designing systems

Daniel Jackson · Autodesk Oslo Workshop · August 25-26, 2025

de/composition:
design is breaking up & putting together

decomposing into parts with purposes

teapot

keeping hot

lid

handle

holding

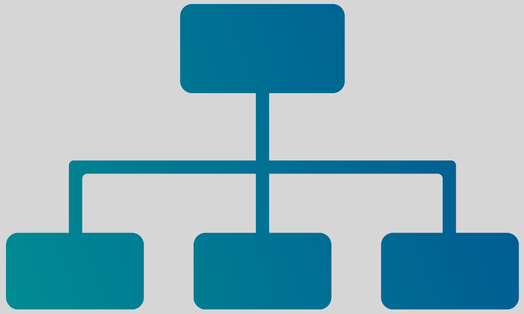
spout

pouring

body

brewing

how does decomposition help?



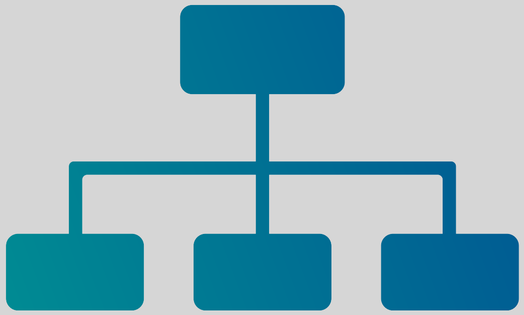
incremental work
division of labor
exploiting AI

reuse
build on experience
reuse across suite too

easier for users
identify familiar parts
learn what you need

design focus
separate concerns
drive by purposes

the two watchmakers



incremental work
division of labor
steady progress

Herb Simon, The Architecture of Complexity (1962)

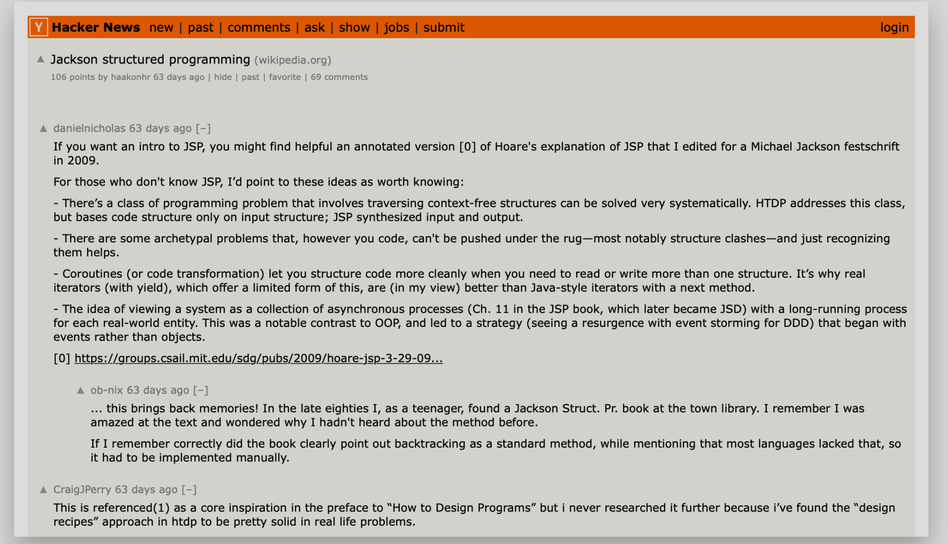
cartoon by ChatGPT

how unique is it?

reuse

build on experience

reuse across suite too



no other app is the same as HackerNews

HackerNews = Post + Comment + Upvote + Karma + ...

but its concepts are mostly identical to the concepts in other apps

Dijkstra: separation of concerns

design focus
separate concerns
drive by purposes

"Let me try to explain to you, what to my taste is characteristic for all intelligent thinking. It is, that one is willing to study in depth an aspect of one's subject matter in isolation for the sake of its own consistency, all the time knowing that one is occupying oneself only with one of the aspects.

It is what I sometimes have called "the separation of concerns", which, even if not perfectly possible, is yet the only available technique for effective ordering of one's thoughts, that I know of. This is what I mean by "focussing one's attention upon some aspect": it does not mean ignoring the other aspects, it is just doing justice to the fact that from this aspect's point of view, the other is irrelevant. It is being one- and multiple-track minded simultaneously.

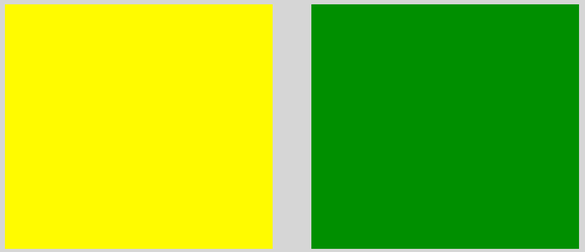
Edsger Dijkstra, On the role of scientific thought (EWD447, 1974)

modularity

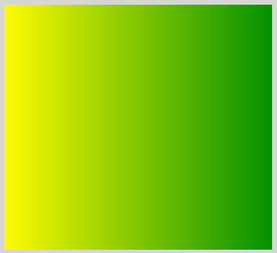
3 criteria

defining modularity

separation
a single module doesn't
conflate unrelated functions

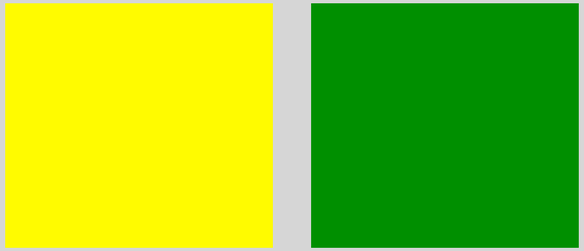


separated: not conflated

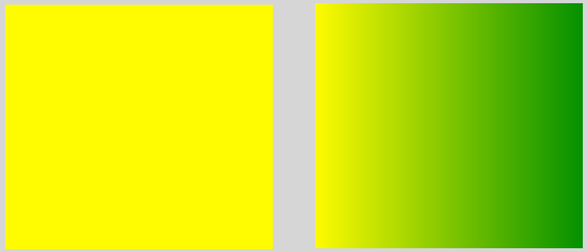


conflated

completeness
a single module contains
all of a function's behavior

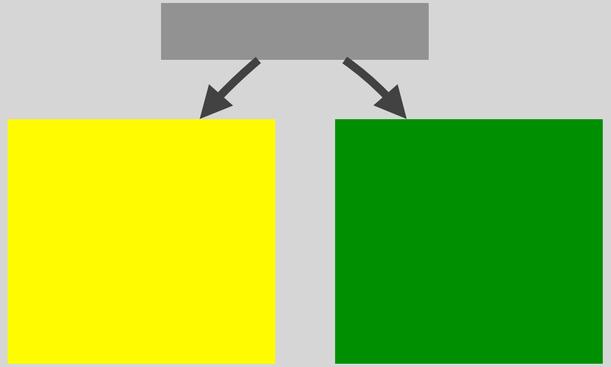


complete: not fragmented

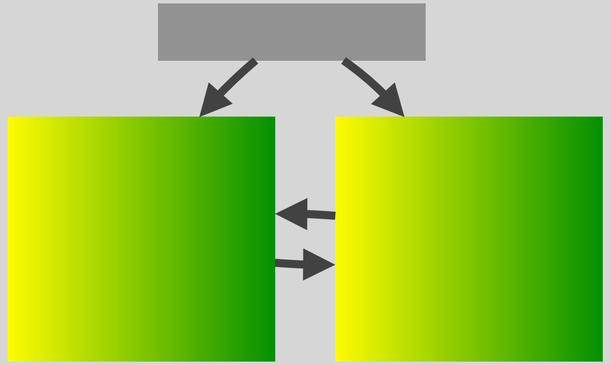


fragmented

independence
one module doesn't
rely on another



independent



dependent

check your understanding

A concept in a design app lets users create projects
that assemble models and track their changes over time.

Which modularity criterion is this likely to violate? (pick one)

(a) Completeness, because it should also include the ability to edit models

(b) Independence, because modifications of models in other concepts will affect this one

(c) Separation, because it mixes purposes related to versioning and aggregation

synchronization
how to decouple

▲ Jackson structured programming (wikipedia.org)

106 points by haakonhr 63 days ago | hide | past | favorite | 69 comments

▲ danielnicholas 63 days ago [–]

If you want an intro to JSP, you might find helpful an annotated version [0] of Hoare's explanation of JSP that I edited for a Michael Jackson festschrift in 2009.

For those who don't know JSP, I'd point to these ideas as worth knowing:

- There's a class of programming problem that involves traversing context-free structures can be solved very systematically. HTDP addresses this class, but bases code structure only on input structure; JSP synthesized input and output.

- There are some archetypal problems that, however you code, can't be pushed under the rug—most notably structure clashes—and just recognizing them helps.

- Coroutines (or code transformation) let you structure code more cleanly when you need to read or write more than one structure. It's why real iterators (with yield), which offer a limited form of this, are (in my view) better than Java-style iterators with a next method.

- The idea of viewing a system as a collection of asynchronous processes (Ch. 11 in the JSP book, which later became JSD) with a long-running process for each real-world entity. This was a notable contrast to OOP, and led to a strategy (seeing a resurgence with event storming for DDD) that began with events rather than objects.

[0] https://groups.csail.mit.edu/sdg/pubs/2009/hoare-jsp-3-29-09...

▲ ob-nix 63 days ago [–]

... this brings back memories! In the late eighties I, as a teenager, found a Jackson Struct. Pr. book at the town library. I remember I was amazed at the text and wondered why I hadn't heard about the method before.

If I remember correctly did the book clearly point out backtracking as a standard method, while mentioning that most languages lacked that, so it had to be implemented manually.

adding application-specific functionality

concept Upvote

purpose rank items by popularity

actions
upvote (user, item)
downvote (user, item)
unvote (user, item)

concept Karma

purpose privilege good users

state
a set of Users with
  a karma Number

actions
reward (user, reward)

concept Posting

purpose share content

state
a set of Posts with
  a body String
  an author User

actions
create (user, body): post
delete (post)
edit (post, body)

suppose I want this behavior:
you can't downvote an item
until you've received
an upvote on your own post

could just modify Upvote
why is this bad?

define a new concept!
a hint: not just used by Upvote

a first synchronization

concept Upvote

actions
upvote (user, item)
downvote (user, item)
unvote (user, item)

when Upvote.upvote (post)
where Posting: author of post is user
then Karma.reward (user, 10)

concept Posting

state
a set of Posts with
  a body String
  an author User

actions
create (user, body): post
delete (post)
edit (post, body)

concept Karma

state
a set of Users with
  a karma Number

actions
reward (user, reward)

a second synchronization

concept Upvote

actions
upvote (user, item)
downvote (user, item)
unvote (user, item)

concept Request

actions
upvote (user, item)
downvote (user, item)
...
edit (post, body)

when Request.downvote (user, post)
where Karma: user has karma >= 20
then Upvote.downvote (user, post)

concept Posting

state
a set of Posts with
  a body String
  an author User

actions
create (user, body): post
delete (post)
edit (post, body)

concept Karma

state
a set of Users with
  a karma Number

actions
reward (user, reward)

controlling downvoting in two syncs

concept Upvote

actions
upvote (user, item)
downvote (user, item)
unvote (user, item)

concept Request

actions
upvote (user, item)
downvote (user, item)
...
edit (post, body)

when Upvote.upvote (post)
where Posting: author of post is user
then Karma.reward (user, 10)

when Request.downvote (user, post)
where Karma: user has karma >= 20
then Upvote.downvote (user, post)

why not upvote (user, post) in first sync?

concept Posting

state
a set of Posts with
  a body String
  an author User

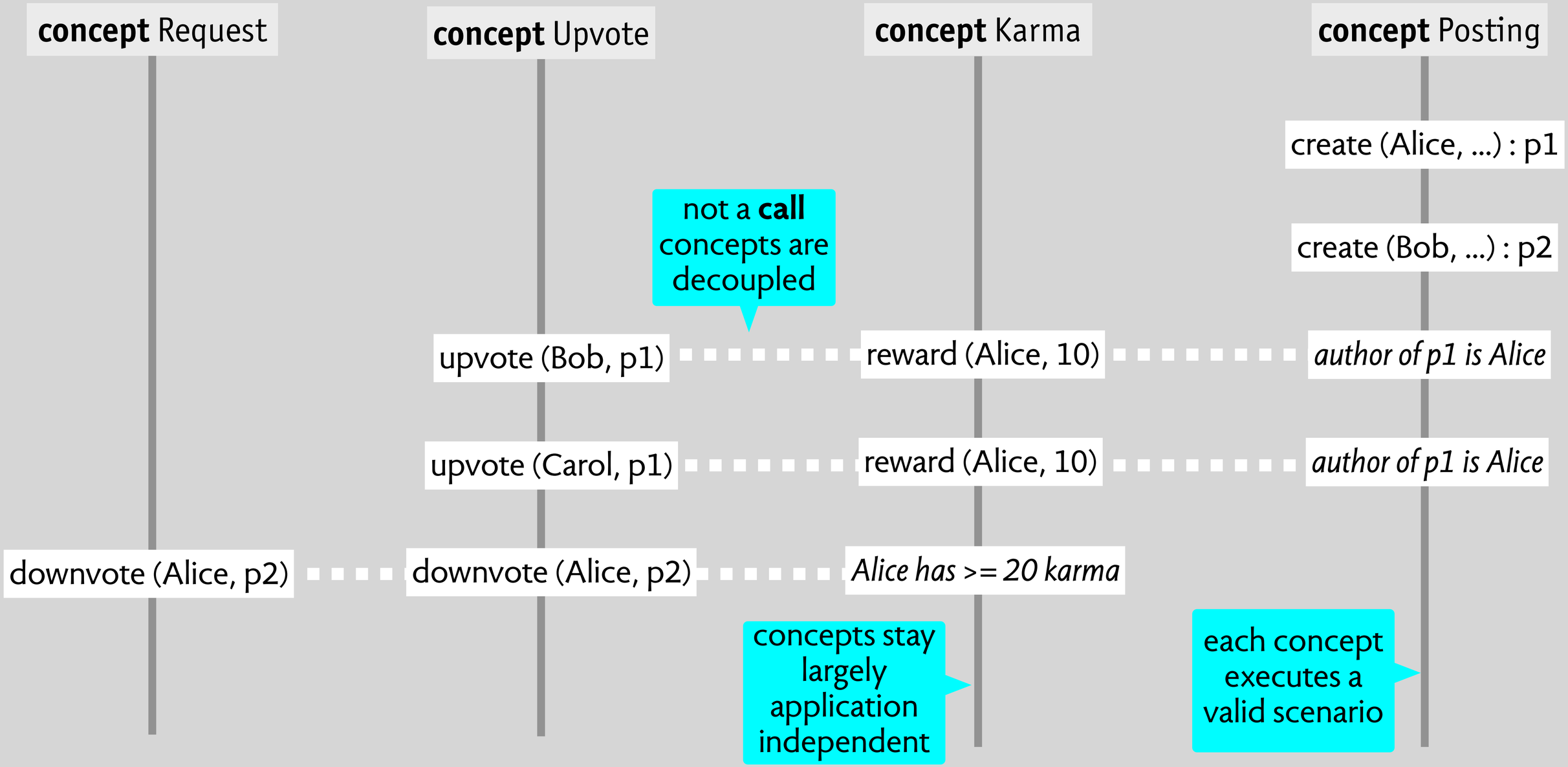
actions
create (user, body): post
delete (post)
edit (post, body)

concept Karma

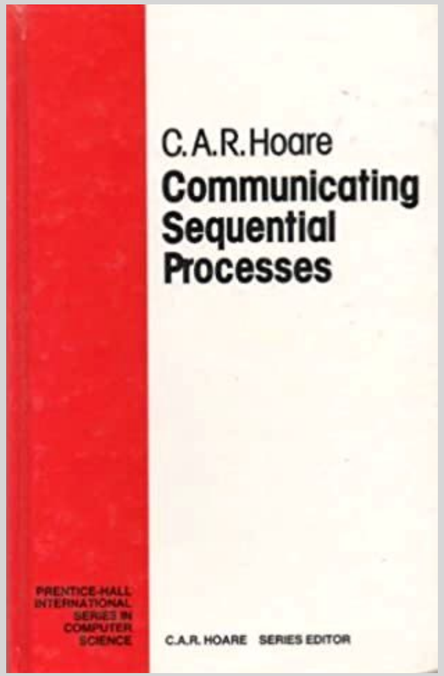
state
a set of Users with
  a karma Number

actions
reward (user, reward)

synchronization viewed over scenarios (traces)



not a new idea



composition uses event sync from Hoare's CSP

Mediators:

Easing the Design and Evolution of Integrated Systems

Kevin J. Sullivan

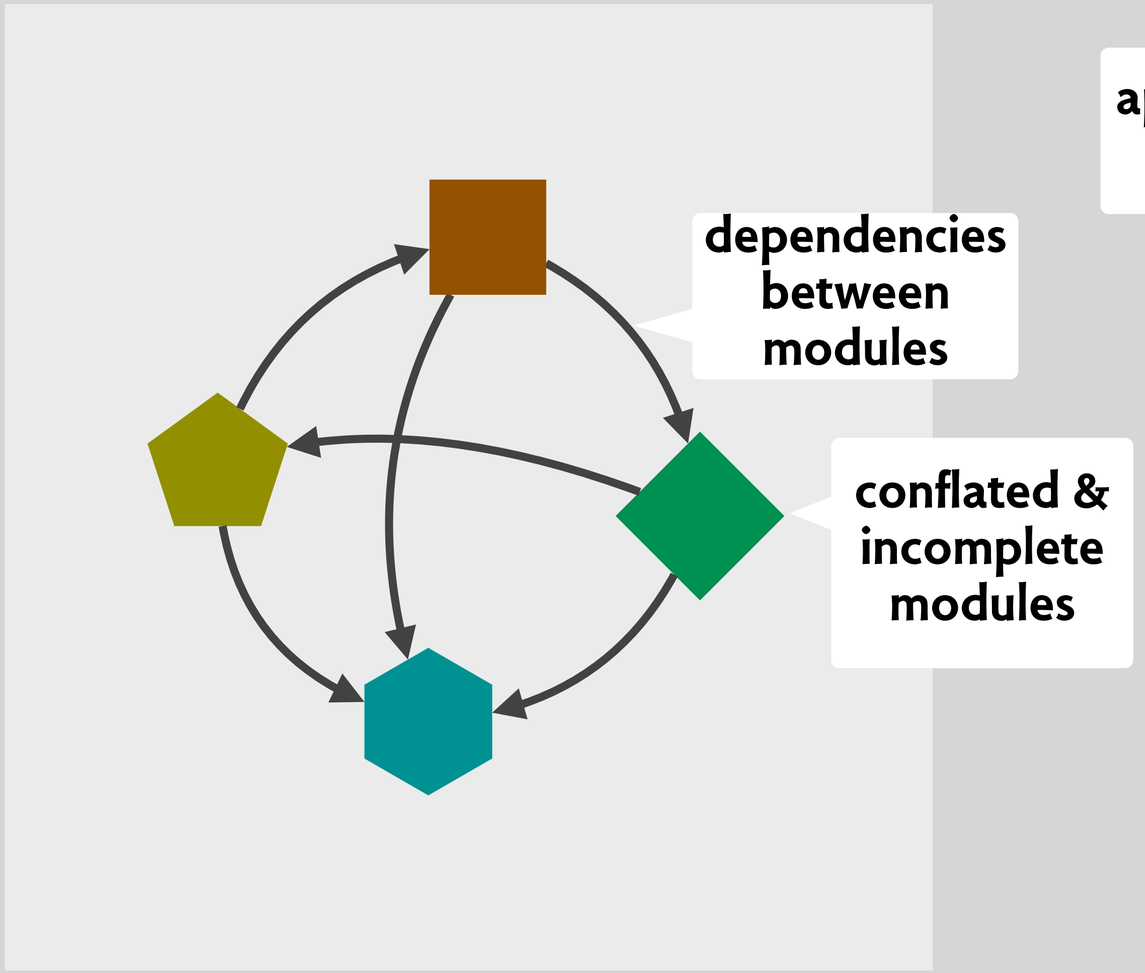
Technical Report 94-08-01

Department of Computer Science and Engineering

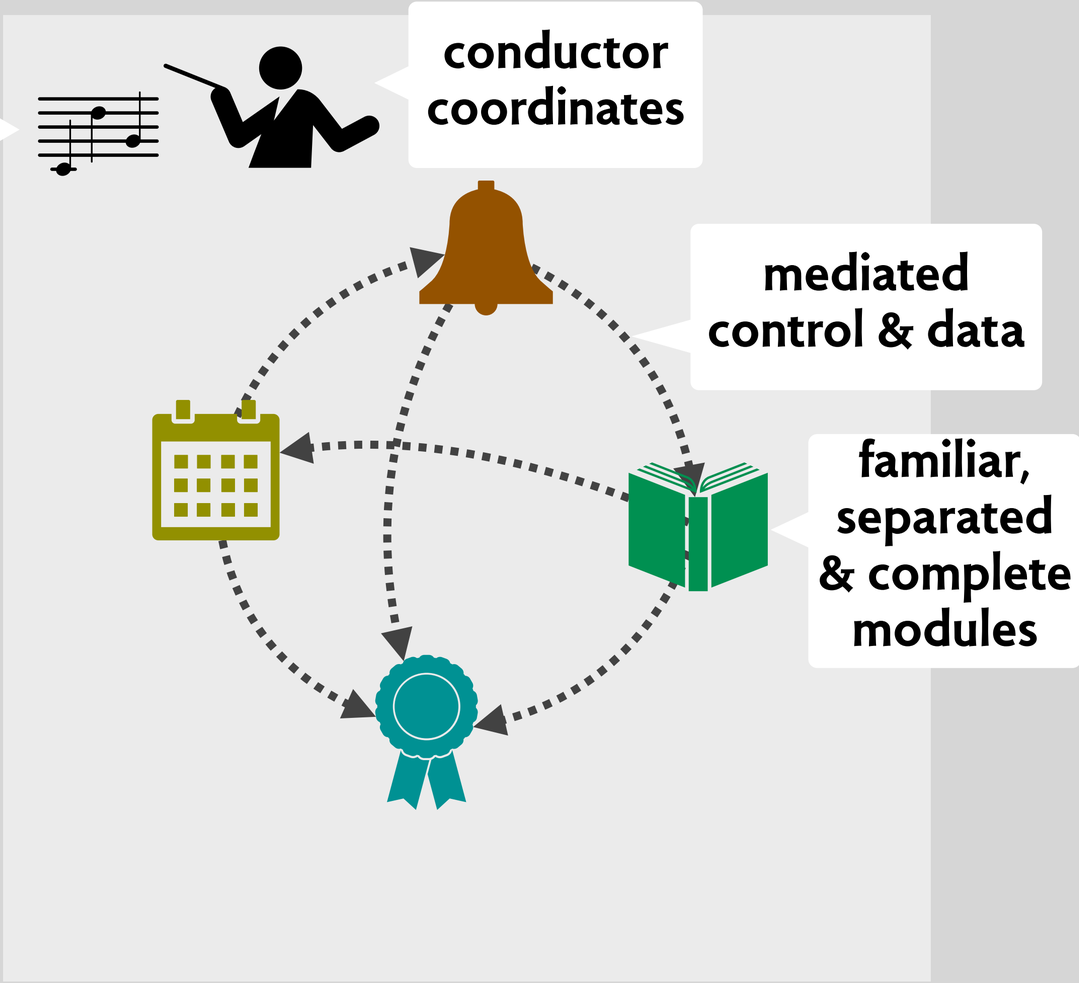
University of Washington

mediator pattern subject of Sullivan's thesis

an architectural view of concept composition



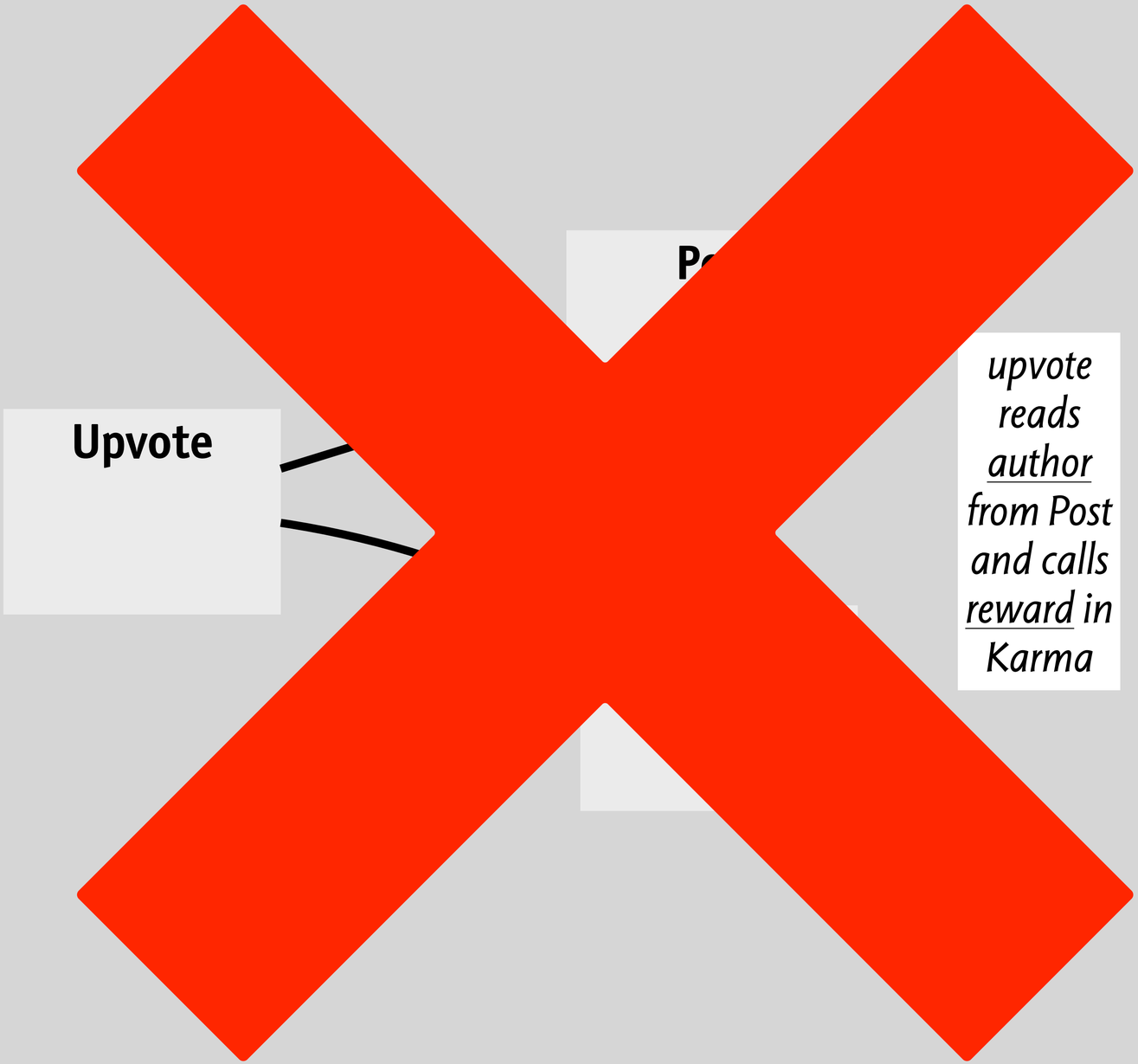
standard software development



concept-based software development

icons by Luis Prado & Zach Bogart, Noun Project

a reminder: how we didn't do it



concepts never
call each other's actions
read or write each other's state
share mutable composite objects

some more synchronization examples

```
when
  Request.createPost (body)
  User.authenticate (): user
then Posting.create (user, body)
```

authenticating users

```
when Commenting.create (post, body)
where Posting: author of post is user
then Notification.notify (user, “Comment “ + body)
```

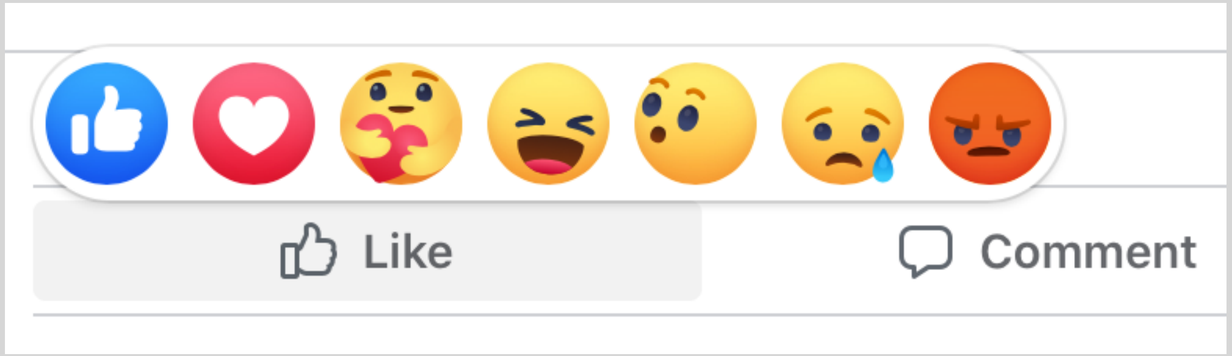
notifying post author when someone comments

```
when Posting.delete (post)
where Commenting: post is target of comment
then Commenting.delete (comment)
```

```
when Request.deletePost (post)
where Commenting: no comments on post
then Posting.delete (post)
```

two ways to handle post deletion and comments

exploring a design with synchronizations



can you explain the design options using synchronizations?

Emoji reactions were a cute addition to Facebook. They became a headache.

Facebook's algorithms gave an "angry" reaction five times the weight of a traditional "like." After years of research, employees realized the result was more "toxicity."

concept Upvote

purpose rank items by popularity

actions

upvote (user, item)
unvote (user, item)
downvote (user, item)

concept Reaction

purpose convey emotion to author

actions

react (user, item, reaction)

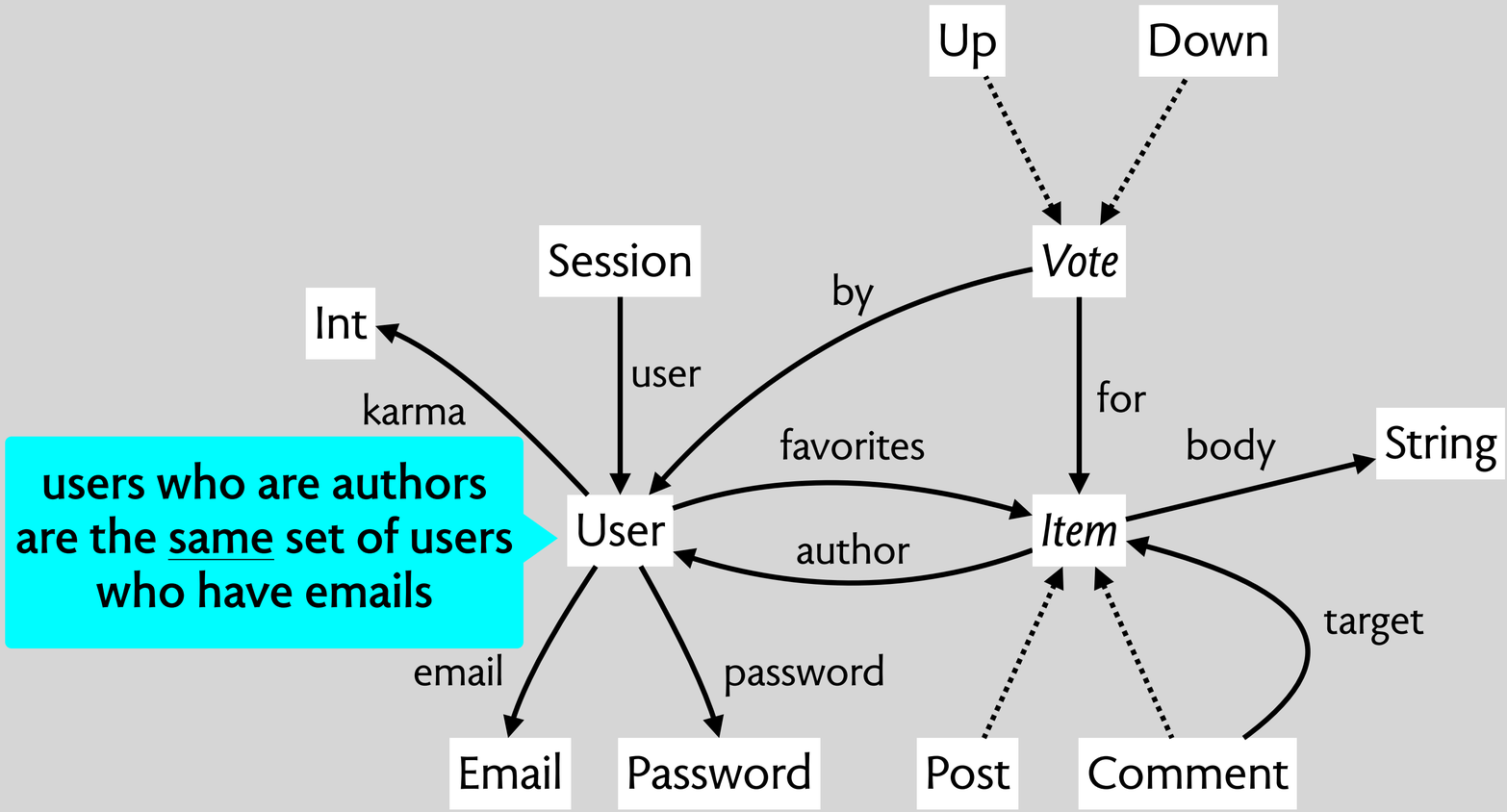
concept Request

actions

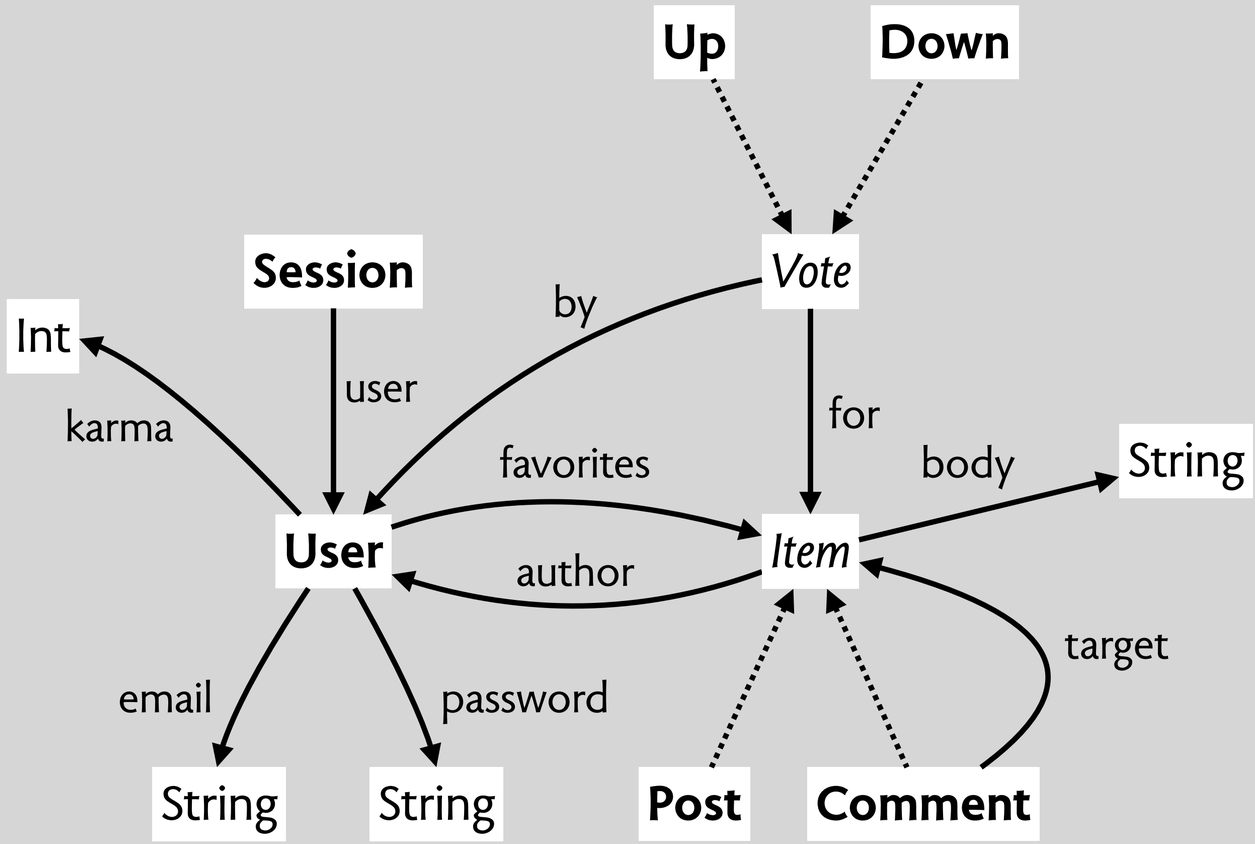
like (user, item)

a data model perspective

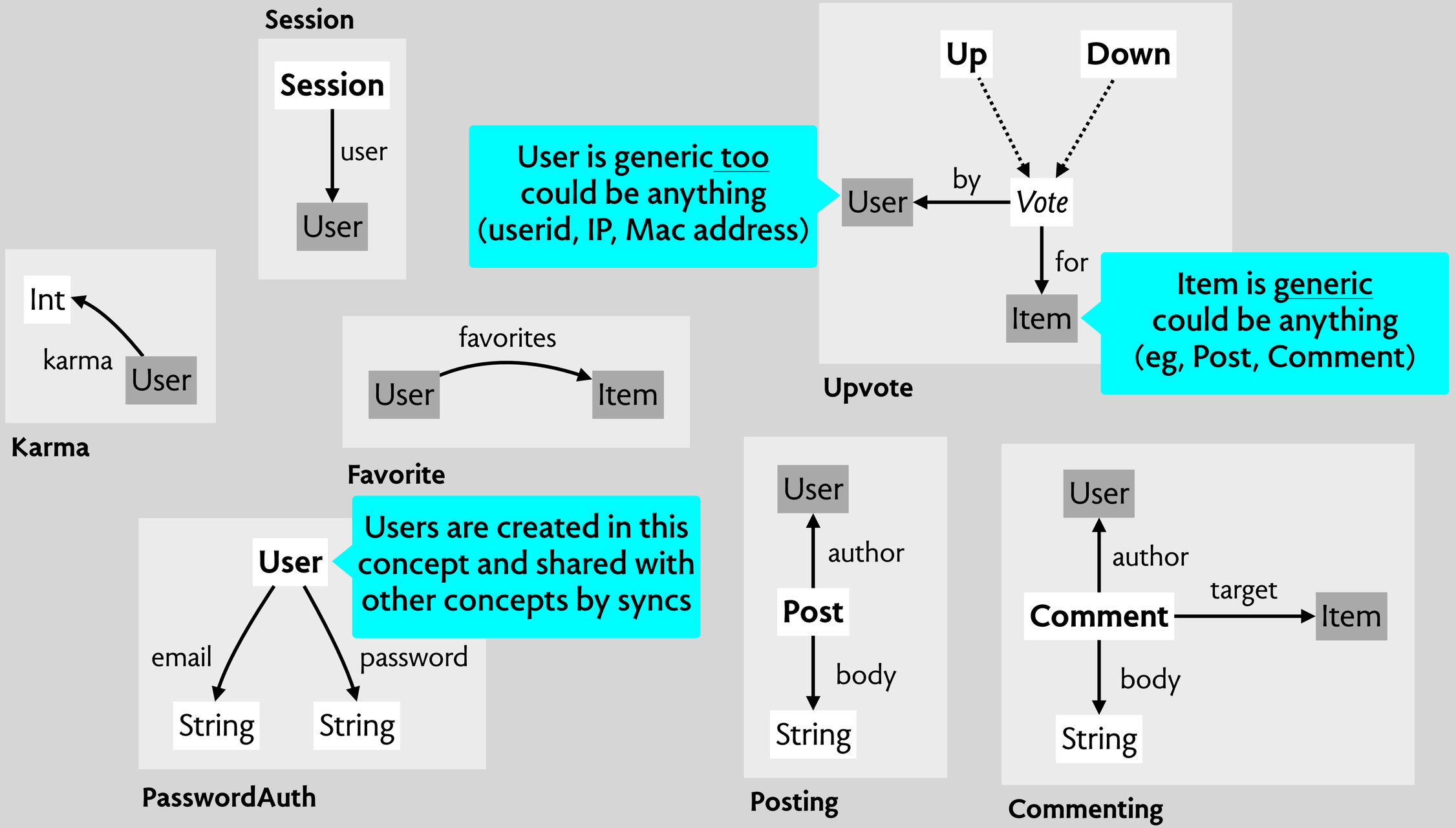
a data model for hacker news



highlighting the entities



data models for concepts



listing the generic types as parameters of the concept

this means Upvote is generic with respect to the User and Item types

concept Upvote [User, Item]

purpose rank items by popularity

state
set of Votes with
  a by User
  a for Item
an Upvotes set of Votes
a Downvotes set of Votes

actions
upvote (user: User, item: Item)
downvote (user: User, item: Item)
unvote (user: User, item: Item)

concept Karma [User]

purpose privilege good users

state
a set of Users with
  a karma Number

actions
reward (user: User, reward: Int)

concept Posting [User]

purpose share content

state
a set of Posts with
  a body String
  an author User

actions
create (user: User, body: String):
  (post: Post)
delete (post: Post)
edit (post: Post, body: string)

check your understanding

In what key respect is data modeling in concept design different? (select all that apply)

(a) Concept design decomposes the data model by functionality

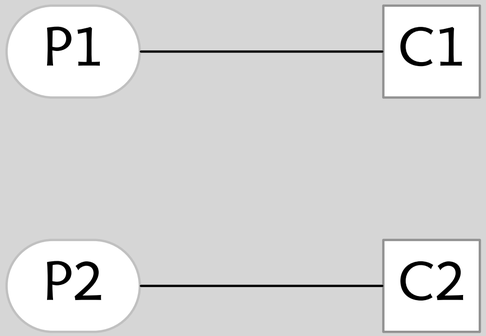
(b) Concept design introduces the idea of generic types from programming into data models

(c) Concept design distinguishes entities from values

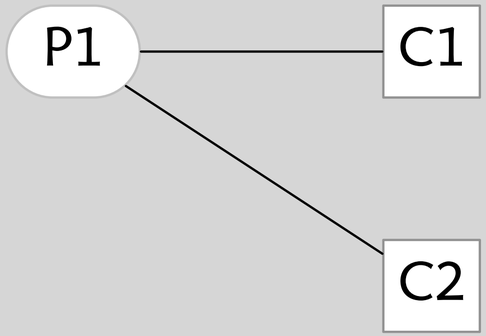
purposes & conflation

a concept design principle

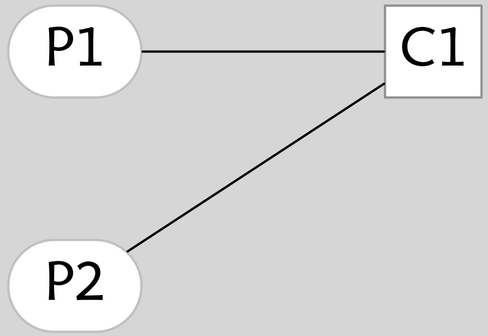
specificity
purposes:concepts are 1:1



redundancy
>1 concept per purpose



overloading
>1 purpose per concept



overloading leads to conflation

purpose 1

purpose 2

conflated: two purposes

concept UserAccount

purpose ????

state
a set of users each with
- **a username**
- **a password**
- **an email address**
- **a phone number**
- **first and last names**
- **profile picture**

concept Password

purpose authenticate users

state
a set of users each with
- a username
- a password

concept Notification [User]

purpose notify users

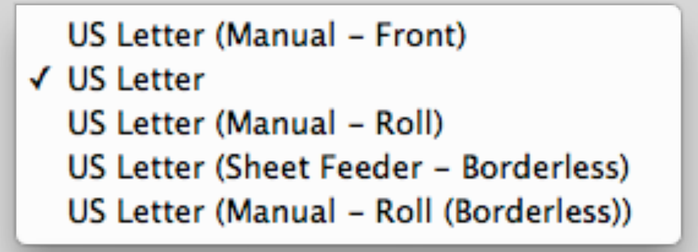
state
a set of users each with
- an email address
- a phone number

concept Profile [User]

purpose share user info

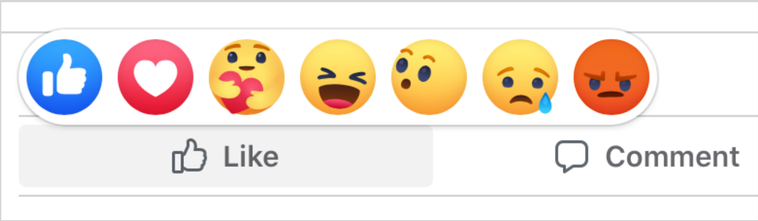
state
a set of users each with
- first and last names
- profile picture

overloading examples from my book

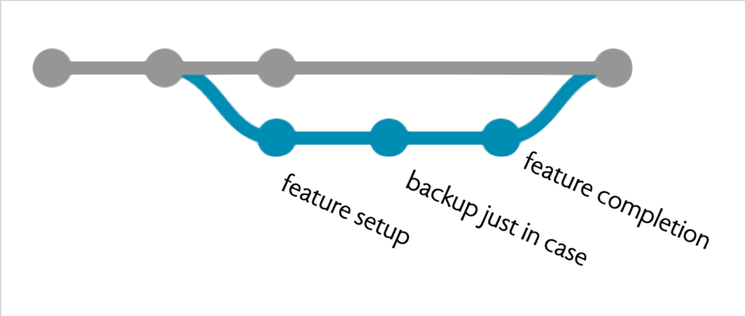


Epson's PaperSize concept

Fujifilm's ImageSize concept



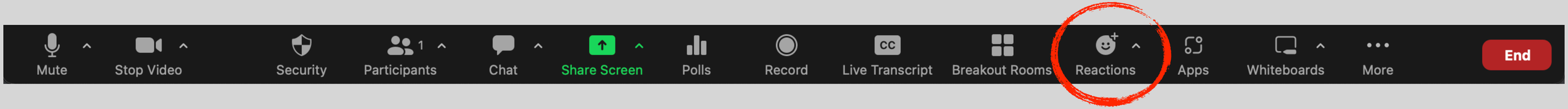
Facebook's Reaction concept

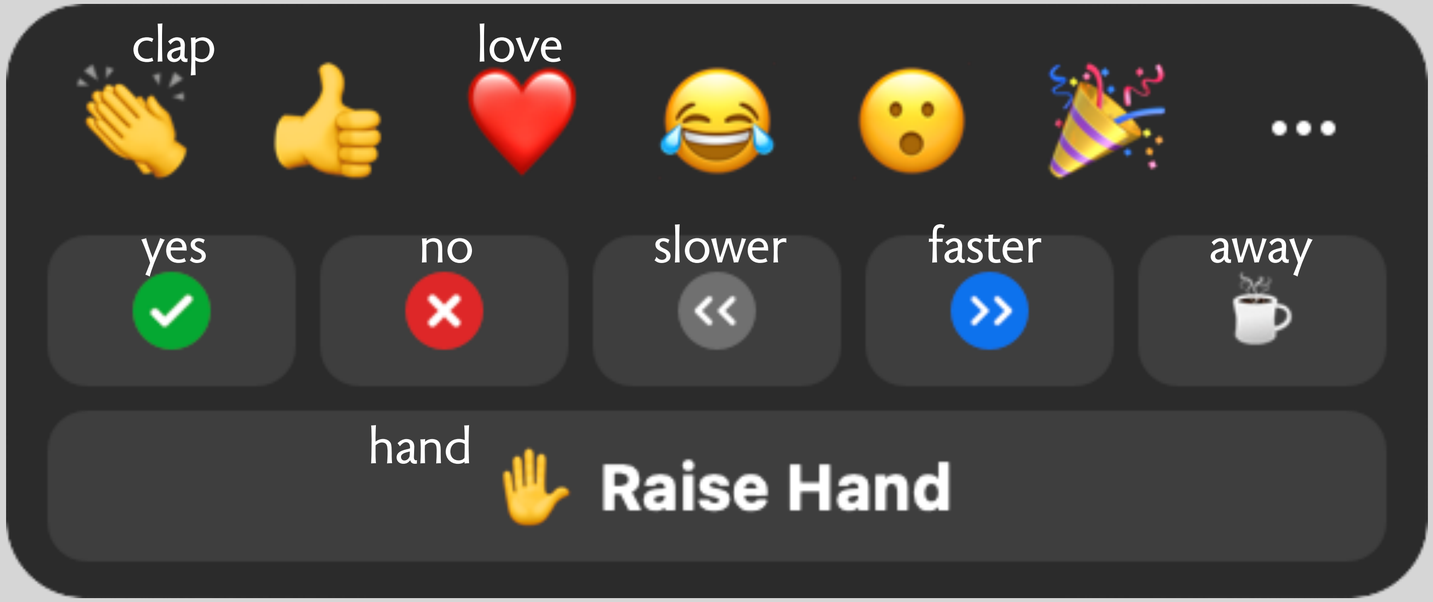


Git's Commit concept

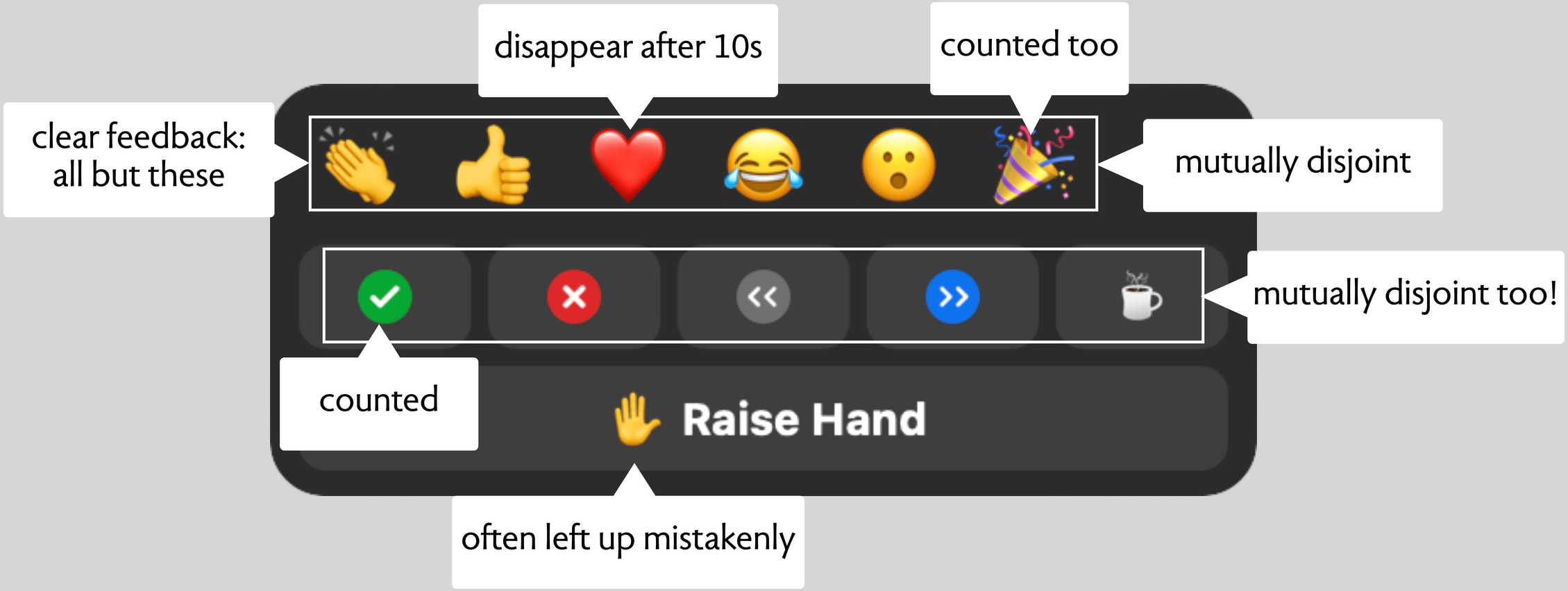
conflation example:
reactions in Zoom

Zoom's reactions

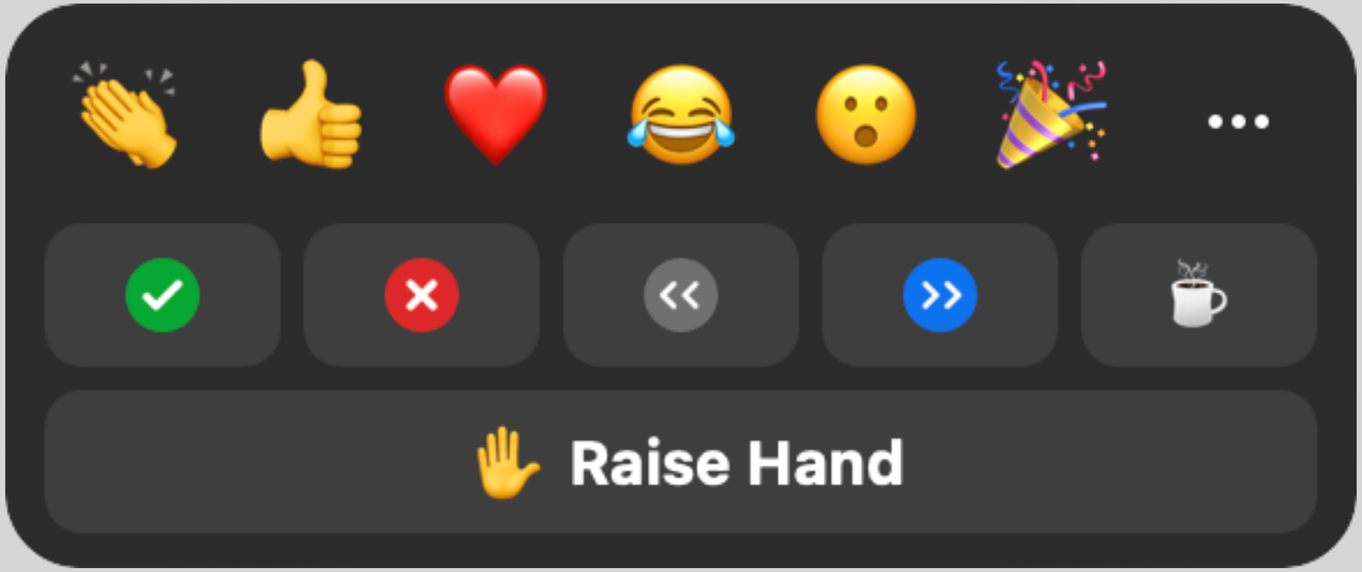




anomalous behaviors



an exercise: can you do better?



goals

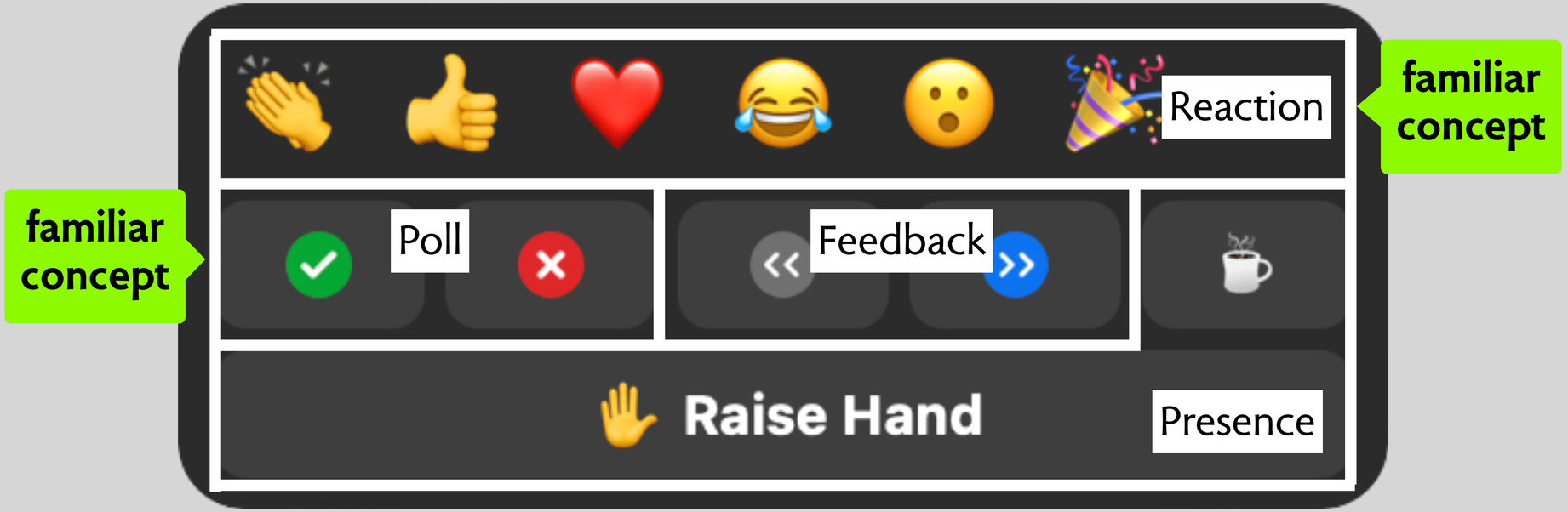
break the behavior into a small set of concepts

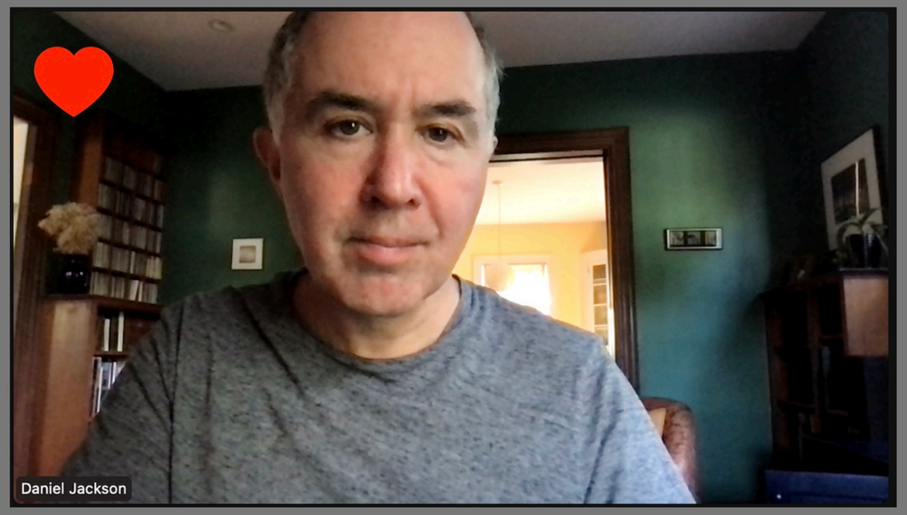
use familiar concepts whenever possible

make each concept simple, robust & understandable

(just outline the concepts)

my take: splitting into coherent concepts





Presence

Chat

Reaction

Feedback

Request to speak

Speaking

Watching/listening

I'm away

Audience

Other emoji

Recent emoji

Slow down

Just right

Speed up

16

24

9

Everyone ▾

Type here…

takeaways

aspects of modularity

separation, completeness, independence

synchronizations

link actions externally, no coupling

concepts & data models

breaking down by concept, making generic

concepts & purposes

if not 1:1, conflation (overloading) or redundancy

3 key aspects of concept design

purpose
asking why

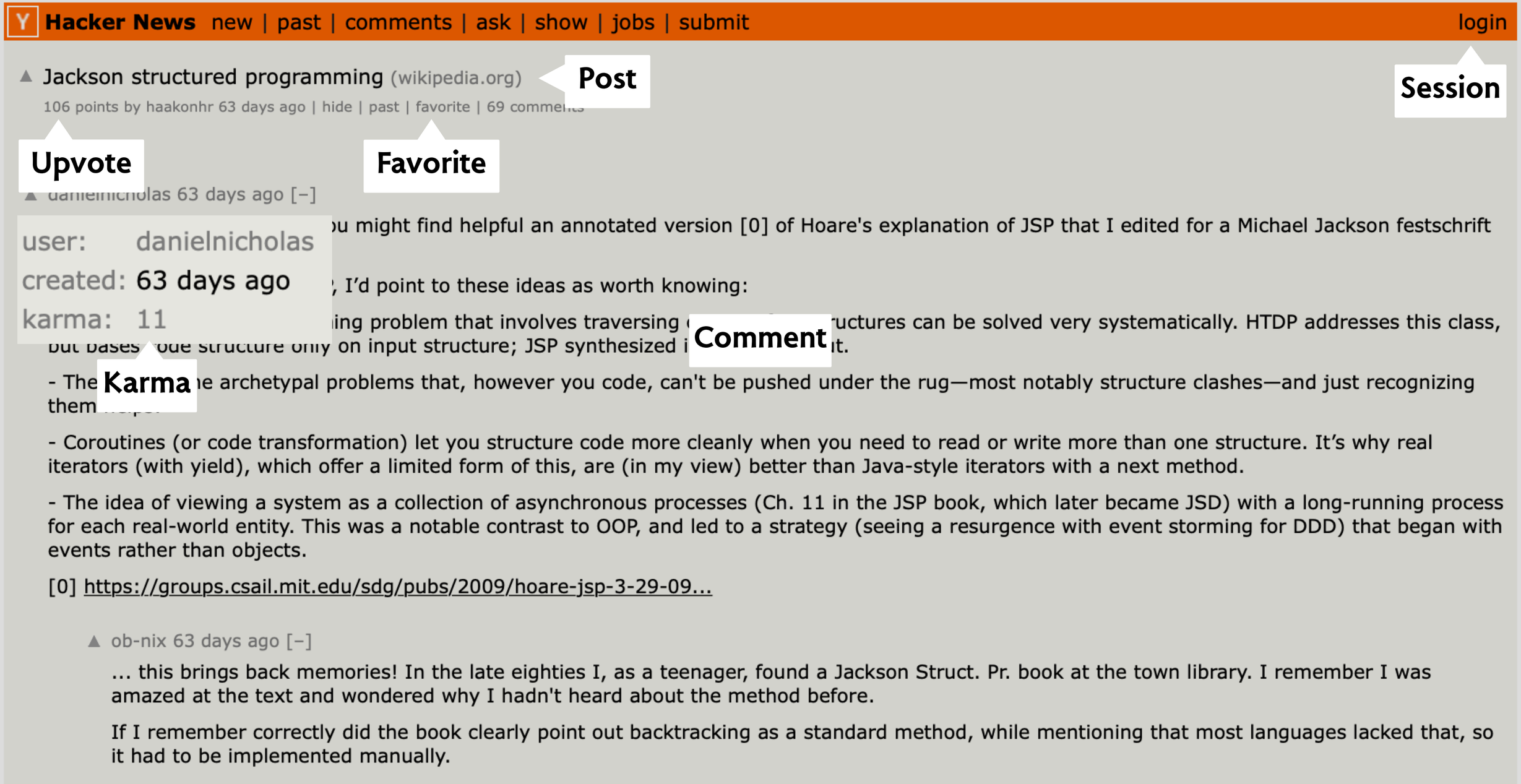
abstraction
focus on behavior

separation
independent parts

backup slides

a code-level explanation

let's look at an example: hacker news



let's build it!

```
class User {
  String name;
  String password;
  User register (n, p) { ... }
  User authenticate (n, p) { ... }
 }
```

```
class Post {
  User author;
  String body;
  Post new (a, b) { ... }
}
```

adding upvoting

```
class User {
  String name;
  String password;
  User register (n, p) { ... }
  User authenticate (n, p) { ... }
}
```

```
class Post {
  User author;
  String body;
  Set [User] ups, downs;
  Post new (a, b) { ... }
  upvote (u) { ... }
  downvote (u) { ... }
}
```

adding karma

```
class User {
  String name;
  String password;
  int karma;
  User register (n, p) { ... }
  User authenticate (n, p) { ... }
  incKarma (i) { ... }
  bool hasKarma (i) { ... }
}
```

```
class Post {
  User author;
  String body;
  Set [User] ups, downs;
  Post new (a, b) { ... }
  upvote (u) { ... }
  downvote (u) {
    if u.hasKarma (10)  ... }
}
```

adding commenting

```
class User {
  String name;
  String password;
  int karma;
  User register (n, p) { … }
  User authenticate (n, p) { … }
  incKarma (i) { … }
  bool hasKarma (i) { … }
}
```

```
class Post {
  User author;
  String body;
  Set [User] ups, downs;
  Seq [Post] comments;
  Post new (a, b) { … }
  upvote (u) { … }
  downvote (u) {
    if u.hasKarma (10)  … }
  addComment (c) { … }
}
```

what's wrong with this code?

```
class User {
  String name;
  String password;
  int karma;
  User register (n, p) { ... }
  User authenticate (n, p) { ... }
  incKarma (i) { ... }
  bool hasKarma (i) { ... }
}
```

```
class Post {
  User author;
  String body;
  Set [User] ups, downs;
  Seq [Post] comments;
  Post new (a, b) { ... }
  upvote (u) { ... }
  downvote (u) {
    if u.hasKarma (10)  ... }
  addComment (c) { ... }
}
```

User authentication

Posting

Upvoting

Commenting

Karma

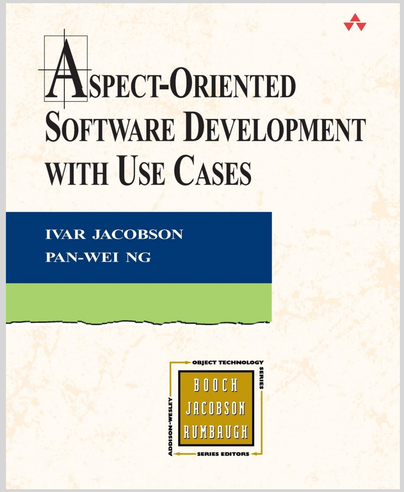
lack of separation
Post class contains posting, commenting, upvoting, karma

classes are not reusable
Post class won't work in an app that doesn't have karma points

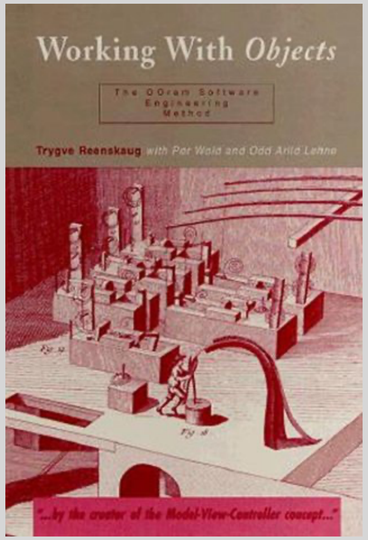
dependence
Post class calls *User* class to get karma points

can't be built independently
to build *Post* class, need *User* class to have been built already

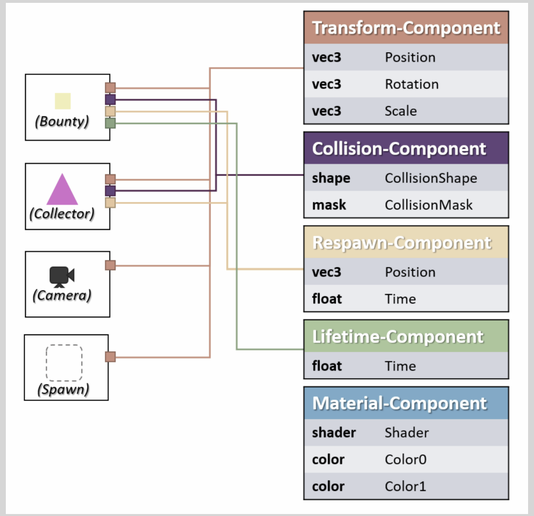
a long history of fixes for OOP's conflation



Aspect-oriented programming
Kiczales et al (1997)



Role-oriented programming
Reenskaug et al (1983)



Entity-component system
Scott Bilas et al (2002)

concepts: modularizing user-facing functions

```
concept User {
  Map [User, String] name;
  Map [User, String] password;
  User register (n, p) { ... }
  User authenticate (n, p) { ... }
}
```

```
concept Karma [U] {
  Map [U, Int] karma;
  incKarma (u, i) { ... }
  hasKarma (u, i) { ... }
}
```

concerns now cleanly separated

coupling is gone: refs are polymorphic

```
concept Post [U] {
  Map [Post, U] author;
  Map [Post, URL] url;
  Post new (a, u) { ... }
}
```

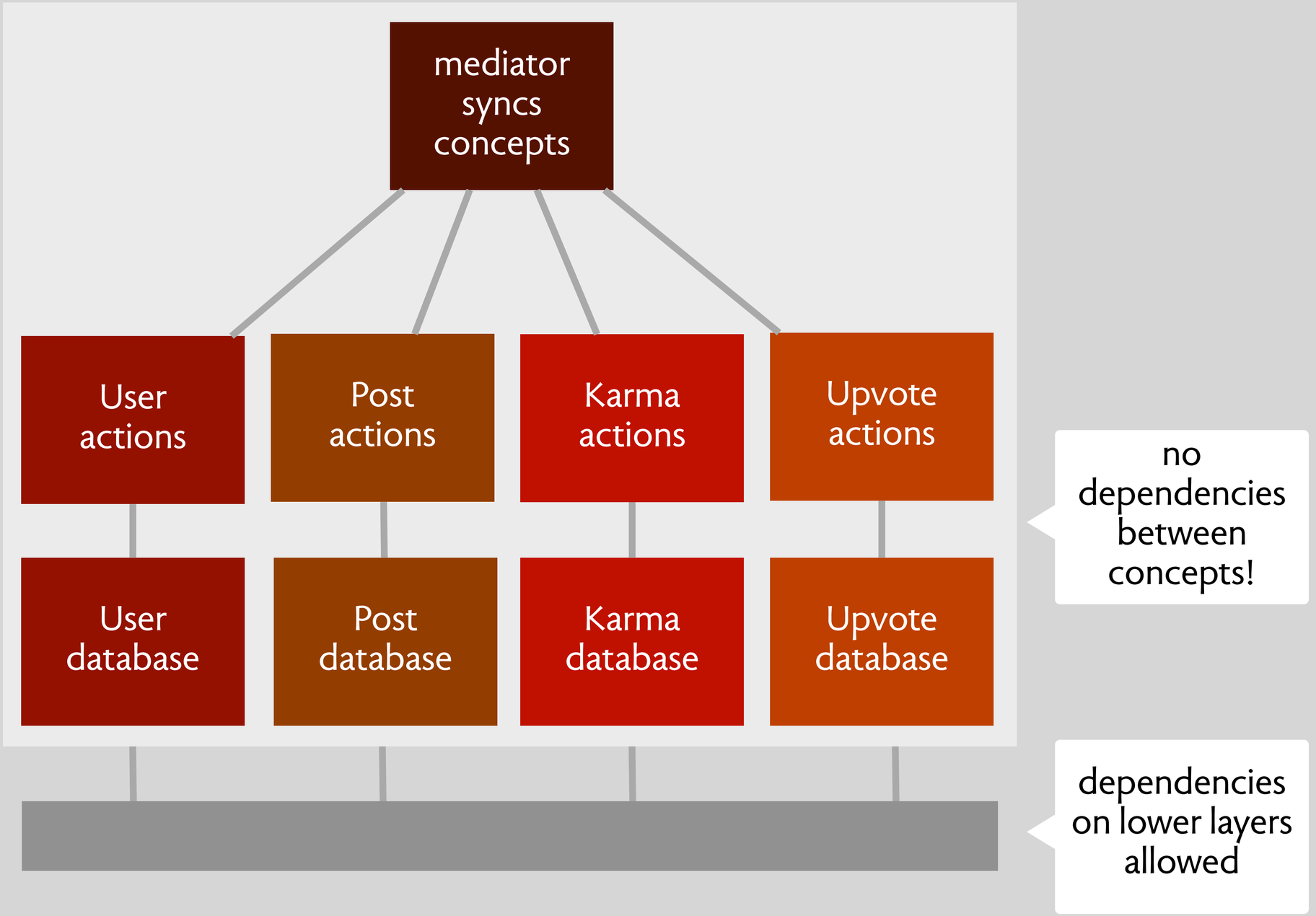
```
concept Upvote [U, I] {
  Map [U, I] ups, downs;
  upvote (u, i) { ... }
  downvote (u, i) { ... }
}
```

```
concept Comment [U, T] {
  Map [Comment, U] author;
  Map [Comment, T] target;
  Map [Comment, String] body;
  Comment new (a, t, b) { ... }
}
```

syncs hold cross concept functionality

```
when
  Web.request (downvote, u, i)
where
  Karma.hasKarma (u, 20)
then
  Upvote.downvote (u, i)
```

a new architectural style



modularity example
restaurant reservations

concept RestaurantReservation [User]

purpose reducing wait time for tables

principle the restaurant makes slots available at various times; a diner reserves for a particular time, and then can be assured of being seated at that time

state

a set of slots each with
 the start time (includes date)
a set of reservations each with
 the user who made it
 the slot being reserved
 whether seated

actions

createSlot (t: Time)
 ensures creates a fresh slot & associates with time t

reserve (u: User, t: Time): Reservation
 requires some slot at time t not yet reserved
 ensures creates & returns a fresh reservation
  associates it with user u and the slot

seat (r: Reservation)
 requires r is a reservation for about now
 ensures mark r as seated

last time, one module
focused on one aspect: reservations

this time, whole system
how to organize variety of functions

main areas of function
identifying users
sending confirmations & reminders
punishing repeat no-shows
laying out tables in dining room
reserving based on party size
defining shifts with different layouts
...

some easy-ish design issues

identifying users
support standard password access & just email/phone
UserAccount concept to track users through password creation
UserPassword concept to manage password access
Capability concept to generate obscure reservation references?

sending confirmations & reminders
Notification concept holds contact preferences, tightly sync'd
Reminder concept, because reminders are different

punishing repeat no-shows
Karma concept debit action, sync'd with noShow action

laying out tables in dining room
FloorPlan concept backing a nice graphical UI

reserving based on party size

concept RestaurantReservation [User]

state
slots with start times
reservations with user, slot

actions
createSlot (start: Time)
reserve (u: User, t: Time): Reservation
cancel (r: Reservation)
noShow (r: Reservation)

concept RestaurantReservation [User, **Table**]

state
slots with **tables** and start times
reservations with user, slot, **party size**

actions
createSlot (start: Time, **t: Table**)
reserve (u: User, **s: Slot, party: int**): Reservation

concept FloorPlan

state
tables with
position and min/max party sizes

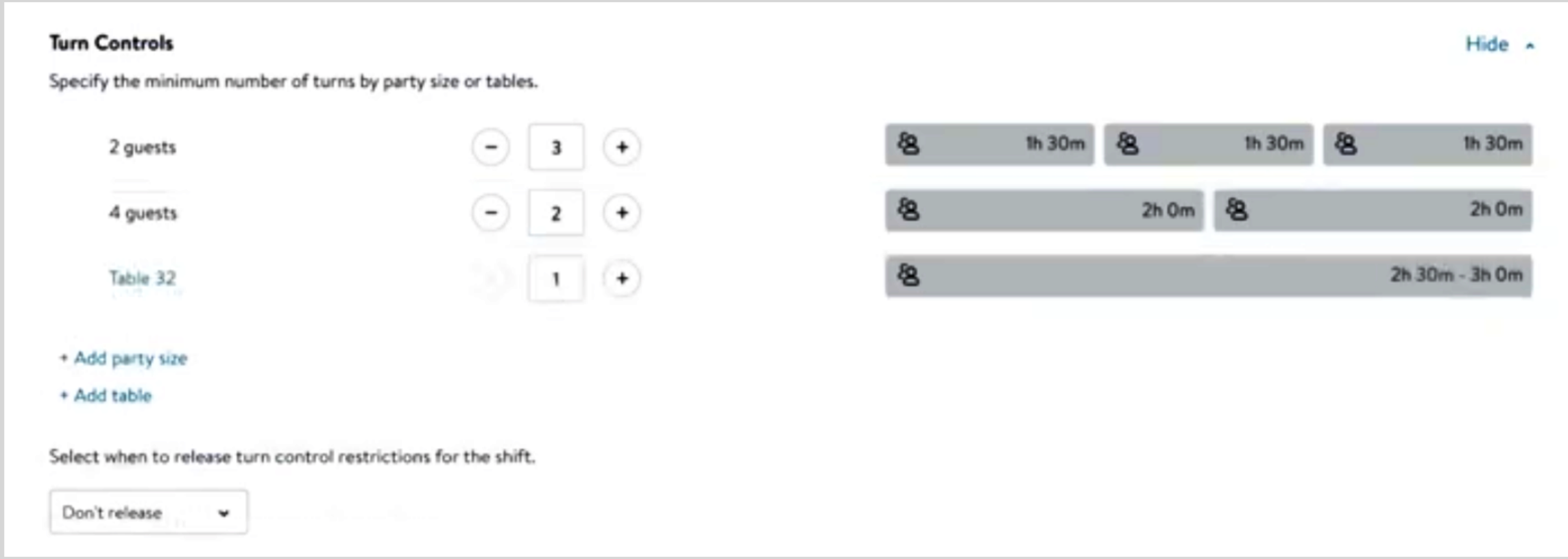
actions
configureTables (...)

when Web.request (*reserve*, user, time, party)
where
slot for table at time (in RestaurantReservation)
party in range for table (in FloorPlan)
then
RestaurantReservation.reserve (user, slot, party)

why does reserve action now take slot?
because need to pick based on floor plan

why is Table generic for RestaurantReservation?
because it doesn't know anything about tables

turn control in Open Table



shifts with different layouts

concept RestaurantReservation [User, **Slot**]

state
reservations with user, slot, party size

actions
~~**createSlot (start: Time, t: Table)**~~
reserve (u: User, s: Slot, party: int): Reservation
cancel (r: Reservation)
noShow (r: Reservation)

concept FloorPlan

state
floor plans with tables, tables with position and number of seats

actions
configureTables (...) : FloorPlan

concept Shift [FloorPlan, Table]

state
shifts with times, floor plan, slots
slots with times, min/max party, table

actions
setupShift (...)
...

when Web.request (*reserve*, user, time, party)
where
slot for table at time with party (in Shift)
then
RestaurantReservation.reserve (user, slot, party)

why does Shift now manage slots?
because of shift-specific functions
(eg, "turn time by party size")

what concept design is and isn't

not a magic potion
helps control complexity
not eliminate completely

a framework/language
for structuring designs
exploring collaboratively