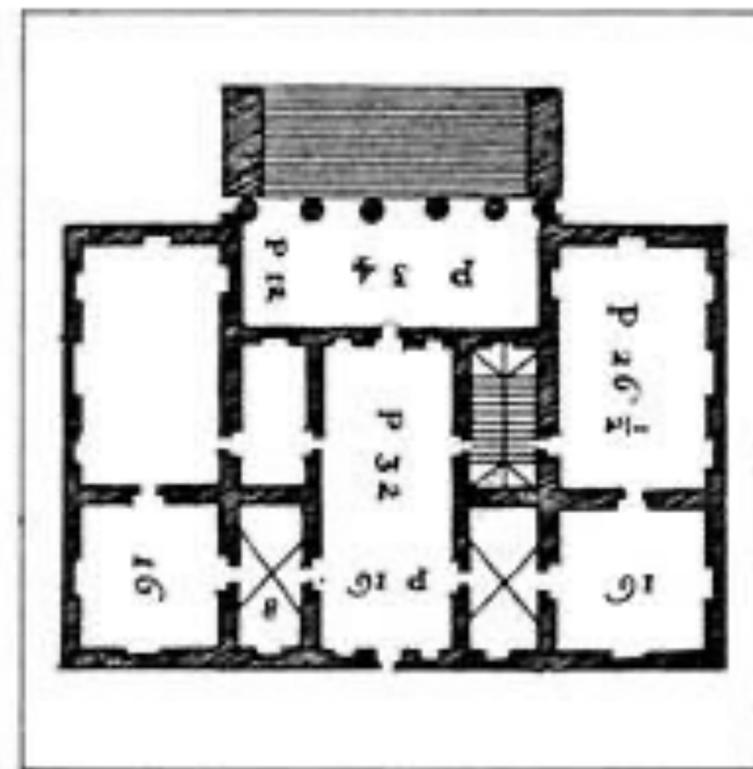
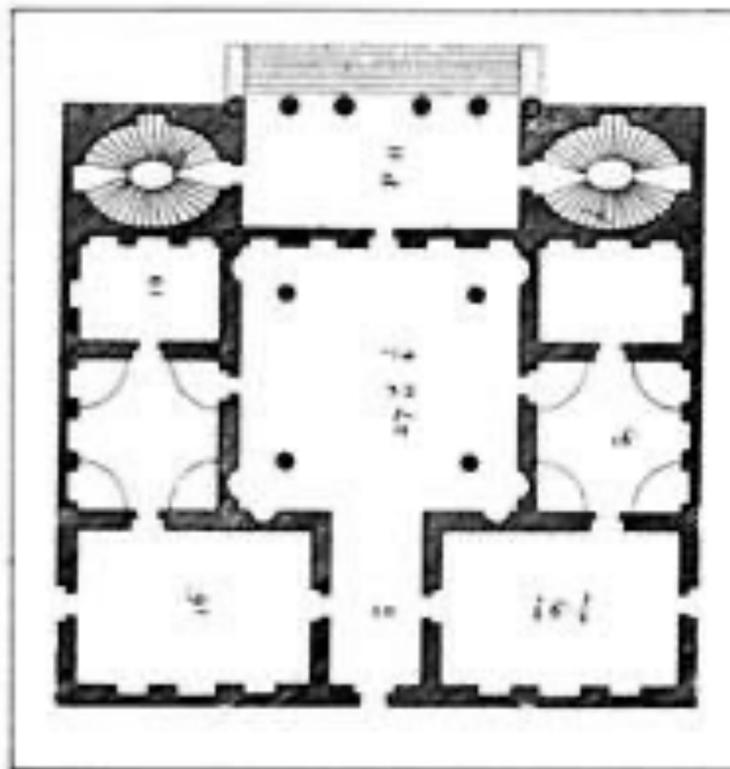
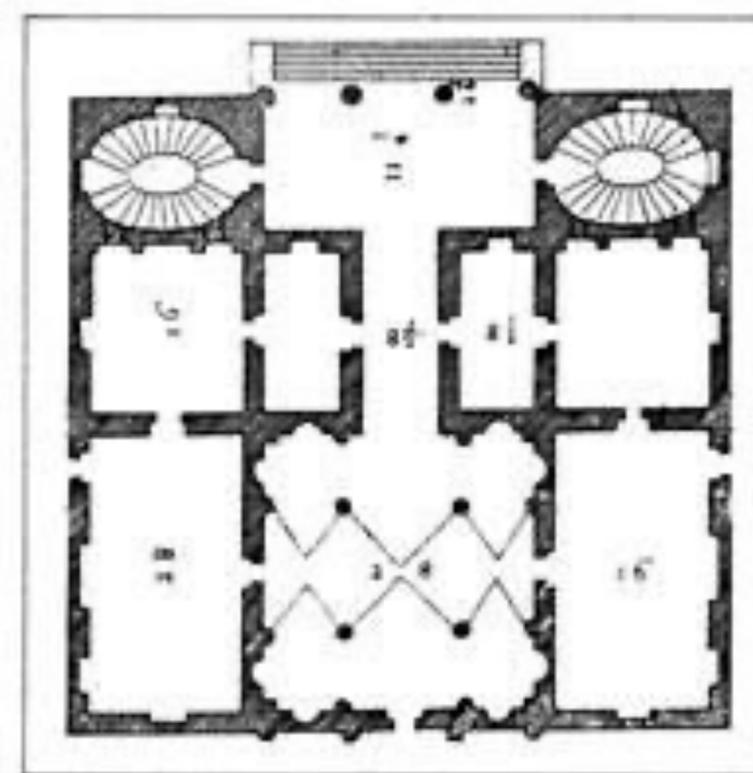
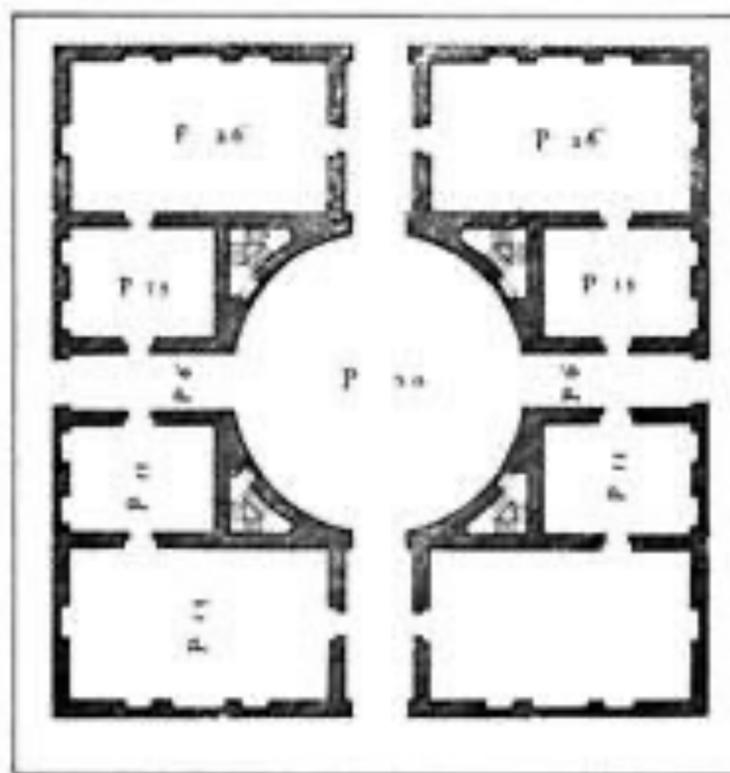
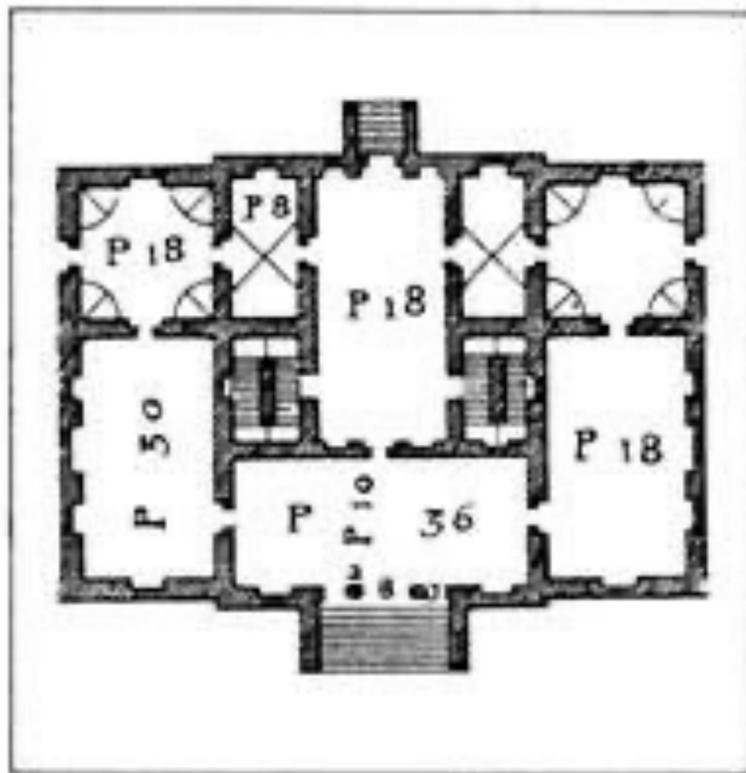


# finding structure in software

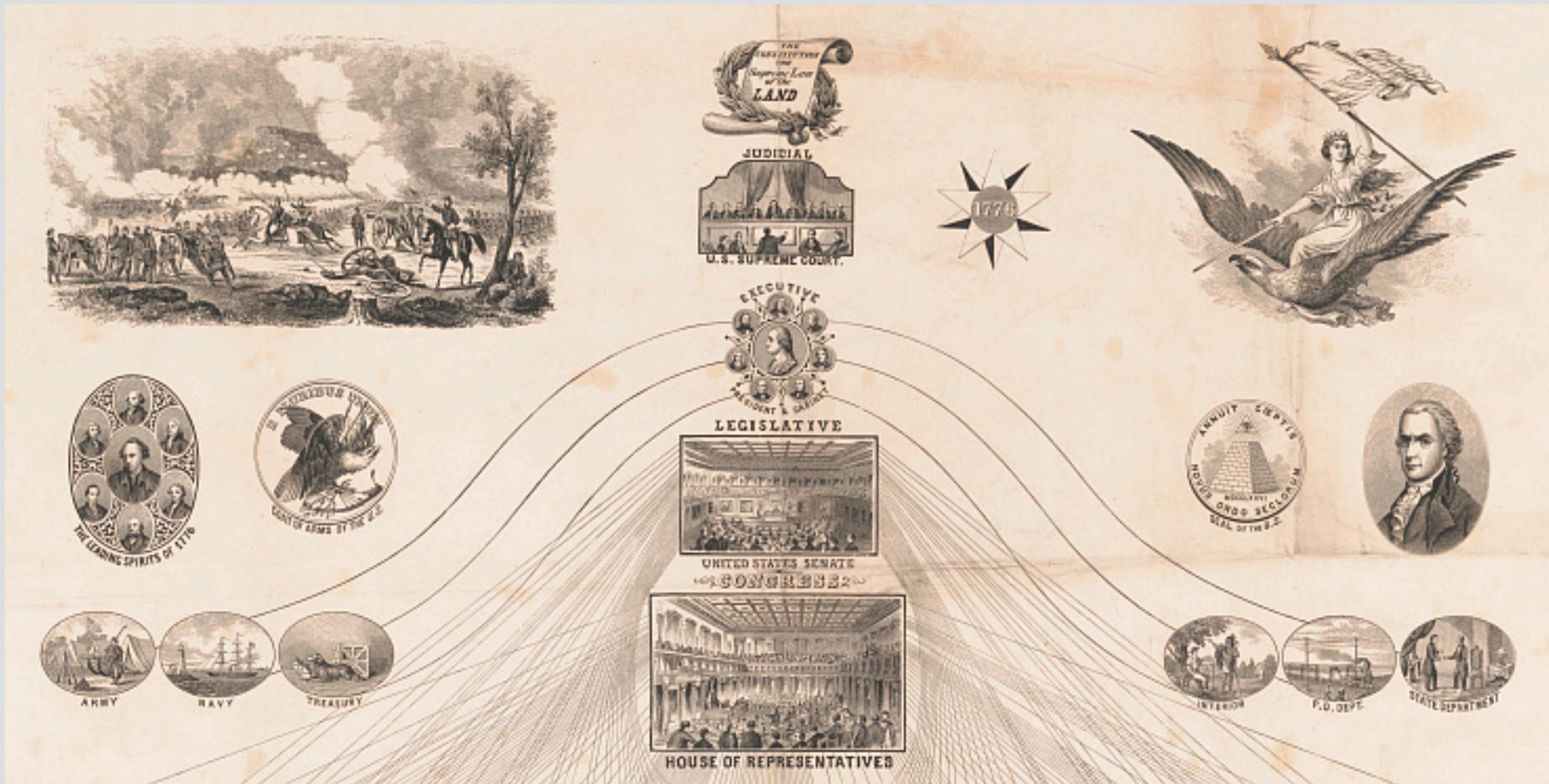
Daniel Jackson, MIT CSAIL · Nasa Formal Methods 2022 · May 26, 2022

**we use structure  
to understand  
artifacts**

# villa designs (andrea palladio, c. 1570)



# american federal government (1864)



# periodic table (mendeleev, c. 1870)

ЕСТЕСТВЕННАЯ СИСТЕМА ЭЛЕМЕНТОВЪ Д. МЕНДЕЛѢЕВА.

		Группа I.	Группа II.	Группа III.	Группа IV.	Группа V.	Группа VI.	Группа VII.	Группа VIII. (переходъ къ I)			
Высшій окиселъ образующій соли:		$R^2O$	$R^2O^2$ или $RO$	$R^2O^3$	$R^2O^4$ или $RO^2$	$R^2O^5$	$R^2O^6$ или $RO^3$	$R^2O^7$	$R^2O^8$ или $RO^4$			$H=I$ $HX$
Типичес. Рядъ		$H=1$ $H^2O, NH, HCl, H^2N, H^4C, ROH.$			$RH^4$	$RH^3$	$RH^2$	$RH$				
		$Li=7$ $LiCl, LiOH, Li^2O, LiX, Li^2CO^2$	$Be=9,4$ $BeCl^2, BeO, Be^3Al^2Si^6O^{13}$	$B=11$ $BCl^3, B^2O^3, BN, B^4Na^2O^3, BF^3$	$C=12$ $CH^4, C^2H^2, CO, CO^2, CO^2M$	$N=14$ $NH^3, NH^4Cl, N^2O, NO, NO^2M, ONM.$	$O=16$ $OH^2, O^2C, O^2O^2, OM^2, O^2R, HOR.$	$F=19$ $FH, BF^3, SiF^4, CaF^2, KF, KHF^2.$				
Периодъ 1-й. Периодъ 2-й. Периодъ 3-й. Периодъ 4-й. Периодъ 5-й. Периодъ 6-й. Периодъ 7-й. Периодъ 8-й. Периодъ 9-й. Периодъ 10-й.		$Na=23$ $NaCl, NaHO, Na^2O, Na^2SO^4, Na^2CO^2$	$Mg=24$ $MgCl^2, MgO, MgCO^2, MgSO^4, MgNH^4PO^4$	$Al=27,3$ $Al^2Cl^3, Al^2O^3, KAIS^2O^3 \cdot 12H^2O.$	$Si=28$ $SiH^4, SiCl^4, SiH^2F^2, KAISI^2O^3 \cdot SiO^2$	$P=31$ $PH^3, PCl^3, PCl^5, P^2O^3, P^2O^5, Ca^2P^2O^7$	$S=32$ $SH^2, SM^2, S^2M^2, SO^2, SO^2X^2, Ba^2SO^4$	$Cl=35,5$ $ClH, ClM, ClCl^2, ClOH, ClO^2H, AgCl.$				
	Рядъ 2.	$K=39$ $KCl, KOH, K^2O, KNO^3, K^2PtCl^6, K^2SiF^6$	$Ca=40$ $CaSO^4, CaOnSiO^2, CaCl^2, CaO, CaCO^2$	$?44=Eb?$	$Ti=48(50?)$ $TiCl^3, TiO^2, Ti^2O^3, FeTiO^3, TiOSO^4$	$V=51$ $VOCl^3, V^2O^3, VO, Pb^2V^2O^7, VO.$	$Cr=52$ $CrCl^3, CrCl^2, Cr^2O^3, CrO^2, K^2CrO^4, CrO^2Cl^2$	$Mn=55$ $MnK^2O, MnKO^4, MnCl^2, MnO, MnO^2$	$Fe=56$ $FeK^2O, FeS^2, FeO, Fe^2O^3, FeK^4Cy^6$	$Co=59$ $CoX^2, CoX^3, CoX^2 \cdot 5NH^3, CoK^2Cy^6$	$Ni=59$ $NiX^2, NiO, NiSO^4 \cdot 6H^2O, NiK^2Cy^4$	$Cu=63$ $CuX, CuX^2, CuH, Cu^2O, CuO, CuKCy^2$
	Рядъ 3.	$Cu=63$ $CuX, CuX^2$	$Zn=65$ $ZnCl^2, ZnO, ZnCO^2, ZnSO^4, ZnEt^2$	$?68=El?$	$?72=Es?$ $?11, EsO^2?$	$As=75$ $AsH^3, AsCl^3, As^4O^6, As^2O^3, As^2S^3$	$Se=78$ $SeH^2, SeO^2, SeO^3, SeM^2, SeM^2O^4$	$Br=80$ $BrH, BrM, BrO^2M, BrAg^*$				
	Рядъ 4.	$Rb=85$ $RbCl, RbOH, Rb^2PtCl^6$	$Sr=87$ $SrCl^2, SrO, SrH^2O^2, SrSO^4, SrCO^2$	$?88=Yt?(92)$ $?Yt^2O^3, YtX^2?$	$Zr=90$ $ZrCl^4, ZrO^2, ZrX^4.$	$Nb=94$ $NbCl^5, Nb^2O^5, Nb^2O^3, NbOK^2F^2$	$Mo=96$ $MoCl^6, MoS^3, MoO^3, M^2MoO^4, nMoO^3$	100	$Ru=104$ $RuO^4, RuCl^4, RuO^2, RuCl^3, RuK^4Cy^6$	$Rh=104$ $RhCl^3, RhCl^2, Rh^2O^3, RhX^2, RhK^2Cy^6$	$Pd=106$ $PdH, PdO, PdI^2, PdCl^2, PdK^2Cy^4$	$Ag=108$ $AgNO^3, AgX, AgCl^2, Ag^2O, AgKCy^2$
	Рядъ 5.	$Ag=108$ $AgX, AgCl^2$	$Cd=112$ $CdCl^2, CdO, CdS, CdSO^4$	$In=113$ $InCl^3, In^2O^3$	$Sn=118$ $SnCl^4, SnCl^2, SnO, SnX^2, SnNa^2O^2$	$Sb=122$ $SbH^3, SbCl^3, Sb^2O^3, Sb^2O^5, Sb^2S^3, SbOX$	$Te=125(?128?)$ $TeH^2, TeCl^2, TeO^2, TeO^2M, TeM^2$	$I=127$ $IH, IAg, IHO^2, IHO, HgI^2, KI$				
	Рядъ 6.	$Cs=133$ $CsCl, CsOH, Cs^2PtCl^6$	$Ba=137$ $BaCl^2, BaH^2O^2, BaO, BaSO^4, BaSiF^6$	$?138=La? = Di?(144)$ $?La^2O^3, LaX^2?$	$Ce=140(138?)$ $CeCl^3, Ce^2O^3, CeO^2, CeX^2, CeX^3, CeK^2X^6$	142	146	148	150	151	152	153
	Рядъ 7.	153	158	160	162	164	166	168				
	Рядъ 8.	175	177	$?177=Er?(169)$ $?Er^2O^3, ErX^2?$	$?180=Di? = La(187)$ $?DiO^2, DiX^2?$	$Ta=182$ $TaCl^5, Ta^2O^5, TaK^2F^5$	$W=184$ $WCl^6, WCl^5, WO^3, K^2WO^4, nWO^3$	190	$Os=193$ $OsO^4, OsH^2O^4, OsCl^3, OsCl^2, OsK^4Cy^6$	$Ir=195$ $K^2IrCl^6, IrCl^3, IrCl^2, Ir^2O^3, IrK^2Cy^6$	$Pt=197$ $PtCl^4, PtO^2, PtCl^2, PtX^2, PtK^2Cy^4$	$Au=197$ $AuCl^3, AuCl, Au^2O^3, Au^3O^4, AuKCy^2$
	Рядъ 9.	$Au=197$ $AuX, AuX^2$	$Hg=200$ $HgCl^2, HgCl^2, Hg^2O, HgO, HgX^2, nHgO$	$Tl=204$ $TlCl^3, Tl^2O, Tl^2O^3, Tl^2SO^4, TlCl^3$	$Pb=207$ $PbCl^2, PbO, PbO^2, PbEt^2, PbSO^4, PbK^2O^3$	$Bi=208$ $BiCl^3, Bi^2O^3, Bi^2O^5, BiX^2, BiOX, BiNO^3(HO)^2$	210	212				
	Рядъ 10.	220	225	227	$Th=231$ $ThCl^4, ThO^2, ThX^4, Th(SO^4)^2$	235	$U=240$ $UCl^4, UO^2, UO^2X^2, UO^2M^2, U^2O^7$	245	246	248	249	250

\* Тѣло твердое, малорастворимое въ водѣ.  
 ^ Тѣло газообразное или летучее.  
 M=K, Ag.... M^2=Ca, Pb....  
 X=Cl, ONO^2, OH, OM.... X^2=SO^2, CO^2, O, S....

# London underground (Harry Beck, 1933)



# **experiential**

structure helps you understand how it behaves not how it's built

# **modular**

components of the structure can be understood independently

# **abstract**

internal workings and structure are not shown

what are the  
elements of  
software?

▲ Jackson structured programming (wikipedia.org)

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

post

session

upvote

favorite

▲ danielnicholas 63 days ago [-]

user: danielnicholas

created: 63 days ago

karma: 11

comment

karma

You might find helpful an annotated version [0] of Hoare's explanation of JSP that I edited for a Michael Jackson festschrift

I'd point to these ideas as worth knowing:

...ing problem that involves traversing structures can be solved very systematically. HTDP addresses this class, but bases code structure only on input structure; JSP synthesized it.

- The archetypal problems that, however you code, can't be pushed under the rug—most notably structure clashes—and just recognizing them
- 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 backtrack standard method, while mentioning that most languages lacked that, so it had to be implemented manually.

reply

▲ CraigJPerry 63 days ago [-]

This is referenced(1) as a core inspiration in the preface to "How to Design Programs" but i never researched it further because i've found the "design recipes" approach in htdp to be pretty solid in real life problems

# but what's a concept? three things it isn't

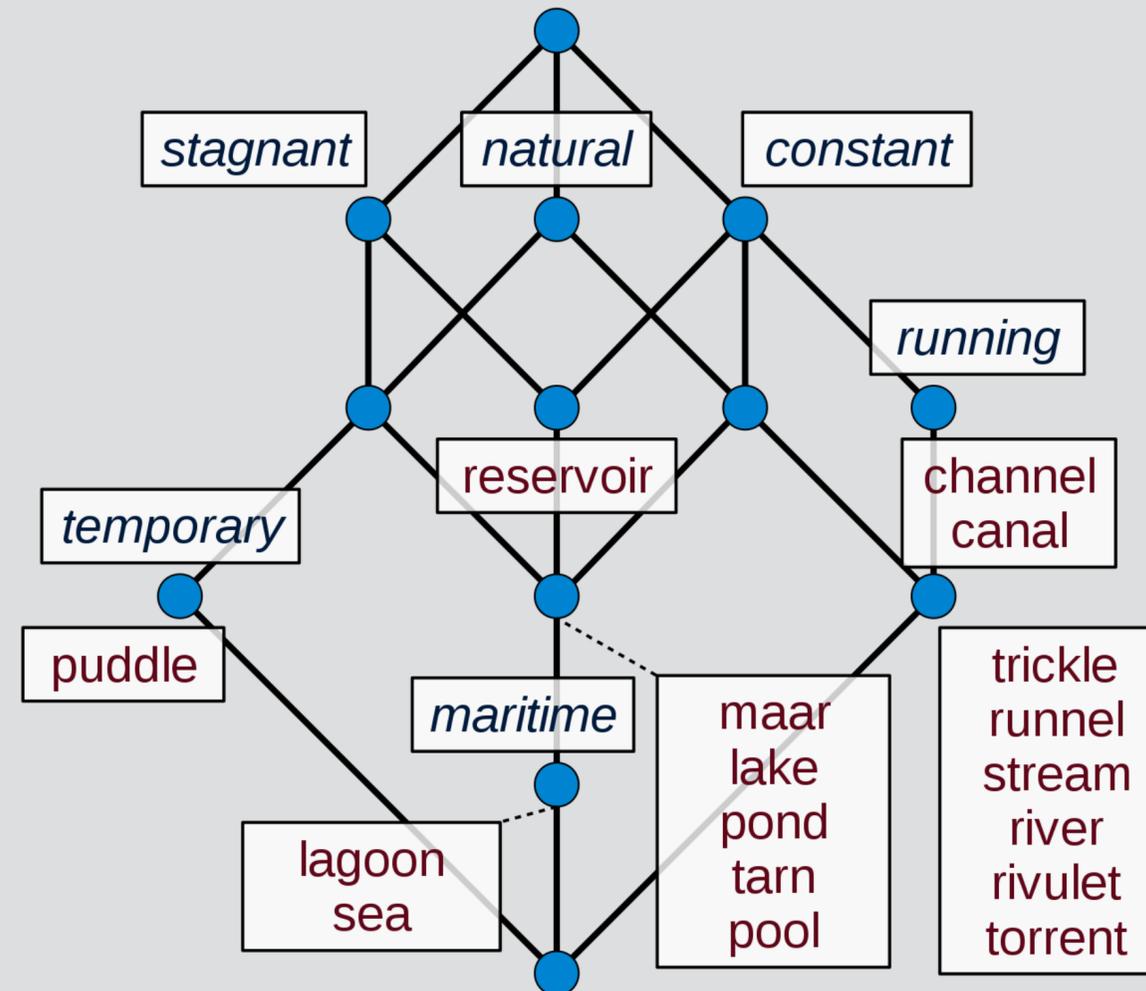
## abstract type, class/object



not limited to built-in types  
encapsulate representation  
defined by operations alone

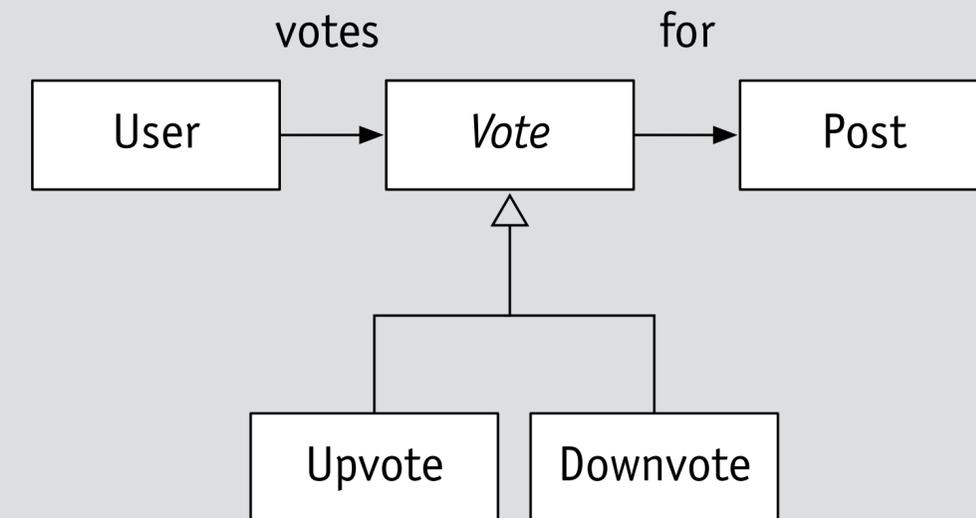
what operations can  
you do on an upvote?

## concept lattice



upvotes and downvotes  
are votes and then what?

## entity in data model



but concept is in the  
relationships, not the entities!

# a concept has a name

**concept** Upvote

same concept in HackerNews,  
NYTimes comment section,  
StackOverflow, etc

**Reader Picks**

All



**John**

Boston | Oct. 27

To protect children? Seems far more likely it's yet one more way to extract personal information to feed the insatiable advertising machines.

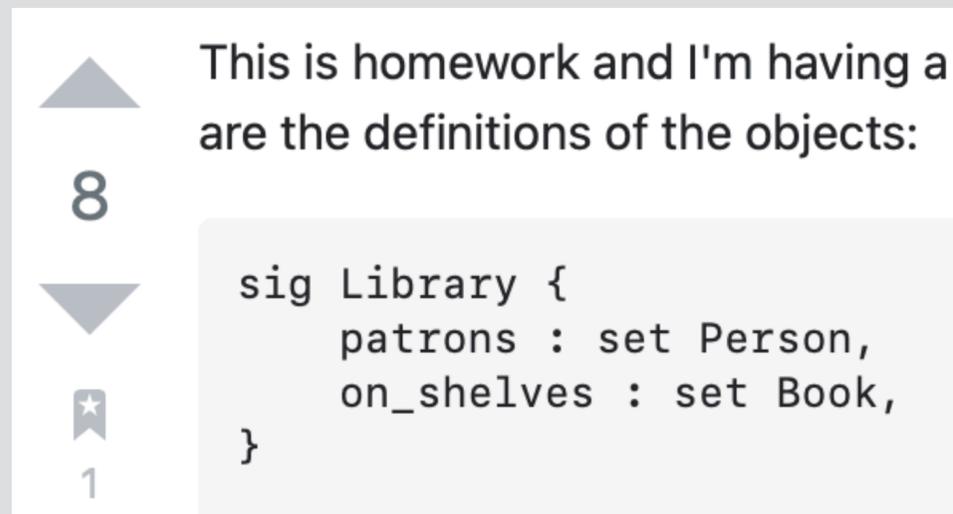
[1 Reply](#) [143 Recommend](#) [Share](#)

[Flag](#)

# a concept has a purpose

**concept** Upvote

**purpose** rank items by popularity



This is homework and I'm having a  
are the definitions of the objects:

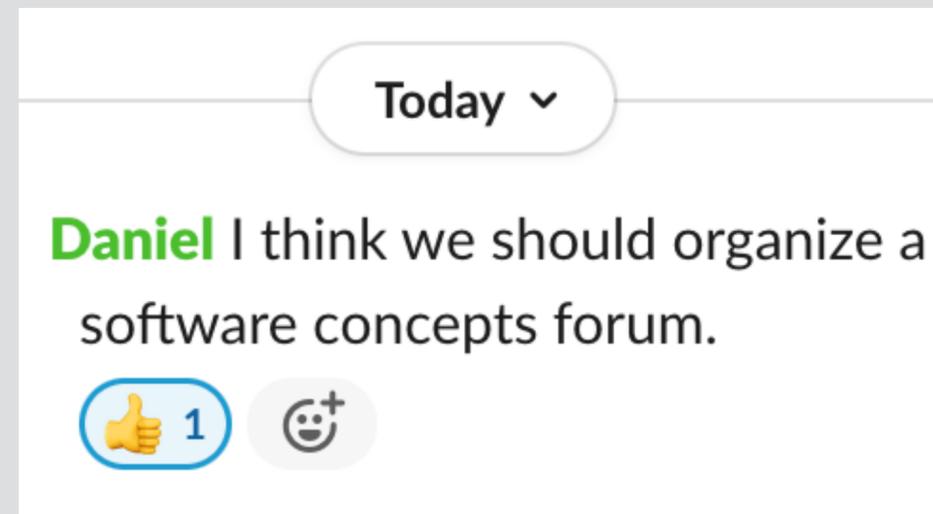
8

```
sig Library {  
  patrons : set Person,  
  on_shelves : set Book,  
}
```

1

**concept** Reaction

**purpose** send reactions to author



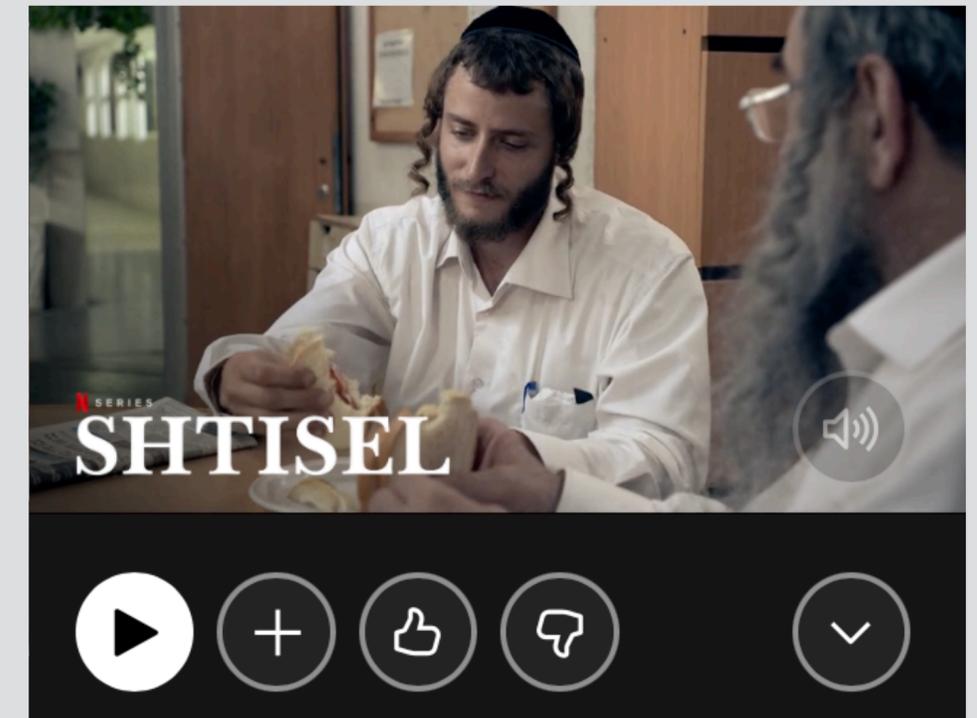
Today ▾

**Daniel** I think we should organize a  
software concepts forum.

👍 1 🗨️

**concept** Recommendation

**purpose** use prior likes to recommend



SHTISEL

🔍 + 👍 🗨️ ▾

# a concept has a state

**concept** Upvote

**purpose** rank items by popularity

**state**

votes: User -> set Vote

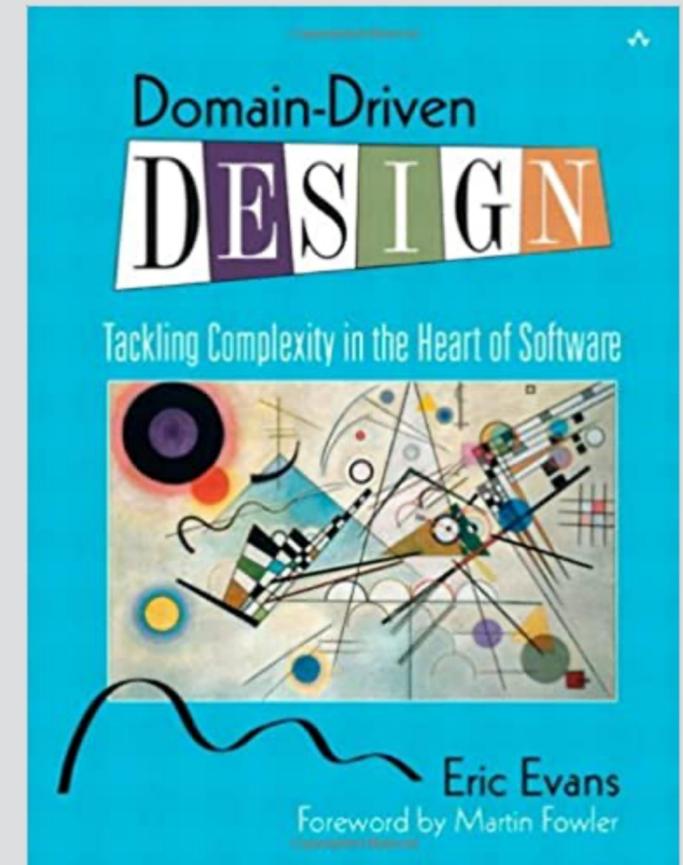
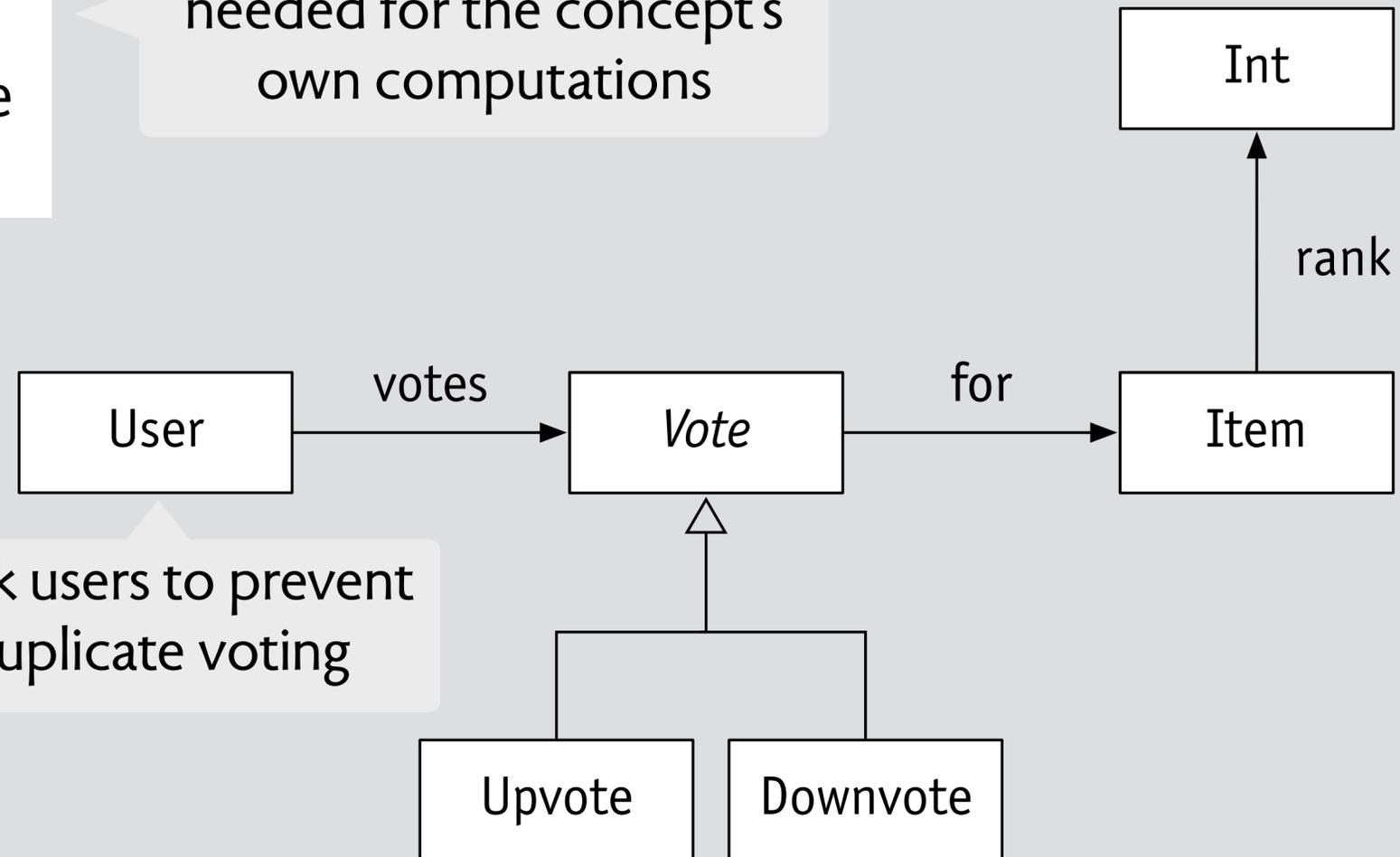
for: Vote -> one Item

Upvote, Downvote: set Vote

rank: Item -> one Int

include in state **only** what's needed for the concept's own computations

track users to prevent duplicate voting



like bounded context in DDD, but even more localized

# a concept has actions

**concept** Upvote

**purpose** rank items by popularity

**state**

votes: User -> set Vote

for: Vote -> one Item

Upvote, Downvote: set Vote

rank: Item -> one Int

**actions**

upvote (u: User, i: Item)

downvote (u: User, i: Item)

unvote (u: User, i: Item)

actions capture the concept  
**behavior in full**

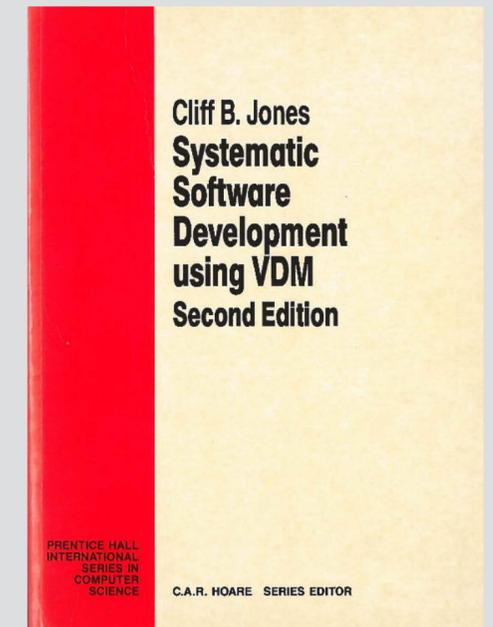
**downvote (i: Item, u: User)**

// no existing Downvote for i in u.votes

// remove any Upvote for i from u.votes

// add a Downvote for i in u.votes

// update i.rank ...



succinct specification  
as actions on states

VDM (1986)

Z (1992)

Larch (1993)

Event-B (2006)

Alloy (2006)

# a concept catalog entry

**concept Upvote**

**related concepts**

Recommendation, Reaction, ...

**design variants**

downvote as unvote  
use age in ranking  
weigh downvotes more

**typical uses**

social media posts  
comments on articles  
Q&A responses



**known issues**

preventing double votes  
(require login, use IP address, save cookie)  
saving storage space  
(freeze old posts and from user info)

**often used with**

Karma, Session, ...

how to  
**compose**  
concepts?

# how to extend behavior?

**concept** Upvote

**actions**

upvote (u: User, i: Item)

downvote (u: User, i: Item)

unvote (u: User, i: Item)

**suppose I want this behavior:**

you can't downvote an item  
until you've received

N upvotes on your own items

**define a new concept!**

a hint: not just used by Upvote

**concept** Karma

**purpose** privilege good users

**state**

karma: User -> one Int

contribs: User -> set Item

**actions**

contribute (u: User, i: Item)

reward (u: User, r: Int)

permit (u: User, r: Int)

**concept** Upvote

**actions**

upvote (u: User, i: Item)

downvote (u: User, i: Item)

unvote (u: User, i: Item)

**when** upvote (u, i)  
**and** i in u'.contribs  
**also** reward (u', 10)

**when** downvote (u, i)  
**also** permit (u, 20)

**concept** Karma

**actions**

contribute (u: User, i: Item)

reward (i: Item, r: Int)

permit (u: User, r: Int)

**concept** Upvote

**concept** Karma

upvote (Bob, post1)

**when** upvote (u, i)  
**also** reward (u, 10)

reward (Alice, 10)

upvote (Carol, post1)

reward (Alice, 10)

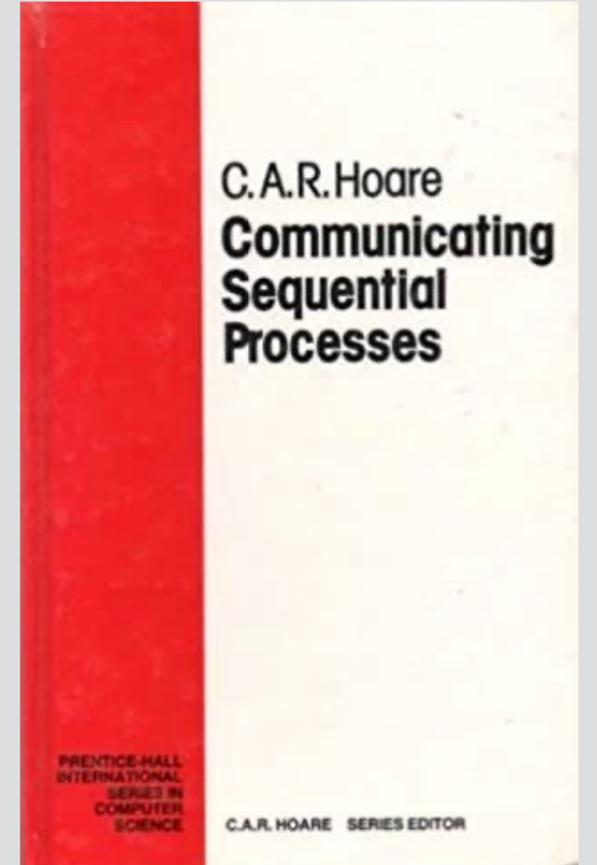
downvote (Alice, post2)

**when** downvote (u, i)  
**also** permit (u, 20)

permit (Alice, 20)

contrib (Alice, post1)

contrib (Bob, post2)

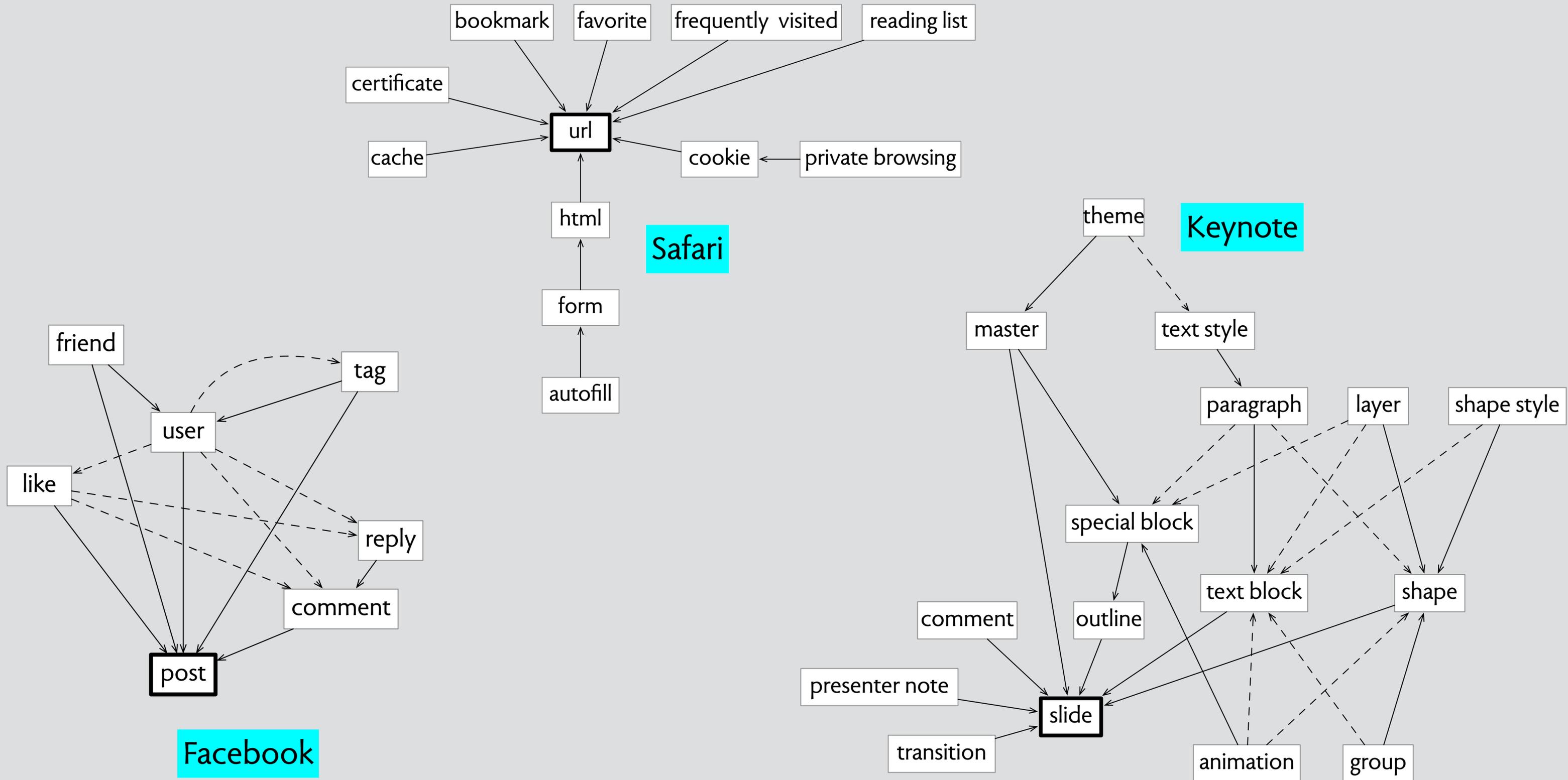


composition uses  
event sync from  
Hoare's CSP

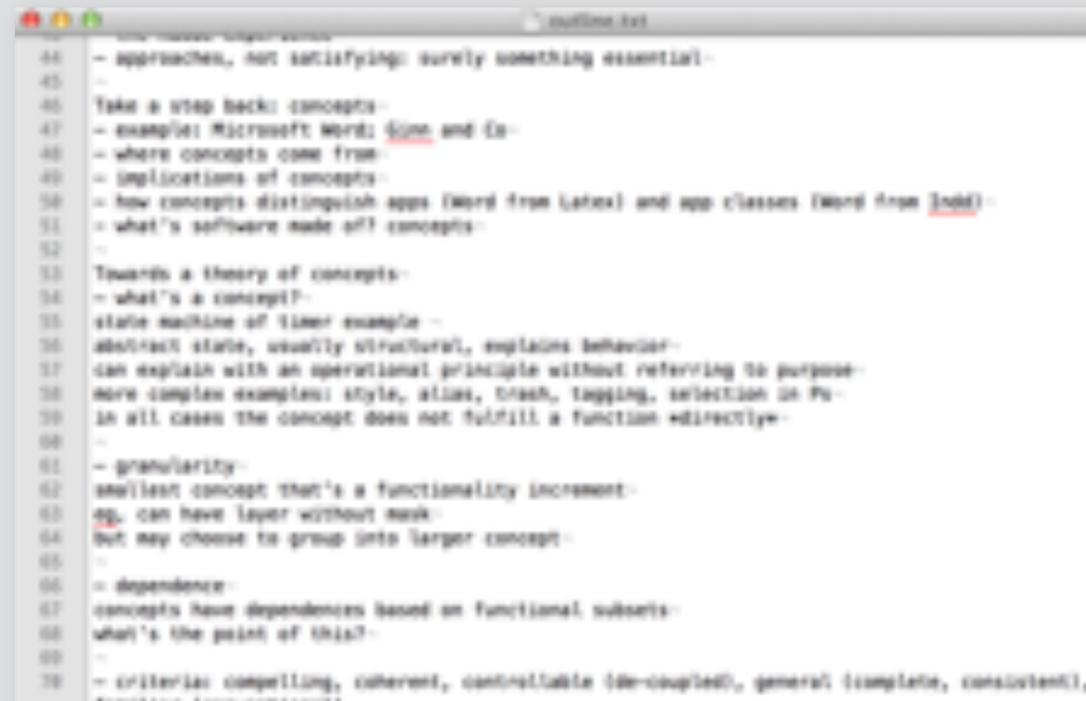
**no concept coupling  
concepts preserve properties**

so what can  
you do with  
concepts?

# characterize apps and families



# characterize apps & families

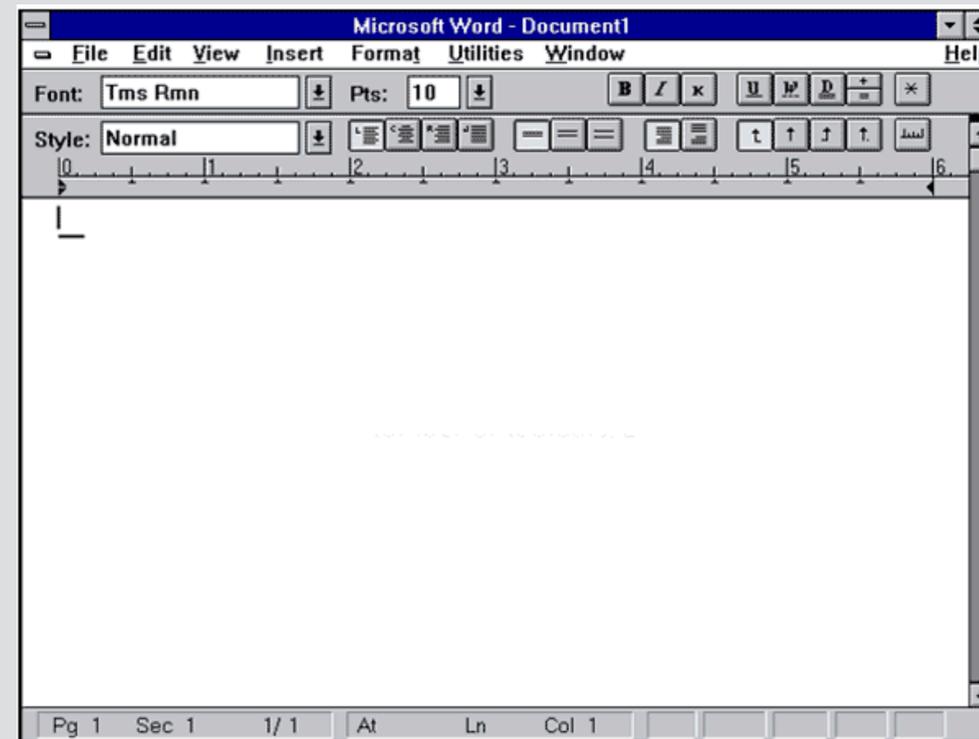


text editor

line

character set

markup

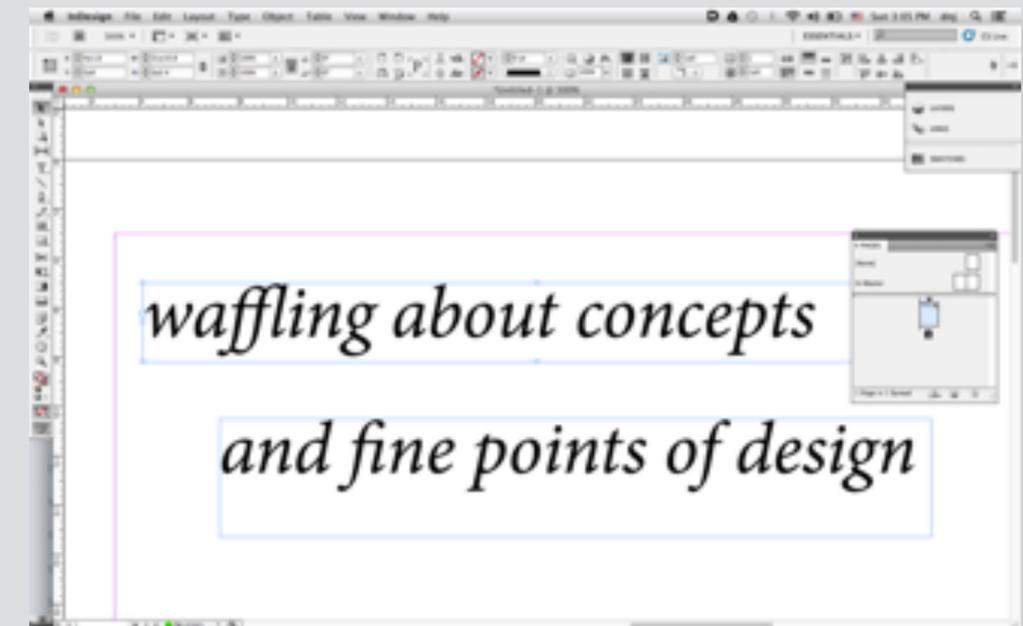


word processor

paragraph

format

style



desktop publishing app

paragraph

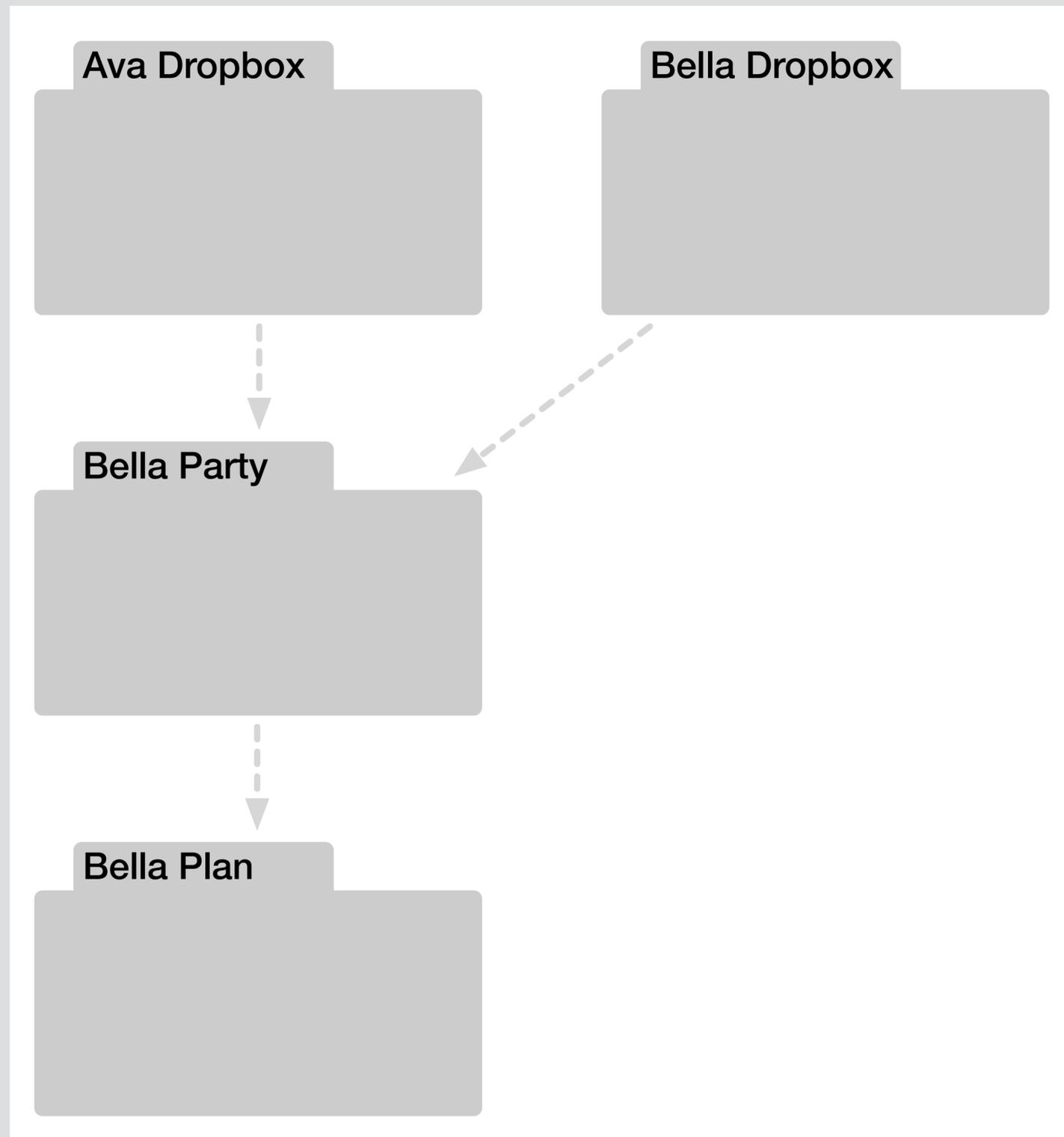
format

style

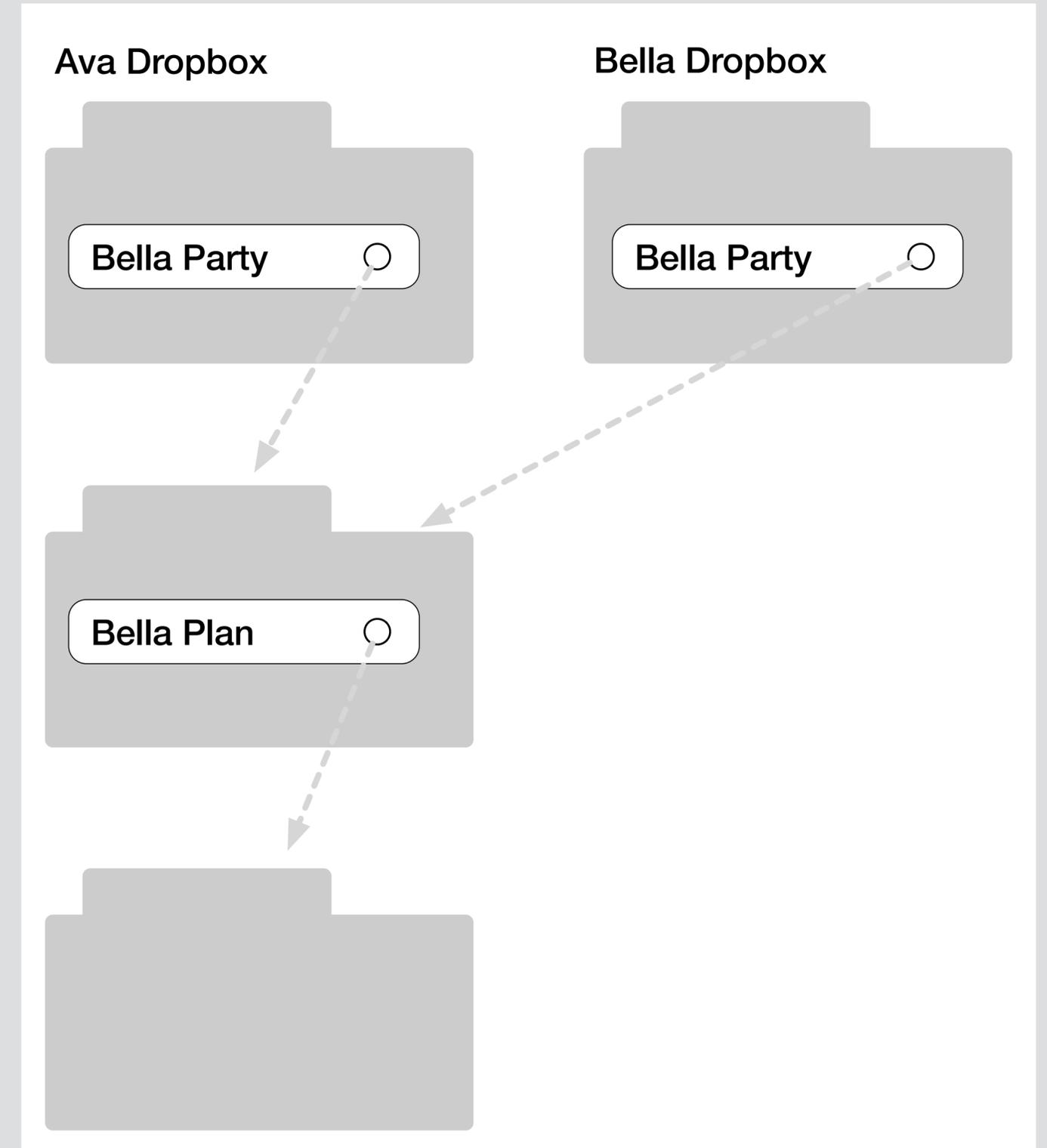
page

textflow

# explore & evaluate individual concepts

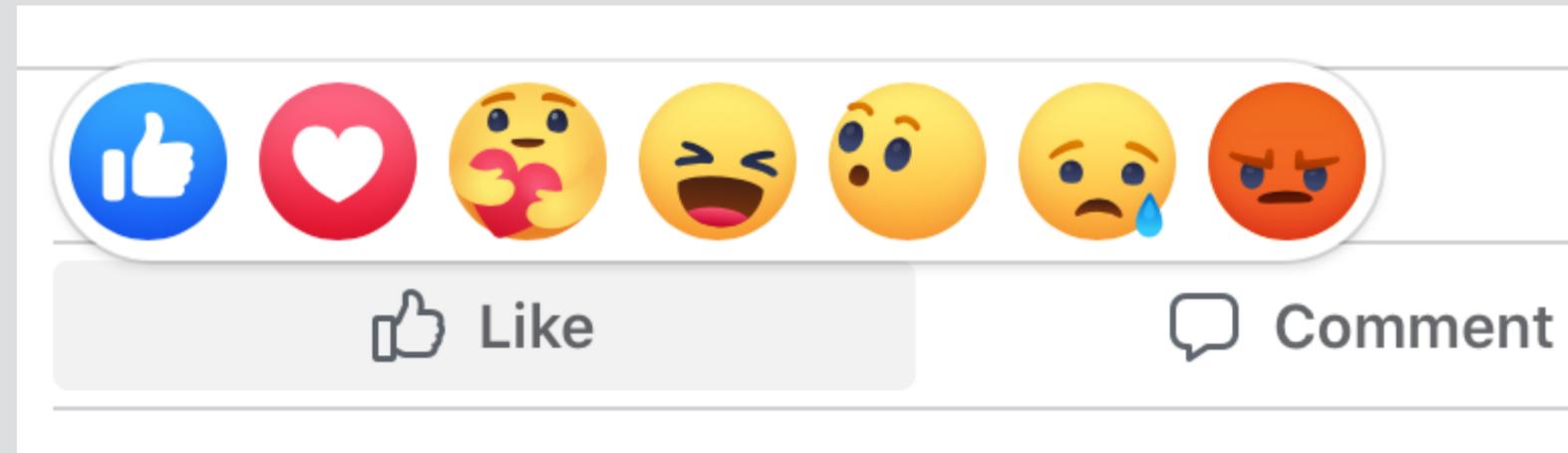


how many users believe the folder concept works



how folders actually work (in Dropbox, Unix, Multics)

# analyze how concepts fit together



**concept** Upvote  
**purpose** rank items by popularity  
**actions**  
upvote (u: User, i: Item)  
...

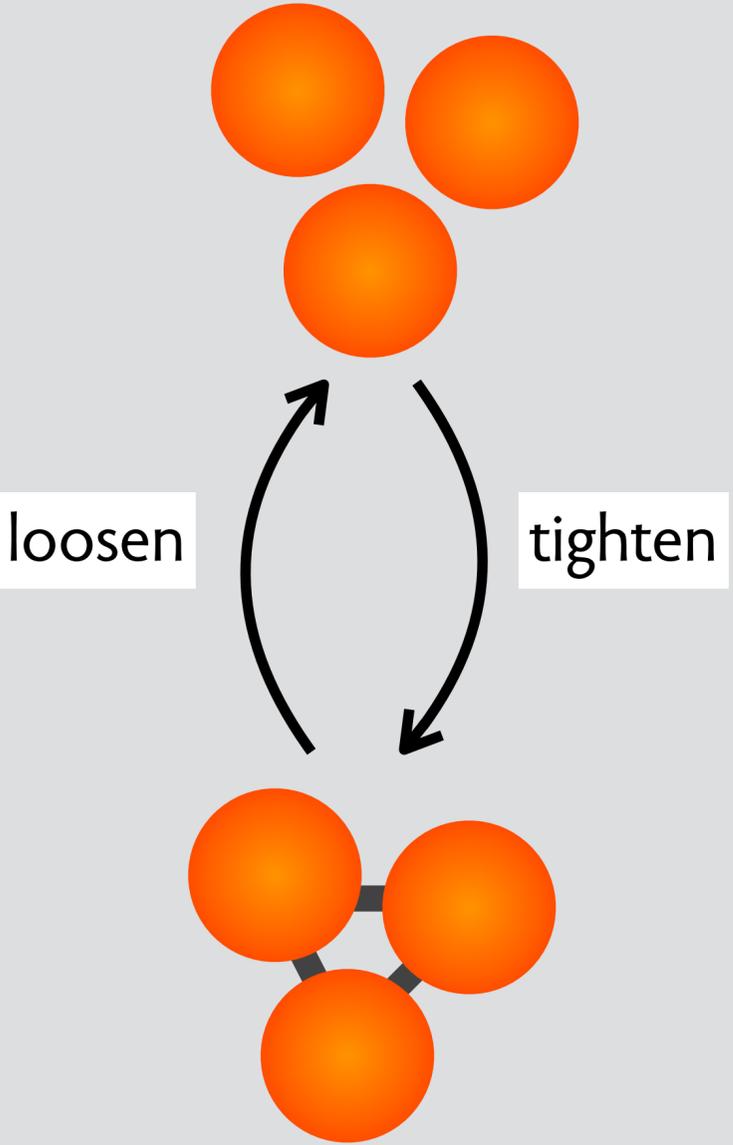
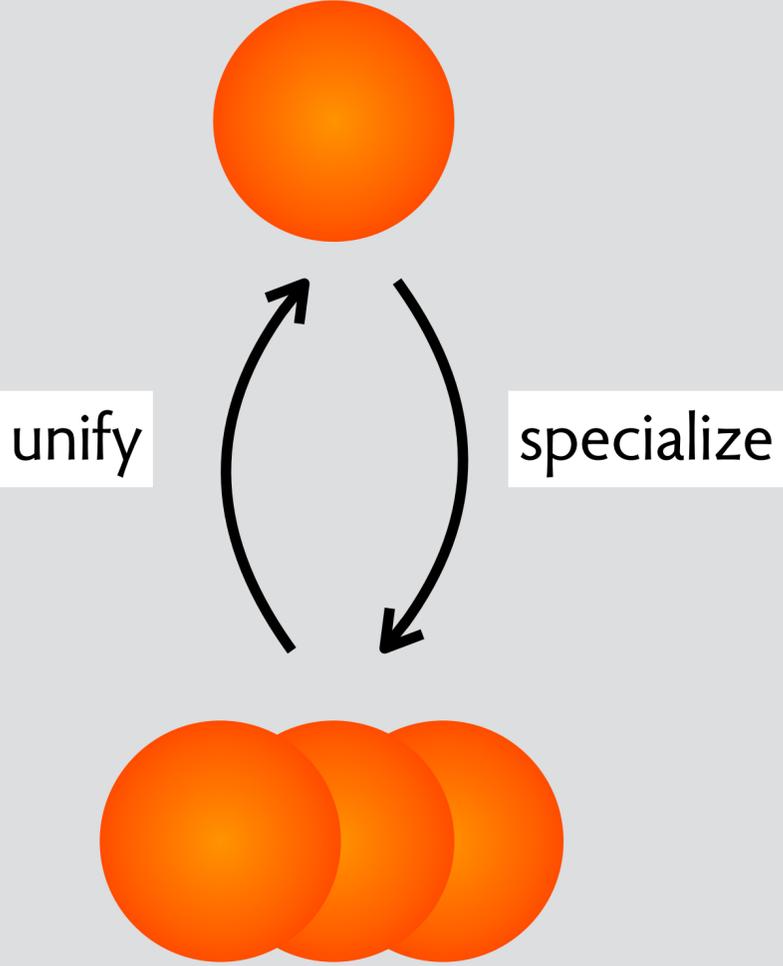
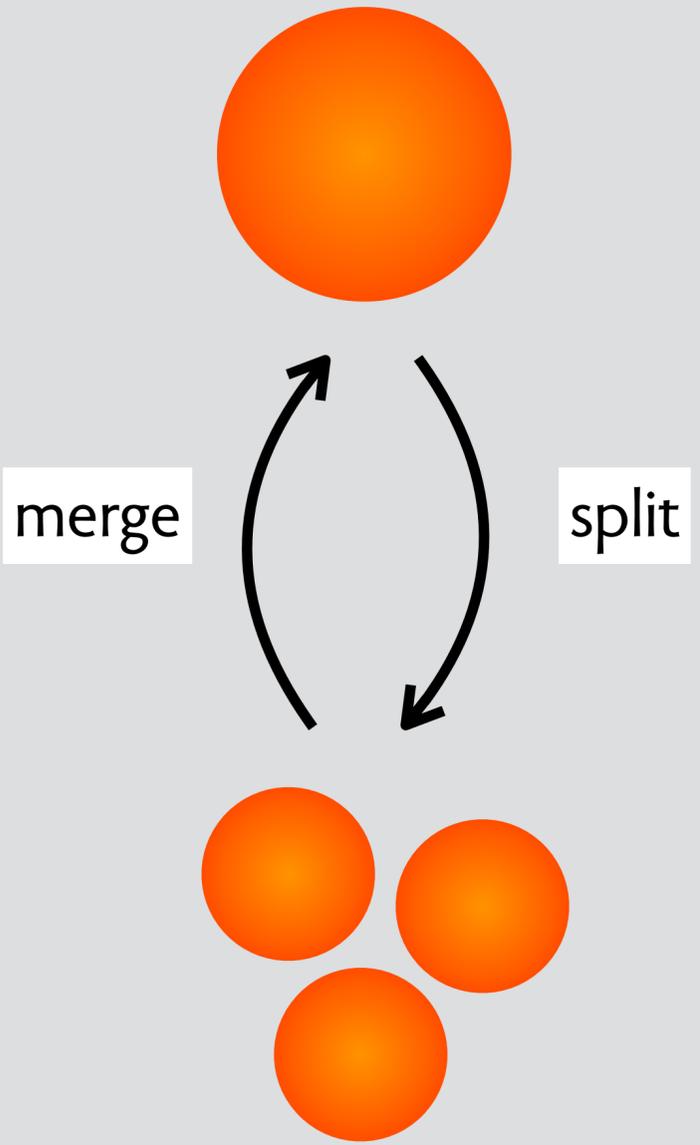


**concept** Reaction  
**purpose** convey emotion to author  
**actions**  
reactAngry (u: User, i: Item)  
...

unwanted  
sync?

**design moves**  
**mechanical analogs**

# three pairs of design moves



# split-merge: tradeoff simplicity/flexibility



photocopier

split



printer + scanner



emergency flashlight

merge



flashlight + battery + charger

# unify-specialize: tradeoff simplicity/specificity



set of wrenches

unify



adjustable wrench

specialize

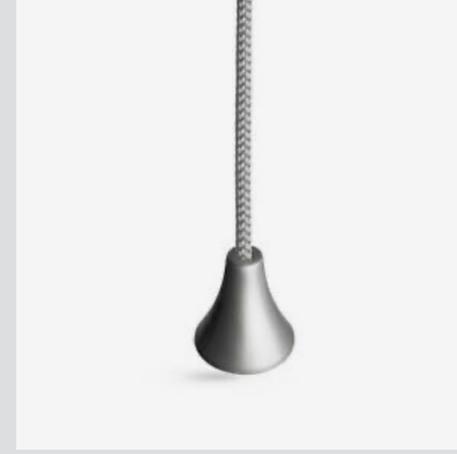


macro lens



general-purpose lens

# tighten-loosen: tradeoff automation/flexibility



tighten



light pull / door lock

airplane toilet lock



loosen

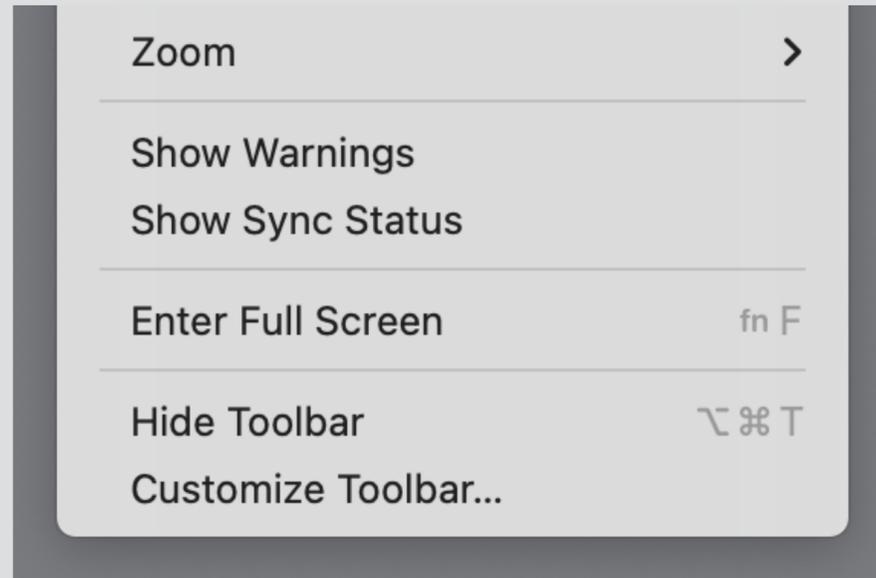


dimmers with separate controls

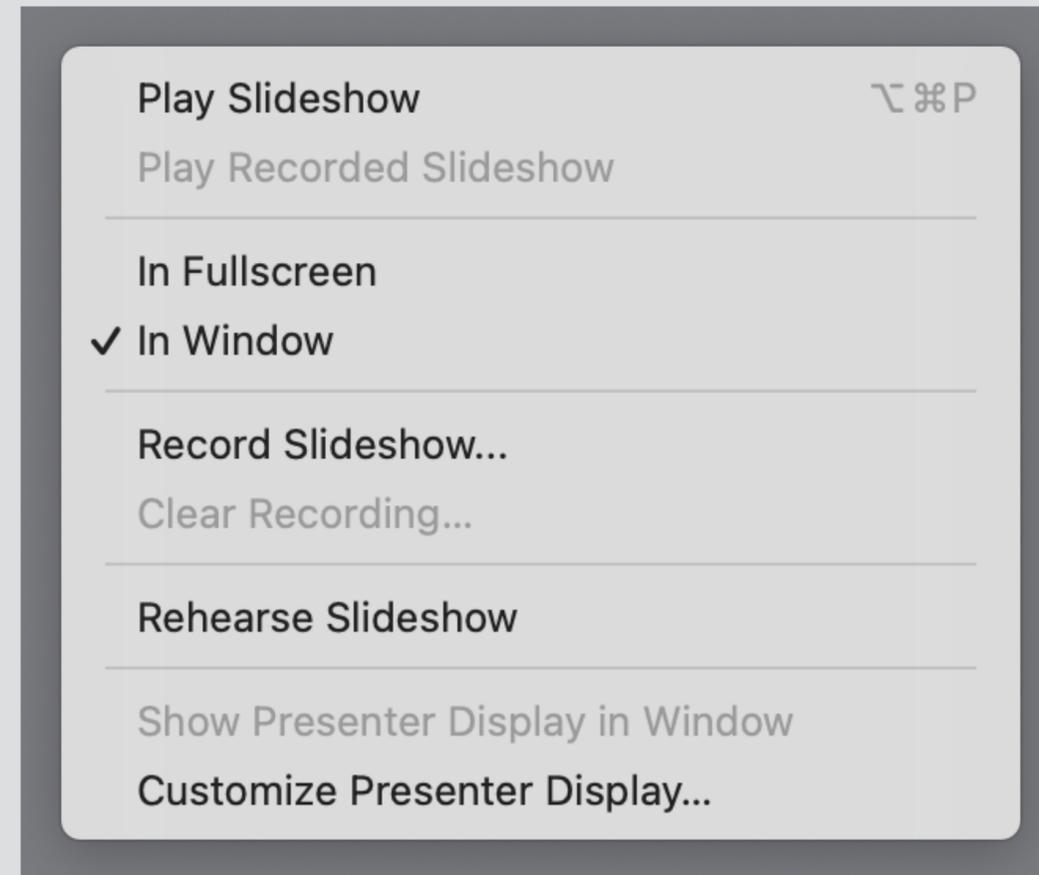
rotary dimmer switch

successful  
design moves  
in software

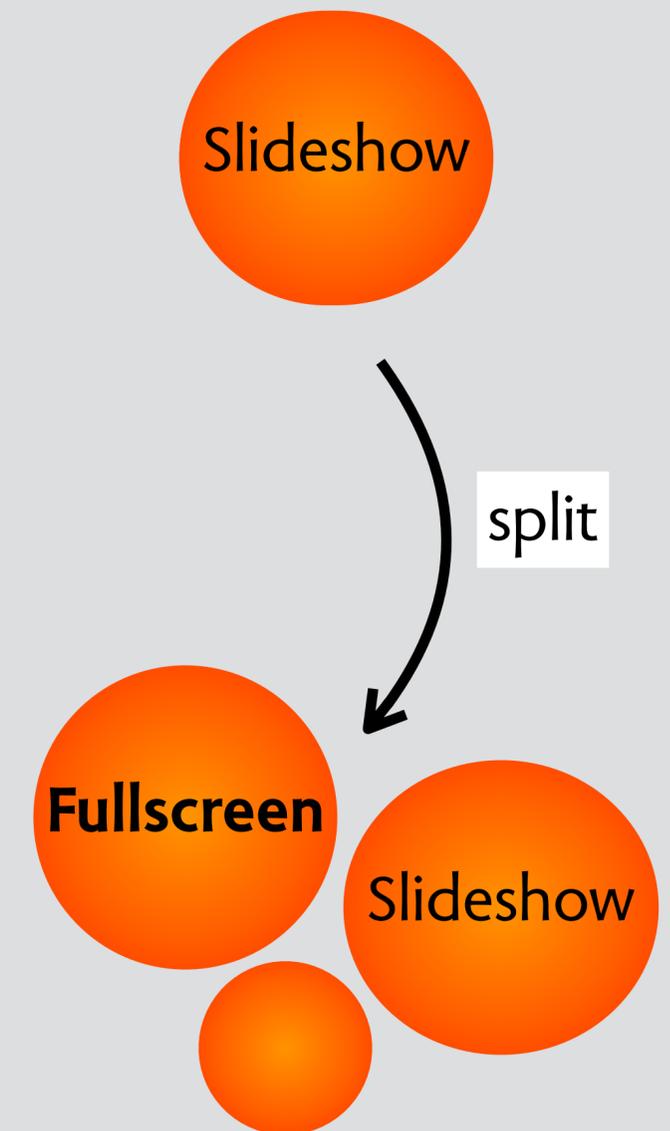
# split: emergence of a concept in Keynote



full screen toggle  
emerges as partial concept  
(c. 2010?)



play-in-window option  
now an independent concept  
(2021)



# unify: subsuming access control in MIT's Moira

can toggle mailing list attribute

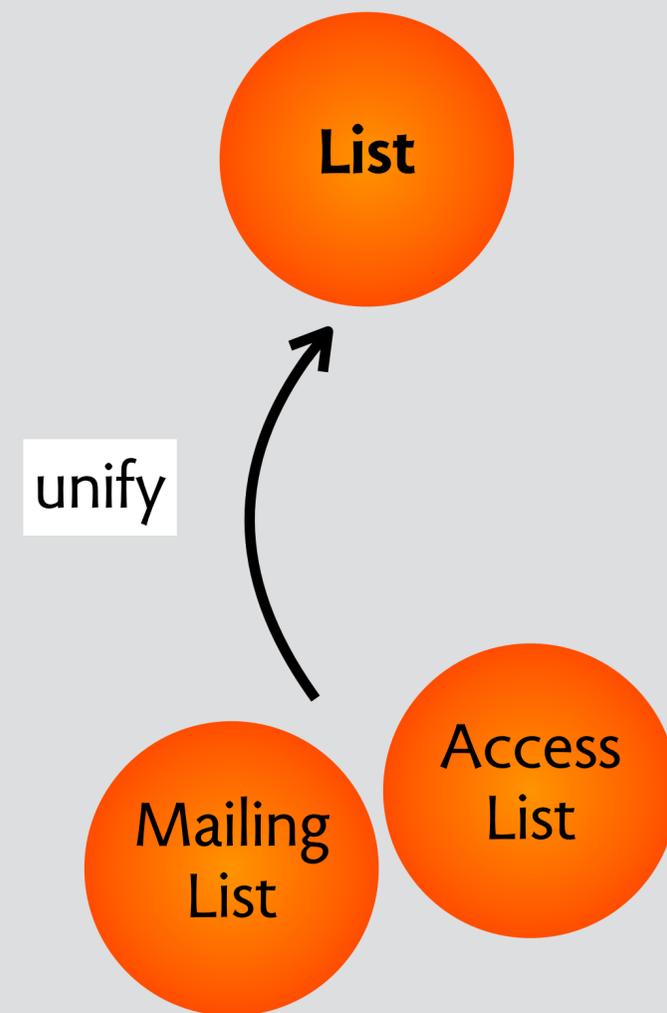
can create admin list with no login users!

**WebMoira List Manager : Daniel Jackson** [Help](#) | [My Lists](#) | [Undo Log \(1\)](#)

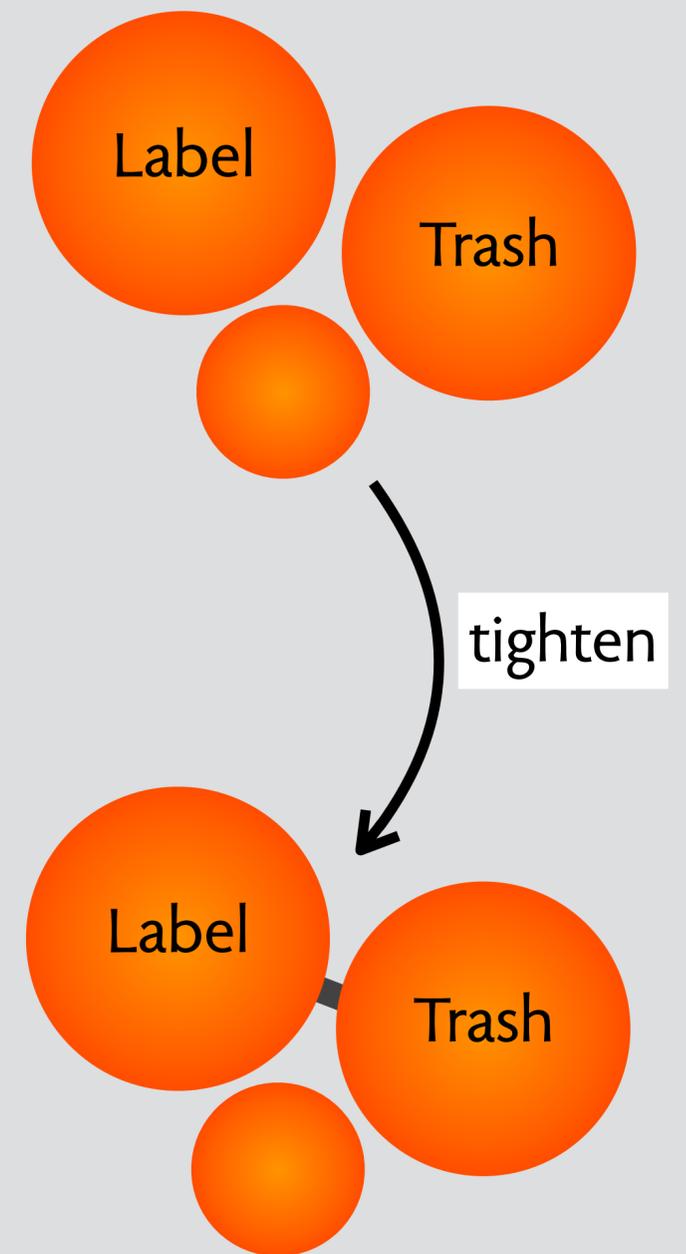
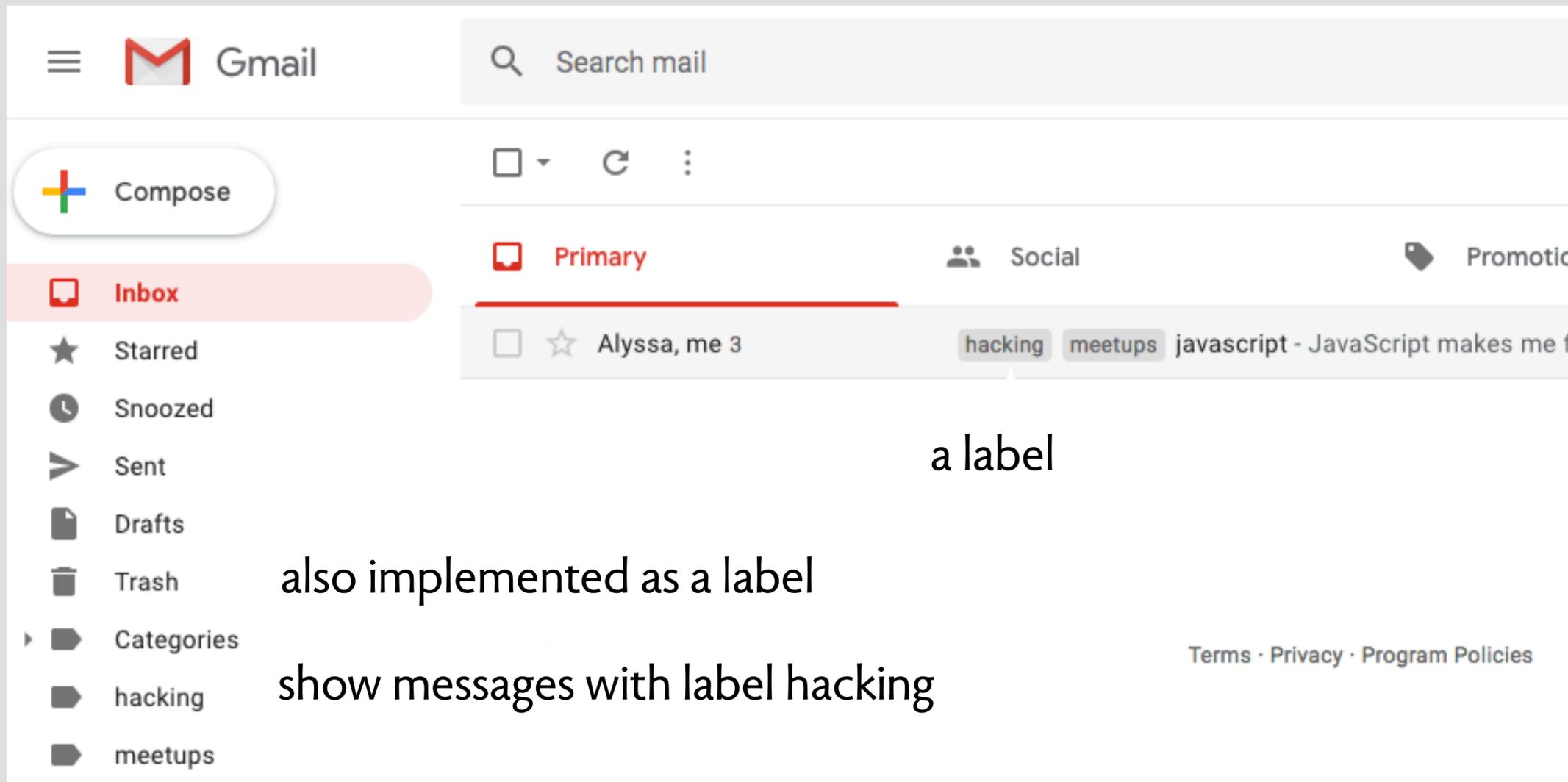
**List Name:** dnj-play1  
**Description:** none  
**Attributes:** active, moira mailing list  
**Permissions:** private, visible  
**Last Modified:** by dnj with moiraws on 22-mar-2022 09:39:00

[Edit](#)

Members	Administrators
<b>Add Member:</b> <input type="text"/> <a href="#">Add</a>	<b>Owner:</b> dnj-play2 (List)
<b>Leave List:</b> <a href="#">Remove Me</a>	<b>Change Owner:</b> <input type="text"/> <a href="#">Change</a>
<b>Add Administrator:</b> <input type="text"/> <a href="#">Add</a>	<b>Leave Owner List:</b> <a href="#">Remove Me</a>
<b>MIT Users</b>	<b>MIT Users</b>
Daniel Jackson (dnj) <a href="#">remove</a>	Daniel Jackson (dnj) <a href="#">remove</a>
<b>Email Addresses</b>	
daniel@dnj.photo <a href="#">remove</a>	



# tighten: label and trash concepts in Gmail





**concept** trash

**purpose** undo deletion

**structure**

trash: **set** Item

**actions**

delete (i: Item)

restore (i: Item)

empty ()



**concept** label

**purpose** organize with overlapping

**structure**

labels: Item -> **set** Label

**actions**

add (i: Item, l: Label)

remove (i: Item, l: Label)

find (ls: **set** Label, **out** is: **set** Item)

**when** delete (i)  
**also** add (i, 'trash')



# integrating these concepts is tricky

click on trash

1-2 of 2

[Empty Trash now](#) (messages that have been in Trash more than 30 days will be automatically deleted)

<input type="checkbox"/>		me, Alyssa (13)	hacking	meetups	todo	javascript - Hello a	11:48 am
<input type="checkbox"/>		Andy from Google	Updates	Ben, welcome to your new Googl			9:01 am

filter on todo label

label:todo

There are no conversations with this label.

filter on todo and trash

label:todo label:trash

1-1 of 1

<input type="checkbox"/>		me, Alyssa	Trash	hacking	meetups	todo	javascript -	10:11 am
--------------------------	--	------------	-------	---------	---------	------	--------------	----------

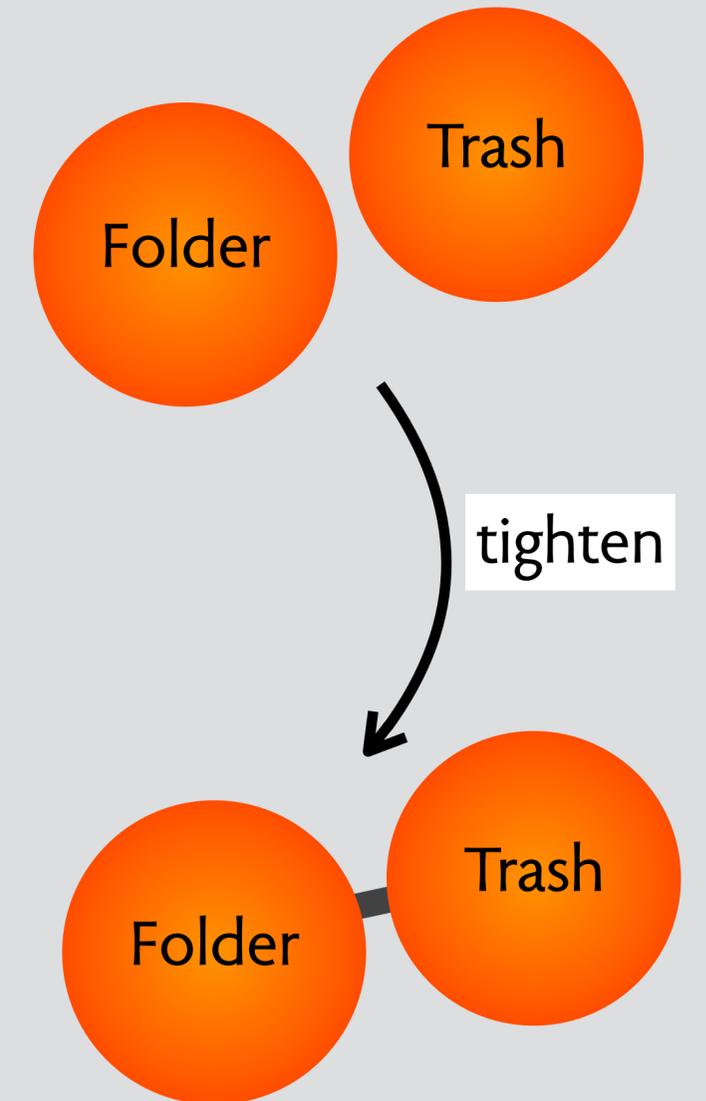
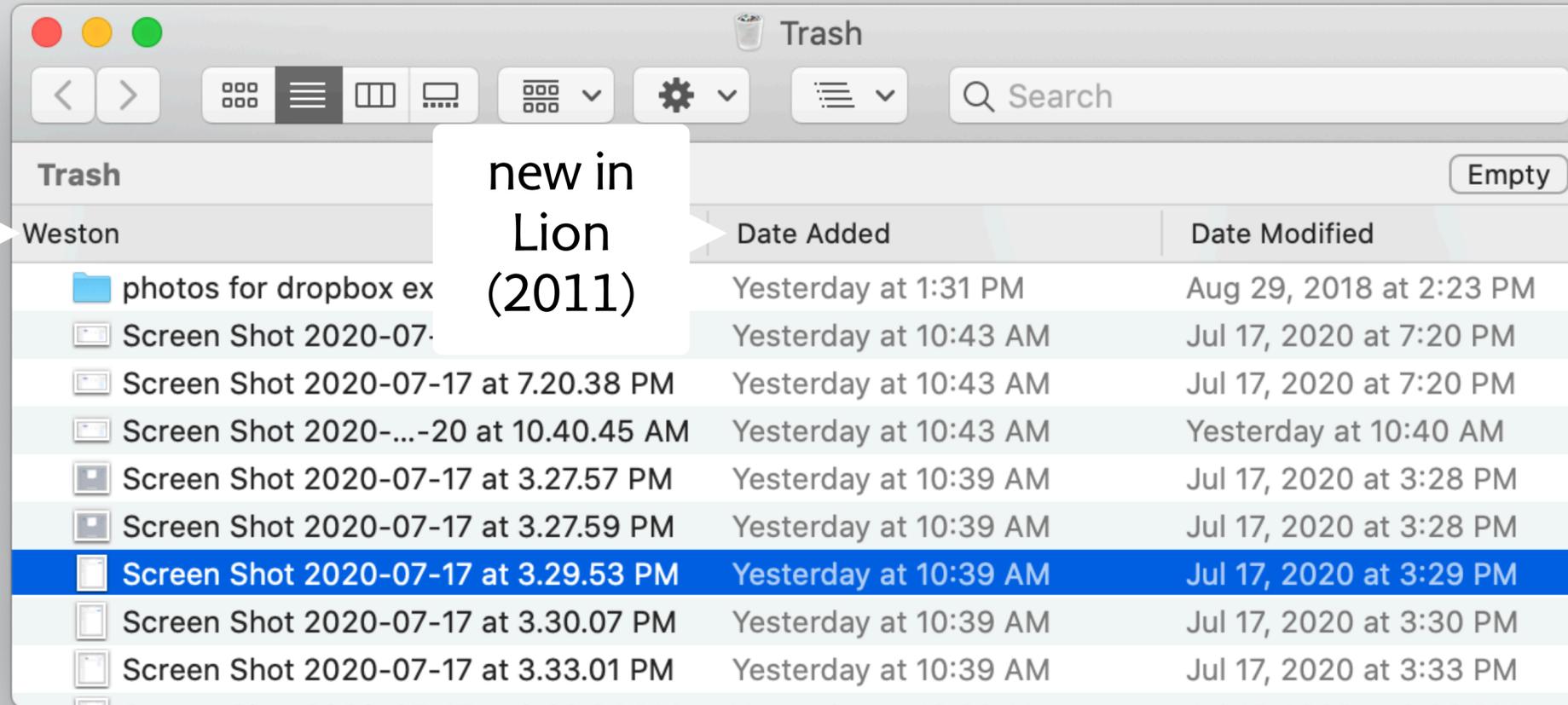
filter on something else

label:todo OR label:meetup

Some messages in Trash or Spam match your search. [View messages.](#)

# a beautiful (but tricky) synergy

folder sortable by volume!



design moves  
in response to  
problems

**aspect ratio**  
**in fujifilm cameras**

# a lovely camera fuji x100



# complex menu system: image quality setting



# aspect ratio



# image size setting



non-standard ratio + raw?



problem #1: no non-standard ratio unless also save JPG!



raw image showing non-destructive aspect ratio crop

# problem #2: very few ratio options

change.org

Petition details Comments Updates



**Fuji, give us 4:3, 5:4, and 6:7 aspect ratios on X-series cameras**

636 have signed. Let's get to 1,000!



At 1,000 signatures, this petition is more likely to be featured in recommendations!

L	3:2	664
L	16:9	681
L	1:1	702
M	3:2	707
M	16:9	719
M	1:1	734
S	3:2	746

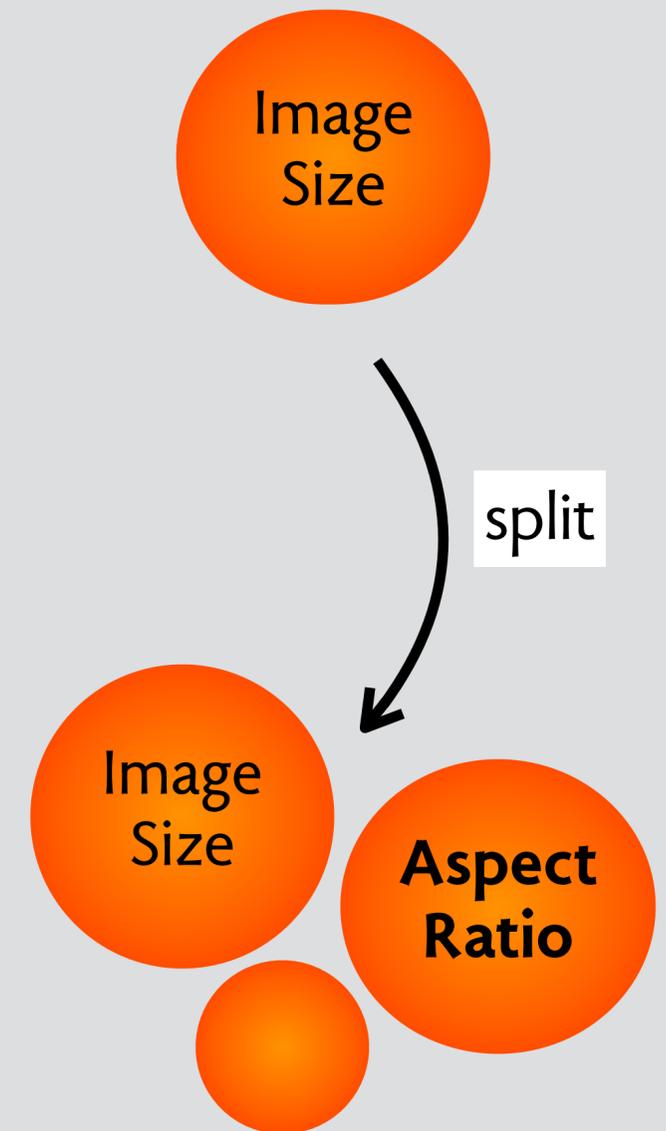
# diagnosis?

## **aspect ratio is not a concept**

merged into JPEG image size concept  
so cannot be controlled independently  
I call this "overloading by piggybacking"

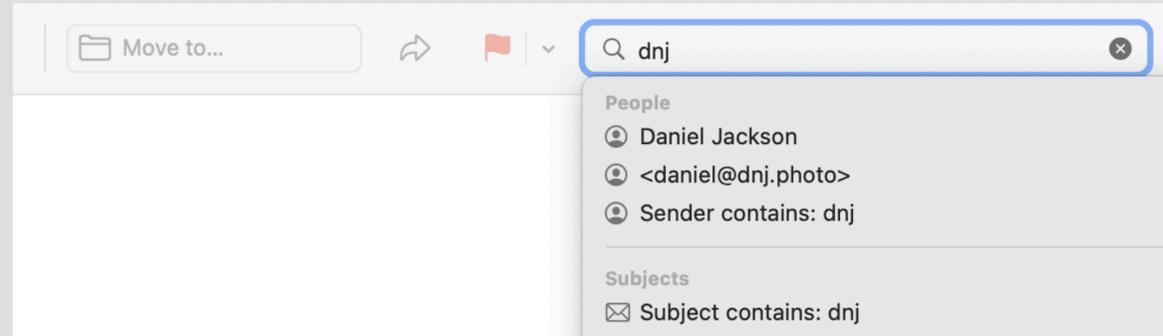
## **solution: split concepts**

would allow ratio change to raws without JPEGs  
would avoid combinatoric explosion of options

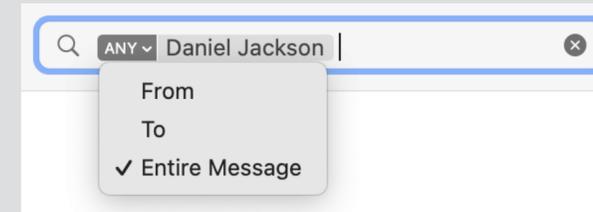


message filters  
in apple mail

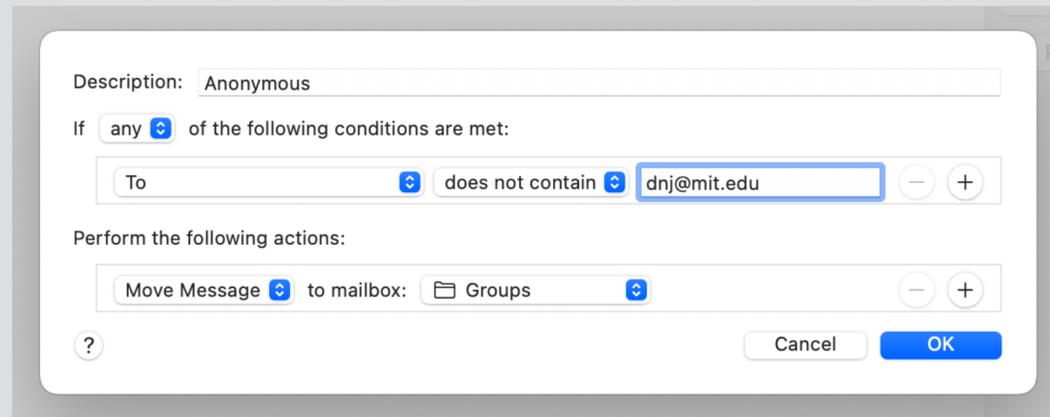
# how many ways to filter messages?



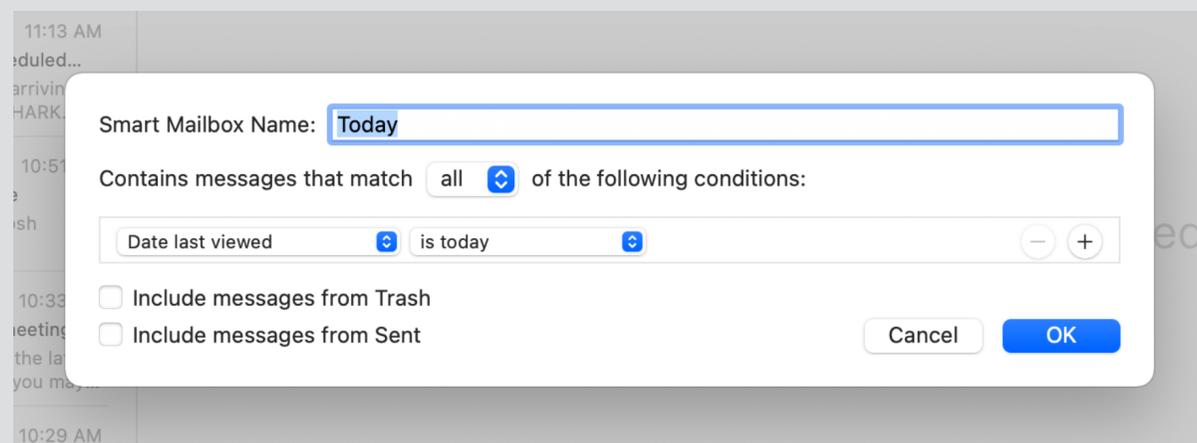
search for a message



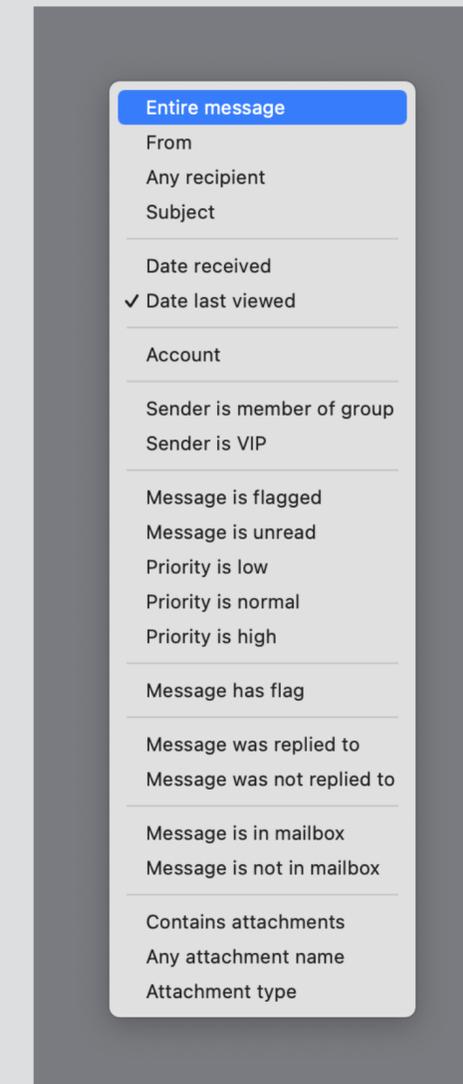
search options



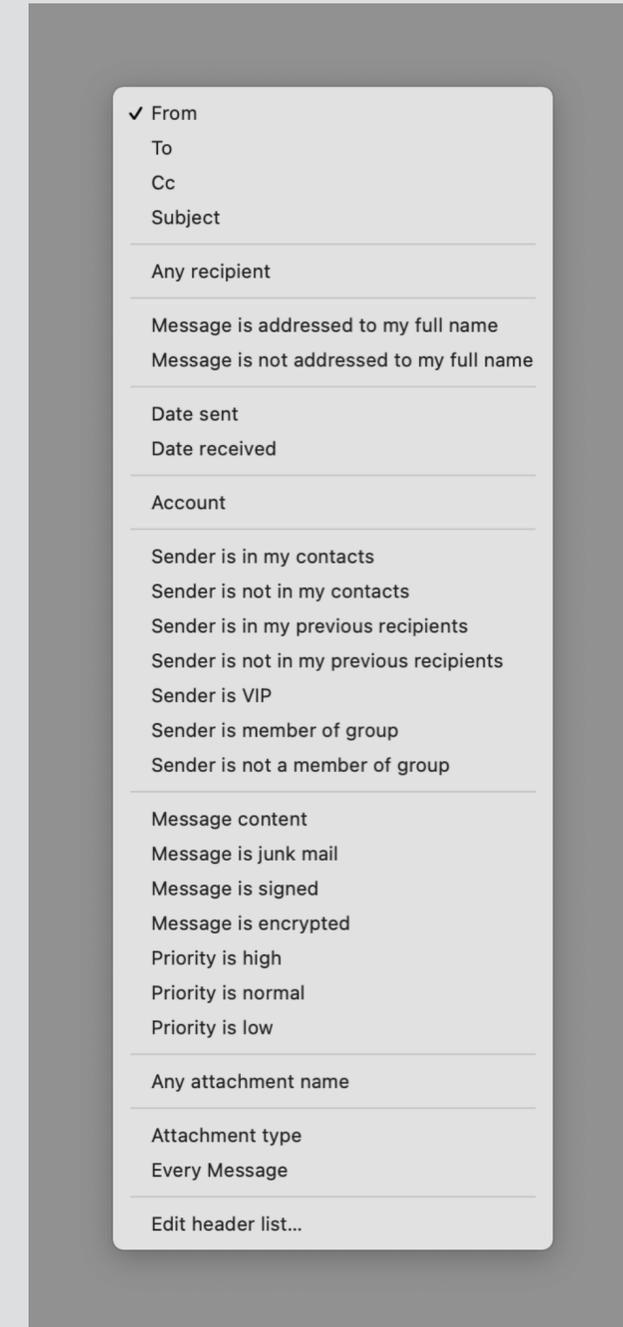
create a rule



define a smart folder



smart folder options



rule options

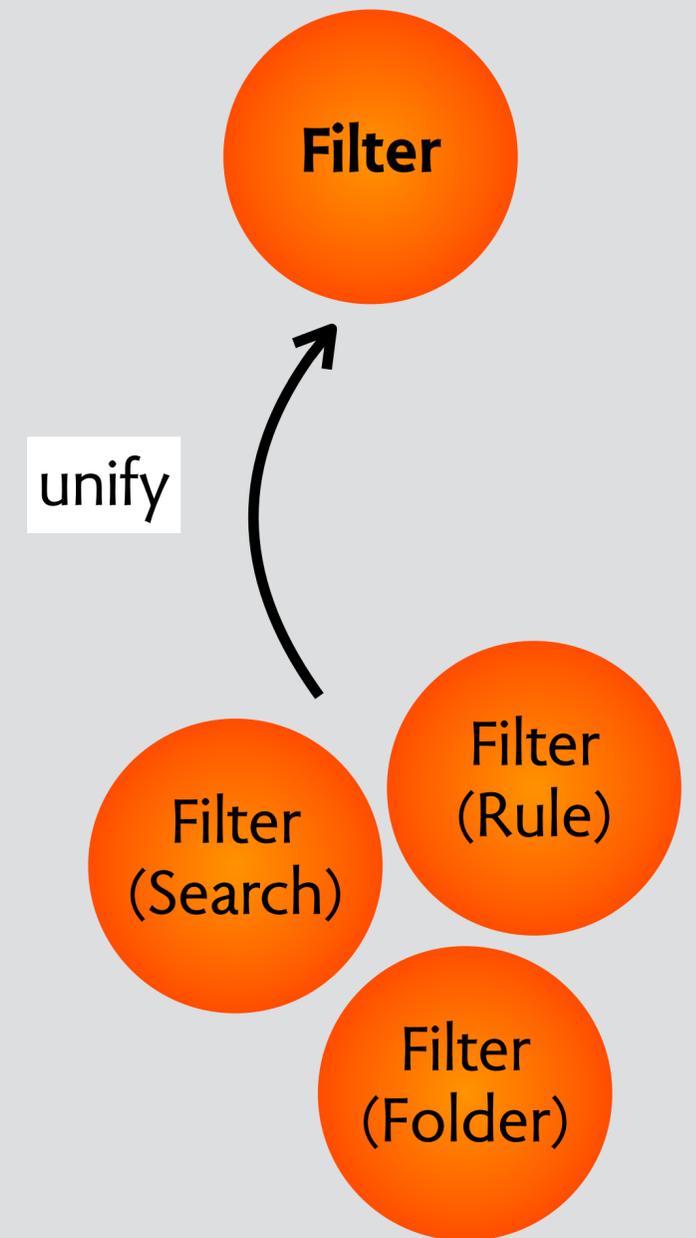
# diagnosis?

## **search, rule and smart folder**

all include their own specialized concepts  
incomparable features, different UIs

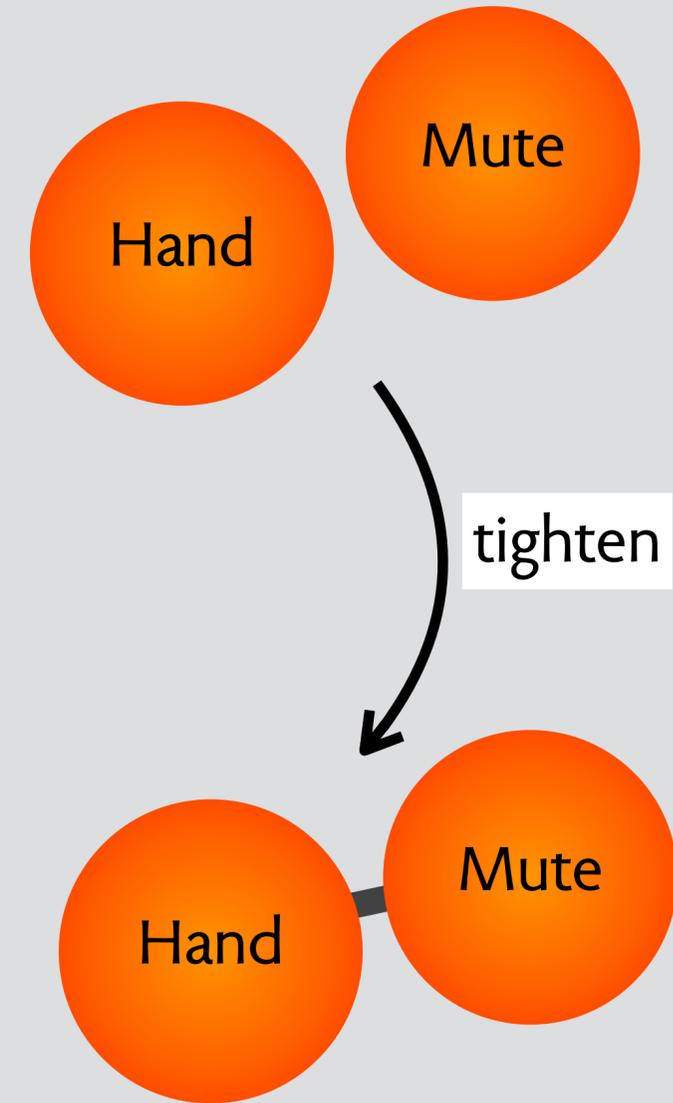
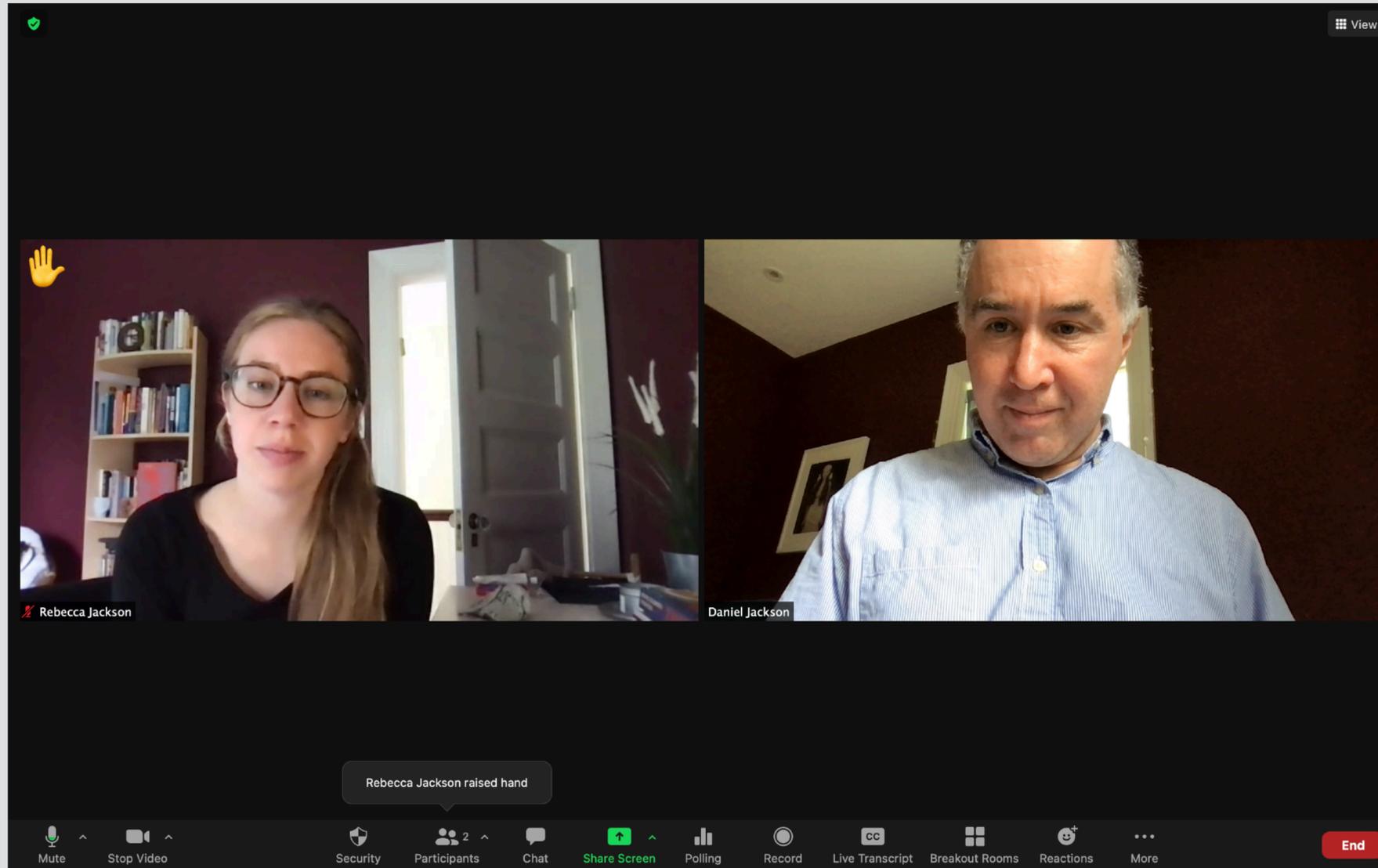
## **unify in a single message filter concept**

include "create folder from search", eg



**sticky hands  
in zoom**

# zoom



**event deletion  
in google calendar**



**Arvind Satyanarayan**

November 15, 2018 at 2:04 PM

Re: TALK: Monday 11-19-2018 Kanit (Ham) Wongsuphasawat: No...

[Details](#)

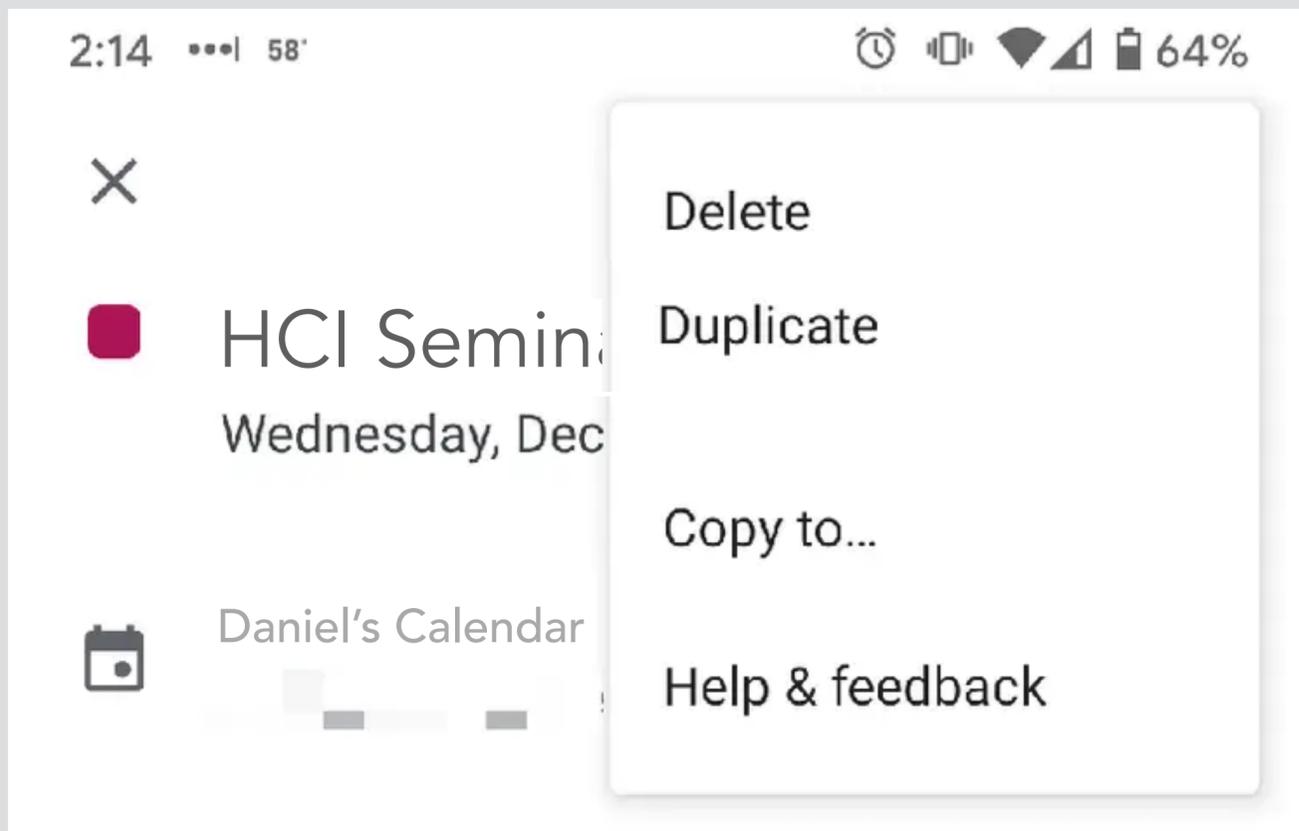
Cc: seminars@csail.mit.edu, HCI-Seminar@lists.csail.mit.edu



This message is from a mailing list.

[Unsubscribe](#) 

Despite some erroneous messages sent to this list accidentally, Kanit's talk is happening!  
Please join us on Monday.



Canceling and deleting events in the Google Calendar mobile app is similar to on a desktop.

1. First, open Google Calendar.
2. Tap on the event you wish to cancel.
3. Press on the three dots in the top right corner of the event window.
4. Select Delete.
5. Tap Delete event. Google Calendar will send a cancellation email to the guests.

Mar 22, 2021

<https://wpamelia.com> › Blog

[How to Cancel an Event in Google Calendar - Amelia booking ...](#)





### **Are you sure you want to delete this event?**

Deleting this meeting will remove it from your calendar and notify the invitees that this event has been deleted. You can't undo this action.

Cancel

Delete

**a long time problem in iCal too**  
how to delete spam calendar events?

# diagnosis?



**concept** calendar  
**purpose** record engagements  
**actions**  
createEvent (...): Event  
deleteEvent (e: Event)  
...



**concept** invitation  
**purpose** coordinate events  
**actions**  
accept (e: Event)  
decline (e: Event)  
...

unwanted  
sync!

# apple's solution



**Are you sure you want to delete this event?**

Deleting this event will notify the organizer that you're declining the event and deleting it from your calendar. You can't undo this action.

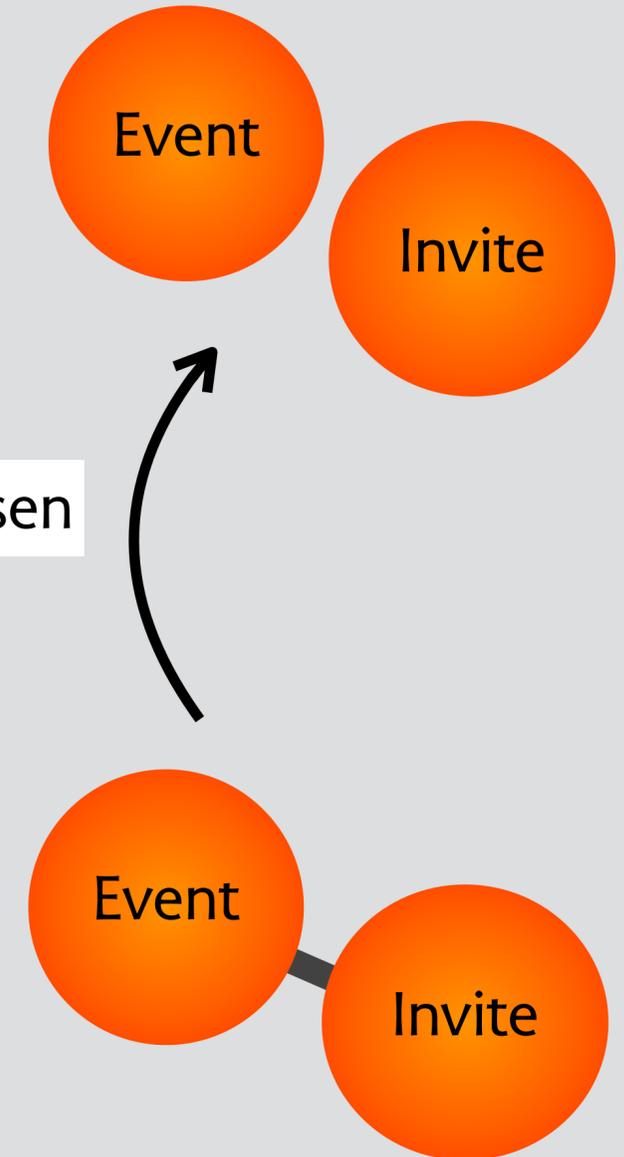
Cancel

Delete and Don't Notify

Delete and Notify

**resolution to design problem**  
make sync optional

loosen



# takeaways

## **structure your software design with concepts**

inventory the concepts, identify the critical ones  
see if you can describe them fully independently  
then formulate interactions as synchronizations

## **apply design moves to explore new options**

never a panacea, always a tradeoff

## **software concepts as patterns**

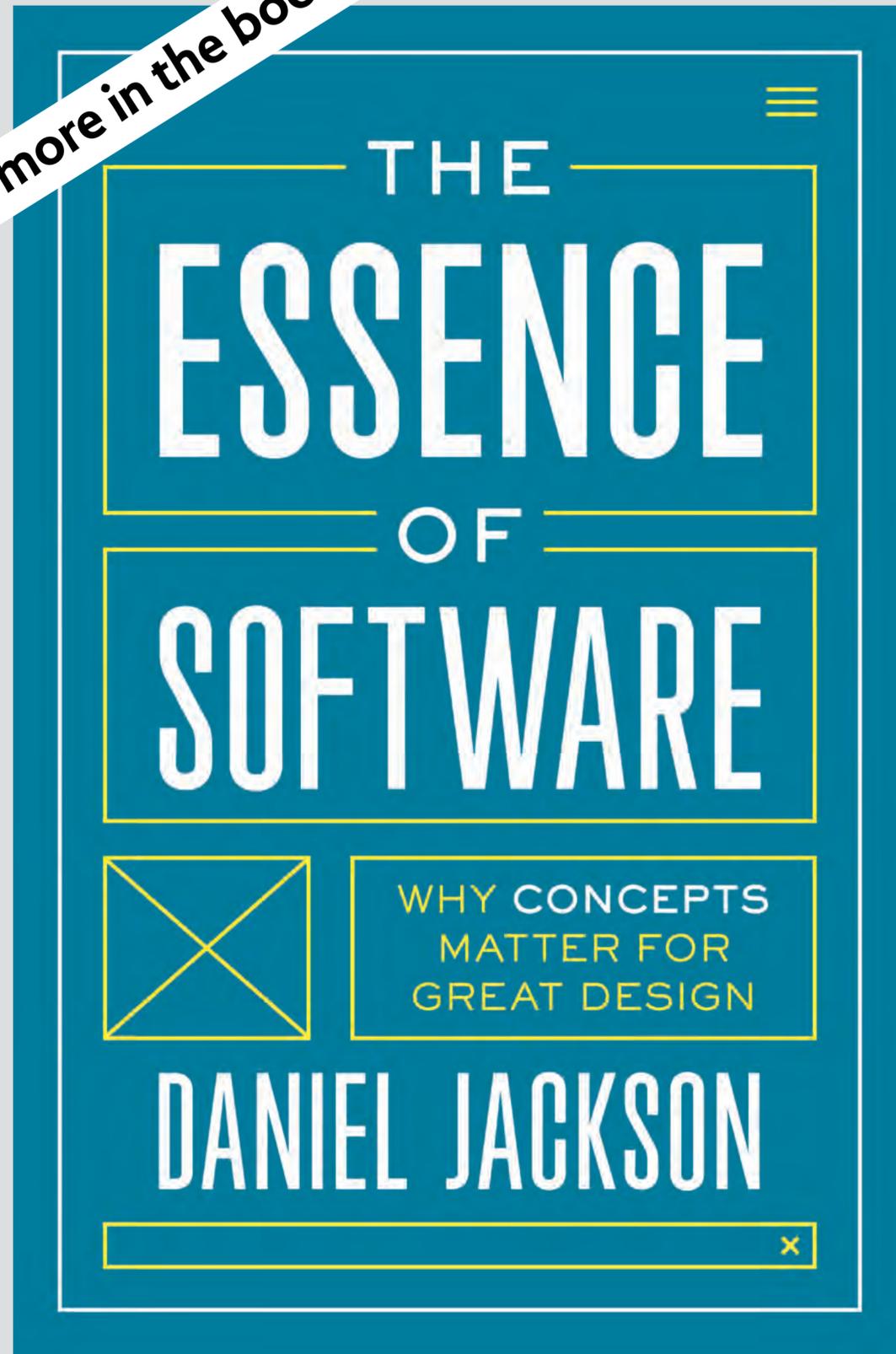
only hinted at this, but equally important  
don't reinvent the wheel!

express your design as sync of familiar concepts?

## **in formal methods**

can concepts help structure & validate models?

**much more in the book**



**[essenceofsoftware.com](http://essenceofsoftware.com)**

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about concept design!  
**[forum.softwareconcepts.io](http://forum.softwareconcepts.io)**