"The issue is not documentation, the issue is understanding."

- Jim Highsmith

Agile Software Development Ecosystems (2003)

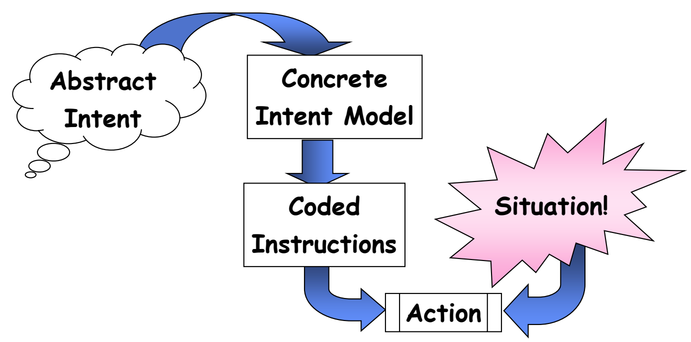
An Anecdote

```
org  $0800
cnt    rmb  2
       org  $F000
main   lds  #$0C00
       movb #$80, $0002
off    bclr $0000,#$80
look   ldd  #4444
       std  cnt
loop   ldaa $0000
       anda #$7F
       cmpa key
       bne  off
       ldx  cnt
       dex
       rpi
       stx  cnt
       bne  loop
       bset $0000,#$80
       bra  look
key    fcb  %00100011
       org  $FFFE
       fdb  main
```

→ RPI instruction tells the processor to
  READ
  PROGRAMMER
  INTENT

→ Wouldn't it be nice if the computer could understand what we are trying to do?

An Overly Simplified View of Intent



➲ Does the action match what we intended?

Expressing Intent to a Computer

- ➔ We have spent decades trying to build programming systems for the purpose of telling a computer what we want it to do.
  - Programming languages define operational behavior
  - Compilers translate intent into instructions
  - Contracts and assertions enforce correct behavior
- ➔ Advanced programming systems:
  - Abstract away concepts specific to the platform
  - Allow for partitioning of sub-tasks and sub-goals
  - Restrict control and data flow
  - Create a virtual environment for problem-solving
- ➔ Errors are behaviors where:
  - Intent is incorrectly expressed to the computer
  - Intent is incompletely understood by the programmer

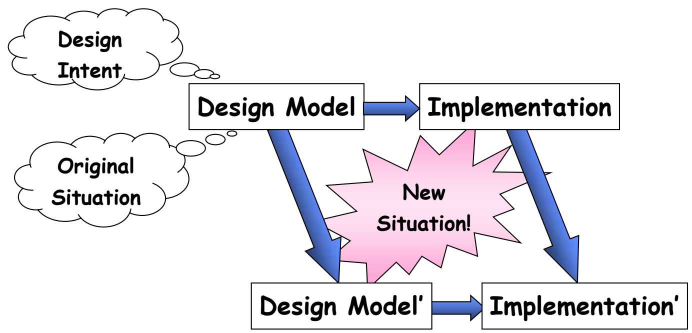
Modern Software Design

- ➔ Primarily a structuring and abstraction problem
  - For functional intent we know:
    - ➢ Group into procedures, classes, modules, etc.
    - ➢ Coupling and cohesion affect:
      - ✓ Performance
      - ✓ Reliability – fewer unexpected or undefined interactions
  - For new functionality:
    - ➢ Low impact of change through good modularity
      - ✓ New interactions are limited in scope
- ➔ Abstraction yields cognitive benefits
  - Fine-grain details are abstracted away
  - Large-scale design becomes possible
  - Abstracted designs can be inspected for design qualities
  - Complex systems can be generally understood quickly

Design is for Humans

- ➔ CLAIM: There are some technical benefits of certain design strategies, but comprehensibility is the primary objective of modern design and analysis.
  - Code elements are given "intentional" names
  - Organization makes "clear" the intent of a set of instructions
  - Modularity (coupling, cohesion) → abstract complexity within an interface
  - The computer has no use for the programmer's "intent"
    - ➢ Counter-example: Expert system?
- ➔ CLAIM: Flexibility, elegance, testability, adaptability, etc. are all aspects of comprehensibility
  - Spaghetti code executes nicely, thank you
  - Counter-example: Distributed or replicated enterprise app.
- ➔ CLAIM: We have spent considerably less time studying how to express intent to people

An Overly Simplified View of Design Intent



- ➲ Does the new design conform to the original intent?
- ➲ Is the original intent still valid?

2

Problem Structuring

- Well-Structured Problems:
  - Relationship between problem, solution methods, and criteria
    - Coding a well-defined algorithm
- Ill-Structured Problems:
  - Not well-structured (i.e., no domain guidance on solution methods or evaluation)
    - Deciding what to build (requirements selection)
- Problem Structuring:
  - The act of turning ISPs into WSPs
  - Software Analysis and Design:
    - Select requirements to implement
    - Given a requirement, decompose into a set of goals
    - Transform goal into a detailed design
    - Treat design as a WSP, and abstract its complexity, and use to solve another goal

Software Design Decisions

- What is a design decision?
  - Separating functional units into procedures (methods)
  - Defining interfaces for procedures
  - Grouping procedures into classes / modules
  - Defining interfaces for modules
  - Etc.
- Prescriptive approaches provide strategies or methods for problem structuring
  - Top-down, Bottom-up, Stepwise refinement
  - OOAD
  - CBSP

How Do Software Designers Think?

- Opportunistic Decision Making
    - Decisions made with partial knowledge influence later decisions as fact
  - Emergent knowledge and partial solutions
    - Discovery of partial WSPs from domain knowledge
  - Emergent requirements need attention
    - Immediate Structuring ISP into WSP
  - Drifting
    - Explore dependencies and assumptions
  - Scenario exploration
    - Make ill-structured requirements concrete
    - Verify partial solutions
    - Confirm inferred requirements
- Early design activities are opportunistic, rather than prescriptive

Rational Decision Making

- A decision is made based on criteria and rationale
- Consequential choice of an alternative
  - Possible actions and outcomes
  - Utility function assigns value to options
  - Probabilities of outcomes
- Assumptions behind Rational Decision Making
  - Set of possible options are known
  - Probabilities of outcomes are known
  - Optimality is desirable
  - Cost of decision process is not a concern or is less than the cost of a sub-optimal decision
- Useful for WSPs

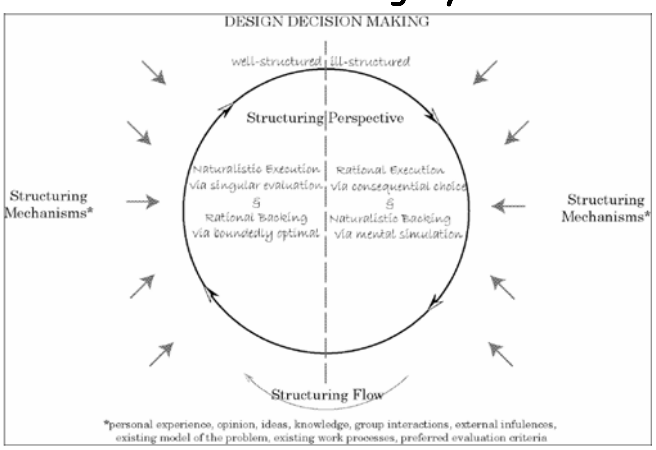
Naturalistic Decision Making

- ➔ Situational decisions
  - Made on partial knowledge + personal expertise
  - Preserved until they are invalidated
- ➔ Characteristics of Naturalistic Decision Making
  - Dynamic or volatile situations
  - Incomplete knowledge and ill-defined tasks and goals
  - Knowledgeable and experienced decision makers
  - Situational assessment over consequential choice
  - Alternatives not considered until rejection
  - Satisficing solutions
- ➔ Useful for ISPs

Problem Structuring and Decision Making

- ➔ Software design is a combination of:
  - Well-structured and Ill-structured problems
  - Opportunistic and Prescriptive structuring methods
  - Rational and Naturalistic decision making
- ➔ Structuring Methods:
  - Personal Experience
  - Opinion, Ideas
  - Domain Knowledge
  - Group Interactions
  - External Influences
  - Existing Models of the Problem
  - Existing Processes
  - Preferred Evaluation Criteria

Decision-Making Cycle



What Were We Trying To Do?

- ➔ So, in the life of a piece of software
  - Some decisions were *rational*
  - Some decisions were *naturalistic*
  - Some decisions were *arbitrary*
  - Some decisions were *deferred*
- ➔ Over time:
  - As rationale is lost, distinction between decision types is lost
    - Rational decisions relate to well-structuredness and optimality
    - Naturalistic decisions were situationally satisficing based on partial solutions and incomplete knowledge
  - Assumptions and Dependencies are forgotten or ignored

What *Are* We Trying to Do?

- The software understanding problem is an attempt to reconstruct:
  - The rationale for rational decisions
  - The situational context and expert knowledge for naturalistic decisions
- We want to:
  - Evolve software
  - Maintain software
  - Reuse software
  - Reuse and transfer design knowledge and expertise
- We have spent the semester looking at ways to:
  - Record design intent and rationale
  - Design for comprehensibility
  - Use design knowledge to recover or infer intent

General-Purpose Rationale Systems

- QOC, IBIS/PHI, DRL, etc.
- Rationale systems have their roots in argumentation
  - Two or more sides (alternatives)
  - Supporting and objecting arguments
- Motivation:
  - Support decision making through visualization
  - Representation in semi-formal notation facilitates computer support
- Two ways to use rationale system:
  - Prescriptive: capture evolving arguments and use utility function on criteria to select among alternatives
  - Descriptive: justify a made decision by recording considered alternatives and criteria

Problems with General Rationale Systems

- Software design decisions are:
  - Non-rational
  - Opportunistic
  - Ill-structured
  - At different levels of abstraction
- Cognitive complexity of argumentation systems occludes opportunistic thought
  - No prescriptive value to software domain
- Documenting rationale provides little upstream value
  - Descriptive value only benefits later designers
- General systems fail to leverage inherent structure of software design decisions

Fake It!

- Because there is something satisfying about rational decisions, treat all decisions as rational
  - In mature engineering professions, many tasks are WSP
  - We want to believe that Software Engineering is an engineering profession
  - Express SE problems as WSP with well-defined goals and decision processes (i.e., that it is rational)
  - Emphasis on prescriptive methods of design

"We will never find a process that allows us to design software in a perfectly rational way… [but] we can present our system to others as if we had been rational designers and it pays to pretend do so during development and maintenance."

Problems with Faking Design Rationale

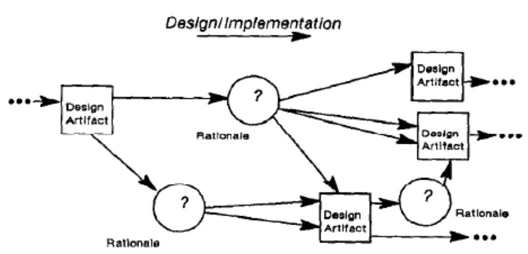
- Naturalistic decisions are situational
  - Difficult to differentiate between essential domain criteria and dynamic or volatile criteria
- Faked rationale tends to be uniform
  - What level of abstraction / granularity to use?
- Does not necessarily reflect real alternatives
  - How many alternative solutions should be faked?
  - Are these alternatives realistic or practical?
- Bad or failed solutions are interesting
  - Faked rationale describes successful designs
  - "The best prototype is a failed project" (Curtis, et.al.)
- Faked rationale uses "timeless" inferential reasoning
  - See Potts & Bruns – infer rationale from an existing design, process description, and natural language documentation
  - If you can infer rationale, why document faked rationale?

Hybrid Software Rationale Systems

- General rationale systems are *semi-formal*
  - Content of nodes is informal
  - Link structure is formal
- Use SE design domain knowledge structure nodes
  - Scope definition of a design "decision"
  - Scope abstraction
  - Define domain-specific criteria and metrics
  - Associate decisions with design artifacts
- Associate with a prescriptive problem structuring process
  - Potts & Bruns
  - Archium
  - SEURat
- Provide upstream and downstream value

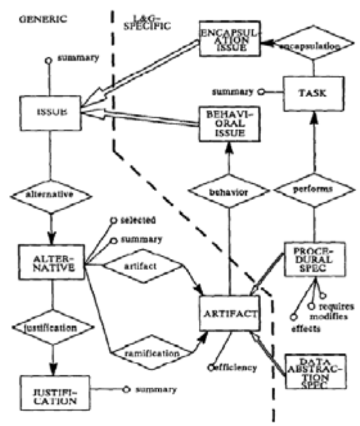
Potts & Bruns (1988)

- Argumentative rationale with design process
  - Modified IBIS
  - Liskov and Guttag (proto-OOAD abstract data type design)
- Incorporates design artifacts into rationale model



Rationale Structure (P&B)

- Relationships between artifacts are defined
- Decisions are classified by type as *issues*
  - Issues correspond to specific steps in L&G process
- Node elements are structured with a semi-formal schema
  - Specific explanations are natural language



Problems with Potts & Bruns

- They fake it
  - Sample problem is taken from L&G book and rationale inferred from descriptive text and process knowledge
  - Do not evaluate cost of documenting process
    - Prototype hypertext tool for supporting the process
  - Problem definition does not allow exploring alternatives
- Who will use it?
  - They do not demonstrate the upstream design value of this form of design visualization
  - They do not demonstrate the queries downstream users might desire
- Many of the same usability problems as general IBIS

Archium

- Seems promising
- Incorporates design visualization with argumentation visualization
  - Architecture elements are first class entities with rationale
  - Explicitly supports design fragments and design evolution
- Still a ways to go
  - Empirical case studies
  - Tool support
  - Need to prove it can provide downstream value

SEURat

- Argumentation + SE decision ontology
  - Integration of knowledge base with IDE
    - Code elements can be associated with rationale elements
  - Core schemas use generalized argumentation concepts
    - Decision, alternative, claim, assumption, etc.
  - Support for some SE concepts
    - Change request, requirement, etc.
  - Rules describe common SE criteria and allow for inferencing
    - Adaptability, Dependability, Maintainability, Performance, etc.
  - Expert system identifies deficiencies in rationale
- Assumes expert approaches problem rationally

Prescriptive Design Methods

- Designs and design processes are non-rational
  - Naturalistic decision making uses incomplete knowledge and relies on the reuse of expertise
- Goal: methodical, prescriptive approach that relates domain, design, and constraints, reusing design knowledge
  - For a set of known inputs, structure them in some methodical way
  - Evaluate against a criteria, and either iterate or terminate
- Observation:
  - Design rationale is "because the method told me so"
  - Documentation is:
    - Process model (a priori)
    - Input knowledge (method by-product)
    - Intermediate and final models (method by-product)
    - Justification for overriding method where appropriate

Goal-Oriented KAOS

- Systematic process for refinement and transformation
  - Each step has defined entry and exit criteria
  - Each step is an ISP with guidance on how to begin and solve common problems
- Intermediate models are used for partial reasoning and evaluation
- Non-Functional goals constrain solutions and are used as evaluation criteria
- Research Question: What kinds of information would need to be stored to justify intuitive leaps?

CBSP Revisited

- Transform requirements into architectural elements
  - Refining requirements into allocatable properties is an ISP
  - How can we prescribe requirements refinement?
    - Is there a manageable set of heuristics for each transformation step?
    - Can we document those changes with pseudo-rationale?
- What information would we need to store with our design to capture our design decisions?
  - Input requirements
  - Refined requirements
  - Voting results
  - Dimensions → Properties table
- Additional upstream value
  - Task prioritization
  - Traceability from arch. elements to requirements and back

Design Maintenance Systems

- Given a specification, apply transformations to yield a program
  - Transformation trace and stepwise justifications form rationale
  - Functional specification defines functional intent
  - Performance specifications define design constraints
- Upstream value of this process is limited
  - Cost to implement for trivial problems is high
  - Might not scale
- However, process prescriptively handles evolving functional specification
  - And provides change rationale associated with the original derivation

Reusing Design Knowledge

- Much of design involves solving the same problems over and over again
- Styles, patterns, idioms, cliches represent solutions to these recurrent patterns
  - They have been selected and refined over time by experts
  - They standardize solution vocabulary
    - Solution patterns can be abstracted to meaningful terms
    - Documentation can be recorded centrally and referred to
  - Identify relationships with other participating elements
    - Can't identify pattern's role in larger problem
    - Can express the problem domain in terms of patterns
- Patterns rarely appear unmodified in code, or may be named for domain concepts
  - SPQR—decompose patterns into elemental design patterns and identify patterns by observing localized EDPs in code
  - Identifying cliches through reverse engineering

Reusing Process By-Products

- Relate process by-products to the design context
  - Evolutionary annotations
    - Associate project communications to change logs
  - Technology books
    - Bind code and domain documentation
    - Difficult to query, but creates contextual relationship
    - No need to compile and maintain separate documentation
- Code analysis techniques to infer intent
  - Lackwit: static type inference to understand variable usage
  - Dependency Structure Matrix
    - Can be used to analyze a design's modularity
    - Or understand modularity in an existing program

Explicit Models of Intent

- Code is complex, and inadequate for effectively expressing functional intent
  - Code is a sequence of low-level imperative commands
- Contracts and specifications are descriptive statements of functional intent
  - You would have to read code to find the error conditions that could be easily stated in a single logic sentence
  - Obligations are not local to the code the requires them
    - Inscape extends contract-based specifications with obligations and a logic for reasoning over semantic interconnections
- Intentional programming and Domain languages expresses domain concepts in domain terms and lets the programming system transform intent into the imperative code that implements it

Back Where We Started

- We have a variety of methods for expressing intent (design and functional) to human designers
- How do we express intent to a computer so it can do what we want it to do?
  - Define functional and design intent in formal terms
  - Associate intent to architectural elements
  - Systems can be dynamically reconfigurable on the basis of changing requirements and environment
    - Express new requirement to self-managing system and let it choose a configuration to meet the new needs
  - Software design becomes a problem of the effective expression of intent to a configuration system
    - WSP?

Summary

- We've looked at the major issues covered this semester in the context of:
  - Problem structuring
  - Prescriptive vs. descriptive modeling
  - Opportunistic problem solving
  - Rational vs. naturalistic decision making
- Software design is not mature enough to be rational
  - Reliance on designer experience and knowledge
  - Prescriptive methods in limited use (WHY?)
  - We should consider upstream and downstream value
  - SE domain has a limited number of design transformations and justifications for them – general systems too complex
  - Faking rationality occludes actual design justification
  - Rationality is overrated

"The road to Hell is paved with bad intent."

Credits

- ➔ C. Zannier and F. Maurer. Decisions in Agile Design. (Submitted to FSE'06)
- ➔ R. Guindon. Designing the Design Process: Exploiting Opportunistic Thoughts.
- ➔ C. Potts and G. Bruns. Recording the Reasons for Design Decisions.
- ➔ D. Parnas and P. Clements. A Rational Design Process: How and Why to Fake it
- ➔ J. Grudin. Evaluating Opportunities for Design Capture

- ➔ Everybody's very fine presentations and All the other papers we've covered this semester!