FOUR RULES OF SOFTWARE ENGINEERING

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UPS Lecture Series—William Paterson University

RULE 1

It Doesn’t Start with the Coding

Providing a context

A software development problem

- Sort a set of student records
- Student name, campus ID,
  major code, number of credits, GPA
  - Plus list of current courses
  - Each course has identifier, name,
    instructor, number of credits
- Simple enough that we can try to do it as a single development step

A software development problem

- What do you need to know?
- Assume that there are no external constraints on
  - Programming language, IDE, tools, other resources
  - Development methodology or team structure
  - *Except as affected by the problem itself, or by testing requirements*
- Suggestions?

How did I get my list (and my lecture)?

- Not fully formed just by looking and writing
- Teaching SW engineering, data structures, databases, statistics, …, for years
- Learning from texts, professional books & blogs, conference papers & posters
- Interaction with colleagues and with students
- Repeated reflection and modification
- At least 40 content changes in this deck in last few weeks
- It would probably change more if I had more time

Some questions—Input

- How many records? How big is each record? Does size vary?
- Do we have all the records at the start?
- Where do we get the records?
  - Local or remote file/files
  - Received individually (user input, streams, …)
- Can records be modified, or are they fixed?
- Same encoding and meaning for fields?
- Is input assumed legitimate (type and range consistent, etc.), or do we need to check?
- User interface—*¿Solamente en ingles?*

- Affect choice of sort algorithms and data structures
- Affect design of interfaces
- With modification may want database
- May require preprocessing

Some questions—Processing

- ***What are we sorting on?***
  - ID #, Name, other, user selection? A tuple (major, ID)?
  - Single pass or repeated—interacts with static or dynamic data set
- Do we need to keep the original data set in original order?
- What do we do with duplicate records?
  - Same exact information, refinements (same or missing), clearly same but newer, conflicts for same key
- What do we do with invalid data?
  - Invalid records, invalid fields, constraint violations

Some questions—Output

- How should the results be presented?
  - Local/remote monitor(s), local/remote file
  - Can the user filter the results?
- If output is presented, what report/display structure is required?
  - Will all the output be available to every viewer?
- If output is stored, what structure should be used?
- Does the output need to be preserved?
  - Very important if input is dynamic or modifiable—timestamps
- What needs to be done for accessibility?

Some questions—Security

- Security and related topics
  - Is the data subject to privacy/confidentiality constraints?
  - Should fields be suppressed/transformed in display of results?
  - Do we need extra security for storage/computation/communication?
  - If either input or output are stored, should they be encrypted?
  - Is access control/validation needed on inputs?
  - Is validation needed to view output?

Some questions—Other concerns

- Other extra-functional constraints
  - Are there criteria for quality, availability, timeliness, …?
  - Does there need to be documentation, a user manual, …?
  - Are there ethical or social issues?
- Meta-questions
  - How long is this application going to last?
  - Are we responsible for fixing problems?
  - Are we going to need to extend this?

Not all of these are fully germane for this problem

RULE 1

It Doesn’t Start with the Coding

The Bigger Picture

BE PREPARED

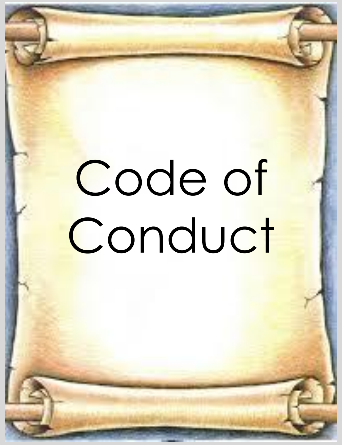
It isn’t just getting the credential!

The Long View—Preparing for a Career

- Technical knowledge
  - Programming, IDEs, software engineering (traditional, Agile, DevOps)
  - Data structures, algorithms, databases, networks, operating systems, …
- Professional competencies
  - Communication, teamwork, leadership, empathy, ethics, standards
  - Critical thinking, problem solving, brainstorming
- WPU CS/IS has prepared you very well
  - Coursework, team projects, undergraduate research, internships
  - Projects become “bigger”, and so has your responsibility within them

The Long View—Preparing for a Career

- Understand your responsibilities
  - To your employer, your customer, your fellow workers, the software development community, and society
  - And the responsibilities others have toward you
    - ACM Code of Ethics (https://www.acm.org/code-of-ethics)
    - ACM Code of Software Engineering Ethics https://ethics.acm.org/code-of-ethics/software-engineering-code/
- Combine generalist skills with developing a specialty
  - Consider professional memberships and certifications



The Enterprise View—Working Together

- You're going to work in a context

  and with others
- Understand the company
  - And its management and technical processes,

    at least at a high level
- Understand job responsibilities (and be willing to change)
- Understand team structure and practices
- Be willing and able to cooperate for success and team building

The Work View

- OK, you’ve got a job as a software developer (Hooray!)
- You’re working on a large project with a team
  - Perhaps communicating with other teams
- The method may be agile, traditional, hybrid, or specialized
- So, we can just start coding?
- Well …

LOOK BEFORE YOU LEAP

Make sure there's water in the pool!

The Project View—Before we start

- Should we be doing this at all?
  - Does it fit with our expertise and business goals?
  - Do we have the resources and training?
  - If for a customer,
    do we feel comfortable in the relationship?

- Do we know what the problem is doing—large scale?
  - Product Vision
    - What problem is it trying to solve, and how will it try to solve it?
  - Business Case
    - How does the solution fit with our business? With the customer's?

The Project View—Before we start

- Do we have the right resources?
  - **Time and money**
  - Personnel
  - Training and support
  - Experts as needed
  - Tools—for development, for management, for communication
- Do we have the right team? Do we have the right process?
- Do we have management backing on project, process, and product?

Tradeoffs in when we investigate,
when we stipulate,
and when we acquire resources
Don't expect full answers right away

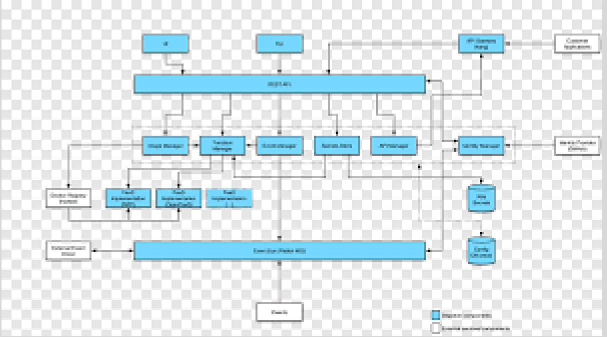
The Project View—Before we start

- What risks might we face?
  - To project, process, product, personnel
  - External risks and catastrophes
- Do we have an RMMM plan and structure?
  - Monitor, manage, and mitigate risk
  - Management task with technical input
  - Avoid or prevent if possible
  - Mitigation—recovery, reduction, restoring morale and productivity, …

More tradeoffs—but
Must anticipate major risks
Must set up structure

The Project View—Artifacts and Views

- Each workflow produces both informal and formal artifacts
  - Code is one—and incorporates others like comments
  - Others come from tools or analyses—like unit test reports
- Artifacts may need views
  - Role Team, management, customer, users, operators/helpdesk
  - Level Precis, overview, details
  - Aspect Behavior, interfaces, security & privacy, timeliness, …
- Understand what belongs/will be found where



AND GET TO WORK

You may specialize, but you need a global view

Requirements—Understand the problem

- What do we need to know at the start (of this pass)?
- What definitely needs to be considered?
  - What must be done? What are its interactions?
    - What's going to be hard? Tricky? Uncertain?
    - Subject to frequent change?
  - How does it need to do it? What about
    - **Security, privacy/confidentiality, intellectual property?**
    - **Timeliness and safety** (active systems), availability, resilience, performance?
    - Business & technical services—accounting & inventory, logging & access?
    - Support—manuals, documentation, on-line, **accessibility**, …?
  - What legal, standards, and ethical issues may arise?

gg59732647 GoGraph.com

Requirements—Understand the problem

- How does this add value for the customer? The user?
- For example

◦ Behavior	Increased functionality
	Better performance, reliability/resiliency, …
◦ Interaction	Improve or add interfaces & improve accessibility
	Better understandability, usability, aesthetics
	Reduce annoyance/inconvenience
◦ Extensibility	Support additional platforms
	Improve internationalization, interoperability
	Address product line consistency

Requirements—Understand the problem

- How do we learn about requirements?
    - Discuss and listen
    - Read (regulations, standards, terminology, common practice, …)
    - Observe
- Check interpretation vs problem & w/ customer (!)
    - And end users/operators if possible
    - Test if possible
- What about problems and constraints?
    - What is missing? What works poorly?
    - What has gone wrong? How and why?
    - Are we introducing new concerns?
    - What needs to be guaranteed?

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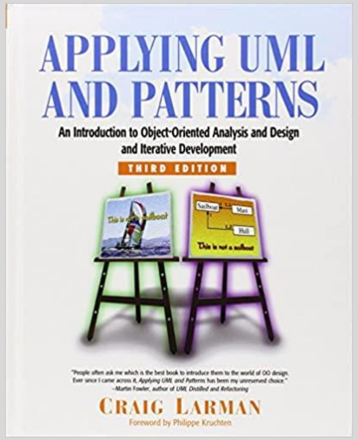
Specification—Understand the workings

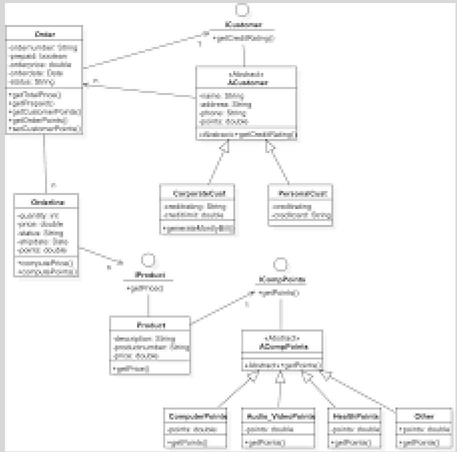
- How do the business processes work?
  - Happy path(s)—when everything goes right
  - Alternative flows—variants and options
  - Handling special cases, exceptions, errors — existing and new
- Our product may provide same services very differently
- What needs special attention?
  - Try to capture implicit assumptions and tacit knowledge
  - Understand concurrency/non-determinism in problem
    - What can happen in parallel? In different order?
  - Where is security an issue? Where are the bottlenecks? Precise timing?


APPLYING UML
AND PATTERNS
An Introduction to Object-Oriented Analysis and Design
and Iterative Development
THIRD EDITION
CRAIG LARMAN
Foreword by Philippe Kruchten

Use when unclear, tricky, or complicated

Modeling—Understand the structure

- Isolate real-world entities and interactions
  - Some entities are not physical — transactions, meetings, …
- Create conceptual objects and information flows to handle
  - Effort focused on less-than-obvious translations &c
- Include (at least) security, timing, safety, accessibility from start
  - Need not be fully implemented
  - But need to be aware and leave flags and hooks
- Be aware of points of fragility—Where can this break?



Design—Understand the solution

- The application world is a model of the model
  - Make a further translation to that model
- Create skeleton for method code
  - Decide on algorithms and data structures
  - Use design patterns, guidelines, and idioms
  - May modify modeling/domain level, largely in predictable ways
    - Example: materializing composite objects/collections
  - Add hooks for essential services—but don't go overboard

In many cases, this isn't much different from creating a code skeleton

So

- We've done all that!
- All that's left is the coding, right?

RULE 2

It Doesn’t End with the Coding

In the real world, you can’t just turn in your assignment

OK, what's left?

- You're a genius coder
- You solved the problem with your team
- Everyone should be smiling
- What have we left out?

  What do we need to do now?
- Any ideas?

Testing—Check the solution

- Goals
  - Do the right thing

    Behavior corresponds to requirements
Constraints are met ✓

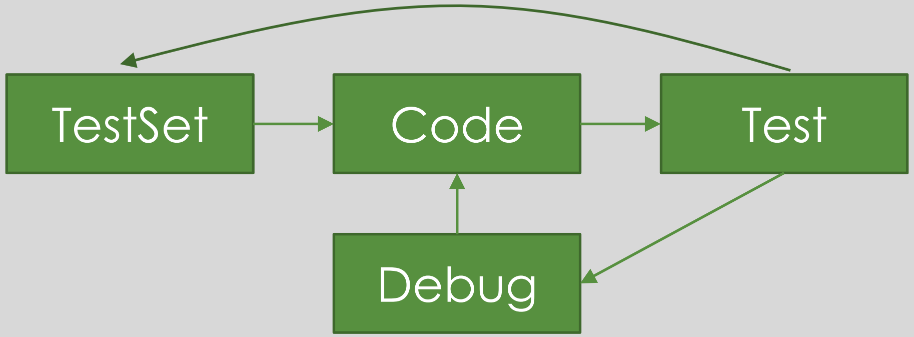
  - Do the thing right

    Implementation is effective and efficient
We aren’t going to get in trouble for it ✓

  - Do the thing well

    Standards are met
Application can evolve ✓

Testing—Check the solution



- Test-driven development
- Integrate testing with implementation
  - Anticipate with prototypes or simulations where appropriate
- Some testing occurs late
  - Stress testing—overload the application or the system
  - Platform testing—test in actual deployment environment
  - Acceptance testing—run working version past customer/users
- Not just testing tools and checking interactions
  - Code reviews, static/dynamic analyzers, security testing, metrics

Maintenance—Assure the solution

- Address user issues and other problems that arise
- Sometimes just a matter of communication
  - Point in the right direction
  - Clear up misconceptions
- May require modifying models, code, or other artifacts
  - Misunderstandings may suggest changes
  - Changes might be to documentation or manual rather than code
  - Some changes can be deferred to next update/release

Maintenance—Assure the solution

- What changes might we have to make?
  - Corrective—debugging and reaction to test issues
  - Adaptive
    - Respond to platform/system changes
    - Support interoperability and portability
  - Preventative
    - Changes needed for security, privacy, and related problems
  - Perfective—make it better
    - Appearance, understanding/learning/use, performance, …

Maintenance—Assure the solution

- What changes need to be immediate?
  - Corrective—Significant errors in behavior that
    - Break the application
    - Endanger life, health, environment, ...
    - Require only minor, transparent changes, or changes to documentation
  - Preventative—Security holes, privacy violations, legal issues
    - That have occurred, are public knowledge, or are likely to occur

Evolution—Extend the solution

- A major focus of agile methods and DevOps
  - Development is sequence of iterations & releases
- Embraces major adaptive and perfective changes
- Move
  - Into new versions and variants of the product
  - From this product to related products or product line
- Adjust to changes in user community or new uses

Reflection—Improve the process

- What went right? What went wrong?
- What felt uncomfortable?
  Could have been simpler?
- Aim to improve
  - The development process
  - Development and management practices and culture
  - Uses of artifacts and tools
  - Team culture and interactions
- Reflect on social, ethical, … issues

So

- OK, we’re ready for that!
- Now, all that’s left is the coding, right?

RULE 3

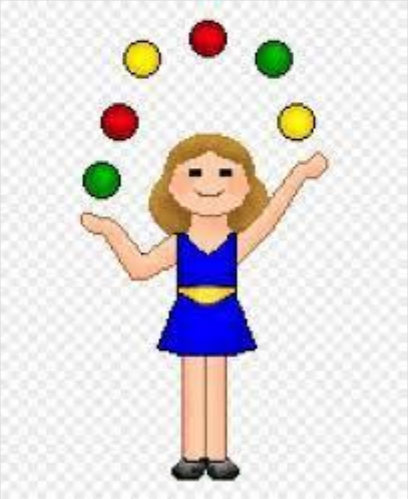
There’s More than Coding While You’re Coding

Preserving Sanity

You’re not alone in the world

- Keep your team aware
  - Of what you’ve done, are doing,
    and any choices you have made
- Often structured and supported
  - Institutional and team practices
  - Team meetings such as Scrums—address all workflows
  - Pair programming in XP
    - One writes code, other checks/critiques/comments/documents

Keep all the balls in the air



- In modern approaches to software engineering
- Coding is interleaved with other workflows
  - Problems and opportunities discovered in coding
  - Incremental incorporation of features and support
- In agile and related methods
  - Interleaved with refinement of requirements and specification
  - Across multiple incremental passes
  - Addressed for example in the (Rational) Unified Process, based on UML artifacts and practices

Repeating myself

- Follow institutional and team testing practices
- Write test code first (or at least understand how to test)
  - As a team, results in development of a test suite for the application
- Sometimes need to use *mocks* or simulations
  - For components that have not yet been developed
  - For external components
  - If actual execution is dangerous (cardiac workstation, atomic plant), impossible (Mars Rover), hard to repeat
- As usual, non-determinism/concurrency and timeliness require extra care

This isn’t just an assignment

- This is an ongoing, dynamic project
- A large project might have
  - Millions of lines, thousands of methods, hundreds of classes, …
  - Dozens of consistent versions, and of families of variants
- Code may be under revision by multiple team members
- To keep track, need to interact with
  - Version control
  - Configuration management and history
- Keep documentation and manual consistent with code

RULE 4

Don’t Forget About the Coding

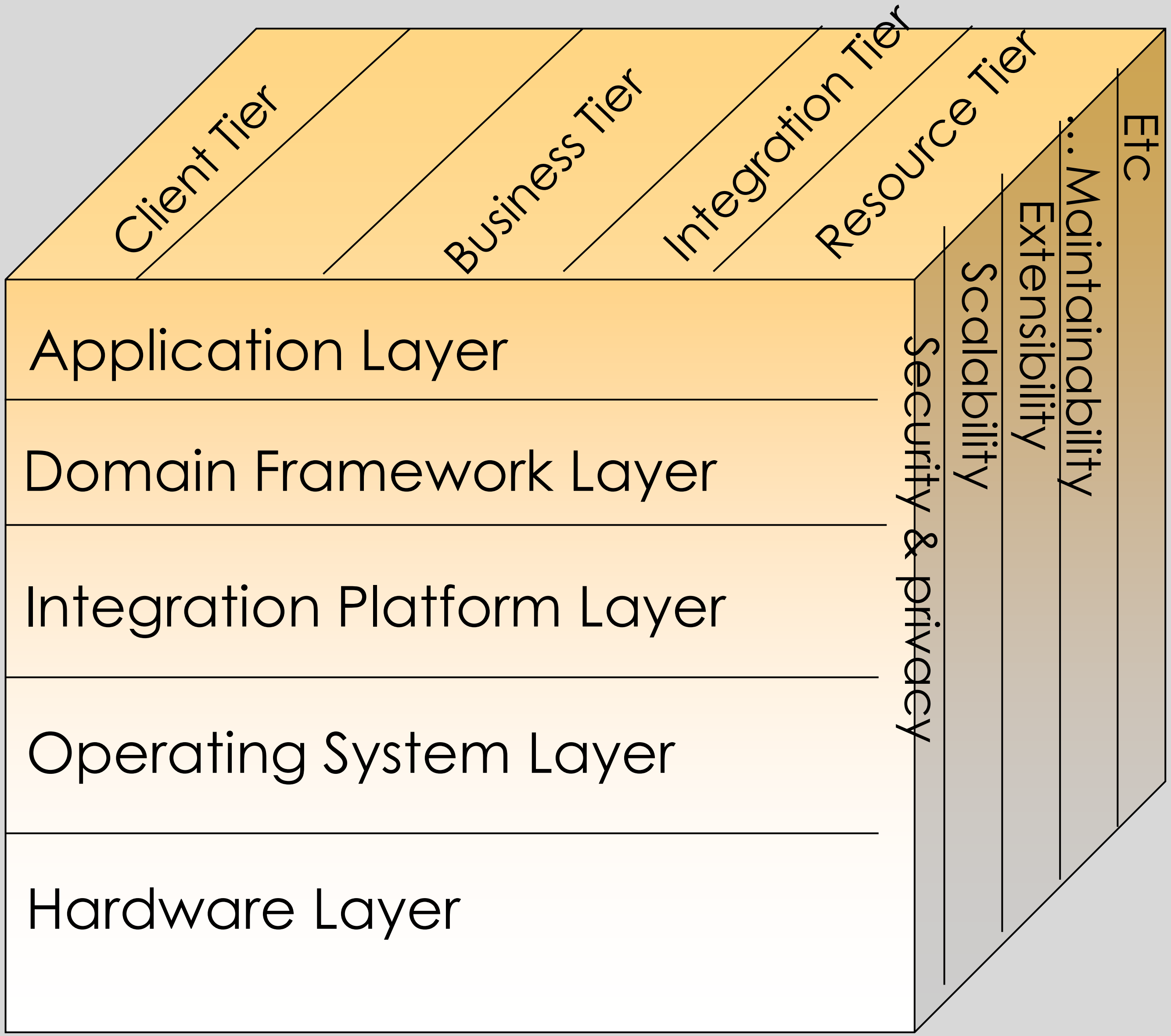
Good Practice is what makes Perfect (or nearly so)

Layered development

- Layer, tier, facet

Layer	How close to "the surface" ?	UI, business logic, services
Tier	What part of the solution?	presentation, rules, …
Facet	What issue is addressed?	security, availability, ...

- May be different tools for layers, services/aspects for tiers/facets
- Underlying infrastructure layer
  - Databases and operating system services
  - Azure/AWS/gcp — PaaS Web services
  - Thick client install, Web-based SaaS, microservices, the cloud



Client Tier

Business Tier

Integration Tier

Resource Tier

Application Layer

Domain Framework Layer

Integration Platform Layer

Operating System Layer

Hardware Layer

Security & privacy

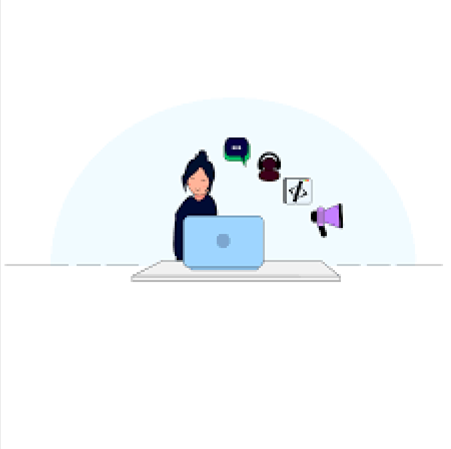
Scalability

Extensibility

… Maintainability

Etc

Full Stack development



- Modern model of web development
- Full stack

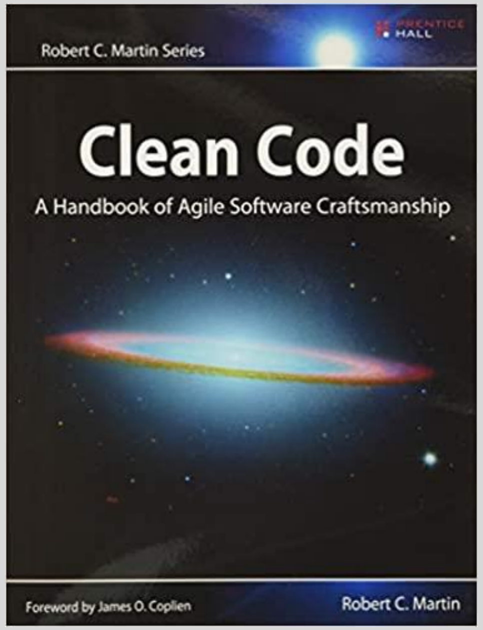
Front end/client	User interface, communication, environment
Back end/server	Business logic
Database	Data, transaction management
Services	Includes OS, network and other technical

- Two examples—order to make acronym neat, not layering

MEAN Stack	MongoDB, Express, AngularJS, Node.js
LAMP Stack	Linux, Apache, MySQL, PHP

Coding Standards

- Write good code
  - See Robert Martin's ***Clean Code*** as a resource
    - Great book!
  - Simple modules, classes, and methods
  - Well-structured, simple interaction
  - Good, informative names
- As before
  - Follow team and enterprise guidelines
  - Aim at good comments and consistent documentation
  - Pay attention to concurrency and non-determinism


Robert C. Martin Series
PRENTICE HALL
Clean Code
A Handbook of Agile Software Craftsmanship
Foreword by James O. Coplien
Robert C. Martin

Coding Standards

- Don’t screw up the future
  - Cute tricks often screw up optimization and inhibit modification
- But don’t overdesign for the future
  - Much of the code will never be changed in major ways
  - And many changes will follow well-known patterns if needed

But!

- Anticipate interfaces/services may vary
- Use design patterns to minimize or localize dependence on
  - Different user interfaces
  - Different services for different variants, situations, …
  - Different implementations of services and collaborators
  - Different algorithms or data structures to implement behavior
  - Local vs remote connections or data
- Adapter, Façade, Proxy, Decorator, Observer, Command, COR

Danger Signs

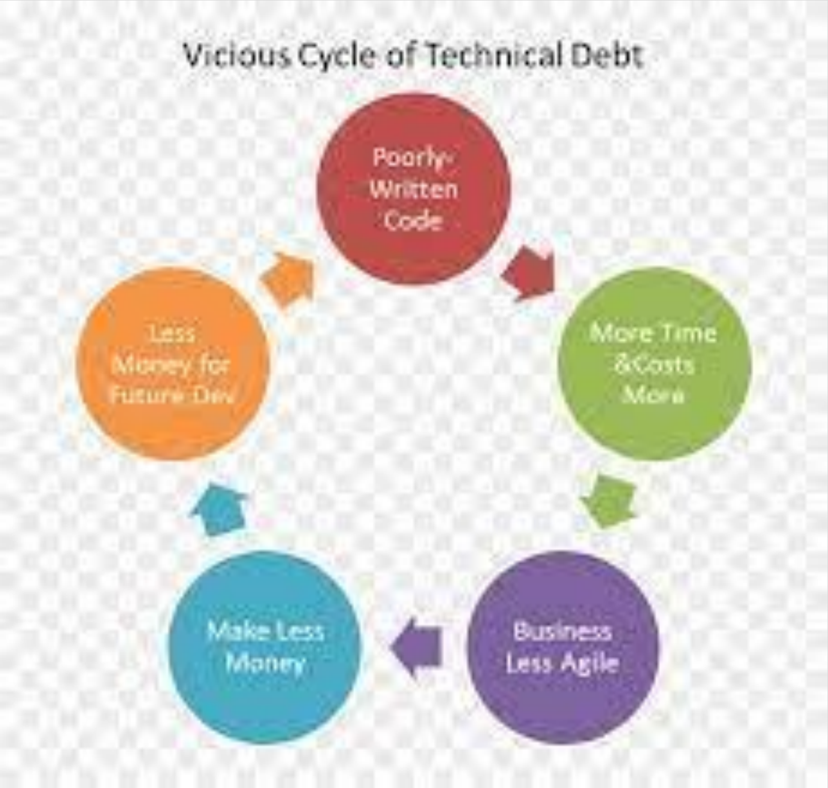
- Be very careful changing code that may interact with
  - Security, privacy, and access control
  - Timing constraints, and safety and health
  - Non-deterministic behavior and concurrency
  - Performance and resiliency with major effects
- Use code reviews, traceability tools, analyzers, and testing to see what is affected by error or change, and where to make changes
- Regression testing is a key tool and should be automated
  - Provides assurance that changes have not broken behavior guarantees

Speed can kill

- Ordinarily, we want to keep up the pace
  - Rapid development key to modern methods
- But if you’re working on something tricky, risky, intricate
  - Talk about it first!
  - Test-first-development essential here
  - Flesh out a skeleton
  - Loop: Discuss, reflect, develop, test, debug
  - Sometimes reflection means you actually “need to sleep on it”

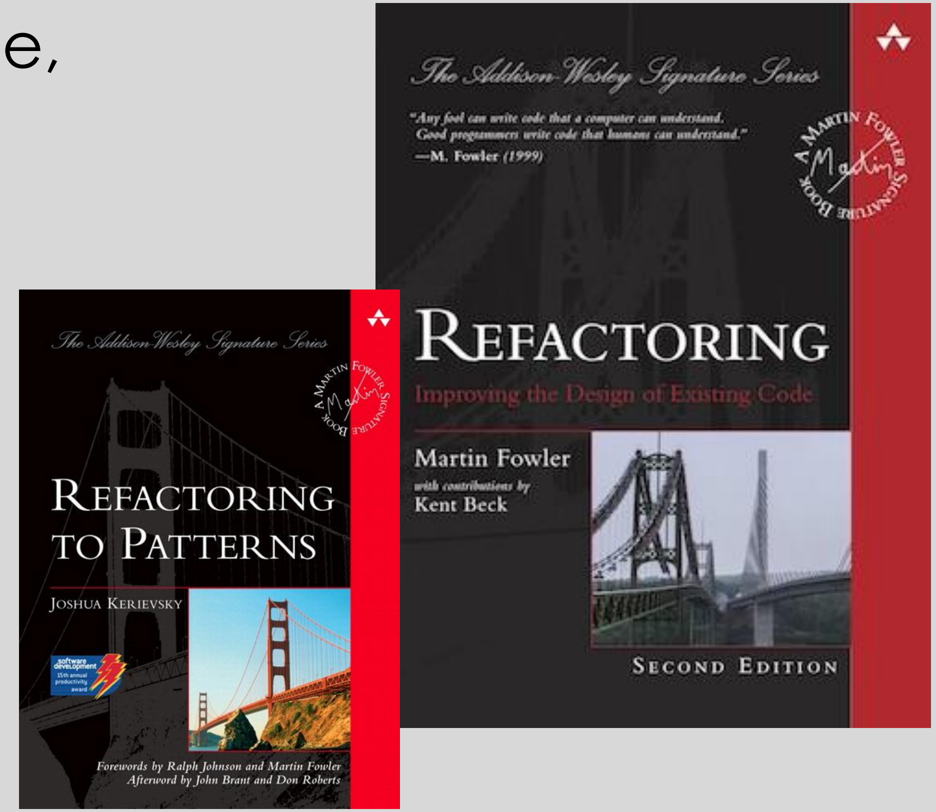
Technical Debt and Refactoring

- Technical debt
  - Code tends to become ugly as it is changed
  - Some code is no longer needed or no longer used
  - Some code works but is confusing
  - Comments and documentation become inconsistent with code
  - Structure of code does not reflect its current function
- Further changes more likely to introduce bugs or confusion



Technical Debt and Refactoring

- Address by local refactoring if possible, redesign if necessary
  - Refactoring uses *code smells* and bugs to identify issues
  - And design patterns to guide sequences of local transformations
- A sequence of refactorings can fix most problems
- A large-scale rewrite is a last choice


The Addison-Wesley Signature Series
"Any fool can write code that a computer can understand. Good programmers write code that humans can understand."
—M. Fowler (1999)
A Martin Fowler Signature Book
Refactoring
Improving the Design of Existing Code
Martin Fowler
with contributions by
Kent Beck
Second Edition
The Addison-Wesley Signature Series
A Martin Fowler Signature Book
Refactoring to Patterns
Joshua Kerievsky
software development 15th annual productivity award
Forewords by Ralph Johnson and Martin Fowler
Afterword by John Brant and Don Roberts

Don’t bother if it’s not worth it

- Focus attention on
  - Code implementing core functionality—as discussed before
    - Meaning of “core” changes as product matures
  - Code that frequently breaks,
    needs rewriting, or has issues
  - Identified threats
  - Interactions with the outside

While you’re coding

- Add meaningful comments
- Document your changes
  (at an appropriate granularity)
- Write document comments (Java ///)
- Make note of
  - Open issues
  - Need for documentation
  - Ugliness in the code—includes inconsistencies with practices

```
/**
* Code Readability
*/
if (readable()) {
    be_happy();
} else {
    refactor();
}
```

Evolution revisited—Extend the solution

- We're never done until the product is retired
- Completing the product we envisioned
  - Go to slide 20 ☺
- Improving the product we envisioned
- Designing variants and versions
- Fitting better into a product line or larger system

Evolution revisited—Extend the solution

- Incremental and iterative development
  - Iterative delivery
  - Versions and variants
  - Product line
  - Configurability
  - Accessibility
- Tree of products
  - Many early products still sellable

Iterative Development of a Chair

Version 1	Wood base, 4 legs
• Variant	Child seat
• Product line	Bench
Version 2	Add back and fabric cover
• Configure	Carpentry style
• Variant	Stool
Version 3	Add arms
Version 4	Upholstered base, arms, back
• Configure	Pattern, stain resist
Version 5	Pillows, optional monogram, …

META-RULE 1

No silver bullets, no golden hammers

Procrustes' Bed is not a comfortable place

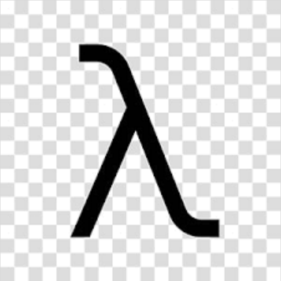
Fit your method to the problem

- Writing a linear-algebra algorithm tool is not the same as writing an intelligent recommender system
  - Requirements are not likely to be dynamic
    - Outside of user and system interfaces
  - Constraints typically on performance or applicability
  - Code chunks for well-understood computations can be larger
    - They won’t change (if correct) and they won’t be misunderstood
  - Parameter lists can be longer
    - Although it may still make sense to pack them in an object
  - It may make sense to call variables x, y, z, and t

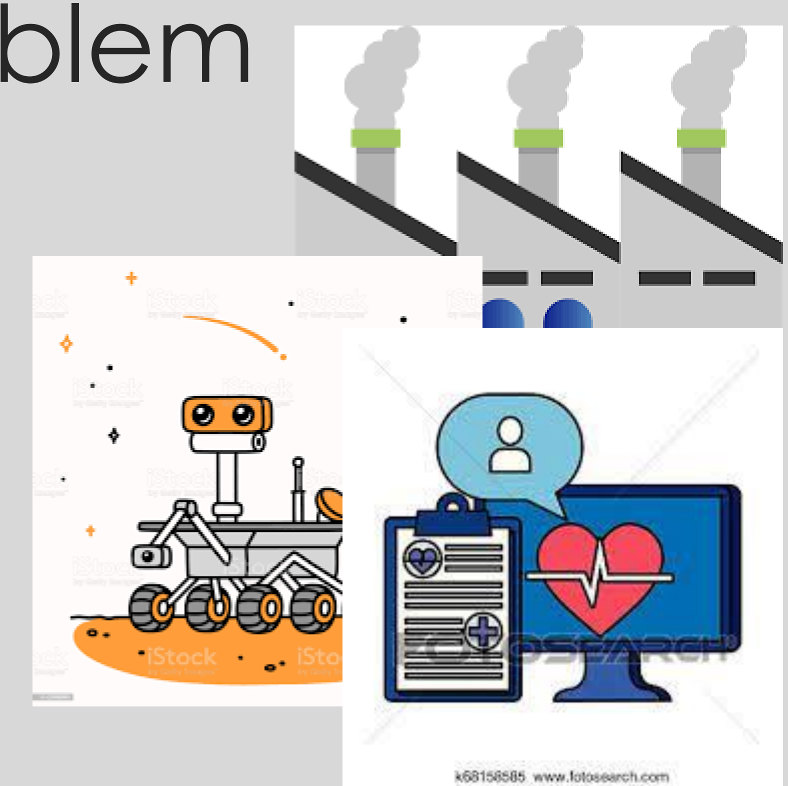
Scalar
Vector
Matrix
Tensor
1
1 2
1 2 3 4
1 2 3 2 1 7 5 4

Fit your method to the problem

- Some pieces may call out for a different coding paradigm
  - Functional code
    - Use of aspects to implement cross-cutting concerns
    - Basis of Kotlin and Scala, and now partially supported in Java
  - Logic code and pattern matching
  - Interactions with a database, even when data isn’t originally in one
- Active and real-time systems always require method and tool enhancements / extensions



Fit your method to the problem



- Lots more to say—some mentioned before
  - Physical constructs like chemical plants
  - Cardiac workstations and atomic power plants
  - The Mars rovers
  - Even financial tools and healthcare records
- Each has different constraints on
  - What can be modified and when
  - What can be tested in the real world—especially extreme situations
  - Whether iterative solutions can be deployed—and where they apply

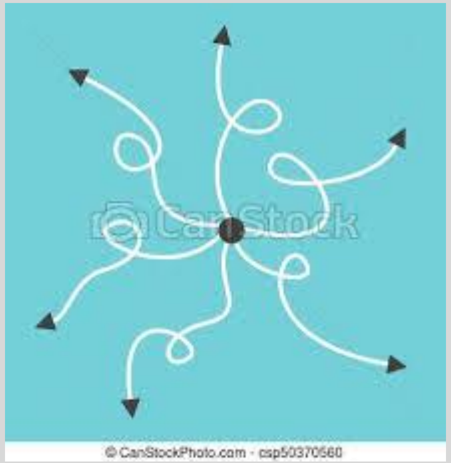
META-RULE 2

It’s an approach, dammit, not a religion!

We’re training critical thinkers, not Bible salesmen!

Don’t complicate without reason

- Support future change only where change is likely
- Don’t use indirection where only one instantiation is likely
- And so on



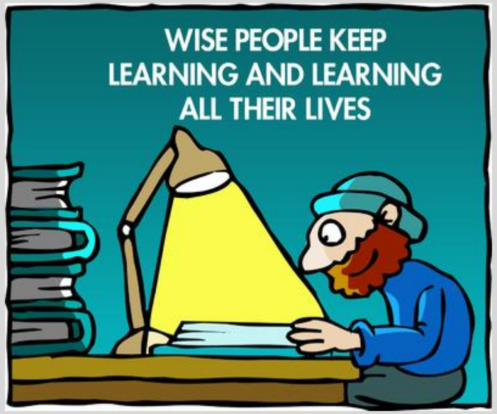
Don’t be afraid to break the rules

- If it doesn’t matter

  and it makes things much simpler
- If it does matter but

  following the rules would create a mess
- But don’t do that without
  - Informing your team, and
  - Leaving a comment—that you’ve done it and why
- Understand how you could redesign or refactor if necessary

Keep learning



- Don't become too attached
  to how you do things now
- While processes and practices improve *on the whole* over time
  - That doesn't mean it's perfect now
  - Some things might be worse than they used to be—it's a transition
  - And others will be replaced by what's better or more effective
- Changes in technology and in theory (!) will affect what you can do and how you can do it
  - And you want to keep up

META-META-RULE

It's Not Just Software Engineering

It's here, it's there, it's everywhere!

These Rules Carry Over

- With appropriate changes in wording and concepts
  - Fancy Latin *mutatis mutandis*—changing what needs to be changed
- Also apply to
  - Mathematical modeling of complex, changing problems
  - Problem solving of ongoing problems
  - Preparing a presentation
  - Investment portfolio analysis and management
  - Project management and agile business processes
  - Security including cybersecurity
  - Much critical thinking
  - And more

Some important references

- Build yourself a library—print, virtual, or a mix
- Robert Martin, ***Clean Code***
  - All of “Uncle Bob’s” stuff is exceptional
- Martin Fowler, ***Refactoring***, *https://martinfowler.com/*
- Johnson, Helm, Gamma, Vlissides, ***Design Patterns***
  - Lots of follow-up books, articles, web pages, …
- Craig Larman, ***Applying UML and Patterns***
- Jeremy Kubica, ***Best Practices of Spell Design*** (fun view of clean/agile)

Acknowledgments

and the UPS Tech staff!

- Dr. Cyril Ku

  and the WPU Department of Computer Science
- UPS and the UPS Lecture Series

◦ Megan Restuccia	WPU CSAB & PJT Partners Bank
◦ Vassilka Kirova	WPU CSAB & Bell Labs Consulting
◦ Garett Chang	President, Highstep Technologies
◦ Om Hashmi	Vice-President, Agile Brains Consulting
◦ Stephen Masticola	Siemens Technology (retired)

Questions?

EXTRA SLIDES

Workflows—A lot of detail

Software Project	
Business Model—Business case, Product Vision	Umbrella Activities & Management Resources, Training, Risk, …
Requirements—Elicitation, acquisition, analysis	
Specification—RW patterns of interaction	
Modeling—Use cases and Domains	
Design—Objects, communication, patterns	
Implement—Data structs, algorithms, details	
Test—Unit, integration, system, stress, platform	
Maintenance—Correct, adapt, prevent, perfect	
Evolution—Extend, refactor	
Reflection—Lessons learned, needed change	

Workflows—Evolution during your major

Introduction		Software Project	
		Business Model	Umbrella Activities & Management
		Requirements	
		Specification	
		Modeling	
		Design	
Implementation		Implementation	
		Testing	
		Maintenance	
		Evolution	
		Reflection	

Workflows—Evolution during your major

Data Structures			Software Project	
			Business Model	Umbrella Activities & Management
			Requirements	
			Specification	
			Modeling	
	Design		Design	
Implementation			Implementation	
Testing			Testing	
			Maintenance	
			Evolution	
			Reflection	

Workflows—Evolution during your major

Databases			Software Project	
			Business Model	Umbrella Activities & Management
	Req’ts		Requirements	
	Spec		Specification	
	Modeling		Modeling	
	Design		Design	
Implementation			Implementation	
Testing			Testing	
			Maintenance	
			Evolution	
			Reflection	

Workflows—Evolution during your major

Software Engineering			Software Project	
	Maybe		Business Model	Umbrella Activities & Management
	Req'ts		Requirements	
	Spec		Specification	
	Modeling		Modeling	
Design			Design	
Implementation			Implementation	
Testing			Testing	
Mainten			Maintenance	
Maybe			Evolution	
			Reflection	