Design by Contract

Prof. Dr. Dirk Riehle

Friedrich-Alexander University Erlangen-Nürnberg
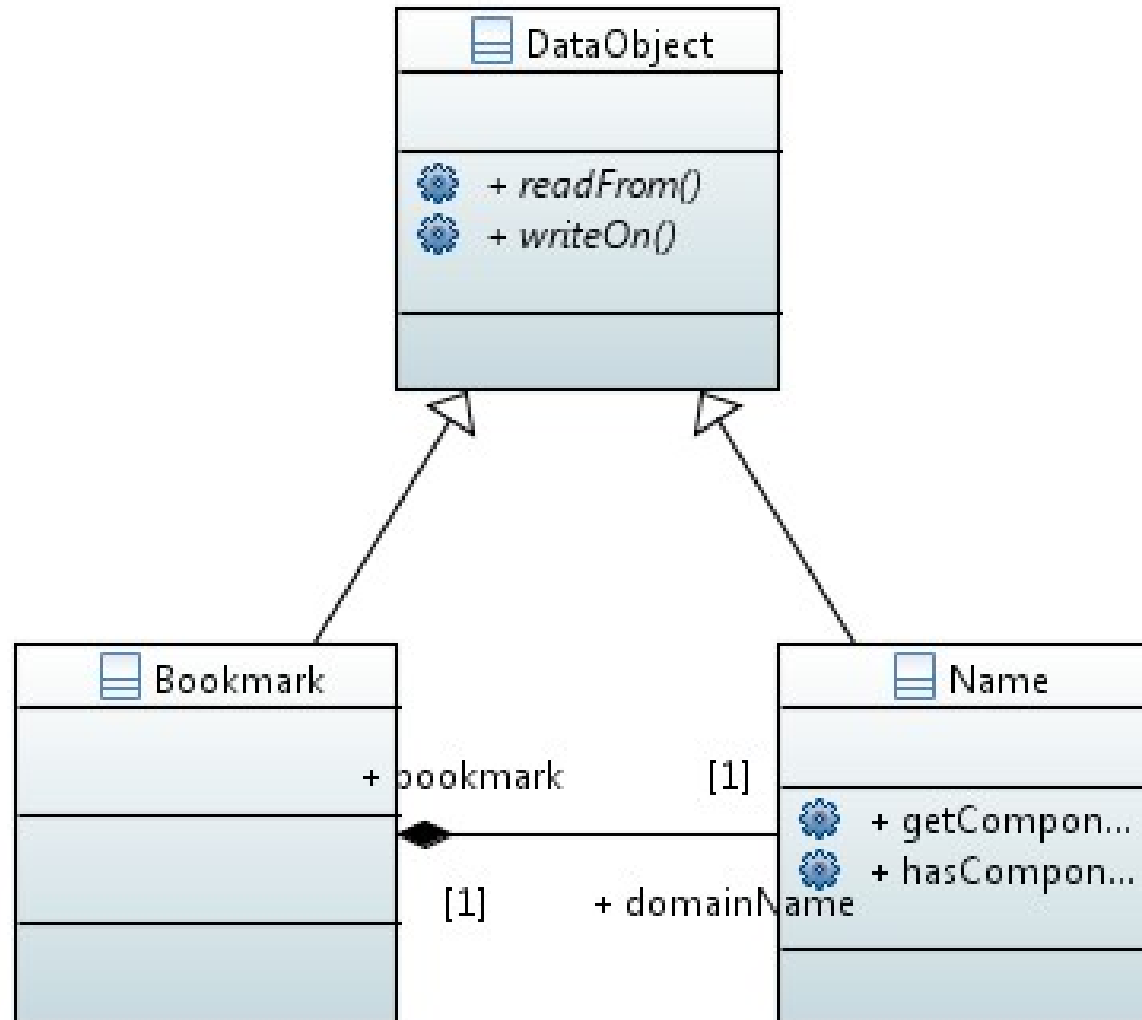
ADAP C05

Design by contract views software design as a succession of contracting decisions [M91].

Design by Contract is method for specifying interfaces as contracts to clarify responsibilities and minimize programming effort while improving reliability [DR].

Classes Specify Object Collaborations

Contracts

- A contract specifies rights (benefits) and obligations
  - Between a client (consumer) and contractor (supplier)
  - Contracts are (ideally) exhaustive; there are no hidden clauses

- Rights and obligations are mutual
  - A client obligation (precondition) is contractor right
  - A contractor obligation (postcondition) is a client right

- The contract protects both sides of the deal
  - The client is guaranteed a result
  - The contractor is guaranteed a specified operating environment

- **A contract is effectively an interface specification**

The AbstractName#insert(...) Method

```java
public void insert(int i, String c) {
  assertClassInvariants();

  assertIsValidIndex(i, getNoComponents() + 1);
  assertIsNonNullArgument(c);
  int oldNoComponents = getNoComponents();

  doInsert(i, c);

  assert (oldNoComponents + 1) == getNoComponents() : "..."; // [1]

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protected abstract void doInsert(int i, String c);
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[1] Please note that assertion checking using the assert keyword can be switched off;
     if you require the assertion be checked, do not use assert, but a classic if clause.

Contract for Name#insert(...)

	Rights	Obligations
Client	**Receives Name object with component inserted**	**Ensures defined environment, i.e. index is valid and component != null**
Contractor	**Operates in defined environment**	**Provides Name object with component inserted**

Defensive Programming

- Defensive programming

  - Wikipedia: "[...] the programmer never assumes a particular function call or library will work as advertised"

  - Meyer: "[...] protect every software module by as many checks as possible, even those which are redundant with checks made by the clients."

- Problems with defensive programming

  - Multiplies the amount of checking code

  - Leads to bloated, hard-to-read, slow code

- **Redundant code is (mostly) a bad idea**

  - Design by contract makes code lean

  - Design by contract removes redundancy

Benefits of Design by Contract

- Leads to well-specified interfaces

- Leads to clean separation of work

- Makes software more reliable

1. Preconditions

2. Class invariants

3. Postconditions

Preconditions

- **A boolean condition to be met for successful method entry**
    - The purpose is to guarantee a safe operating environment
    - If violated, the method should not be executed

- The client must make sure preconditions are met
    - A violation in the preconditions indicates a bug in the client

- Preconditions are method-level components of a contract

Preconditions of Name#insert(...)

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Postconditions

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Class Invariants

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Class Invariants of Name

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  doInsert(i, c);

  assert (oldNoComponents + 1) == getNoComponents() : "...";

  assertClassInvariants();
}

protected abstract void doInsert(int i, String c);

protected void assertClassInvariants() {
  assert getNoComponents() >= 0;
  ...
}
```

Realizing Design by Contract

- Annotate interface with class invariants

- Annotate methods with pre- and postconditions
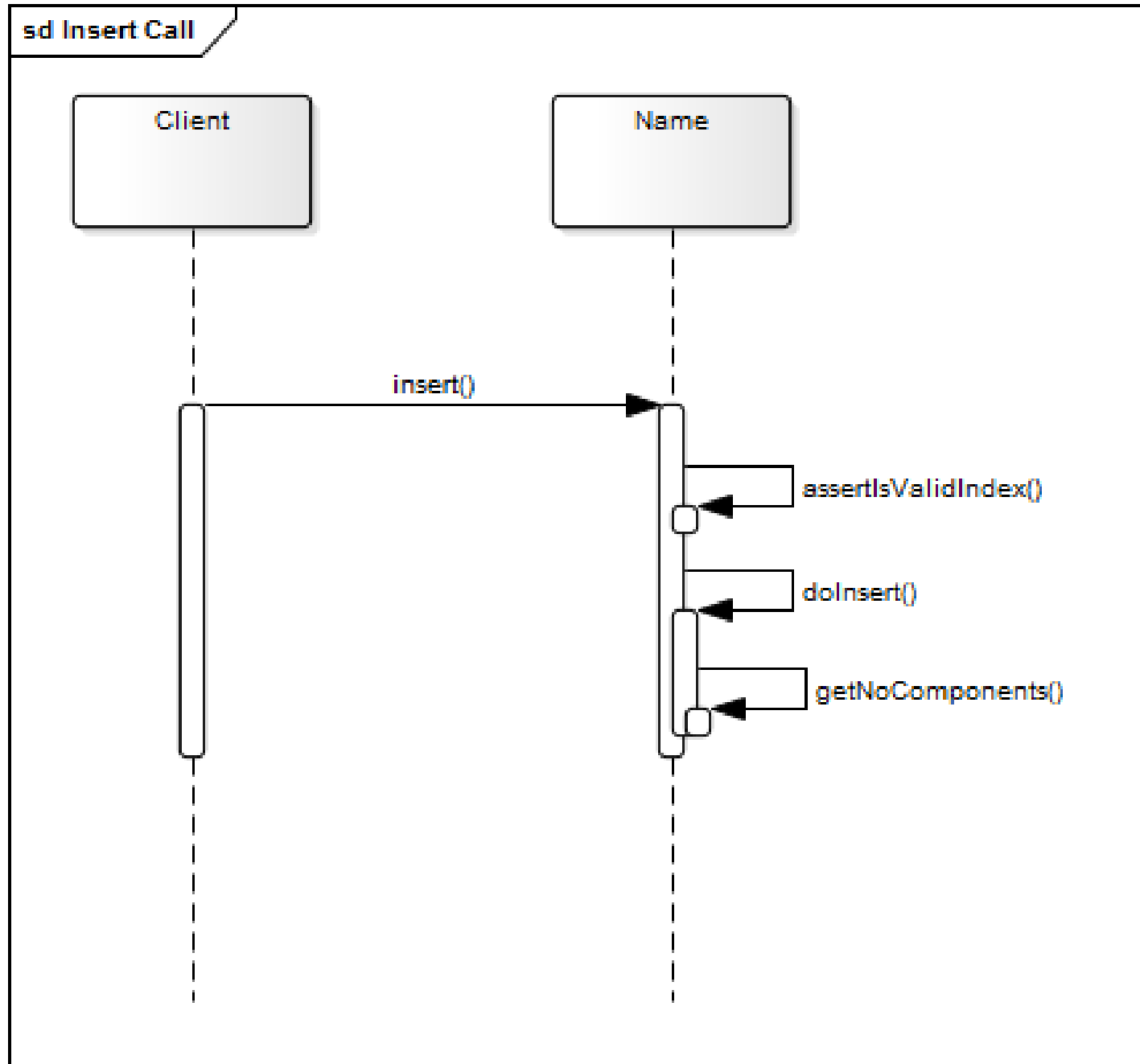
Implementing Design by Contract

- In Java, use **assert** or assertion methods

  - Preconditions guard the entry to the method

  - Postconditions ensure successful completion

  - Class invariants add to postconditions

- **Assertions should be side-effect free**

  - Do not call mutation methods

Use of Assertion Methods

- Use dedicated assertion method if …
  - the assertion is used more than twice
  - a generic assertion failure exception is insufficient
  - you want to avoid that your assertion checking can be switched off

```
protected void assertIsValidIndex(int i, int upperLimit)
  throws IndexOutOfBoundsException {
  if ((i < 0) || (i >= upperLimit)) {
    String msg = String.valueOf(i) + "(of " +
      String.valueOf(getNoComponents()) +")";
    throw new IndexOutOfBoundsException(msg);
  }
}
```

Design by Contract and Assertions

Semantics of Various Exceptions

- IllegalArgumentException

- IndexOutOfBoundsException

- NullPointerException

- IllegalStateException

- ...

Pragmatics of Design by Contract

- Use design by contract ...

  - for code that needs to be highly reliable

  - for code that is called often

- **Focus on preconditions ...**

  - **to protect method operations**

  - **to document expectations**

- Why not postconditions and class invariants?

  - One method's postconditions are another method's precondition

  - Class invariants are implied postconditions for all methods

  - Pragmatically, tests already check for contract fulfillment

Design by Contract and Multithreading

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}
```

```java
protected void doInsert(int index, String component) {
  int newSize = getNoComponents() + 1;
  String[] newComponents = new String[newSize];
  for (int i = 0, j = 0; j < newSize; j++) {
    if (j != index) {
      newComponents[j] = components[i++];
    } else {
      newComponents[j] = component;
    }
  }
  components = newComponents;
}
```

Design by Contract and Inheritance

- Preconditions may "accept more cases"
    - Subclasses may require less (weaken preconditions)
        - Preconditions get disjunctively ("or") connected

    - Subclasses may **contravariantly redefine method argument types**

- Postconditions may "provide better results"
    - Subclasses may provide more (strengthen postconditions)
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- Class invariants may "provide better results"
    - Subclass invariants may not require less
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Preconditions and super.method() Calls

- Ensure preconditions of super.method(...) before using it

```
public Name AbstractName#insert(int index, String component) {
  assertIsValidIndex(index, getNoComponents() + 1);
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```
public LazyName LazyName#insert(int index, String component) {
  ensureLength(index);
  return super.insert(index, component);
}

protected void ensureLength(int length) {
  // extend internal representation with empty components
  ...
}
```

Postconditions and Dual Hierarchies

- Covariant redefinition of return type strengthens postcondition

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public Name AbstractName#insert(int index, String component) {
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Quiz: Violating Class Invariants

- Can you violate a class invariant in between two methods calls?
  - Yes
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Normal vs. Abnormal Operation

- **Normal situation**

  - "All is good" about the program; system is performing its function
  - Program pointer is in regular code, not exception handling code

- **Abnormal situation**

  - A contract was violated; the system needs to recover from the violation
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- **Modern programming languages distinguish both modes**

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Contracts and Control Flow [1]

	Control Flow	
	Normal Return by `return`	**Abnormal Return by Exception**
Contract Fulfilled	X	–
Contract Not Fulfilled	–	X

[1] Meyer's first two "laws" of exception handling reframed.

Handling an Exception

- **Resumption**

- **Organized Panic**

More on this in lecture on error handling

Two Alternatives of Handling Violations

- Resumption
  - Try again
  - Try alternative implementation

- Organized panic
  - Clean up as far as possible
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Quiz: Switching off Assertions

- Should you switch off assertions? (If so, when?)

  - Yes

  - No

Review / Summary of Session

- Design by contract

  - Definition, benefits, and realization

  - DbC vs defensive programming

  - DbC implementation in Java

- Design-by-contract in context

  - Multi-threading

  - Inheritance

Thanks! Questions?

dirk.riehle@fau.de – **http://osr.cs.fau.de**

dirk@riehle.org – http://dirkriehle.com – @dirkriehle

DR

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- Contributions

  - ...

Design by Contract

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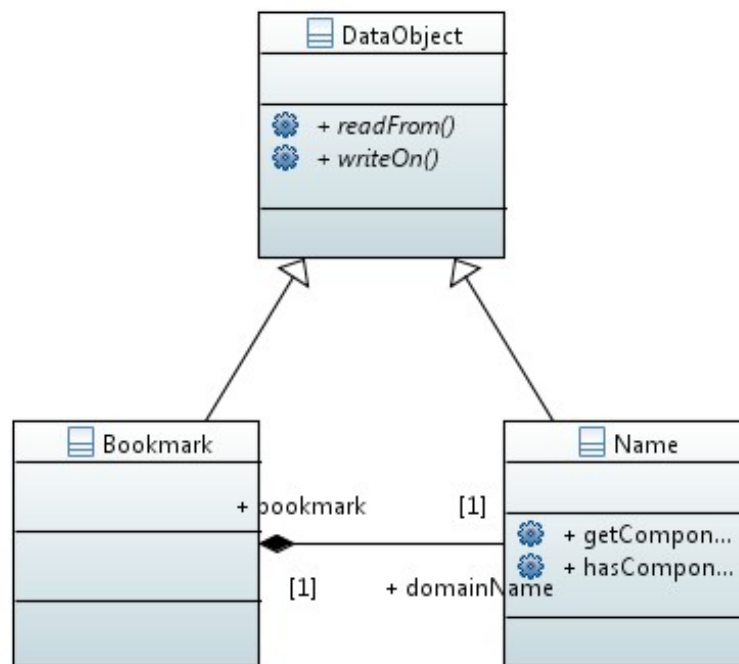**Friedrich-Alexander University Erlangen-Nürnberg**

ADAP C05

It is Friedrich-Alexander University Erlangen-Nürnberg – FAU, in short.

Corporate identity wants us to say "Friedrich-Alexander University".

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Dilbert on Bugs

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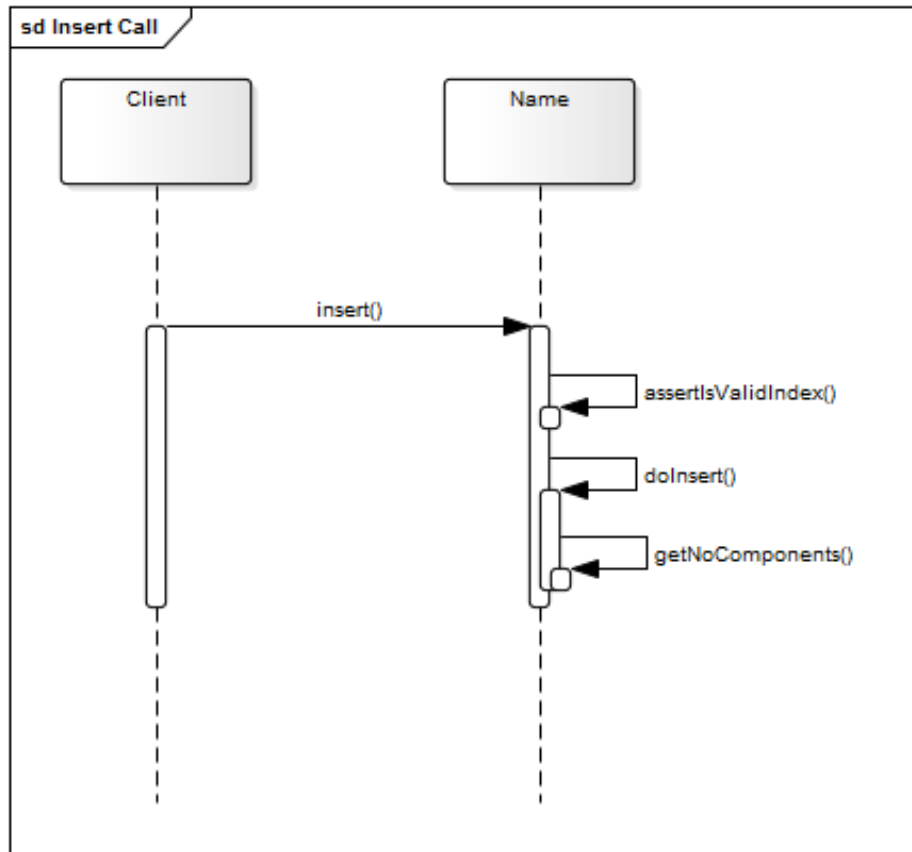
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Design by Contract and Assertions

sd Insert Call

Client → Name : insert()

Name : assertIsValidIndex()

Name : doInsert()

Name : getNoComponents()

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    } else {
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Contract Fulfilled	**X**	**─**
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Advanced Design and Programming
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Handling an Exception

- # Resumption

- # Organized Panic

More on this in lecture on error handling

Two Alternatives of Handling Violations

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  - Multi-threading
  - Inheritance

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dirk.riehle@fau.de – **http://osr.cs.fau.de**

dirk@riehle.org – http://dirkriehle.com – @dirkriehle

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