CS 4320 / 7320 Software Engineering

Software Engineering Lifecycle

& Basic Concepts

CS 4320 / 7320
Software Engineering

Software Engineering Lifecycle

& Basic Concepts

Software Engineering

- What is engineering, as a discipline?
- What is software?
- What are the consequences of poor engineering?

Software Engineering

- What is engineering, as a discipline?

"The application of scientific, economic, social, and practical knowledge in order to design, build, and maintain structures, machines, devices, systems, materials and processes"

- wikipedia

Software Engineering

- What is software?

Computer programs **and related documentation of requirements, designs, models, and manuals.**

- Sommerville

Software Engineering

- What are the consequences of poor engineering?

Horrible, horrible consequences!!!

Engineering Failures

Engineering Failures

- What are the consequences of poor engineering?

Source: http://en.wikipedia.org/wiki/File:TacomaNarrowsBridgeCollapse_in_color.jpg

Engineering Failures

- What are the consequences of poor engineering?

Tacoma Narrows Bridge Collapse (1940):

42 mph winds

- http://www.wsdot.wa.gov/tnbhistory/machine/machine3.htm
- Poor engineering practices did not account for aerodynamics of suspension bridge design
- See:

http://upload.wikimedia.org/wikipedia/commons/1/19/Tacoma_Narrows_Bridge_destruction.ogg

Engineering Failures

- What are the consequences of poor engineering?

But, what about today, with current computer modeling techniques?

2007 I-35 bridge collapse in Minneapolis

"An employee of the NTSB had written his doctoral thesis on possible failure scenarios of this specific bridge while he was a student at the nearby University of Minnesota. That thesis, including his computer model of the bridge for failure mode analysis, was used by the NTSB to aid in their investigation."

- http://en.wikipedia.org/wiki/I-35W_Mississippi_River_bridge

Eng

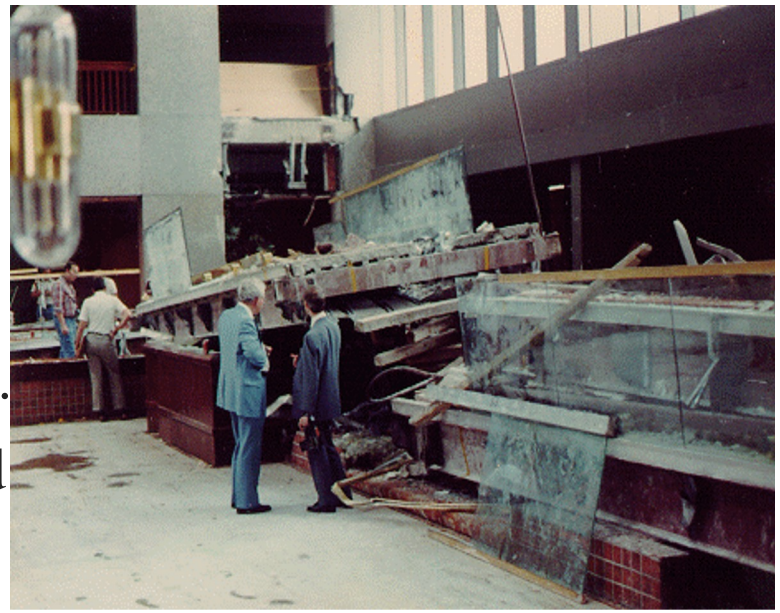
Source: http://en.wikipedia.org/wiki/File:I35_Bridge_Collapse_4crop.jpg

Engineering Failures

- What are the consequences of poor engineering?

Hyatt Regency, KCMO

An elevated walkway gathered a crowd watching a dance below. The static load of crowd = failure

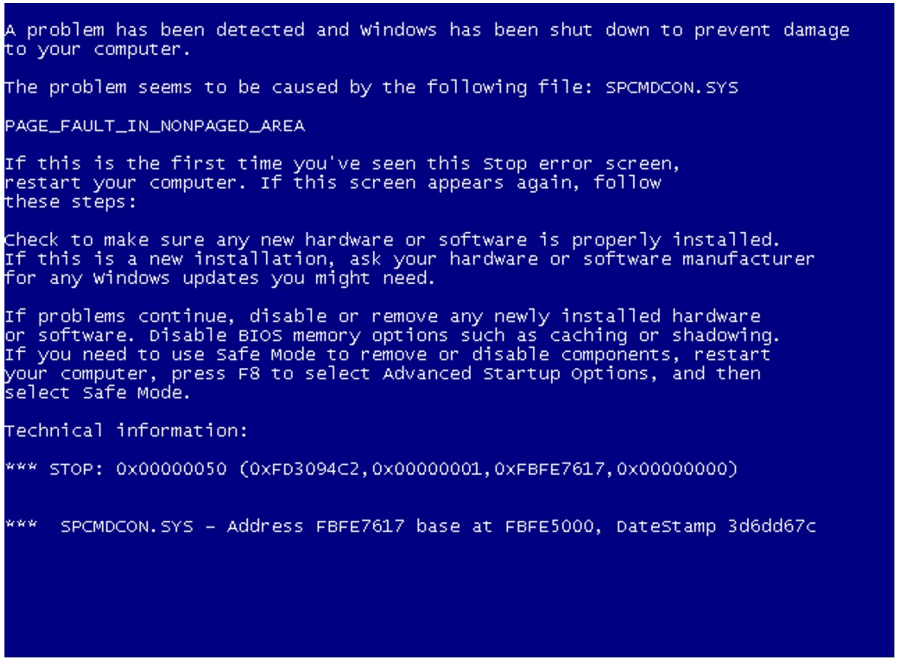


Source: http://en.wikipedia.org/wiki/File:Hyatt_Regency_collapse_floor_view.PNG

Engineering Failures

- What about when software fails?

Windows XP Blue Screen of Death



- Frustrating

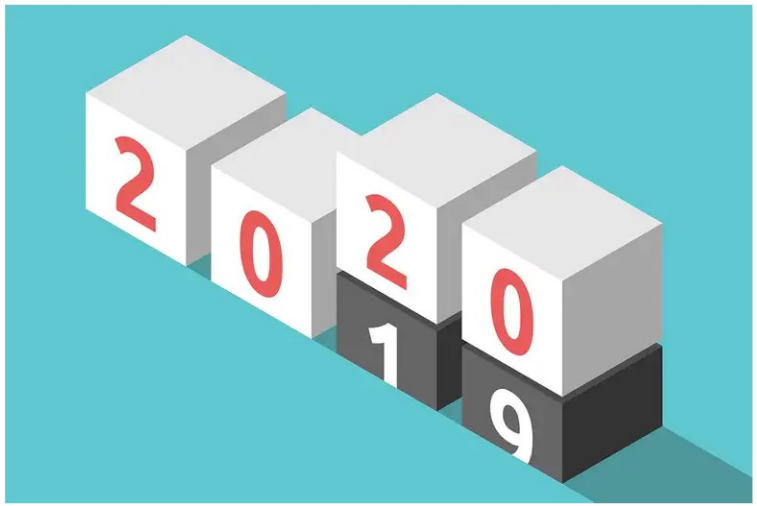
Source: http://en.wikipedia.org/wiki/File:Windows_XP_BSOD.png

Recent Software Engineering Failures

A lazy fix 20 years ago means the Y2K bug is taking down computers now

TECHNOLOGY 7 January 2020

By Chris Stokel-Walker



Recent Software Engineering Failures

LILY HAY NEWMAN SECURITY 10.01.2019 11:12 AM

Decades-Old Code Is Putting Millions of Critical Devices at Risk

Nearly two decades ago, a company called Interpeak created a network protocol that became an industry standard. It also had severe bugs that are only now coming to light.

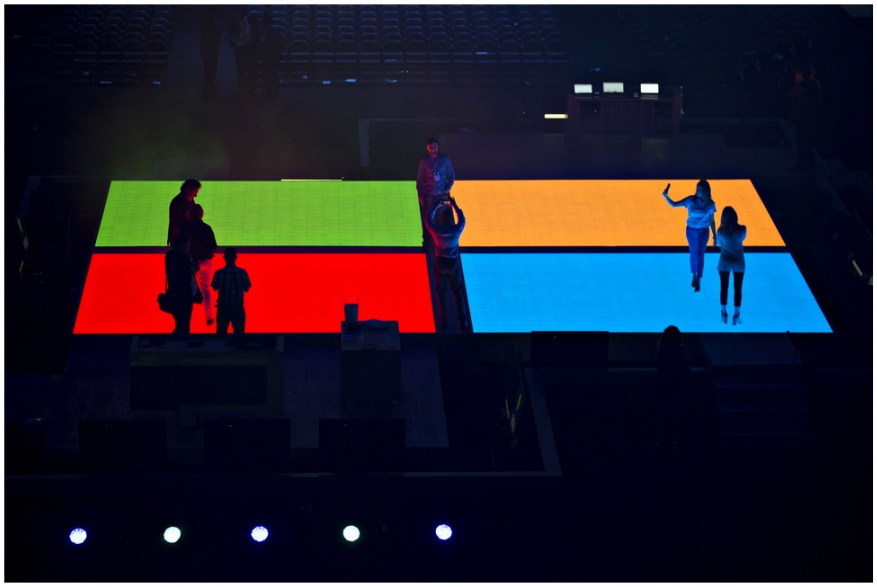
PHOTOGRAPH: LEON WERDINGER/ALAMY

Recent Software Engineering Failures

ALEX BAKER-WHITCOMB SECURITY 01.14.2020 05:45 PM

An Alarming Windows Bug, a Triumph for Tesla, and More News

Catch up on the most important news from today in two minutes or less.



PHOTOGRAPH: ANDREW HARRER/GETTY IMAGES

Engineering Failures

- … or very costly! "

Date: 9/1997

(By James Gleick) It took the European Space Agency **10 years and $7 billion to produce Ariane 5**, a giant rocket capable of hurling a pair of three-ton satellites into orbit with each launch and intended to give Europe overwhelming supremacy in the commercial space business.

All it took to **explode** that rocket **less than a minute into its maiden voyage** last June, scattering fiery rubble across the mangrove swamps of French Guiana, was a small **computer program** trying to stuff a **64-bit number into a 16-bit space**.

...

This shutdown occurred 36.7 seconds after launch, when the guidance system's own computer tried to convert one piece of data -- the sideways velocity of the rocket -- from a 64-bit format to a 16-bit format. The number was too big, and an overflow error resulted. When the guidance system shut down, it passed control to an identical, redundant unit, which was there to provide backup in case of just such a failure. But the second unit had failed in the identical manner a few milliseconds before. And why not? It was running the same software.

"

Source: http://www.cse.lehigh.edu/~gtan/bug/softwarebug.html#ariane

Engineering Failures

- … or life threatening! "

Date: 9/14/**2004**

(IEEE Spectrum) -- It was an air traffic controller's worst nightmare. Without warning, on Tuesday, 14 September, at about 5 p.m. Pacific daylight time, air traffic controllers lost voice contact with 400 airplanes they were tracking over the southwestern United States. Planes started to head toward one another, something that occurs routinely under careful control of the air traffic controllers, who keep airplanes safely apart. But now the controllers had no way to redirect the planes' courses.

...

The controllers lost contact with the planes when the main voice communications system shut down unexpectedly. To make matters worse, a backup system that was supposed to take over in such an event crashed within a minute after it was turned on. The outage disrupted about 800 flights across the country.

...

Inside the control system unit is a countdown timer that ticks off time in milliseconds. The VCSU uses the timer as a pulse to send out periodic queries to the VSCS. It starts out at the highest possible number that the system's server and its software can handle—2^32. It's a number just over 4 billion milliseconds. When the counter reaches zero, the system runs out of ticks and can no longer time itself. So it shuts down.

Counting down from 2^32 to zero in milliseconds takes just under 50 days. The FAA procedure of having a technician reboot the VSCS every 30 days resets the timer to 2^32 almost three weeks before it runs out of digits. "

Source: http://www.cse.lehigh.edu/~gtan/bug/softwarebug.html#aircontrol

Software Engineering

- Software Engineering:

"Engineering discipline that is concerned with all aspects of software production"

- Sommerville

- Recall that software is:

Computer programs and related documentation of requirements, designs, models, and manuals.

Software Engineering

- Theories, methods and tools for professional software development
  - Computer Code/Programs
  - Requirements Documents
  - Design Documents
  - Data, Process, and other models
  - User manuals
- In other words; coding is a small portion of software engineering, the majority is technical documentation.

Technical Documents

- Software engineering does not exist outside the creation of a variety of technical documents
- Analogous to:
  - Blue prints for construction projects
  - Logic design and wiring diagrams for hardware fabrication
  - Models, prototypes, and computer simulations for aircraft and space vehicles

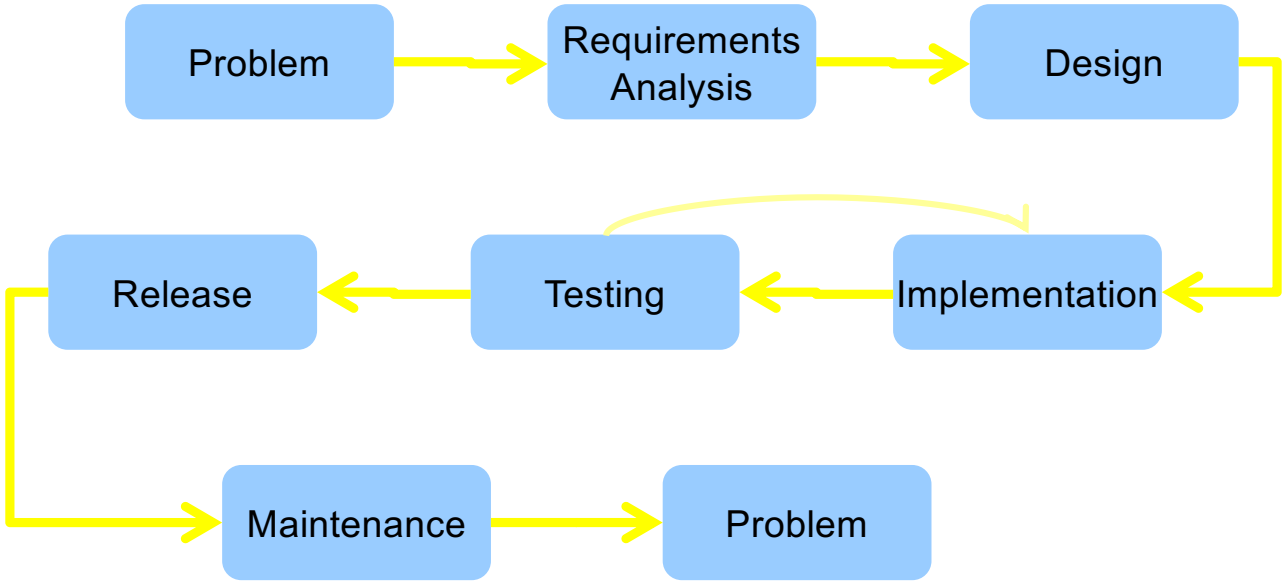
NASA happens to have some of the best software engineers for a reason

Software Engineering

- Why is it so important to get software engineering right?
- Software engineering is more than just
  - Designing a solution
  - Coding a solution
- Software engineering is also about process management

Software Engineering

- What is the high-level process?



Software Development Lifecycle

- Problem: Some entity (program, process, etc) that requires software to be created as the preferred solution.
- Requirements: The explicit, well defined, thorough goals of the software - i.e., what should it do?
- Design: The detailed plans that will facilitate the construction of computer code to sufficiently solve the problem.

Software Development Lifecycle

- Implementation: The construction of the computer program that is a solution to the problem.

- Testing: Validating the requirements are met and the outcomes of computer programs match the expectations set forth in the Requirements and Design stages.
  - Note: Testing can drive further implementation

Software Development Lifecycle

- Release: The transition of computer programs from the developers to the users.
- Maintenance: The continual upkeep of the software, including computer programs, documentation, requirements, design, testing, and enhancement/bug-fix implementation.
- Problem: ?

Software Development Lifecycle

- Problem: ???
  - A problem is the end of all software.
  - Usually, the software is no longer needed

    Obsolete or replaced
- New software takes the place of old software, as a clean solution to a problem that is usually different, or broader scoped, than the original problem.
  - Eventually, all software becomes obsolete.
  - The hardware that runs the most solid, perfect legacy code is eventually replaced.

Characteristic Goals for SWE

- Maintainability:
  - Designed to evolve to meet the changing needs of the customer
  - Change is inevitable, hence *Change Management*
- Dependability:
  - Reliable, performs consistently as expected
  - Should not cause damage or fail
- Security:
  - Operate with integrity, must be able to trust the results of the software

Characteristic Goals for SWE

- Efficiency:
  - No wasteful consumption of resources, e.g.
    network bandwidth, CPU cycles,
    RAM, Secondary storage
  - Responsive to environment and/or users
- Acceptability (compatibility):
  - Software should be designed for the appropriate user base
  - Does the user understand, and can they efficiently operate the software, compatible with environment

The Software Development Lifecycle

Topics covered

Software process models

Process activities

Coping with change

Process improvement

The software process

A structured set of activities required to develop a software system.

Many different software processes but all involve:

- Specification – defining what the system should do;
- Design and implementation – defining the organization of the system and implementing the system;
- Validation – checking that it does what the customer wants;
- Evolution – changing the system in response to changing customer needs.

A software process model is an abstract representation of a process. It presents a description of a process from some particular perspective.

Software process descriptions

When we describe and discuss processes, we usually talk about the activities in these processes such as specifying a data model, designing a user interface, etc. and the ordering of these activities.

Process descriptions may also include:

- Products, which are the outcomes of a process activity;
- Roles, which reflect the responsibilities of the people involved in the process;
- Pre- and post-conditions, which are statements that are true before and after a process activity has been enacted or a product produced.

Plan-driven and agile processes

Plan-driven processes are processes where all of the process activities are planned in advance and progress is measured against this plan.

In agile processes, planning is incremental and it is easier to change the process to reflect changing customer requirements.

In practice, most practical processes include elements of both plan-driven and agile approaches.

There are no right or wrong software processes.

Software process models

Software process models

The waterfall model

Plan-driven model. Separate and distinct phases of specification and development.

Incremental development

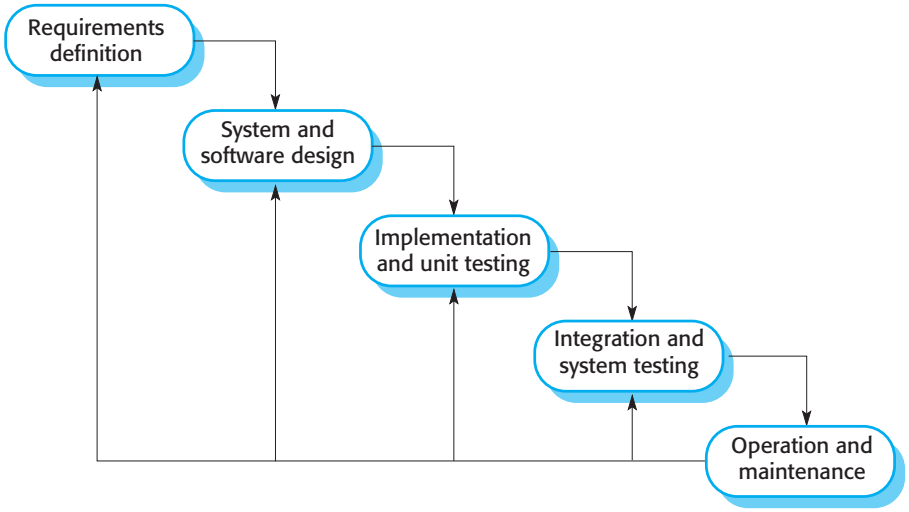
Specification, development and validation are interleaved. May be plan-driven or agile.

Integration and configuration

The system is assembled from existing configurable components. May be plan-driven or agile.

In practice, most large systems are developed using a process that incorporates elements from all of these models.

The waterfall model



Waterfall model phases

There are separate identified phases in the waterfall model:

- Requirements analysis and definition
- System and software design
- Implementation and unit testing
- Integration and system testing
- Operation and maintenance

The main drawback of the waterfall model is the difficulty of accommodating change after the process is underway. In principle, a phase has to be complete before moving onto the next phase.

Waterfall model problems

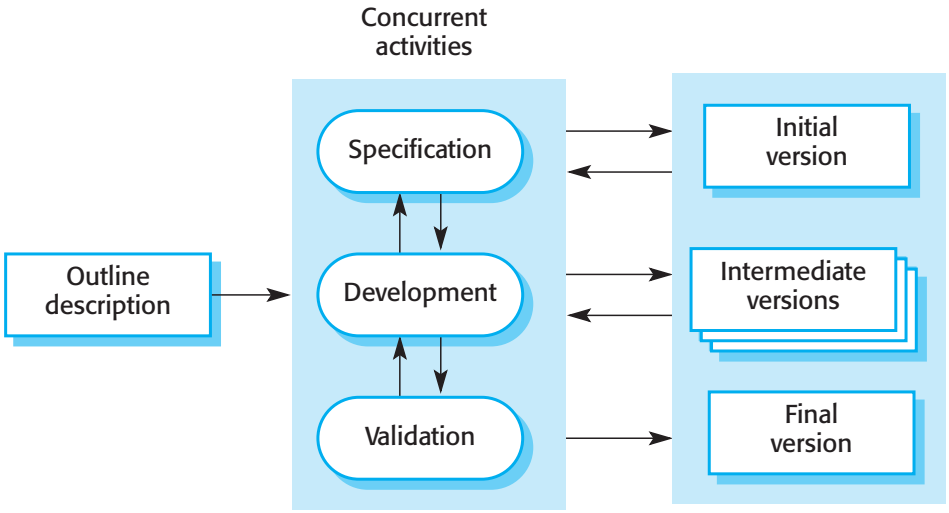
Inflexible partitioning of the project into distinct stages makes it difficult to respond to changing customer requirements.

- Therefore, this model is only appropriate when the requirements are well-understood and changes will be fairly limited during the design process.
- Few business systems have stable requirements.

The waterfall model is mostly used for large systems engineering projects where a system is developed at several sites.

- In those circumstances, the plan-driven nature of the waterfall model helps coordinate the work.

Incremental development



Incremental development benefits

The cost of accommodating changing customer requirements is reduced.

- The amount of analysis and documentation that has to be redone is much less than is required with the waterfall model.

It is easier to get customer feedback on the development work that has been done.

- Customers can comment on demonstrations of the software and see how much has been implemented.

More rapid delivery and deployment of useful software to the customer is possible.

- Customers are able to use and gain value from the software earlier than is possible with a waterfall process.

Incremental development problems

The process is not visible.

- Managers need regular deliverables to measure progress. If systems are developed quickly, it is not cost-effective to produce documents that reflect every version of the system.

System structure tends to degrade as new increments are added.

- Unless time and money is spent on refactoring to improve the software, regular change tends to corrupt its structure. Incorporating further software changes becomes increasingly difficult and costly.

Integration and configuration

Based on software reuse where systems are integrated from existing components or application systems (sometimes called COTS -Commercial-off-the-shelf) systems).

Reused elements may be configured to adapt their behaviour and functionality to a user's requirements

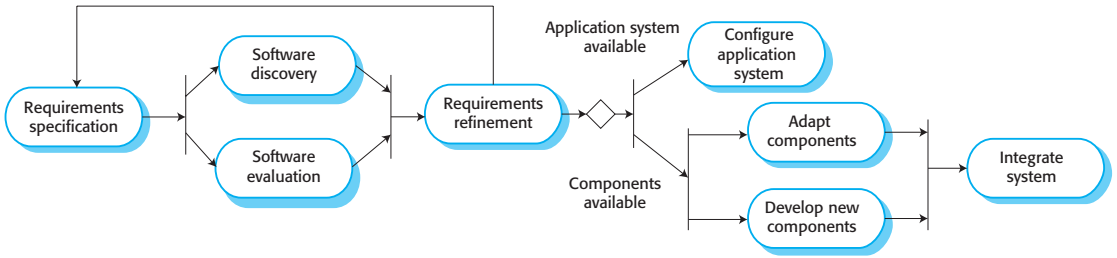
Types of reusable software

Stand-alone application systems (sometimes called COTS) that are configured for use in a particular environment.

Collections of objects that are developed as a package to be integrated with a component framework such as .NET or J2EE.

Web services that are developed according to service standards and which are available for remote invocation.

Reuse-oriented software engineering



Key process stages

Requirements specification

Software discovery and evaluation

Requirements refinement

Application system configuration

Component adaptation and integration

Advantages and disadvantages

Reduced costs and risks as less software is developed from scratch

Faster delivery and deployment of system

But requirements compromises are inevitable so system may not meet real needs of users

Loss of control over evolution of reused system elements

SDLC activities

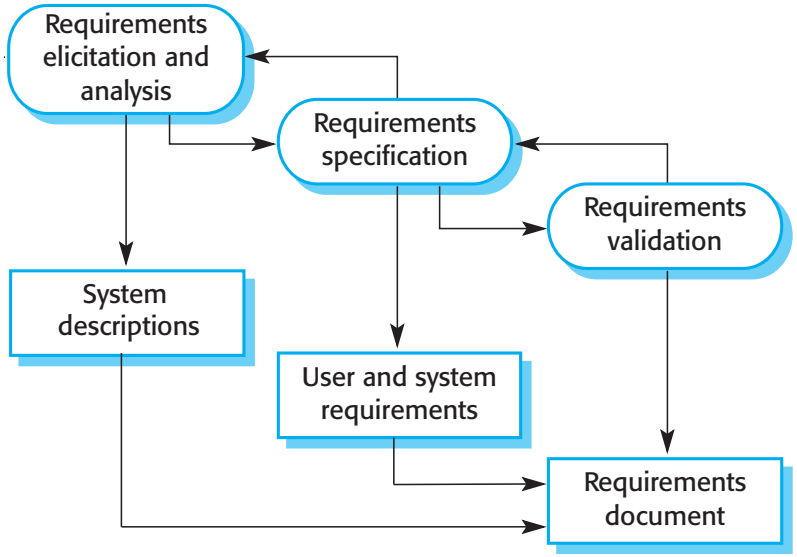
SDLC activities

Real software processes are inter-leaved sequences of technical, collaborative and managerial activities with the overall goal of specifying, designing, implementing and testing a software system.

The four basic process activities of specification, development, validation and evolution are organized differently in different development processes.

For example, in the waterfall model, they are organized in sequence, whereas in incremental development they are interleaved.

The requirements engineering process



Software specification

The process of establishing what services are required and the constraints on the system's operation and development.

Requirements engineering process

- Requirements elicitation and analysis
  - *What do the system stakeholders require or expect from the system?*
- Requirements specification
  - *Defining the requirements in detail*
- Requirements validation
  - *Checking the validity of the requirements*

Software design and implementation

The process of converting the system specification into an executable system.

Software design

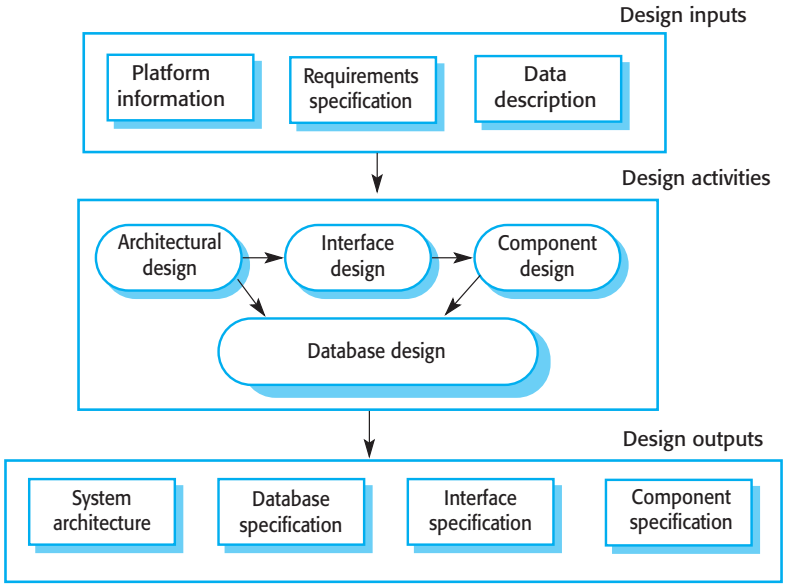
Design a software structure that realises the specification;

Implementation

Translate this structure into an executable program;

The activities of design and implementation are closely related and may be inter-leaved.

A general model of the design process



Design activities

Architectural design, where you identify the overall structure of the system, the principal components (subsystems or modules), their relationships and how they are distributed.

Database design, where you design the system data structures and how these are to be represented in a database.

Interface design, where you define the interfaces between system components.

Component selection and design, where you search for reusable components. If unavailable, you design how it will operate.

System implementation

The software is implemented either by developing a program or programs or by configuring an application system.

Design and implementation are interleaved activities for most types of software system.

Programming is an individual activity with no standard process.

Debugging is the activity of finding program faults and correcting these faults.

Software validation

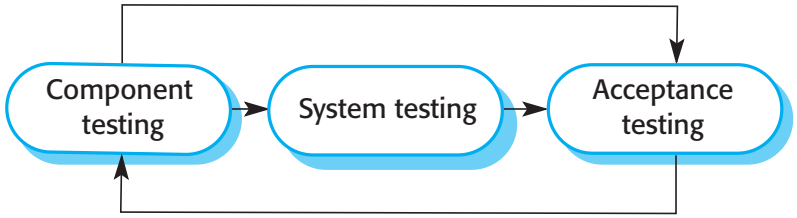
Verification and validation (V & V) is intended to show that a system conforms to its specification and meets the requirements of the system customer.

Involves checking and review processes and system testing.

System testing involves executing the system with test cases that are derived from the specification of the real data to be processed by the system.

Testing is the most commonly used V & V activity.

Stages of testing



Testing stages

Component testing

Individual components are tested independently;

Components may be functions or objects or coherent groupings of these entities.

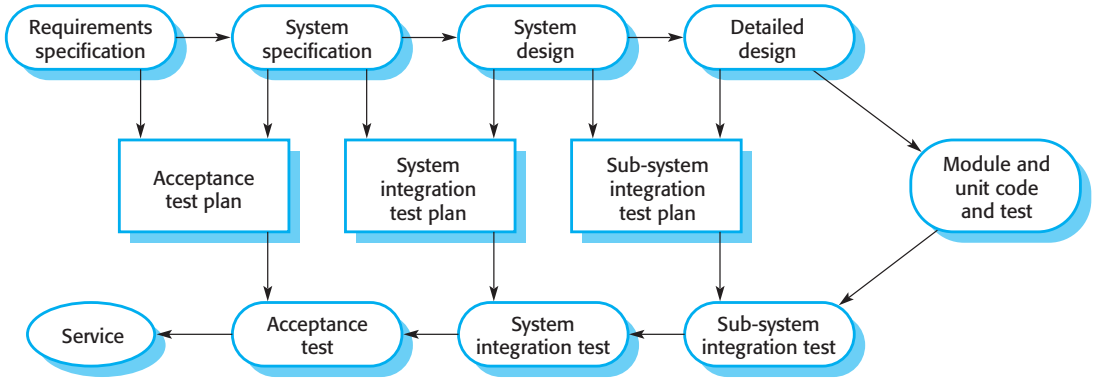
System testing

Testing of the system as a whole. Testing of emergent properties is particularly important.

Customer testing

Testing with customer data to check that the system meets the customer’s needs.

Testing phases in a plan-driven software process (V-model)



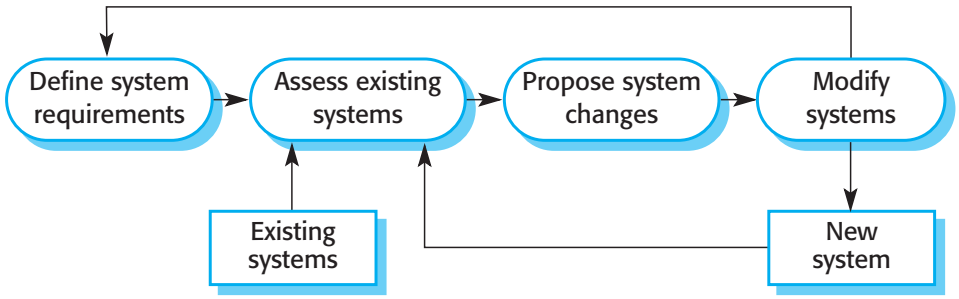
Software evolution

Software is inherently flexible and can change.

As requirements change through changing business circumstances, the software that supports the business must also evolve and change.

Although there has been a demarcation between development and evolution (maintenance) this is increasingly irrelevant as fewer and fewer systems are completely new.

System evolution



Coping with change

Coping with change

Change is inevitable in all large software projects.

- Business changes lead to new and changed system requirements
- New technologies open up new possibilities for improving implementations
- Changing platforms require application changes

Change leads to rework so the costs of change include both rework (e.g. re-analyzing requirements) as well as the costs of implementing new functionality

Reducing the costs of rework

Change anticipation, where the software process includes activities that can anticipate possible changes before significant rework is required.

- For example, a prototype system may be developed to show some key features of the system to customers.

Change tolerance, where the process is designed so that changes can be accommodated at relatively low cost.

- This normally involves some form of incremental development. Proposed changes may be implemented in increments that have not yet been developed. If this is impossible, then only a single increment (a small part of the system) may have be altered to incorporate the change.

Coping with changing requirements

System prototyping, where a version of the system or part of the system is developed quickly to check the customer's requirements and the feasibility of design decisions. This approach supports change anticipation.

Incremental delivery, where system increments are delivered to the customer for comment and experimentation. This supports both change avoidance and change tolerance.

Software prototyping

A prototype is an initial version of a system used to demonstrate concepts and try out design options.

A prototype can be used in:

- The requirements engineering process to help with requirements elicitation and validation;
- In design processes to explore options and develop a UI design;
- In the testing process to run back-to-back tests.

Benefits of prototyping

Improved system usability.

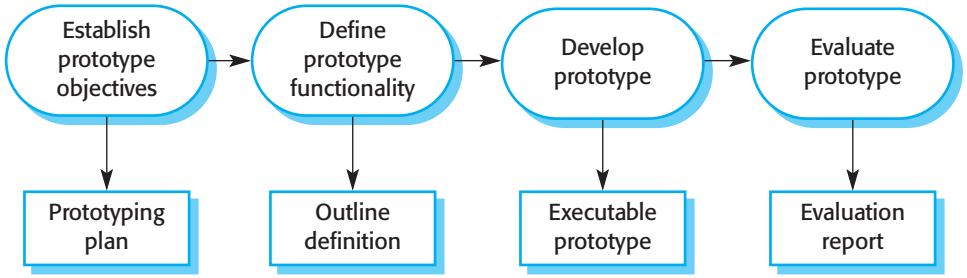
A closer match to users' real needs.

Improved design quality.

Improved maintainability.

Reduced development effort.

The process of prototype development



Prototype development

May be based on rapid prototyping languages or tools

May involve leaving out functionality

- Prototype should focus on areas of the product that are not well-understood;
- Error checking and recovery may not be included in the prototype;
- Focus on functional rather than non-functional requirements such as reliability and security

Throw-away prototypes

Prototypes should be discarded after development as they are not a good basis for a production system:

- It may be impossible to tune the system to meet non-functional requirements;
- Prototypes are normally undocumented;
- The prototype structure is usually degraded through rapid change;
- The prototype probably will not meet normal organisational quality standards.

Incremental delivery

Rather than deliver the system as a single delivery, the development and delivery is broken down into increments with each increment delivering part of the required functionality.

User requirements are prioritised and the highest priority requirements are included in early increments.

Once the development of an increment is started, the requirements are frozen though requirements for later increments can continue to evolve.

Incremental development and delivery

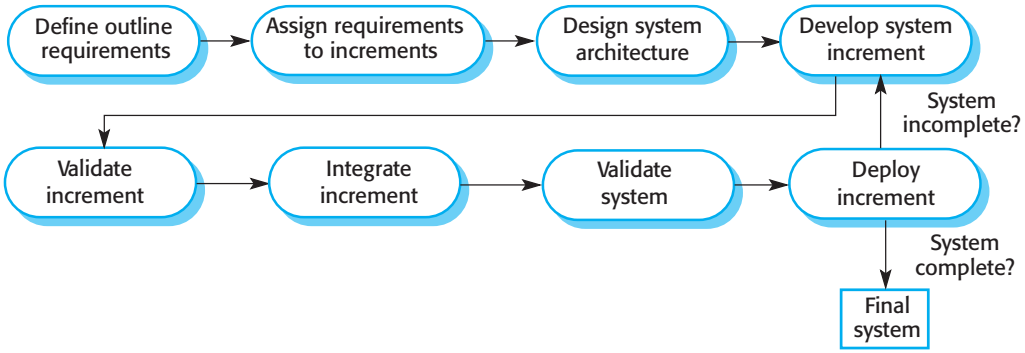
Incremental development

- Develop the system in increments and evaluate each increment before proceeding to the development of the next increment;
- Normal approach used in agile methods;
- Evaluation done by user/customer proxy.

Incremental delivery

- Deploy an increment for use by end-users;
- More realistic evaluation about practical use of software;
- Difficult to implement for replacement systems as increments have less functionality than the system being replaced.

Incremental delivery



Incremental delivery advantages

Customer value can be delivered with each increment so system functionality is available earlier.

Early increments act as a prototype to help elicit requirements for later increments.

Lower risk of overall project failure.

The highest priority system services tend to receive the most testing.

Incremental delivery problems

Most systems require a set of basic facilities that are used by different parts of the system.

- As requirements are not defined in detail until an increment is to be implemented, it can be hard to identify common facilities that are needed by all increments.

The essence of iterative processes is that the specification is developed in conjunction with the software.

- However, this conflicts with the procurement model of many organizations, where the complete system specification is part of the system development contract.

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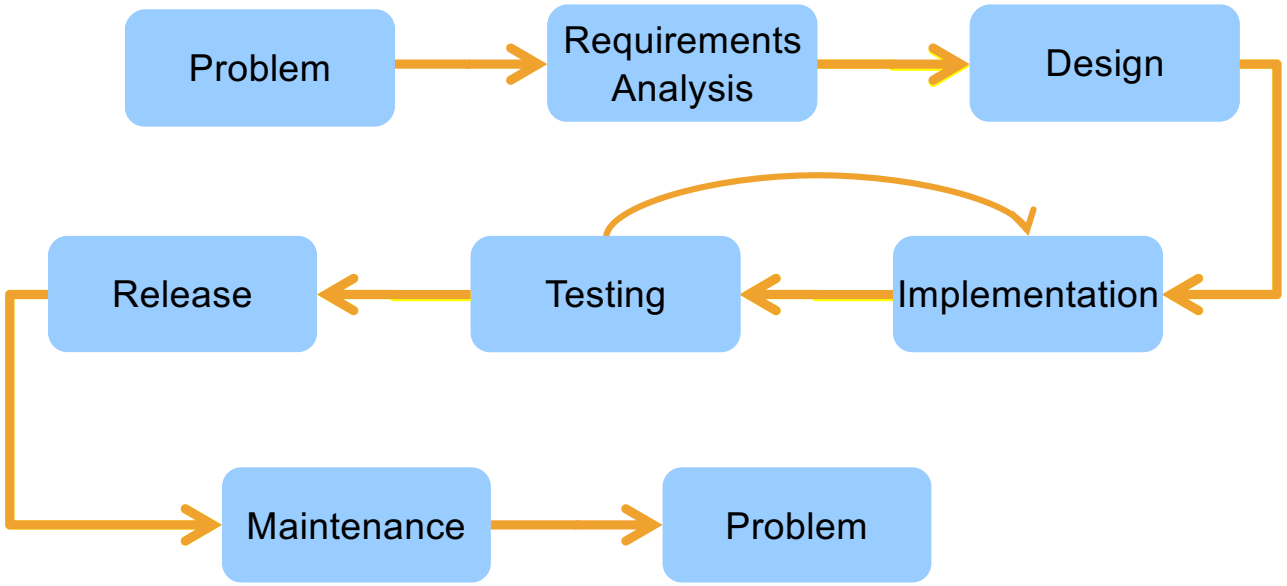
What is the SDLC?



… and back to the beginning…

What are the key factors for a
DEFINITION
of Software Engineering?

Software Engineering is…

"…the application of a systematic, disciplined, *quantifiable* approach to the development, operation, and maintenance of software; that is, the application of engineering to software."

ISO/IEC/IEEE Systems and Software Engineering Vocabulary

Goals of Software Engineering

What are the key items to include in a
LIST OF GOALS
for Software Engineering?

Goals of Software Engineering:

1. Dependability
2. Maintainability
3. Efficiency
4. Acceptability
5. Security

Ian Sommerville, Software Engineering 9th ed.

Software Engineering Methods

Organized and **systematic** approaches
to developing software

As an engineer, you choose
an appropriate ***method*** or ***methods***

** See SWEBOK Chapter 9

Software Engineering Methods

Types:

- Heuristic
- Formal
- Prototyping
- Agile

Heuristic Methods

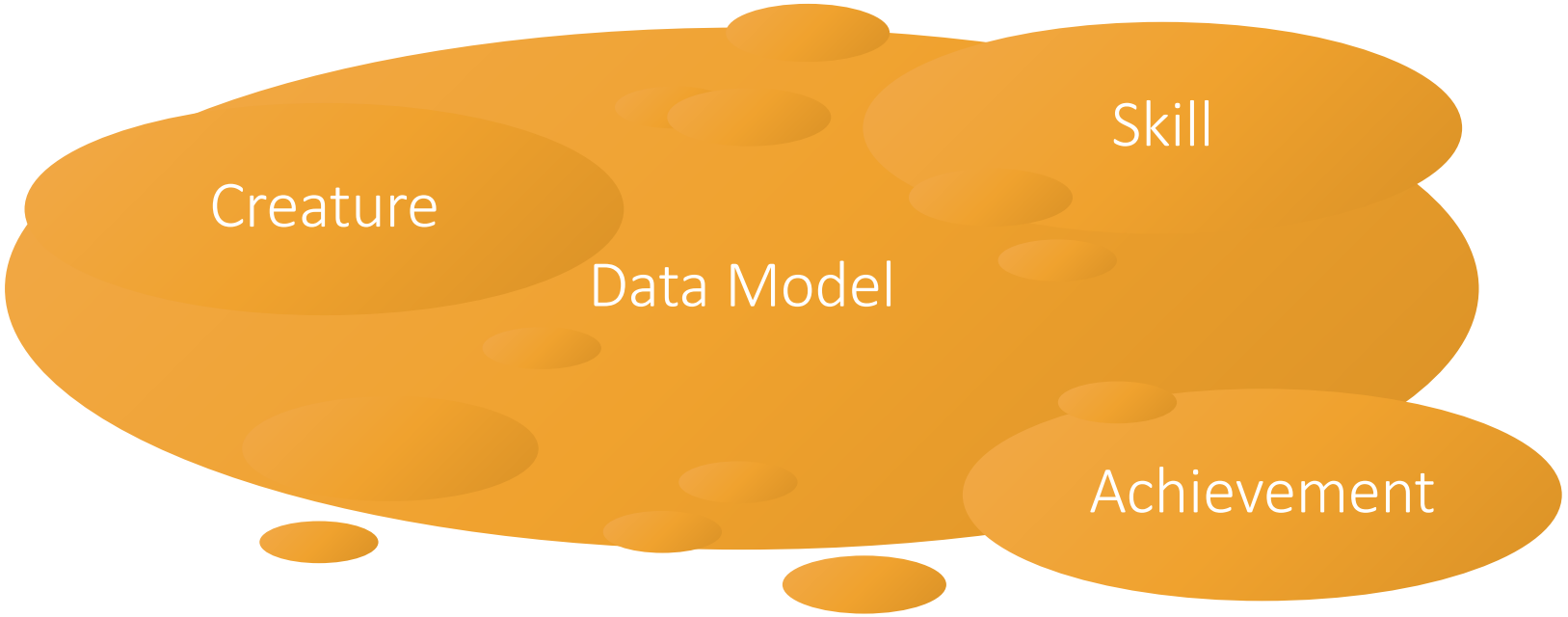
Structured Analysis and Design Methods

Data Modeling Methods

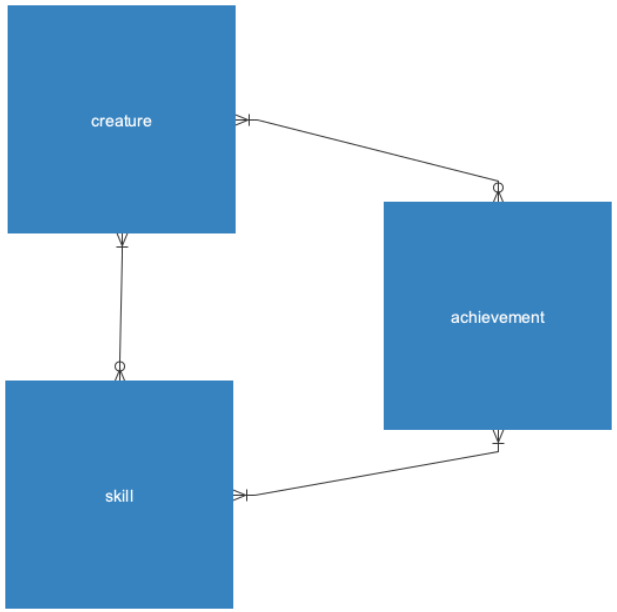
Object Oriented Analysis and Design Methods

Heuristic Methods: Structured Analysis and Design

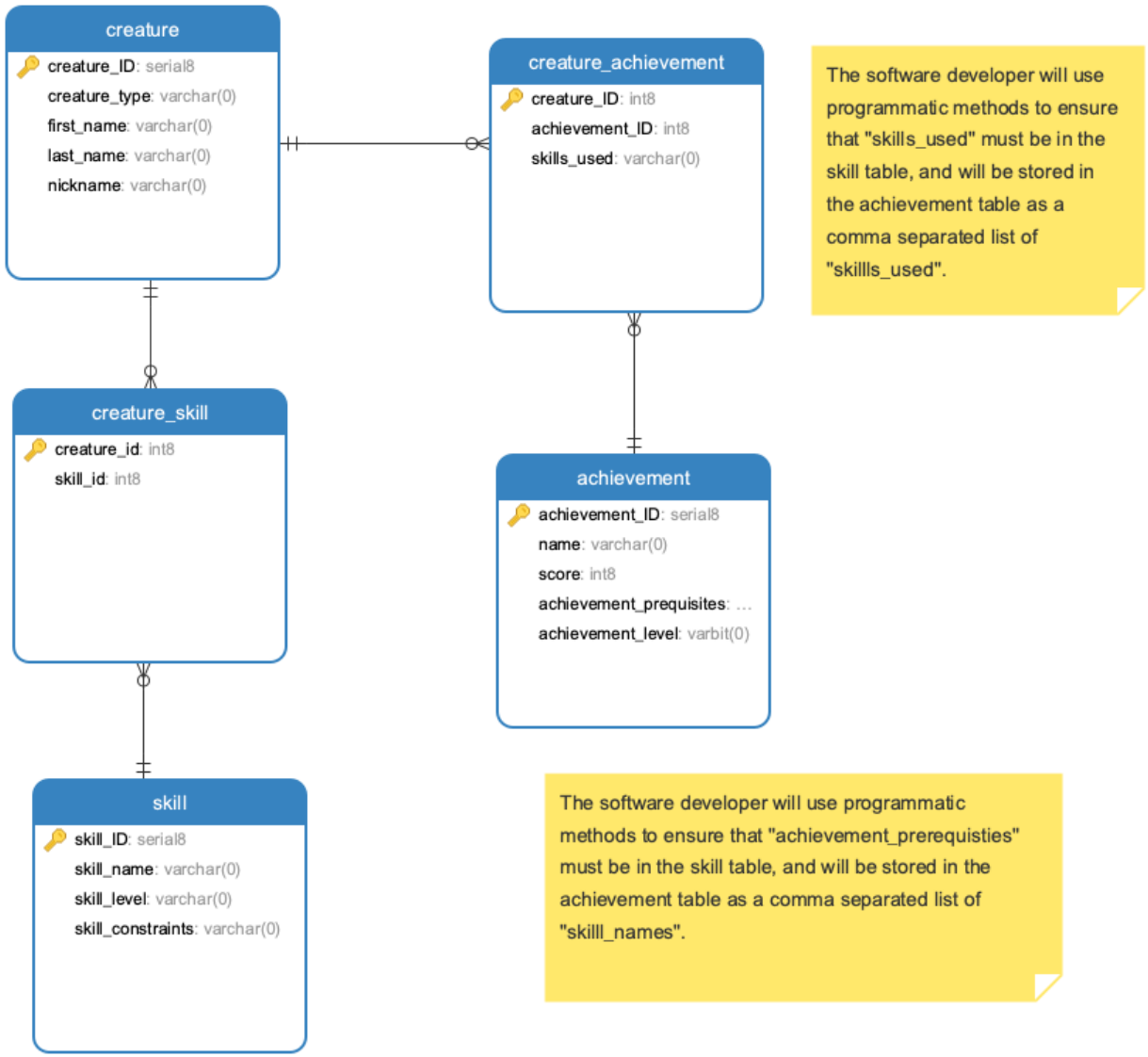
Heuristic Methods: Data Modeling



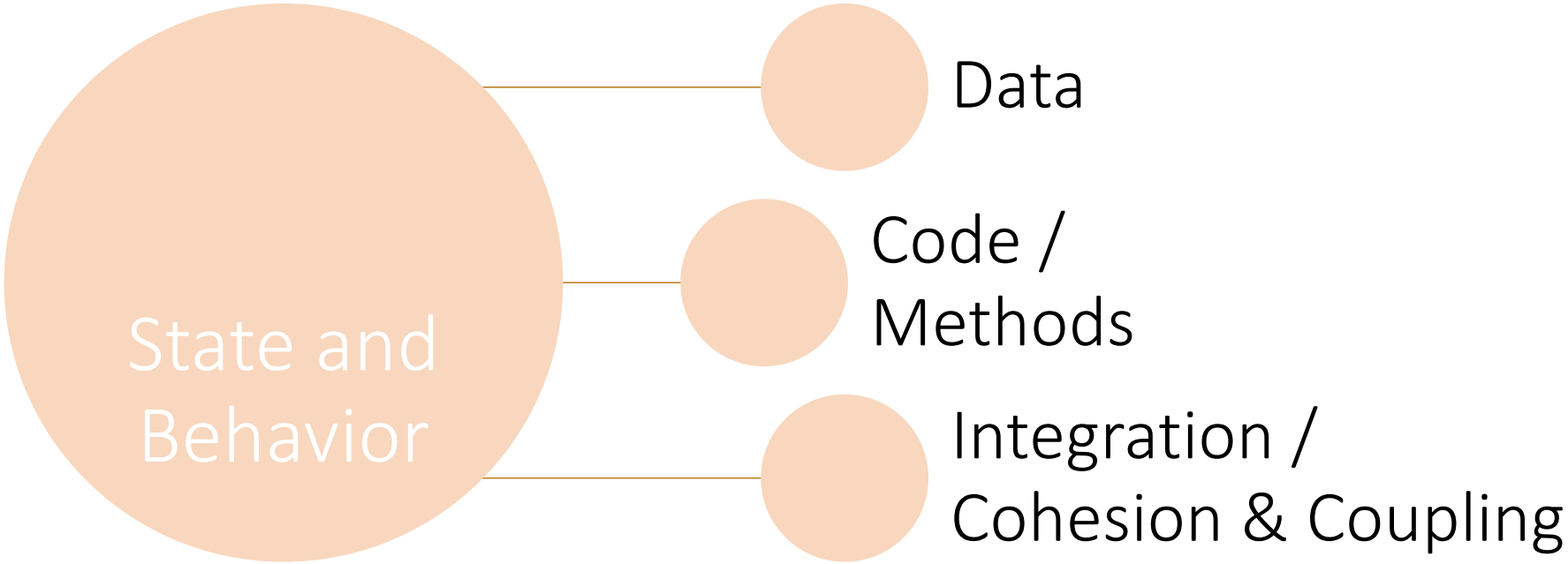
Conceptual Model




creature
creature_ID: DECIMAL
creature_type: VARCHAR
first_name: VARCHAR
last_name: VARCHAR
nickname: VARCHAR
creature_achievement
creature_ID: DECIMAL
achievement_ID: DECIMAL
skills_used: VARCHAR
creature_skill
creature_id: DECIMAL
skill_id: DECIMAL
achievement
achievement_ID: DECIMAL
name: VARCHAR
score: DECIMAL
achievement_prequisites: ...
achievement_level: BLOB
skill
skill_ID: DECIMAL
skill_name: VARCHAR
skill_level: VARCHAR
skill_constraints: VARCHAR


creature
creature_ID: serial8
creature_type: varchar(0)
first_name: varchar(0)
last_name: varchar(0)
nickname: varchar(0)
creature_achievement
creature_ID: int8
achievement_ID: int8
skills_used: varchar(0)
The software developer will use programmatic methods to ensure that "skills_used" must be in the skill table, and will be stored in the achievement table as a comma separated list of "skillls_used".
creature_skill
creature_id: int8
skill_id: int8
achievement
achievement_ID: serial8
name: varchar(0)
score: int8
achievement_prequisites: ...
achievement_level: varbit(0)
skill
skill_ID: serial8
skill_name: varchar(0)
skill_level: varchar(0)
skill_constraints: varchar(0)
The software developer will use programmatic methods to ensure that "achievement_prerequisties" must be in the skill table, and will be stored in the achievement table as a comma separated list of "skilll_names".

Heuristic Methods:
Object Oriented Analysis and Design



Formal Methods

Safety Critical Systems

Systems that must be maximally deterministic

Mathematically verifiable

Prototyping Methods

What is a prototype?

Styles:

1. *Throwaway*
2. *Evolutionary*
3. *Executable Specification*

Prototyping Methods

Examples of prototyping targets:

1. *Requirements specification*
2. *Architectural design element*
3. *Human-machine user interface*

Prototyping Methods

Evaluation techniques:

(Depends on the reason for prototyping)

Evaluated against implemented software

Evaluated against target set of requirements

Serve as a model for software development

Agile Methods in Historical Context

1990's

From a desire to reduce overhead associated with plan-based methods ("waterfall") **readings

Agile founders were concerned with values and principles rather than rigid, codified methodologies **readings

** Also Historical and comparative readings

Agile Methods

Typical characteristics of agile methodologies:

- Short, iterative development cycles
- Working product each iteration
- Self-organizing teams
- Refactoring
- Test-driven development
- Close customer involvement

Agile Methods:
Rapid Application Development (RAD)

Agile Methods:
eXtreme Programming (XP)

Agile Methods: Scrum

Agile Methods:
Feature-Driven Development

Done!