XOTcl @ Work

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What is XOTcl

- **XOTcl = Extended Object Tcl**
- **"High-level" object-oriented programming**
- **Advanced Component Glueing**

- **XOTcl is freely available from:** http://www.xotcl.org
- **Outline:**
  - Scripting and object-orientation
  - Programming the "basic" XOTcl Language
  - Component Glueing
  - XOTcl high-level language constructs
  - Some provided packages

Tcl-Strengths

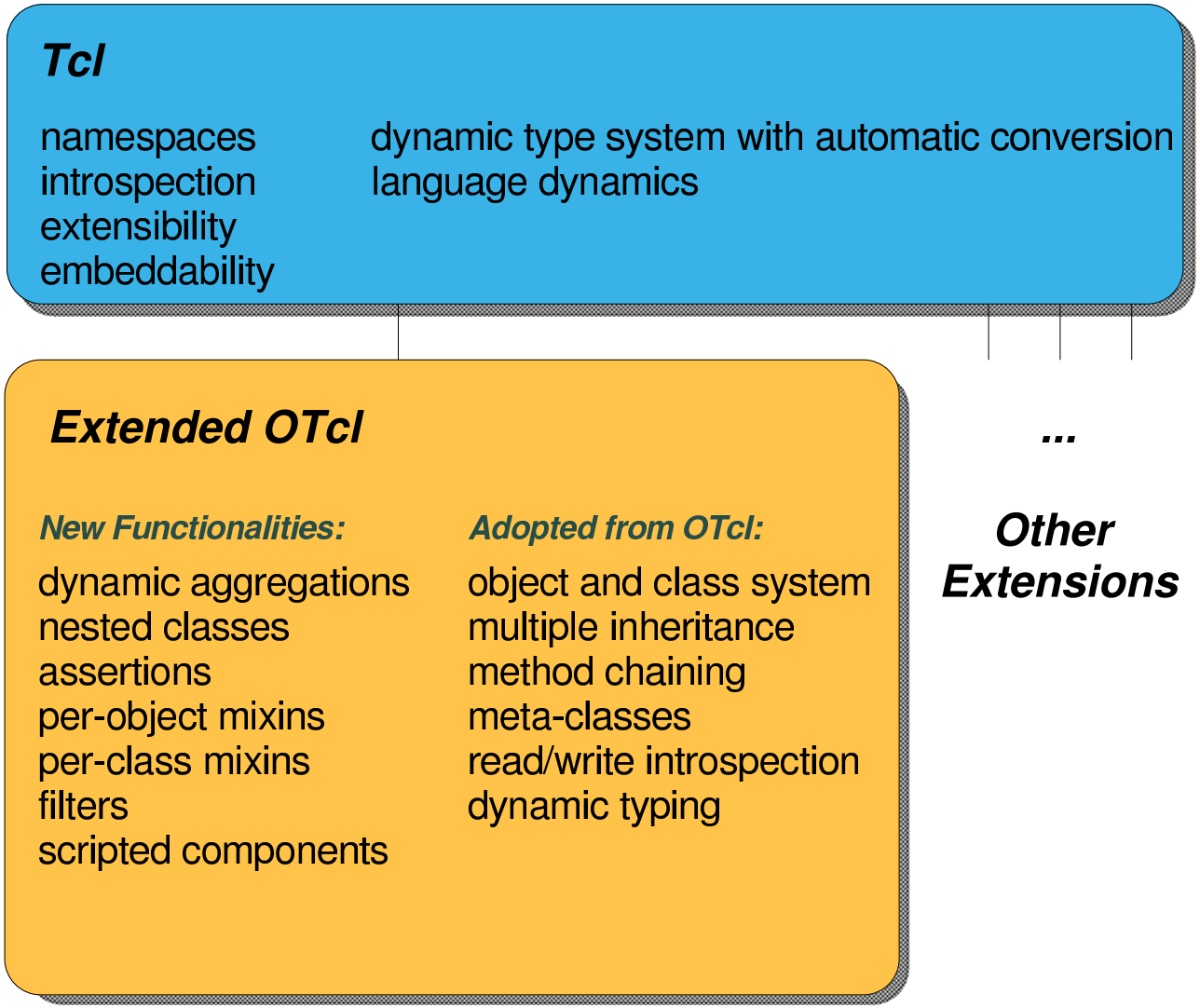
Important Ideas in Tcl:

- **Fast & high-quality development through component-based approach**
- **2 levels: "System Language" and "Glue Language"**
- **Flexibility through . . .**
  - Dynamic extensibility,
  - Read/write introspection,
  - Automatic type conversion.
- **Component-Interface through Tcl-Commands**
- **Scripting language for glueing**

Motivation for XOTcl

- **Extend the Tcl-Ideas to the OO-level.**
- **Just "glueing" is not enough! Goals are . . .**
  - Architectural support
  - Support for design patterns (e.g. adaptations, observers, facades, . . .)
  - Support for composition (and decomposition)
- **Provide flexibility rather than protection:**
  - Introspection for all OO concepts
  - All object-class and class-class relationships are dynamically changeable
  - Structural (de)-composition through *Dynamic Aggregation*
  - Language support for high-level constructs through powerful interceptors (*Filters* and *Per-Object Mixins*)

XOTcl Overview



XOTcl is similar Tcl

- **XOTcl is dynamic:**
  - Definitions of objects and classes can be extended and modified at runtime
  - Classes and objects can be dynamically destroyed
  - All relationships between object and classes are fully dynamic
- **XOTcl is fully introspectible with `info` methods**
- **Syntax similar to Tcl**
- **Objects and classes are Tcl commands**
- **Objects and classes "live" in a Tcl namespace**

Example: Soccer Team

- **Soccer team abstraction:**
  - Has members (players)
  - Has properties (name, location, type)
  - Players can be added and transfered
  - Each player has properties (name, player role)
- **Similar abstractions in many "real-world" applications**

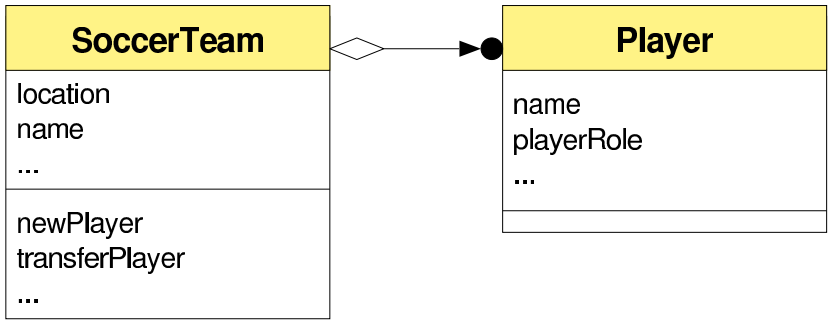
Soccer Team In Ordinary Tcl

```
set teams($teamid-name) "Schalke"                    ;# Associative array for teams
set teams($teamid-location) "Gelsenkirchen"
set teams($teamid-playerids) {}

set $id-players($playerid-name) "Emile Mpenza"       ;# Player array for each team
...

proc newPlayer {teamid name} {                       ;# Procedure
  global teams $teamid-players                       ;# Import global structure
  ...                                                ;# Work on global structure
  return $playerid
}
```

Problems: Missing data encapsulation, global data, name collision, no bundled behavior/data, no specialization/generalization, central modification is hard to achieve, ...

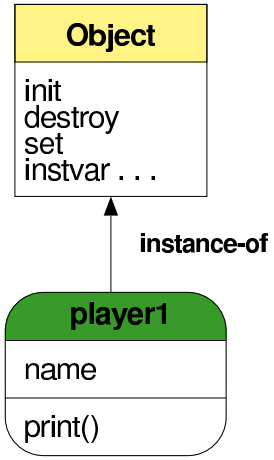
Object-Oriented Solution

- **Initial Design: Soccer team aggregates players.**
- **Used Concepts:**
  - Classes abstract over soccer team and player
  - Instance variables
  - Instance methods
  - 1-to-many relationship
  - (Dynamic) object aggregation



Objects in XOTcl

- Each created object has `Object` as class or superclass. Methods on `Object` are usable for all objects
- Each object can have object-specific variable slots and methods (`procs`)
- Variables and methods are stored in the object's namespace
- Each object has a class



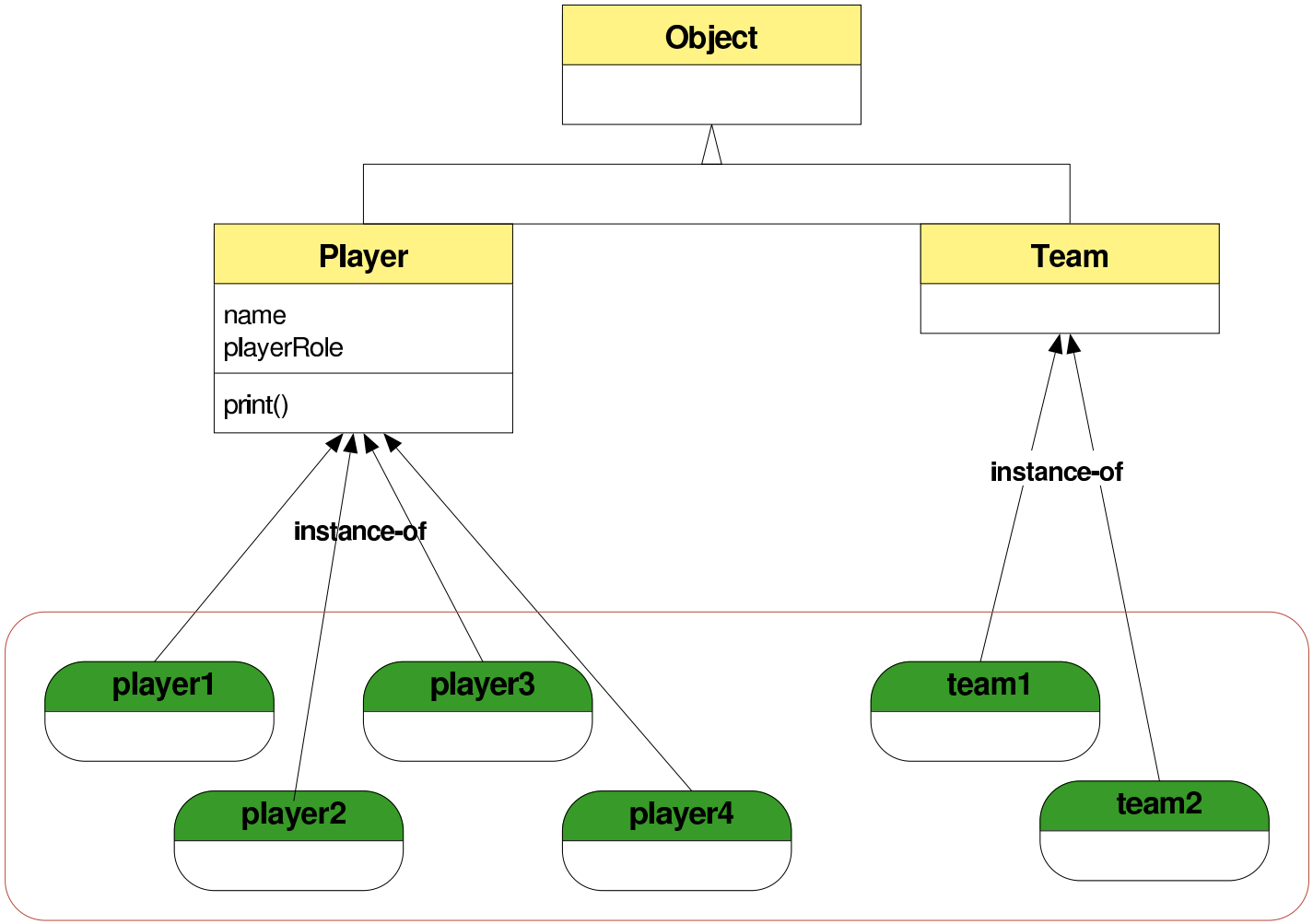
Creation and Definition of Objects

```
Object player1                                  ;# Object definition

player1 set name "Emile Mpenza"                 ;# Set instance variable

player1 proc print {} {                         ;# Print procedure for name
  [self] instvar name                           ;# Get var into proc scope
  puts "Name:        $name"                     ;# Print name to stdout
}

player1 print                                   ;# Call ‘‘print’’

player1 destroy                                 ;# And delete player object
```

Objects versus Classes

- **Instances (objects) can be derived from a class**
- **A class describes the intrinsic type of an object:**
  - Common data slots
  - Instance methods (`instprocs`)
  - ...
- **Classes in XOTcl "know" about their instances and vice versa (introspection)**
- **Classes in XOTcl have all object abilities plus class abilities:**
  - Deriving objects
  - Instance method definition
  - Inheritance
  - ...

Class Instances



Classes

is-instance-of relationship

Objects

Class Definition and Instance Methods on Classes

```
Class Player -parameter {                          ;# Class definition
  name
  {playerRole NONE}
}
Player instproc print {} {                         ;# Print instance method
  [self] instvar name playerRole
  puts "Name:        $name"
  puts "Player Role: $playerRole"
}

Player emile -name "Emile Mpenza" \                ;# Definition of a player object
  -playerRole Forward

emile print                                        ;# Calling print operation
```

Stepwise refinement of class definition, syntax & conventions similar to Tcl

Object Construction/Destruction

- **Constructor – Special instance method `init`:**

```
Player instproc init args {
  # perform initializations
}
Player p -name "My Name"
```

- **Destructor – Special instance method `destroy`:**

```
Player instproc destroy args {
  # perform destruction
}
p destroy
```

Introspection

- **In XOTcl every language is introspective and dynamic ⇒ Similar to Tcl.**
- **Using the `info` instance method.**
- **Example – Reading instproc definition:**
  ```
  Player info instbody print
  ```
- **Example – List of instances:**
  ```
  Player info instances
  ```
- **Object- vs. class-specific introspection options. Example – Obtaining an object's class:**
  ```
  player1 info class
  ```

Callstack Information

- **Retrieve information that is dynamically created on the callstack:**

`self`	current object name
`self class`	current class name
`self proc`	current proc/instproc name
`self callingobject`	calling class name
`self callingclass`	calling object name
`self callingproc`	calling proc/instproc name
...	...

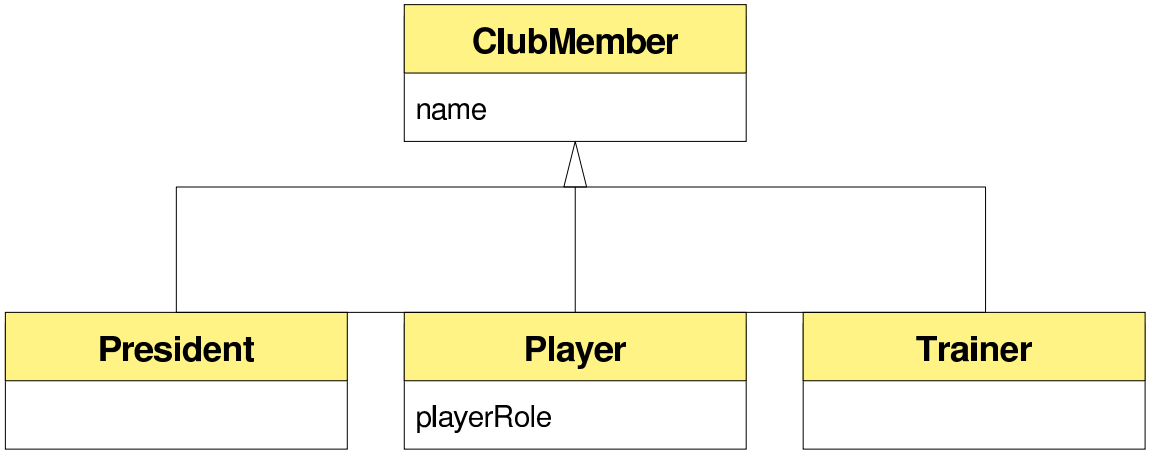
- **Example – Discriminating on calling object type:**

```
Player instproc reactOnPlayer {} {
  set co [self callingobject]
  if {[$co istype Player]} {...}
  ...
}
```

```
# example instproc
# get calling object
# type => player-specific behavior
# else: default behavior
```

Inheritance

- **Defining a class hierarchy with "is-a" relationships**
- **Generalization/specialization ⇒ Reusing class definitions**

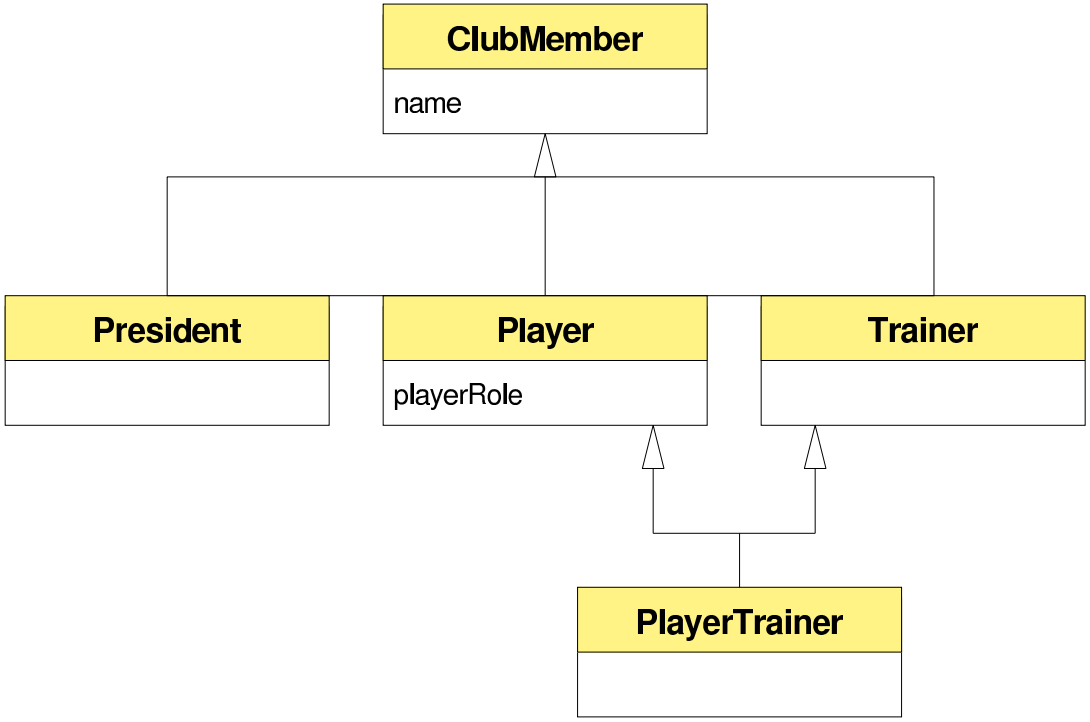



```
Class ClubMember -parameter {name}
Class Player -superclass ClubMember -parameter {{playerRole NONE}}
Class Trainer -superclass ClubMember
Class President -superclass ClubMember
```

Multiple Inheritance

- **Multiple Inheritance = one class has more than one superclass**
- **Directed Acyclic Graph**

→ **Linearization with Method Chaining**




```
Class PlayerTrainer -superclass {Player Trainer}
```

Method Overloading and Next Path

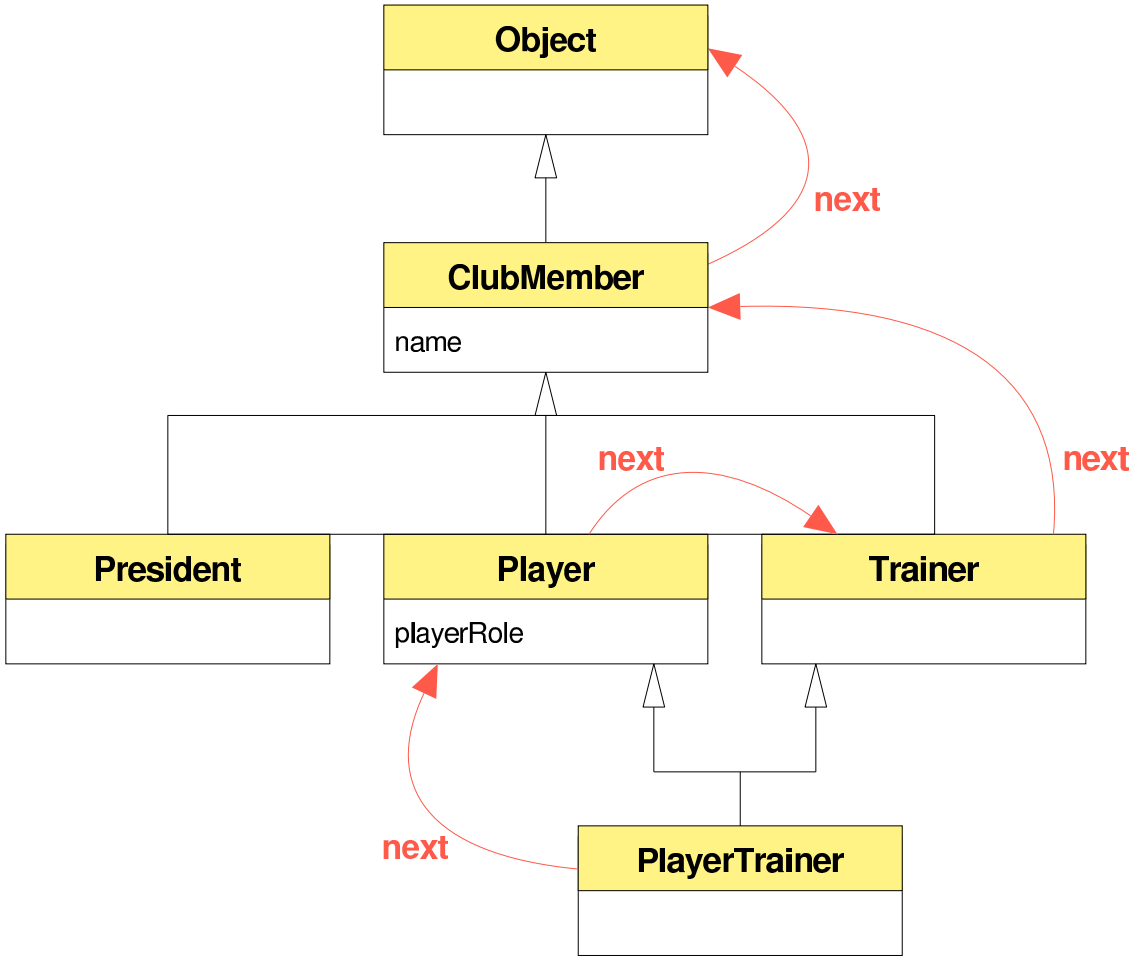
- Each method call is performed on an object
- If the method is not defined on the object, then the class and its superclasses are searched
- If the method is found it may contain a `next` call.
- Then the "`next`" method on the class graph is searched and mixed into the current method
- "`next`" determines if, at which position, and with which arguments the next method is called
- Per default, "`next`" calls with the same arguments

Method Chaining: Extending Print Operation

```
Class ClubMember -parameter {name}                ;# Class definition
ClubMember instproc print {} {                    ;# Default print operation
  [self] instvar name
  puts "Name:        $name"                       ;# Print ‘‘name’’
  next
}
Class Player -superclass ClubMember \             ;# Subclass definition
  -parameter {{playerRole NONE}}
Player instproc print {} {                        ;# Extended print operation
  [self] instvar playerRole
  puts "Player Role: $playerRole"                 ;# Print player role
  next                                            ;# Call superclass implementation
}
```

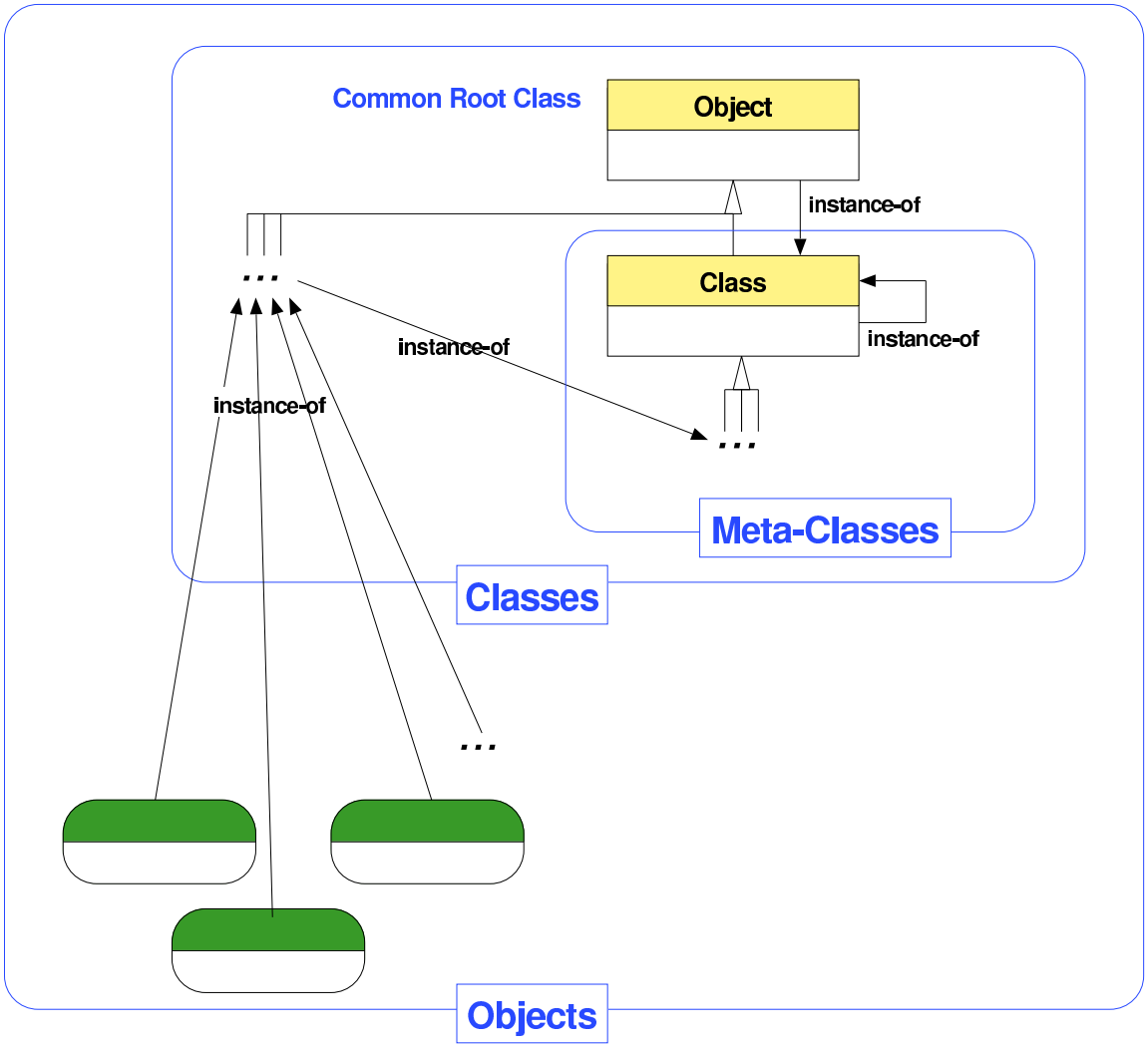
Composability: `next` functions without naming the targeted superclass.

Method Chaining: Next Path for Player Trainer



Class-Path Linearization: Each class is visited once. Unambigous precedence order.

XOTcl Class and Object System



Dynamic Re-Classing

- **Dynamic classes and superclasses ⇒ Modeling life-cycle of objects.**
- **Example – Player becomes president:**

```
Player p -name "Franz Beckenbauer" \          ;# Create player
  -playerRole PLAYER
...                                           ;# Life-cycle induces change
$fb class President                           ;# Reclassing to President
```

- **Redefining class behavior may imply modifications → specializing `class`:**

```
Player instproc class args {                  ;# Specializing class operation
  [self] unset playerRole                     ;# Delete player role property
  next                                        ;# Call Object->class
}
```

Dynamic Object Aggregation

- *Dynamic object aggregation*: **An object system supports dynamic aggregation iff arbitrary objects may be aggregated or disaggregated at arbitrary times during execution.**

```
Class Stadium                              ;# Class for stadium
Class SoccerTeam                           ;# Soccer team class
SoccerTeam instproc init args {            ;# Constructor
  Stadium [self]::homeStadium              ;# Automatically aggregate stadium
  next
}
SoccerTeam bayern                          ;# New team instantiation
President bayern::president \              ;# Aggregate president
  -name "Franz Beckenbauer"
bayern::president destroy                  ;# President leaves club -> disaggregate
```

Object Aggregation – Examples

Aggregate with autoname:

```
SoccerTeam instproc newPlayer args {
  eval Player [self]::[[self] autoname player%02d] $args
}
```

Iterate over children:

```
SoccerTeam instproc printMembers {} {
  puts "Members of [[self] name]:"
  foreach m [[self] info children] {puts "  [$m name]"}
}
```

Retrieving club name from parent:

```
ClubMember instproc getClubName {} {
  return [[[self] info parent] name]
}
```

Object Aggregation – Life-Cycle Issues

- *Object creation*: **Every object is created with an identifier that is unique in the scope where it was created**

- *Object hierarchy restructuring*: **A copy/move/delete operation works on the subtree of the object hierarchy starting with the named object**

```
SoccerTeam instproc transferPlayer {playername destinationTeam} {
  foreach player [[self] info children] {
    if {[$player istype Player] && [$player name] == $playername} {
      $player move [set destinationTeam]::[$destinationTeam autoname player%02d]
    }
  }
}
```

- **Object aggregation implies that the whole has responsibility of the life-time of the parts**

Dynamic Component Loading in XOTcl

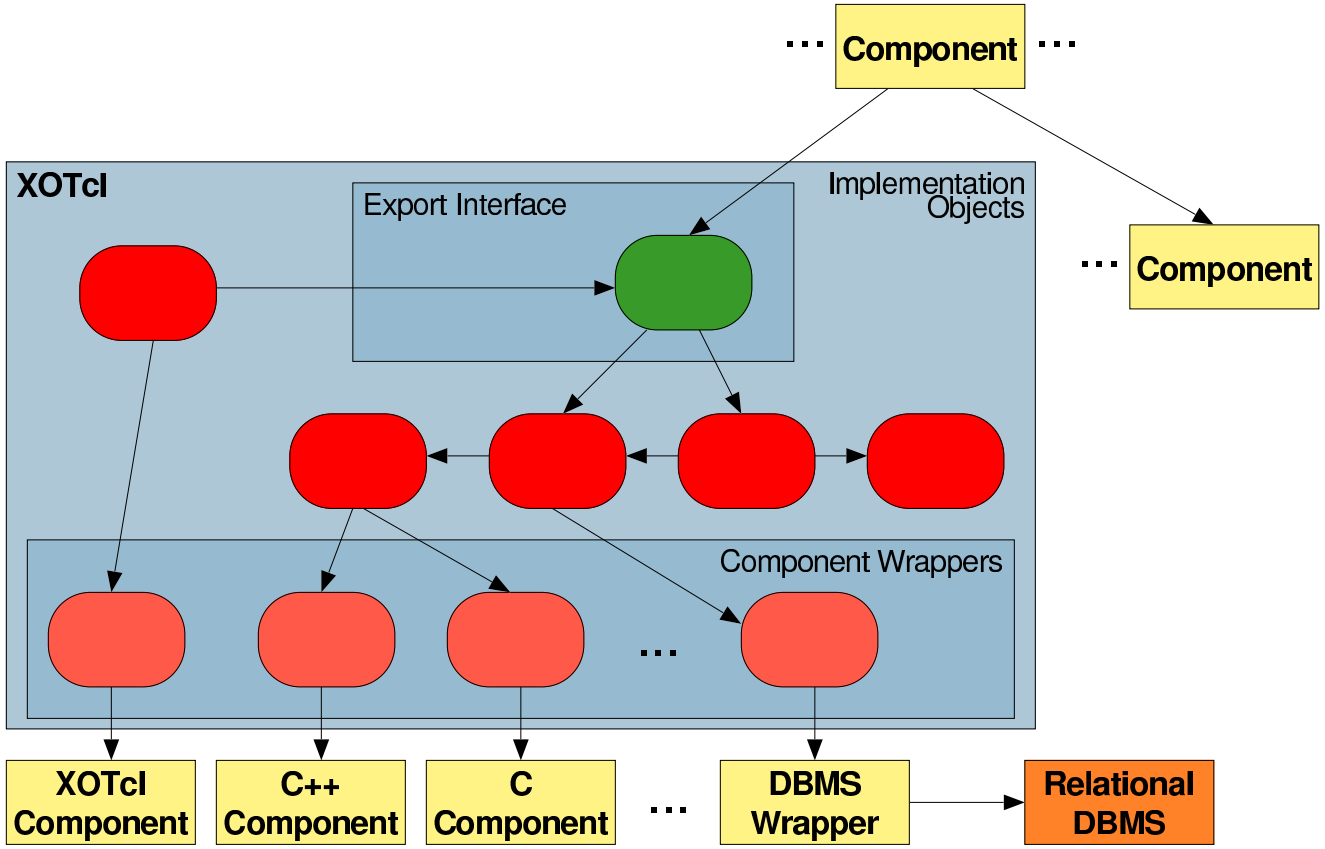
- **Component in XOTcl:**
  - Any assembly of several structures, like objects, classes, procedures, functions, etc.
  - Granularity: self-contained entity, i.e. subsystem or substantial part of a subsystem

- **Component has to declare its name and optional version information with:**
  `package provide` ***componentName ?version?***

- **Component can be loaded with:**
  `package require` ***componentName ?version?***

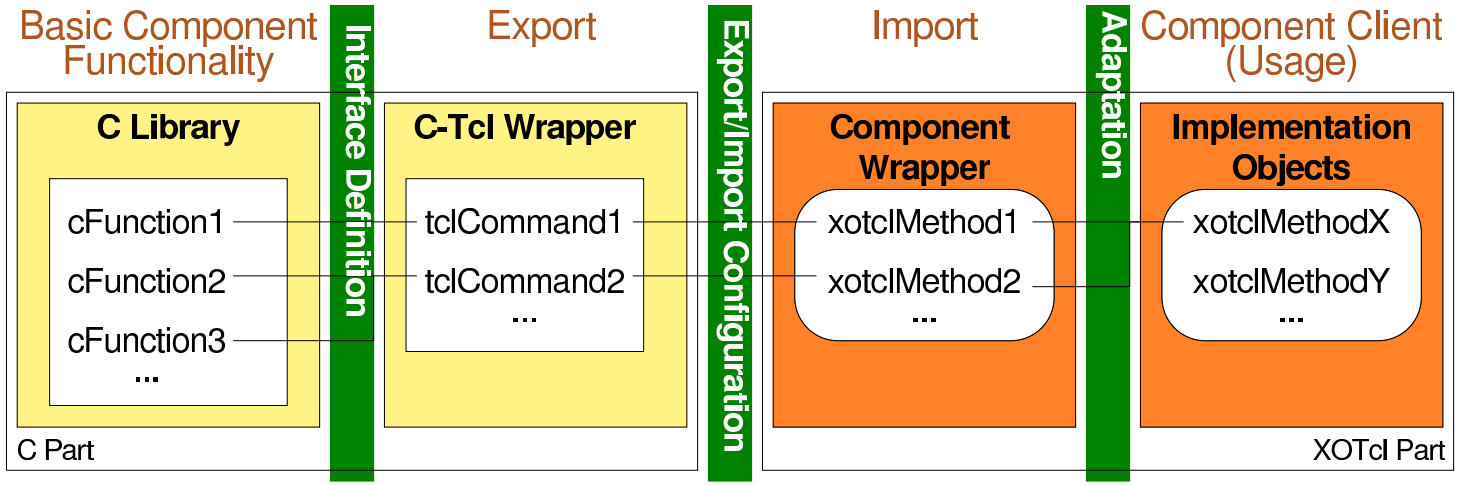
- **Automatic component indexing, tracking, and tracing**

Component Wrapping



Component Wrapper: White-box placeholder for (multi-paradigm) components → Place for central adaptations, decorations, etc.

Wrapping a C Component with Explicit Export/Import



- **Many different component wrapping schemes: Wrapper Facade, Proxy, . . .**
- **Different configurations: Tcl C Wrapper, XOTcl C Wrapper, . . .**
- ***Three-Level Component Configuration*: Make export and import explicit, first-class objects**

→ **Dynamic, runtime replaceability**

Problems of a Pure Class-Based Implementation

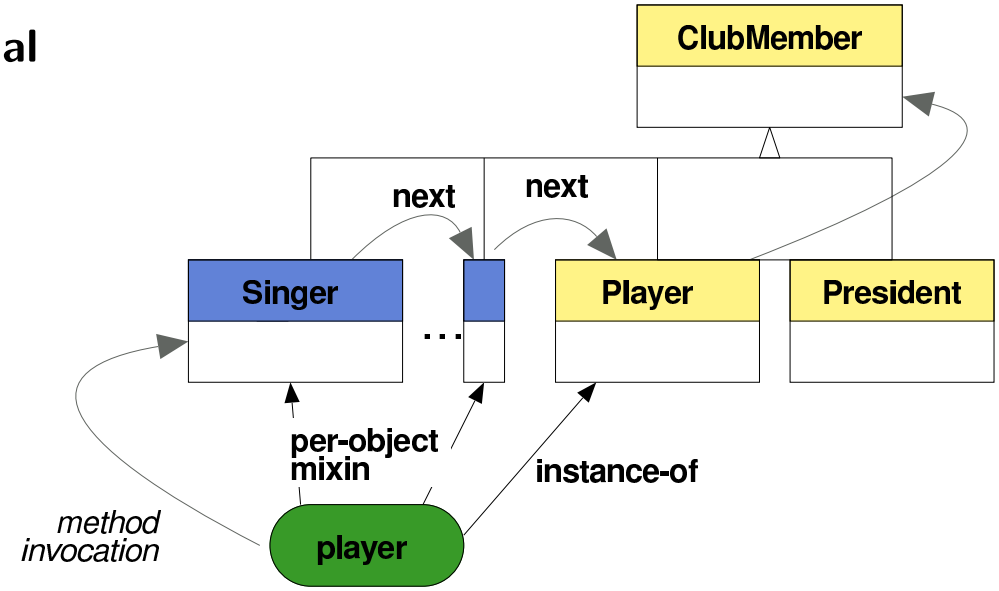
- **Transparency** – The client should not rely on concrete implementation details.
- **Decoration/Adaptation:**
  - Concerns that cross-cut the component wrapper hierarchy,
  - Object-specific component wrapper extensions or adaptations.
- **Coupling of Component and Wrapper**
  - Should appear as one runtime entity,
  - But: Should be decomposed in the implementation.
- **Component Loading** – Dynamical and Traceable

⇒ **Interception Techniques for Flexible Component Wrapping**

Per-Object Mixins for Object-Specific Extensions

A per-object mixin is a class which is mixed into the precedence order of an object in front of the precedence order implied by the class hierarchy.

- **Model behavioral extension for individual objects (Decorator).**
- **Model Adapter for individual objects.**
- **Handle orthogonal aspects not only through multiple inheritance.**
- **Intrinsic vs. extrinsic behavior, similar to roles.**



Example Code for Per-Object Mixins

```
Player bayern::franz \                          ;# Player object
  -name "Franz Beckenbauer"

Class Singer                                    ;# Define the singer class
Singer instproc sing text {                     ;# Singing method
  puts "[[self] name] sings: $text, lala."
}

bayern::franz mixin Singer                      ;# Register class as per-object mixin

bayern::franz sing "lali"                       ;# Perform singing

bayern::franz mixin {}                          ;# Better stop it
```

Per-Class Mixins

A per-class mixin is a class which is mixed into the precedence order of the instances of a class and all its subclasses.

Example – Observing the player transfer operation:

```
Class TransferObserver                              ;# Class definition
TransferObserver instproc transferPlayer \          ;# Transfer observer method
  {pname team} {
  puts "Player '$pname' is transfered."
  puts "Destination Team '[$team name]'"
  [self] set transfers($pname) $team
  next
}

SoccerTeam instmixin TransferObserver               ;# Per-class mixin registration

bayernMunich transferPlayer \                       ;# Example transfer
  "Giovanne Elber" chelsea
```

Architectural Constraints

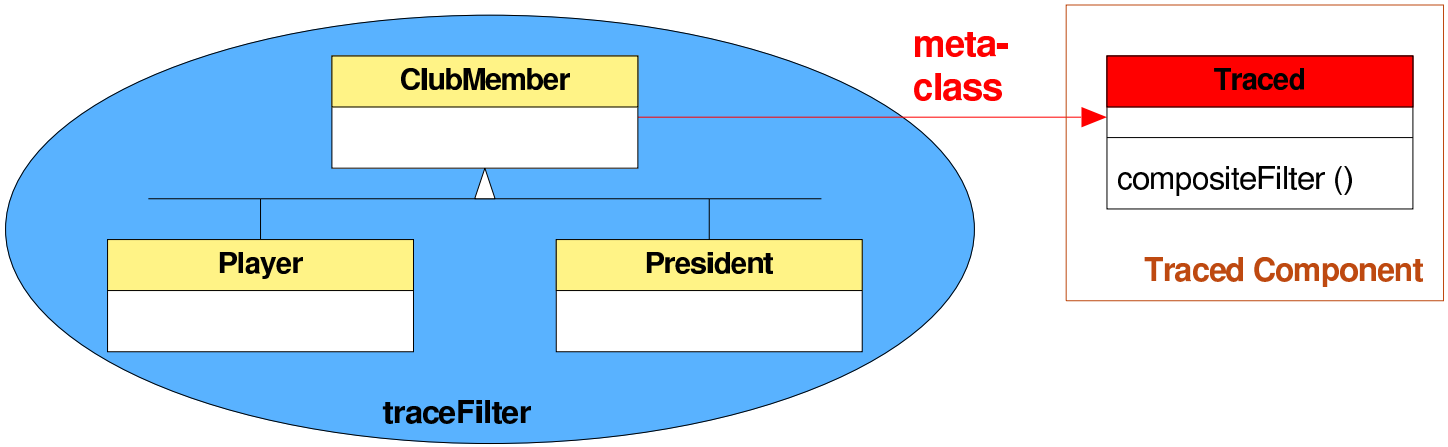
- **Restrict dynamic classes of sub-hierarchy to be static.**
- **Requests are split objects with C++ objects $\Rightarrow$ Dynamic classing is impossible.**

```
Class RestrictToSubClassOfRequest
RestrictToSubClassOfRequest instproc class args {
  set cl [[self] info class]
  next
  if {![[self] istype Request]} {
    [self] class $cl
  }
}
Request instmixin RestrictToSubClassOfRequest
```

Filters for Cross-Cutting Concerns

A filter is a special instance method registered for a class C. Every time an object of class C receives a message, the filter is invoked automatically.

→ Aspects that cross-cut several classes in a hierarchy.



Example: Trace Filter Definition

```
package provide xotcl::Traced 0.8                    ;# Define component
...
Class Traced -superclass Class                       ;# Meta-class definition
Traced instproc traceFilter args {                   ;# Trace filter method
  set r [self calledproc]                            ;# Get callstack info
  if {[[self regclass] exists operations($r)]} {     ;# Check for registered operation
    puts stderr "CALL [self]->$r"                    ;# Print to stderr
  }
  return [next]                                      ;# Perform target operation
}
Traced instproc init args {                          ;# Meta-class constructor
  [self] array set operations {}
  next
  [self] filterappend Traced::compositeFilter        ;# Register filter
}
```

Example: Traced Filter Usage

```
package require xotcl::Traced                    ;# Load component dynamically
...
Traced ClubMember \                              ;# Define traced class
  -addOperations {name ...}                      ;# Add traced operations

Class Player -superclass ClubMember              ;# Define different subclasses
Class President -superclass ClubMember           ;# => They are also traced now
```

Self-Documentation

- **XOTcl contains self-documentation/metadata facility with @**
- **Components:**
  - Static metadata analysis,
  - Dynamic metadata analysis,
  - HTML generation.
- **Syntax similar to definition of described constructs.**
- **Flexibly extensible with new tokens and properties.**
- **Per-default: not interpreted $\Rightarrow$ no memory/performance wasted, if runtime metadata is not required.**

Self-Documentation Examples

- **Example – Describing a class:**

```
@ Class SoccerTeam {
  description {A soccer team class.}
}
```

- **Example – Describing a method:**

```
@ SoccerTeam instproc transferPlayer {
  player "name of the player to transfer"
  team "destination team"
} {
  Description {
    Move player object into destination team.
  }
  return "empty string"
}
```

XOTcl Component Library & Application

- **XOTcl contains rich component library:**
  - Object persistence
  - XML parser and interpreter framework
  - RDF parser and interpreter framework
  - HTTP Server
  - Client-side of various web protocols (HTTP, FTP, LDAP, ...)
  - ActiWeb: Active Web Objects and Mobile Code
  - Reusable pattern implementations
  - ...
- **Example Applications**
- **Regression Test Suite**
- **Documentation (Tutorial, Language Reference, Papers, Articles, etc.)**

How to get involved

- **Download XOTcl from** http://www.xotcl.org
  - Source Distribution
  - Linux Binaries & RPMs (Red Hat, Debian)
  - Windows Binaries

- **Mailing List with Archives at:**
  http://wi.wu-wien.ac.at/mailman/listinfo/xotcl