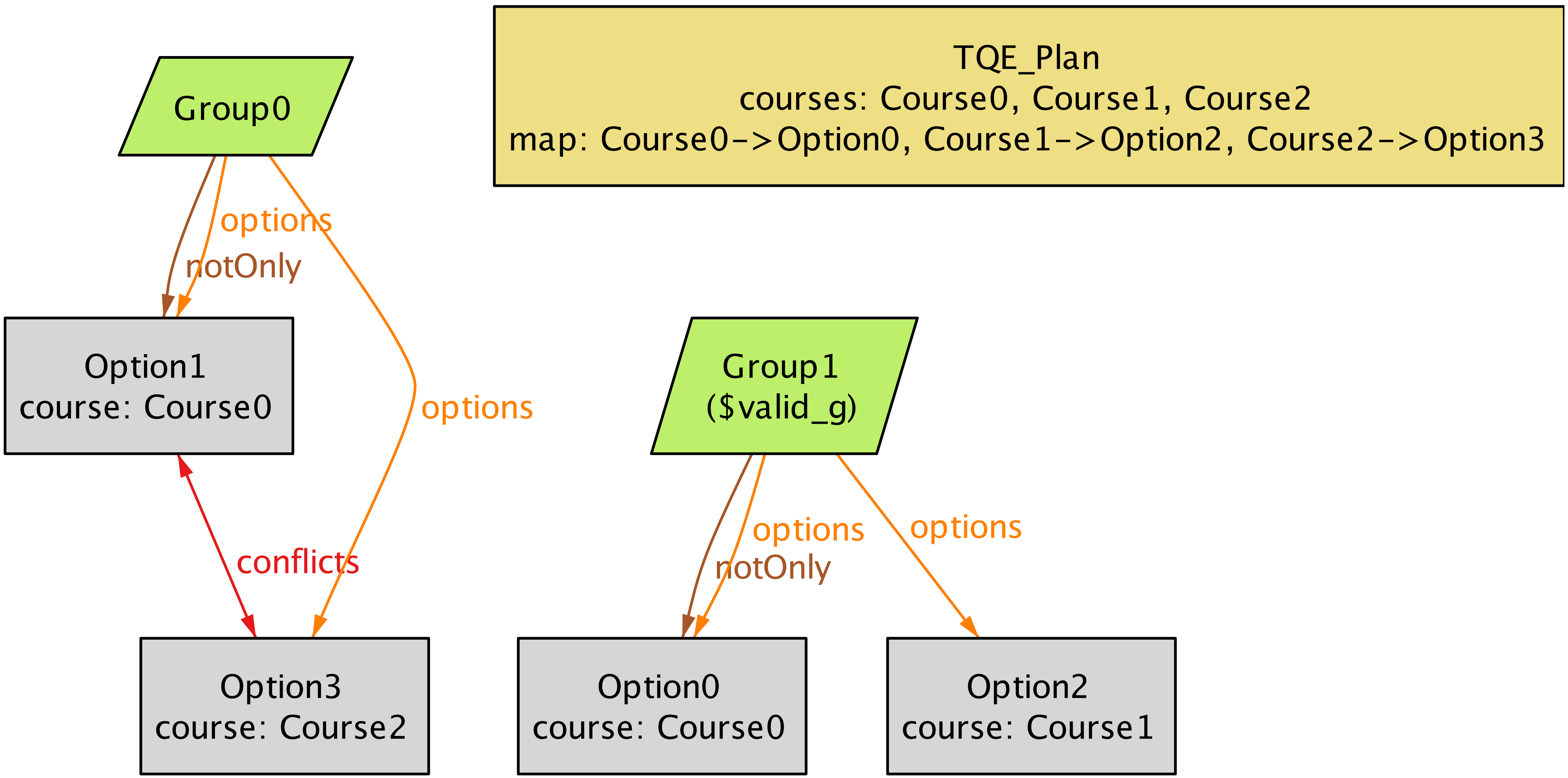
a. select one more course than groups
b. select at least one course per group
c. courses may not conflict

alloy model

forward: check {
  all p: TQE_Plan | valid[p] **implies** simpler_valid[p]
  } **for** 4 **but** 1 TQE_Plan

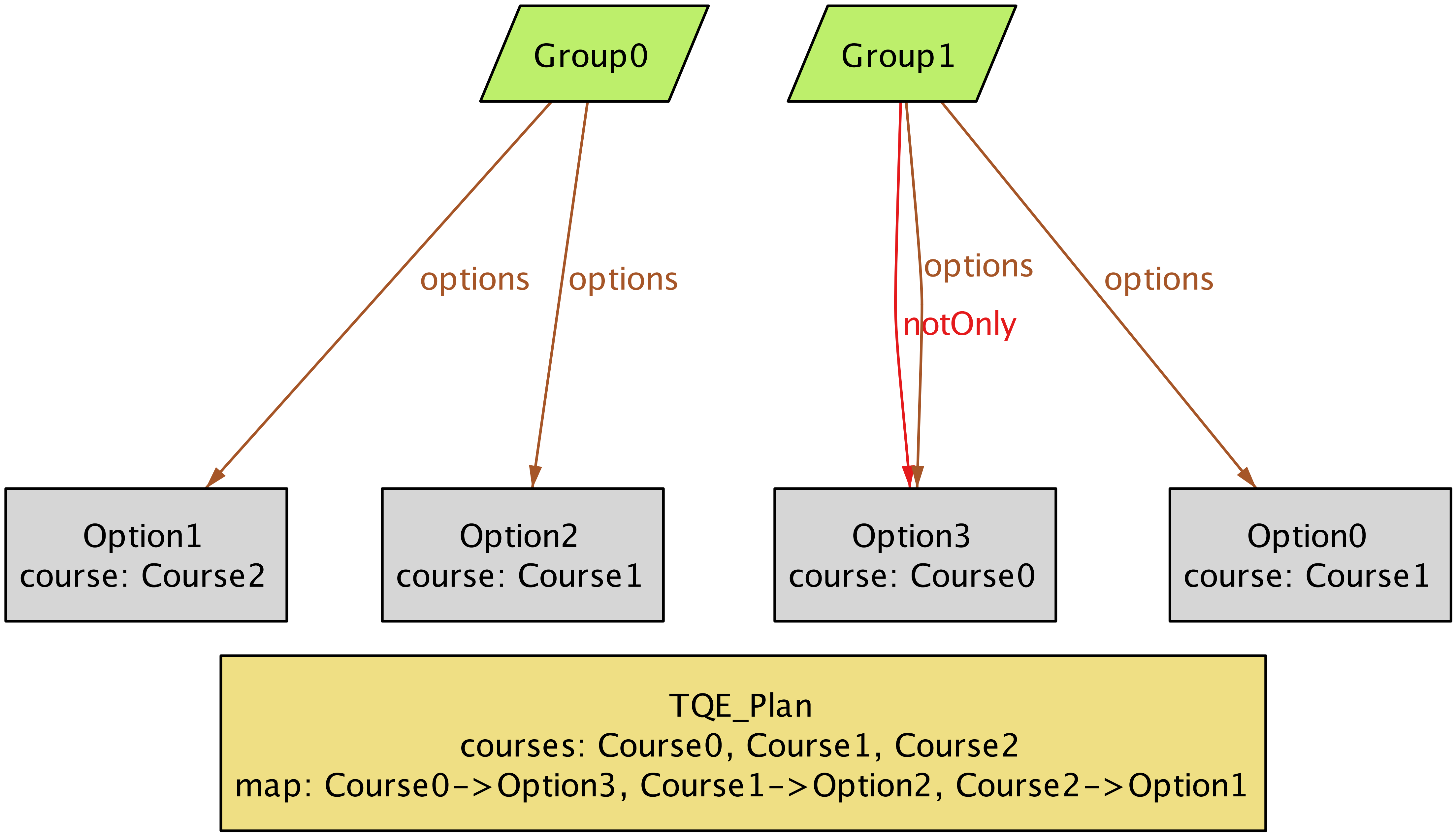
backward: check {
  all p: TQE_Plan | simpler_valid[p] **implies** valid[p]
  } **for** 4 **but** 1 TQE_Plan

counterexample: new too strong



plan rejected by new rules but accepted by old ones
because courses 0 and 2 only conflict for some options

counterexample: new too weak



plan rejected by old rules but accepted by new ones because option was chosen for course 1 that leaves a 'not only' course in group 1

when is simplification valid?

P1. When two options conflict, any other pair of options that corresponds to the same two courses also conflicts.

P2. If two options (in different groups) are for the same course, then those options are “not only” options

conclusions

simple invariants expose subtle problems
use idioms to explore standard solutions

formal methods might help
cost amortized when applied to idiom

conceptual modeling: old idea with new challenges
Analysis Patterns (Fowler, 1997)
Data Model Patterns (Hay, 2011)
Conceptual Models (Henderson & Johnson, 2011)