CSE584: Software Engineering

Lecture 3 (April 15, 1997)

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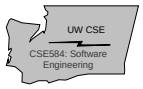


Lecture 3, Outline [approximate minutes]

- Administrivia (rescheduling) [5]
- Software architecture [30]
- Design patterns [40]
- Break [10]
- Roundtable [30]
  - Possible topics include
    - » Design disasters you've seen upfront and personal
    - » Design issues and approaches I haven't addressed
- Open implementation [40]
- Wrap-up and slop [20]

Modern issues in design

- Software architecture
  - Families of designs
- Design patterns
  - Common patterns in object-oriented programming
- Open implementations
  - Overcoming shortcomings of black-box design

Software architecture

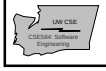
- An area of significant attention in the last five years
  - Garlan and Shaw
  - Perry and Wolf
- There are two basic goals
  - Capturing, cataloguing, and exploiting experience in software designs
  - Allowing reasoning on classes of designs

An aside: compilers I

- The first compilers had *ad hoc* designs
- Over time, as a number of compilers were built, the designs became more structured
  - Experience yielded benefits
    - » Compiler phases, symbol table, etc.
  - Plenty of theoretical advances
    - » Finite state machines, parsing, ...

An aside: compilers II

- Compilers are perhaps the best example of shared experience in design
  - Lots of tools that capture common aspects
  - Undergraduate courses build compilers
  - Most compilers look pretty similar in structure
- We still don't fully generate compilers



Other domains?

- Which other domains are as successful in this regard as compilers?

Back to software architecture

- The hope is that by studying our experiences with a variety of systems, we can gain leverage as we did with compilers
- Capture the strengths and weaknesses of various software structures
  - Perhaps enabling designers to select appropriate architectures more effectively
- Benefit from high-level study of software structure

Components and connectors

- Software architectures are composed of *components* and *connectors*
  - Components define the basic computations comprising the system
    - » Abstract data types, filters, etc.
  - Connectors define the interconnections between components
    - » Procedure call, event announcement, etc.

Architectural style

- Defines the vocabulary of components and connectors for a family (style)
- Constraints on the elements and their combination
  - Topological constraints (no cycles, register/announce relationships, etc.)
  - Execution constraints (timing, etc.)
- By choosing a style, one gets all the known properties of that style
  - For any given architecture in that style

Not just boxes and arrows

- Consider pipes & filters
  - Pipes must compute local transformations
  - Filters must not share state with other filters
  - There must be no cycles
- If these constraints are not satisfied, it's not a pipe & filter system

Benefits

- In the pipes & filters example, a benefit of the constraints is that deadlock will not arise
  - Again, in any instantiation of the style that satisfies the constraints
- One can think of the constraints as obligations on the designer
  - Some properties can be automatically checked

Specializations

- Architectural styles can have specializations
  - A pipeline might further constrain an architecture to a linear sequence of filters connected by pipes
  - A pipeline would have all properties that the pipe & filter style has, plus more

Well, do they help?

- I like the basic software architecture research as an intellectual tool
  - The work is helping us better understand classes of software structures that have shown themselves as useful
  - Simply improving our shared terminology is a benefit
- It may not be fully distinct from Parnas's families of systems, but enough to benefit

Open questions I

- What properties can be analyzed?
  - Wright [Allen & Garlan]
    - » Reason about architectures in terms of protocols, using a CSP-like language
    - » Roughly, type-checking of architectural styles
  - Of these, which are sufficiently important to justify the investment
    - » The investment is high, but in theory amortized
  - What about across heterogeneous architectures?

Open questions II

- How does one go from an architectural style to an architecture?
- How does one produce new architectural styles?

Open questions III

- What is the relationship between architectural and implementation?
  - Does architectural information aid in going from design to implementation?
  - What happens as the implementation evolves in ways inconsistent with the architecture?
    - » Which properties still hold, and how do we know this?

Experience

- It's a hot area, with lots of companies paying attention
- Allen & Garlan recently reported on a case study in applying architectural modelling to the AEGIS Weapons System
  - Used formalism to help "expose and resolve some of the architectural problems that arose in implementing the system"

AEGIS Prototype Architecture

On-going research

- Environments to support the design of architectural styles and architectures
- Architectural design languages (ADLs)
- Formal models of architectures
- Architectural case studies
- Use of informal architectures
- ...

Design patterns

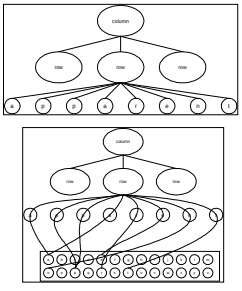
- Design patterns are idioms that are intended to be *"simple and elegant solutions to specific problems in object-oriented software design."*
- They are drawn from actual software systems
- They are intended to be language-independent

A weak analogy

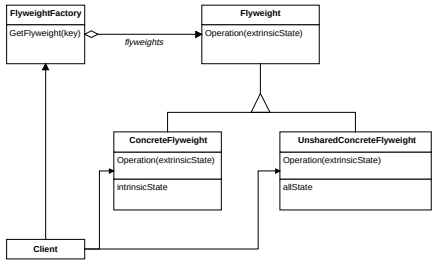
- I view high-level control structures in programming languages as quite the same
  - For example, a while loop is an idiomatic collection of machine instructions
- Knuth's 1974 article ("Structured Programming with go to Statements") shows that this is not a language issue alone
- Patterns are a collection of "mini-architectures"

Example: **flyweight** [Gamma et al.]

- Intent
  - Use sharing to support many fine-grained objects efficiently
  - Can't usually afford to have small elements (like characters) be full-fledged objects
- Separate logical model from physical model



Flyweight structure



Categories of patterns

- Creational
- Structural
- Behavioral

An enlightening experience

- At a workshop a year or two ago, I had an experience with two of the Gang of Four
- They sat down with Griswold and me to show how to use design patterns to (re)design a software architecture we had published
- The rate of communication between these two was unbelievable
  - And much of it was understandable to us without training (good sign for a learning curve)

This is the real thing

- Design patterns are not a silver bullet
- But they are impressive, important and worthy of attention
- I think that (slowly?) some of the patterns will become part and parcel of designers' vocabularies
  - This will improve communication and over time improve the designs we produce
- The relatively disciplined structure of the pattern descriptions may be a plus

The future

- I'm somewhat worried that "second wave" R&D will hurt more than help
- How do patterns interact?

Patterns resources

- Patterns Home Page
  - `http://st-www.cs.uiuc.edu/users/patterns/patterns.html`
- Portland Pattern Repository
  - `http://c2.com/ppr/index.html`
- FAQ
  - `http://g.oswego.edu/dl/pd-FAQ/pd-FAQ.html`
- Gang of Four book
  - *`Design Patterns: Elements of Reusable Object-Oriented Software.`* `Gamma et. al.`
- OO journals, OOPSLA, etc.

Open implementation

- Last week in discussing information hiding I listed some central premises
- Two important ones are especially questionable
- Kiczales et al. have studied this question carefully, leading to some work generally called Open Implementation
  - `http://www.parc.xerox.com/spl/projects/oi/`

Central premises III and IV

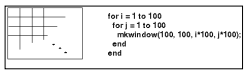
- The semantics of the module must remain unchanged when implementations are replaced
  - Specifically, the client should not care how the interface is implemented by the module
- One implementation can satisfy multiple clients
  - Different clients of the same interface that need different implementations would be counter to the principle of information hiding
    - » Clients should not care about implementations, as long as they satisfy the interface

These are often false

- What defines the semantics of the interface?
  - Much is not (cannot?) be defined, but is inferred by the client
- Once properties are inferred, clients start to assume that they are true
- Multiple clients may infer different properties
  - So changing those properties consistently may be impossible
- Client do, in practice, care about (aspects of) the implementation

Examples

- The flyweight pattern example points out a few of these issues
- Logically, any implementation of the interface is OK
  - But not all implementations are equally adequate for all clients
- The Kiczales spreadsheet example



Two approaches often taken

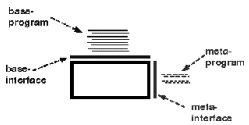
- Programmers often respond to these problems in one of two ways
  - Write own windowing system
  - Clever coding tricks
    - » Paging example

The experts say

- "I found a large number of programs perform poorly because of the language's tendency to hide `what is going on' with the misguided intention of `not bothering the programmer with details'"
  - N. Wirth, 1974
- "An interface should capture the *minimum* essentials of an abstraction."
- When an interface undertakes to do too much, the result is a large, slow complicated implementation."
  - B. Lampson, 1984

The OI solution

- Define two interfaces
  - The *base interface*, which provides the essential semantics
  - The *meta-interface*, which is used to customize aspects of the implementation of the base
- Based on experience
  - Common Lisp Meta-Object Protocol (CLOS MOP)
  - Reflective computing



Allows the client to

- Use the module's primary functionality alone when the default implementation is adequate
- Control the module's implementation-strategy decisions when necessary
- Deal with functionality and implementation strategy decisions in largely separate ways

Design issues: OI claims

- The base interface design requires similar techniques to current interface design
- The design of the meta-interface and of the coupling of the meta- and base interface is more complicated
  - Requires expertise in the definition and uses of the components

Design issues: meta-interface

- Scope control
  - Are controls over the implementation for instances, classes, other?
- Conceptual separation & incrementality
  - Can the client of the meta-interface understand and use just parts of it?
- Robustness
  - Are bugs in a client's meta-program limited in effect?

It's not an entirely new idea

- Compiler pragmas
- Multiple implementations of an interface
  - With client choice [Hermes]
- User-directed parallelization
- Unix `madvise`
  - Influence page replacement
- Many more

Ongoing

- Examples
- Design guidelines
- Analysis techniques

Frameworks

- Frameworks are another design buzzword
- One way to think about them is as upside-down layers
  - That is, layered systems allow us to construct families of systems by sharing lower layers
  - Frameworks allow us to construct families of systems by sharing upper "layers"
- Instantiate and specialize provided classes
  - "More" than patterns

More frameworks

- User interface frameworks (MVC, HotDraw, …)
- Distributed systems
- Network protocols
- More information
  - `http://www.ide.hk-r.se/frameworks/frameworks.html`
  - `http://iamwww.unibe.ch/~scg/./Research/iscf.html`

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