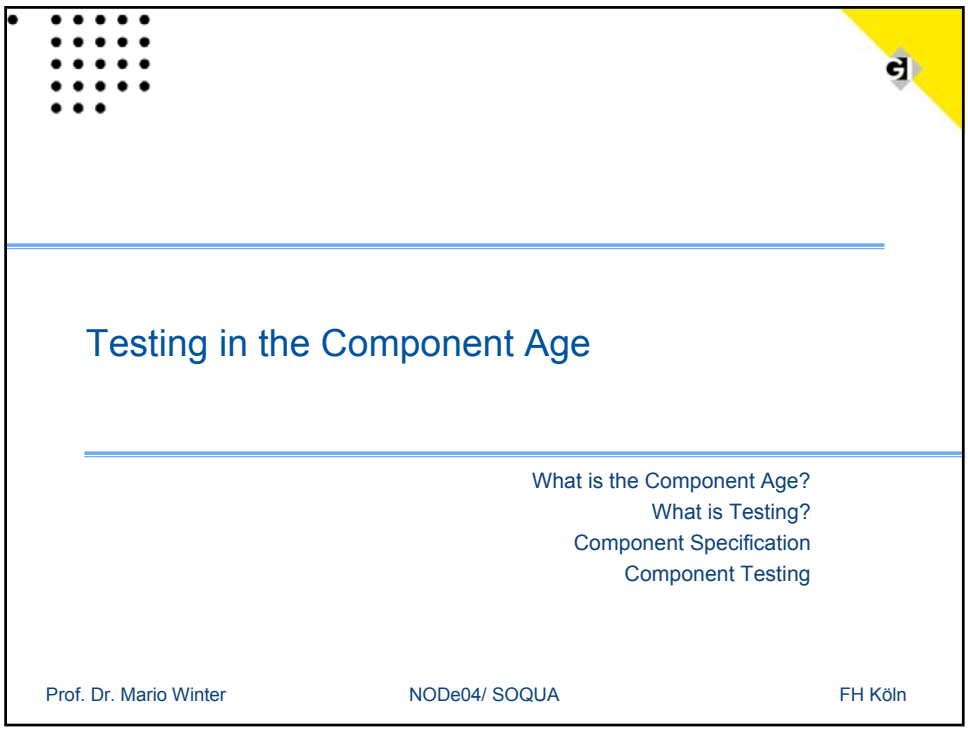
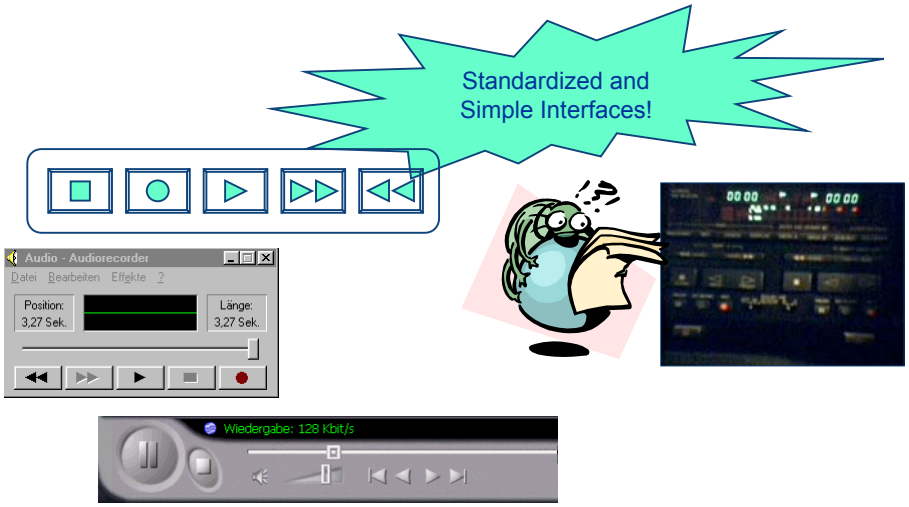


Overview

- What is the Component Age?
- What is Testing?
- Component Specification
- Component Testing

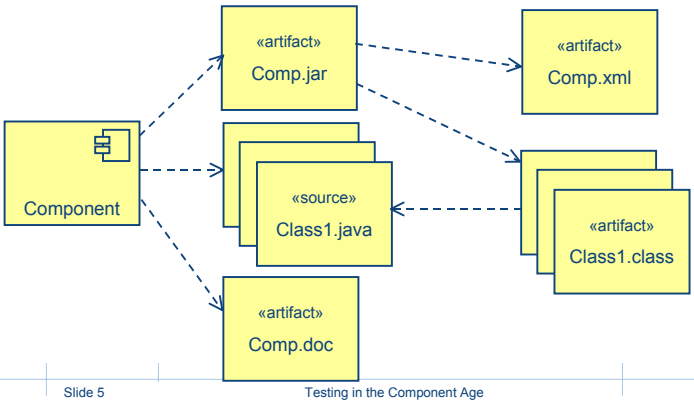
What are Components? Why are they composable?

Why are we able to use Components?



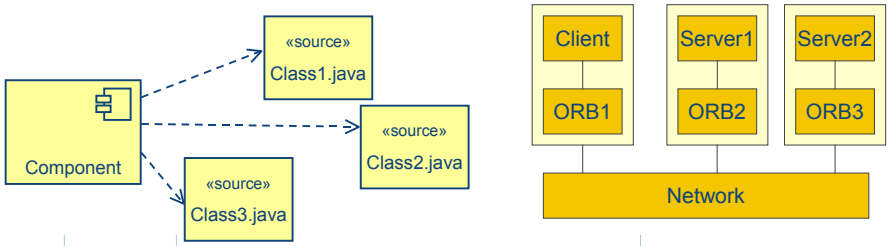
What are Software Components?

"A software component is a unit of composition with contractually specified interfaces and explicit context dependencies only. A software component can be deployed independently and is subject to composition by third parties". C. Szyperski, 1998

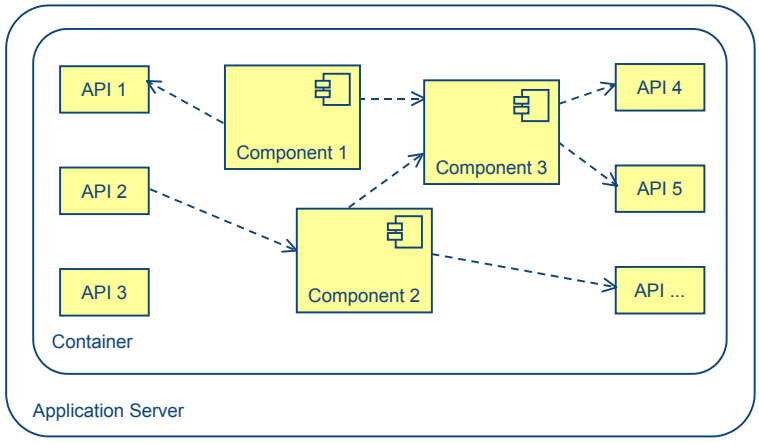


Are Components just „big" Objects or Classes?

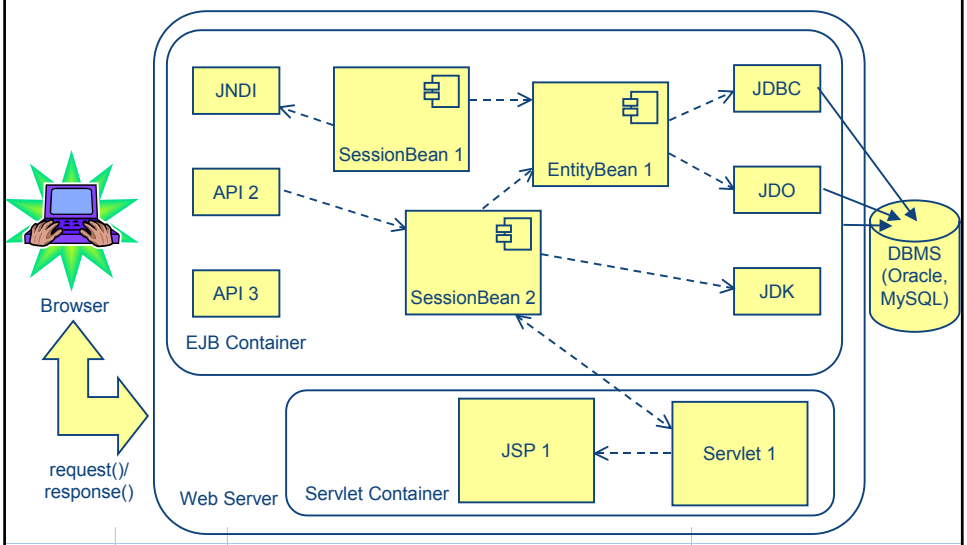
- Components …
  - Are bigger than classes
  - Can be build from classes (but must not)
  - Adhere to component standards (not to programming language standards)
  - Can be deployed independently
  - Are subject to composition by third parties
  - Are (should be) executable in different operational environments
  - Are used to build distributed, heterogeneous services and systems



Programming Modell of the Component Age

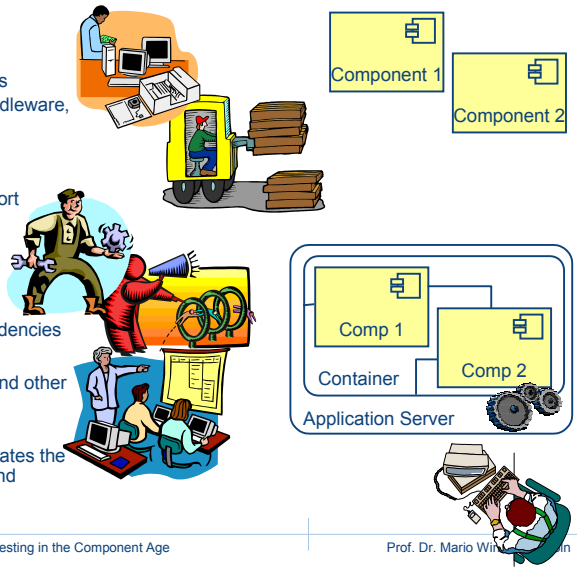


J2EE / EJB - Container Architecture



Roles in the Component Age

- Application Server Provider
  - Low level system services
  - Typically OS vendor, middleware, or database vendor
- Container Provider
  - Deployment tools and component runtime support
- Component Provider
  - Producer of Components
  - Domain Expertise
- Component Deployer
  - Resolves external dependencies
- Application Assembler
  - Combines components and other software into application
- System Administrator
  - Configures and administrates the enterprise's computing and networking infrastructure



Software Components: Some Conclusions

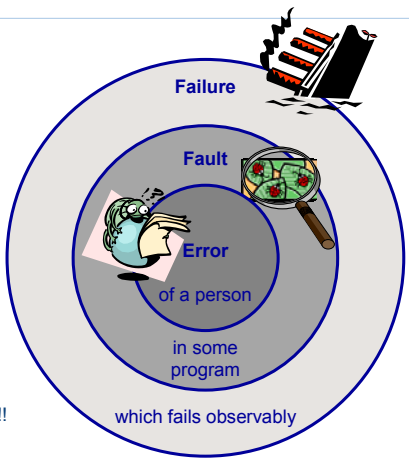
- Components could facilitate software reuse, but …
- Component specifications today are informal and (often) incomplete
  - Java/IDL-Interfaces (APIs) only specify types
  - (In EJB) focus on ensured interfaces
  - "Formal" specification for the "standard" life cycle only (state charts)
- Some more observations
  - Business operations most often only specified informally
  - Component Provider (normally) has
  - … no access to "real world" requirements
  - … no control over the components usage
  - Component deployer and application assembler (normally) have …
  - … no access to the components source code
  - … no control over the components maintenance and evolution
  - … no way to get rid of the components extra functionality

Where are we now?

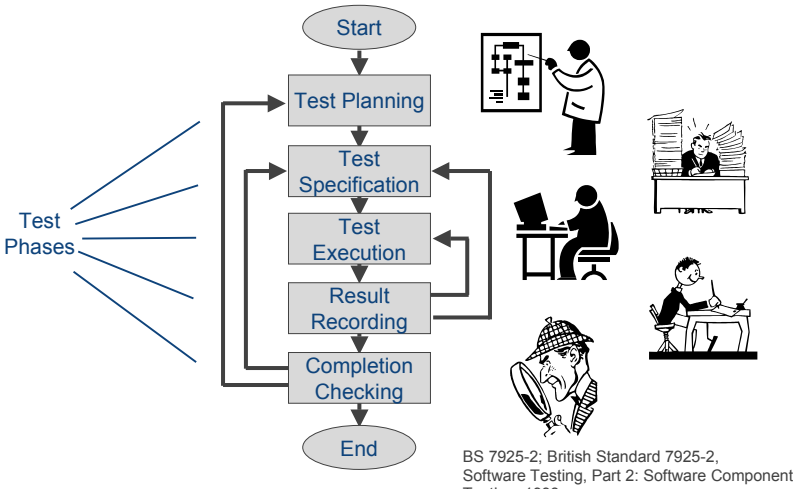
- What is the Component Age?
- **What is Testing?**
- Component Specification
- Component Testing

Why do we Test?

- Errare humanum est! (Err is human)
- Even with formal specification and program generation ...
  - Spec could be wrong
  - Generator doesn't work as expected
  - Platform doesn't work as expected
  - ...
- Testing checks that the Software
  - ... does what it should do and ...
  - ... doesn't what it shouldn't do
- But always remember that ...
  - ... „testing can only show the presence of faults (i.e. bugs), not their absence"!!! [E.W. Djikstra]

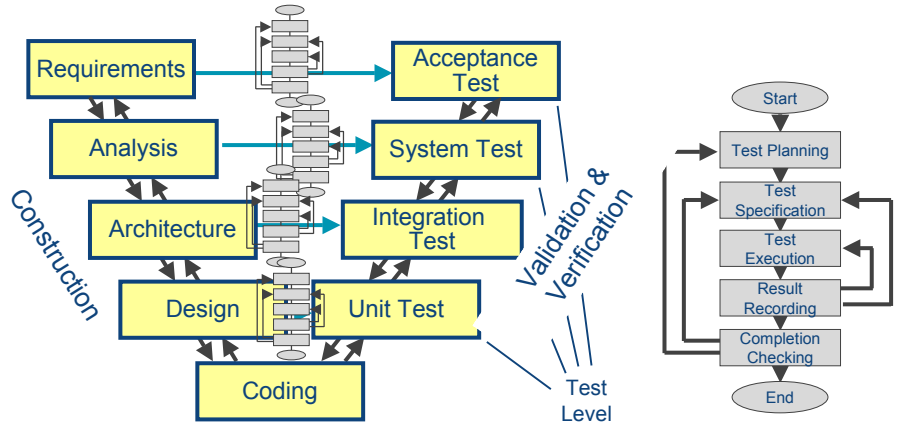


What is the Testing Process?



BS 7925-2; British Standard 7925-2, Software Testing, Part 2: Software Component Testing, 1998

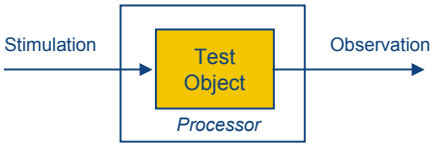
When do we Test?



→ Test cases based on work artifacts (documents)

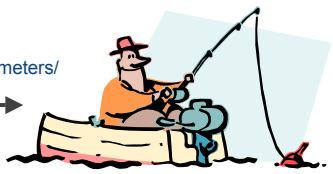
How do we Test?

- Static Testing
  - No executables necessary
  - Manually: reviews, inspections
  - Automated: source code analysis
- Dynamic Testing
  - Executables necessary
  - Test cases with input and expected behaviour/output
  - Test harness for unit and integration testing needed

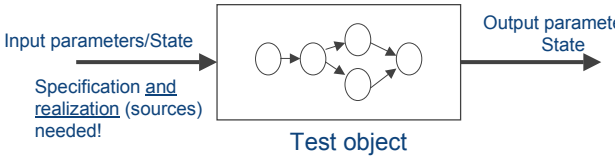


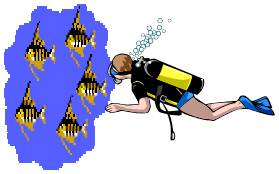
Black Box Testing vs. White Box Testing

Black Box Testing



White Box Testing

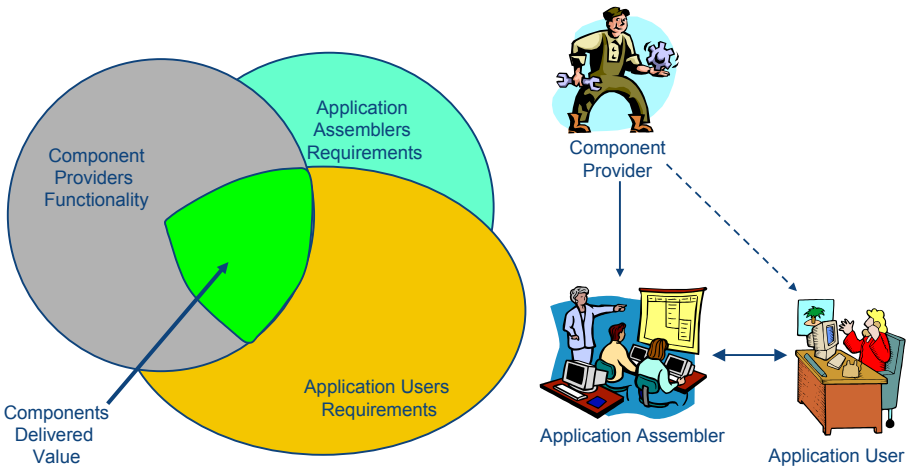




Where are we now?

- What is the Component Age?
- What is Testing?
- **Component Specification**
- Component Testing

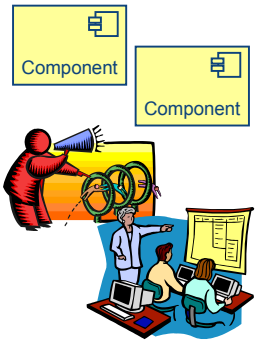
Who Specifies Components?



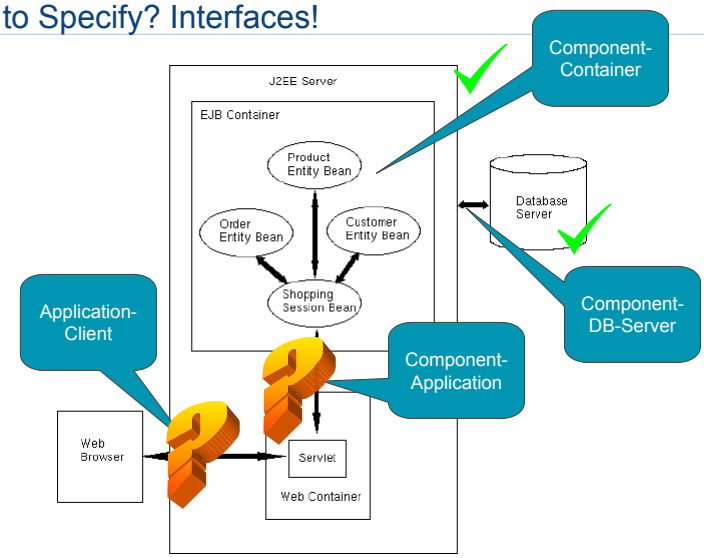
Is Component Specification Different?

Our observations on component software:

- Component Provider (normally) has
  - … no access to "real world" requirements
  - … no control over the components usage
- Component deployer and application assembler (normally) have …
  - … no access to the components source code
  - … no control over the components maintenance and evolution
  - … no way to get rid of the components extra functionality
- Component interfaces are the minimal contractual base between component provider and component customer (deployer / application assembler)
- Business operations most often only specified informally



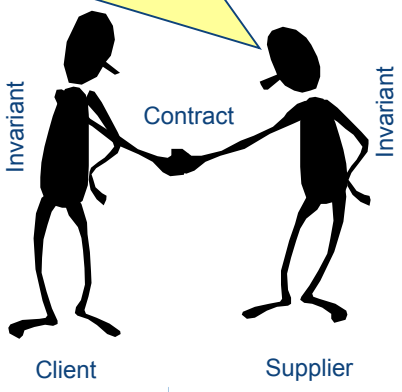
What to Specify? Interfaces!



How to Specify Interfaces? Design by Contract (B. Meyer)

If you promise to call me with the **precondition** satisfied then I, in return, promise to deliver a final state in which the **postcondition** (and my **invariant**) is satisfied

- Client uses suppliers (public) operations
  - Precondition = clients price
  - Postcondition = suppliers obligation
  - Invariant = "eternal" assumptions
- Contract
  - **Iff** the client satisfies the precondition, **then** the supplier guarantees the postcondition!
  - Client **and** supplier satisfy their invariants before and after each (public) operation execution
- A contract is a prescription, not only a description!



Specification of Component Interfaces with Assertions

- Precondition (of an operation)
  - States the properties that must hold whenever the operation is called.
  - Refers to input-parameters of the operation und the state of the component
- Postcondition (of an operation)
  - States the properties that the operation guarantees when it returns (assuming its precondition was satisfied)
  - Refers to output-parameters of the operation und the state of the component
- Both preconditions and postconditions describe properties of individual operations – but often there are more general properties
- Invariant (of the Component)
  - Expresses global properties of all instances of a component, which must be preserved by all operations
  - Refers to the state of the component
  - Must be satisfied before and after each execution of an operation

Example: BoundedStack (Stack with Bounded Capacity)

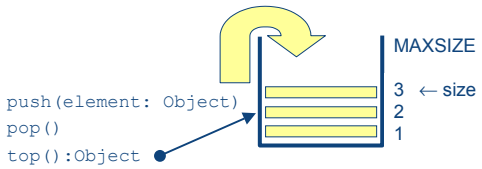
component BoundedStack

State preserving operations

```
size():integer;      // Number of elements
MAXSIZE(): integer; // Maximum count of elements
top():Object;       // Pointer to topmost element
```

State changing operations

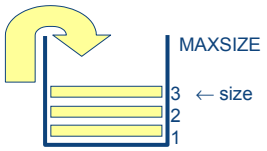
```
BoundedStack(maxSize: integer);// Constructor
~BoundedStack();               // Destructor
push(element: Object);         // Stack element on top
pop();                         // Removes topmost element
```



Contract of Component BoundedStack

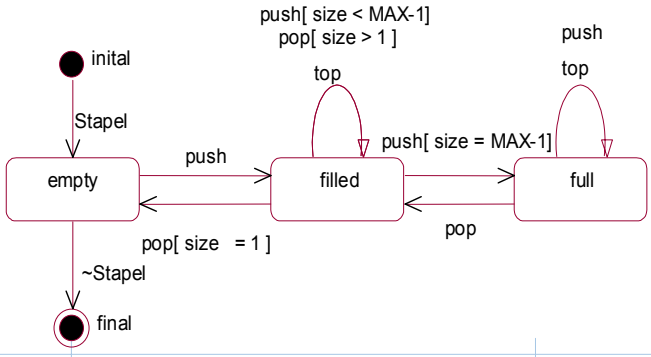

```
component BoundedStack {

        /** invariant@ self.size() >= 0 AND self.size() <= self.MAXSIZE() */

        public BoundedStack (Integer maxSize){
        /** pre@  maxSize > 0 */
        /** post@ self.MAXSIZE() = maxSize@pre */
        }
        public void push (Object item) throws FullStackException {
        /** pre@ self.size() < self.MAXSIZE() */
        /** post@ self.size() = self.size()@pre + 1 */
        }
        public Object top () throws EmptyStackException {
        /** pre@ self.size() > 0 */
        /** post@ return != null */
        }
        public void pop () throws EmptyStackException {
        /** pre@ self.size() > 0 */
        /** post@ self.size() = self.size()@pre - 1 */
        }
        public Collection all () {
        /** pre@ true */
        /** post@ (self.size() > 0 implies return.size() = self.size()) AND
                  (self.size() = 0 implies return = null)*/
        }
}
```

State-Based Specification for BoundedStack



Three (five) states:

```
empty:  size() = 0;
filled: 0 < size() < MAXSIZE();
full:   size() = MAXSIZE();
initial: before construction;
final:  after destruction;
```

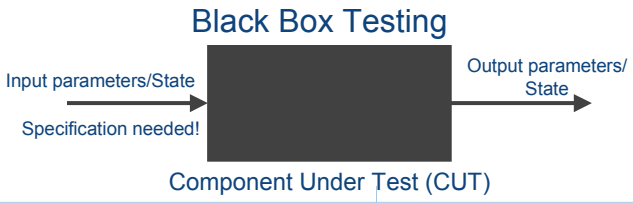


Where are we now?

- What is the Component Age?
- What is Testing?
- Component Specification
- **Component Testing**

Black Box Testing of Components

- Goal
  - Validation of the components interface, i.e. its public operations (and members)
- Value
  1. Conformance of the components realization w.r.t. its specification
  2. Robustness of the component
- Needs
  - Assertions, i.e. pre- and postconditions for each public operation of the component under test (CUT) together with its invariant
- Result
  - Reusable and extendable component test cases which validate the components interface conformance and its robustness



Contract-Based Test Cases for BoundedStack

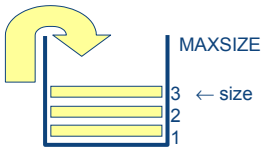
Conformance testing: precondition satisfied
Robustness testing: precondition not satisfied
Test oracle: postcondition satisfied

```
Context BoundedStack
invariant@ self.size() >= 0 AND
           self.size() <= self.MAXSIZE()
BoundedStack() pre@ maxSize > 0
BoundedStack()post@ self.size() = 0 AND
                    self.MAXSIZE() = maxSize
push() pre@ self.size() < self.MAXSIZE()
push() post@ self.size()=self.size()@pre+1
top() pre@ self.size() > 0
top() post@ return != null
pop() pre@ self.size() > 0
pop() @post self.size() = self.size()@pre – 1
all() pre@ true
all() post@ self.size() > 0 AND
            ( return.size() = self.size() OR
              not self.size() > 0 AND
              return = null )
```

TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
TRUE					
TRUE					
TRUE					
TRUE	TRUE				
–	TRUE				
FALSE	TRUE	TRUE			
–	–	TRUE			
FALSE	TRUE	TRUE	TRUE		
–	–	–	TRUE		
TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
–	–	–	–	FALSE	TRUE
–	–	–	–	dc	TRUE
–	–	–	–	TRUE	FALSE
–	–	–	–	TRUE	dc

Don't Care

Life Cycle-Based Test Cases (State Based)



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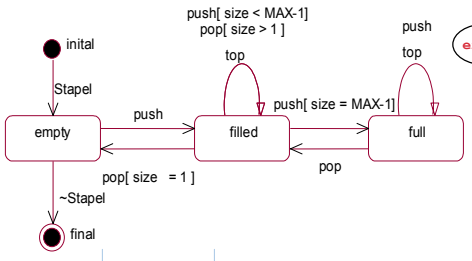
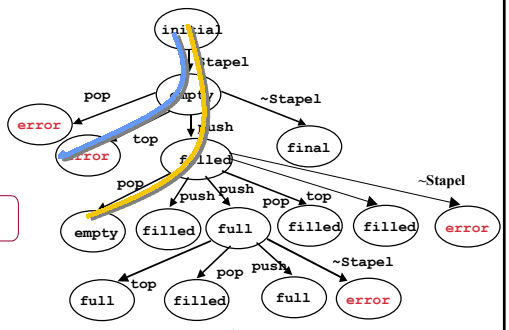


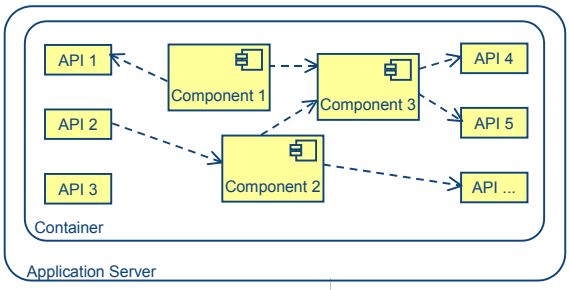


Applicable Black Box Testing Models and Methods

Specification	Type	Concrete Syntax	Method / Coverage Criteria
Contract based (declarative)	Formal language	UML-OCL	All conditions, MC/DC, ...
	Formal theory	Object-Z, VDM	All clauses
	Informal (natural language)	API	All functions
State based (operational)	Diagram with formal semantics	UML state chart	All states, all transitions, n-Paths, ..., all paths
Interaction based (operational)	Message based	SDL MSC,UML sequence diagram	All messages, all nodes, all branches, ..., all paths
	Structure based	UML communication diagram	All messages, all links
Function based (declarative/ operational)	Informal (natural language)	UML use case diagram	Normal flow, all alternate flows, ..., all flows
	Diagram with formal semantics	UML activity diagram	All actions, all transitions, n-Paths, ..., all paths
		UML sequence diagr.	All messages, all nodes, all branches, ..., all paths

Component Testing Levels

- Container test
  - Standard conformity, performance, robustness, …
- Component functional test
  - Standard conformity, delivered functionality, required functionality
- Component non-functional test
  - Deployability, robustness, performance, vulnerability, security, …
- Component integration test
  - Interoperability, …



Component Testing Viewpoints

- Container provider
  - Adheres to standards
  - Validates containers standard conformity
  - Provides black box standard conformity test cases

- Component provider
  - Provides specification (API + Assertions)
  - Validates component with black box and white box testing
  - Validates components standard conformity (Container provider / versions / ...)
  - Provides black box test cases
  - Confirms white box coverage (e.g. C1)

- Component deployer
  - Demands black box test cases (jUnit, ...)
  - Validates components deployability
  - Re-validates components delivered functionality

- Application assembler
  - Demands specification (API + Assertions)
  - Demands white box coverage
  - Validates components required functionality with more black box test cases

Some Lessons Learned

- Specify your requirements (!)
- Standardize your infrastructure
  - Application server provider / versions ...
  - Container provider / versions ...
  - Application architecture (product lines)
- Ask for component specification and test cases
- Automate your tests (regression testing will come)
- Ask for component maintenance and evaluation arrangements
- In doubt: ask for source code agreements!
- Educate your people
  - Component modelling, architecture, and design
  - Design by contract
  - Black box testing techniques

What Did We Cover?

- What is the Component Age?
  - Components are more than objects/classes
  - Reusability in predefined environments (application server, container, …)
  - New roles
- What is Testing?
  - Testing process: phases and levels
  - Black box vs. white box testing
- Component Specification
  - Specifications needed (especially for business operations)
  - Specify required / ensured interfaces
  - Use design by contract (pre- and post-conditions, invariants, exceptions)
- Component Testing
  - New testing viewpoints and levels
  - White box testing only for component provider
  - Do black box conformance and robustness testing
  - Ask for component specification and black box test cases

Literature and Links

- Booch, G., Rumbaugh, J. und Ja… …l.: The Unified Modeling Language. Addison-Wesley, 1999
- Sneed, H., Winter, M.: Testen objektorientierter Software – Das Praxishandbuch für den Test objektorientierter Client/Server-Systeme. Hanser Verlag, München, 2002
- Szyperski, C.: Component Software - Beyond Object-Oriented Programming. Addison-Wesley / ACM Press, 1998
- Sun Microsystems, Enterprise JavaBeans™ Specification, Version 2.0, 2000
- Weyucker, E.: Testing Component-Based Software: A Cautionary Tale. IEEE Software, Sept./Oct. 1998, pp. 54-57
- Winter, M: Testfallermittlung aus Komponentenschnittstellen. Beitrag zum Imbus QS-Tag 01, Nürnberg, 2001

- GI-TAV Arbeitskreis „Testen objektorientierter Programme“: Test von Komponenten. 18. GI-TAV Workshop, June 20./21. 2002, Hasso Plattner Institut, University of Potsdam
- GI Fachgruppe “Test, Analyse und Verifikation von Software” (TAV) www.gm.fh-koeln.de/~winter/tav Next Workshop: **17./18. February 2005, University of Appl. Sciences Bremen**