Java Specialists in Action

Using dynamic proxies to write less code

Introduction

- **Heinz Kabutz**
- **Java Programmer since 1997**
- **Publisher of The Java™ Specialists' Newsletter**
  - **http://www.javaspecialists.co.za**
- **Read in 111 countries by about 20000 Java developers**
  - **Not for Java beginners ☺**

Questions

- **Please please please please ask questions!**
- **There *are* some stupid questions**
  - **They are the ones you didn't ask**
  - **Once you've asked them, they are not stupid anymore**
- **Assume that if you didn't understand something that it was my fault**
- **The more you ask, the more interesting the talk will be**

Introduction to Topic

- **In this talk, we will look at:**
  - **Design Patterns**
  - **Dynamic Proxies in Java**
  - **Soft, Weak and Strong references**
- **For additional resources, or to find out how "hi there".equals("cheers!") == true, visit:**
  - **The Java™ Specialists' Newsletter**
  - **http://www.javaspecialists.co.za**

Design Patterns

- **Mainstream of OO landscape, offering us:**
  - **View into brains of OO experts**
  - **Quicker understanding of existing designs**
    - **e.g. Visitor pattern used by Annotation Processing Tool**
  - **Improved communication between developers**
  - **Readjusting of "thinking mistakes" by developers**

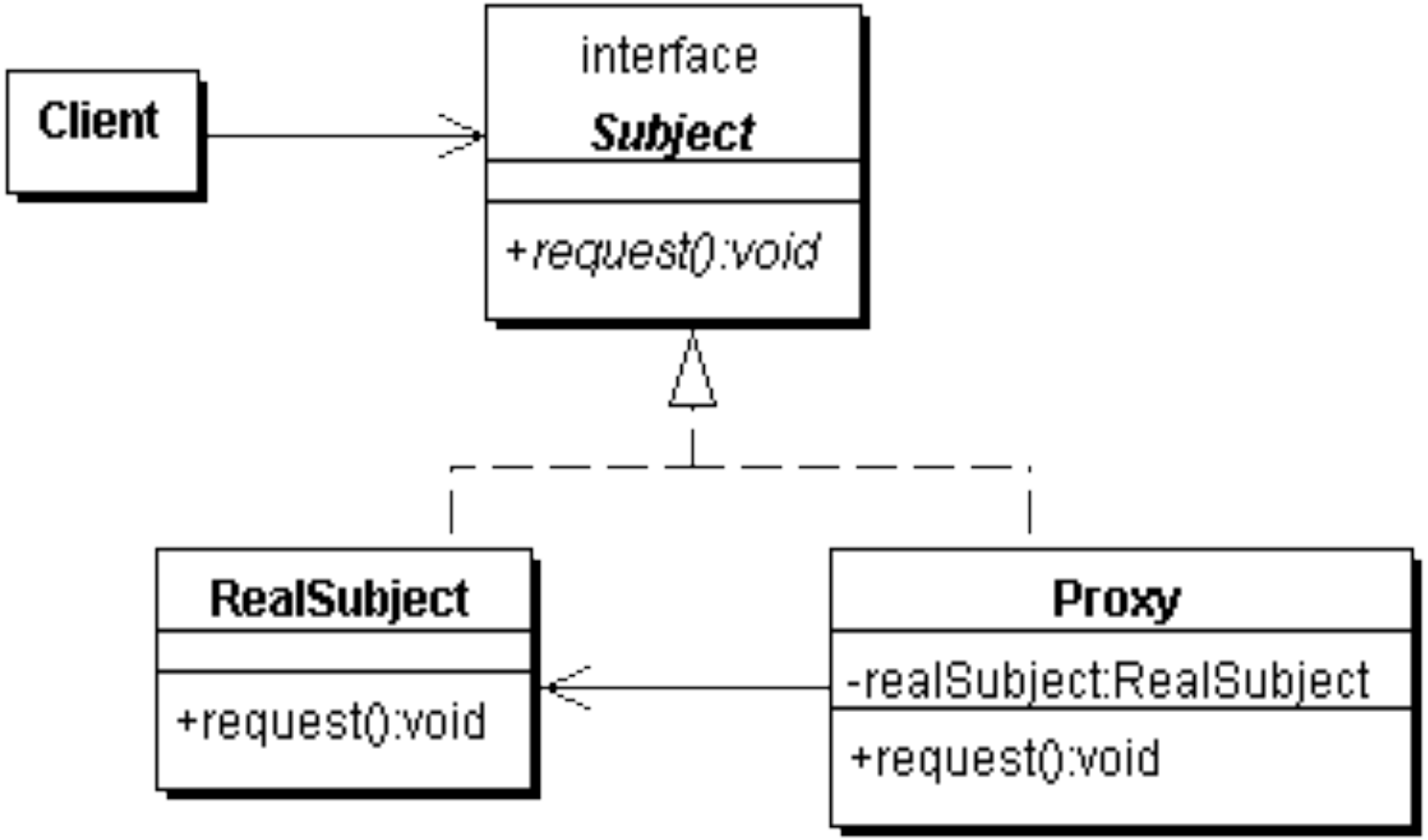
Vintage Wines

- **Design Patterns are like good red wine**
  - **You cannot appreciate them at first**
  - **As you study them you learn the difference between *plonk* and vintage, or bad and good designs**
  - **As you become a connoisseur you experience the various textures you didn't notice before**
- **Warning: Once you are hooked, you will no longer be satisfied with inferior designs**

Proxy Pattern

- **Intent [GoF95]**
  - **Provide a surrogate or placeholder for another object to control access to it.**

Proxy Structure



Types of Proxies

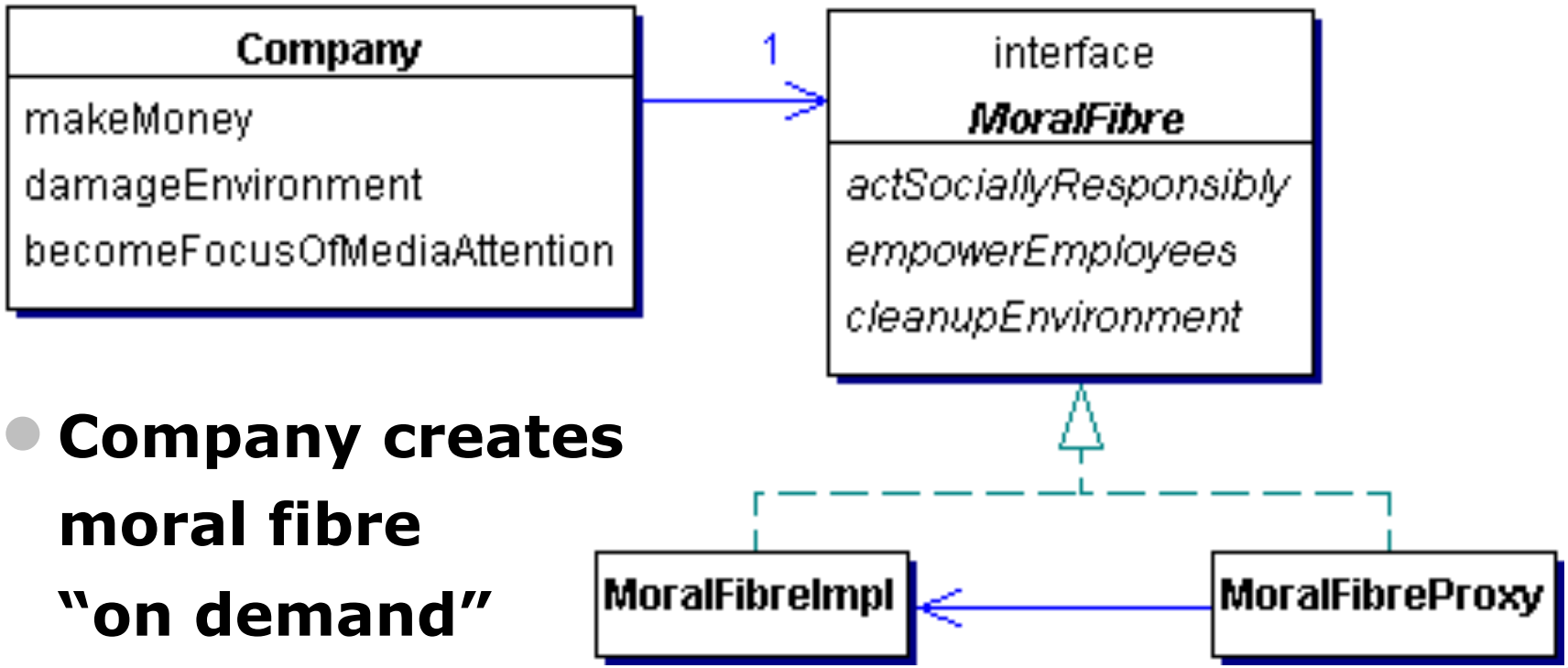
We will focus on this type

- **Virtual Proxy**
  - **creates expensive objects on demand**
- **Remote Proxy**
  - **provides a local representation for an object in a different address space**
- **Protection Proxy**
  - **controls access to original object**

Approaches to writing proxies

- **Handcoded**
  - **Only for the very brave … or foolish**
- **Autogenerated code**
  - **RMI stubs and skeletons created by rmic**
- **Dynamic proxies**
  - **Available since JDK 1.3**
  - **Dynamically creates a new class at runtime**
  - **Flexible and easy to use**

Model for example



- **Company creates moral fibre "on demand"**

```
public class Company {
  // ...
  private final MoralFibre moralFibre; // set in constructor

  public void becomeFocusOfMediaAttention() {
    System.out.println("Look how good we are...");
    cash -= moralFibre.actSociallyResponsibly();
    cash -= moralFibre.cleanupEnvironment();
    cash -= moralFibre.empowerEmployees();
  }


  @Override
  public String toString() {
    Formatter formatter = new Formatter();
    formatter.format("%s has $ %.2f", name, cash);
    return formatter.toString();
  }
}
```

```
public class MoralFibreImpl implements MoralFibre {
  // very expensive to create moral fibre!
  private byte[] costOfMoralFibre = new byte[900 * 1000];

  { System.out.println("Moral Fibre Created!"); }
  // AIDS orphans
  public double actSociallyResponsibly() {
    return costOfMoralFibre.length / 3;
  }
  // shares to employees
  public double empowerEmployees() {
    return costOfMoralFibre.length / 3;
  }
  // oiled sea birds
  public double cleanupEnvironment() {
    return costOfMoralFibre.length / 3;
  }
}
```

Handcoded Proxy

- **Usually results in a lot of effort**
- **Good programmers have to be lazy**
  - **DRY principle**
    - **Don't repeat yourself**
- **Shown just for illustration**

```
public class MoralFibreProxy implements MoralFibre {
  private MoralFibreImpl realSubject;
  public double actSociallyResponsibly() {
    return realSubject().actSociallyResponsibly();
  }
  public double empowerEmployees() {
    return realSubject().empowerEmployees();
  }
  public double cleanupEnvironment() {
    return realSubject().cleanupEnvironment();
  }
  private MoralFibre realSubject() {
    if (realSubject == null) { // need some synchronization
      realSubject = new MoralFibreImpl();
    }
      return realSubject;
  }
}
```

```
import static java.util.concurrent.TimeUnit.SECONDS;

public class WorldMarket0 {
  public static void main(String[] args) throws Exception {
    Company maxsol = new Company("Maximum Solutions",
        1000 * 1000, new MoralFibreProxy());
    SECONDS.sleep(2); // better than Thread.sleep(2000);
    maxsol.makeMoney();
    System.out.println(maxsol);
    SECONDS.sleep(2);
    maxsol.damageEnvironment();
    System.out.println(maxsol);
    SECONDS.sleep(2);
    maxsol.becomeFocusOfMediaAttention();
    System.out.println(maxsol);
  }
}
```

```
Oh goodie!
Maximum Solutions has $ 2000000.00
Oops, sorry about that oilspill...
Maximum Solutions has $ 8000000.00
Look how good we are...
Moral Fibre Created!
Maximum Solutions has $ 7100000.00
```

Dynamic Proxies

- **Allows you to write a method call handler**
  - **Is invoked every time any method is called on interface**
  - **Previous approach broken – what if toString() is called?**
- **Easy to use**
  - **But, seriously underused feature of Java**

Strong, Soft and Weak References

- **Java 1.2 introduced concept of soft and weak references**
- **Weak reference is released when no strong reference is pointing to the object**
- **Soft reference can be released, but will typically only be released when memory is low**
  - **Works correctly since JDK 1.4**

Object Adapter Pattern – Pointers

- **References are not transparent**
- **We make them more transparent by defining a Pointer interface**
  - **Can then be Strong, Weak or Soft**

```
public interface Pointer<T> {
  void set(T t);
  T get();
}
```

```
public class StrongPointer<T> implements Pointer<T> {
  private T t;
  public void set(T t) { this.t = t; }
  public T get()       { return t; }
}

import java.lang.ref.Reference;
public abstract class RefPointer<T> implements Pointer<T> {
  private Reference<T> ref;
  protected void set(Reference<T> ref) { this.ref = ref; }
  public T get() { return ref == null ? null : ref.get(); }
}

import java.lang.ref.SoftReference;
public class SoftPointer<T> extends RefPointer<T> {
  public void set(T t) { set(new SoftReference<T>(t)); }
}

import java.lang.ref.WeakReference;
public class WeakPointer<T> extends RefPointer<T> {
  public void set(T t) { set(new WeakReference<T>(t)); }
}
```

Using Turbocharged enums

- **We want to define enum for these pointers**
- **But, we don't want to use switch**
  - **Switch and multi-conditional if-else are anti-OO**
  - **Rather use inheritance, strategy or state patterns**
- **Enums allow us to define abstract methods**
  - **We implement these in the enum values themselves**

```
public enum PointerType {
  STRONG { // these are anonymous inner classes
    public <T> Pointer<T> make() { // note the generics here
      return new StrongPointer<T>();
    }
  },
  WEAK {
    public <T> Pointer<T> make() {
      return new WeakPointer<T>();
    }
  },
  SOFT {
    public <T> Pointer<T> make() {
      return new SoftPointer<T>();
    }
  };


  public abstract <T> Pointer<T> make();
}
```

Danger – References

- **References put additional strain on GC**
- **Only use with large objects**
- **Memory space preserving measure**
  - **But can severely impact on performance**
- **Even empty finalize() methods can cause OutOfMemoryError**
  - **Additional step in GC that runs in separate thread**

Defining a Dynamic Proxy

- **We make a new instance of an interface class using java.lang.reflect.Proxy:**

```
Object o = java.lang.reflect.Proxy.newProxyInstance(
  Thread.currentThread().getContextClassLoader(),
  new Class[]{ interface to implement },
    implementation of java.lang.reflect.InvocationHandler
);
```

- **The result is an instance of *interface to implement***

```
import java.lang.reflect.*;

public class VirtualProxy<T> implements InvocationHandler {
  private final Pointer<T> realSubjectPointer;
  private final Object[] constrParams;
  private final Constructor<? extends T> subjectConstructor;

  public VirtualProxy(Class<? extends T> realSubjectClass,
                      Class[] constrParamTypes,
                      Object[] constrParams,
                      PointerType pointerType) {
    try {
      subjectConstructor = realSubjectClass.
        getConstructor(constrParamTypes);
      realSubjectPointer = pointerType.make();
    } catch (NoSuchMethodException e) {
      throw new IllegalArgumentException(e);
    }
    this.constrParams = constrParams;
  }
```

```
  public Object invoke(Object proxy, Method method,
                       Object[] args) throws Throwable {
    T realSubject;
    synchronized (this) {
      realSubject = realSubjectPointer.get();
      if (realSubject == null) {
        realSubject = subjectConstructor.newInstance(
          constrParams);
        realSubjectPointer.set(realSubject);
      }
    }
    return method.invoke(realSubject, args);
  }
}
```

- **Whenever <u>any</u> method is invoked on the proxy object, it gets the real subject from the Pointer and creates it if necessary**

A word about synchronization

- **We need to synchronize whenever we check the value of the pointer**
  - **Otherwise several realSubject objects could be created**
  - **However, no one else will have a pointer to this object**
  - **Thus, it is fairly safe to synchronize on "this"**
- **Allegedly double-checked locking idiom was broken pre-Java 5**
  - **I have personally not seen evidence to support this**

Proxy Factory

- **To simplify our client code, we define a Proxy Factory:**

```
@SuppressWarnings("unchecked") // be very careful of using this!
public class ProxyFactory {
  public static <T> T virtualProxy(Class<T> subjectIntf) { ... }

  public static <T> T virtualProxy(Class<T> subjectIntf,
    PointerType type) { ... }

  public static <T> T virtualProxy(Class<T> subjectIntf,
    Class<? extends T> realSubjectClass, PointerType type) { ... }

  public static <T> T virtualProxy(Class<T> subjectIntf,
    Class<? extends T> realSubjectClass,
    Class[] constrParamTypes,
    Object[] constrParams, PointerType type) { ... }
```

Proxy Factory

- **We will just show the main ProxyFactory method:**
  - **The other methods send default values to this one**

```
public class ProxyFactory {
  public static <T> T virtualProxy(Class<T> subjectInterface,
      Class<? extends T> realSubjectClass,
      Class[] constrParamTypes,
      Object[] constrParams, PointerType type) {
    return (T) Proxy.newProxyInstance(
        Thread.currentThread().getContextClassLoader(),
        new Class[]{subjectInterface},
        new VirtualProxy<T>(realSubjectClass,
            constrParamTypes, constrParams, type));
  }
}
```

```
import static com.maxoft.proxy.ProxyFactory.virtualProxy;
import static java.util.concurrent.TimeUnit.SECONDS;

public class WorldMarket1 {
  public static void main(String[] args) throws Exception {
    Company maxsol = new Company("Maximum Solutions",
      1000 * 1000, virtualProxy(MoralFibre.class));
    SECONDS.sleep(2);
    maxsol.makeMoney();
    System.out.println(maxsol);
    SECONDS.sleep(2);
    maxsol.damageEnvironment();
    System.out.println(maxsol);
    SECONDS.sleep(2);
    maxsol.becomeFocusOfMediaAttention();
    System.out.println(maxsol);
  }
}
```

```
Oh goodie!
Maximum Solutions has $ 2000000.00
Oops, sorry about that oilspill...
Maximum Solutions has $ 8000000.00
Look how good we are...
Moral Fibre Created!
Maximum Solutions has $ 7100000.00
```

- **Weak Pointer is cleared when we don't have a strong ref**

```
Company maxsol = new Company("Maximum Solutions", 1000000,
  virtualProxy(MoralFibre.class, WEAK));
SECONDS.sleep(2);
maxsol.damageEnvironment();
maxsol.becomeFocusOfMediaAttention();
```

Oops, sorry about that oilspill...
Look how good we are...
Moral Fibre Created!
Oops, sorry about that oilspill...
Look how good we are...
Moral Fibre Created!

```
// short term memory...
System.gc();
SECONDS.sleep(2);
maxsol.damageEnvironment();
maxsol.becomeFocusOfMediaAttention();
```

- **Soft Pointer more appropriate**

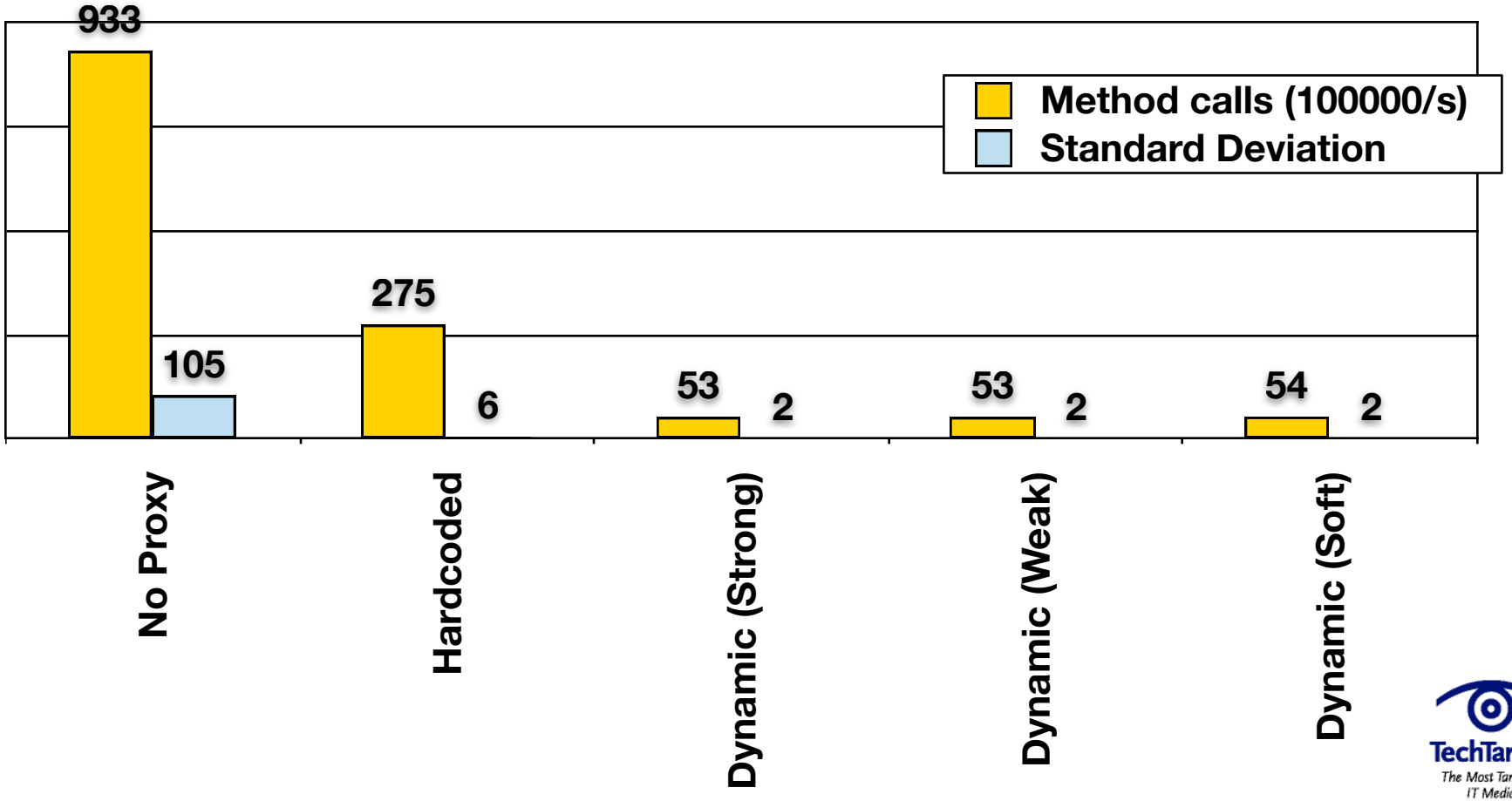
```
Company maxsol = new Company("Maximum Solutions", 1000000,
    virtualProxy(MoralFibre.class, SOFT));
 SECONDS.sleep(2);
 maxsol.damageEnvironment();
 maxsol.becomeFocusOfMediaAttention();


 System.gc(); // ignores soft pointer
 SECONDS.sleep(2);
 maxsol.damageEnvironment();
 maxsol.becomeFocusOfMediaAttention();


 forceOOME(); // clears soft pointer
 SECONDS.sleep(2);
 maxsol.damageEnvironment();
 maxsol.becomeFocusOfMediaAttention();
}
private static void forceOOME() {
 try {byte[] b = new byte[1000000000];}
```

Oops, sorry about that oilspill...
Look how good we are...
Moral Fibre Created!
Oops, sorry about that oilspill...
Look how good we are...
java.lang.OutOfMemoryError:
Java heap space
Oops, sorry about that oilspill...
Look how good we are...
Moral Fibre Created!

Performance of Dynamic Proxies

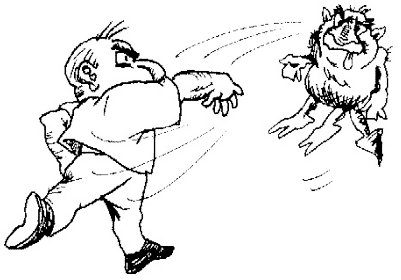


Analysis of Performance Results

- **Always look at performance in real-life context**
  - **In your system, how often does a method get called per second?**
  - **What contention are you trying to solve – CPU, IO or memory?**
    - **Probably the wrong solution for CPU bound contention**
- **Big deviation for "No Proxy" – probably due to HotSpot compiler inlining method call.**

Virtual Proxy Gotchas

- **Be careful how you implement equals()**
  - **Should always be *symmetric (from JavaDocs)*:**
    - **For any non-null reference values** x **and** y**,** x.equals(y) **should return** true **if and only if** y.equals(x) **returns** true
- **Exceptions**
  - **General problem with proxies**
    - **Local interfaces vs. remote interfaces in EJB**
  - **Were checked exceptions invented on April 1st ?**



Checkpoint

- **We've looked at the concept of a *Virtual Proxy* based on the GoF pattern**
- **We have seen how to implement this with dynamic proxies (since JDK 1.3)**
- **We have also looked at Soft and Weak refs**
- **Lastly, we were unsurprised that dynamic proxy performs worse than handcoded proxy**

Further uses of Dynamic Proxy

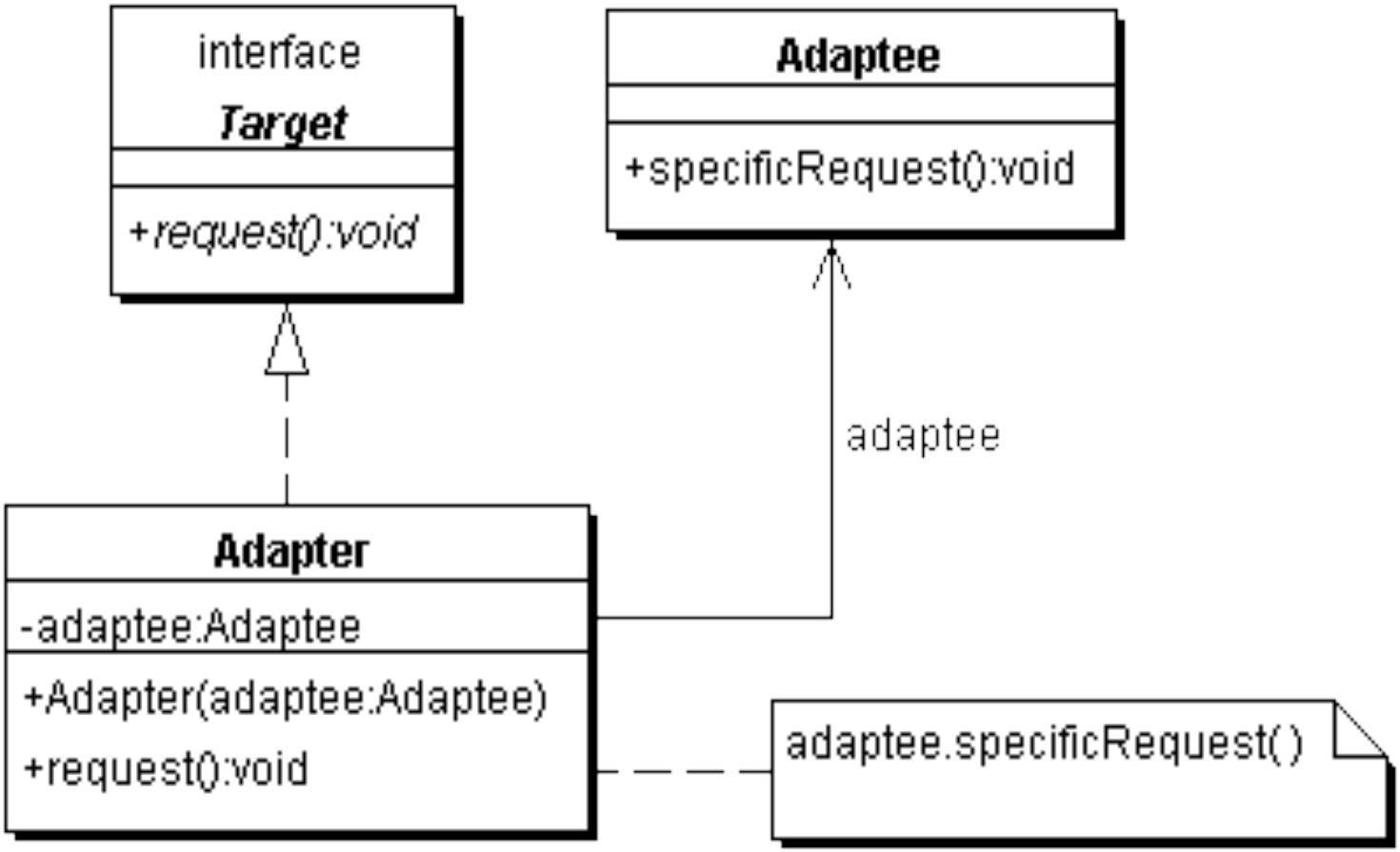
- **Protection Proxy**
  - **Only route the call when caller has the correct security context**
    - **Similar to the "Personal Assistant" pattern**

- **Dynamic Decorator or Filter**
  - **We can add functions dynamically to an object**
  - **See http://www.javaspecialists.co.za/archive/Issue034.html**
  - **Disclaimer: I tried to read it today, and don't understand it either**

Dynamic Object Adapter

- **Based on Adapter pattern by GoF**
- **Plain Object Adapter has some drawbacks:**
  - **Sometimes you want to adapt an interface, but only want to override some methods**
  - **E.g. java.sql.Connection**
- **Structurally, the patterns Adapter, Proxy, Decorator and Composite are almost identical**

Object Adapter Structure (GoF)



- **We delegate the call if the adapter has a method with this signature**
- **Objects adaptee and adapter can be of any type**

```
public Object invoke(Object proxy, Method method,
                     Object[] args) throws Throwable {
  try {
    // find out if the adpter has this method
    Method other = adaptedMethods.get( // only declared methods
        new MethodIdentifier(method));
    if (other != null) { // yes it has
      return other.invoke(adapter, args);
    } else { // no it does not
      return method.invoke(adaptee, args);
    }
  } catch (InvocationTargetException e) {
    throw e.getTargetException();
  }
}
```

- **The ProxyFactory now get a new method:**

```
public class ProxyFactory {
  public static <T> T adapt(Object adaptee,
                            Class<T> target,
                            Object adapter) {
   return (T) Proxy.newProxyInstance(
      Thread.currentThread().getContextClassLoader(),
      new Class[]{target},
      new DynamicObjectAdapter<T>(adapter, adaptee));
  }
}
```

- **Client can now adapt interfaces very easily**

```
import static com.maxoft.proxy.ProxyFactory.*;

// ...

Connection con = DriverManager.getConnection("...");
Connection con2 = adapt(con, Connection.class,
  new Object() {
    public void close() {
      System.out.println("No, do not close connection");
    }
  });
```

- **For additional examples of this technique, see**
  - **http://www.javaspecialists.co.za/archive/Issue108.html**

Benefits of Dynamic Proxies

- **Write once, use everywhere**
- **Single point of change**
- **Elegant coding on the client**
  - **Esp. combined with static imports & generics**
- **Slight performance overhead**
  - **But view that in context of application**

Demo

- **Short demonstration using Dynamic Virtual Proxy for new interface**

Conclusion

- **Thank you very much for listening to me ☺**
- **In my experience, Dynamic Proxies are easy to use**
- **Look for applications where they are appropriate**

Audience Response

Question?