
OUR GOAL IS TO WRITE BUG-FREE SOFTWARE. I'LL PAY A TEN-DOLLAR BONUS FOR EVERY BUG YOU FIND AND FIX.
S. Adams E-mail: SCOTTADAMS@AOL.COM
YAHOO!
WE'RE RICH
YES!!! YES!!! YES!!!
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I HOPE THIS DRIVES THE RIGHT BEHAVIOR.
I'M GONNA WRITE ME A NEW MINIVAN THIS AFTER-NOON!

Defect Detection and Collaborative Development

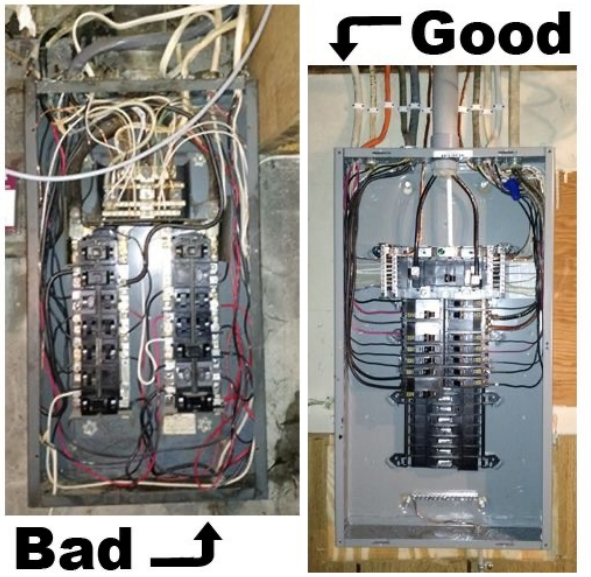
CSCI 2134: Software Development

Agenda

- Lecture Contents
  - Motivation
  - Types of Collaborative Software Development
  - Pair Programming
  - Technical Reviews
  - Brightspace Quiz
- Readings:
  - This Lecture: Chapter 21
  - Next Lecture: Chapter 22

Why Does Software Quality Matter

- User Perspective: It’s harder to sell bad software.



- Developer Perspective: Software needs to be
  - Developed
  - Maintained
  - Fixed
  - Updated
  - Extended
  - Etc.
- **General Principle of Software Quality:**
  Improving software quality reduces development costs

Debugging and Fixing Is Expensive

- **Debugging takes more than 50% of the time! (McConnel, pg 474)**
- **Key Idea:** The earlier a bug/defect is identified (or avoided), the cheaper it is to fix
- Goal: Reduce software defects (good quality software)

Table 3-1 Average Cost of Fixing Defects Based on When They're Introduced and Detected

	Time Detected				
Time Introduced	**Requirements**	**Architecture**	**Construction**	**System Test**	**Post-Release**
Requirements	1	3	5–10	10	10–100
Architecture	—	1	10	15	25–100
Construction	—	—	1	10	10–25

Source: Adapted from "Design and Code Inspections to Reduce Errors in Program Development" (Fagan 1976), *Software Defect Removal* (Dunn 1984), "Software Process Improvement at Hughes Aircraft" (Humphrey, Snyder, and Willis 1991), "Calculating the Return on Investment from More Effective Requirements Management" (Leffingwell 1997), "Hughes Aircraft's Widespread Deployment of a Continuously Improving Software Process" (Willis et al. 1998), "An Economic Release Decision Model: Insights into Software Project Management" (Grady 1999), "What We Have Learned About Fighting Defects" (Shull et al. 2002), and *Balancing Agility and Discipline: A Guide for the Perplexed* (Boehm and Turner 2004).

(McConnell, "Code Complete 2nd Edition, 2004, pg 29)

Techniques to Reduce Software Defects

Avoid software defects

- Set software quality objectives
- Require explicit quality assurance activity
  - Measure the software quality objectives
  - Allocate time to meet the objectives
  - Reward developers for meeting objectives
- Use software engineering guidelines
- Use collaborative development

Detect and fix existing defects

- Use collaborative development
- Perform technical reviews
- Have a testing strategy
  (next week's lectures)
- Have external audits

Set Software Quality Objectives

- All developers must be aiming for the same set of characteristics
  E.g., Maintainability, usability, testability, robustness, correctness
- Developers will focus on the required objectives if they know what they are and that they are being measured!

Table 20-1 Team Ranking on Each Objective

Objective Team Was Told to Optimize	Minimum memory use	Most readable output	Most readable code	Least code	Minimum programming time
Minimum memory	1	4	4	2	5
Output readability	5	1	1	5	3
Program readability	3	2	2	3	4
Least code	2	5	3	1	3
Minimum programming time	4	3	5	4	1

Source: Adapted from "Goals and Performance in Computer Programming" (Weinberg and Schulman 1974).

(McConnell, "Code Complete 2nd Edition, 2004, pg 469)

Setting Software Quality Objectives

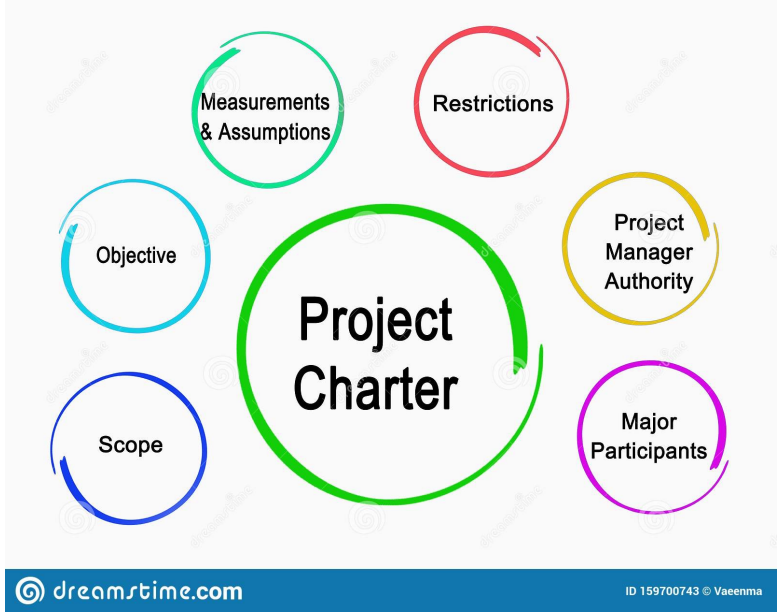
Software quality objectives must be

- Defined and clear
  - There should not be multiple interpretation of the same objective
  - Software quality objectives should be thought of as standards
- Stable
  - Objectives should not change as the project progresses
  - It's hard to meet objectives that are changing
- Consistent
  - Different objectives should not apply to different developers
  - All developers are held to the same standard
- Prioritized
  - If two objectives are in conflict, a clear precedence order must be defined
- Known by all
  - All developers must be onboarded with the same quality objectives
  - It is impossible to be consistent if different developers are working to different objectives.

But how?

Use a Project Charter to Set QA Objectives

- A **Project Charter** is a document that outlines the goals of a project and the responsibility of the team members
- It is the “constitution” of the project team
- Embedding the quality objectives into the project charter is a good way of ensuring that all developers are on the same page
- You will use project charters in
  - CSCI 3130 Software Engineering
  - CSCI 2691, CSCI 3691, CSCI 4691 Project courses
  - Some 4th year courses that have group projects



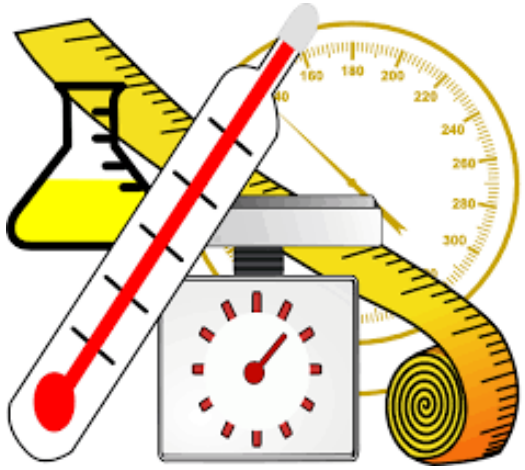
Examples of Software Quality Objectives

- **Readable code**: All code shall follow a specified style guide
- **New code does not break existing code**: All code must compile and pass all tests before being checked in
- **Code must be testable**: All code must be checked in with a full test suite
- **Code is verified**: All code must pass a formal review before being merged
- **Acceptable defect rate**: The number of defects per X lines of code should be less than Y

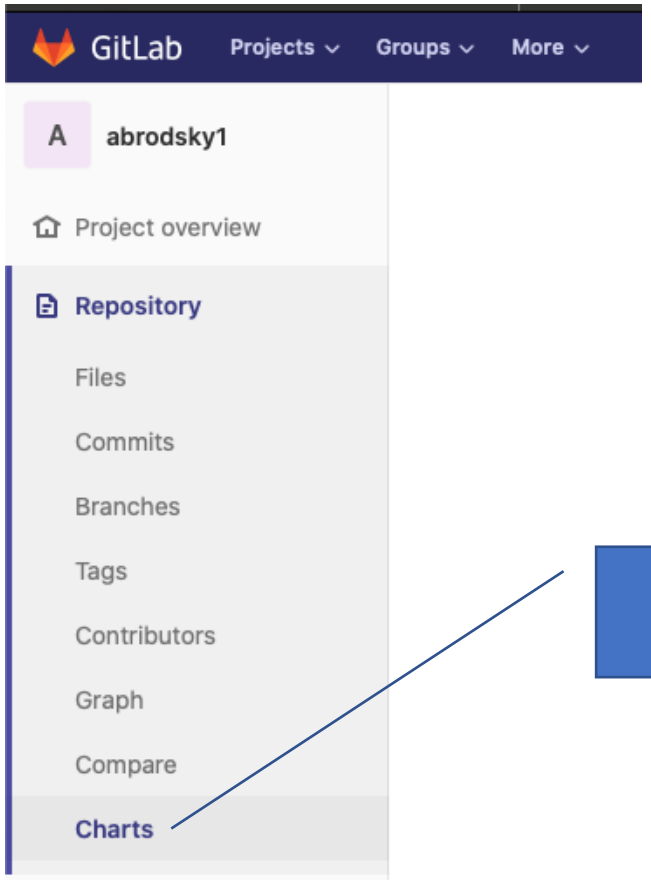
Explicit Quality Assurance Activity

- Quality assurance is not secondary.
  It's a prime part of your job!

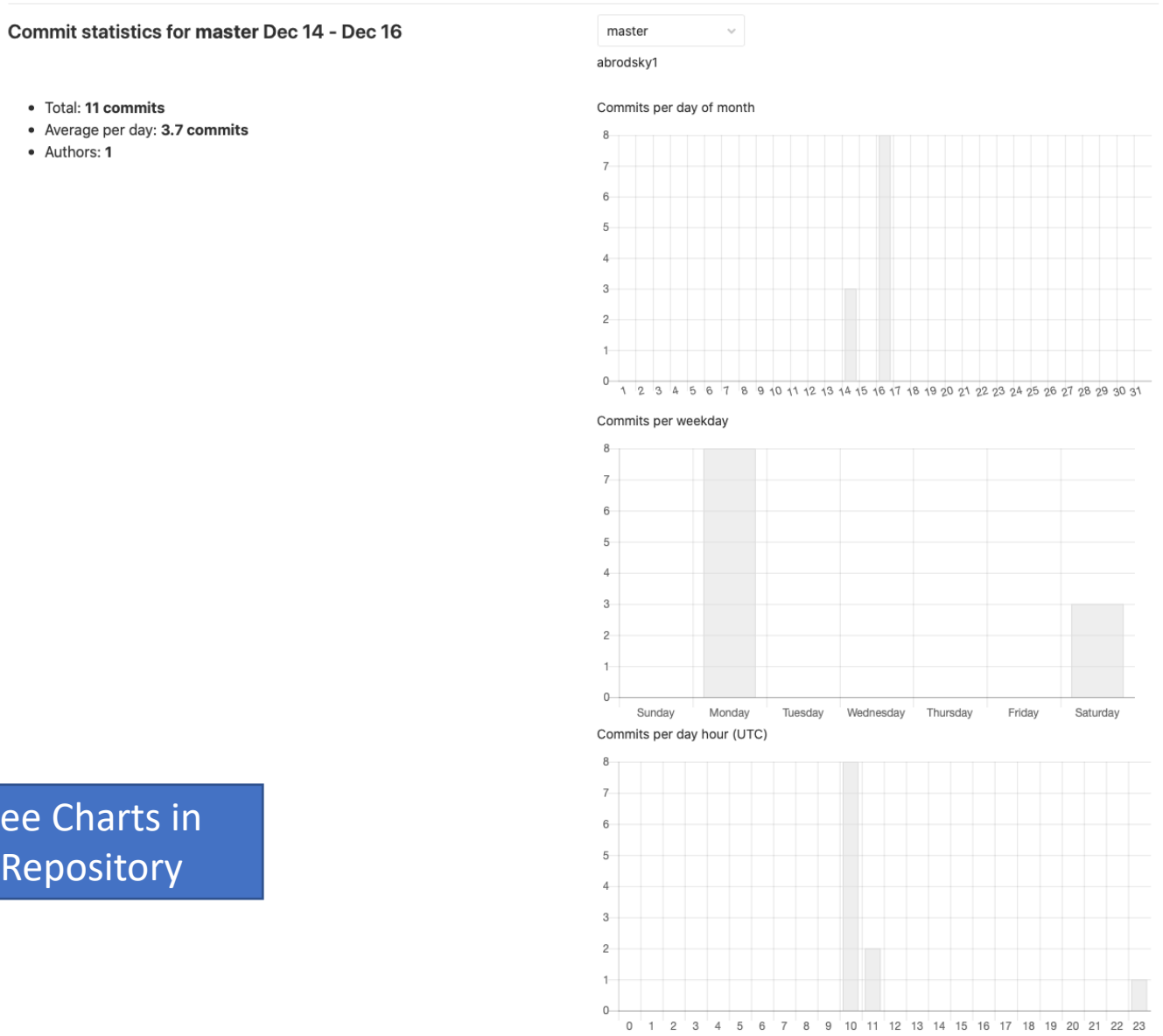
- Measure the software quality objectives
  - If you are not measuring, how do you know if you have achieved it?
  - Determine how and what to measure. E.g.,
    - Number of bugs found in code
    - Amount of time spent debugging
    - Number of corrections needed after a code review
    - Number of merges rejected
  - Take time to gather and review the data and act on it



Example: Use Statistics from GitLab

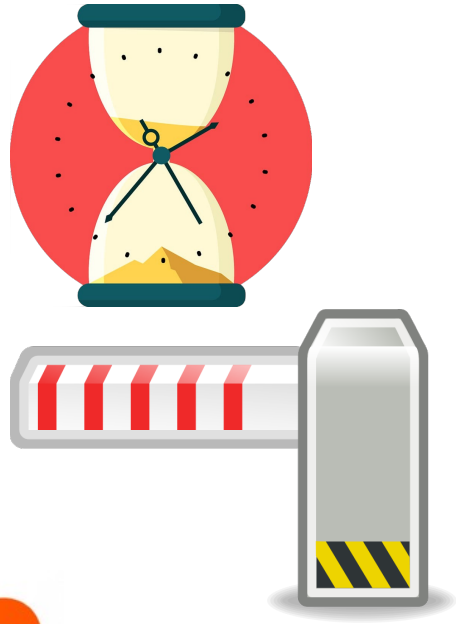


See Charts in Repository



Explicit Quality Assurance Activity

1. Allocate time to meet the objectives
   - If developers are not expected to explicitly do something, they will not!
   - Allocate time for code reviews and audits
   - Plan for time to remediate when objectives are not met
2. Enforce quality objectives
   - Do not allow code to be merged until it meets standards
   - **Gating**: Do not allow a project to proceed until objectives are met
   - Creates more work for supervisors
   - Viewed as a barrier by some
3. Reward developers for meeting objectives
   - Allow project to proceed to next stage
   - Social recognition
   - Monetary rewards



Software Engineering Guidelines

Guidelines are:

- Rules and heuristics that help us make good choices
- Used at each stage of the software development life cycle
- Either:
  - **External:** formulated by a third party or outside organization

    E.g., design patterns, SOLID principles, etc
  - **Internal:** formulated by your organization to be used by its members

    E.g., code style guide
- Not always right, but are right most of the time

  If you are not following the guidelines being used by your team, you should have a very good reason why

Why Use Guidelines?

- **Consistency**

  Similar design and coding scenarios result in the same decisions, leading to similar solutions
- **Correctness**
  - Guidelines are typically based on past experiences and past practices that have resulted in better outcomes
  - Guidelines typically encode “best practices”, which are the current state-of-the-art knowledge for doing things the “right” way
- **Understandability**
  - Guidelines provide standard approaches to problems that are better understood because they have been applied in the past
  - Standard approaches allow the reader to abstract the details, allowing them to focus on the system as a whole
- **Reliability**
  - Guidelines provide standard approaches that have worked well in the past and are more lilely to work in similar instances

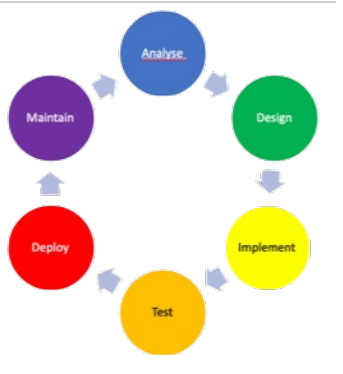
Example: Coding Style Guidelines

- Provide a set of rules for formatting code to make it more readable
- This creates code that is
  - **Consistent**: Code will look as if it is written by the same programmer
  - **Understandable**: Readers of the code will not need to search for information as it will be in the expected places, e.g., comments
  - **More correct and reliable**: Programmers will avoid making common errors, such as closing a code block in the wrong place
- Code readability is an important software quality objective as readable code is much easier to maintain and debug

Intermission

Next: Detecting Defects

Detecting Software Defects (Bugs)



We have many techniques for detecting defects: **Which one do we use?**

- **Informal design reviews** 🔵🟢**:** Informal team discussion of major design decisions
- **Formal design inspections** 🔵🟢: A review of each design decision, where each person has a specific role
- **Informal code reviews** 🟡: Informal team look-over of the one or more pieces of code
- **Formal code inspection** 🟡: A line-by-line review of code, where each person has a specific role
- **Personal desk-checking of code** 🟡: Individual review of personal code
- **Modeling or prototyping** 🟢🟡: Creation of proof-of-concept or simplified versions of the system to verify design decisions
- **Unit test** 🟡🟠🔴🟣: Execution of a complete class, routine, or small program, which is tested in isolation from the more complete system
- **New function (component) test** 🟡🟠🔴🟣: Execution of a class, package, small program, or other program element that involves the work of multiple programmers or programming teams, which is tested in isolation from the more complete system
- **Integration test** 🟡🟠🔴🟣: Combined execution of two or more classes, packages, components, or subsystems that have been created by multiple programmers or programming teams
- **System test** 🟡🟠🔴🟣: Execution of the software in its final configuration, including integration with other software and hardware systems.

Use Combinations of Techniques

- Different techniques are useful for finding different defects in different stages of development
- No technique is 100% effective on its own
- **In combination**, these techniques are **95% effective** (McConnel)

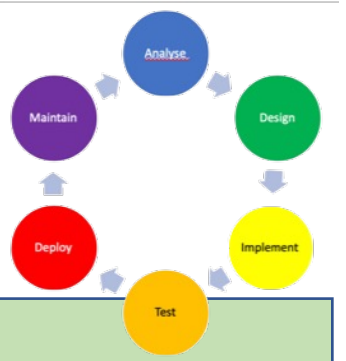
Table 20-2 Defect-Detection Rates

Removal Step	Lowest Rate	Modal Rate	Highest Rate
Informal design reviews	25%	35%	40%
Formal design inspections	45%	55%	65%
Informal code reviews	20%	25%	35%
Formal code inspections	45%	60%	70%
Modeling or prototyping	35%	65%	80%
Personal desk-checking of code	20%	40%	60%
Unit test	15%	30%	50%
New function (component) test	20%	30%	35%
Integration test	25%	35%	40%
Regression test	15%	25%	30%
System test	25%	40%	55%
Low-volume beta test (<10 sites)	25%	35%	40%
High-volume beta test (>1,000 sites)	60%	75%	85%

Source: Adapted from *Programming Productivity* (Jones 1986a), "Software Defect-Removal Efficiency" (Jones 1996), and "What We Have Learned About Fighting Defects" (Shull et al. 2002).

(McConnell, "Code Complete 2nd Edition, 2004, pg 470)

Detecting Software Defects (Bugs)



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What Is Collaborative Development?

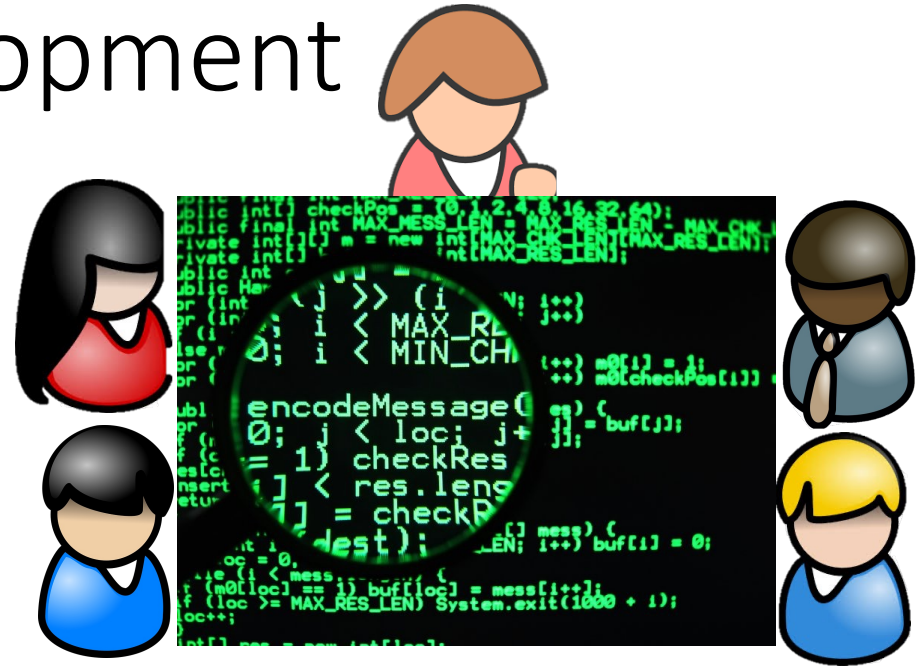
- **Collaborative Development** (Construction) is any technique in which developers share responsibility for creating code and other work products (McConnel, “CC2”, 2004)

- **Assumption**:
  - Every individual has blind-spots, weaknesses, biases that will cause them to create or miss software defects.
  - A team working together will compensate for each other’s blind-spots and make fewer mistakes
  - It is useful for us (developers) to have someone else look at our work

- **African Proverb**:

  “If you want to go quickly, go alone. If you want to go far, go together.”

Collaborative Software Development



- What does collaboration give you?
  - More eyes on the code to find defects
  - More points of view to get to good solutions
  - Shared understanding of the code
  - Shared ownership of the code
- In general, collaborative practices
  - May feel to some like they are wasting time because several people are doing what one person could do alone
  - Typically shorten development time and increase quality because we
    - Find defects earlier, which shortens the later stages of development
    - Make solutions that are more thoughtful

    Principle of software quality

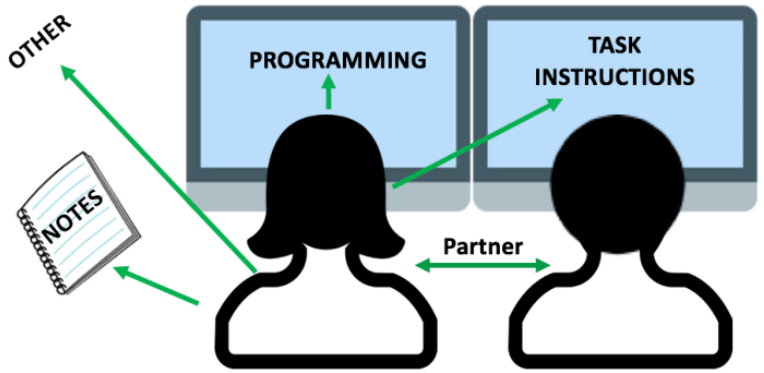
Examples of Collaborative Techniques

Technical Reviews

- Informal reviews
- Code readings
- Code walkthroughs
- Formal code reviews

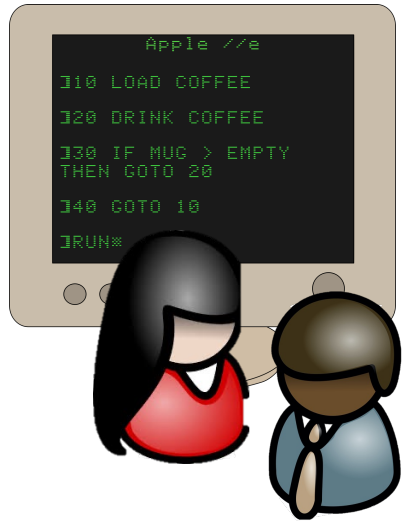
Collaborative Construction

- Extreme programming
- Pair programming



Organizations select the mode(s) that work best for them

Pair Programming



- Develop the code by two people and one keyboard
  - One person is entering the code (driver)
  - The other person (the **navigator**) is “shoulder surfing”
    – actively watching the coder
- Navigator’s Role:
  - Catch bugs as they happen
  - Think ahead of where the design is going so the current code fits well into that plan
  - Look up information on the side to support the coding, like standards, interfaces, data requirements, etc.
- The roles rotate periodically
  - This gives all developers equal opportunity to practice their skills
  - Ensures joint ownership of the work
  - Ensures that both developers are paying attention
- More on this at the end of the course

Technical Reviews

- Reviews must focus on detection of defects

- Reviews should stay away from solving the defects

  We get distracted with solving one defect and:

  - miss other defects
  - run out of time
  - spend the time of many people to solve a defect that takes one person to fix

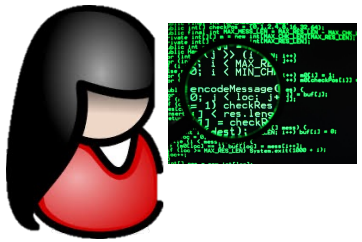
- In almost all reviews, the reviewers must prepare in advance.
  - The reviewers must be familiar with the code being reviewed

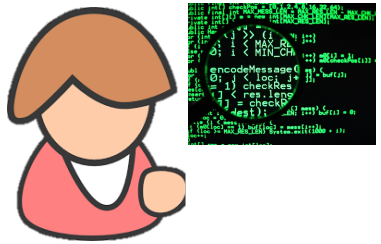
Informal Code Review

- Actions:
  - Ask someone to do a quick check of the code before proceeding in the development process
  - Provide quick feedback
  - Little recording of the defects found
- Advantages:
  - A lightweight (fast) process
  - Typically, good for detecting defects related to
    - layout
    - style
    - common errors
- Disadvantages
  - Only one other person looks at the code
  - Code is not thoroughly reviewed
  - Less effective with finding subtle design flaws

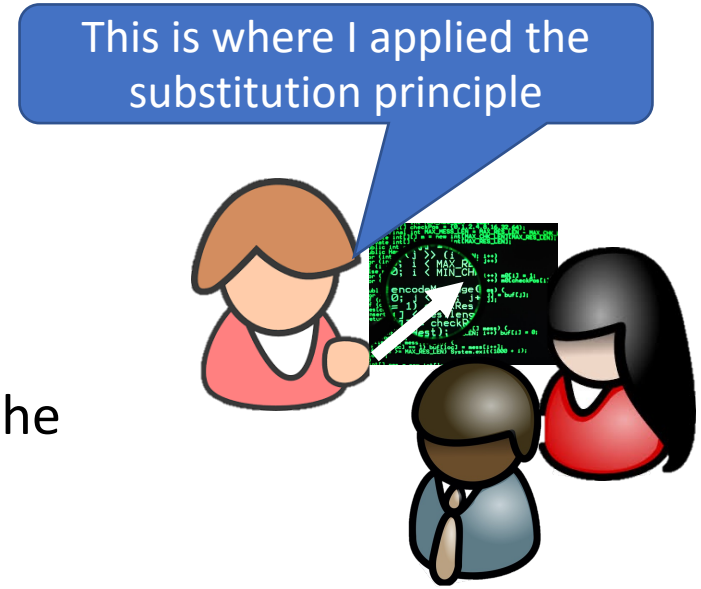
Code Reading

- Action:
  - Provide the code to 1-2 other people to read over
  - Discuss what they found in a small meeting
- Advantages
  - Provides more independent review time
  - More convenient review times (reviewers can read at their own pace)
- Disadvantages
  - Doesn’t ensure that code has been reviewed with the same degree of scrutiny





Code Walkthrough



- Actions:
  - Author-led meeting where the author explains the code or the design to a group of reviewers
- Advantages:
  - Efficient because the author knows the key elements
  - Effective when there are quite a few reviewers with diverse background
- Disadvantages:
  - Unintended bias

    Can lead the reviewers into the author's biases without them knowing
  - Unequal scrutiny of the code

    Author may focus what they are most proud of rather than the where the bugs might lie

Formal Code Review

- Actions:
  - Structured meeting with a clear focus / agenda
  - Not lead by the author of the code
  - Review team of 3-6 people

    Team size depends on the complexity of what you are reviewing
  - Distinct roles are assigned and performed by review members
  - All members of the review have prepared by reading the code
- Advantages:
  - Misses fewer defects than less focused methods
  - Can be done efficiently
- Disadvantages:
  - More time consuming

Formal Code Review Roles

- **Moderator**: Keeps the meeting on track (cannot be the author)
- **Author(s)**: Wrote the code being reviewed
- **Reviewer(s)**: Inspect the code as it is being read
  - Ask questions about it and point out defects
  - Take turns being readers
  - Cannot be the author
  - Different reviewers, may be assigned specific areas to watch. E.g.,
    - Layout and style issues
    - Integrity / security issues
    - Efficiency issues
- **Reader:** Reads the code out load and asks questions about it. (Not the author: unintended bias!)
- **Scribe**: records the location and severity of discovered defects
  - Can be merged with other roles

Checklist-Based Reviews

- It is useful to keep a checklist of common defects
  - Provides consistency in the review process
  - Allows the reviewers to focus on several categories of defects
  - Makes less experienced reviewers more effective
- Defect location(s) and severity are noted down in the appropriate row

CSCI 2134 Code Review Checklist[1]

Reviewers:			
Date:		Project:	
Files:			

Rating: (**A**) Occasional occurrence (**B**) Frequent occurrence (**C**) Pervasive (really bad)

Hygiene and understandability	Rating	Locations if present (File/Line #)
• Commented-out code fragments		
• Magic numbers (instead of constants)		
• Improper or inconsistent naming convention		
Formatting (adheres to code guidelines)	Rating	Locations if present (File/Line #)
• Inconsistent indentation		
• Inconsistent horizontal spacing: between operators, keywords		
• Inconsistent vertical spacing between methods, blocks, classes, etc		
Comments	Rating	Locations if present (File/Line #)
• Needless or redundant comments		
• No method headers to document parameters and functional dependencies		
• Inconsistent in format and level of detail		
Error Handling	Rating	Locations if present (File/Line #)
• Confusing or incomplete error messages		
• Unhandled boundary and edge cases (null, 0, negative)		
• Unvalidated use of parameters or inputs		
Code Decisions	Rating	Locations if present (File/Line #)
• Redundant code present		
• Inappropriate accessibility (public, private, etc.)		
• Unnecessary or redundant classes or objects		
• Variables not in lowest scope		
Logic	Rating	Locations if present (File/Line #)
• Out of bounds array indexes		
• Incorrect conditions in conditional statements and loops		
• Loops may not terminate		
• Division by zero possible		

[1] Based on https://courses.cs.washington.edu/courses/cse403/12wi/sections/12wi_code_review_checklist.pdf

Process of Formal Review

- Moderator arranges the logistics of the review
  - Books a meeting time and location
  - Distributes the code
- **Everyone reads the code before-hand**
- During the review
  - Reviewers take turns reading / paraphrasing the code
  - All reviewers are checking for consistency with desired goal/task
  - Defects are recorded to be fixed later; only discuss solutions which require design changes
    - Resist fixing the defects now
- After the review
  - **Inspection report** is produced and circulated
  - Author(s) are assigned to fix the defects
  - Organization should use reports as part of their software measurement process
  - An additional meeting may be scheduled to discuss solutions
  - Update checklists as needed

Example

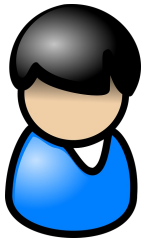
Adding to a linked list

- **add()** takes a key and a value and returns a boolean
- **added** is false, nothing has been added yet
- **found** is true
- Start at head of list, so **current** is **head**
- While key not found and not at end of list
- If current node has the same key as being added
- Set **found** to true

```
public boolean add(String key, int value) {
  boolean added = false;
  boolean found = true;
  Node current = head;

  // See if the key is already in the list.
  while (!found && (current != null)) {
    if (key == current.key) {
      found = true;
    }
    current = current.next;
  }

  // Add it to the list if not found.
  if (!found) {
    current = new Node();
    current.next = head;
    current.key = key;
    current.value = value;
  }
  return added;
}
```



author

reviewer

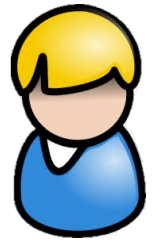
reviewer

- **H**as something been found initially?
- This loop will never execute!!!!

…

- head **is never set to current!**

moderator



scribe

- **found** is not initialized properly
- **head** is not updated

Video of a Formal Code Review

https://www.youtube.com/watch?v=JaJ_nNk3f1o

Key 

Points

- The earlier a software defect is identified (or avoided), the cheaper it is to fix
- Software quality objectives help a team work together to make good code
- Use a combination of techniques to find different defects at different stages of development
- Collaborative Software development gives more eyes, more points of view and a shared understanding but is more time consuming
- Collaborative Software development includes techniques like pair programming, informal code review and formal code review

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