Object-Oriented Software Reengineering

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1. Object-Oriented Software Reengineering

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WWW: `http://www.iam.unibe.ch/~scg`

Sources

- *Software Engineering*, Ian Sommerville, Addison-Wesley, 5th edn., 1995
- *Software Reengineering*, Ed. Robert S. Arnold, IEEE Computer Society, 1993

Goals of this course

The "Software Crisis" is an artefact of short-sighted software practices

- try to understand factors that lead to software maintenance problems

Legacy systems are "old systems that must still be maintained"

- study legacy systems to understand what problems they pose

Reverse Engineering

- examine ways to recover design and analysis models from existing systems

Reengineering

- explore techniques to transform systems to make them more maintainable

Object-Oriented Reengineering

- survey the particular *problems* and *opportunities* of reengineering object oriented legacy systems

Course Overview

1.	30/10	Introduction	
2.	06/11	Metrics Introduction	
3.	13/11	Metrics in Industry	— *Dr. Simon Moser*
4.	20/11	Y2K	— *Prof. Dr. Gerhard Knolmayer*
5.	27/11	Design Extraction with UML	
6.	04/12	Language Issues and Extraction Tracks	
7.	11/12	Detecting Duplicated Code	
	18/12	*no course*	
	25/12	*winter holiday*	
	01/01	*winter holiday*	
8.	08/01	Refactoring	
9.	15/01	Metrics in Reengineering	
10.	22/01	Refactoring Browser	
	29/01	*open*	
11.	05/02	Code Repositories	

What is a Legacy System?

legacy

> *A sum of money, or a specified article, given to another by will; anything handed down by an ancestor or predecessor.*
>
> *— OED*

A legacy system is a piece of software that:

- you have *inherited*, and
- is *valuable* to you.

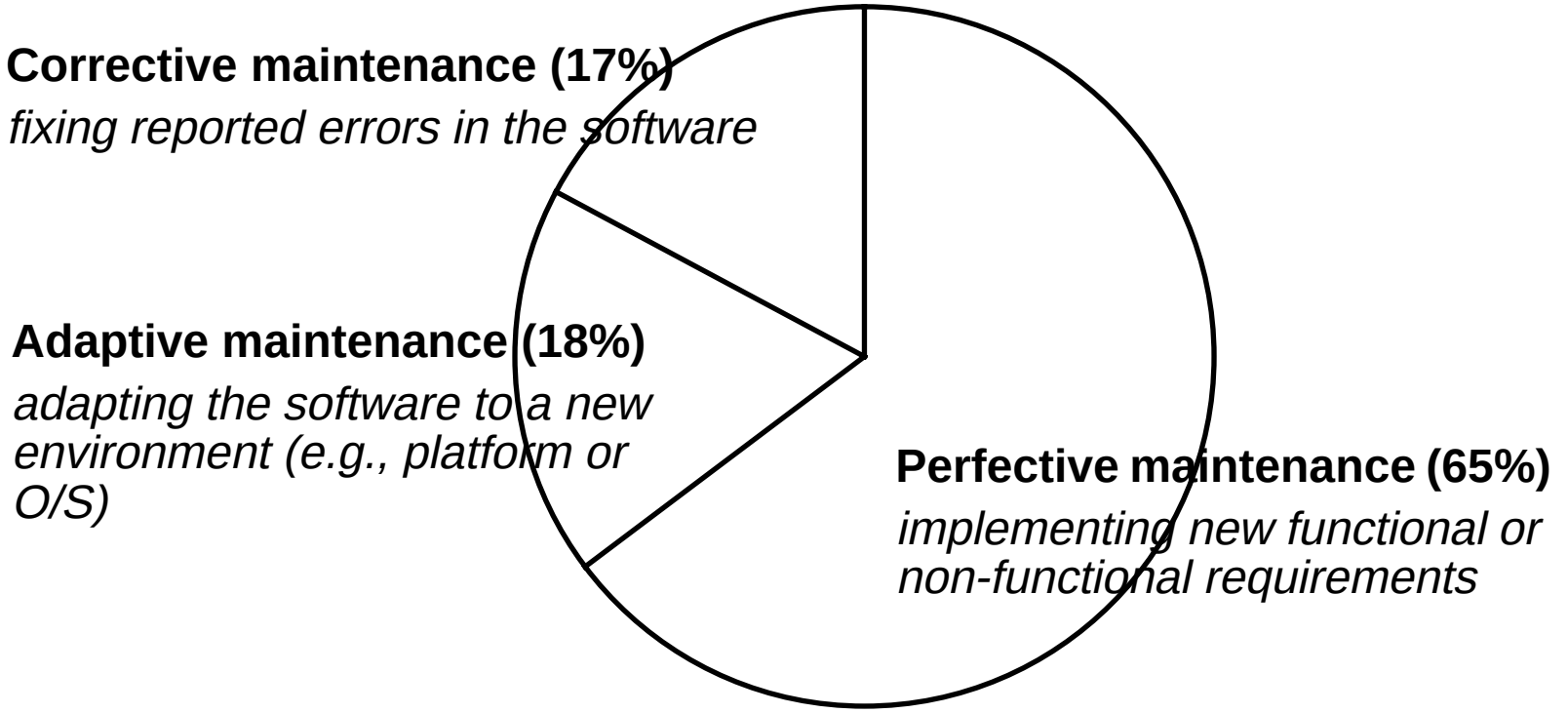
Typical problems with legacy systems are:

- original developers no longer available
- outdated development methods used
- extensive patches and modifications have been made
- missing or outdated documentation

so, *further evolution and development may be prohibitively expensive*

Software Maintenance

Software Maintenance is the “modification of a software product after delivery to correct faults, to improve performance or other attributes, or to adapt the product to a changed environment” [ANSI/IEEE Std. 729-1983]



Why is Software Maintenance Expensive?

Various studies show 50% to 75% of available effort is spent on maintenance.

Costs can be high because:

- Maintenance staff are often *inexperienced* and *unfamiliar with the application domain*
- Programs being maintained may have been developed without modern techniques; they may be *unstructured*, or *optimized for efficiency*, not maintainability
- *Changes may introduce new faults*, which trigger further changes
- As a system is changed, its *structure tends to degrade*, which makes it harder to change
- With time, *documentation may no longer reflect the implementation*

Lehman's Laws

A classic study by Lehman and Belady (1985) identified several "laws" of system change.

Continuing change

- A program that is used in a real-world environment *must change, or become progressively less useful* in that environment.

Increasing complexity

- As a program evolves, it *becomes more complex, and extra resources are needed* to preserve and simplify its structure.

Factors Affecting Maintenance

- Module independence
- Programming language
- Programming style
- Program validation and testing
- Quality of documentation
- Configuration management techniques
- Application domain
- Staff stability
- Age of program
- Dependence on external environment
- Hardware stability

Maintainability Metrics

Hypothesis: Program maintainability is related to complexity

- McCabe (1976): measures a program's complexity in terms of the graph of its decision structure
- Halstead (1977): measures complexity in terms of number of unique operators and operands, and total frequency of operands
- Kafura and Reddy (1987): used a cocktail of seven different metrics

Definitions

"Forward Engineering is the traditional *process of moving from* high-level abstractions and logical, implementation-independent *designs to the physical implementation* of a system."

"Reverse Engineering is the process of *analyzing a subject system* to

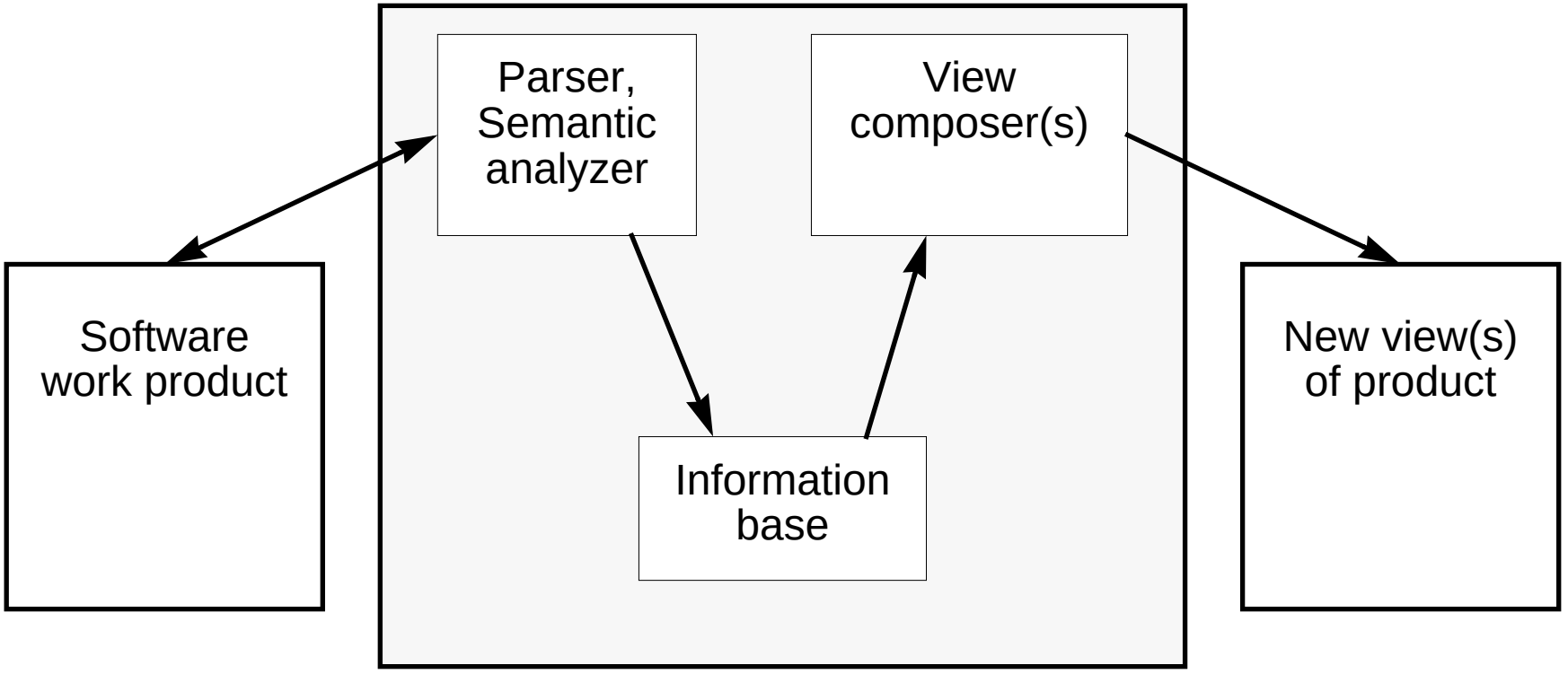
- identify the system's components and their interrelationships and
- create representations of the system in another form or at a higher level of abstraction."

"Reengineering ... is the examination and *alteration of a subject system* to reconstitute it in a new form and the subsequent implementation of the new form."

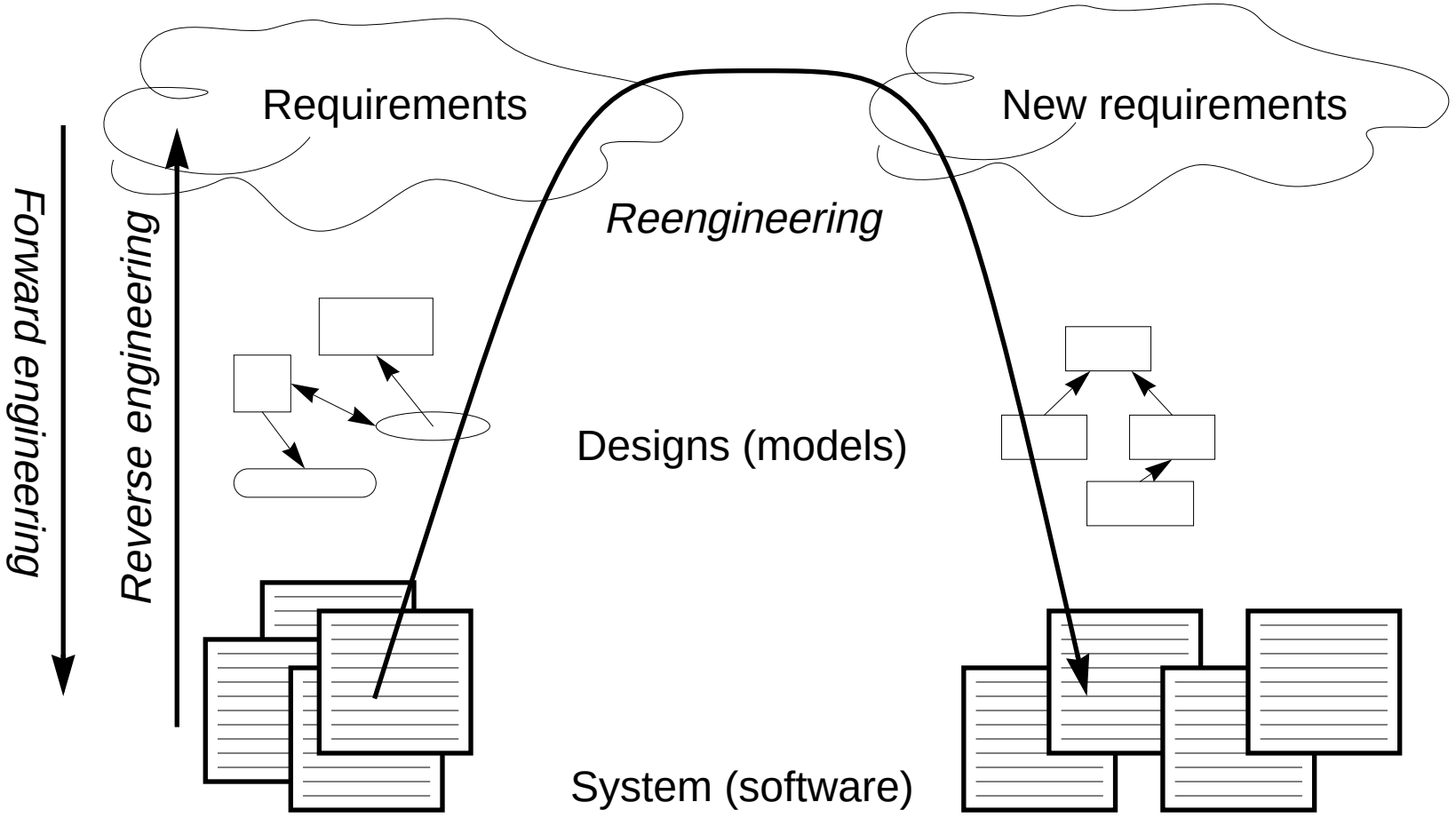
— Chikofsky and Cross [in Arnold, 1993]

Tools Architectures

"Most tools for reverse engineering, restructuring and reengineering use the same basic architecture."



Reverse and Re-engineering



Goals of Reverse Engineering

Cope with complexity

- need techniques to understand large, complex systems

Generate alternative views

- automatically generate different ways to view systems

Recover lost information

- extract what changes have been made and why

Detect side effects

- help understand ramifications of changes

Synthesize higher abstractions

- identify latent abstractions in software

Facilitate reuse

- detect candidate reusable artifacts and components

— Chikofsky and Cross [in Arnold, 1993]

Reverse Engineering Techniques

"Redocumentation is the *creation or revision of a semantically equivalent representation* within the same relative abstraction level."

- pretty printers
- diagram generators
- cross-reference listing generators

"Design recovery *recreates design abstractions* from a combination of code, existing documentation (if available), personal experience, and general knowledge about problem and application domains." [Biggerstaff]

- software metrics
- browsers, visualization tools
- static analyzers
- dynamic (trace) analyzers

Goals of Reengineering

Unbundling

- split a monolithic system into parts that can be separately marketed

Performance

- “first do it, then do it right, then do it fast”

Port to other Platform

- the architecture must distinguish the platform dependent modules

Design extraction

- to improve maintainability, portability, etc.

Exploitation of New Technology

- i.e., new language features, standards, libraries, etc.

Reengineering Techniques

"Restructuring is the *transformation from one representation form to another* at the same relative abstraction level, while preserving the system's external behaviour."

- automatic conversion from unstructured ("spaghetti") code to structured ("goto-less") code
- source code translation

"Data reengineering is the process of analyzing and *reorganizing the data structures* (and sometimes the data values) in a system to make it more understandable."

- integrating and centralizing multiple databases
- unifying multiple, inconsistent representations
- upgrading data models

Refactoring is restructuring within an object-oriented context

- renaming/moving methods/classes etc.

Architectural Problems

Insufficient documentation

- most legacy systems suffer from inexistent or inconsistent documentation

Duplicated functionality

- “cut, paste and edit” is quick and easy, but leads to maintenance nightmares

Lack of modularity

- strong coupling between modules hampers evolution

Improper layering

- missing or improper layering hampers portability and adaptability

Refactoring Opportunities

Misuse of inheritance

- for composition, code reuse rather than polymorphism

Missing inheritance

- duplicated code, and case statements to select behaviour

Misplaced operations

- unexploited cohesion — operations outside instead of inside classes

Violation of encapsulation

- explicit type-casting, C++ “friends” ...

Class misuse

- lack of cohesion — classes as namespaces

Summary

- We will *always* have legacy systems, because valuable software systems outlive their original requirements
- Early adopters of OO methods now find themselves with *OO legacy software*
- Reverse engineering techniques help to *recover designs* from legacy software
- Reengineering techniques are needed to restructure valuable legacy software so that it can *meet new requirements*, both now, and in the future

2. Metrics

Outline

- What are metrics? Why do we need them?
- Metrics for cost estimation
- Metrics for software quality evaluation

Sources

- *Software Metrics: A Rigorous and Practical Approach*, Norman Fenton and Shari Lawrence Pfleeger, 2d edn, PWS Publishing Co., 1997.
- *Software Engineering*, Ian Sommerville, Addison-Wesley, 5th edn., 1995
- *Tutorial on Software Metrics*, Simon Moser, Brian Henderson-Sellers, C. Mingins, 1997

Why Measure Software?

Estimate cost and effort

- measure correlation between specifications and final product

Improve productivity

- measure value and cost of software

Improve software quality

- measure usability, efficiency, maintainability ...

Improve reliability

- measure mean time to failure, etc

Evaluate methods and tools

- measure productivity, quality, reliability ...

...

"You cannot control what you cannot measure" — De Marco, 1982

"What is not measurable, make measurable" — Galileo

What is a Metric?

Software metrics

- Any type of measurement which relates to a software system, process or related documentation
  - Lines of code in a program
  - the Fog index
  - number of person-days required to develop a component
  - ...
- Allow the software and the software process to be quantified
- Measures of the software process or product
- Should be captured automatically if possible

GQM

Goal - Question - Metrics approach [Basili et al. 1984]

- Define *Goal*
  - e.g., “How effective is the coding standard XYZ?”
- Break down into *Questions*
  - “Who is using XYZ?”
  - “What is productivity/quality with/without XYZ?”
- Pick suitable *Metrics*
  - Proportion of developers using XYZ
  - Their experience with XYZ ...
  - Resulting code size, complexity, robustness ...

Metrics assumptions

Assumptions

- A software property can be measured
- The relationship exists between what we can measure and what we want to know
- This relationship has been formalized and validated

It may be difficult to relate what can be measured to desirable quality attributes

Measurement analysis

- Not always obvious what data means. Analysing collected data is very difficult
- Professional statisticians should be consulted if available
- Data analysis must take local circumstances into account

Cost estimation objectives

- To establish a budget for a software project
- To provide a means of controlling project costs
- To monitor progress against the budget
  - ☞ comparing planned with estimated costs
- To establish a cost database for future estimation
- Cost estimation and planning/scheduling are closely related activities

Estimation techniques

- Expert judgement
- Estimation by analogy
- Parkinson's Law
- Pricing to win
- Top-down estimation
- Bottom-up estimation
- Algorithmic cost modelling

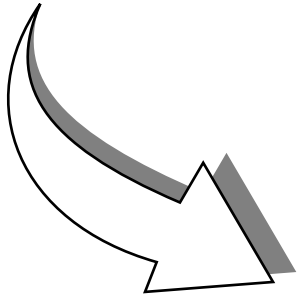
Algorithmic cost modelling

- Cost is estimated as a mathematical function of product, project and process attributes whose values are estimated by project managers
- The function is derived from a study of historical costing data
- Most commonly used product attribute for cost estimation is LOC (code size)
- Most models are basically similar but with different attribute values

Measurement-based estimation

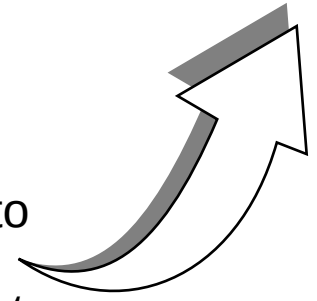
A. Measure

Develop a *system model* and measure its size



B. Estimate

Determine the effort with respect to an *empirical database* of measurements from *similar projects*



C. Interpret

Adapt the effort with respect to a specific *development project plan*

Lines of code

Lines of Code as a measure of system size?

- Easy to measure; but not well-defined for modern languages
  - What's a line of code?
  - What programs should be counted as part of the system?
- Assumes linear relationship between system size and volume of documentation
- A poor indicator of productivity
  - Ignores software reuse, code duplication, benefits of redesign
  - The lower level the language, the more productive the programmer
  - The more verbose the programmer, the higher the productivity

Function points

Function Points (Albrecht, 1979)

- Based on a combination of program characteristics:
  - external inputs and outputs
  - user interactions
  - external interfaces
  - files used by the system
- A weight is associated with each of these
- The function point count is computed by multiplying each raw count by the weight and summing all values
- Function point count modified by complexity of the project

Good points, bad points

- Can be measured already after design
- FPs can be used to estimate LOC depending on the average number of LOC per FP for a given language
- LOC can vary wildly in relation to FP
- FPs are very subjective — depend on the estimator. They cannot be counted automatically

Programmer productivity

A measure of the rate at which individual engineers involved in software development produce software and associated documentation

Productivity metrics

- Size related measures based on some output from the software process. This may be lines of delivered source code, object code instructions, etc.
- Function-related measures based on an estimate of the functionality of the delivered software. Function-points are the best known of this type of measure

Productivity estimates

- Real-time embedded systems, 40-160 LOC/P-month
- Systems programs , 150-400 LOC/P-month
- Commercial applications, 200-800 LOC/P-month

Quality and productivity

- All metrics based on volume/unit time are flawed because they do not take quality into account
- Productivity may generally be increased at the cost of quality
- It is not clear how productivity/quality metrics are related

The COCOMO model

- Developed at TRW, a US defense contractor
- Based on a cost database of more than 60 different projects
- Exists in three stages
  - Basic - Gives a 'ball-park' estimate based on product attributes
  - Intermediate - modifies basic estimate using project and process attributes
  - Advanced - Estimates project phases and parts separately

Basic COCOMO Formula

- Effort = $C \times PM^S \times M$
  - C is a complexity factor
  - PM is a product metric (size or functionality)
  - exponent S is close to 1, but increasing for large projects
  - M is a multiplier based on process, product and development attributes (~1)

Project classes

- *Organic mode* small teams, familiar environment, well-understood applications, no difficult non-functional requirements (EASY)
  - Effort = 2.4 (KDSI) $^{1.05} \times M$
- *Semi-detached mode* Project team may have experience mixture, system may have more significant non-functional constraints, organization may have less familiarity with application (HARDER)
  - Effort = 3 (KDSI) $^{1.12} \times M$
- Embedded Hardware/software systems, tight constraints, unusual for team to have deep application experience (HARD)
  - Effort = 3.6 (KDSI) $^{1.2} \times M$

COCOMO assumptions

- Implicit productivity estimate
  - Organic mode = 16 LOC/day
  - Embedded mode = 4 LOC/day
- Time required is a function of total effort NOT team size
- Not clear how to adapt model to personnel availability

Staffing requirements

- Staff required can't be computed by dividing the development time by the required schedule
- The number of people working on a project varies depending on the phase of the project
- The more people who work on the project, the more total effort is usually required
- Very rapid build-up of people often correlates with schedule slippage

Product quality metrics

- A quality metric should be a predictor of product quality.
- Most quality metrics are design quality metrics and are concerned with measuring the coupling or the complexity of a design.
- The relationship between these metrics and quality as judged by a human may hold in some cases but it is not clear whether or not it is generally true.

Design maintainability

- Cohesion
  - How closely are the parts of a component related?
- Coupling
  - How independent is a component?
- Understandability
  - How easy is it to understand a component's function?
- Adaptability
  - How easy is to change a component?

Coupling metrics

Associated with Yourdon's 'Structured Design'/ Measures 'fan-in and fan-out' in a structure chart:

- High fan-in (number of calling functions) suggests high coupling because of module dependencies.
- High fan-out (number of calls) suggests high coupling because of control complexity.

Henry and Kafura's modifications

- The approach based on the calls relationship is simplistic because it ignores data dependencies.
- Informational fan-in/fan-out takes these into account.
  - Number of local data flows + number of global data structures updated.
  - Data-flow count subsumes calls relation. It includes updated procedure parameters and procedures called from within a module.
- Complexity = Length * (Fan-in * Fan-out)2
  - Length is any measure of program size such as LOC.

Validation of quality metrics

- Some studies with Unix found that informational fan-in/fan-out allowed compex and potentially fault components to be identified.
- Some studies suggest that size and number of branches are as useful in predicting complexity than informational fan-in/fan-out.
- Fan-out on its own also seemed to be a better quality predictor.
- The whole area is still a research area rather than practically applicable.

Program quality metrics

Design metrics also applicable to programs

- Other metrics include
  - Length. The size of the program source code
  - Cyclomatic complexity. The complexity of program control
  - Length of identifiers
  - Depth of conditional nesting
- Anomalous metric values suggest a component may contain an above average number of defects or may be difficult to understand

Metric utility

- Length of code is simple but experiments have suggested it is a good predictor of problems
- Cyclomatic complexity can be misleading
- Long names should increase program understandability
- Deeply nested conditionals are hard to understand. May be a contributor to an understandability index

Metrics maturity

- Metrics still have a limited value and are not widely collected
- Relationships between what we can measure and what we want to know are not well-understood
- Lack of commonality across software process between organizations makes universal metrics difficult to develop

Summary

- Factors affecting productivity include individual aptitude, domain experience, the development project, the project size, tool support and the working environment
- Prepare cost estimates using different techniques. Estimates should be comparable
- Algorithmic cost estimation is difficult because of the need to estimate attributes of the finished product
- The time required to complete a project is not simply proportional to the number of people working on the project
- Metrics gather information about both process and product
- Control metrics provide management information about the software project. Predictor metrics allow product attributes to be estimated
- Quality metrics should be used to identify potentially problematical components

3. Object-Oriented Metrics in Industry

Invited Lecture by Dr. Simon Moser

See:

`http://www.iam.unibe.ch/~scg/Teaching/OOReen/`

4. The Year 2000 Problem

Invited Lecture by Prof. Dr. Gerhard Knolmayer

See:

`http://www.ie.iwi.unibe.ch/zeit/y2k/`

5. Design Extraction with UML

Lecture by Stéphane Ducasse

Design Extraction - Purpose of this lecture

- Design is not code with boxes and arrows
- Design extraction is not trivial
- Design extraction should scale up
- Design extraction can be supported by computers but not fully automatize
- Give a critic view on hype: “we read your code and produce design”
- Fertilize you with some basic techniques that may help you
- Show that UML is not that simple and clear

Outline

- Why
- UML Basics (What is design?
- Basic UML static elements (operations attributes and associations)
- Displaying code with boxes is not design
- Languages specific issues
- Tracks for extraction
- Case studies

Intro

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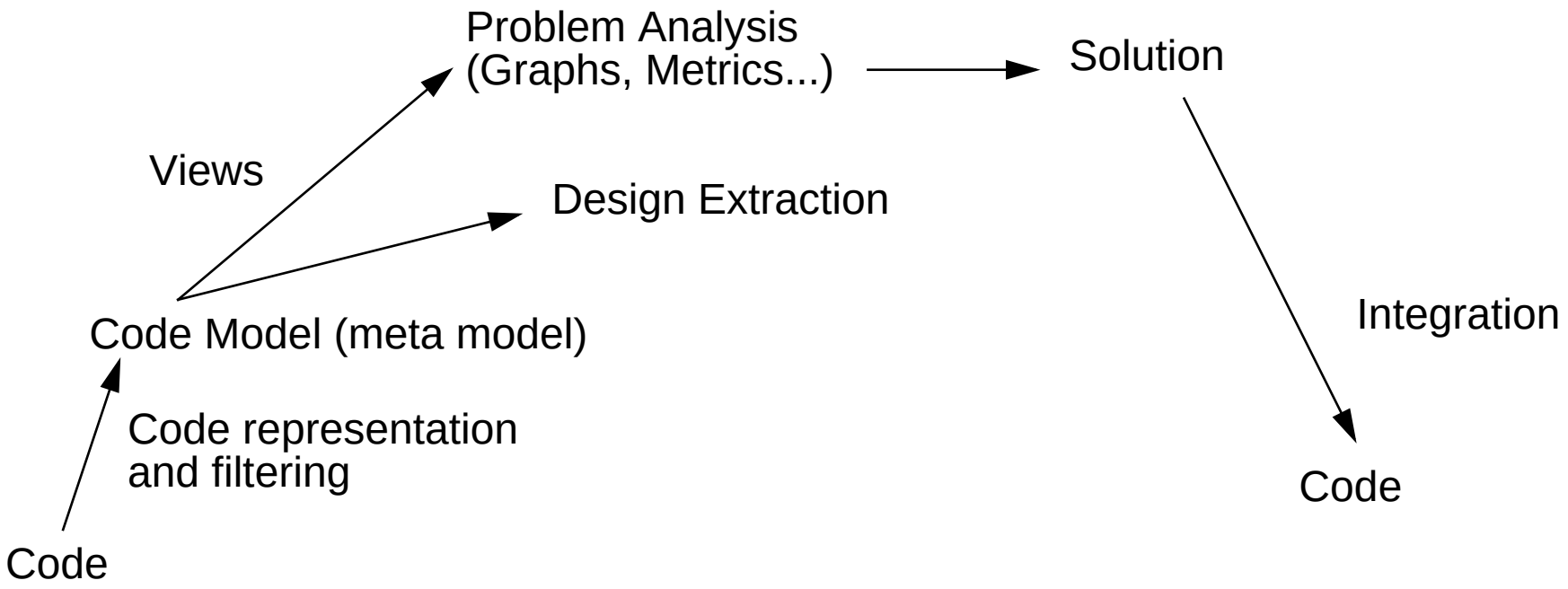
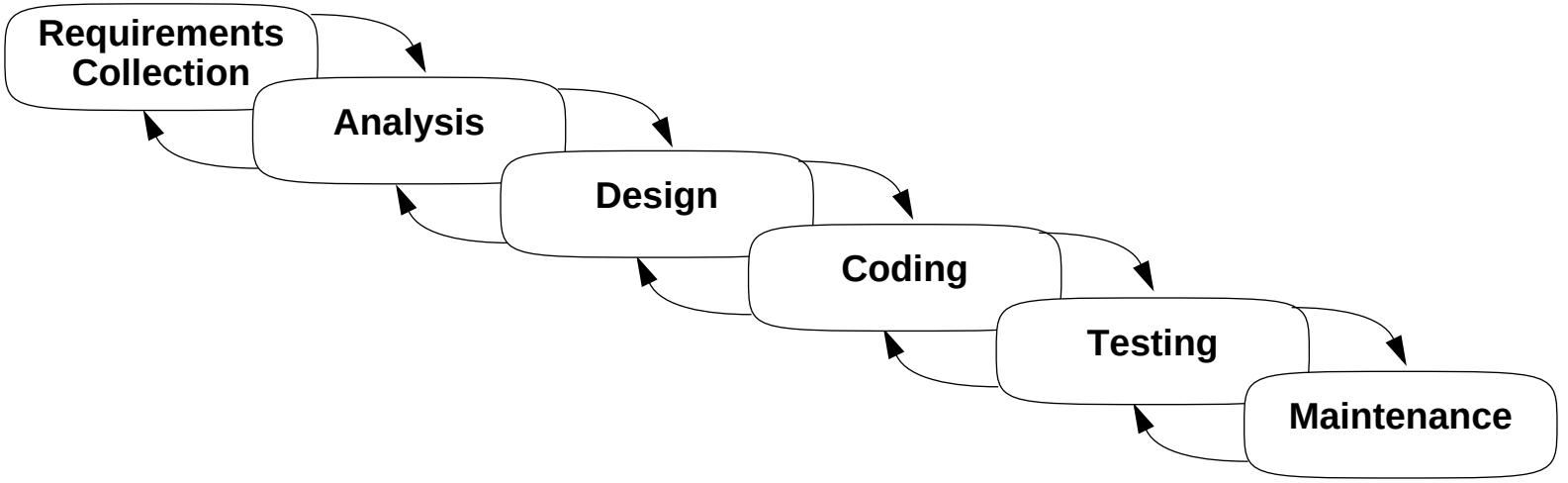
Design In Reengineering LifeCycle



Design In Forward Engineering

Waterfall



Quote Golberg ”...”

Why Design Extraction is needed?

- Documentation inexistent, obsolete or too prolix
- Abstraction needed to understand applications (complexity)
- Original programmers left
- Only the code available
- Emphasize literate programming approach

Why UML?

- Standard
- Communication based on a common language
- Can support documentationif we are precise about its interpretation
- (Hype and market)

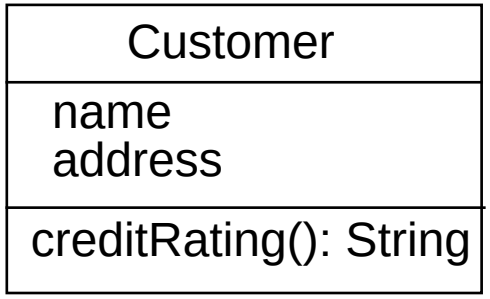
UML (Unified Modeling Language)

What is the Unified Modeling Language?

- Successor of OOAD&D methods of late 80 & early 90
- Unifies Booch, Rumbaugh (OMT) and Jacobson
- Currently standardized by OMG

- UML = a modeling language and not a methodology (no process)

- UML defines
  - a notation (it is the syntax of the modeling language)
    Ex:



  - a meta-model = a model to define the “semantics” of a model (what is well-formed), defines in itself but weak!

Terminology

UML	Class	Association	Generalization	Aggregation
Booch	Class	Has	Inherits	Containing
Coad	Class & Object	Instance connection	Gen-Spec	Part-Whole
Jacobson	Object	Acquaintance Association	Inherits	Consist of
Odell	Object Type	Relationship	Subtype	Composition
Rumbaugh	Class	Association	Generalization	Aggregation
Shlaer/Mellor	Object	Relationship	Subtype	N/A

Levels of Interpretations: Perspectives

UML purists do not propose different levels of interpretation, they refer to the UML semantics. Perspectives are not part of the formal UML

However levels of interpretation are valuable.

For example:

- What would be the sense of representing inheritance (subclassing) between two classes using generalization (subtyping)?

  Dictionary is a subclass of Set in Smalltalk (subclassing)

  but a Dictionary is not a subtype nor generalization of Set

  See stereotypes

Three Levels

- Conception: we draw a diagram that represents the concepts that are somehow related to the classes but there is often no direct mapping.
- Specification: we are looking at interfaces of object not implementation, types rather than classes. Types represent interfaces that may have many implementations (lot of design patterns are based on interfaces and delegation)
- Implementation: implementation classes

UML Static Elements

...

Static Class Diagram Elements

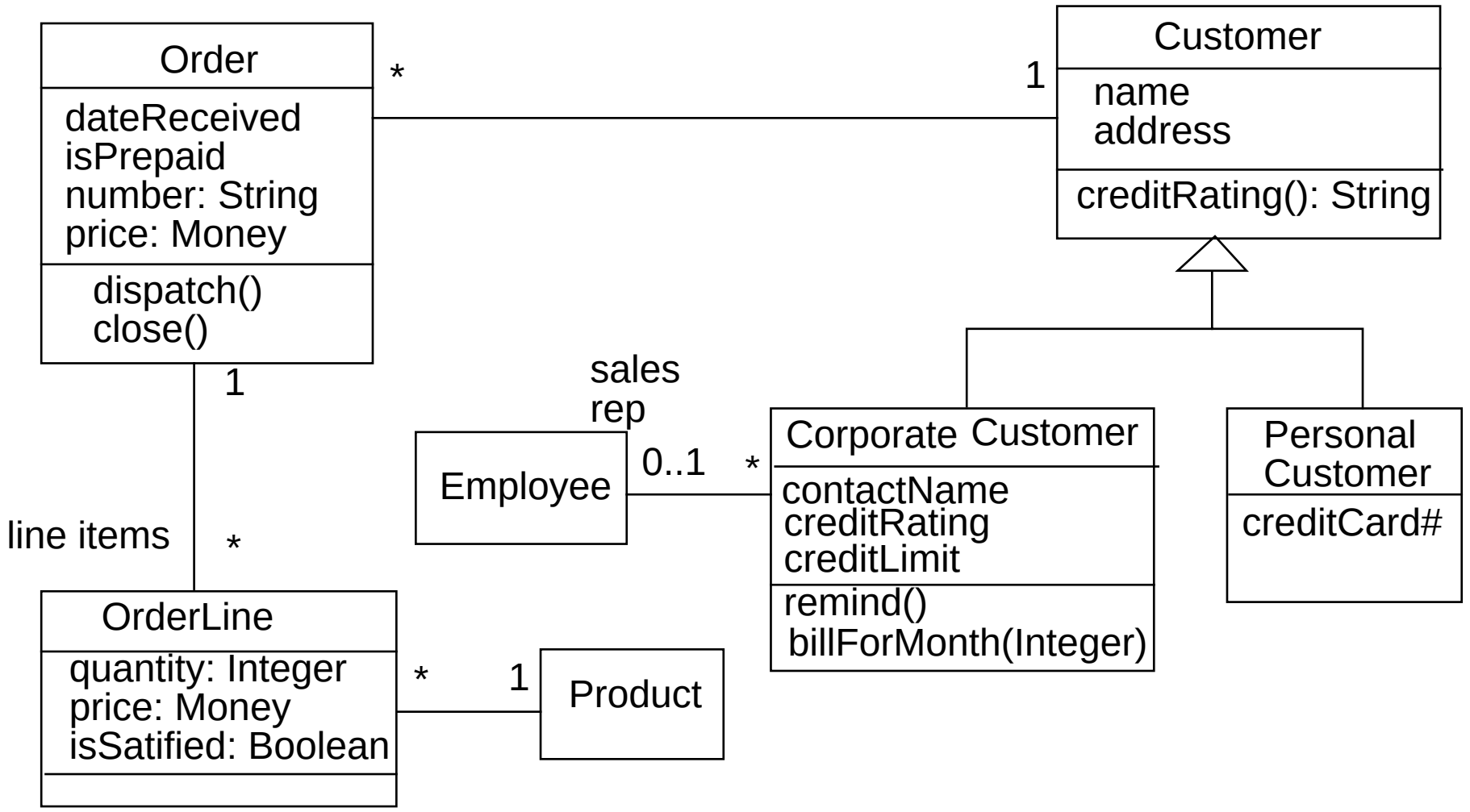
A class diagram describes the type of the objects and the various kinds of static relationships that exist among them.

Two main static relationships

- Association
  ex: a customer rents a video
- 'Is-a'
  ex: a nurse is a kind of person

A class diagram defines:

- attributes
- operations
- constraints that apply to the way objects are connected


Order
dateReceived
isPrepaid
number: String
price: Money
dispatch()
close()
*
1
Customer
name
address
creditRating(): String
1
sales
rep
Employee
0..1
*
Corporate Customer
contactName
creditRating
creditLimit
remind()
billForMonth(Integer)
Personal
Customer
creditCard#
line items
*
OrderLine
quantity: Integer
price: Money
isSatified: Boolean
*
1
Product

Attributes

Syntax:

visibility attributeName: attributeType = defaultValue

+ name: String

Conceptual:

Customer name = Customer has a name

Specification:

Customer class is responsible to propose some way to query and set the name

Implementation:

Customer has an attribute that represents its name

Possible Refinements

Attribute Qualification
- Immutable: Value never change
- Read-only: Client cannot change it

Operations

Can be approximate to methods.
- Conceptual: principal functionality of the object (CRC Cards),
  in design phase, it is often better to use a sentence that describes the functionality
- Specification: public methods on a type
- Implementation: methods

Syntax: visibility name (parameter-list):return-type
+ public, # protected, - private

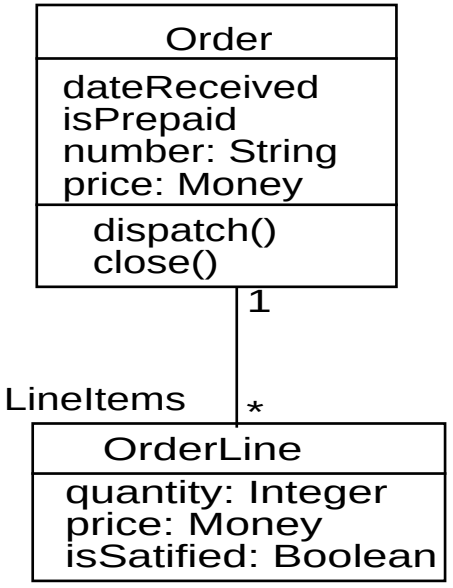
Possible Refinements:
-Method qualification: Query (does not change the state of an object)
Cache (does cache the result of a computation), Derived Value (depends on the value of other values), Getter, Setter
- Reuse Contract: To explicit method interdependencies and evaluate impact on subclassing and specialising. OCL (Object Constraint Language) Extension: You can specify which other methods a method invokes (reuse contracts)

```
accept: aPacket {invokes send:}
```

Associations

- Represents relationships between instances

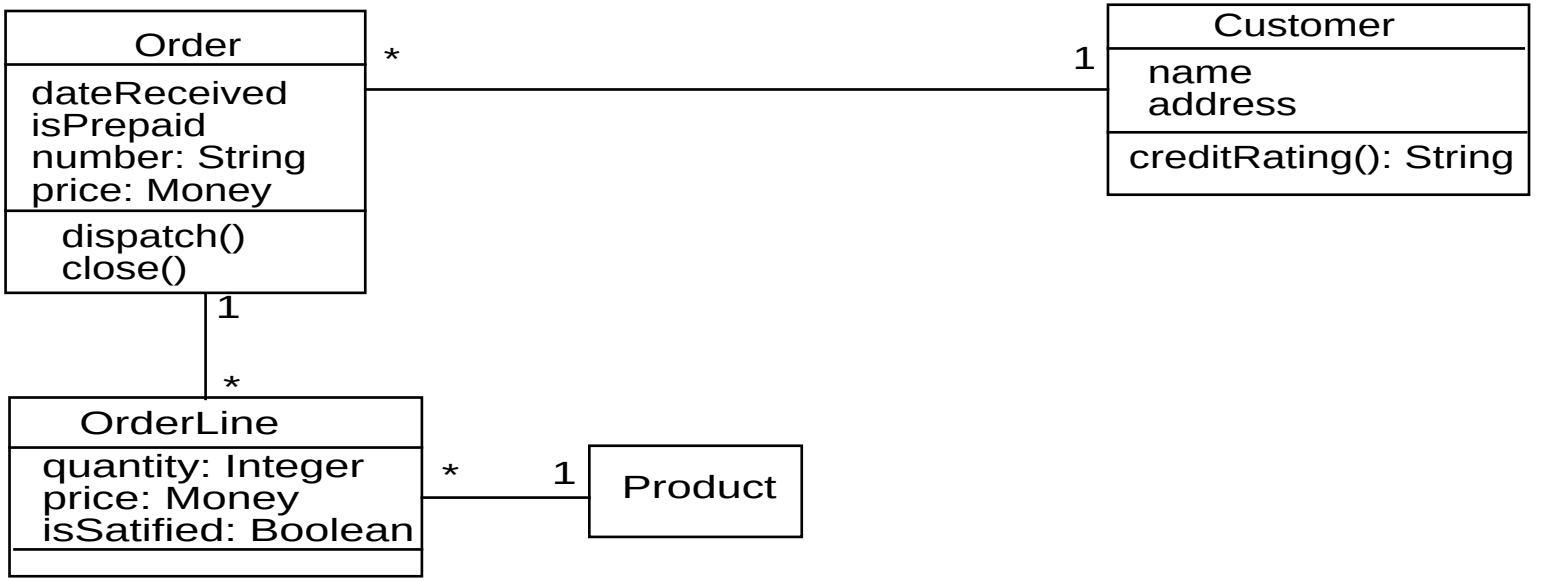
- Each association has two roles: each role is a direction on the association.
  - a role can be explicitly named, labeled near the target class
    if not named from the target class and goes from a source class to a target class
  - a role has a multiplicity: 1, 0, 1..*, 4



LineItems = role of direction Order to OrderLines
LineItems role = OrderLine role
One Order has several OrderLines

Associations: Conceptual Perspective

Conceptual Perspective: associations represent conceptual relationships between classes



An Order has to come from a single Customer.

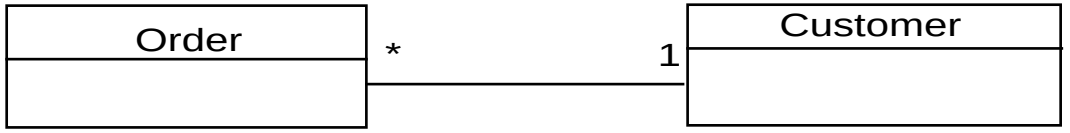
A Customer may make several Orders.

Each Order has several OrderLines that refers to a single Product.

A single Product may be referred to by several OrderLines.

Associations: Specification Perspective

Specification Perspective: Associations represent responsibilities



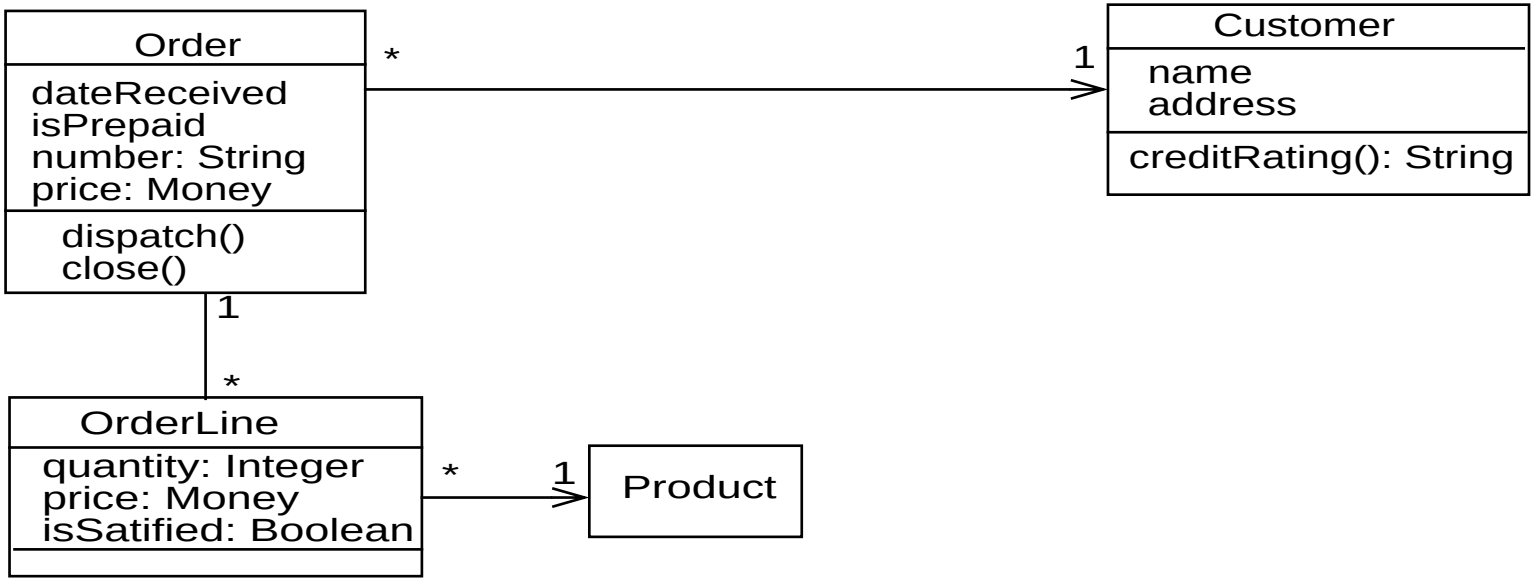
Implications:

- One or more methods of Customer should tell what Orders a given Customer has made.
- Methods within Order will let me know which Customer placed a given Order and what Line Items compose an Order

Associations also implies responsibilities for updating the relationship, like:

- specifying the Customer in the constructor for the Order
- add/removeOrder methods associated with Customer

Arrows: Nagivability



No arrow = navigability in both sides or unknown (so conventions!)

- Conceptual perspective: no real sense
- Specification perspective: responsibility
  an Order has the responsibility to tell which Customer it is for but Customer don't
- Implementation perspective:
  an Order points to a Customer
  an Customer doesn't

Attributes vs. Associations

Conceptual: No real difference. Attribute is another convenient notation association may be optional, attribute don't

Specification and Implementation:

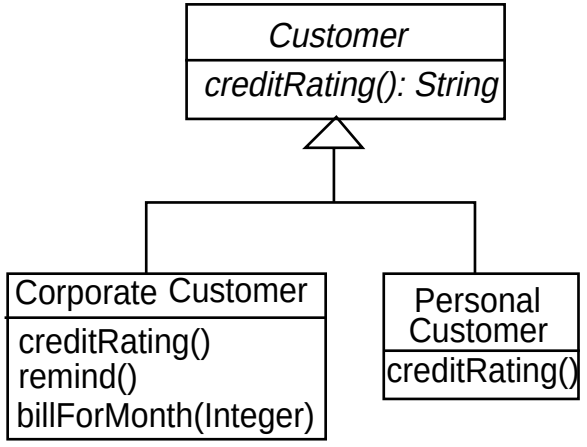
- attributes imply navigability from the type to the attribute only
- Fowler: "attribute imply that the type contains its own copy of the attribute object. Type used as attribute has value rather than reference semantics." Not true in all the languages!!!

Generalization

UML semantics only supports generalization and not inheritance.

Subtyping is not subclassing!

So we should interpret it.



Conceptual: What is true for an instance of a superclass is true for a subclass (associations, attributes, operations).

Corporate Customer is a subtype of Customer

Specifications: interface of a subtype must include all elements from the interface of a superclass (conformance).

Substituability principle: if that's works for superclass that should works for a subclass.

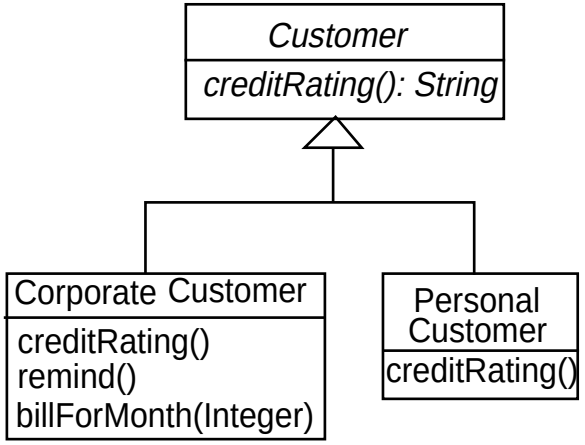
Implementation: Generalization semantics is not inheritance. But we should interpret it this way for representing extracted code.

A subclass inherits all the methods and fields of its superclass(es). It may override some of them.

Subclassing is one way to implement generalization.

Abstract classes and Interfaces

Abstract classes and methods are in italic



Abstract classes depending on the language defined only empty methods (Java, C++) or incomplete class behavior (Smalltalk, Eiffel)

- Smalltalk:

```
self subclassResponsibilities
```

- C++:

```
virtual ~Board(void) =0;
```

- Java: abstract
- Eiffel: deferred method

Differences between interfaces and abstract classes:

Interface does not support the definition of templates methods, i.e. do not support the definition of behavior and relationships between methods. Interface are purely methods declaration.

Experimentations

...

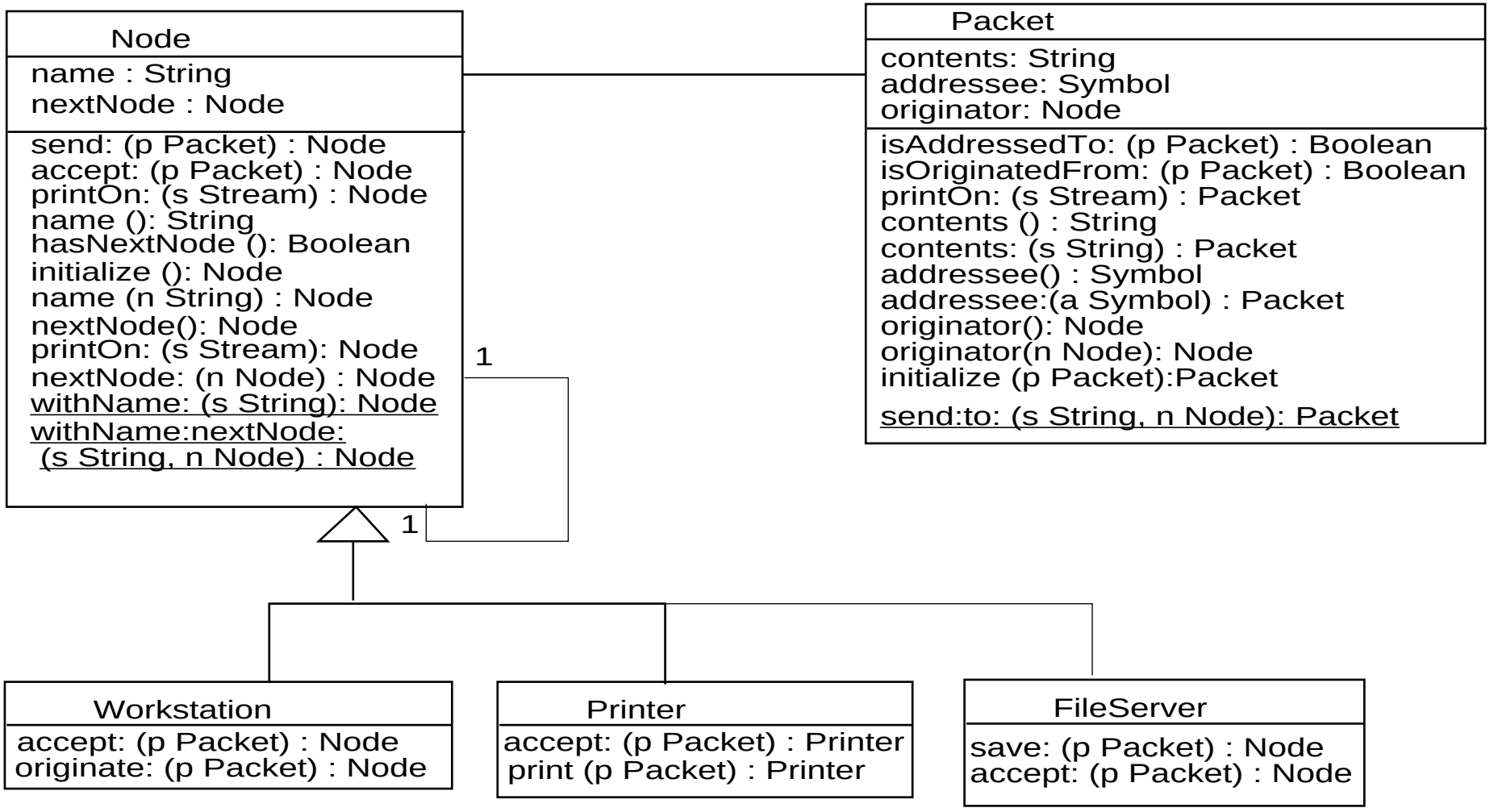
Extraction without Analysis Works for Toy

Let us do it with a Smalltalk example

```
Node          ('initialize-release' #initialize)
              ('sending/receiving' #accept: #send:)
              ('printing' #printOn:)
              ('private' #name #name: #nextNode #nextNode:)
              ('accessing' #hasNextNode)
Workstation   ('sending/receiving' #accept:)
              ('originating' #originate:)
Printer       ('printing' #print:)
              ('sending/receiving' #accept:)
FileServer    ('sending/receiving' #accept:)
              ('saving' #save:)
Packet        ('printing' #printOn:)
              ('accessing' #isAddressedTo: #isOriginatingFrom:)
              ('initialize-release' #initialize)
              ('private' #addressee #addressee: #contents #contents: #originator #originator:)
```

Extraction without Analysis Works for Toy

A tiny LAN simulator in Smalltalk



Another Tiny Example in C++

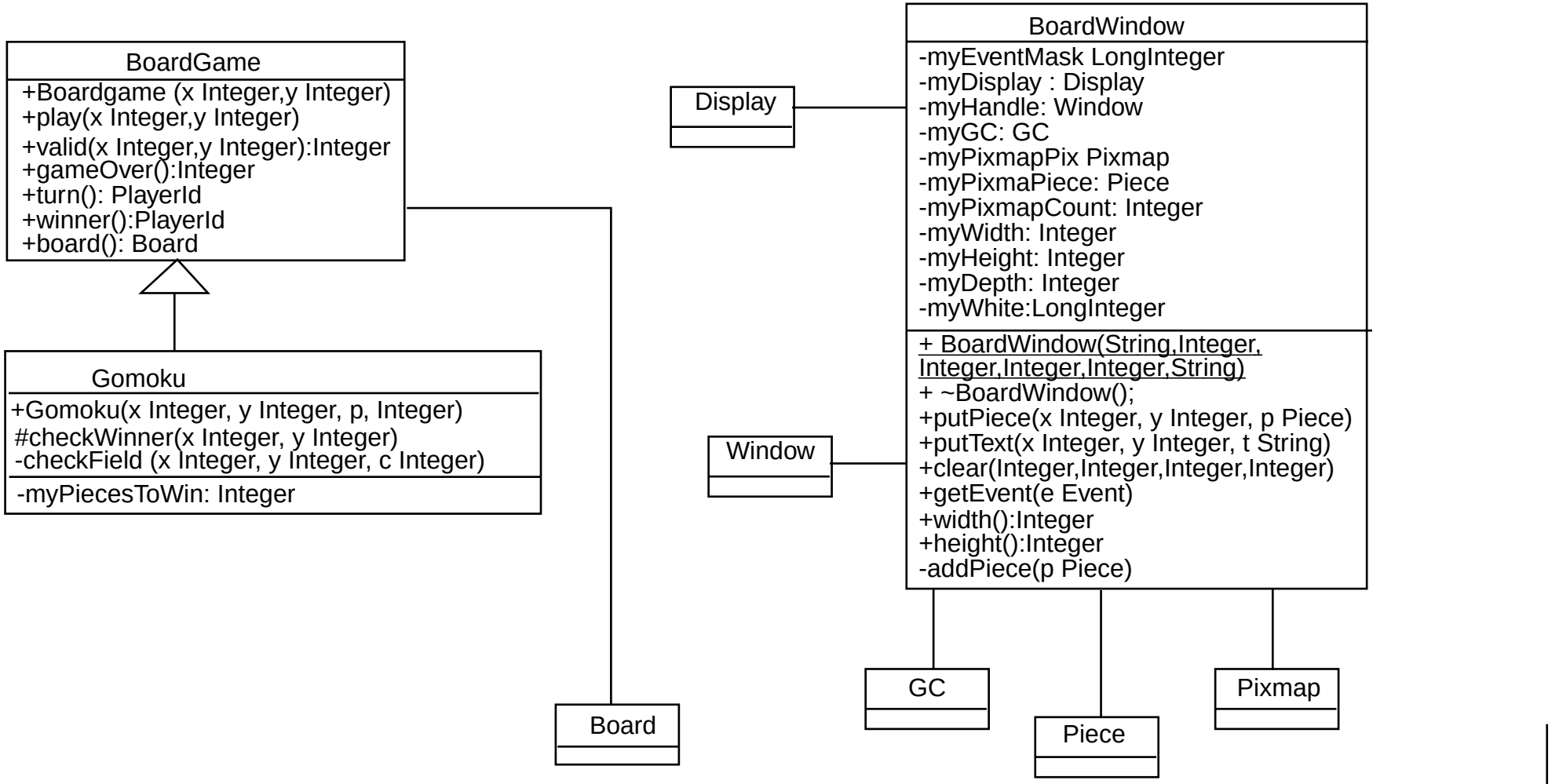
A Tic-Tac-Toe Game!

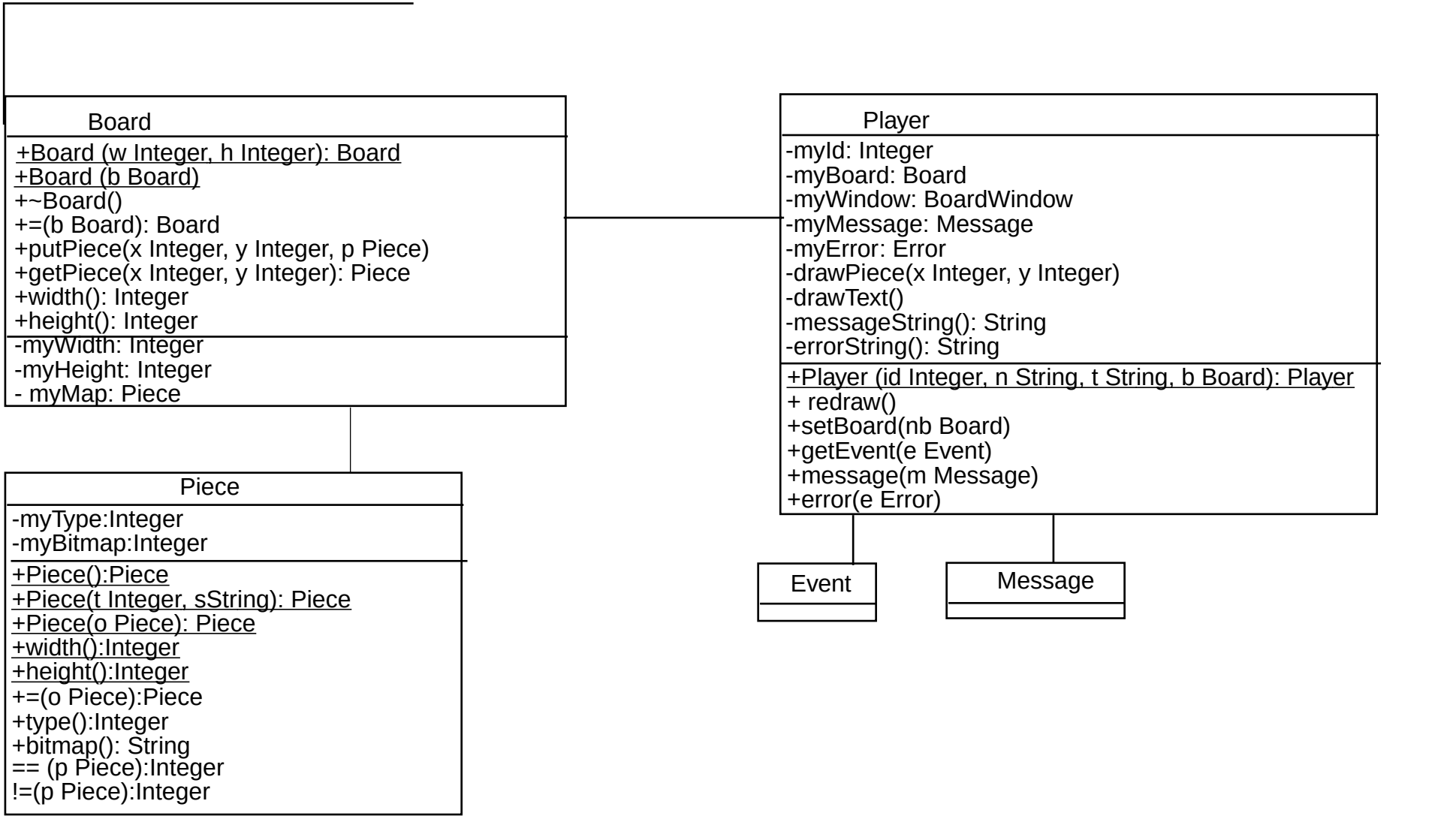
You will do it now.....

But:

- do not interpret the code
- do not make any assumption about it
- do not filter out anything

Another Tiny Example in C++



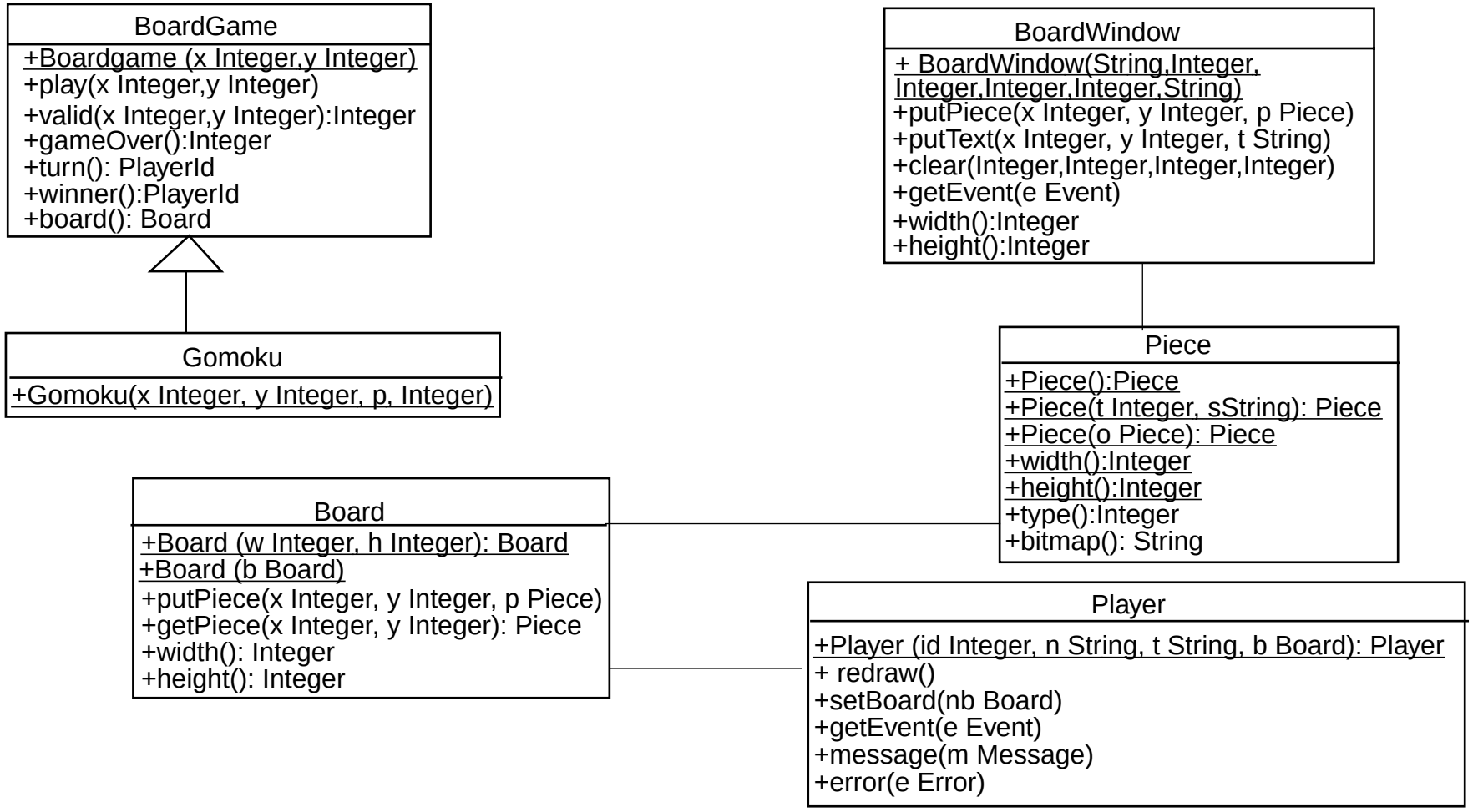

Board
+Board (w Integer, h Integer): Board
+Board (b Board)
+~Board()
+=(b Board): Board
+putPiece(x Integer, y Integer, p Piece)
+getPiece(x Integer, y Integer): Piece
+width(): Integer
+height(): Integer
-myWidth: Integer
-myHeight: Integer
- myMap: Piece
Player
-myId: Integer
-myBoard: Board
-myWindow: BoardWindow
-myMessage: Message
-myError: Error
-drawPiece(x Integer, y Integer)
-drawText()
-messageString(): String
-errorString(): String
+Player (id Integer, n String, t String, b Board): Player
+ redraw()
+setBoard(nb Board)
+getEvent(e Event)
+message(m Message)
+error(e Error)
Piece
-myType:Integer
-myBitmap:Integer
+Piece():Piece
+Piece(t Integer, sString): Piece
+Piece(o Piece): Piece
+width():Integer
+height():Integer
+=(o Piece):Piece
+type():Integer
+bitmap(): String
== (p Piece):Integer
!=(p Piece):Integer
Event
Message

Evaluation

We should have heuristics to extract the design.
Try to clean the previous solution you found
Try some heuristics
Like removing:

- private information,
- remove association with non domain entities,
- simple constructors,
- destructors, operators
-

A Cleaner View

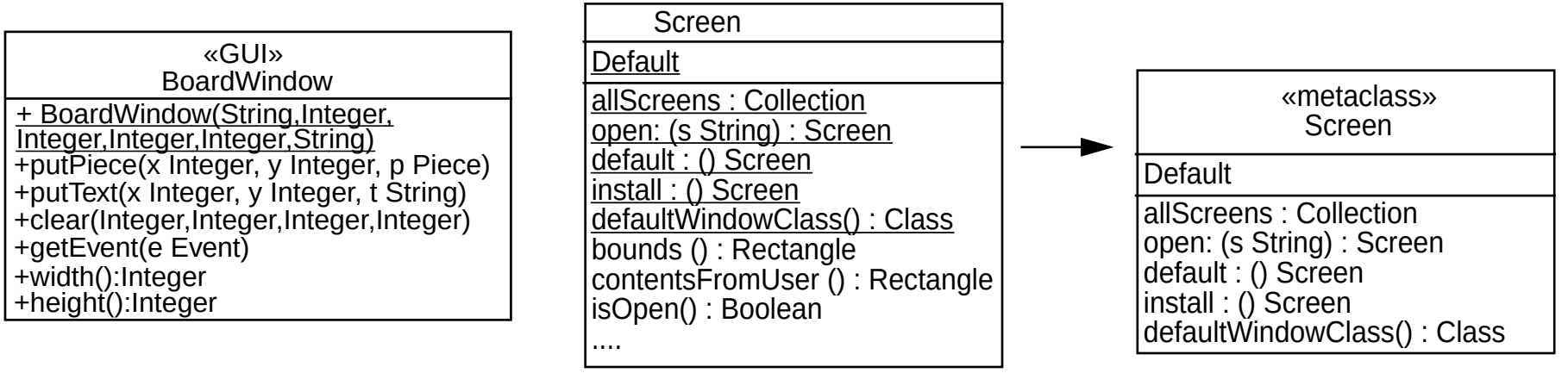


6. Languages Issues and Extraction Tracks

...

Stereotype: a Way to Extend UML

- Mechanism to specialize the semantics of the UML elements
- New properties are added to an element
- When a concept is missing or does not fit your needs
  select a close element and extend it



- 40 predefined stereotypes (c = class, r = relation, o = operation, a = attribute, d = dependency, g = generalization):
  metaclass (c), instance (r), implementation class (c)
  constructor (o), destructor(o), friend (d), inherits (g), interface (c), private (g), query (o), subclass (g), subtype (g), utility (classifier) (only class scope operations and attributes)

Languages Specific Issues (i)

- UML has no direct mapping to a specific language. Even if it is close to C++
- We should interpret it and extend it to find the rigth mapping

In C++, examples show that:

```
Board& board()
Board& operator =(const Board& other) throw (const char*);
```

board(): Board

```
Piece* myMap;
```

myMap: Piece

```
class Gomoku : public Boardgame {
```

«public»

```
virtual void checkWinner(int x, int y);
```

checkWinner

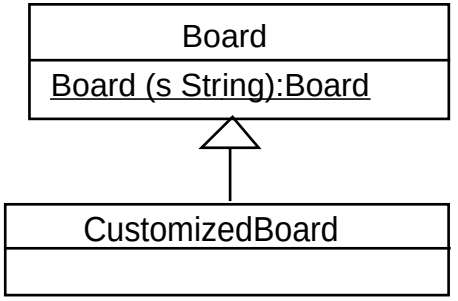
```
static int width();
```

width:Integer

Class Method Inheritance

Does it mean that CustomizedBoard can be instantiated by calling Board(‘’Player 1’’)?

In Smalltalk: Yes there is normal inheritance between (meta) classes.



In Java: No there is no inheritance between non-default class constructor.

```
CustomizedBoard instance = new CustomizedBoard() -> Board() is called
CustomizedBoard instance = new Board(“player 1”) -> does not work
```

Define a stereotype if you need it

Language Specific Issues (ii)

- In Smalltalk return-type is boring because all methods returns self per default. So you may choose to only specify return if it it not the same as the class.
- Attributes are all private
- All methods are public but ‘private categories’

Visibility Semantics Variations

What is the semantics of private, protected and public. For example, is it class-based (C++) or instance based (Smalltalk)?

in C++: - any public member is visible anywhere in the program
- a private member may be used only by the class that defines it
- a protected member may be used by the class that defines it or its subclasses
class based private

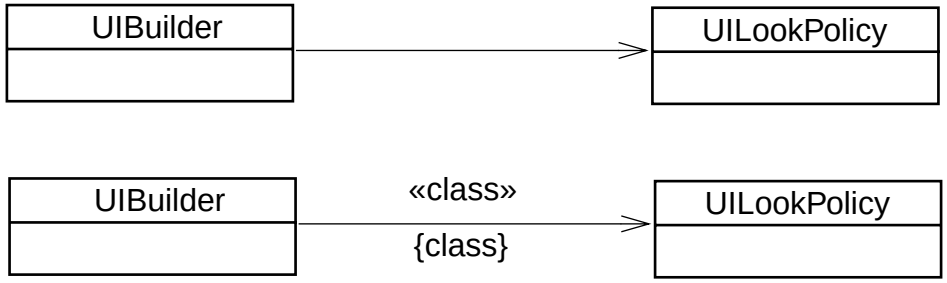
in Smalltalk: - instance variables are private = C++ protected
- instance based private
- methods are public

in Java class based like C++ but package rules:
- a member with package visibility may be accessed only by instances of other classes in the same package
- a protected member may be accessed by subclasses but also by any other classes in the same package as the owing class
=> protected is more public than package
- classes can be marked as public or package
a package class may be used only by other classes in the same package

Instance/Class Associations

How to distinguish between associations between classes and association between instances?

UIBuilder (class) is related to the UILookPolicy (class)



But an instance of UIBuilder is also related to an instance of UILookPolicy

Use a stereotype or a constraint

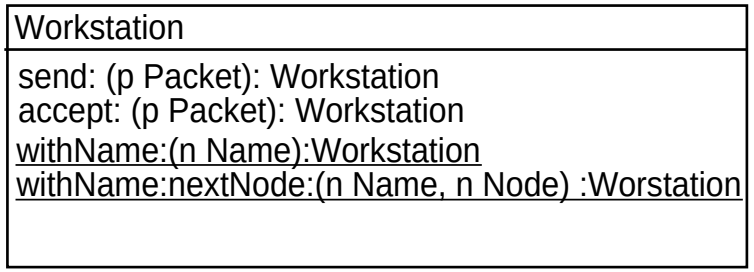
Class Information and Metaclasses

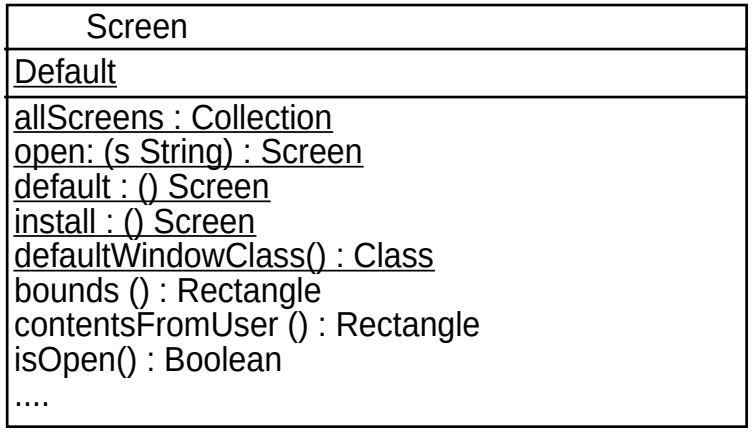
Class information are underlined (attribute and methods)

But class information: methods and attributes are not limited to instance creation methods (constructors static methods).

=> Mixing of levels and confusing!

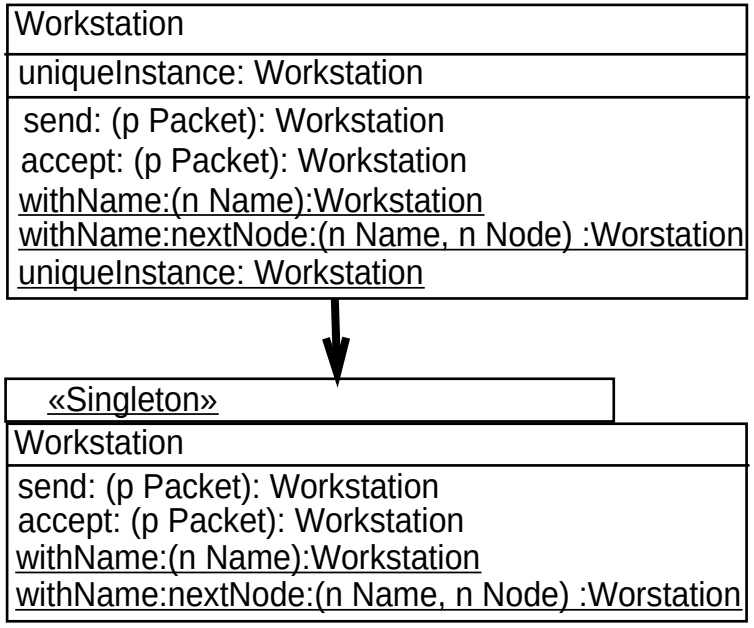
uniqueInstance (c Class): Scheduler
defaultWindowClass (): Class
returns the class window

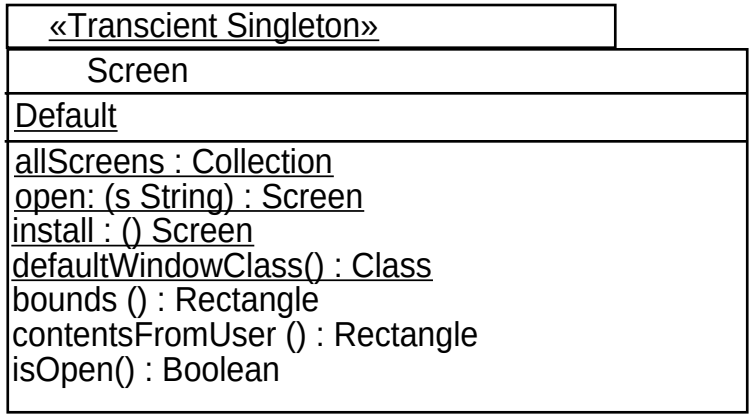




Stereotypes for Class Behavior

Could work for well defined situation





But still fragile

Association Extractions (i)

Goal: Explicit references to domain classes

1: Domain Objects

- Qualifying as attributes only implementation attributes that are not related to domain objects.

Value objects -> attributes and not associations,

Object by references -> associations

Ex: name: String -> an attribute

order: anOrder -> an association

myDisplay : Display -> not an association

2: Filtering based coding conventions or visibility

In Java, C++

filter out private attributes

_*

Association Extractions (ii)

In Smalltalk depending on code practices you may filter out attributes

- attributes
- that have accessors and are not accessed into subclasses.
- with name: *Cache.
- attributes that are only used by private methods.

Two classes possess attributes on each other

=> an association with navigability at both side

Code Inferring or Design Extraction

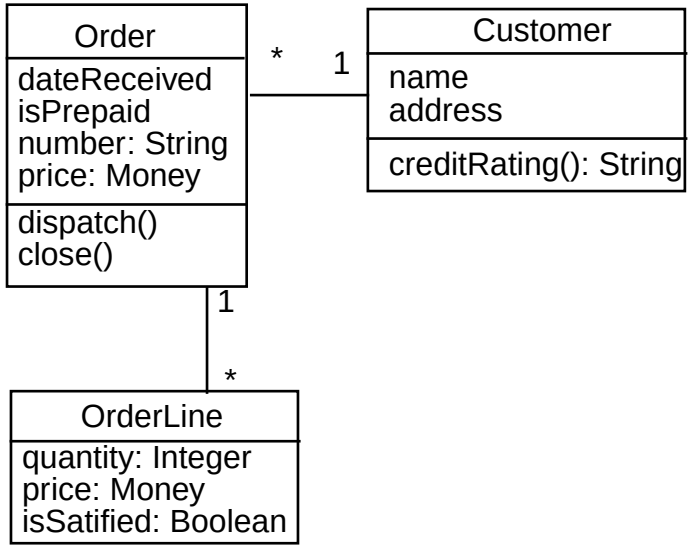
If there are some coding conventions

In Java

```
class Order {
   public Customer customer(); (single value)
   public Enumerator orderLines(); (multi-val-
ues)
}
```

In Smalltalk

```
Order>>customer (single value)
Order>>orderLinesCollect: (multi-values)
Order>>orderLinesDo:
Order>>orderLinesSelect:
Order>>orderIsEmpty
```



From the specification level note that responsibilities do not imply data structure.
Cannot be able to say if Order contains a pointer to Customer or something else

Associations: Implementation Perspective

Associations represent pointers in both directions between related classes

In Java

```
class Order{
   private Customer _customer;
   private Vector _orderLines; }
class Customer {
   private Vector _orders }
```

In Smalltalk

```
Object subclass: #Order
   instanceVariable: 'customer orderLines'
Order>>initialize
   orderLines := OrderedCollection new: 5

Object subclass: #Customer
   instanceVariable: 'orders'
Customer>>initialize
   orders := OrderedCollection new: 5
```

Operation Extraction

You may not extract

- accessors,
- operators,
- simple instance creation methods
  (new in Smalltalk, constructor with no parameters)
- non-public methods,
- methods already defined in superclass,
- methods already defined in superclass that are not abstract, recursively
- methods that are responsible for the initialization, printing of the objects

Operation Extraction (ii)

If there are several methods with more or less the same intent

- select the method with the smallest prefix
  you want to know that the fonctionality exists not all the details
- select the method with the more parameters
  you want to know all the possibilities but not all the ways you can invoke them
- categorize methods according to the number of time they are reference into clients
  but a method can be a hook method that is often called but still important

Use company conventions to filter

- Access to database
- Calls for the UI
- Naming patterns

In Smalltalk, do not show

- methods that belongs to categories: ‘printing’, ‘accessing’, ‘initialize-release’, ‘private’
- methods with name: #printOn:, #storeOn:,
- methods with the name of an attribute

What is important to show

Smalltalk class methods in ‘instance creation’ category,
Constructors in Java or C++

=> represent the creation interface of an object

Case Study

...

UIBuilder of VisualWorks

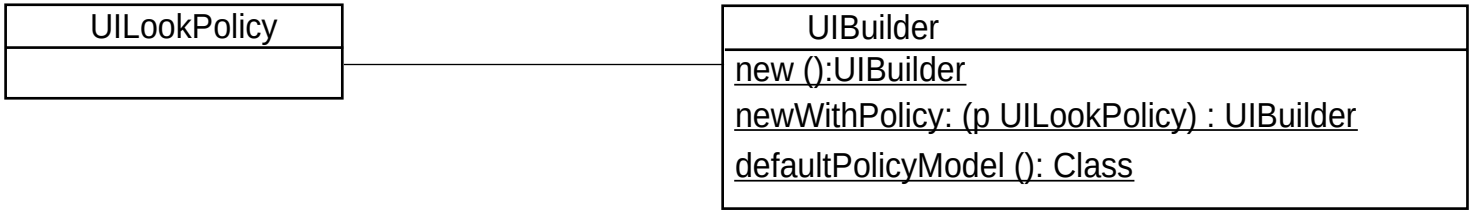
- By hand just to prove the point
- VisualWorks: a middle size frameworks (700 classes)
- UIBuilder: central to the frameworks, responsible of the building of the interface
- Quit complex class
- No type but senders and implementors to identify client

To Help You to Follow

```
UIBuilder

	('initialize-release' #initialize #newSubBuilder)

	('accessing' #bindings #bindings: #cacheWhileEditing #cacheWhileEditing: #component #compo-
nent: #componentAt: #componentAt:put: #composite #composite: #converterClass #converterClass: #dec-
orator #decorator: #isEditing #isEditing: #keyboardProcessor #keyboardProcessor: #labels #labels:
#namedComponents #namedComponents: #noTabbing #policy #policy: #source #source: #spec #spec: #visuals
#visuals: #window #window: #windowSpec #windowSpec: #wrapper #wrapper:)

	('adding' #add: #addCollection: #addCollectionRecyclingSpecs: #addSpec:)

	('binding' #actionAt: #actionAt:put: #arbitraryComponentAt: #arbitraryComponentAt:put: #as-
pectAt: #aspectAt:put: #clientAt: #clientAt:put: #labelAt: #labelAt:put: #listAt: #menuAt: #menu-
At:put: #metaInfoAt: #metaInfoAt:put: #subCanvasAt:at: #subCanvasAt:at:put: #usingMenuBar: #visu-
alAt: #visualAt:put:)

	('building composites' #endComposite #endCompositeLayout: #endCompositeLayout:properties:
#newComposite #newComposite: #popComposite)

	('building windows' #windowLabeled: #windowOn: #windowOn:label:)

	('scheduling' #doFinalHookup #open #openAroundCursorWithExtent:andType: #openAt: #openDialog
#openDialogWithExtent: #openDialogWithExtent:postOpen: #openIn: #openPopUpIn: #openPopUpIn:type:
#openPopUpIn:type:postOpen: #openWithExtent: #openWithExtent:andType:)

	('private' #addComponent #applyLayout: #attemptCompositeKey: #cancelAction: #defaultAction:
#defaultProperties#findBindingFor:selector:cache:#fixWindowWith:#raiseErrorMessage:with:#safely-
Perform: #safelyPerform:key: #sendKeyboardTo: #setupKeyboard #setWindow: #stack #stack: #startNew-
Component #wrapWith:)
```

Class Method Extraction

categories: ‘class initialization’ ‘ examples’ ‘private’ ‘Signal constants’
=> ‘policies’ ‘instance creation’
policies:
defaultPolicyClass defaultPolicyClass: (accessor for a classVariable)
+ only called by the instance level
=> defaultPolicyModel
instance creation: new, newWithPolicy: UILookPolicy



UIBuilder: methods at instance level (i)

categories filtered: ‘initialize-release’ ‘private’ ‘accessing’
=> ‘adding’ ‘binding’ ‘building composites’ ‘building windows’ ‘scheduling’

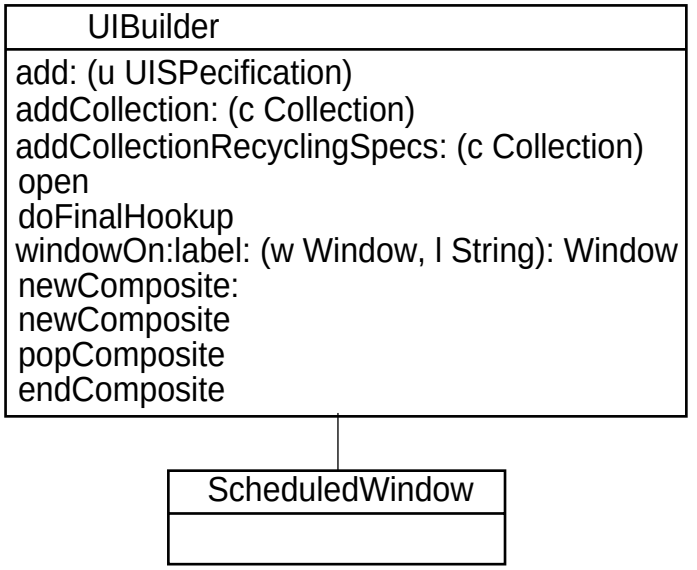
‘adding’ => add: , addSpec:, addCollection:, addCollectionRecyclingSpecs:
(addSpec: only called by add: and windowOn: Label: of UIBuilder)
We may apply “select only the simpler prefix here add”

‘scheduling’ => doFinalHookup
open (select only the simpler prefix)

‘building windows’ =>
windowOn:Label: (select longer parameter)

‘building composites’ =>
newComposite:,
newComposite (called heavily by clients)
popComposite (only called by UILookPolicy)
endComposite

‘binding’ => clientAt:, clientAt:put:,labelAt:,labelAt:put:
....
remove *at: and *at:put:



UIBuilder attributes

Remove: not domain entities: KeyboardProcessor

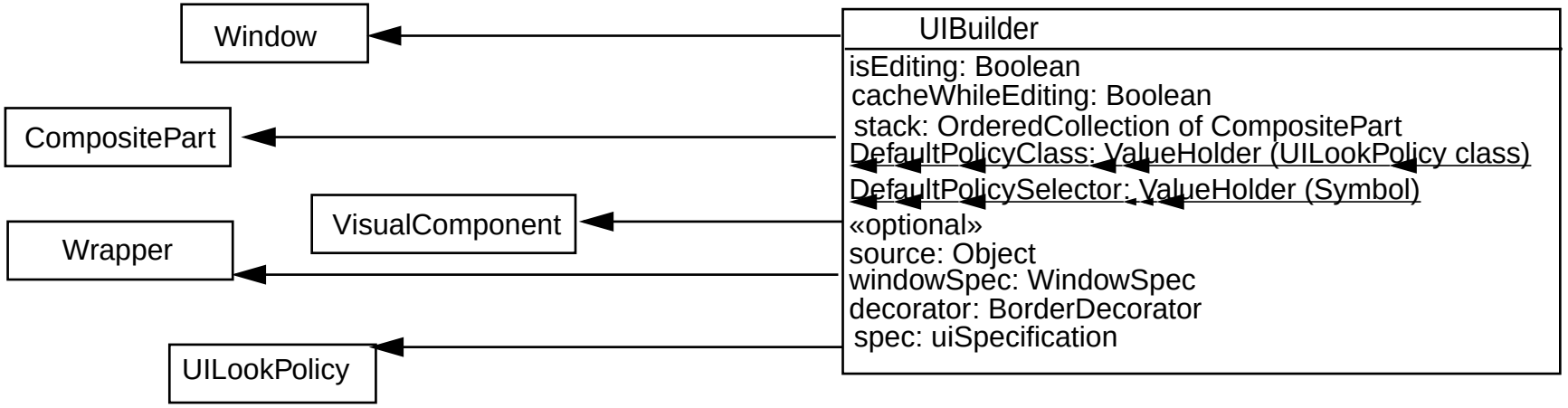
As association:

windowSpec | nil, BorderDecorator | nil -> optional stereotype

other domain entity: UILookPolicy, UISpecification, BorderDecorator

As attributes: spec are kind of arrays that encode a visual description

Filter out the Dictionary based attributes: Too few information



Classes Pointing to UIBuilder

Smalltalk is dynamically typed, so look for “builder” as attributes and method “builder”

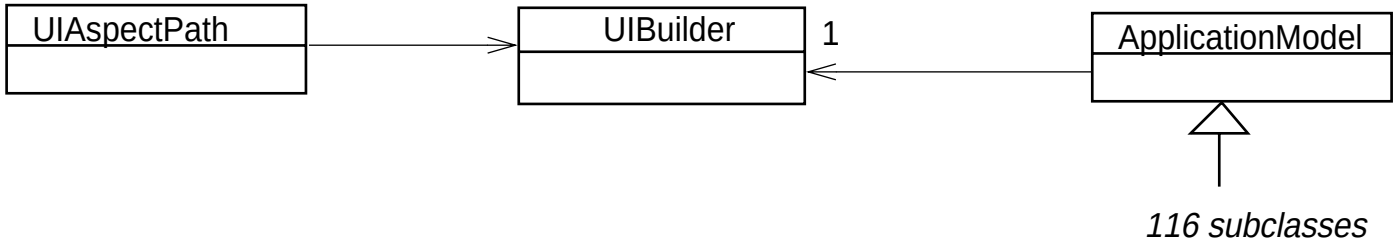
With typed language or a type inference algorithm we would look at attributes with type UIBuilder or methods that return UIBuilder.

But we restrict the lookup to frameworks itself.

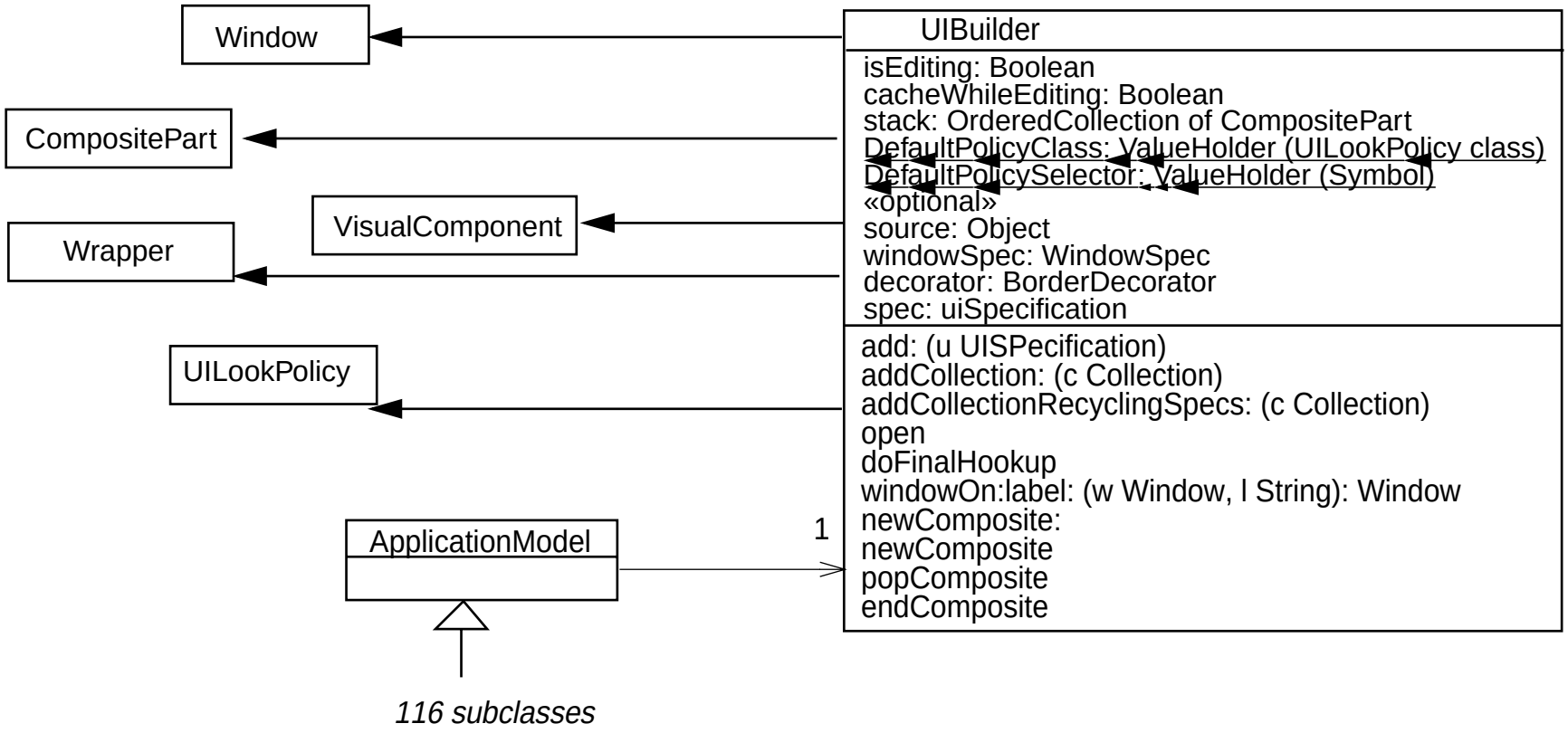
Inheritance impact the result:

-> two classes with builder as attributes (UIAspectPath, ApplicationModel)

-> two classes with accessors (ApplicationModel, UIPainterController but via a model)



The Overall Picture



=> Better knowledge of the domain class

A tool should help an expert of the domain, it will not deduce everything automatically

Qualified Associations

Associative arrays, maps, dictionaries

In the context of an Order you need a product to identify anOrderLine.

Conceptual: you cannot have two OrderLines within an Order for the same product

Specification:

```
class Order {
    public OrderLine lineItem (Product aProduct);
   public void addLineItem(number Amount, Product forProduct);
```

=> access to a given LineItem requires aProduct

Implementation:

```
class Order {
   private Dictionary _lineItems; (key is a product)
```

Aggregation

Aggregation is part-of relationship

Ex: A car has an engine and wheels as its parts

Simple at first glance but complex in fact !!

Difficult because there are a lot of different notions and definitions. Even Gurus disagree!

Aggregation is just a special kind of association.

The distinction is purely conceptual.

The open diamond distinguishes the whole from the part.

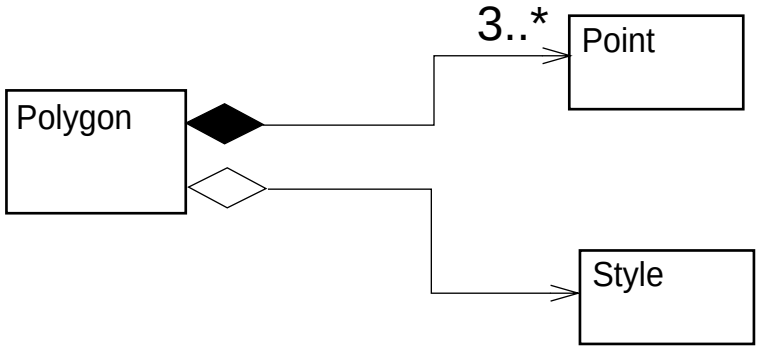
Does not change the navigation or the lifetimes of the whole/part

Aggregation and Composition

UML proposes a limited view of aggregation where lifetime and sharable issues are linked

In UML composition implies that

- (non-sharable) parts belong to only one whole
- (constrained lifetime) parts live and die with the whole



UML does not offer predefined way to express:

- different liteime sharing dependency
- reference, embedded value

USe stereotype

Aggregations or/and Multiplicity Extraction

Iterators or collections =>

- aggregation
- associations 1..* between class and the class of the collection elements.

Private Inheritance semantics = aggregation [Riel96]

About Aggregations: an Analysis View

From “A Taxonomy...” article (Linguistic, logic and cognitive psychology) different part-of relationship are identified:

Component integral, material-object, portion-object, place-area, collection-members, container-content, member-partnership

Three criteria:

- Configuration: whether or not parts have a functional and structural relationship either to one another or to the whole they constitute
- Homeomerous: whether or not parts are the same kind of thing as the whole
- Invariance: whether or not parts can be separated from the whole

	Configurational	*Homeomeric*	*Invariant*
Component integral	*yes*	*no*	*no*
Material object	*yes*	*no*	*yes*
Portion	*yes*	*yes*	*no*
Place-Area	*yes*	*yes*	*yes*
Member	*no*	*no*	*no*
Partnership	*no*	*no*	*yes*

Component-Integral Object Aggregation

Configurational: yes Homeomeric: no Invariant: no

“Defines a configuration of parts within a whole”

- Also called assembly-parts
- Component parts are objects in their own right even when they are not part of the whole
- Parts can be removed
- The configuration of the parts should be particular (structural or functional)
- The integral object exibits a patterned structure organization
- But a part cannot be removed without affecting the concept of the whole

Examples:

Scenes are part of films

Wheels are part of a car, a keyboard is part of a computer

Bristles are part of toothbrush

Nuclear physics is part of physics

Projective geometry is part of mathematics

When a component ceases to support the overall pattern of an object a different kind of association result (part-of -> piece-of)

Material-Object Aggregation

Configurational: yes Homeomeric: no Invariant: yes

“Defines an invariant configuration of parts within a whole”

- Define what objects are made of
- Parts cannot be removed
- Parts lose their identity when they are used to make a whole

With material obejct relationships, the relationship between the parts is no longer known once they become part of the whole.

Example:

A cappucino is partly milk

A car is made of iron

Portion-Object Aggregation

Configurational: yes Homeomeric: yes Invariant: no
“Defines a homoemeric configuration of parts within a whole”

- The parts are the “same” kind as the whole
- The parts can be removed
- Certain properties of the whole can apply to the parts

Examples:

- A slice of bread is a portion of a loaf of bread
- A meter is part of a kilometer
- An hour is part of a day

Place-Area Aggregation

Configurational: yes Homeomeric: yes Invariant: yes
“Defines a homeomeric and invariant configuration of parts within a whole”

- Non sharable configuration of the parts within a whole.
- Parts cannot be removed

Example:

San-Franscico is part of california
A peak is part of a mountain

Odell said that this is UML composition but it is not!!

Member-Bunch Aggregation

Configurational: no Homeomeric: no Invariant: no

“Defines a collection of parts as a whole”

- Also called Collection-Member
- Parts can be removed
- No organization pattern but may have an implicit ordering
- Based on spatial, temporal or social connectivity
- Different from classification

Examples:

A tree is part of a forest

An employee is part of an union

A day is part of a montly planner

Member Parternship Aggregation

Configurational: no Homeomeric: no Invariant: yes

“Defines an invariant collection of parts as a whole”

- Member cannot be removed without destroying the partnership

Examples:

- Laurel is part of Laurel&Hardy

Non-Aggregation Forms

- Spatial inclusion: relation between a container , an area or a temporal duration and that which is contained

- Classification inclusion: Christine is a car

- Attribution: properties of an object (height, color)

- Attachement:
  - -Toes are attached to feet (part-of)
  - - Earings are attached to Ear but are not part-of Ear

in UML & OML

May consider to group:

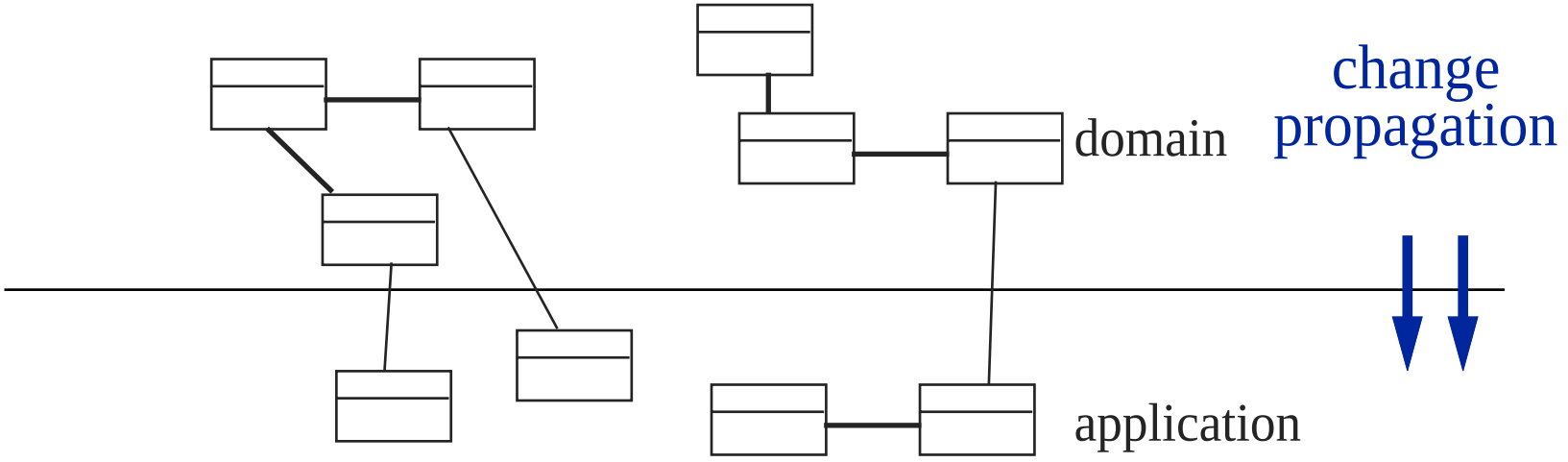
- configurational aggregations as aggregation
- non-configurational aggregations as membership

In UML no configurability issues

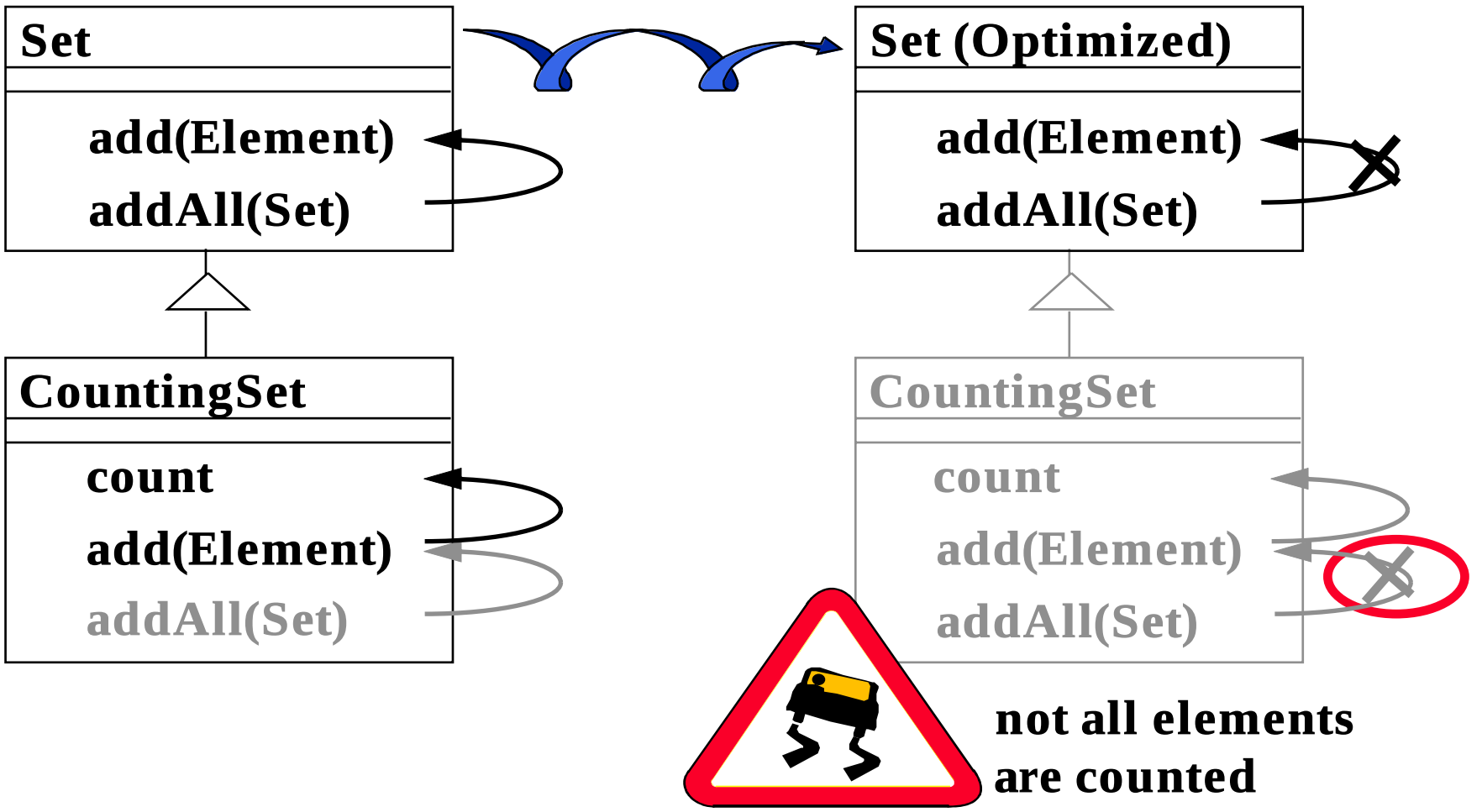
- sharable
- lifetime

Documenting for Evolution: Reuse Contract

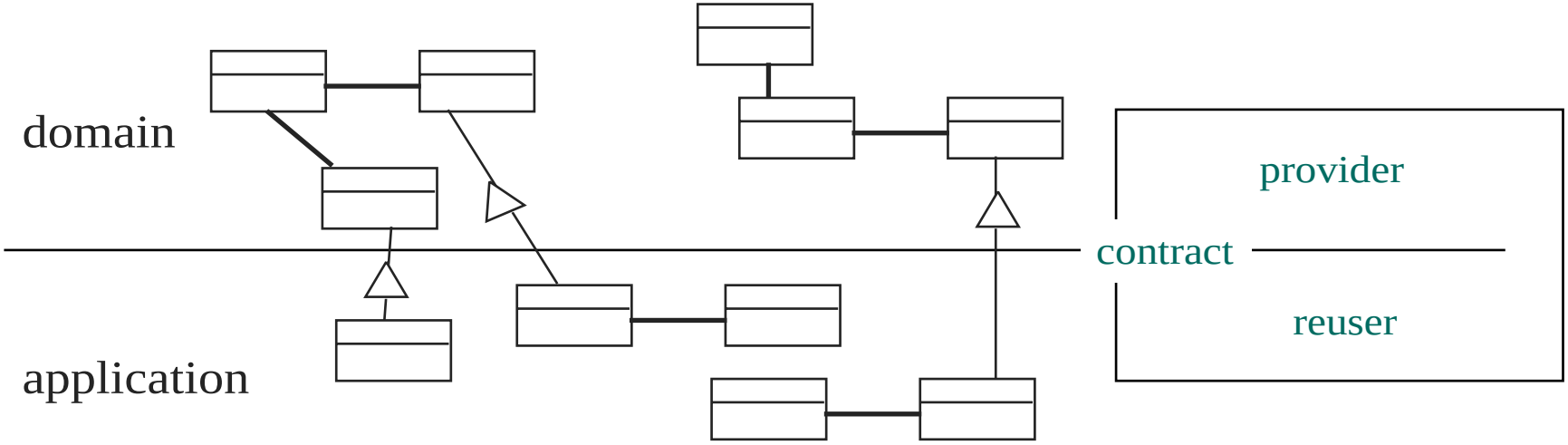
How to identify the impact of changes?



Example


Set
add(Element)
addAll(Set)
Set (Optimized)
add(Element)
addAll(Set)
CountingSet
count
add(Element)
addAll(Set)
CountingSet
count
add(Element)
addAll(Set)
not all elements
are counted

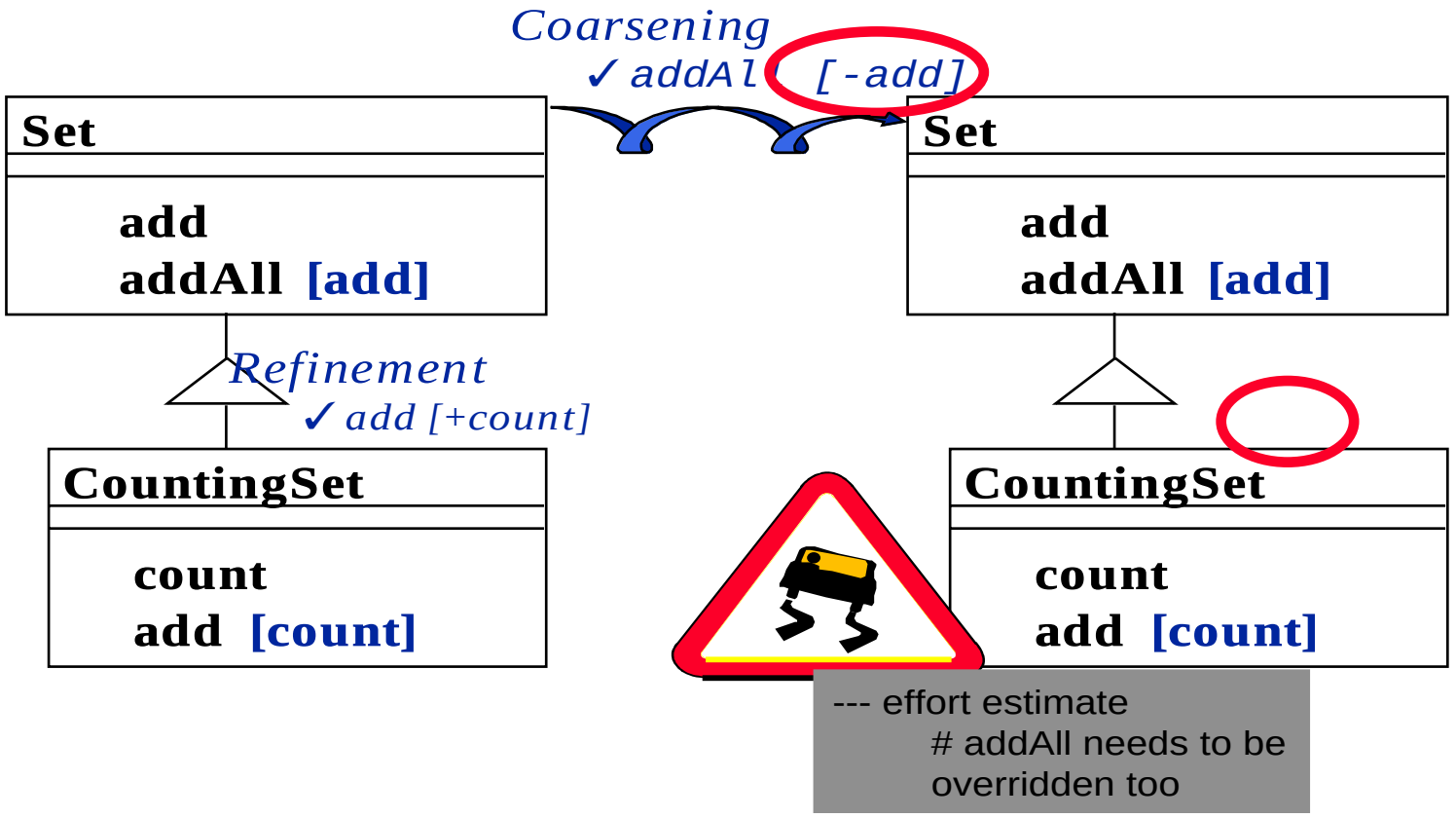
Reuse Contracts: General Idea



Propose a methodology to:

- specify and qualify extensions
- specify evolution
- detect conflicts
- Classification Browser support Reuse Contract extraction

Example



You can specify which other methods a method invokes (reuse contracts)

In class Set

+ addAll: (c Collection): Collection {invokes add}

Dynamic Behavior

You want to document a dynamic aspect of a system that static documentation is not able to show.

- Interaction Diagrams = Sequence Diagram or Collaboration Diagram

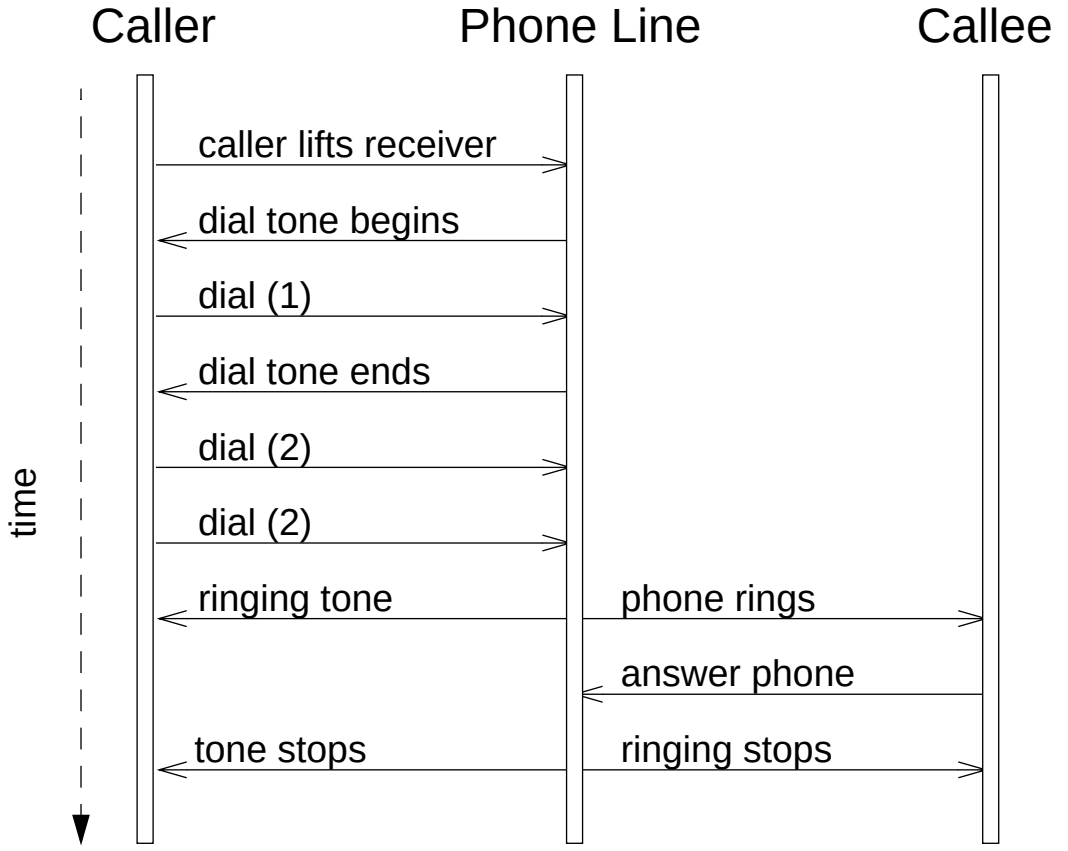
Sequence Diagrams

A *sequence diagram* depicts a scenario by showing the interactions among a set of objects in temporal order.

Objects (not classes!) are shown as vertical bars.

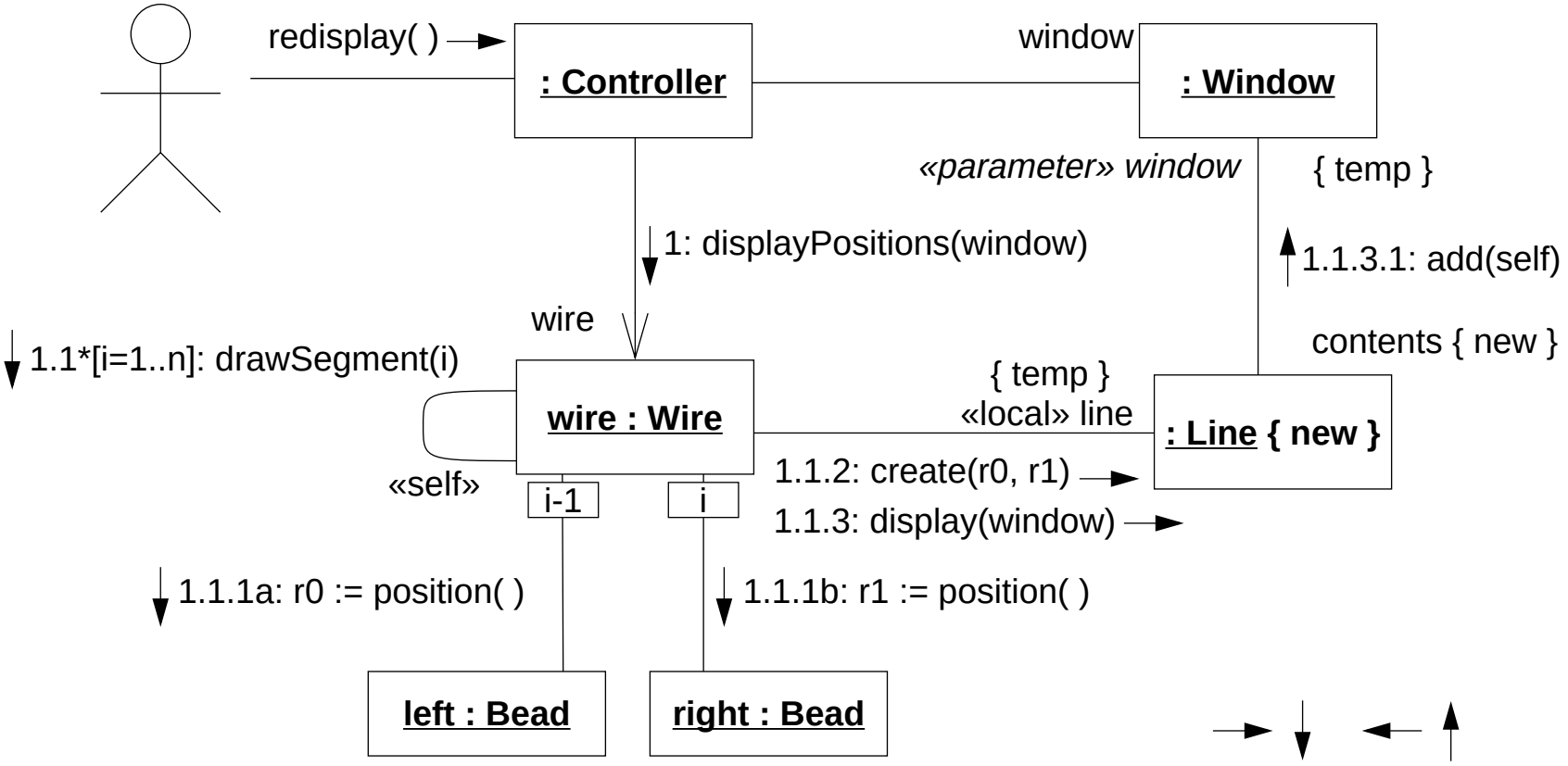
Events or message dispatches are shown as horizontal (or slanted) arrows from the send to the receiver.

Recall that a scenario describes a typical *example* of a use case, so conditionality is not expressed!



Collaboration Diagrams

Collaboration diagrams depict scenarios as flows of messages between objects:



Implications Under Considerations

But extracting runtime information needs

- reflective language support (MOP, message passing control)
- code instrumentation (heavy)
- storing retrieved information (may be huge)

Amount of generated data is HUGE

- selection of the parts of the system that should be extracted
- selection of the functionality
- selection of the use cases
- filters should be defined

(severals classes as the same, severals instance as the same...

UML as Support for Design Extraction

- Influenced by C++ private protected public
- Generalization and not inheritance
- Composition aggregation limited (see OML references)
- Do not support well reflexive models
- Fuzzy: Packages
- But UML is extensible, define your own stereotype
- You should be clear about:
  - home conventions like navigability
  - level of interpretations

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7. Code Duplication

Code Duplication

a.k.a. Software Cloning, Copy&Paste Programming, Code Scavenging

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What is Code Duplication?

Duplicated Code = Source code segments that are found indifferent places of a system.

- in different files
- in the same file but in different functions
- in the same function

The segments must contain some logic or structure that can be abstracted, i.e.

```
...
computeIt(a,b,c,d);
...
```

```
...
computeIt(w,x,y,z);
...
```

is not considered duplicated code.

```
...
getResult(hash(tail(a)));
...
```

```
...
getResult(hash(tail(z)));
...
```

could be abstracted to a new function

Copied artefacts range from expressions, to functions, data structures to entire subsystems.

Copying: *I do it, you do it, everybody does it!*

Reasons for Copy & Paste Programming

- **Time Pressure**

  There is no time to design and implement and test a component. And the problem has been solved before.

- **Lazyness**

  Making something reusable always takes some extra effort over making the code work for one particular case only.

  Rethinking an implementation if you suddenly see similarities between different parts of the implemementation, requires energy.

- **Efficiency Considerations**

  In time critical applications, a procedure call may seem to cost too much.

- **Maintaining Multiple Versions**

  Keeping the code for multiple versions in separate files may be preferable to working with a lot of `#ifdef`'s.

- **Programmer Productivity**

  If productivity is evaluated by looking at the number of lines of code written, there is incentive to produce new code rather than working on old code.

How Code Duplication happens

A possible scenario.

Context: Software Maintenance, enhancements of a legacy system.

12. A sub-component similar to an existing sub-component is defined.
13. New functionality requires substantial change on the exisiting component. Current uses of the existing component will be affected.
14. The analysis of the exisiting component will be lengthy and difficult. Significant regression testing will be required to ensure functioning in the old context.

Now add a little time pressure. This is when it happens!

15. A copy of the exisiting component is made. Systematic renaming is done to avoid naming conflicts. The component is tailored to its new use.
16. Code that is not understood and therefore cannot be deleted remains as *red herring* or even *dead code*.

Problems entailed by Code Duplication

General negative effect:

- Code bloat

Negative effects on Software Maintenance:

- Defects are found in a segment that has possibly been copied
  - find the clones of the code segment
  - assess the impact of the correction in each new context
- Errors in the systematic renaming
  - unintended aliasing
  - latent bugs that show up much later
- Red herrings and dead code
  - add to the cognitive load of future maintainers

Metaphorically speaking:

software aging, “hardening of the arteries”, “software entropy” increases

- small design changes become very difficult to effect

Justified Duplication

Advantages of code cloning:

- helps to meet short term goals
  - ☞ the code is already designed, implemented *and* debugged!
- necessary if programming language lacks an abstraction mechanism (e.g. no mechanism for generic programming in C).

Duplication that is less problematic:

- C++ templates (“glorified macros”)
- Inlining

  - ☞ duplication is hidden from the programmer and handled by the compiler

Code Duplication: Problem Statement

Code Duplication: a fact of life as a programmer/maintainer

Deal with it!

Locate the ‘enemy’

☞Code Duplication Detection

Other Reasons to Detect Duplicated Code

Program understanding: looking at a system through its structure of repetitive repetitive source code patterns, or programming idioms

Extraction of a library from a system: library functionality should be removed completely from the application

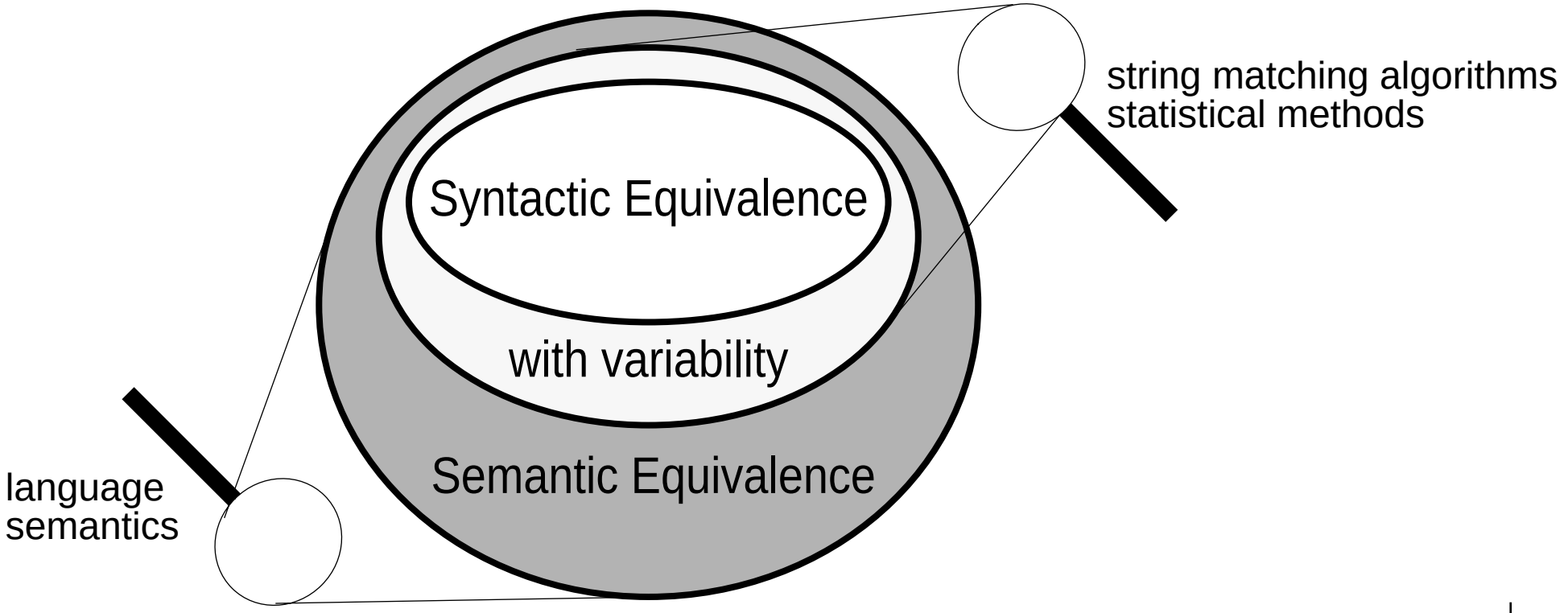
Understanding change: comparing different versions of the same program unveils the hot spots of change

Repairing Design flaws: In OOP, duplicated code may indicate design problems like missing use of inheritance

System partitioning: code cloning as a clustering criterion

Code Duplication Detection

What can be called a clone of a code segment?



Definition of a Clone

Refining the notion of what we are looking for.

For two code fragments C_1, and C_2, C_2 is a clone of C_1 if

1. C_1 and C_2 are syntactically identical (e.g. are found identical using the Unix utility `diff`).

2. C_1 and C_2 have the same structure but modified variable names or data types.

3. C_1 and C_2 have the same structure but modified statements or expressions.

4. one differs from the other on inserted, deleted or substituted statements and expressions (the bigger the set of insertions and deletions is, the less similar the two fragments are to each other).

The selection of the category of clones determines the algorithmic effort.

Exact Matches

Only simple algorithms needed to detect exact matches

- Multiple possibilitites for preprocessing:
  - remove white space, except for line separators (layout preserving)
  - remove white space including line separators
  - remove comments
  - replace identifiers with an identifier marker (requires lexical analysis)
- Generate the substrings that will be tested against each other
  - number and size of substrings determines size of possible matches and size of search space
- Match each substring against each other
  - hashing used to reduce the search space quickly in a first pass
  - sorting reduces $O(n^2)$ to $O(n*\log n + n)$
  - recursing over suffix trees reduces to $O(n+m)$

Parameterized Matches I

Assumption: Programmers copy code segments and systematically replace variable names to fit in the new context.

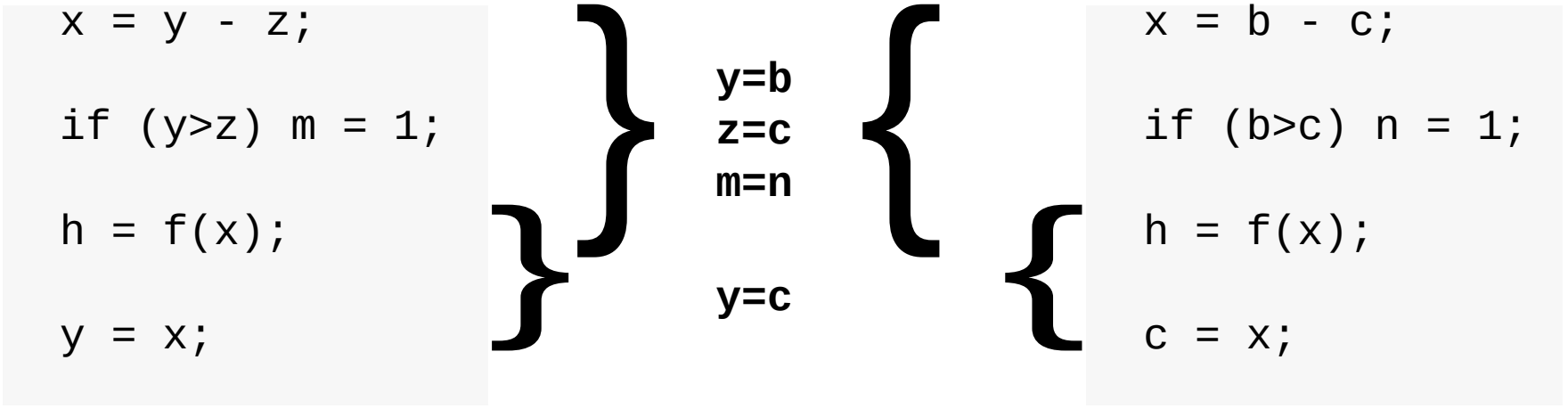
- Lexical analysis of the source Code.
  - token names that are a candidate for a parameter are changed into a `P`. `x = 3*y;` => `P = P * P;` .
- Search exact matches among the transformed lines
  - Substring size = 1 line (preservation of layout)

```
...
P = P - P;
if (P>P) P = 1;
P = f(P);
P = P;
...
```

```
...
P = P - P;
if (P>P) P = 1;
P = f(P);
P = P;
...
```

Parameterized Matches II

- Exact matches are examined further to find parameterized matches.
  - one-to-one correspondence between the parameters of the two code segments



Syntax Based Detection: Metrics

Creation of an Abstract Syntax Tree (AST)

Important Nodes of the AST (allows for matching at different levels of granularity):

- epressions
- statements
- blocks
- functions

Calculation of a number of data and control flow related metrics -> metrics signature for each of these nodes

Compute the Euclidean distance between the signatures.

Benefits: –fast

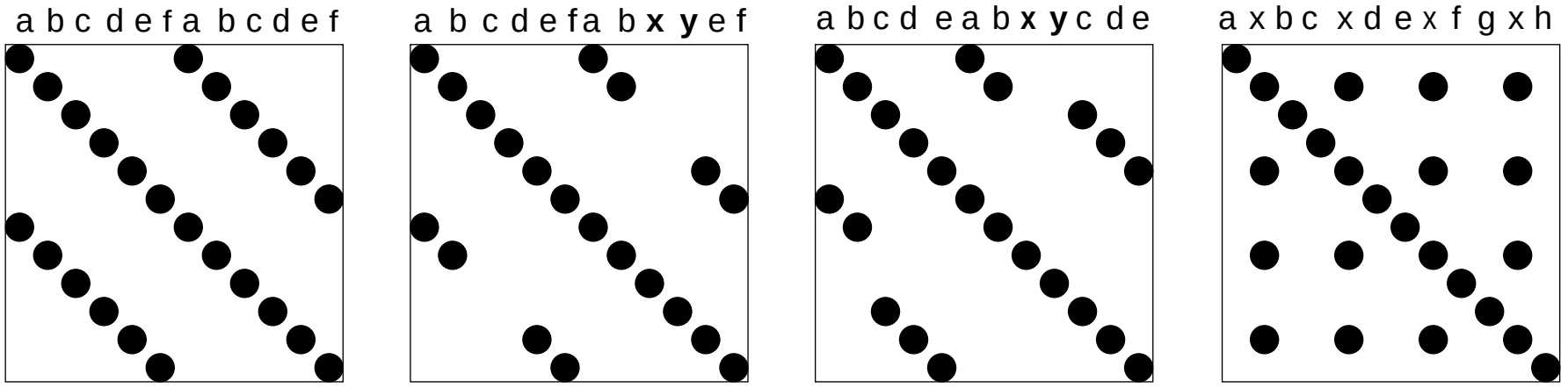
- allows for matching in the presence of arbitrary local changes in the code

Drawback: low precision

Visualization of Duplicated Code I

Technique from DNA Analysis: Scatterplots

Certain dot configurations can be interpreted right away:

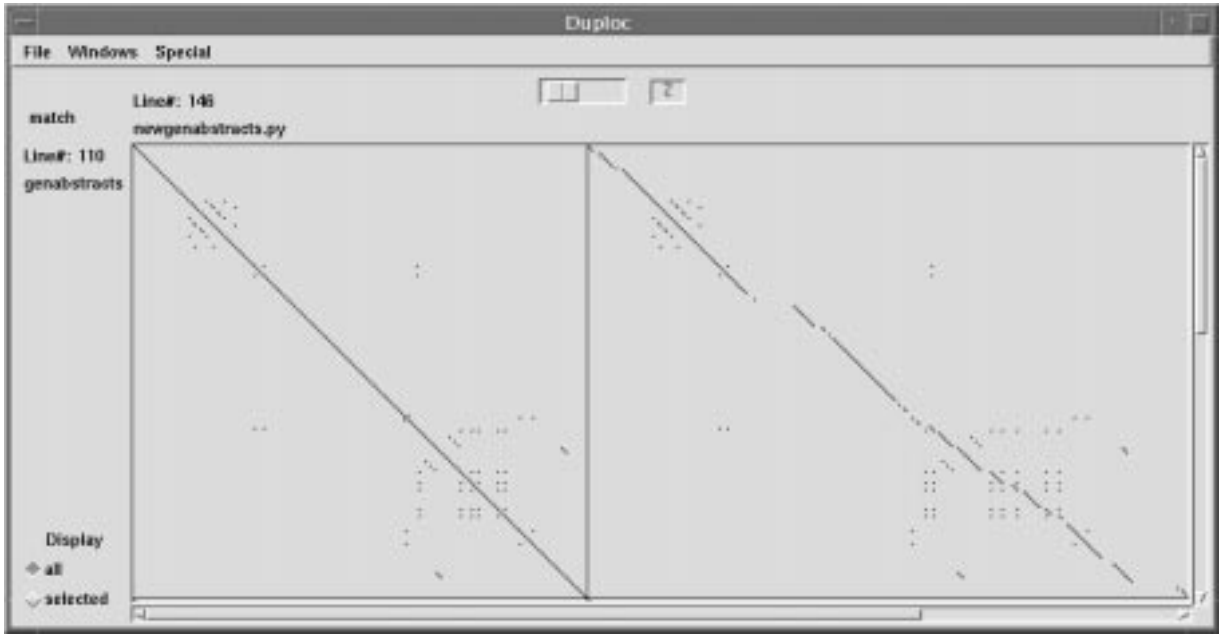


Diagonals | D. with Holes | Broken Diagonals | Rectangles

- intuitive insights into the duplication situation
- anomalies may be detected (be open for surprises)
- quick source code access

Visualization of Duplicated Code II

Example: Software Evolution, immediately graspable through the eye



On the left, the file compared with itself. On the right, the file compared to a newer version of itself.

Tradeoffs

Language Dependency:

- String Matching
- Lexical Analysis
- Parsing

Pattern space:

- we know what we are looking for
  - ☞ pattern matching approaches (grep) allow fine-tuning
- we do not know what weare looking for
  - ☞ the patterns to look for are derived from the search space

Refactoring Duplicated Code I

What can we do with found instances of duplication?

Redesigning is too much effort (and introduces too much new bugs).

Refactoring is Redesigning in the small.

When you refactor, you do not change the functionality of your program; rather you change its internal structure in order to make it easier to understand and work with.

Refactoring steps are usually very lightweight:

- renaming a method
- moving a field from on e class to another
- consolidating two similar methods into a superclass

> *Write every piece of logic once and only once (Kent Beck)*

Refactoring Duplicated Code II

- If you have a piece of duplication in methods of the same class
  - ☞ refactor code into a function or method
- If you have pieces of duplication in two sibling subclasses.
  - ☞ refactor code into a method and put it into the common superclass
- If the code in the subclasses is not the same but just similar, (e.g. the same algorithmic structure with some differences in the details)
  - ☞ consider applying the *Template Method Pattern* (Gamma et. al., 1995)
- If you have found duplicated code in unrelated classes
  - ☞ consider making the code into a component (function object) or think again, in which class the method really belongs.
- If you have found repetitive code
  - ☞ try to rewrite it using arrays and loops

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8. Refactorings

"Interface design and functional factoring constitute the key intellectual content of software and are far more difficult to create and re-create than code"

Peter Deutch

Beware of 'pet alligator' phenomenon !!!

"It's cute while it's small, but it keeps growing"

Anonymous

Outline

- Definitions
- Why?
- Low-Level Refactorings
- High-Level Refactorings
- Strategies for Refactoring
- Obstacles
- Bibliography

Some Definitions

- The process of redesigning the abstractions in a program
- A behavior-preserving source-to-source program transformation [Roberts&Brant98]
- The process of changing a software system in such a way that it does not alter the external behavior of the code, yet improves its internal structure [Fowler99]
- A change made to the internal structure of a software component to make it easier to understand and cheaper to modify, without changing the observable state of that software component [Fowler99]
- Refactoring = reorganization plan for a system to improve reuse

Why? The Lie and the Reality

”Build one to throw away” Fred Brooks

The lie:

- *First,* you gather requirements
- *Then*, you analyse them
- *Then*, you design the system
- *Then*, you code it
- *Then*, you test it
- *Then*, you are done

The reality:

- You will never get it right the first time
  - Can’t fully understand the problem domain
  - Can’t understand user requirements (when the user itself really knows)
  - Can’t understand how the system will evolve
- Result
  - Original design is inadequate
  - System becomes convoluted and brittle
  - Changes become more and more difficult

Why? The Obvious

Programs

- that are hard to read are hard to understand and to modify
- that have duplicated logic are hard to modify
- where additional behavior requires you to change running code are hard to modify
- with complex conditional logic are hard to modify

Good programmers refactor because:

Even if a good design comes first and the coding comes second.

☞ Over the time the code will get modified and the structure of the system according to the design gradually fades

Fit in Evolutionary Software Development

" Grow, don't build software" Fred Brooks

- Prototype
  - solidifies user requirements
  - sketch of system design
- Expansion
  - add functionality
  - determine hot-spots
- Consolidation
  - correct design defects
  - introduce new abstractions

Cultural Issues

- Clean *first*
- *Then* add new functionality

- Performance issue

  - Refactoring may slow down the execution
  - The secret to write fast software:

  Write tunable software first then tune it

  Normally only 10% of your system consumes 90% of the resources so just focus on 10 %.

  - ☞ Refactorings help to localize the part that need change
  - ☞ Refactoring help to concentrate the optimizations

Obstacles to Refactorings

- Complexity
  - Understanding the design is hard
  - Changing the design of an existing system is hard
  - Errors can be introduced
- Schedules and Culture
  - Every software product is under time pressure
    (refactoring pahse should occur after delivery)
  - Get paid to add new features
  - If it doesn't break, doesn't fix it
  - Refactoring can take time
  - Producing negative lines of code is out of our culture
- Databases Mapping
- Changing Interfaces

What Refactorings Are Good For?

- Help you to develop software more quickly
- Improve the structure of existing code
- Enable sharing of logic
- Isolate change
- Reduce the code size
- Eliminate duplicated code
- Make your code more readable (Reveal intention)
- Help you to understand unfamiliar code
- Enhance code to support new requirementsRefactorings

Refactorings are

- Behavior-preserving (observable behavior does not changed)
- Some are semantics-preserving i.e. we can garantee that there is no change
  Example: renaming an instance variable
- Have precondition to ensure their semantics preserving behavior

Renaming Methods

Renaming Methods Help You to Understand Code

Example

```
setType: aVal
    "compute and store the variable type"
    self addTypeList: (ArrayType with: aVal).
    currentType :=  (currentType computeTypes: (ArrayType with: aVal))
```

Give to the reader a good idea of the functionality and not about the implementation

```
computeAndStoreType: aVal
    "compute and store the variable type"
    self addTypeList: (ArrayType with: aVal).
    currentType :=  (currentType computeTypes: (ArrayType with: aVal))
```

The code that uses the method will gain in readibility!!

Examples of Refactoring Scripts

- Creating a new empty class
  pred: a class with the same name does already exist
  refact: create a class

- Renaming all methods with a given name:
  pred: no method locally exists with the same name

5. Check if a method does not exist in the class and superclass/subclasses with the same “name”
6. Browse all the implementers
7. Browse all the senders
8. Edit and rename all implementers
9. Edit and rename all senders
10. Remove all implementers
11. Test

Some Refactorings

Create Empty Class
Add Instance Variable
Add Method
Delete Class
Delete Instance Variable
Delete Methods
Rename Class
Rename Instance Variable
Rename Method
Convert Variable Reference to Message
Extract Code as Method
Inline Method
Change Superclass
Move Instance Variable into Component
Move Method into Component

Add Method Argument
Delete Method Argument
Reorder Method Argument
Pull Up Instance Variable
Pull Up Method
Push Down Instance Variable
Push Down Method

Low-Level (i): Adding/Deleting

- Creating a program entity

  - create empty class: define a new class with no instance variables, nor methods

  - create instance variable: add an unreferenced instance variable to a class

  - create method: add a method to a class that either is unreferenced or is identical to an already inherited method

- Deleting a program entity

  - delete unreferenced class

  - delete unreferenced instance variable

  - delete methods: delete a set of methods; either each method is redundant, or the only references to it are by other methods that are also being deleted

Low-Level (ii): Changing a Program Entity

- change class name (the precondition ensures distinct class names)
- change variable name

  variable name should not already exist in superclasses/subclasses
- change method name: change the name of a method and any corresponding methods defined in subclasses, and any corresponding message sends
- change type (C++): change the type of a set of (pointer) variables and functions (i.e. change the types of the variables and return types of the functions)
- change access control mode: (e.g. ‘private’, ‘protected’, ‘public’)

Low-Level (iii): Renaming

- add method argument: to the definition of a method in its class (and subclasses that override it). In each method invocation, add an argument which is a dynamically created instance
- delete method argument: from the definition of a method in its class (and subclasses that override it). In each method invocation, the argument is removed
- reorder method arguments: in a method definition in its class (and subclasses that override it) and in all invocations of that method
- add method body: an existing method (signature)
- delete method body: from an existing method (making it a signature only)

Low-Level (iv): Moving

Moving an instance variable

- pull up instance variable to superclass:
  from all subclasses where it is defined
- push down instance variable to subclasses:
  from its current containing class to each of its immediate subclasses

Composite refactorings

- abstract access to instance variable:
  by defining accessor and mutator methods, and replacing all variable references with invocations of these methods
- Extract method
  define a new method, with a unique name, whose body is equivalent to a segment of an existing method. Replace that segment in the method with an invocation of the new method
- move class
  change the superclass of a class

Strategies for Refactoring

Top Ten of Code Bad Smells

"Let the code tell you where to refactor" and "If it stinks, changes it" [Kent Beck]
http://c2.com/cgi/wiki?CodeSmells

- Duplicated Code
- Long Method
- Large Class
- Long Parameter List
- Case Statement
- Divergent Change
- Shotgun Surgery
- Feature Envy
- Co-occuring Parameters
- Parallel Inheritance Hierarchies
- Lazy Class
- Similar Subclasses
- Temporary Field

Duplicated Code

"Say everything exactly once" Kent Beck

Makes the system harder to understand and to maintain

- In the same class
  - ☞ Extract Method
- Between two sibling subclasses
  - ☞ Extract Method + Push identical methods up to common superclass + Form Template Method
- Between unrelated class
  - ☞ Create common superclass
  - ☞ Move to Component
  - ☞ Extract Component (e.g. Strategy)

Long methods

- A method is the smallest unit of overriding
  - Extract pieces as smaller method
  - Comments are good delimiters
- Method body should be at the same level of abstraction: Template Method
- Except for crazy code (e.g. 600 lines to 5000 lines of code) metrics will not really help!
- Lot of temporary variables
  - Replace Method With Method Object (A method is really complex and can be an object)
- Long list of parameters
  - Introduce Parameter Object
  - Replace parameter with Method (send a message to an object you know instead of using a parameter)

Large class

- Find logical sub-components (set of working methods/instance variables)
  - Move methods and instance variables into components
  - Extract component
- If not using all the instance variables
  - Extract Subclass
- Except for crazy code, metrics will not really help!
- For crazy method with lot of temporary
  - Replace Method with Object Method

Nested Conditionals

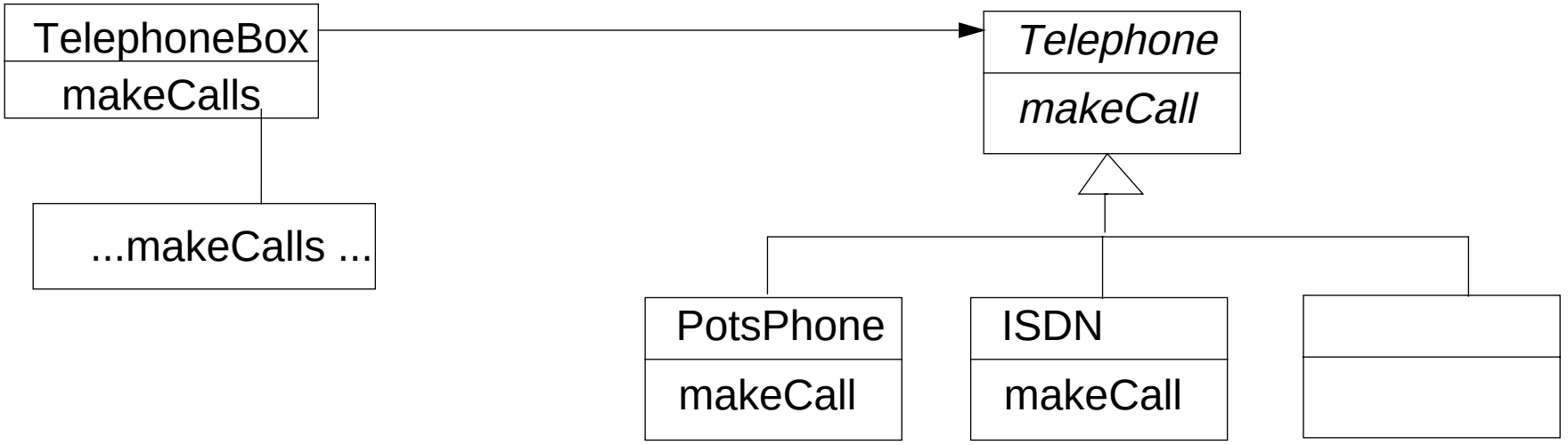
New cases should ideally not require changing existing code

- Use dynamic dispatch
- May apply the State / Strategy pattern

```
void makeCalls (Telephone * phineArray[])
   {
   for (Telephone *p = phoneArray;p;p++{
      switch (p->phoneType()){
      case TELEPHONE::POTS{
      POTSPhone * potsp = (POTSPhone *) p;
      potsp->tourneManivelle();
      potsp->call(); break}
      case TELEPHONE::ISDN
      ISDNPhone * isdnp = (ISDN*) p;
      isdnp->initializeLIne ().....
      ...
      }
   }
```

Define classes if not created + Define abstract method in superclass + Define makeCall methods + Extract Methods

Nested Conditionals (ii)

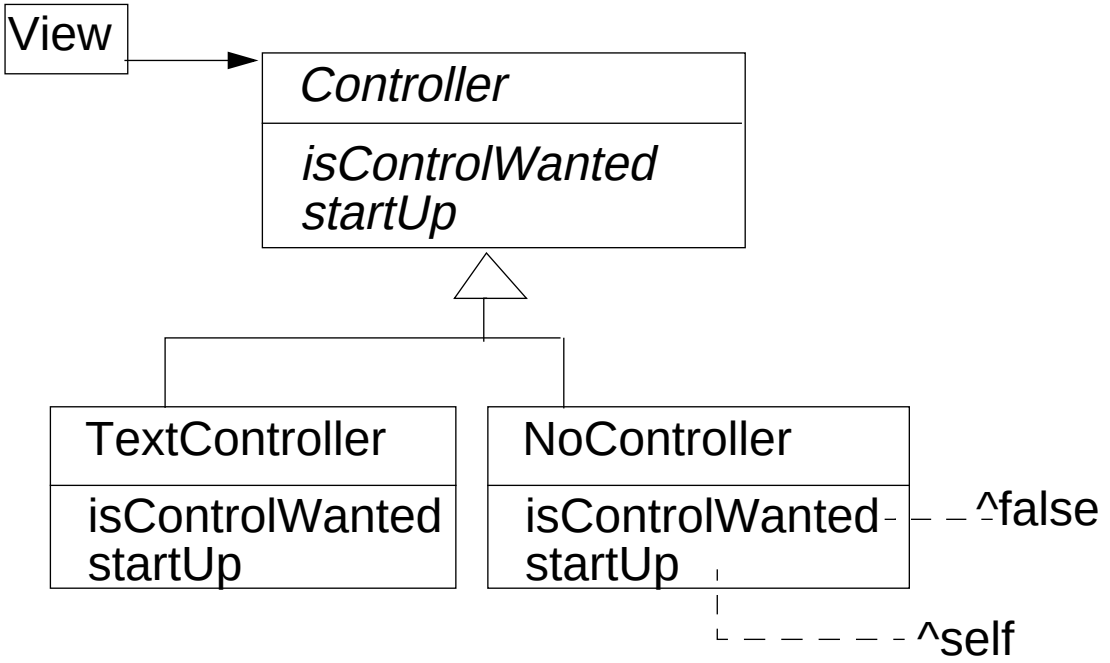


Nested Conditionals

- For default value testing
  - consider the Null Object Pattern

```
VisualPart>>objectWaintingControl
    ...
    ^ ctrl isNil ifFalse:
          [ctrl isControlWanted
             ifTrue: [self]
             ifFalse: [nil]]

VisualPart>>objectWantingControl
    ...
    ^ctrl isControlWanted
             ifTrue: [self]
             ifFalse: [nil]]
```



Others

Co-occuring parameters (also called Data Clumps)

- Create missing abstraction (x y -> point)
- Pass it around
- Find methods that should be on the new object

Divergent Change

- If you have to change always the same methods when introducing new objects (database, financial instrument)
  - ☞ Extract Component

Shotgun Surgery

- Lot of little changes to a lot of different classes
  - ☞ Move Method, Move Instance Variable -> into a single class
  - ☞ Create a new class if needed

Feature Envy

- Functionality not define in the right class (e.g. a method calling a lot of getter from another object)
  - ☞ Extract Method, Move Method to the class that has most of the data

Summary

- Refactorings fit in real development process
  - Clean the code then add new functionality
  - Write negative lines of code if needed!
- Refactorings help you
  - to write code that lives
  - to build reliable software
  - to write code that communicates their intent
- If you develop real software in Smalltalk, try the refactoring browser to make your own opinion

Tool Support and Bibliography

- In Smalltalk use the Refactoring Browser

http://st-www.cs.uiuc.edu/~brant/Refactory/RefactoringBrowser.html

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9. Refactoring Tools

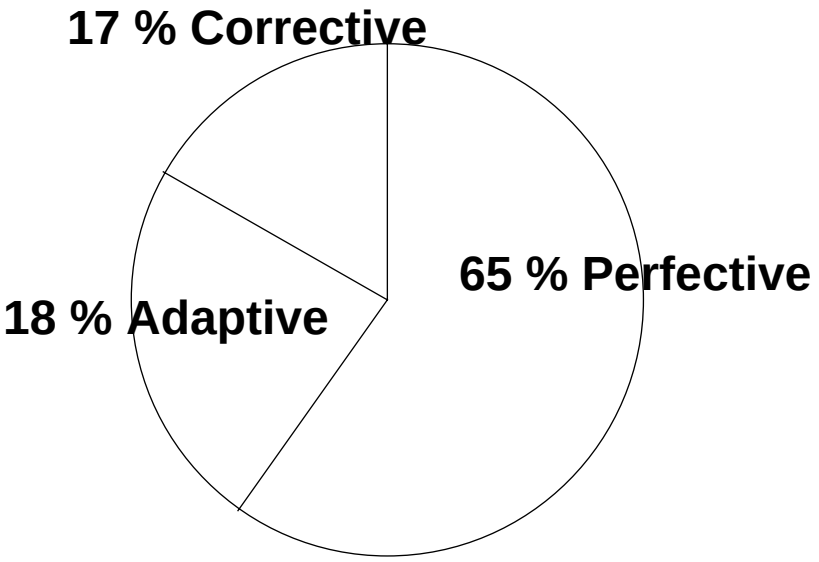
Outline

- Why Refactoring Tools?
- Iterative Development Life-cycle
- Which Refactoring Tools?
- Case-study: Internet Banking
  - prototype
  - consolidation: design review
  - expansion: concurrency
  - consolidation: more reuse
- Conclusion

Why Refactoring Tools?

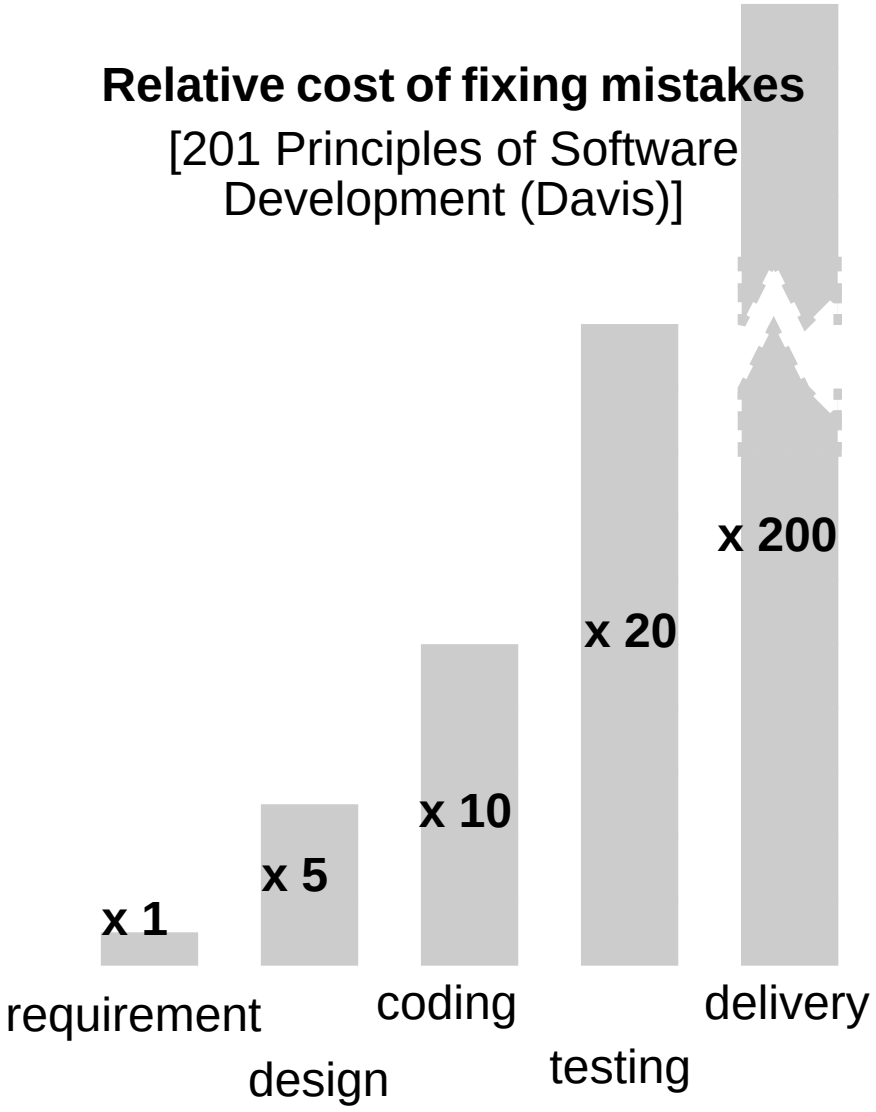
Relative Effort of Maintenance

[Software Engineering (Sommerville)]

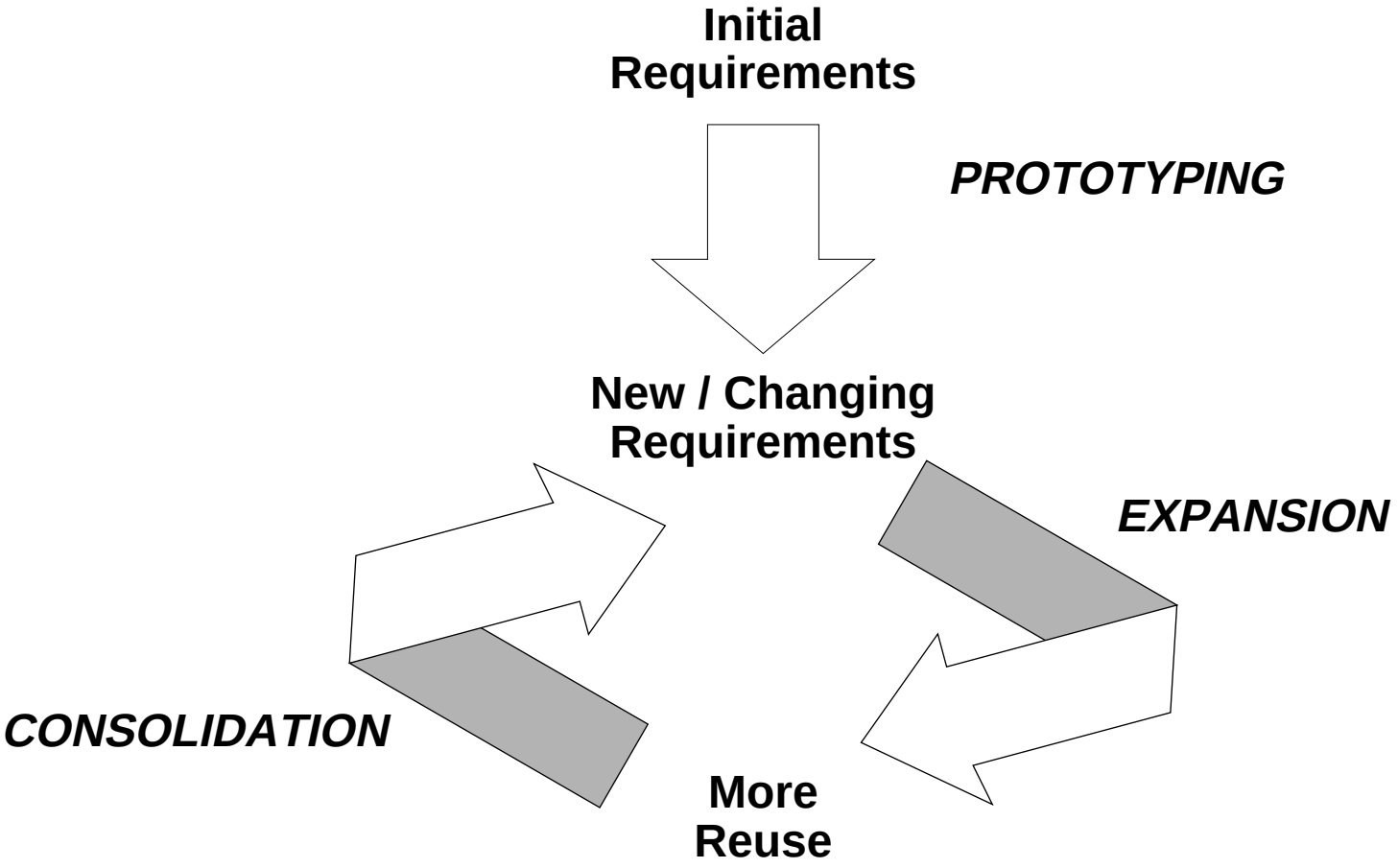


Relative cost of fixing mistakes

[201 Principles of Software Development (Davis)]



Iterative Development Life-cycle



Which Refactoring Tools?

Change Efficient *Failure Proof*

Refactoring

- Source-to-source program transformation
- Behaviour preserving

=> ameliorate the program structure

Regression Testing

- Repeating past tests.
- Tests require no user interaction.
- Tests are deterministic.
- Answer per test is yes / no

=> verify if ameliorated structure does not screw up previous work

Programming Environment

- Fast edit-compile-run cycles
- Support small-scale reverse engineering activities

=> convenient for “local” amiliorations

Configuration & Version Management

- keep track of versions that represent project milestones

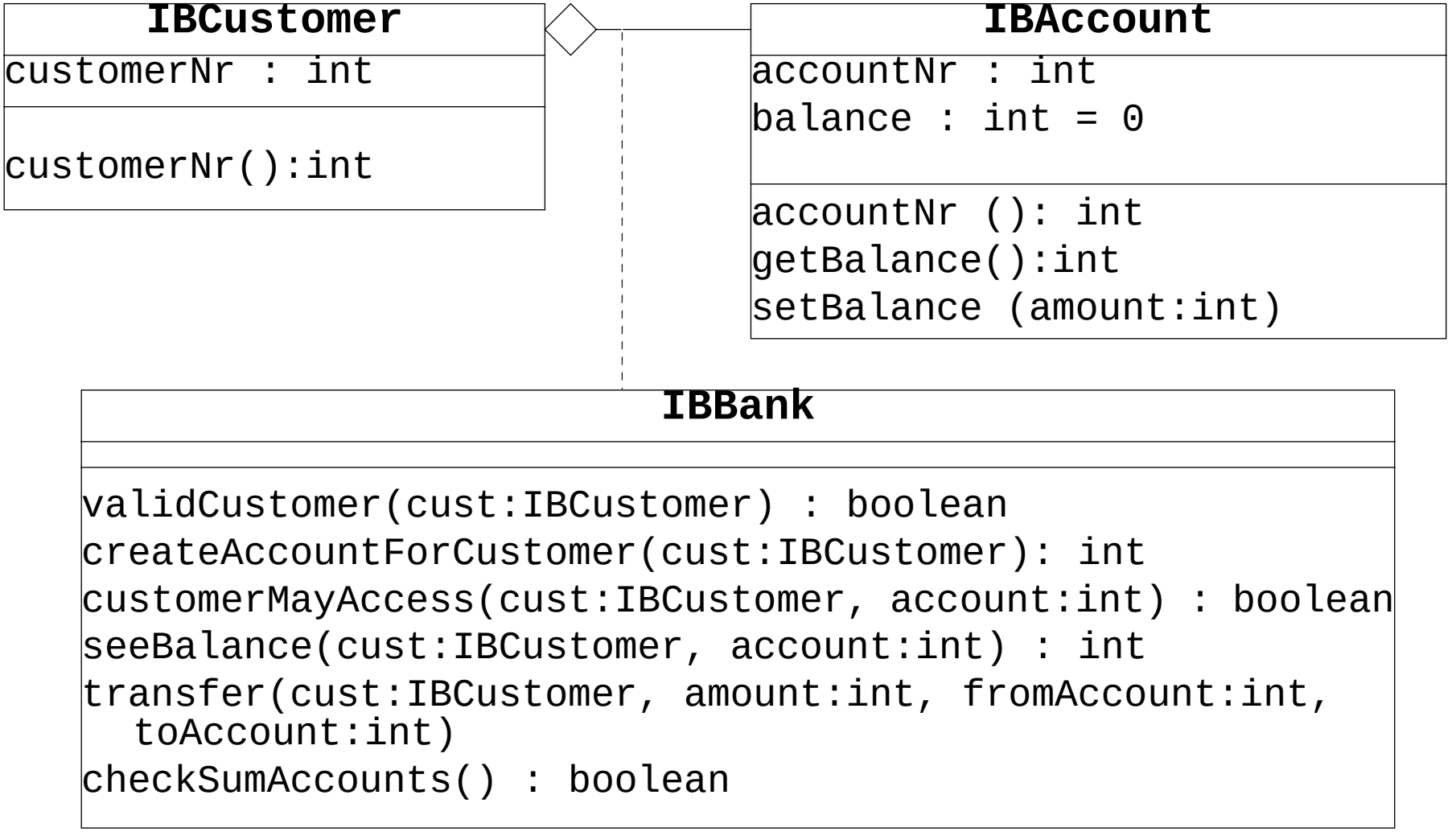
=> possibility to go back to previous version

Internet Banking: Initial Requirements

- a bank has customers
- customers own account(s) within a bank
- with the accounts they own, customers may
  - deposit / withdraw money
  - transfer money
  - see the balance

- *secure:* only authorised users may access an account
- *reliable:* all transactions must maintain consistent state

Prototype Design: Class Diagram



Prototype Design: Contracts

Ensure the "*secure*" and "*reliable*" requirements.

```
createAccountForCustomer(cust:IBCustomer): int
        require: validCustomer(cust)
        ensure: customerMayAccess(cust, <<result>>)

seeBalance(cust:IBCustomer, account:int) : int
        require: (validCustomer(cust)) AND
                (customerMayAccess(cust, account))
        ensure: checkSumAccounts()

transfer(cust:IBCustomer, amount:int, fromAccount:int,
   toAccount:int)
        require: (validCustomer(cust))
                AND (customerMayAccess(cust, fromAccount))
                AND (customerMayAccess(cust, toAccount))
        ensure: checkSumAccounts()
```

Prototype Implementation

=> see demo “IBanking1”

Include test cases for

- IBCustomer
  - customerNr()
- IBAccount
  - getBalance()
  - setBalance() [#Demo of rapid edit/compile/run#]
- IBBank
  - createAccountForCustomer() (initBank)
  - transfer() / seeBalance() (single transfer)
  - transfer() / seeBalance() (multiple transfers)

Prototype Consolidation

Design Review (i.e., apply refactorings AND RUN THE TESTS!)

- Rename attribute
  - manually rename “balance” into “amountOfMoney” (run test!)
  - apply “rename attribute” refactoring to reverse the above
    + run test!
    + check the effect on source code
- Rename class
  - check all references to “IBCustomer”
  - apply “rename class” refactoring to reverse the above
    + run test!
    + check the effect on source code
- Rename method
  - rename “init()” into “initialize()” (run test!)
  - see what happens if we rename “initialize()” into “init))
  - change order of arguments for “transfer” (run test!)

Expansion

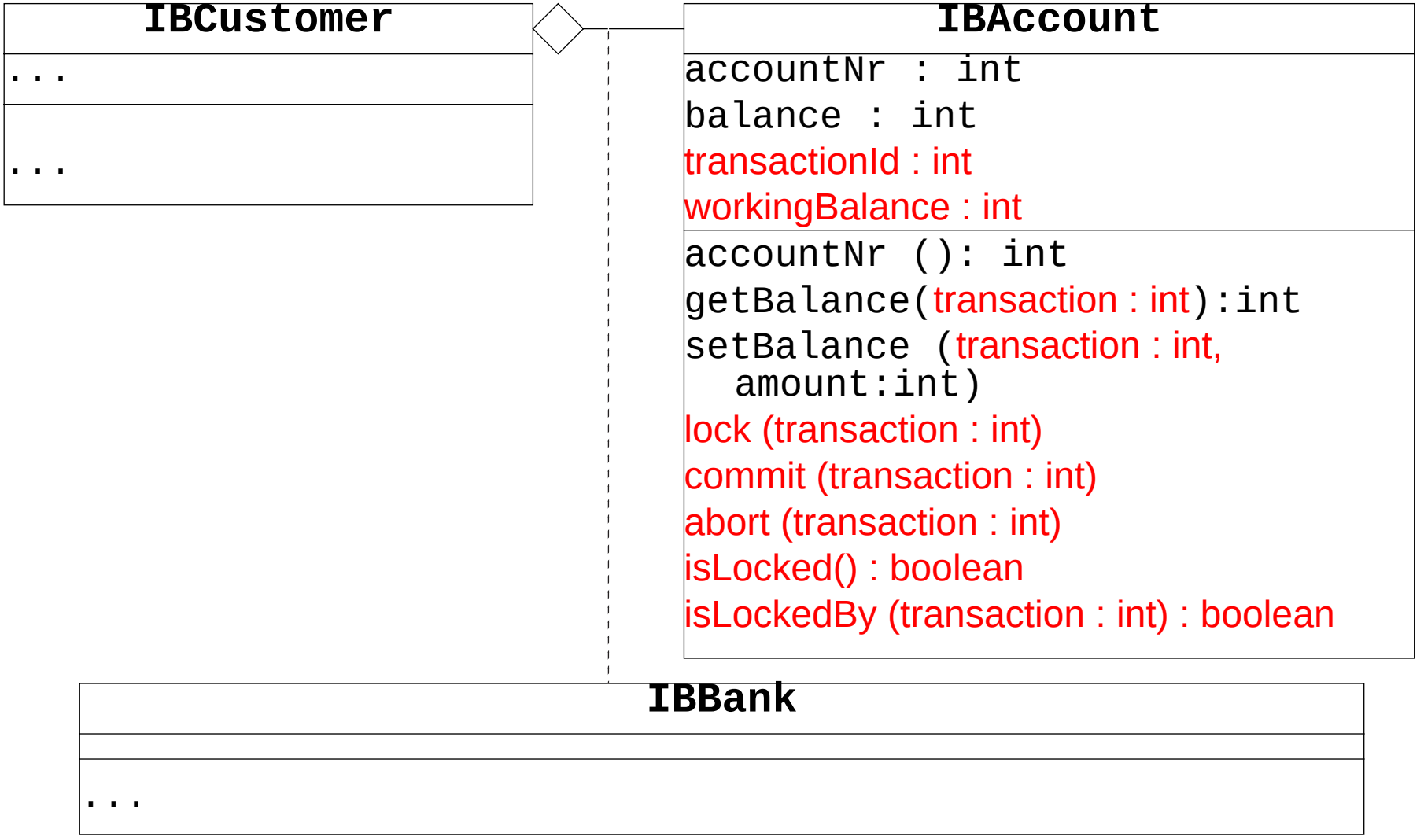
Additional Requirement

- *concurrency*: concurrent access of customers

Add test case for

- IBBank
  - testConcurrent: Launches 2 processes that simultaneously transfer money between same accounts
    => test fails!

Expanded Design: Class Diagram



Expanded Design: Contracts

```
getBalance(transaction:int): int
        require: isLockedBy(transaction)
        ensure:
setBalance(transaction:int, amount: int)
        require: isLockedBy(transaction)
        ensure: getBalance(transaction) = amount
lock(transaction:int)
        require:
        ensure: isLockedBy(transaction)
commit(transaction:int)
        require: isLockedBy(transaction)
        ensure: NOT isLocked()
abort(transaction:int)
        require: isLockedBy(transaction)
        ensure: NOT isLocked()
```

Expanded Implementation

Adapt implementation

- apply “add attribute” on IBAccount with “transactionId” and “workingBalance”
- apply “add parameter” to “getBalance()” and “setBalance()” with “transaction”
- apply “add class” to create “IBTransactionManager”
- use normal editing to expand functionality of “seeBalance()” and “transfer()”
  => load “IBanking2”

Expand Tests

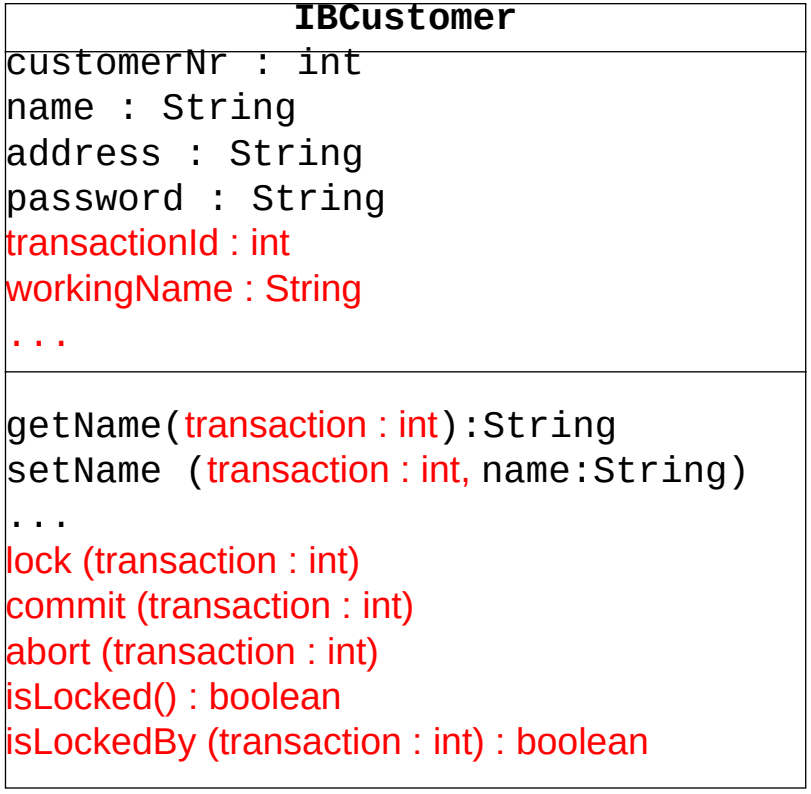
- previous tests for “getBalance()” and “setBalance()” should now fail
- new tests for the transaction contracts, incl. commit and abort
- testConcurrent works!
  => we can confidently ship a new release

Consolidation: More Reuse (Problem Detection)

More Reuse

Assume the following scenario

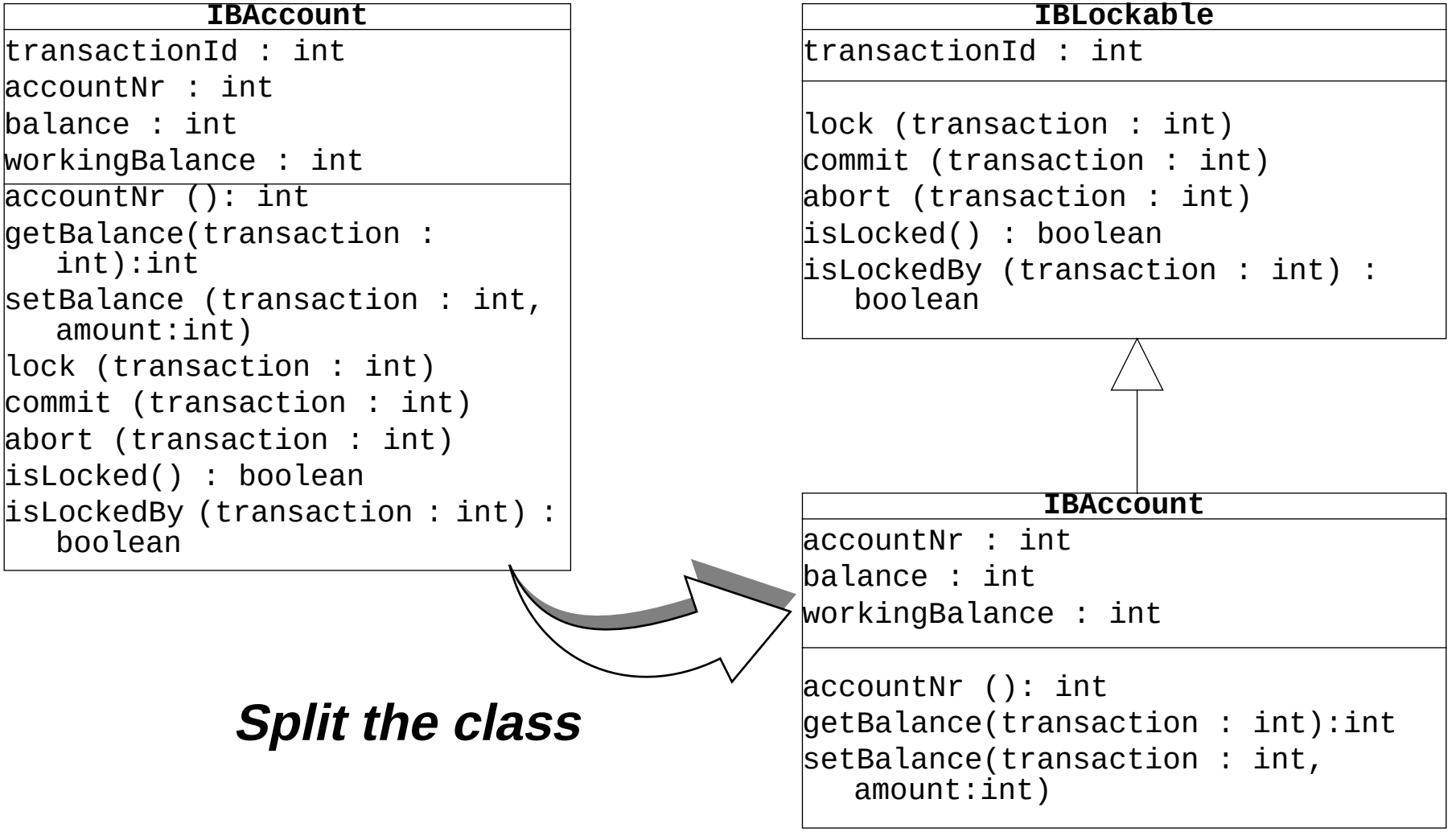
- Other people applied a similar transaction interface to customer (change of name, address, password, ...)
- A design review reveals that this “transaction” stuff is a good idea and should become a separate component



Code Smells

- duplicated code (lock, commit, abort + transactionId)
- large classes (extra methods, extra attributes)

Consolidation: More Reuse (Refactored Class Diagram)



Consolidation: More Reuse (Refactoring Sequence)

- apply “create subclass” to create “IBLockable” with “IBAccount” as subclass
- apply “abstract attribute” to “transactionId” [#check source code#]
- apply “pull up attribute” to move “transactionId” up
- apply “push up” to move accessor methods on transactionId up
- apply “push up” to “isLocked”, “isLockedBy”, “notLocked”
- apply “push up” to “abort:”, “commit:”, “lock:”
  - fails; accesses local attributes
  - apply “extract method” on groups of accesses to local attributes (Do you want to extract assignment ? -> Yes)
  - apply “push up” to “abort:”, “commit:”, “lock:”
  - define the extracted methods as new abstract methods in the hierarchy (this is done via normal editing; not semantic preserving !)
- apply “inline all self sends” on accessor methods on transactionId up
- check references to “transactionId” to check if all of them are local

Conclusion (1/2)

Do not apply refactoring tools in isolation

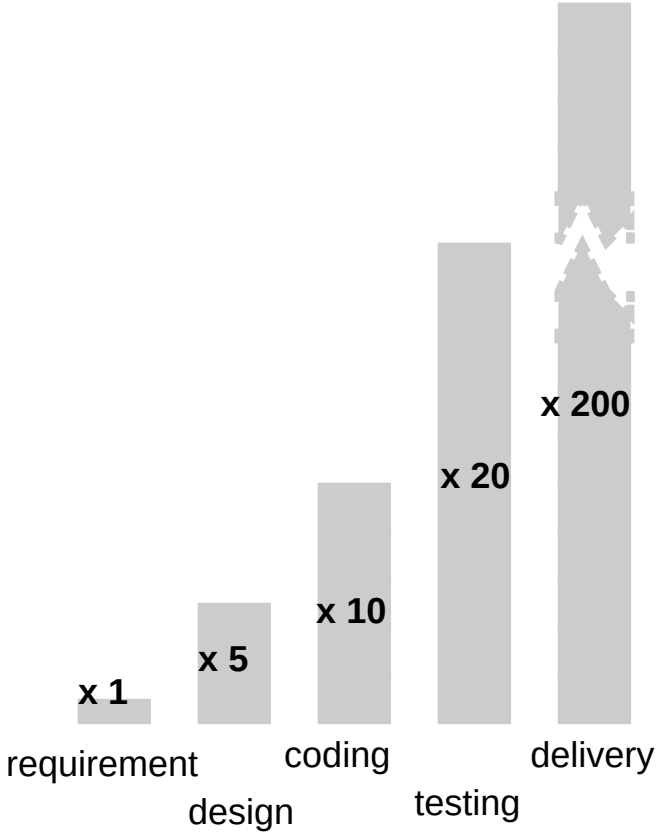
Combine with ...

	Smalltalk	*C++*	*Java*
❑ refactoring tools	+	- (?)	...
❑ rapid edit-compile-run cycles	+	-	+-
❑ reverse engineering facilitie	+-	+-	+-
❑ regression testing !!	+	+	+
❑ version & configuration management	+	+	+

Know when is as important as know-how

- ❑ Refactored designs are more complex
- ❑ Use “code smells” as symptoms
- ❑ Rule of the thumb: State everything exactly once (Kent Beck)
  => things stated more than once implies refactoring

Conclusion (2/2)

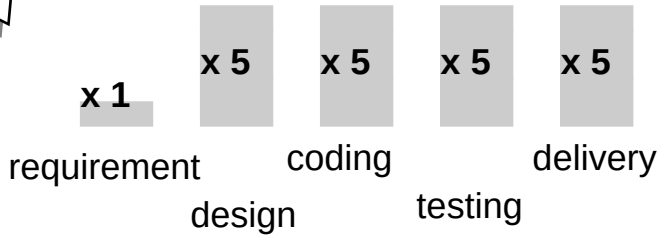


With proper

- *tool support*
- *culture chock*
- *management support*

one can reduce the costs between the different phases in the development cycles.

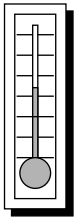
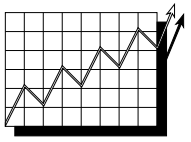
The tools are there ...



10. Metrics in OO Reengineering

Outline

- Why Metrics in OO Reengineering?
- Which Metrics to Collect?
  - Goal-Question-Metric paradigm
  - Metric Definitions
- Case studies
- Applicability for...
  - Problem Detection
  - Stability Assessment
  - Reverse Engineering
- Conclusion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Why Metrics in OO Reengineering?

OO Reengineering = Iterative Development

Cost Estimation

- What's the effect of reuse?
- Is it worthwhile to reengineer, or is it better to start from scratch?

=> See lecture 3, "Metrics in Industry"

Software Quality Evaluation

- Which parts have bad quality? (Hence, should be reengineered first)
- Which parts have good quality?

=> Metrics as a project management tool!

Iterative Development

- Can I use metrics to measure changes?
- Can I use change metrics to reverse engineer design?

=> Metrics as a reengineering tool!

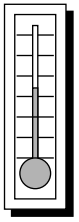
Which Metrics to Collect (GQM)?

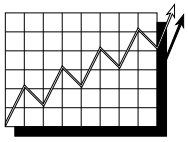
Goal

- Support reverse and reengineering of object-oriented programs in an iterative development context.

Question

1. Which parts of the design will cause problems with future extensions?
2. Which parts of the design are unstable?
3. Which parts of the design have been refactored?





Metric

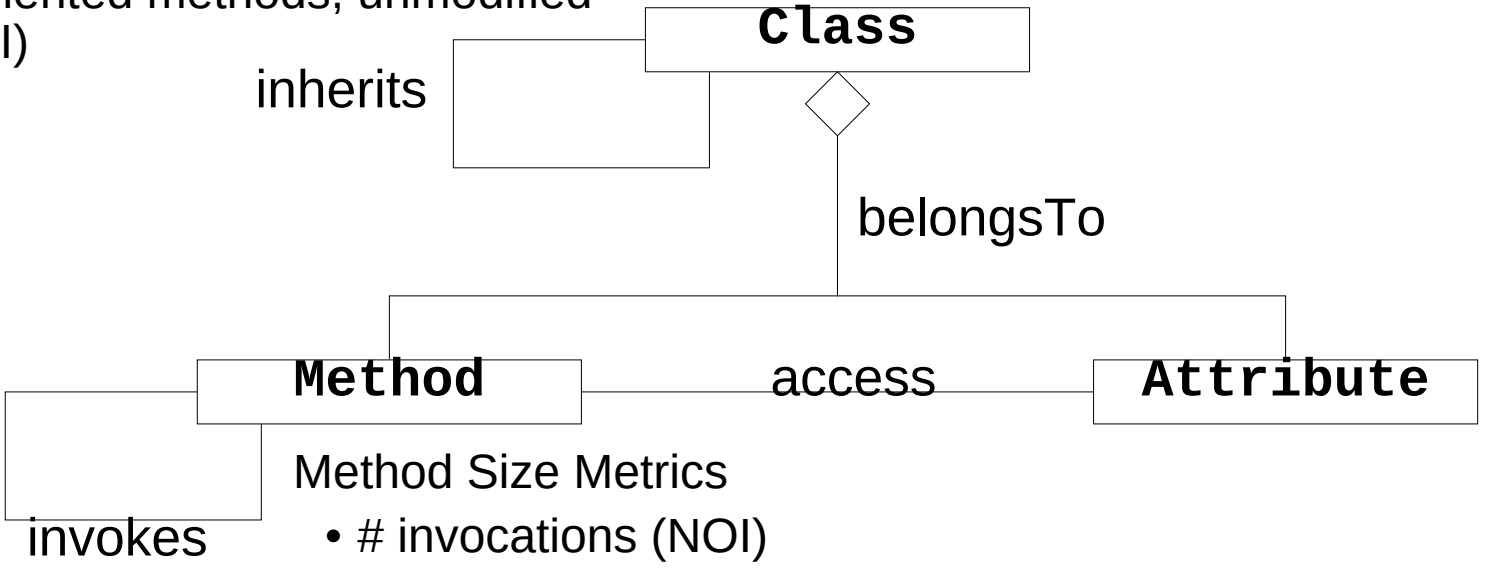
- Low overhead for developer
- Take advantage of OO structure
- Exploit existence of different releases

  => Collect from source code

Which Metrics to Collect (Definitions)?

Class Size Metrics
- # methods (NOM)
- # instance attributes (NIA)
- # class attributes (NCA)
- Σ of method size (WMC)

Inheritance Metrics
- hierarchy nesting level (HNL)
- # immediate children (NOC)
- # inherited methods, unmodified (NMI)



Method Size Metrics
- # invocations (NOI)
- # statements (NOS)
- # Lines of Code (LOC)

Case Studies

Requirements

- *Representative* for iterative OO development.
  => acceptance of results
- Development occurred *independent*.
  => experiments did not influence results
- Source code is publicly *accessible*.
  => reproducing results
- Functionality changes are *documented*.
  => validating experimental findings

Case Studies

- VisualWorks (4 releases)
- HotDraw (3 releases)
- Refactoring Browser (2 releases)

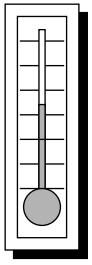
Problem Detection: Experiment

Question:

- Can metrics predict which parts of the design will cause trouble in future extensions?

Release n

{∀ Metric m, Component c_n | $m(c_n) > threshold$}



Release n+1

1. c_{n+1} deleted
2. $m(c_{n+1}) <= threshold$
3. $m(c_{n+1})$ $m(c_n)$
4. $m(c_{n+1}) > m(c_n)$

Cases 1 & 2 confirm the prediction capabilities of metric m

Cases 3 & 4 disprove the prediction capabilities of metric m

Problem Detection: Results

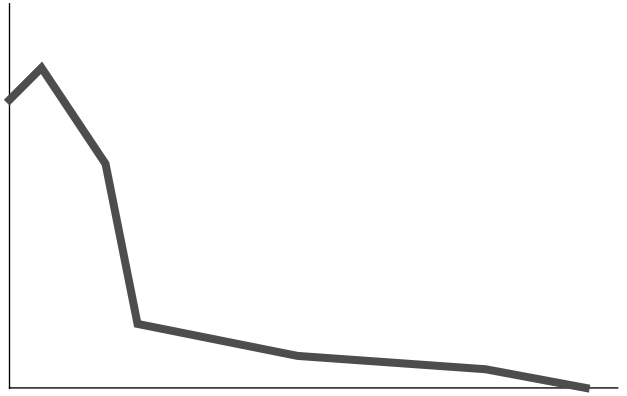
- between 2/3 and 1/2 of detected problems are left unchanged in subsequent release
- considerable amount of detected problems measure worse in subsequent release

=> unreliable as problem detection tool

- some metrics perform better than others (WMC-NOI, WMC-NOS)?

=> expensive parsing

- 80%-20% distribution as a litmus test



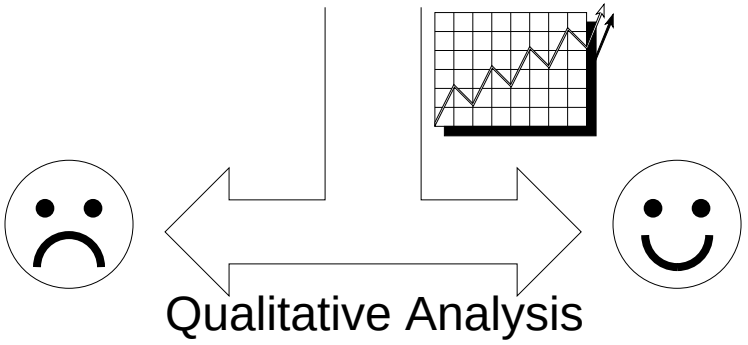
Stability Assessment: Experiment

Question:

- Can metrics assess which parts of the design are unstable?

Release n-1 *Release n*

{∀ Metric m, Component c_{n-1}, Component c_n |
$m(c_{n-1})$ $m(c_n)$}



Stability Assessment: Results

- all documented changes are detected
- some undocumented changes are detected
- all changes are relevant

=> no false positives

- changes may go unnoticed

=> false negatives are possible

Reverse Engineering

Question:

- Can metrics reveal which parts of the design have been refactored?

Four heuristics for reverse engineering

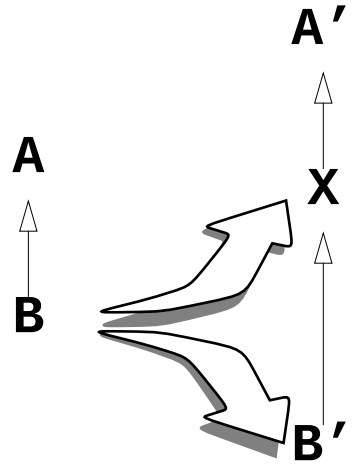
- Split into Superclass / Merge with Superclass
- Split into Subclass / Merge with Subclass
- Move to Other Class (Superclass, Subclass, Sibling class)
- Split Method / Factor Out Common Functionality

Split into Superclass / Merge with Superclass

Recipe

- Use change in “Hierarchy Nesting Level” (HNL) as main indicator
- Complement with changes in “# methods” (NOM), “# instance attributes” (NIA) and “# class attributes” (NCA) to look for push-up, push down of functionality
- Include changes in “# inherited methods” (NMI) to assess overall protocol

SPLIT



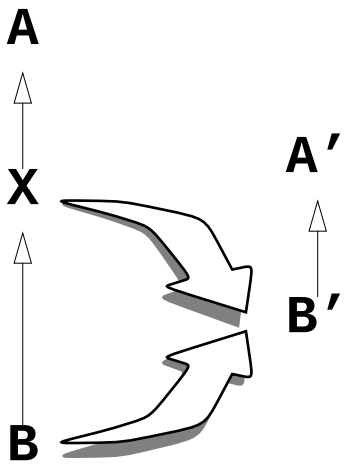
Split B into X and B’

(delta_HNL(B’) > 0) and
((delta_NOM(B’) < 0)
or (delta_NIA(B’) < 0)
or (delta_NCA(B’) < 0))

Merge X and B into B’

(delta_HNL(B’) < 0) and
((delta_NOM(B’) >0)
or (delta_NIA(B’) > 0)
or (delta_NCA(B’) > 0))

MERGE

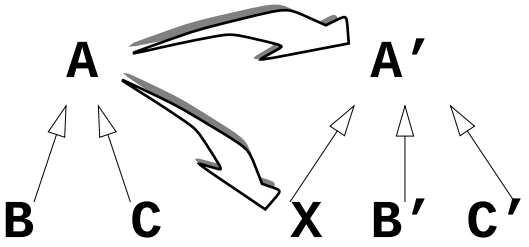


Split into Subclass / Merge with Subclass

Recipe

- Use change in "# immediate children" (NOC) as main indicator
- Complement with changes in "# methods" (NOM), "# instance attributes" (NIA) and "# class attributes" (NCA) to look for push-up, push down of functionality

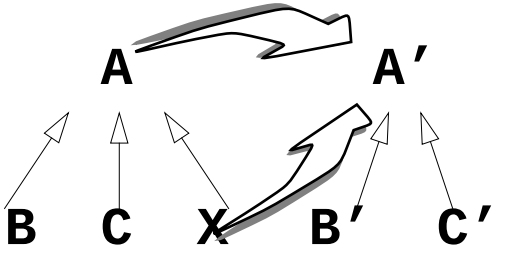
SPLIT

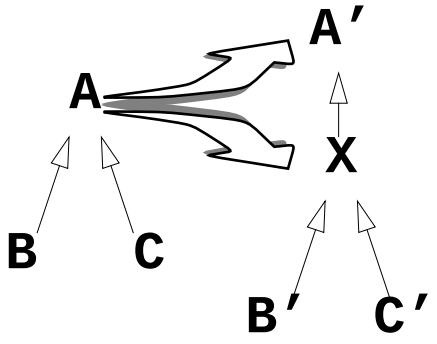


Split A into X and A'

(delta_NOC(A') <> 0) and
((delta_NOM(A') < 0)
or (delta_NIA(A') < 0)
or (delta_NCA(A') < 0))

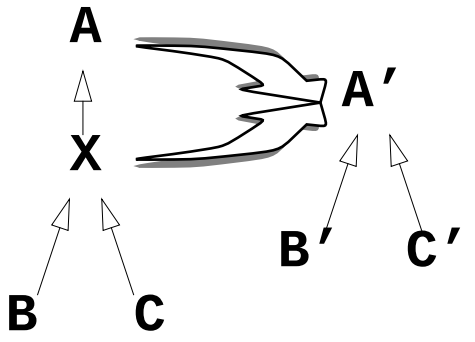
MERGE





Merge X and A into A'

(delta_NOC(A') <> 0) and
((delta_NOM(A') >0)
or (delta_NIA(A') > 0)
or (delta_NCA(A') > 0))

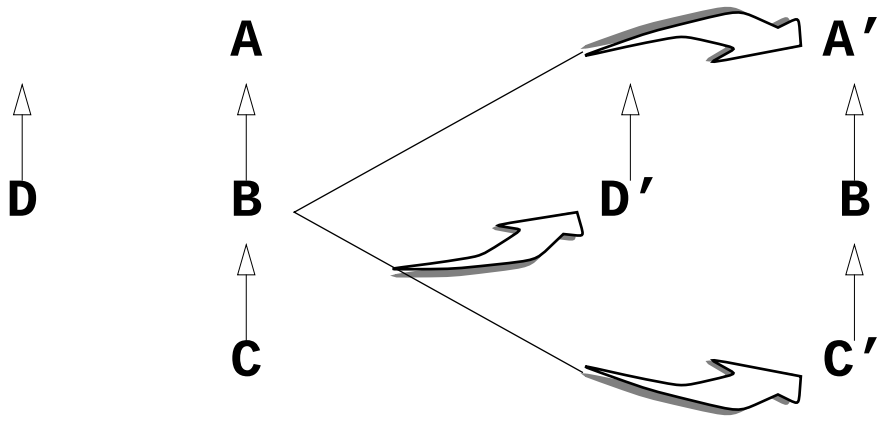


Move to Superclass, Subclass or Sibling Class

Recipe

- Use decreases in "# methods" (NOM), "# instance attributes" (NIA) and "# class attributes" (NCA) as main indicator
- Select only the cases where "# immediate children" (NOC) and "Hierarchy Nesting Level" (HNL) remains equal

MOVE



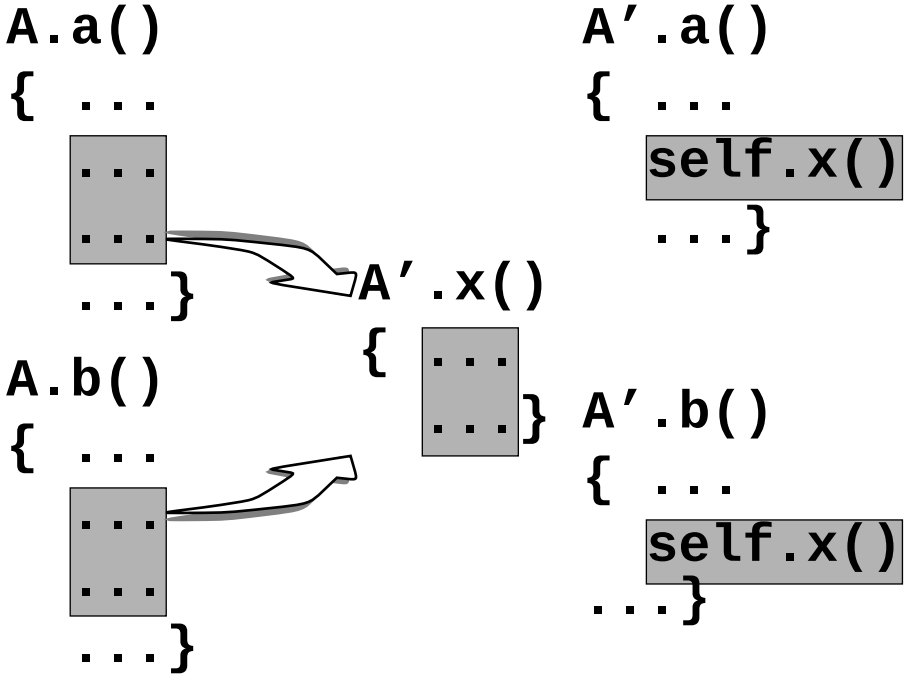
Move from B to A', C' or D'

((delta_NOM(B') < 0)
or (delta_NIA(B') < 0)
or (delta_NCA(B') < 0))
and (delta_HNL(B') = 0)
and (delta_NOC(B') = 0)

Split Method / Factor Common Functionality

Recipe

- Use decreases in "# invocations" (NOI) as main indicator
- Combine with "# statements" (NOS) and "# Lines of Code" (LOC)
- Check similar decreases in other methods defined on the same class



Split part of A.a() in A'.x()

(delta_NOI(A'.a()) < 0)

Factor out part of A.a() and A.b() into A'.x()

(delta_NOI(A'.a()) < 0)
and (delta_NOI(A'.b()) < 0)
and (delta_NOI(A'.a())
= delta_NOI(A'.b()))

Heuristics Performance

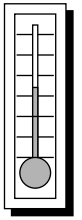
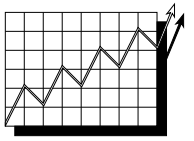
	Accuracy	False Negatives	False Positives
Split into Superclass / Merge into Superclass	*0%-3% (0-20)*	*Yes, but...*	*Yes, but...*
Split into Subclass / Merge into Subclass	*1% - 6% (11-43)*	*Yes, but...*	*Yes, but...*
Move to Superclass, Subclass, Sibling Class	*1%-10% (12-79)*	*Yes, but...*	*Yes, but...*
Split Method / Factor Common Functionality	*1%-3% (42-211)*	*Yes, but...*	*Yes, but...*

It works, but...

- vulnerable to renaming
- imprecise for large restructuring sequences
- by experts only
- heavyweight technique

Main advantage: focuses on interactions between classes and methods!

Conclusion (1/2)

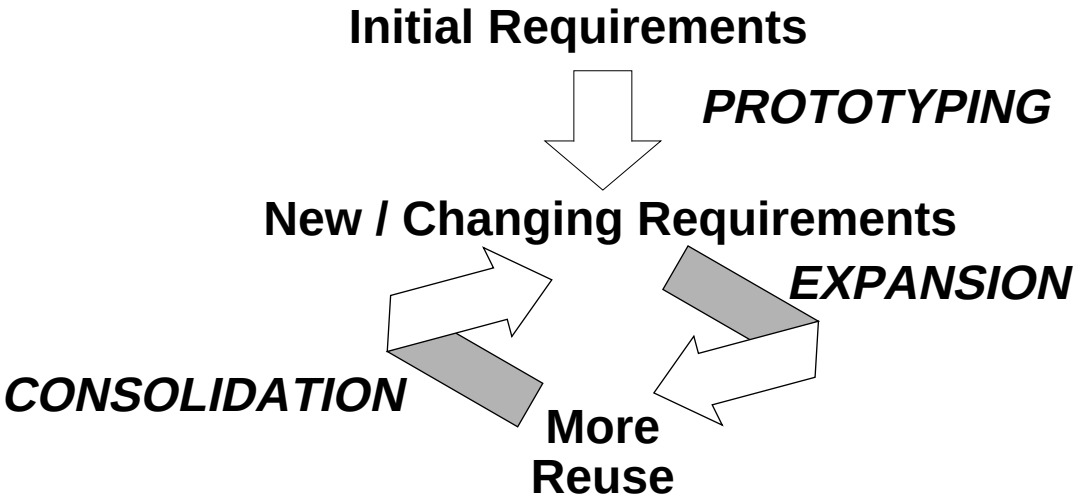




Question

Can metrics help to answer the following questions?

1. Which parts of the design will cause problems with future extensions? — *Not reliably*
2. Which parts of the design are unstable? — *Yes*
3. Which parts of the design have been refactored? — *Yes*

Conclusion (2/2)



- Iterative development is both a blessing and a curse
  => exploit the presence of versions
  => metrics are but one of the ways

11. Reengineering Repositories

Outline

- Why Reengineering Repositories?
- What is a Reengineering Repository?
- Taxonomy (Functionality + Integration Options)
- What to Store?
- How to Obtain Data?
- Exchange Standards

Literature

- Ian Sommerville, Software Engineering Fifth Edition, Addison-Wesley, 1996.
- Roger S. Pressman, Software Engineering: A Practitioner's Approach, McGraw-Hill, 1994.
- Alan M.Davis, 201 Principles of Software Development, McGraw-Hill, 1995.

Why Repositories - CARE

Tools

Tools are necessary to improve productivity.

However: Give Software Tools to Good Engineers [Davis'95]
(You want bad engineers to produce less, not more, poor-quality software)

Towards CARE

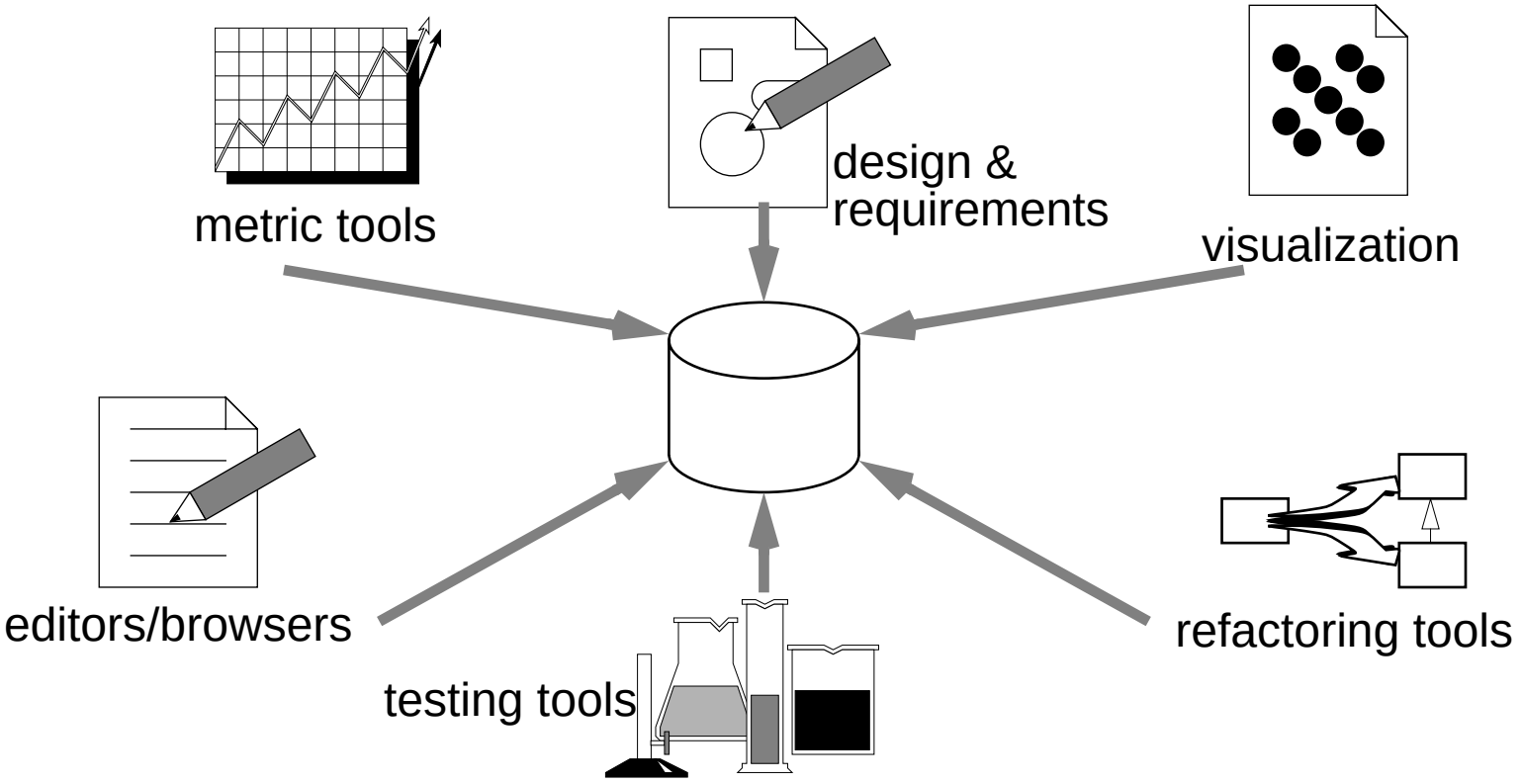
- Late 70's: CAD/CAM = Computer Aided Design / Manufacturing
  = Drawing tools to create and validate design diagrams and steer manufacturing processes
- Late 80's: CASE = Computer Aided Software Engineering
  = Tool support for (parts of) the Software Engineering Process
- CARE = Computer Aided Reengineering
  = Automated support for Software Reengineering
  - Y2K tools
  - Iterative Development (i.e., *round-trip engineering*)

Why Repositories - Tool Integration

Reengineering tools must work together

- They are supplied by different vendors
- They must share data

  => need a common “database”



What is a Repository - Definition?

Definitions for Repository

- A repository is a shared database of information about engineered artifacts. (Philip Bernstein, “An overview of Repository Technology”, Proceedings of the 20th VLDB Conference - 1994)
- A repository is a database that acts as the centre for both accumulation and storage of software engineering information. [Pressman’94]
- The tools are integrated around an object management system which includes a public, shared data model describing the data entities and relationships which can be manipulated by the tools. This model is accessible to all tools but not an inherent part of them. [Sommerville’96]

=> Reengineering Repository

- A reengineering repository is a common database used for integrating reengineering tools and providing all relevant information about the software system to be reengineered.

What is a Repository - Issues?

A reengineering repository is a common database used for integrating reengineering tools and providing all relevant information about the software system to be reengineered.

Issues

- Wide range of supporting “database” technology
  Flat file <-> Relational Database <-> Object Database
- PROVIDING all information?
  Often a reference to the actual place where the information is stored
  => Repository maintains meta-data, i.e. data about the data
- RELEVANT information?
  Who decides what is relevant?
  => open and extensible database schema (i.e., repository model)
- Tool integration?
  Not all tools work together smoothly
  - different information needs
  - not designed to work together

  => redundant information + necessary patching

Taxonomy - Functionality

What kind of functionality does one expect from a CARE-tool?

Adapted from [Sommerville'96]

Classification	Examples of tool functionality	CARE-specific
• Tracking	Requirement Tracking, Bug Tracking	x
• Configuration Management	Version Mngmnt., Configuration Mngmnt	
• Source Code Manipulation	Code Editors, Browsers	
• Restructuring	Pretty-printing, Refactoring	x
• Data Collection	Parsers, Run-time Data Collectors	x
• Data Analysis	Metrics, Visualisation, Clustering	
• Testing	Regression Tests, Coverage Analysis	

Buying all these tools from a single vendor is not a realistic scenario

=> need for integration facilities

Taxonomy - Integration

What kind of integration facilities does one expect in a CARE-tool?

Adapted from [Pressman'94]

Classification	Examples of integration facilities
• Completely Closed	--
• Data Exchange	Import/Export facilities available in most tools
• Common Tool Access	Unix shell, emacs
• Common Data Management	Link libraries, Java byte-code
• Data Sharing	java.lang.reflect
• Interoperability	Most "open environments" from a single vendor

Tool integration is even more important in reengineering than in forward engineering

- ❑ forward engineering tools are chosen deliberately
- ❑ reengineering tools must integrate with what's already in place

Integration Example (1/3)

Data Sharing

Here's a piece of Java-code that uses the reflection facilities to inspect a class

```
import java.lamg.reflect.*;

public class ClassInspector
{
   ... /* definition of auxiliary methods Print... */

   public static void Inspect (Class c) {
      System.out.println("Contents of class " + c.getName());
      PrintFields (c.getFields());
      PrintConstructors(c.getConstructors());
      PrintMethods(c.getMethods());
   }
}
```

Integration Example (2/3)

Interoperability

Here's a piece of C-code which accesses the SNiFF+ API

```
int main ( int argc, char *argv[] )
{ SNiFFACCESS slot;
  .... /*other declarations */

  ParseArgs( argc, argv, &host, &proj, &session );
  __si__module__init( );
  slot = si_open( session, host );
  if( slot && si_open_project( slot, proj ) )
    {full = si_Query(eQImplFiles,eSGlobal,0);
    .... /* enumerate pointer structure in 'full' */
    si_close_project( slot, proj );
    }
  si_exit(slot);
return 0;
}
```

Integration Example (3/3)

Interoperability

Here's a piece of VisualBasic-code which accesses the Rational/Rose API

```
Sub GenerateClassIn (theClassName As String,
     theCategory As Category)
   Dim theClass As Class
   Set theClass = theCategory.AddClass(theClassName)
End Sub
Sub GenerateInheritanceIn (theSubclassName As String,
     theSuperclassName As String, theCategory As Category)
   Dim theSub As Class
   Dim theInherit As InheritRelation
   Set theSub = theCategory.GetAllClasses().GetFirst(theSubclassName)
   Set theInherit = theSubclass.AddInheritRel("", theSuperclassName)
End Sub
Sub Main
   Dim theCategory As Category
   Set theCategory = RoseApp.CurrentModel.RootCategory
   GenerateClassIn "JPeg1", theCategory
   GenerateClassIn "JPEGImageDescription", theCategory
   GenerateInheritanceIn "JPEGImageDescription", "JPeg1", theCategory
End Sub
```

What to Store?

- Core OO constructs
  - Classes
  - Inheritance
  - Methods
  - Attributes
  - Types
- Procedural constructs
  - Packages
  - Functions & Procedures
  - Global Variables
- Details
  - Formal Parameters
  - Other Variables (local,...)
  - Arguments
- Relations
  - {Methods, Functions, Procedures} *access* {Attributes, Variables}
  - {Methods, Functions, Procedures} *invoke* {Methods, Functions, Procedure}
  - {Classes} *own* {Methods, Attributes,...}
  - {Packages} *own* {Classes, ,...}
  - {Methods, Functions, Procedures} *accept* {Formal Parameters}
  - {Invocations} *bind* {Formal Parameters} *to* {...}
  - {Types} *correspond to* {Classes}
  - {Attributes, Formal Parameters, Variables,...} *have* {Types}
  - {Types} *correspond_to* {Classes}

How to Obtain Data (1/4)?

Build your own parser

- Technique
  - Use parser generator to build a parser for the language
- Advantage
  - Full control {dialects, pre-compilers}
- Disadvantage
  - Experts only (formal syntax grammars)
  - Costly
  - Uncertain about reliability and scalability
  - Build your own = Maintain your own
  - Tools to integrate with require source code or API
- Remarks
  - C++ requires full control (lot's of dialects + pre-compiling tricks)
  - ... but 100% reliability is very difficult for parser generators

How to Obtain Data (2/4)?

Translate between file-formats

- Technique
  - Build gateways between existing tools by translating import/export file formats
- Advantage
  - Relatively cheap (assuming formats are documented)
  - Offers reasonable integration
  - Reasonable scalability (limited by file system)
- Disadvantage
  - Faith in external tools
  - Maintenance is difficult (future releases easily change file-formats)
  - Effort to be duplicated for every tool
- Remarks
  - Works only when few gateways must be build
  - Standardization efforts are under way (CDIF, MOF)
    => tackles “maintenance” and “duplication of efforts” problems
    => improves scalability and allows multiple tools

How to Obtain Data (3/4)?

Communicate via API's (application programmer's interface)

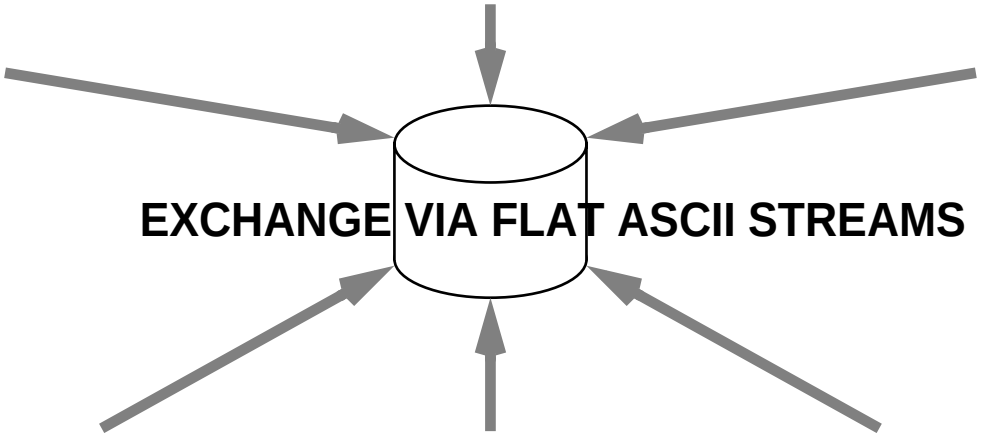
- Technique
  - Build gateways between existing tools using wrappers that extract info via API's
- Advantage
  - Cheap
  - Good integration
  - Good scale-up (limited by wrapping tool)
  - Maintenance effort is reasonable (API's don't change that frequently)
- Disadvantage
  - Faith in external tools
  - Effort to be duplicated for every tool
  - Robustness
- Remarks
  - Works only when few gateways must be build
  - May be combined with "Translate between file-formats"

How to Obtain Data (4/4)

Collect Execution Traces

- Technique
  - Acquire traces of sequences of method invocations
    (code instrumentation, method wrapping, debuggers, virtual machines)
- Advantage
  - Good insight in the ‘real’ execution trace
- Disadvantage
  - Expensive with current state of the art
  - Relies on reliable usage scenarios
  - Explosive data-growth
- Remarks
  - Currently not often used, but gives spectacular results

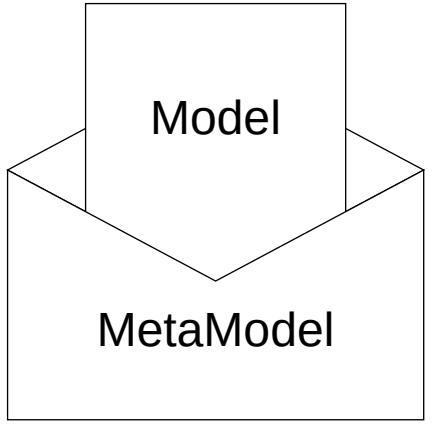
Exchange Standards



Standardization Efforts

- CDIF (CASE data interchange format) - see http://www.eigroup.org/
  Mature standard (approved by ISO).
  Little commitment from tool vendors
- MOF (Meta-Object Facility) from OMG - see http://www.omg.org/
  Currently immature.
  Major commitment from tool vendors to be expected
  Builds on UML and XML.

Exchange Standards - Meta Models



Issue: Who decides what is relevant information? Tools have different information needs

=> open and extensible repository model

=> need for a meta-model

Layer	Description	Example
User Objects	Describes a specific situation in an information domain.	Student#3, Course#5, Student#3.enrolled_in.Course#5
Model	Defines a language to describe an information domain.	Student, Course, enrolled_in
Meta Model	Defines a language for specifying Models	Class, Attribute, Operation
Meta Meta Model	Defines the core ingredients sufficient for defining languages for specifying meta-models	MetaEntity, MetaRelationship

Exchange Standards - CDIF example

```
CDIF, SYNTAX "SYNTAX.1" "02.00.00", ENCODING "ENCODING.1" "02.00.00"

(:HEADER ...
   (:META-MODEL
      (:SUBJECTAREAREFERENCE Foundation
         (:VERSIONNUMBER "01.00"))
      ...)

   (MetaEntity Class
      (Name *Class*))
   (MetaAttribute nameClass
      (Name *name* )
      (DataType <StringValue>)
      (isOptional -FALSE-))
   (MetaAttribute.IsLocalMetaAttributeOf.AttributableMetaObject
      nameClass Class)
   ...
)

(:MODEL ...
   (Class 001
      (Name “Student”))
   (Class 002
      (Name “Course”))
   ...)
```

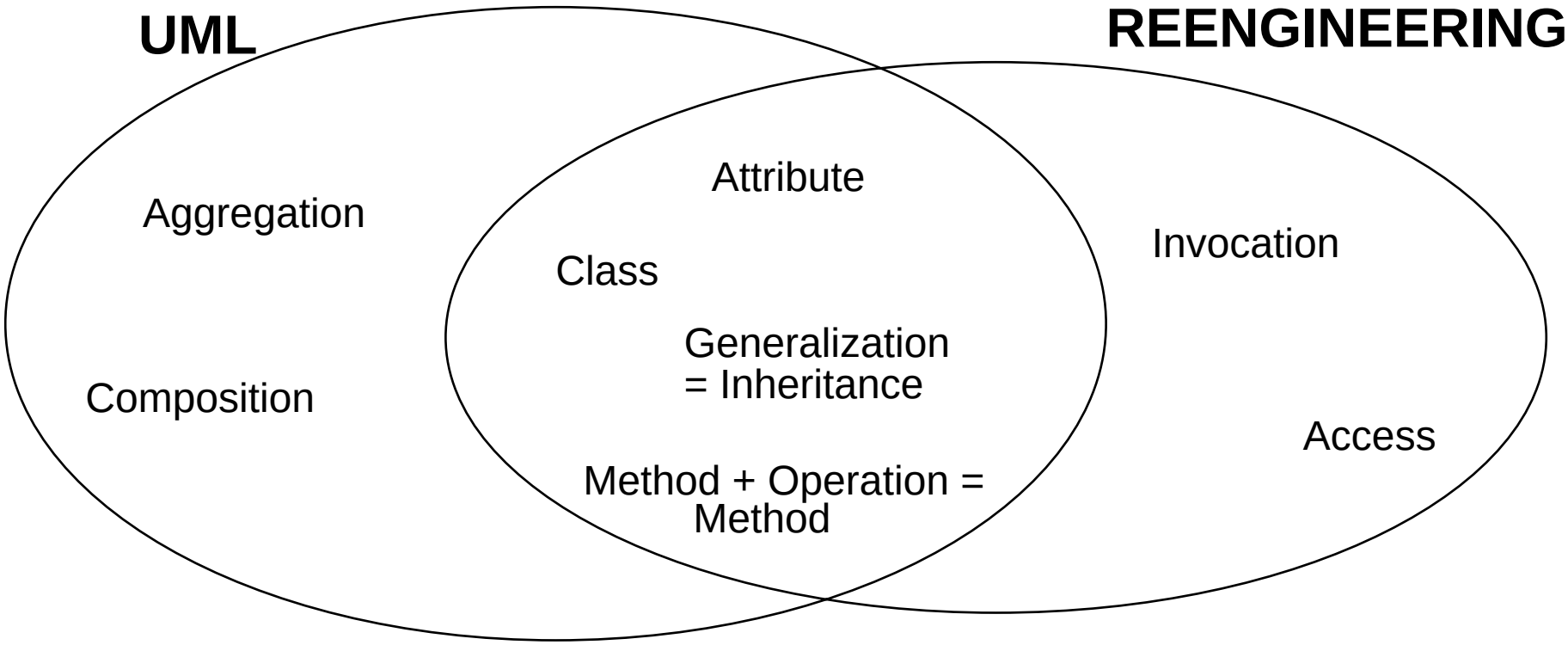
→ Obligatory Introduction Stuff

→ Definition of a meta-model concept “Class” as having one attribute “name”

→ Definition of 2 classes “Student” & “Course”

Exchange Standards - UML ?

Current standardization efforts are geared towards UML. This may not be enough for reengineering purposes.



- use extension mechanisms on the meta-model
  => how standard is standard ?
- define a special reengineering standard (i.e., own meta-model)

Conclusion

- Reengineering requires Tools
  - Much in common with forward engineering
  - Must integrate with what's already in place
- Tool integration via data exchange and/or data sharing
  - Repositories as the central "database"
  - A repository is not so much a passive data store ...
  - ... but more an object which knows where the data is
- "Help yourself" approach
  - Build your own parser
  - Translate between file-formats
  - Communicate via API's
  - Collect Execution Traces
- Standardization Efforts
  - CDIF is mature / MOF is safest bet for future
  - Extensibility via Meta models (4 layer architecture !)
  - UML emphasis may cause problems