

SWE 621

SPRING 2021

DESIGN FOR CHANGE

LOGISTICS

- ▶ Midterm grades will be posted later this week
- ▶ HW3 due next week
- ▶ Lecture slides for today are posted on course website

IN CLASS EXERCISE

- ▶ What's an example of a decision you've hidden behind an interface?

DESIGN FOR CHANGE

- ▶ Design consists of making decisions.
- ▶ What happens when these decisions change?
- ▶ Some decisions may be more likely to change than others.
- ▶ How can we design software in ways that make likely to change decisions easier to change?

CHOOSING ELEMENTS

- ▶ We've looked at three ways so far to divide systems into elements
 - ▶ Design as domain modeling: choose elements that correspond to domain elements
 - ▶ Design for abstraction: choose elements that hide irrelevant details and make writing code easy
 - ▶ Architectural styles: choose elements which respect constraints which enable quality attributes to be satisfied
- ▶ Will look at a fourth today: dividing systems into elements to support change

KEY WORDS IN CONTEXT (KWIC) PROBLEM

- ▶ Accepts an ordered set of lines, each line is an ordered set of words, and each word is an ordered set of characters.
- ▶ Any line may be "circularly shifted" by repeatedly removing the first word and appending it at the end of the line.
- ▶ Outputs a listing of all circular shifts of all lines in alphabetical order.

"CLASSIC" FLOW CHART DECOMPOSITION

- ▶ Each module (except master control) corresponds to step in flow chart
- ▶ Input: reads data from input and stores into data structures
- ▶ Circular shift: prepares data structure shifting words
- ▶ Alphabetizer: alphabetizes words
- ▶ Output: creates output listing
- ▶ Master control: invokes other modules

MODULARIZATION 2

- ▶ Line storage: functions and subroutines which give access to line data structures
- ▶ Input: reads input, calls line storage to store lines
- ▶ Circular shifter: offers interface for accessing circularly shifted lines as index on same underlying data structure
- ▶ Alphabetizer: alphabetizes words
- ▶ Output: renders data to console
- ▶ Master control: invokes other modules

WHAT ARE SOME DESIGN DECISIONS WHICH MIGHT CHANGE?

1. Input format: how is data entered into system
2. In memory: reading and storing data in memory rather than externally on disk
3. Representation: the data structure used to store data efficiently in memory
4. Index: generating output as an index into original data rather than as a copy of original data
5. Eager sort: make search faster by sorting list rather than doing a search on demand

DIFFERENCES BETWEEN MODULARIZATIONS

- ▶ Changing (2) in memory decision and (3) data structure decisions would require making edits to **all** modules in first decomposition
 - ▶ Input: reads data from input and stores into data structures
 - ▶ Circular shift: prepares data structure shifting words
 - ▶ Alphabetizer: alphabetizes words
 - ▶ Output: creates output listing
 - ▶ Master control: invokes other modules

DIFFERENCES BETWEEN MODULARIZATIONS

- ▶ Changing (2) in memory decision and (3) data structure decisions would require making edits to **one** module in second decomposition
 - ▶ Input: reads data from input and stores into data structures
 - ▶ Circular shift: prepares data structure shifting words
 - ▶ Alphabetizer: alphabetizes words
 - ▶ Output: creates output listing
 - ▶ Master control: invokes other modules

WHY?

- ▶ Knowledge of the exact way that the lines are stored is entirely hidden
- ▶ Decisions (2) and (3) can be changed, and only the Line Storage module would ever know

INFORMATION HIDING

- ▶ Can change a decision locally in a module **without** change rippling to cause change in other module
- ▶ Modules characterized by knowledge of a design decision and what it hides from others
- ▶ Usually expressed as inverse: here's what decisions are exposed to clients through interface

INFORMATION HIDING VS. ABSTRACTION

- ▶ Isn't this abstraction all over again?
- ▶ Goal is different
 - ▶ Abstraction: offer operations that make writing client code compact and easy
 - ▶ Information hiding: enable design decisions in module to change
- ▶ Are there examples where a design increases abstraction but decreases information hiding?

ASIDE: GOOD ABSTRACTIONS REALLY MATTER

- ▶ Parnas originally estimated that KWIC could be built in a week or two in 1972
 - ▶ Assumed C style language with few collection abstractions
- ▶ Can implement in a few dozen lines with modern collection abstractions

EXAMPLE: UNIVERSAL RESOURCE IDENTIFIER (URI) DESIGN

- ▶ Uniquely describes a resource
 - ▶ <https://mail.google.com/mail/u/0/#inbox/157d5fb795159ac0>
 - ▶ https://www.amazon.com/gp/yourstore/home/ref=nav_cs_ys
 - ▶ http://gotocon.com/dl/goto-amsterdam-2014/slides/StefanTilkov_RESTIDontThinkItMeansWhatYouThinkItDoes.pdf
 - ▶ Which is a file, external web service request, or stored in a database?
 - ▶ It does not matter
- ▶ As client, only matters what actions we can *do* with resource, not how resource is represented on server

PRIVATE MEMBERS

- ▶ Information hiding offered important motivation for inclusion of access control in modern OO languages
 - ▶ Can specify **private** or **protected** access to limit access to "implementation details" (a.k.a. hidden design decisions) that clients should not know about
- ▶ But principle applies much more broadly to design decisions
 - ▶ Not necessarily about computing / caching data or how data is stored
 - ▶ Design decisions may not be closely associated with a data structure or method

EXAMPLE: URI DESIGN

- ▶ Which is better?
 - ▶ <http://myservice.com/cities>
 - ▶ <http://myservice.com/cities.cfm>
 - ▶ <http://myservice.com/cities.aspx>

TYRANNY OF THE DOMINANT DECOMPOSITION

- ▶ Many design decisions
 - ▶ Can you hide all of them?
- ▶ No
 - ▶ Inevitably, will make some design decisions easier to change than others

COSTS OF INFORMATION HIDING

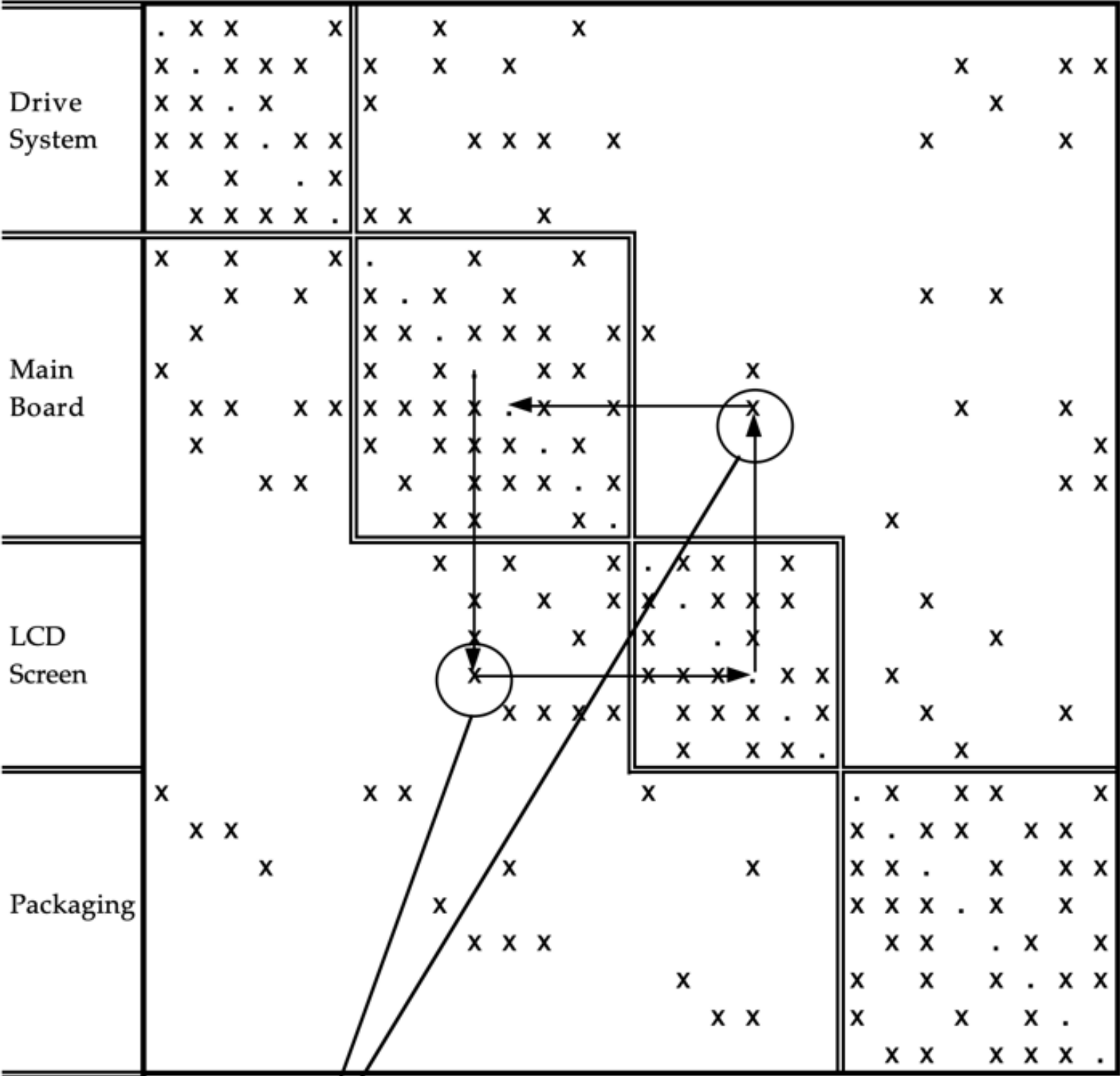
- ▶ Can't hide everything
 - ▶ Will inevitably make some design decisions easy to change, others harder to change
- ▶ What should you hide?
 - ▶ Decisions that are most likely to change
 - ▶ Get best payoff by reducing cost of making these expected changes easier

REAL OPTIONS

- ▶ Having a design decision that you can change at low cost creates **options**
 - ▶ Second modularization offers the **option** to consider whether data should be stored or handled online at low cost
- ▶ Option provides the right to make a change without the obligation
- ▶ Important mechanism for risk mitigation
 - ▶ If decision is wrong, project might fail
 - ▶ Mitigate risk by making it easy to change decision after made, by reducing dependencies on decision

EXAMPLE: OPTIONS IN A COMPUTER

Design Structure Matrix Map of a Laptop Computer



Graphics controller on Main Board or not?
If yes, screen specifications change;
If no, CPU must process more; adopt different interrupt protocols

MAKING DEPENDENCY STRUCTURE EXPLICIT

- ▶ How do you know what options you have?
- ▶ Build a design structure matrix (DSM)
- ▶ Design decisions (or "design parameters") are rows
- ▶ What they depend on (every other design decision) are columns
- ▶ What might happen if design decision A changed?

	A	B	C
A	.		
B	X	.	X
C		X	.

best choice of design decision B
depends on choice of design decision A

IN CLASS ACTIVITY: BUILD A DSM FOR A LAYERED ARCHITECTURE

- ▶ In groups of 2 or 3, build DSM that depicts dependency structure of a system in the layered architectural style

CREATING MODULARITY

- ▶ How do you break dependencies between modules that you'd like to be independent?
- ▶ Organize dependency structure so that there are shared decisions that others depend on and assert that they won't change.

	A	B	C
A	.		
B	X	.	X
C		X	.



	I	A	B	C
I	.			
A	X	.		
B	X		.	X
C			X	.

- ▶ B and C are now independent of A, because they depend on I

DSM FOR MODULARIZATION 1

	A	B	C	D	E	F	G	H	I	J	K	L	M
A - In Type	.												X
B - In Data	X	.	X		X	X		X	X			X	
C - In Alg	X	X	.										
D - Circ Type				.									X
E - Circ Data		X		X	.	X		X	X				
F - Circ Alg		X		X	X	.							
G - Alph Type							.						X
H - Alph Data		X			X		X	.	X			X	
I - Alph Alg		X			X		X	X	.				
J - Out Type										.			X
K - Out Data										X	.	X	
L - Out Alg		X						X		X	X	.	
M - Master	X			X			X			X			.

Type: procedure interfaces

Data: data structures decisions

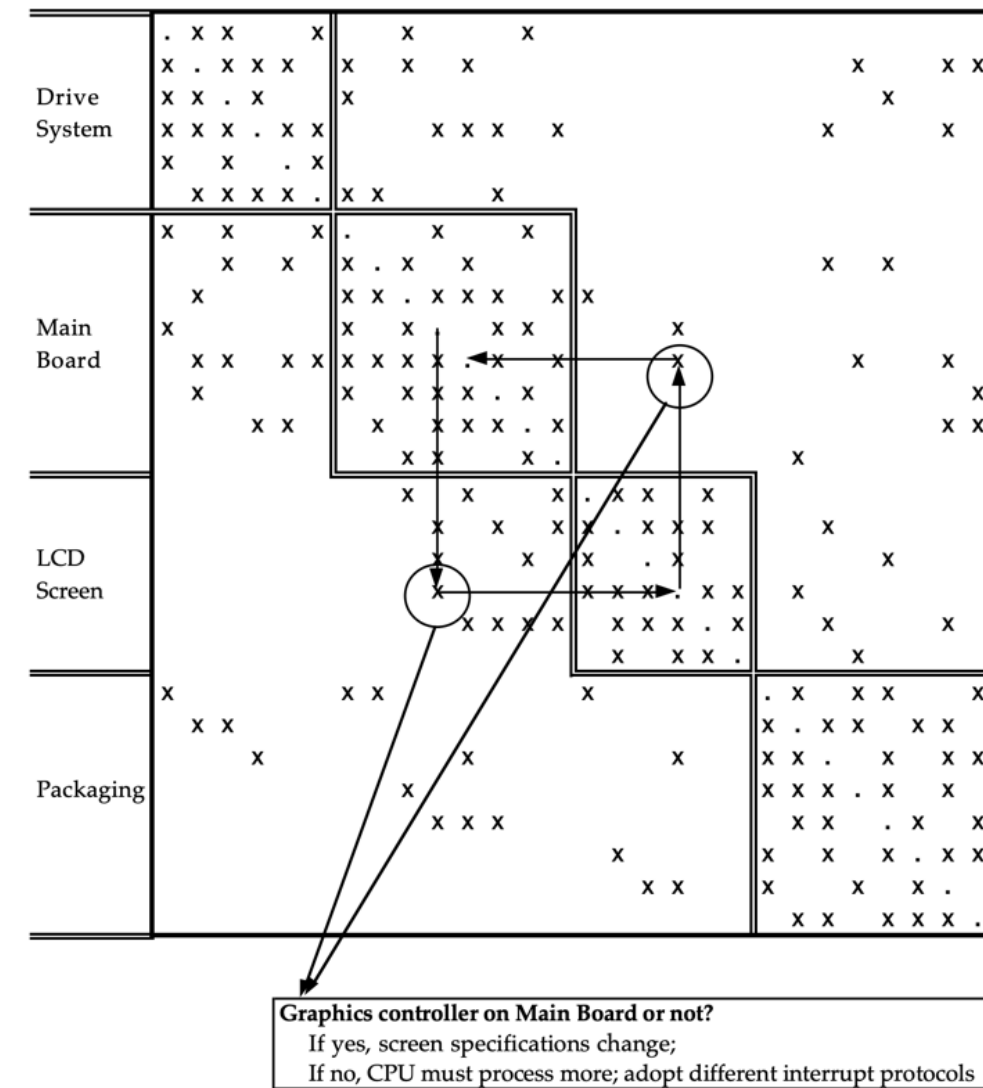
Alg: algorithm decisions

DSM FOR MODULARIZATION 2

	N	A	D	G	J	O	P	B	C	E	F	H	I	K	L	M
N - Line Type	.															
A - In Type		.														
D - Circ Type			.													
G - Alph Type				.												
J - Out Type					.											
O - Line Data	X					.	X									
P - Line Alg	X					X	.									
B - In Data		X						.	X							
C - In Alg	X	X						X	.							
E - Circ Data	X		X							.	X					
F - Circ Alg	X		X							X	.					
H - Alph Data	X			X								.	X			
I - Alph Alg	X			X								X	.			
K - Out Data					X									.	X	
L - Out Alg	X				X									X	.	
M - Master	X	X	X	X	X											.

CONWAY'S LAW

- ▶ The structure of a designed system is isomorphic to the organizational structure of those who built it
- ▶ If a design decision depends on a design decision made by another (e.g., developer, team, company), there must be coordination when this decision changes (e.g., email, face to face meeting) to stay consistent



SOCIO-TECHNICAL CONGRUENCE

- ▶ What happens when the required coordination does not happen?
 - ▶ e.g., the infrastructure team that owns the datastore just changed the query engine
- ▶ Poor design (if system still works, but less well)
- ▶ Defects (if system no longer works)
 - ▶ Can observe empirically by comparing decision dependencies (module references) against coordination (emails sent) to find divergences, which correlate with defects

Cataldo, M., & Herbsleb, J. D. (2013). Coordination Breakdowns and Their Impact on Development Productivity and Software Failures. *IEEE Transactions on Software Engineering* 39(3), 343-360.

INFORMATION HIDING AND COORDINATION

- ▶ Want to have clear idea of what the external interface of your team constitutes
- ▶ What design decisions which might change would others care about?
- ▶ Need to manage coordination around these decisions

HYRUM'S LAW: A PESSIMISTIC VIEW

- ▶ With a sufficient number of users of an API,
 - ▶ it does not matter what you promise in the contract:
 - ▶ all observable behaviors of your system
 - ▶ will be depended on by somebody.
-
- ▶ Interfaces evaporate with additional clients, as every observable behavior eventually is depended on by someone

<http://www.hyrumslaw.com/>

SUMMARY

- ▶ Different organizations of functionality into elements leads to different design decisions being modularized and hidden behind interfaces
- ▶ What is hidden in a module is a design decision, not just a variable or method
- ▶ Hidden decisions offer real options, making it cheaper to explore alternative designs
- ▶ Technical dependencies require coordination between people, or defects may result

IN CLASS ACTIVITY

DESIGN ACTIVITY: DESIGN TODO APPLICATION FOR CHANGE

- ▶ Form group of 2 or 3
- ▶ Consider again Todo application requirements
 - ▶ User interactions with todos: add, delete, rename, complete, copy
 - ▶ Display todos to user
 - ▶ Persist todos
- ▶ Design a todo application for change, hiding decisions likely to change behind interfaces
 - ▶ These decisions are likely to be decisions that are not architectural, which would be hard to hide
- ▶ Deliverables:
 - ▶ component and connector model showing elements in your system
 - ▶ list of functionality for each element
 - ▶ list of important design decisions
 - ▶ DSM which shows dependencies between these design decisions
 - ▶ short description of how your design supports changes to a subset of these decisions

DESIGN ACTIVITY: STEP 2: DISCUSSION