# Fortgeschrittene objektorientierte Programmierung (Advanced Object-Oriented Programming)

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| Studies: | Software Engineering & Internet Computing<br>Computational Intelligence<br>Visual Computing |
| Requirements: | experience in object-oriented programming |
| Registration: | in TISS until 10.03.2017<br>group building: 10.03.2017 during lecture |

# Substitutability and Assertions

# Principle of Substitutability

**Type S is subtype of a type T iff**
**each instance of S is usable where an instance of T is expected**

Principle of substitutability holds if

types of input parameters are contravariant,
types of variables and through-parameters are invariant,
types of constants, results, output parameters are covariant,

and corresponding methods in S show same behaviour as those in T

# Substitutability and Behaviour

Methods in subtype S show same behaviour as those in supertype T if

assertions to be fulfilled by clients (= preconditions)
in S not stronger than those in T

assertions to be fulfilled by servers (= postconditions and invariants)
in S not weaker than those in T

assertions to be fulfilled by clients and servers
(only useful for invariants in some cases) equivalent in S and T

methods in S do not throw more exceptions than those in T
(in corresponding situations)

# Expressing Assertions

In theory, all assertions formally expressible (logics, algebra), relationships between assertions statically checkable

In practice, many assertions not expressible and relationships not checkable because

- programming language has insufficient support (informal comments, usually ambiguous)
- clients have not enough information about object state (data hiding in conflict with Design-by-Contract)
- object state changes in non-predictable way (concurrency, aliasing)

# Example of Using Assertions

```
class IntSet {
    public boolean find(int x) { ... }
    // true iff x is in set
    public void insert(int x) { ... }
    // immediately afer insertion x is in set
    ...
}
```

```
    ...
    IntSet set = new IntSet();
    set.insert(1);        // now 1 is in set
    boolean a = set.find(1);
    do_something_not_using_set();
    boolean b = set.find(1);
```

# Possible Problems in Example

“Immediately after” is ambiguous

Usual interpretation: Element remains in set as long as no “delete” is invoked (that could be defined in a subtype)

Constructor creating “set” could have introduced alias (different from “set”) that causes “do_something_not_using_set” to change the set
$\longrightarrow$ “b” possibly false

Concurrent thread (spawned in the constructor) could have deleted element
$\longrightarrow$ “a” and “b” possibly false

# How to Solve the Problems

Invoke "find" to check if the element is in the set

often bad solution because nothing useful to do if check fails

Prevent aliasing altogether

bad solution because extremely expensive

In case of concurrency always ensure atomic actions

often a good idea, but sometimes very expensive

**avoid unexpected side-effects** (e.g., in constructor)

only useful alternative
however, expectations hardly ever formally expressible

# History Constraints

Advice: Use **all** available information, no matter how easily expressible as usual assertions (pre-, post-conditions, invariants)

Example: **History constraints** constrain the evolution of objects in a way hardly expressible as usual assertions

> like "value of 'counter' can only increase one by one" (server responsible), or "'unlock' invokable only after 'lock'" (client responsible).

History constraints to be fulfilled by servers resemble invariants;
they can be more restrictive in subtypes.

History constraints to be fulfilled by clients restrict invocation sequences;
subtypes can support more invocation sequences than supertypes.

# Suggestions about Assertions

Considering all possibilities would be too expensive; don't try to do so.

Be predictable, avoid tricks, rely on "usual" behaviour of programmers.

Use design rules (specific to company or project).

Use all available information as assertions (including history constraints).

First rule: **Avoid unnecessary dependences!**

- no avoidable assertions,
- no unneeded invocations and parameters,
- no unnecessary visibility of variables and methods,
- only well-considered parameter types
- code only at lowest level in class hierarchy (= avoid inheritance)

# Names

# Significance of Names

Names are **abstractions** of object behaviour, method behaviour and variable properties, thereby resembling informal assertions.

Names support **intuition**;
comments necessary only if intuition insufficient
$\longrightarrow$ good programs readable even without comments

Intuitive names cause programmers to be **predictable**
(bad names $\rightarrow$ no trust $\rightarrow$ unnecessary code)

Names of types provide **semantic** information
(not only for programmers, also for machines)

# Examples of Structural Types

Two **structural** (= anonymous) types in subtyping relation:

```
{ String name; String address() }
{ String name; String address(); int regNr }
```

Member names used as type names:

```
{ String name; String address(); void isPerson() }
{ String name; String address(); void isPerson();
                    int regNr; void isStudent() }
```

In theory we mainly use structural types,
in practice we mainly use **nominal** (= named) types.

Structural types can simulate nominal types, but accidental coincidence possible (can be faked)

# Structural versus Nominal Types

| | structural | nominal |
|---|---|---|
| type equivalence | same structure | same name |
| subtyping | implicit | explicit (inheritance) |
| usability | simple | more difficult |
| plug & play | easier | not that easy |
| name conflicts | possible | easily possible |
| accidental relations | possible | unlikely |
| readability | not so good | good |
| abstraction of behaviour | no | yes |

# Nominal Types Ensure Properties

Example:

```
class SortedList<A extends Comparable<A>> { ... }
```

Property “sorted” hardly directly checkable, except by class membership

Each instance of `SortedList<T>` initialized by a constructor in `SortedList` and its subclasses (faking almost impossible)

If `SortedList` and its subclasses ensure the property “sorted”, we can rely on it

# Structural Types have Benefits

as bounds for bounded genericity

when using plug & play on software components

when introducing supertypes of already existing subtypes

# Genericity with Anonymous Bounds

Java example: `class SortedList<A extends Comparable<A>>`

Why has `A` to inherit from `Comparable<A>`?

Only requirement: `A` provides methods of `Comparable<A>`

because `Comparable<A>` does not imply further properties

Example in Ada showing the use of anonymous bounds:

```
generic
    type T is private;
    with function compare(x,y: T) returns Boolean
package SortedList
    ...
```

# Kinds of Bounded Genericity

**F-bounded Genericity:** $S \leq T\langle S\rangle$

can deal with binary methods, but restricted to one inheritance level

Java example: `Integer` $\leq$ `Comparable<Integer>`
(subtype relation $=$ relation on bounds)

**Higher Order Subtyping:** $S <\# T$ if $\forall U : S\langle U\rangle \leq T\langle U\rangle$

also called **matching** (on functions over types)

supports binary methods directly, but does not provide substitutability

statically type-safe as bound in bounded genericity
(subtype relation $\neq$ relation on bounds)