# Dynamic Proxies in Java

Dr Heinz M. Kabutz

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# Dynamic Proxies in Java

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2020/04/18, 07:27

To Java Champions List

Hello everyone,

In Java there are two things that I keep being surprised that I don't know why it's not working.

One is the rules around generics.

The other one is reflection with JPMS.

Here is what I had today. You will probably tell me that I'm just a dumb ignorant but if I have an explanation, it worth it :-)

I have an application launched with -jar and the classpath in the manifest. No module defined and no module name. Illegal access is "allow". A bunch of --add-opens were added

The application throws an exception from some library we use.

```
Caused by: java.lang.reflect.InaccessibleObjectException: Unable to make field private static java.lang.reflect.Method
com.sun.proxy.jdk.proxy2.$Proxy84.m1 accessible: module jdk.proxy2 doe
s not "opens com.sun.proxy.jdk.proxy2" to unnamed module @7ce29a2d
```

My understanding is that the unnamed module can perform reflection anywhere. I should just get a warning about it. But here it fails.

What am I missing?

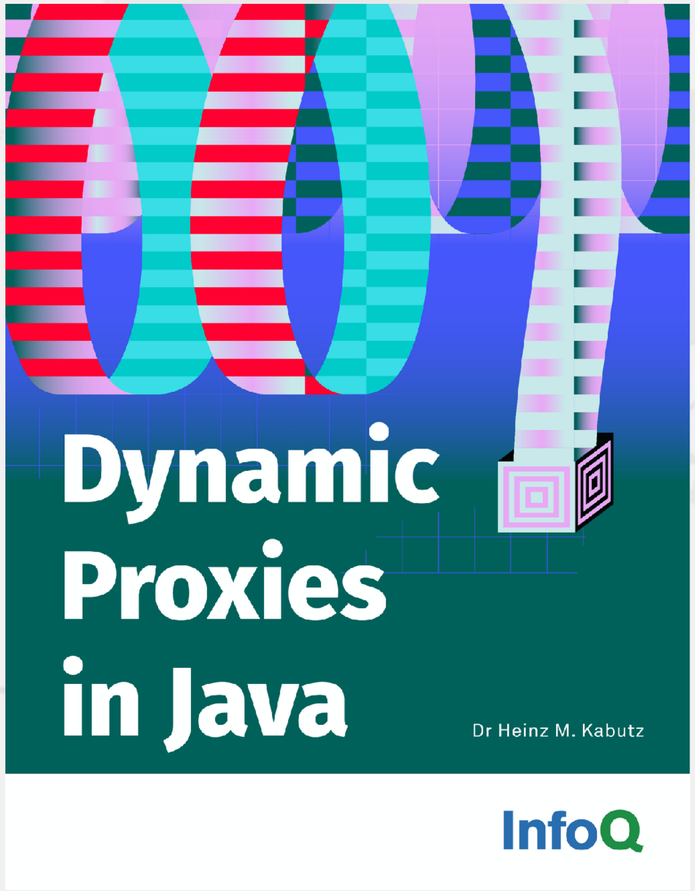
Thanks,

[redacted]

# whois

- Not ketchup
- 10+ years teaching remotely from Crete
  - learning.javaspecialists.eu
  - Threading and concurrency
  - Design patterns
  - Advanced Java topics
  - Refactoring old code to modern Java constructs
  - Contact: heinz@javaspecialists.eu
- Java Champion, Speaker, bla bla
- Gift: tinyurl.com/MontrealJUG2020

# Dynamic Proxies in Java




- **Free download from**
  - **https://www.infoq.com/minibooks/java-dynamic-proxies/**

# Questions

- Please ask questions in the webinar software
  - My assistant John Green will send them to me
- Questions make a talk far more fun
  - And we all learn more

# History of Dynamic Proxies

- **RMI used to need a separate compile step**
  - **Tool "rmic" still found in JDK/bin directory**
    - **Creates *stubs* and *skeletons* to manage remote method invocations**
- **Java 1.3 released in May 2000**
  - **First version with dynamic proxies**
  - **Functional interface of InvocationHandler to service *all* methods on proxy**
  - **Not necessary to use "rmic" or similar tools for deployment**
  - **Made it possible to build flexible, dynamic systems**

# Big Win

- Don't Repeat Yourself (DRY) at its best
  - Write a single InvocationHandler implementation
  - Reuse for hundreds of classes
- We once replaced 600,000 code statements with 1 dynamic proxy
  - Code had been generated, but was maintained by hand
  - Dynamic proxy easier to maintain
  - Less code

# Infrastructure Code

- **Dynamic proxies in tools and frameworks**
  - **Spring**
  - **Annotations**
  - **Dependency injection**
  - **Hibernate**
  - **Gradle**

# 1: Handcrafted Proxies

# Handcrafted Proxies

- **Before learning how to avoid duplicate code, we will copy & paste**
  - **And then in next section will use *dynamic proxies* instead**

# Virtual Proxy

# Virtual Proxy

- **Delays expensive object creation**
  - **placeholder object creates costly object on demand**

# CustomMap Interface

- **Reduced version of the Map interface**

```
public interface CustomMap<K, V> {
  int size();
  V get(Object key);
  V put(K key, V value);
  V remove(Object key);
  void clear();
  void forEach(BiConsumer<? super K, ? super V> action);
}
```

# CustomHashMap Implementation

- **Delegates methods to a java.util.HashMap**
  - **Repetitive and error prone**

```
public class CustomHashMap<K, V> implements CustomMap<K, V> {
  private final Map<K, V> map = new HashMap<>();
  { System.out.println("CustomHashMap constructed"); }
  public int size() { return map.size();}
  public V get(Object key) { return map.get(key); }
  public V put(K key, V value) { return map.put(key, value); }
  public V remove(Object key) { return map.remove(key); }
  public void clear() { map.clear(); }
  public void forEach(BiConsumer<? super K, ? super V> action) {
    map.forEach(action);
  }
  public String toString() { return map.toString(); }
}
```

# VirtualCustomMap Virtual Proxy

- **Has a reference to a Supplier for CustomMap**
  - **Is created in the getRealMap() method**

```
public class VirtualCustomMap<K, V> implements CustomMap<K, V> {
  private final Supplier<CustomMap<K, V>> mapSupplier;
  private CustomMap<K, V> realMap;
  public VirtualCustomMap(Supplier<CustomMap<K, V>> mapSupplier) {
    this.mapSupplier = mapSupplier;
  }
  private CustomMap<K, V> getRealMap() { // not thread-safe
    if (realMap == null) realMap = mapSupplier.get();
    return realMap;
  }
```

# VirtualCustomMap Methods

```
  public int size() {
    return getRealMap().size();
  }
  public V get(Object key) {
    return getRealMap().get(key);
  }
  public V put(K key, V value) {
    return getRealMap().put(key, value);
  }
  public V remove(Object key) {
    return getRealMap().remove(key);
  }
  public void clear() { getRealMap().clear(); }
  public void forEach(BiConsumer<? super K, ? super V> action) {
    getRealMap().forEach(action);
  }
}
```

# Using VirtualCustomMap

- **CustomHashMap made when method called**
  - **Does not matter which method we call first**

```
CustomMap<String, Integer> map =
    new VirtualCustomMap<>(CustomHashMap::new);
System.out.println("Virtual Map created");
map.put("one", 1);
map.put("life", 42);
System.out.println("get(\"life\") = " + map.get("life"));
System.out.println("size() = " + map.size());
System.out.println("clearing map");
map.clear();
System.out.println("size() = " + map.size());
```

```
Virtual Map created
CustomHashMap constructed
get("life") = 42
size() = 2
clearing map
size() = 0
```

# 2: Dynamic Proxy

# 2: Dynamic Proxy

- Avoid copy and paste programming
  - A bug needs to be fixed everywhere
- Better is static or dynamic code generation

# Proxy.newProxyInstance()

# Proxy.newProxyInstance()

- **Takes three parameters**
  - **ClassLoader where the new proxy class is loaded**
  - **Class<?>[] an array containing all interfaces our proxy object must implement**
  - **InvocationHandler a handler that's called when any proxy method is invoked**

# InvocationHandler

- **Invoked when *any* method is called on proxy**

```
public interface InvocationHandler {
  public Object invoke(Object proxy,
                       Method method,
                       Object[] args) throws Throwable;
}
```

  - Object proxy **is the instance of the dynamic proxy class that is calling invoke()**
  - Method method **is a java.lang.reflect.Method for the method that was called**
    - **Either an interface method or equals(), hashCode(), or toString()**
  - Object[] args **is an array of parameters passed into the method**
    - **This is** null **when method has no parameters**

# LoggingInvocationHandler

# LoggingInvocationHandler

- **We will log all method calls**
  - **Optionally measuring how long they take**
- **The constructor parameters are**
  - Logger log **a java.util.Logger to log to**
  - Object obj **the object that we want to delegate the calls to**
    - **Must implement the same interfaces as the proxy**

```
public final class LoggingInvocationHandler
    implements InvocationHandler {
  private final Logger log;
  private final Object obj;
  public LoggingInvocationHandler(Logger log, Object obj) {
    this.log = log;
    this.obj = obj;
  }
```

# invoke() Method for Logging

```
public Object invoke(
    Object proxy, Method method, Object[] args)
    throws Throwable {
  log.info(() -> "Entering " + toString(method, args));
  // optimization - nanoTime() is an expensive native call
  final boolean logFine = log.isLoggable(Level.FINE);
  long start = logFine ? System.nanoTime() : 0;
  try {
    return method.invoke(obj, args);
  } finally {
    long nanos = logFine ? System.nanoTime() - start : 0;
    log.info(() -> "Exiting " + toString(method, args));
    if (logFine) log.fine(() -> "Time " + nanos + "ns");
  }
}
```

# toString() Prints Methods with Args

```
  private String toString(Method method,
                          Object[] args) {
    return String.format("%s.%s(%s)",
        method.getDeclaringClass().getCanonicalName(),
        method.getName(),
        args == null ? "" :
            Stream.of(args).map(String::valueOf)
                .collect(Collectors.joining(", ")));
  }
}
```

# Demo of LoggingInvocationHandler

```
@SuppressWarnings("unchecked")
var map = (Map<String, Integer>)
  Proxy.newProxyInstance(
    Map.class.getClassLoader(), new Class<?>[] {Map.class},
    new LoggingInvocationHandler(
      Logger.getGlobal(), new ConcurrentHashMap<>()));
map.put("one", 1);
map.put("two", 2);
System.out.println(map);
map.clear();
```

```
Jan 24, 2020 7:32:20 AM
eu.javaspecialists.books.dynamicproxies.ch03.logging.LoggingInvocationHandler invoke
INFO: Entering java.util.Map.put(one, 1)
Jan 24, 2020 7:32:21 AM
eu.javaspecialists.books.dynamicproxies.ch03.logging.LoggingInvocationHandler invoke
INFO: Exiting java.util.Map.put(one, 1)
Jan 24, 2020 7:32:21 AM
eu.javaspecialists.books.dynamicproxies.ch03.logging.LoggingInvocationHandler invoke
FINE: Time 61622ns
```

# Dissecting a Dynamic Proxy

# Dissecting a Dynamic Proxy

- **We will start with a simple interface**

```
public interface ISODateParser {
  LocalDate parse(String date) throws ParseException;
}
```

# Dynamic Proxy Class Name

- **Dynamic proxy with empty InvocationHandler**

```
System.out.println(
    Proxy.newProxyInstance(
        ISODateParser.class.getClassLoader(),
        new Class<?>[] {ISODateParser.class},
        (proxy, method, arguments) -> null
    ).getClass()
);
```

```
class com.sun.proxy.$Proxy0
```

# Decompiling $Proxy0

- We can dump generated proxy classes
  - And then decompile with a tool like CFR
    - https://www.benf.org/other/cfr/
  - Java 9+: -Djdk.proxy.ProxyGenerator.saveGeneratedFiles=true
  - Earlier versions: -Dsun.misc.ProxyGenerator.saveGeneratedFiles=true

```
public final class $Proxy0 extends Proxy
    implements ISODateParser {
  private static Method m0;
  private static Method m1;
  private static Method m2;
  private static Method m3;
  static {
    try {
      m0 = Class.forName("java.lang.Object").getMethod("hashCode");
      m1 = Class.forName("java.lang.Object").getMethod("equals",
              Class.forName("java.lang.Object"));
      m2 = Class.forName("java.lang.Object").getMethod("toString");
      m3 = Class.forName("eu.javaspecialists.books.dynamicproxies." +
              "ch03.ISODateParser").getMethod("parse",
                   Class.forName("java.lang.String"));
    } catch (NoSuchMethodException e) {
      throw new NoSuchMethodError(e.getMessage());
    } catch (ClassNotFoundException e) {
      throw new NoClassDefFoundError(e.getMessage());
    }
  }
```

```
public $Proxy0(InvocationHandler h) {super(h);}

public final int hashCode() {
  try {
    return (Integer) h.invoke(this, m0,
      (Object[]) null);
  } catch (RuntimeException | Error e) {
    throw e;
  } catch (Throwable e) {
    throw new UndeclaredThrowableException(e);
  }
}
public final boolean equals(Object o) {
  try {
    return (Boolean) h.invoke(this, m1, new Object[] {o});
  } catch (RuntimeException | Error e) {
    throw e;
  } catch (Throwable e) {
    throw new UndeclaredThrowableException(e);
  }
}
```

```
  public final String toString() {
    try {
      return (String) h.invoke(this, m2,
        (Object[]) null);
    } catch (RuntimeException | Error e) {
      throw e;
    } catch (Throwable e) {
      throw new UndeclaredThrowableException(e);
    }
  }

  public final LocalDate parse(String s) throws ParseException {
    try {
      return (LocalDate) h.invoke(this, m3, new Object[] {s});
    } catch (RuntimeException | ParseException | Error e) {
      throw e;
    } catch (Throwable e) {
      throw new UndeclaredThrowableException(e);
    }
  }
}
```

# Virtual Dynamic Proxy

# Virtual Dynamic Proxy

- **InvocationHandler for virtual proxies**

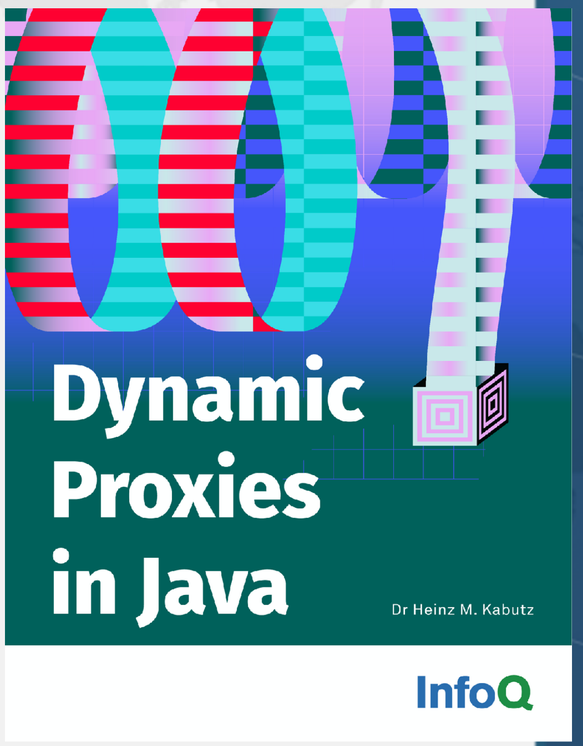
```
public final class VirtualProxyHandler<S>
    implements InvocationHandler, Serializable {
  private final Supplier<? extends S> subjectSupplier;
  private S subject;
  public VirtualProxyHandler(Supplier<? extends S> subjectSupplier) {
    this.subjectSupplier = subjectSupplier;
  }
  private S getSubject() {
    if (subject == null) subject = subjectSupplier.get();
    return subject;
  }
  public Object invoke(Object proxy, Method method,
                       Object[] args) throws Throwable {
    return method.invoke(getSubject(), args);
  }
}
```

# Proxies Facade virtualProxy()

- **Facade has a virtualProxy() method**

```
public static <S> S virtualProxy(
    Class<? super S> subjectInterface,
    Supplier<? extends S> subjectSupplier) {
  Objects.requireNonNull(subjectSupplier, "subjectSupplier==null");
  return castProxy(subjectInterface,
      new VirtualProxyHandler<>(subjectSupplier));
}
```

- **More details in book**
  - **https://www.infoq.com/minibooks/java-dynamic-proxies/**



# Creating Virtual Proxy

- **We can create virtual proxies of anything**
  - **Here we replace the handcrafted proxy with dynamic**
    - **Less code, less chance of bugs**

```
CustomMap<String, Integer> map =
    Proxies.virtualProxy(CustomMap.class, CustomHashMap::new);
System.out.println("Virtual Map created");
map.put("one", 1); // creating CustomHashMap as side effect
map.put("life", 42);
System.out.println("map.get(\"life\") = " + map.get("life"));
System.out.println("map.size() = " + map.size());
System.out.println("clearing map");
map.clear();
System.out.println("map.size() = " + map.size());
```

```
Virtual Map created
CustomHashMap constructed
map.get("life") = 42
map.size() = 2
clearing map
map.size() = 0
```

# Dynamic Proxy Restrictions

# Interfaces Only

- **Dynamic proxies cannot extend classes**
  - **All proxies are subclasses of java.lang.reflect.Proxy**
    - **No multiple inheritance in Java**
  - **Might need to use tools like CGLib or ByteBuddy**

# UndeclaredThrowableException

- **InvocationHandler.invoke() throws Throwable**
  - **However, we should only throw declared exceptions**
    - **Error and RuntimeException always allowed**

```
Runnable job = Proxies.castProxy(
  Runnable.class,
  (proxy, method, params) -> {
    // will be wrapped with an UndeclaredThrowableException
    throw new IOException("bad exception");
  });
job.run();
```

```
Exception in "main" java.lang.reflect.UndeclaredThrowableException at
com.sun.proxy.$Proxy0.run(Unknown Source)
at UndeclaredExceptionThrown.main()
Caused by: java.io.IOException: bad exception
at UndeclaredExceptionThrown.lambda$main$0() ... 2 more
```

# Return Types Have to be Correct

```
public interface FooBar {
  void foo();
  boolean bar();
  int baz();
}

public class FooBarInvocationHandler implements InvocationHandler {
  public Object invoke(Object proxy, Method method,
                       Object[] args) throws Throwable {
    switch (method.getName()) {
      case "foo": return true; // ignored
      case "bar": return 42; // ClassCastException
      case "baz": return null; // NullPointerException
      default: throw new UnsupportedOperationException();
    }
  }
}
```

# Naming Mysteries

```
public class ProxyNaming {
  public interface PublicNotExported {
    void open();
  }
  interface Hidden {
    void mystery();
  }
  public static void main(String... args) {
    show(BaseComponent.class); // exported from module
    show(PublicNotExported.class);
    show(Hidden.class);
  }
  private static void show(Class<?>... intf) {
    System.out.println(Proxy.newProxyInstance(
      intf[0].getClassLoader(), intf,
      (p, m, a) -> null).getClass());
  }
}
```

```
class com.sun.proxy.$Proxy0
class com.sun.proxy.jdk.proxy1.$Proxy1
class eu.javaspecialists.books.dynamicproxies.ch03.gotchas.$Proxy2
```

# Deeper Call Stacks

- **Call stacks have references to $Proxy0**
  - **Can increase each call by an additional 5 layers**
  - **IntelliJ IDEA folds this information away**

```
micProxy$Factorial.invoke(RecursiveDynamicProxy.java:46) <5 internal calls>
micProxy$Factorial.invoke(RecursiveDynamicProxy.java:49) <5 internal calls>
micProxy$Factorial.invoke(RecursiveDynamicProxy.java:49) <5 internal calls>
micProxy$Factorial.invoke(RecursiveDynamicProxy.java:49) <5 internal calls>
```

- **Actual stack trace contains all the gory details**

```
at RecursiveDynamicProxy$Factorial.invoke()
at com.sun.proxy.$Proxy0.apply(Unknown Source)
at java.base/NativeMethodAccessorImpl.invoke0()
at java.base/NativeMethodAccessorImpl.invoke()
at java.base/DelegatingMethodAccessorImpl.invoke()
at java.base/Method.invoke()
at RecursiveDynamicProxy$Factorial.invoke()
```

# Shared Proxy Classes

- Java tries to minimize dynamic proxy classes
  - When we call Proxy.newProxyInstance() it checks
    - Have we had the same interfaces (in that order)?
    - And for the same class loader?
  - If it has seen it before, it returns a cached class
    - This is stored inside weak references to prevent memory leaks

# Performance

# Performance

- Dynamic proxies used in infrastructure code
  - Some methods called billions of times
- Calling methods on dynamic proxies may be slower
  - Primitive return types and parameters might be boxed
  - Parameters need to be wrapped with Object[]
    - Escape analysis can eliminate the array if it does not escape from invoke()
  - Method suffers from amnesia and checks our permission on every call

# Model for Benchmark using JMH

```
public interface Worker {
  long increment();
  void consumeCPU();
}

public class RealWorker implements Worker {
  private long counter = 0;

  public long increment() { return counter++; }
  public void consumeCPU() { Blackhole.consumeCPU(2); }
}

public class ProxyWorker implements Worker {
  private final RealWorker worker = new RealWorker();

  public long increment() { return worker.increment(); }
  public void consumeCPU() { worker.consumeCPU(); }
}
```

# increment() and consumeCPU()

- We use five ways of calling these methods
  - directCall
  - staticProxy
  - dynamicProxyThenDirectCall
    - Avoids cost of reflective method calls, but might need to box return value
  - dynamicProxyThenReflectiveCall
    - Delegates all calls to the RealWorker using reflection
    - Method call might be turbo-boosted by turning off accessibility checks

# Benchmark increment() Results

- **Analysis of results**
  - **dynamicProxyDirectCall 1.4 ns slower in Java 14**
  - **dynamicProxyReflectiveCall is another 3.1 ns slower and allocates 24 bytes**
  - **Without our turbo boost, it is another 1.4 ns slower**

| Benchmark | ns/op ± Error |
|---|---|
| directCall | 1.957 ± 0.004 |
| staticProxy | 2.369 ± 0.018 |
| dynamicProxyDirectCall | 3.726 ± 0.016 |
| dynamicProxyReflectiveCall (turbo) | 6.853 ± 0.201 |
| dynamicProxyReflectiveCall (no turbo) | 8.238 ± 0.282 |

# Benchmark consumeCPU() Results

- **Analysis of results**
  - **dynamicProxyDirectCall 0.7 ns slower in Java 14**
  - **dynamicProxyReflectiveCall is another 0.8 ns slower**
  - **Without our turbo boost, it is another 1.7 ns slower**

| Benchmark | ns/op ± Error |
|---|---|
| directCall | 3.270 ± 0.028 |
| staticProxy | 3.788 ± 0.018 |
| dynamicProxyDirectCall | 4.461 ± 0.020 |
| dynamicProxyReflectiveCall (turbo) | 5.231 ± 0.053 |
| dynamicProxyReflectiveCall (no turbo) | 6.960 ± 0.409 |

# Summary of Benchmark Results

- **Method call overhead for our experiments**
  - **4.5 nanoseconds for increment()**
  - **1.4 nanoseconds for consumeCPU()**
- **In a typical business application, such overheads are negligible**
  - **Unless called in performance sensitive code**

# 3: Related Patterns

# 3: Related Patterns

- **Proxy has a similar structure to**
  - **Decorator / Filter**
  - **Object Adapter**
  - **Composite**

# Filtering for Immutability

# Filtering for Immutability

- **Java collections are sometimes unmodifiable**
  - **Might throw UnsupportedOperationException**
- **Alternative is to split the interfaces into immutable and mutable**

```
public interface ImmutableIterable<E> {
  void forEach(Consumer<? super E> action);
  Spliterator<E> spliterator();
}

public interface MutableIterable<E> extends ImmutableIterable<E> {
  Iterator<E> iterator();
}
```

# ImmutableCollection

- **Does not contain any mutating methods**

```
public interface ImmutableCollection<E>
    extends ImmutableIterable<E> {
  int size();
  boolean isEmpty();
  boolean contains(Object o);
  Object[] toArray();
  <T> T[] toArray(T[] a);
  <T> T[] toArray(IntFunction<T[]> generator);
  boolean containsAll(Collection<?> c);
  Stream<E> stream();
  Stream<E> parallelStream();

  // to try out default methods
  default void printAll() {
    forEach(System.out::println);
  }
}
```

# HandcodedFilter

- **We only offer methods that do not mutate**

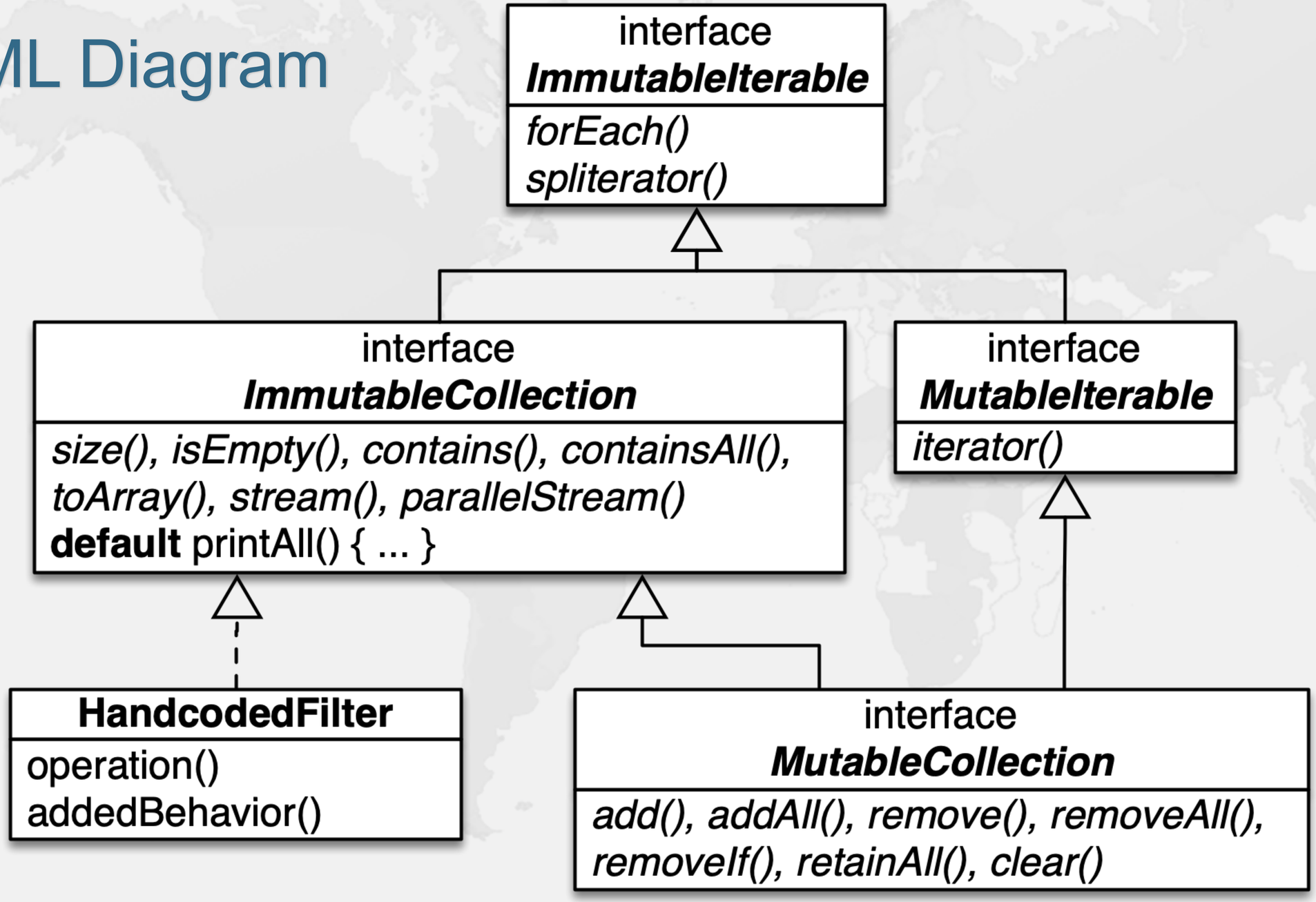
```
public class HandcodedFilter<E>
    implements ImmutableCollection<E> {
  private final Collection<E> c;

  public HandcodedFilter(Collection<E> c) { this.c = c; }

  public int size() { return c.size(); }
  public boolean isEmpty() { return c.isEmpty(); }
  public boolean contains(Object o) { return c.contains(o); }
  public Object[] toArray() { return c.toArray(); }
  // etc.
  // No mutable methods are offered to client
}
```

# MutableCollection

- **Allows us to modify the collection**

```
public interface MutableCollection<E>
    extends ImmutableCollection<E>, MutableIterable<E> {
  boolean add(E e);
  boolean remove(Object o);
  boolean addAll(Collection<? extends E> c);
  boolean removeAll(Collection<?> c);
  boolean removeIf(Predicate<? super E> filter);
  boolean retainAll(Collection<?> c);
  void clear();
}
```

# UML Diagram



# HandcodedFilter

- **We only offer methods that do not mutate**

```
ImmutableCollection<String> names =
    new HandcodedFilter<>(Arrays.asList("Peter", "Paul", "Mary"));
// names.remove("Peter"); // does not compile
System.out.println(names);
System.out.println("Is Mary in? " + names.contains("Mary"));
System.out.println("Class: " + names.getClass().getSimpleName());
names.printAll();
```

**Oopsie!**

```
eu.javaspecialists.books.dynamicproxies.ch04.immu
tablecollection.HandcodedFilter@2d38eb89
Is Mary in? true
Class: HandcodedFilter
Peter
Paul
Mary
```

# FilterHandler

- Easier than writing decorators by hand
- Our rules will be
  - We will create our filter from an interface and an object
  - We will map each public method from the filter to the object
    - To keep it simple, we will only consider the name of the method and parameter types. The return type must match, or we will reject that method
  - We need to include support for default interface methods
  - If the object does not have all the methods in the filter, constructing the dynamic filter should fail
- Method matching should be as fast as possible

# FilterHandler

```
public final class FilterHandler
    implements InvocationHandler {
  private final ChainedInvocationHandler chain;

  public FilterHandler(Class<?> filter, Object component) {
    VTable vt = VTables.newVTable(component.getClass(), filter);
    VTable defaultVT = VTables.newDefaultMethodVTable(filter);

    chain = new VTableHandler(component, vt,
        new VTableDefaultMethodsHandler(defaultVT, null));
    chain.checkAllMethodsAreHandled(filter);
  }
  public Object invoke(
      Object proxy, Method method, Object[] args) throws Throwable {
    return chain.invoke(proxy, method, args);
  }
}
```

# Proxies Facade Gets filter() Method

- **We can filter components with an interface**
  - **The** component **must have matching methods**
    - **Unless they are default methods in the interface**
  - **The** component **does not need to implement the** filter **interface**

```
public static <F> F filter(Class<? super F> filter,
                           Object component) {
  Objects.requireNonNull(component, "component==null");
  return castProxy(filter, new FilterHandler(filter, component));
}
```

# Dynamic Filter

- **We can filter away the mutating methods**

```
ImmutableCollection<String> names =
    Proxies.filter(ImmutableCollection.class,
        Arrays.asList("Peter", "Paul", "Mary"));
// names.remove("Peter"); // does not compile
System.out.println(names);
System.out.println("Is Mary in? " + names.contains("Mary"));
System.out.println("Class: " + names.getClass().getSimpleName());
names.printAll();
```

**Yeah!**

```
[Peter, Paul, Mary]
Is Mary in? true
Class: $Proxy0
Peter
Paul
Mary
```

# What Happened?

- VTable matches methods
  - Details left as homework
- ChainedInvocationHandler uses chain of responsibility pattern
- We need *deep reflection* to call default interface methods
  - Dynamic proxies automatically implement them
    - No easy way to call the super-interface's default interface methods
  - We need to *open* whichever JPMS module we want to call default methods on
    - e.g. --add-opens java.base/java.util=eu.javaspecialists.books.dynamicproxies if the interface is in the java.util package

# Dynamic Composite

# Dynamic Composite

- The Java Specialists' Newsletter
  - Started as 80 contacts in a Microsoft Outlook list
  - Once it grew to maximum size, we created lists of lists
- Model
  - A contact is either an individual subscriber or a distribution list
    - Can be nested

# Contact and Person

```
public interface Contact {
  default boolean add(Contact c) {return false;}
  default boolean remove(Contact c) {return false;}
  void sendMail(String body);
  int count();
}

public class Person implements Contact {
  private final String email;
  public Person(String email) { this.email = email; }
  public void sendMail(String body) {
    // connecting to JavaMail and off it goes ...
    System.out.println("Sending " + body + " to " + email);
  }
  public int count() {
    return 1;
  }
}
```

# DistributionList

- **Other composites would look similar**

```
import java.util.*;

public class DistributionList implements Contact {
  private final Collection<Contact> contacts = new ArrayList<>();

  public boolean add(Contact c) { return contacts.add(c); }
  public boolean remove(Contact c) { return contacts.remove(c); }

  public void sendMail(String body) {
    contacts.forEach(contact -> contact.sendMail(body));
  }
  public int count() {
    return contacts.stream().mapToInt(Contact::count).sum();
  }
}
```

# Let's Build a Mailing List

```
Contact tjsn = new DistributionList();
System.out.println(tjsn.count());
tjsn.add(new Person("john@aol.com"));
tjsn.sendMail("Issue 1");
System.out.println(tjsn.count());

Contact students = new DistributionList();
students.add(new Person("peter@absa.co.za"));
students.add(new Person("mzani@absa.co.za"));
tjsn.add(students);

tjsn.sendMail("Issue 2");
System.out.println(tjsn.count());
```

```
0
Sending Issue 1 to john@aol.com
1
Sending Issue 2 to john@aol.com
Sending Issue 2 to peter@absa.co.za
Sending Issue 2 to mzani@absa.co.za
3
```

# BaseComponent<T>

- **Represents any composite pattern hierarchy**
  - **Generic type parameter T is the extension interface**
  - **The two default methods both return false**
    - **Typical behaviour for a leaf component**

```
public interface BaseComponent<T> {
  default boolean add(T t) { return false; }
  default boolean remove(T t) { return false; }
}
```

# Contact extends BaseComponent

- **Our Contact inherits add() and remove()**

```
public interface Contact extends BaseComponent<Contact> {
  void sendMail(String body);
  int count();
}
```

- **Person remains exactly the same**

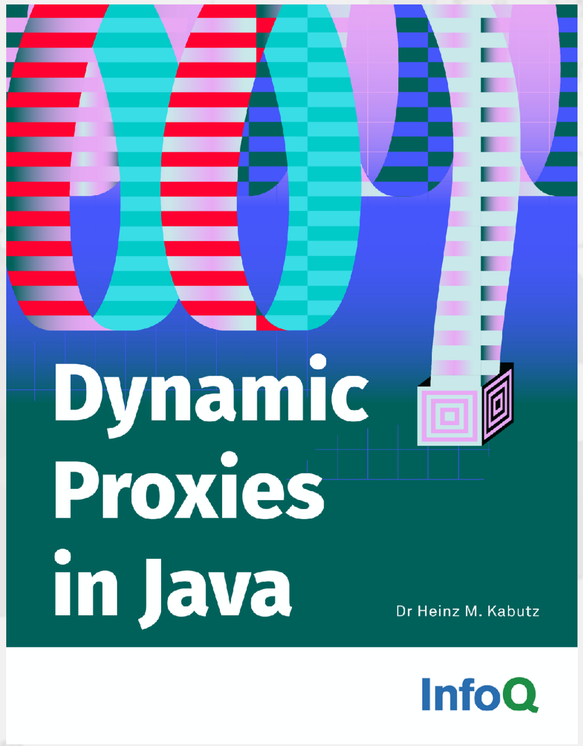
# Dynamic Composite Contact

```
var reducers = Map.of(
  new MethodKey(Contact.class, "count"),
  new Reducer(0, (r1, r2) -> (int)r1 + (int)r2)
);

Contact tjsn = Proxies.compose(Contact.class, reducers);
System.out.println(tjsn.count());
tjsn.add(new Person("john@aol.com"));
tjsn.sendMail("Issue 1");
System.out.println(tjsn.count());

Contact students = Proxies.compose(Contact.class, reducers);
students.add(new Person("peter@absa.co.za"));
students.add(new Person("mzani@absa.co.za"));
tjsn.add(students);
tjsn.sendMail("Issue 2");
System.out.println(tjsn.count());
```

```
0
Sending Issue 1 to john@aol.com
1
Sending Issue 2 to john@aol.com
Sending Issue 2 to peter@absa.co.za
Sending Issue 2 to mzani@absa.co.za
3
```

# Questions?

- Don't forget gift: tinyurl.com/MontrealJUG2020
- Please say "hello" : heinz@javaspecialists.eu

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