SWE 621

SPRING 2021

DESIGN FOR REUSE

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LOGISTICS

- HW5 due on 4/20
- Project presentation on 4/27
  - Will focus on a single design decision common to your reference system and two additional systems
  - For each of the three systems, describe the alternative design choices each of these systems made. What are the consequences of these design choices?
  - Presentation should be 10 minutes. To ensure we have enough time for all presentations, we will stop you and you will lose points if go over 11 mins. Please practice to ensure your talk is the correct length.

FINAL EXAM

- Open book
- Comprehensive (covers all lectures and readings)
- Take place during scheduled final exam time slot
- Entirely short answer and essay questions

OVERVIEW

- What is reuse?
- What can make it hard?
- How can you design **for** reuse to make it easier?

IN-CLASS ACTIVITY

- You're using a framework you've never used before (e.g., React, Enterprise Java Beans, ASP.NET)
- You're writing some code, but it just doesn't seem to work.
- What do you do next?

WHAT IS REUSE?

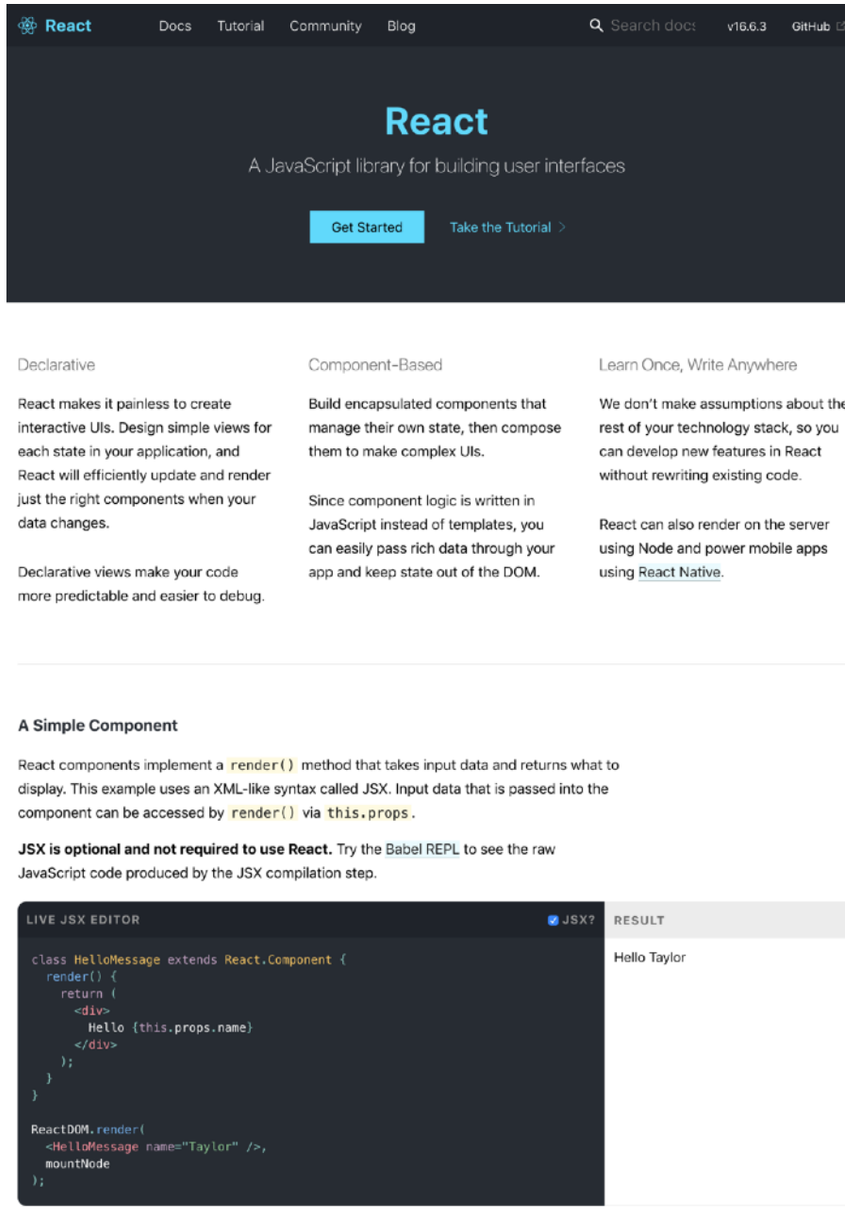
- Making use of previously written code rather than writing new code

- Often, reuse takes form of reusing a **library** or a **framework**

- Once made choice to reuse a library or framework, need to understand how to achieve specific behavior with library or framework
  - Often finding ***code snippets*** that achieve desired behavior

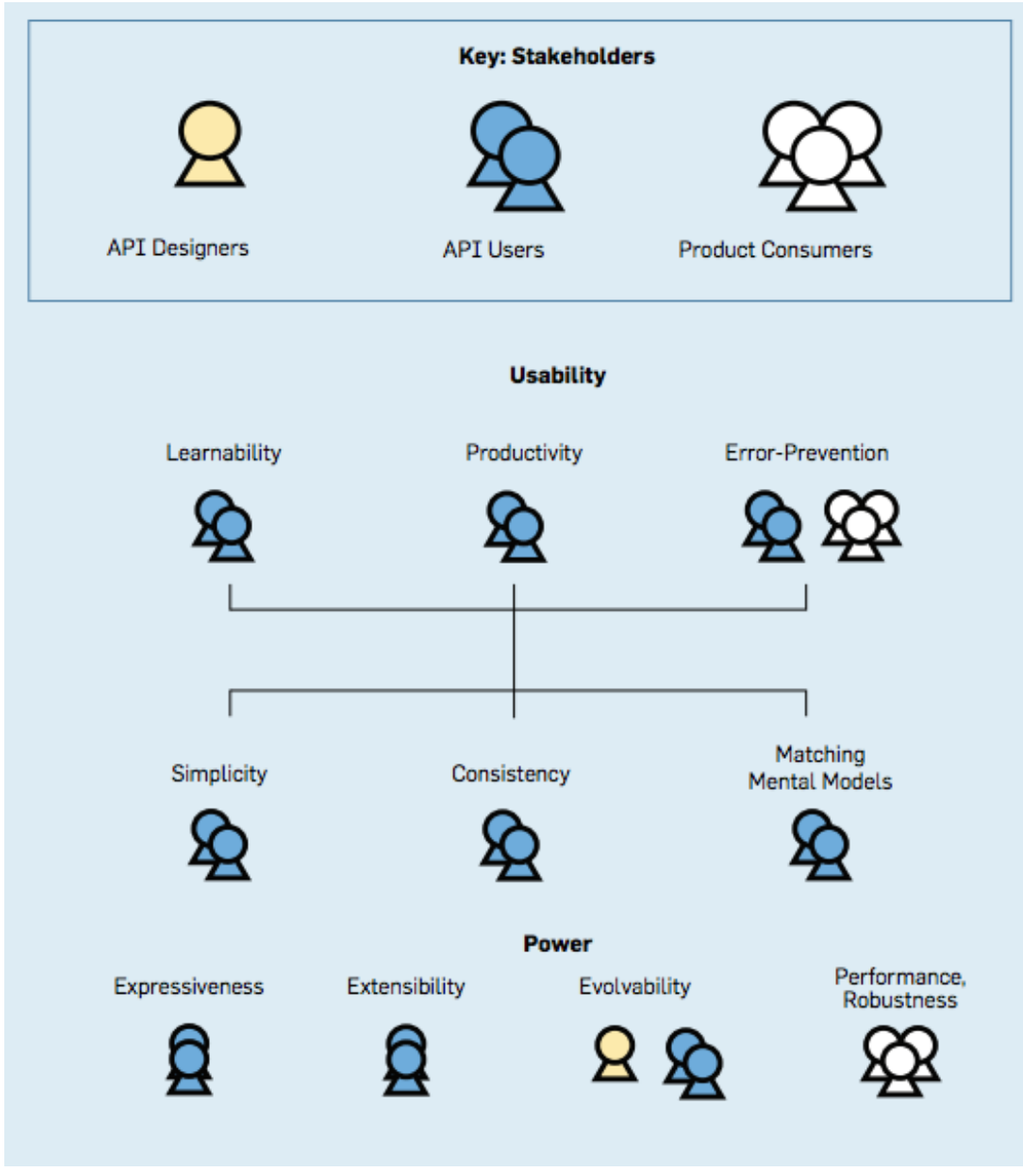
APPLICATION PROGRAMMING INTERFACE (API)

- Boundary between code to be reused (library or framework) and client which reuses code
- We've looked previously at abstractions
  - Design goal: chose operations which make key reuse scenarios short
  - Choice of what operations to support one of the most important choices in API design
- Today we'll look more broadly at considerations in designing code **for** reuse

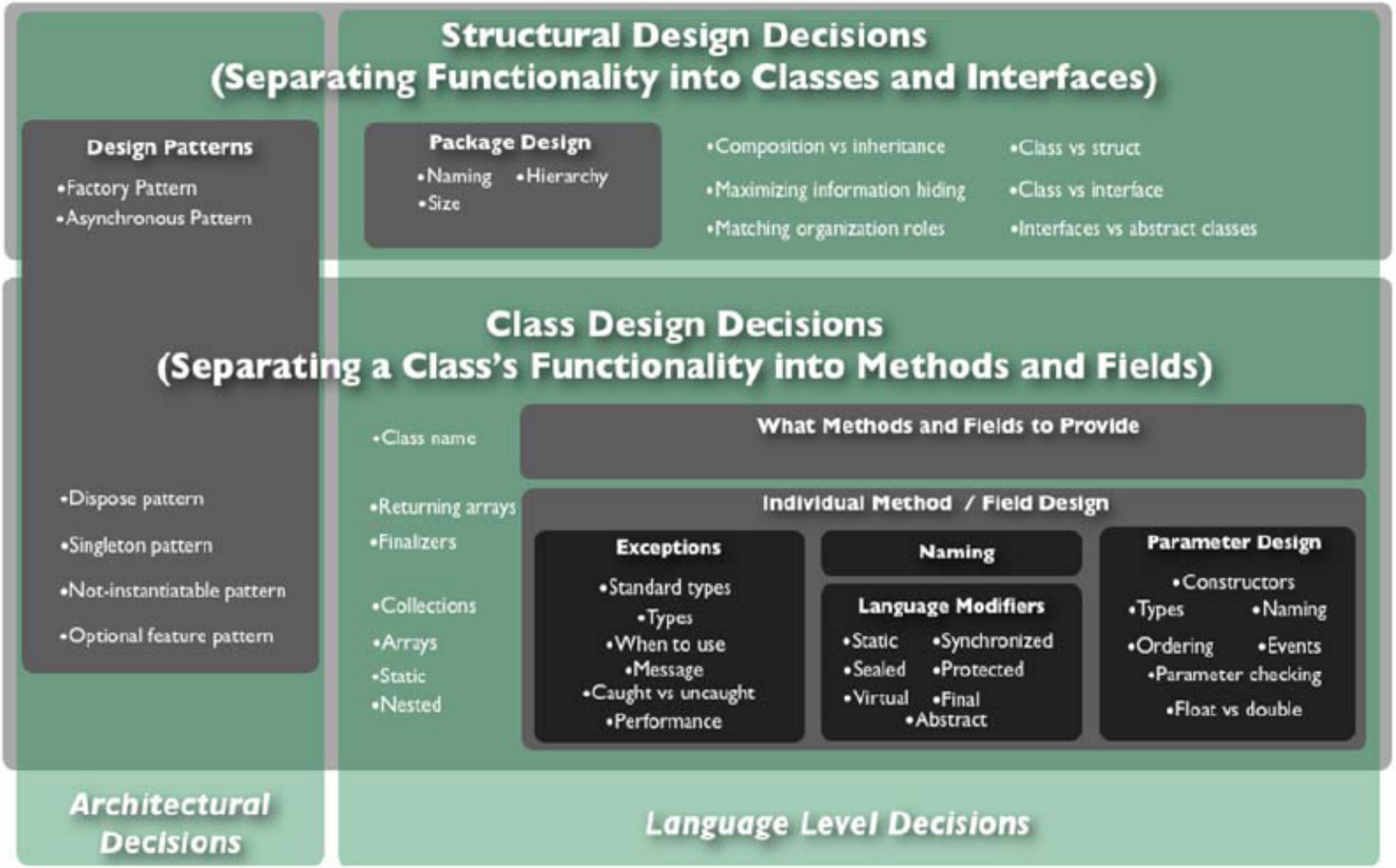


API QUALITY ATTRIBUTES

- Largely similar to normal system design, but for client code
- Usability
  - Learnability
  - Error prevention
  - Consistency
    - Matching user mental models
- Power
  - Extensibility: ability for users to create new elements
  - Evolvability: ability for designers to change API
  - Performance: speed, memory consumption
  - Security



SOME EXAMPLES OF API DESIGN DECISIONS



MORE API DESIGN DECISIONS

- Documentation
  - What to cover
  - How to communicate: descriptions of methods? examples?
  - Audience: experts? novices? users of competing APIs?

WHAT CAN MAKE REUSE HARD?

- Software engineering researchers run user studies to identify general strategies and challenges developers experience
- User experience researchers at companies with large API ecosystems (e.g., Google, Facebook, Microsoft) run user studies to evaluate and improve specific API designs

SOME CHALLENGES WITH REUSE

- **Design** barriers—inherent cognitive difficulties of the programming problem, separate from notation used
  - I don't know what I want the computer to do
- **Selection** barriers—finding programming interfaces available to achieve a particular behavior
  - I don't know what to use
- **Coordination** barriers—constraints governing how languages & libraries can be combined
  - I don't know how to make them work together
- **Use** barriers—determining how API how to use API
  - I don't know how to use it
- **Understanding** barriers—environment properties such as compile & runtime errors that prevent seeing behavior
  - It didn't do what I expected
- **Information** barriers—environment properties that prevent understanding runtime execution state
  - I think I know why didn't behave as expected, but don't know how to check

CHALLENGES WITH REUSE

- Mapping an abstract conceptual solution into the appropriate elements
  - *"How do I create a rectangle? Why is there no Rectangle tool?"*
- Understanding control & data flow, hidden dependencies due to run-time binding or inheritance, between classes in the API
  - *"I'm over-riding SelectionTool, and in particular mouseDown() so that when the figure is clicked the box is drawn. This bit works, however when trying to drag the figure, if I do something similar the rectangle flickers like mad."*
- Understanding how functionality works
  - *"How does … work?", "What does … do?" or, "Where is … defined/created/called?"*
- Making changes consistent w/ architectural constrains of API
  - Violating constraints of MVC architecture by passing references in prohibited ways

Douglas Kirk, Marc Roper, and Murray Wood. 2007. Identifying and addressing problems in object-oriented framework reuse. *Empirical Softw. Eng.* 12, 3 (June 2007), 243-274.

VOCABULARY PROBLEM

- API users are familiar with concepts using one set of terminology.
- API, tutorials, or other resources use different terminology
- Domain driven design suggests that all terminology should be the same. But what happens when it isn't?
- How do API users find the right concepts with alternative terms?

CHALLENGES MAY VARY BY CONTEXT

- Size of desired snippet
  - Reusing a line of code? A whole algorithm?
- Alternatives
  - How many alternatives are there? How important is it to find the best alternative?
- Integration
  - What libraries or frameworks does a snippet require? How can they be integrated?

SOME EXAMPLES OF REUSE TECHNIQUES

- You'd like to reuse method x in framework f. How do you figure out how to do this?
- Example reuse techniques
  - Read the documentation
  - Read tutorials
  - Find StackOverflow snippets
  - Find similar code in your own codebase that also reuses x
  - Try out API functions, see what they do

OPPORTUNISTIC VS. SYSTEMATIC DEVELOPERS

- Developers vary in which sorts of strategies they prefer
- Key choice: how completely do you need to understand API before deciding your understanding is "good enough"
  - Systematic: as much as possible
  - Opportunistic: as little as possible
- This leads to different developers preferring different types of strategies
  - Opportunistic developers more likely to start with example code
  - Systematic developers more likely to read the documentation first
- ---> API documentation should support both types of strategies

STRATEGIES VARY WITH DEGREE OF PRIOR KNOWLEDGE OF API

WEB SESSION INTENTION:	LEARNING	CLARIFICATION	REMINDER
Reason for using Web	Just-in-time learning of unfamiliar concepts	Connect high-level knowledge to implementation details	Substitute for memorization (*e.g.*, language syntax or function usage lookup)
Web session length	Tens of minutes	$\sim$ 1 minute	$<$ 1 minute
Starts with web search?	Almost always	Often	Sometimes
Search terms	Natural language related to high-level task	Mix of natural language and code, cross-language analogies	Mostly code (*e.g.*, function names, language keywords)
Example search	"ajax tutorial"	"javascript timer"	"mysql_fetch_array"
Num. result clicks	Usually several	Fewer	Usually zero or one
Num. query refinements	Usually several	Fewer	Usually zero
Types of webpages visited	Tutorials, how-to articles	API documentation, blog posts, articles	API documentation, result snippets on search page
Amount of code copied from Web	Dozens of lines (*e.g.*, from tutorial snippets)	Several lines	Varies
Immediately test copied code?	Yes	Not usually, often trust snippets	Varies

Joel Brandt, Philip J. Guo, Joel Lewenstein, Mira Dontcheva, and Scott R. Klemmer. 2009. Two studies of opportunistic programming: interleaving web foraging, learning, and writing code. *Conference on Human Factors in Computing Systems* (CHI '09), 1589-1598.

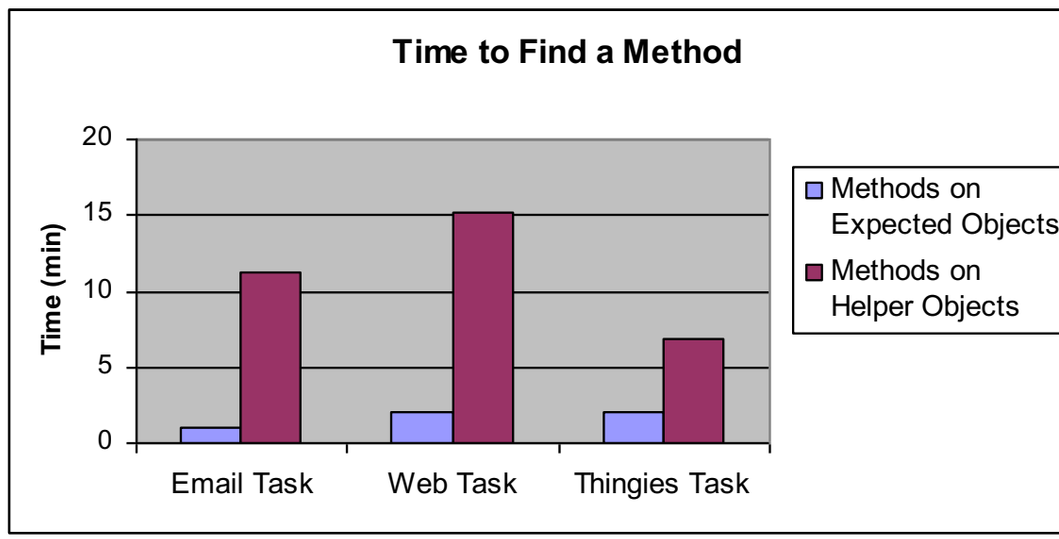
TYPES OF REUSE

- Learning—relies on selecting highest quality tutorials tutorials
  - e.g., “update web page without reloading php”
- Clarification—learning syntax based on exiting understanding of the domain concepts
  - e.g., reminding use of syntax of HTML forms
  - Often search by analogy to domain concepts in other languages / frameworks
    - e.g., Perl has a function to format dates as strings, what’s the one for PHP?
- Reminder—using web as external memory aid
  - e.g., forgot a word in a long function name
  - e.g., 6 lines of code necessary to connect and disconnect from MySQL database copied hundreds of times by individual

Joel Brandt, Philip J. Guo, Joel Lewenstein, Mira Dontcheva, and Scott R. Klemmer. 2009. Two studies of opportunistic programming: interleaving web foraging, learning, and writing code. *Conference on Human Factors in Computing Systems* (CHI ’09), 1589-1598.

EFFECTS OF API DESIGN CHOICES: METHOD PLACEMENT

- Where to put functions when doing object-oriented design of APIs
  - mail_**Server**.send(mail_Message)
  - vs.
  - mail_**Message**.send(mail_Server)
- When desired method is on the class that they start with, users were between **2.4** and **11.2** times faster

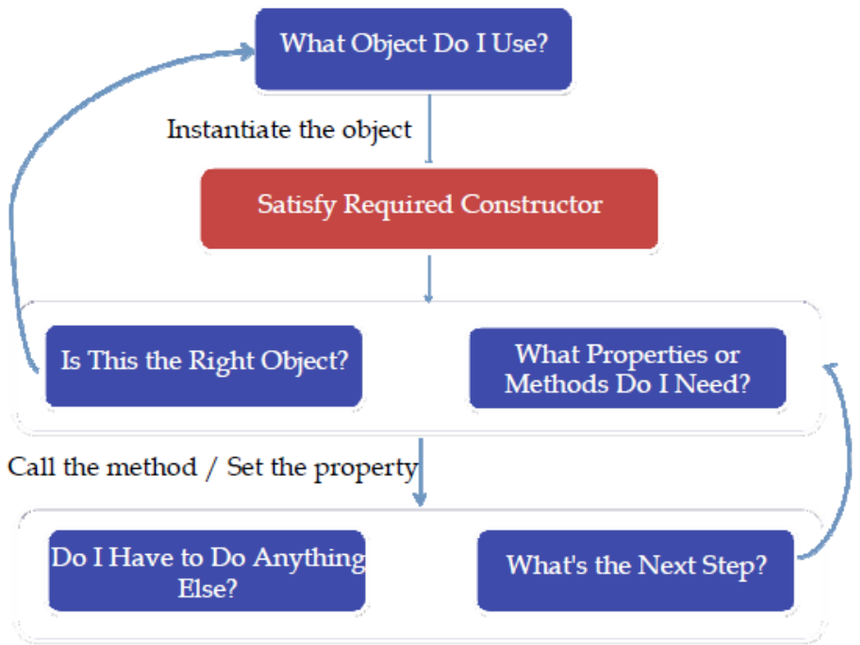


[Stylos FSE, 2008]

EFFECTS OF API DESIGN CHOICES: REQUIRED PARAMETERS IN CONSTRUCTORS

- Compared **default** constructor (create-set-call)
  - var foo = **new FooClass()**;
  - foo.Bar = barValue;
  - foo.Use();
- Results
  - All developers assumed there would be a default constructor
  - Required constructors imposed premature commitment: had to figure out how to construct object before could decide if it was the right object for task
  - Did not insure valid objects – passed in null

- vs. **required** constructor
  - var foo = **new FooClass(barValue)**;
  - foo.Use();



[Stylos & Clarke, ICSE'07]

EFFECTS OF API DESIGN CHOICES: FACTORIES

- Compared “normal” creation: Widget w = new Widget();
- vs. creation using factory pattern
  - AbstractFactory f = AbstractFactory.getDefault();
  - Widget w = f.createWidget();
- Factory pattern frequently in Java (>61) and .Net (>13) and SAP
- Results
  - Time to develop using factories took **2.1** to **5.3** times longer compared to regular constructors (20:05 vs 9:31, 7:10 vs 1:20)
  - All developers had difficulties using factories in APIs
- --> Very important if using factory to document how to create objects
  - Particularly in class developers might start with

[Ellis 2007]

HOW CAN YOU DESIGN FOR REUSE TO MAKE IT EASIER?

- Given these (and other) findings, how can an API be designed **for** reuse?
- Some recommendations
  - Create effective documentation
  - Apply natural programming method
  - Make API design choices which optimize for usability and power quality attributes

CREATE EFFECTIVE DOCUMENTATION

- Include **short code snippets** that document API usage patterns of how multiple methods work together and capture **best** way to use API
- Focus on documenting higher level usage, not boilerplate documentation that adds little beyond method signatures
- Match **scenarios** capturing common use cases to how to do that in API
- Include discussion of **performance** consequences of specific API usage
- Examples:
  - https://reactjs.org/docs/getting-started.html
  - https://github.com/d3/d3-brush/blob/v1.1.5/README.md#brush_clear
  - https://developer.mozilla.org/en-US/docs/Web/JavaScript/Guide/Working_with_Objects

ACTIVITY

- In groups of 2 or 3,
  - Pick a library or framework of your choice
  - Critique the documentation: what works, what could be improved
- Deliverables: be prepared to present back to class

NATURAL PROGRAMMING METHOD

- Give developers a task, ask them imagine that there's a framework that does this task, ask them to write code on a blank screen to complete task
  - It definitely won't compile
- Examine code they wrote to understand what elements and methods they **expect** to see
  - Elicits their mental model of how they expect API to work

Stylos, J. and Myers., B.A. (2008) The implications of method placement on API learnability. FSE, 105–112.

MAKE EFFECTIVE DESIGN CHOICES FOR USABILITY

- Design problem similar to designing for software for users more generally
- Can apply Nielsen's Heuristic evaluation heuristics to API design (see SWE 632 for more!)

VISIBILITY OF SYSTEM STATUS

- Should be easy for API user to check state of framework
  - e.g., whether file is open or closed
- Using wrong operation for the current state should generate appropriate feedback
  - e.g., writing to closed file should generate meaningful error message

MATCH BETWEEN SYSTEM AND REAL WORLD

- Names given to methods and organization of methods into classes should match API users' expectations
  - e.g., user wanting to write to File most likely to look for File class first, not FileOutputStream
- Users often interact with class first by creating an instance

USER CONTROL AND FREEDOM

- API users should be able to abort or reset operations and return the API back to previous state

CONSISTENCY AND STANDARDS

- All design choices should be consistent across API
  - e.g., naming of classes and methods, naming of arguments, order of arguments, placement of methods into classes
- Example violation: order of arguments in opposite order
  - void writeStartElement(String **namespaceURI**, String **localName**)
  - void writeStartElement(String prefix, String **localName**, String **namespaceURI**)

ERROR PREVENTION

- API should guide user into doing the right thing
- Have defaults that match users' expectations
- Avoid using String parameters, particularly long sequences of String parameters
  - Compiler cannot check if arguments in correct order
  - e.g., void setShippingAddress (String firstName, String lastName, String street, String city, String state, String country, String zipCode, String email, String phone)

RECOGNITION RATHER THAN RECALL

- API users often try to find the right method through autocomplete
- Make names clear and understandable, so users can recognize what they want

FLEXIBILITY AND EFFICIENCY OF USE

- API users should be able to accomplish their tasks efficiently

HELP USERS RECOGNIZE, DIAGNOSE, RECOVER FROM ERRORS

- When a developer uses API incorrectly, API should offer error messages that **explain** the problem and offer suggestions on how to **resolve** issue

SUMMARY

- Developers spend much of their time interacting with libraries and frameworks through APIs
- Developers differ in use of opportunistic and systematic strategies for reuse, requiring different considerations in API and documentation design
- Documentation that focuses on scenarios and best practice usages, rather than boilerplate, can make big impact in usability
- Many design choices such as naming, organization of functionality into classes, and error messages can have a profound choice on usability
- Can apply usability heuristics to API design

IN CLASS ACTIVITY

APPLY API DESIGN HEURISTICS

- Pick a framework (e.g., .NET framework, Java standard library, React, …)
- Critique the framework using API design heuristics (Slides 28-35)
- Identify one example for **each** heuristic (8 total) where the framework either follows or violates the heuristic
  - For example of the 8 examples, list the name of the heuristic, give an element within the framework (e.g., method, class), and describe how element either follows or violates the heuristic
- Deliverables
  - Names of group members, choice of framework, description of 8 examples