

The logo of Swinburne University of Technology. It features the word "SWIN" in large white letters, "BURNE" in smaller white letters below it, and "NE" in large white letters at the bottom, all set against a dark grey background. Below this, a red rectangular box contains the text "SWINBURNE UNIVERSITY OF TECHNOLOGY" in white.

**SWE30003**  
**Software Architectures and Design**

Lecture 4  
The Role of Abstraction in Software



A dark grey square containing the university's crest, which includes a shield with various symbols and a crest featuring a horse.

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**Logistical matters**

- Weekly submissions – A & Q
  - Week 2: 362 and 341 out of 459;
  - Week 3: 397 and 375 out of 459;
  - Week 4:
  - Week 5:
    - Note that this is a **hurdle requirement**
    - No late submission
- Assignment 1: should be well on the way ...

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## Question to Answer from Week 3



*Why can quality attributes, in general, **not** be considered in isolation? Give two examples of quality attributes that impact other quality attributes for a system under consideration.*

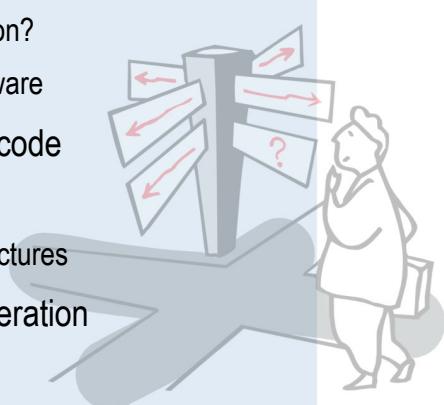
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## Outline



- Abstractions
  - What is an abstraction?
  - Abstractions in Software
- Abstractions beyond code
  - Domain Models
  - Patterns and Architectures
- Questions for Consideration



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## Principal References



- Len Bass, Paul Clements, and Rick Kazman, *Software Architecture in Practice* (4<sup>th</sup> or 3<sup>rd</sup> Edition), Addison-Wesley, 2021, Chapter 1
- Guy Steele, *Growing a Language*, Higher-Order and Symbolic Computation, Number 12, 1999 (available from Canvas)

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## Complexity in Software Systems



*“It is not possible to remove the inherent complexity of large-scale software systems, but it is possible to use adequate development techniques to master complexity! ”*

— Anonymous

- Moving towards solution of the problem ... Analysis & Design

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## Design vs. Design



*“Design is the creative process of transforming the problem into a solution. The description of the solution is also called the design.”*

**Activity & Artefact** — Shari Lawrence Pfleeger, 1998

*“The design of a system determines a set of components and inter-component interfaces that satisfy a specified set of requirements.”*

**Artefact** — DeMarco, 1982

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## Design (cont.)



*“A design is a plan how to build a thing. To design is to build a thing in one’s mind but not yet in the real world — or, better yet, to plan how the real thing can be built.”*

— Guy Steele, OOPSLA 1998

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## Software Design Methods



Many design methods have been defined:

- Modular:
    - focus on functions and procedures
  - Data-oriented:
    - focus on external data sources
  - Event-oriented:
    - how events change states
  - Middle-out:
    - Jackson System Development (JSD)
  - Object-oriented:
    - identify classes of objects and their inter-relationships
  - Process-oriented:
    - focus on communication between independent processing entities
- ... *abstractions*

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Common to all software design  
methods: support for -

*abstraction*,

decomposition & composition!

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## Abstraction

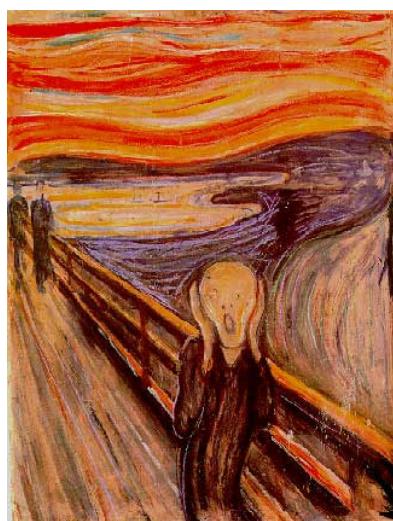


- A *concept* or *idea* not associated with any specific instance,
- Leaving out irrelevant detail, *highlighting important elements*,
- Mathematically, an abstraction is a *mapping*.

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## Abstraction - Example



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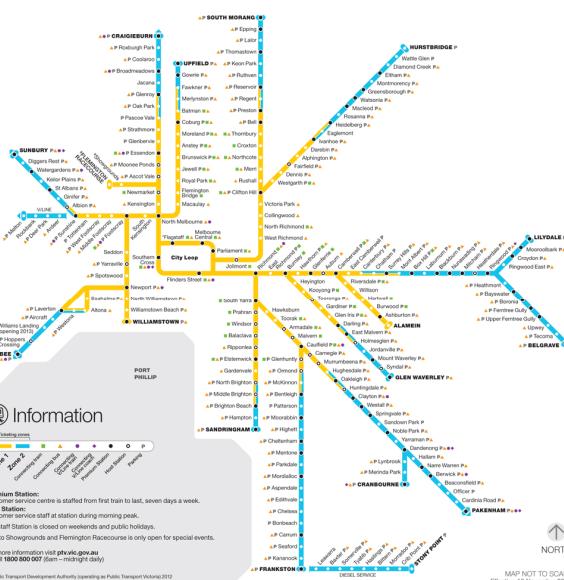
## Abstraction - Example (cont.)



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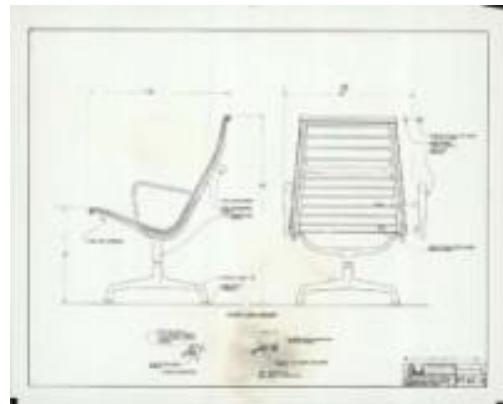
## Abstraction - Example (cont.)



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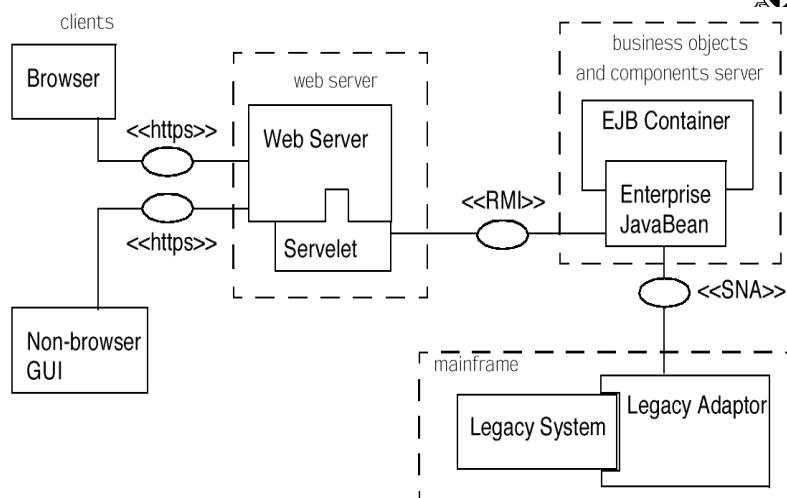
## Abstraction - Example (cont.)



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## Abstraction - Example (cont.)



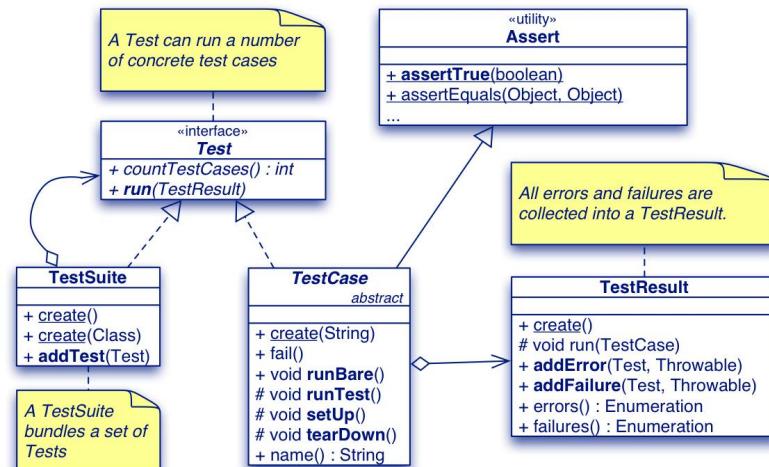
4-Tier Architecture

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## Abstraction - Example (cont.)



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## Abstraction - Example (cont.)

```

function sort(array)
  var list less, greater
  if length(array) ≤ 1
    // array of zero or one elements is already sorted
    return array
  // select and remove a pivot value pivot from array
  for each x in array
    if x ≤ pivot then append x to less
    else append x to greater
  return concatenate(sort(less), pivot, sort(greater))
  
```

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## Abstraction - Example (cont.)



```

deferred class STACK [G]
feature -- Element change
    push (v : G) is           -- Push v onto top
        deferred
        ensure
            item_pushed: top = v
            size_increased: size = old size + 1
        end;
    pop is                      -- Remove top
        deferred
        require
            not_empty: size > 0
        ensure
            item_removed: size = old size - 1
        end;
    top : G is                  -- Get top element
        deferred
        require
            not_empty: size > 0
        ensure
            sizeInvariant: size = old size
        end;
end -- class Stack

```

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## General View of Abstraction



### Real World

- ☞ Phenomenon with messy details

- ☞ Facts and laws governing the real world

### Abstract World

- ☞ Model with “simple” properties

- ☞ Representation subject to “formal” manipulation



*Abstraction: mapping from real world to abstract world*

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Break

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*But what kinds of abstractions  
do exist in software?*

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## Fundamental Programming Abstractions



- Instruction
- Sequence
- Condition
- Repetition
- Abstraction:
  - Data abstraction
  - Functional abstraction

*Most (if not all...) programming languages are based on these fundamental abstractions!*

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## “Abstraction Stack” in Software



- Subsystems
- Components
- Packages
- Interfaces
- Objects
- Abstract Data Types (e.g., list, tree)
- Functional abstractions (e.g., procedures, methods)
- Primitive data types (e.g., int, bool, char)
- Simple arithmetic expressions and control structures
- Macros
- Symbolic names (for instructions and memory cells)
- Machine instructions, memory cells ...

*Directly or indirectly, they all related to program code!*

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*But what about if we abstract  
from the code/program itself?*

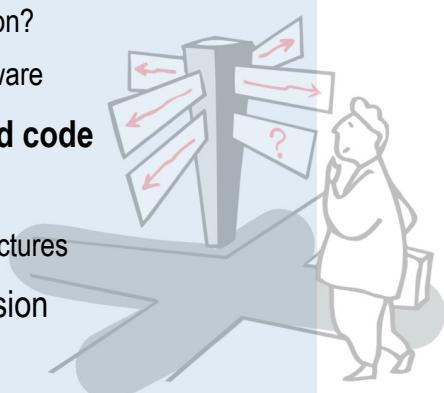
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## Outline



- Abstractions
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- Questions for Discussion



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## Models are Abstractions



- A model is a *simplification of reality*.
- (many) models are created for better understanding of the problem, domain or system to build.
- A model can capture and represent,
  - Structure (static model)
  - Behavior (dynamic model)
- Examples:
  - Architectural blue-print of a house
  - Hand-drawn screen



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## Domain Models



- A *domain model* captures the domain entities (or concepts) relevant to a given problem specification
- A *domain vocabulary* generally defines the meaning (or interpretation) of domain entities
- The relationships between domain entities define an *abstraction over the problem domain*.

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## Recap - Domain Model Development



### ■ Process

- Step 1. Perform a *textual analysis* of the problem specification for understanding the problem domain
    - Circle all *nouns* and underline the *verbs*
  - Step 2. Write down relevant *domain entities*. They are normally (some of) the nouns defined above.
  - Step 3. Revisit the specification to extract the *associations*
  - Step 4. Record associations with the corresponding domain entities.
- ☞ Note: *domain modeling is not design; it is merely a way to understand the abstract concepts relevant to the problem!*

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## “Exercise for the Reader”



*Develop a domain model for a chess game that allows a human player to play a game of chess against a computer.*

- ☞ We may come back to this problem later in the semester...

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## Software Design



*The activity of software design can be seen as translating and refining a (problem) domain model into abstractions that can be directly mapped to an implementation in a programming language.*

- ☞ In general some “intermediate” steps will become necessary... solutions at different levels of abstraction
- ☞ The “closer” the domain abstractions are to the target language, the easier this process will become...

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## Design Patterns are Abstractions



Design patterns document standard solutions to common (software) design problems:

*“Each pattern systematically names, explains, and evaluates an important and recurring design in object-oriented systems. Our goal is to capture design experience in a form that people can use effectively.”*

— Gamma et al., Design Patterns, 1995

*We will cover Design Patterns in more detail in Lecture 7*

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## Software Architecture

*"In most successful software projects, the expert developers working on that project have a **shared understanding** of the system to be implemented. This shared understanding is called **architecture** and includes how the system is divided into processing elements (i.e. **components**) and their **interaction** through interfaces. These components are usually composed of smaller components, but the architecture only includes the ones that are understood by all developers."*

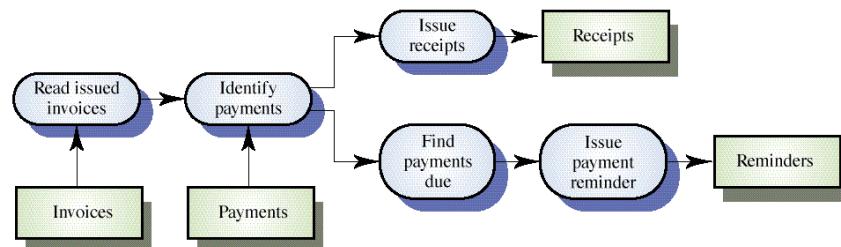
— Ralph Johnson, 2003

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## Example - Invoice Processing System



©Ian Sommerville 1995

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## “Growing a Language”



*“A design is a plan how to build a thing. To design is to build a thing in one’s mind but not yet in the real world — or, better yet, to plan how the real thing can be built.”*

— Guy Steele, OOPSLA 1998

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## “Growing a Language” (cont.)



- Keynote address at OOPSLA 1998 (Vancouver)
  - Main message: the importance of an appropriate *vocabulary* in communicating software design.
  - Lessons to be learnt: software designers need
    - a large vocabulary of design elements,
    - based on a small set of well-founded and well-understood principles,
    - experience when and how to use the vocabulary.
- ☞ Abstraction is an important aspect of such a vocabulary!

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## Closing Remarks



- Abstraction and modeling are used at every phase of the software development process.
- The level, benefit, and value of a particular abstraction depend on its purpose.
- Abstraction is key to mastering complexity in software systems.
- Abstraction is key to decomposition.

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## Question for Review



1. Explain the relation between words, vocabulary and language, in the context of computer programming.
2. Explain why designing and implementing a small language that has limited functionality, but has the potential to grow, is a better alternative to developing a larger, more expressive language in the first place.
3. What is the difference between abstraction and modularity in a system and how can they be used to enhance the system?
4. Explain the analogy of Cathedrals, shopping malls and bazaars in relation to programming languages.

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## Question to Answer - Week 4 (for week 5)



A good programmer in these times does not just write programs, *he/she builds a working vocabulary*. Provide examples and explain this statement.

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## Required Reading Lecture 5



- Rebecca Wirfs-Brock and Alan McKean, *Object Design: Roles, Responsibilities, and Collaborations*, Addison-Wesley, 2003, Chapter 1 (available from Google Books)
- Timothy A. Budd, *An Introduction to Object-Oriented Programming* (3<sup>rd</sup> Edition), Addison-Wesley, 2002, Chapter 3 (available from Canvas)

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