TECHNISCHE UNIVERSITÄT DRESDEN

32. Practical Refactoring-Based Framework Upgrade with *Comeback!*

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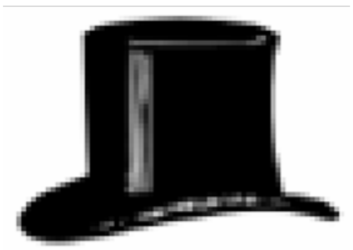


John Thompson , hatter, makes and
sells hats for ready money.

Benjamin Franklin, as cited in Kerievsky, 2004

Refactoring and Software Evolution

"A large program that is used undergoes continuing change or becomes progressively less useful."

Lehman's first law — Lehman and Belady, p. 250

"As a large program is continuously changed, its complexity … increases unless work is done to maintain or reduce it."

Lehman's second law — Lehman and Belady, p. 253

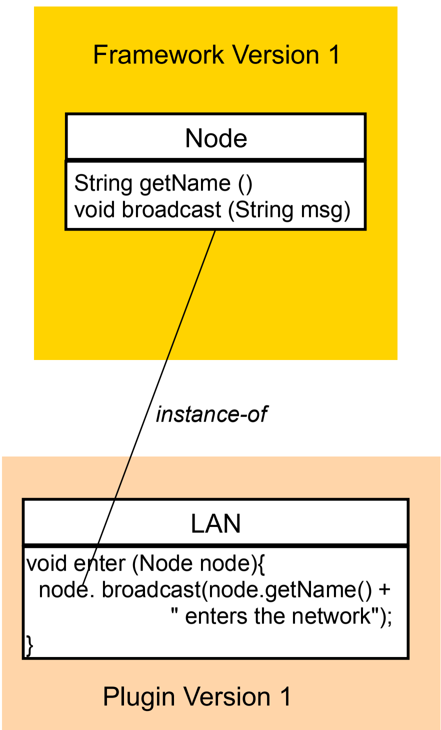
"Refactoring is the process of changing a software system in such a way that it does not alter the external behavior of the code yet improves its internal structure."

Fowler et al., 1999, xvi

Behavior-preserving yet structural-improving

Opdyke, 1992; Roberts, 1999

Software Frameworks and Plugins

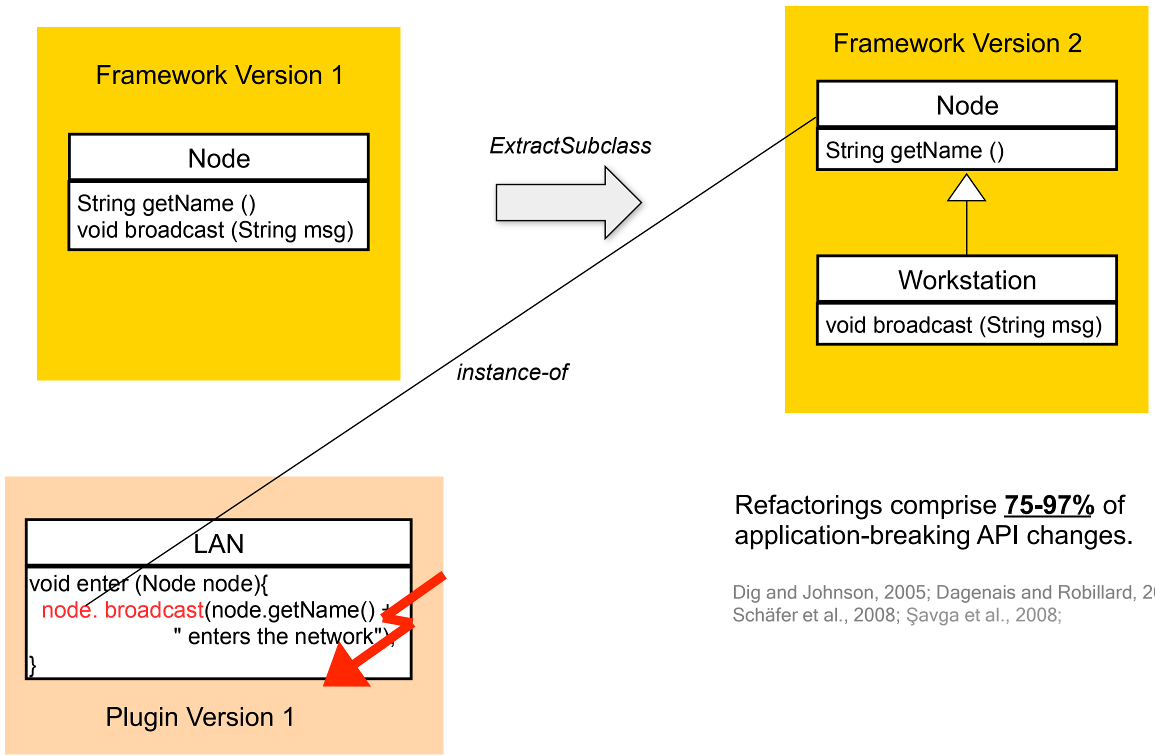


A software framework is a software component that embodies a skeleton solution for a family of related software products and is instantiated by modules containing custom code (*plugins*).

Johnson and Foote, 1998

Examples inspired by Demeyer et al., 2005

Framework Refactoring Breaking a Plugin



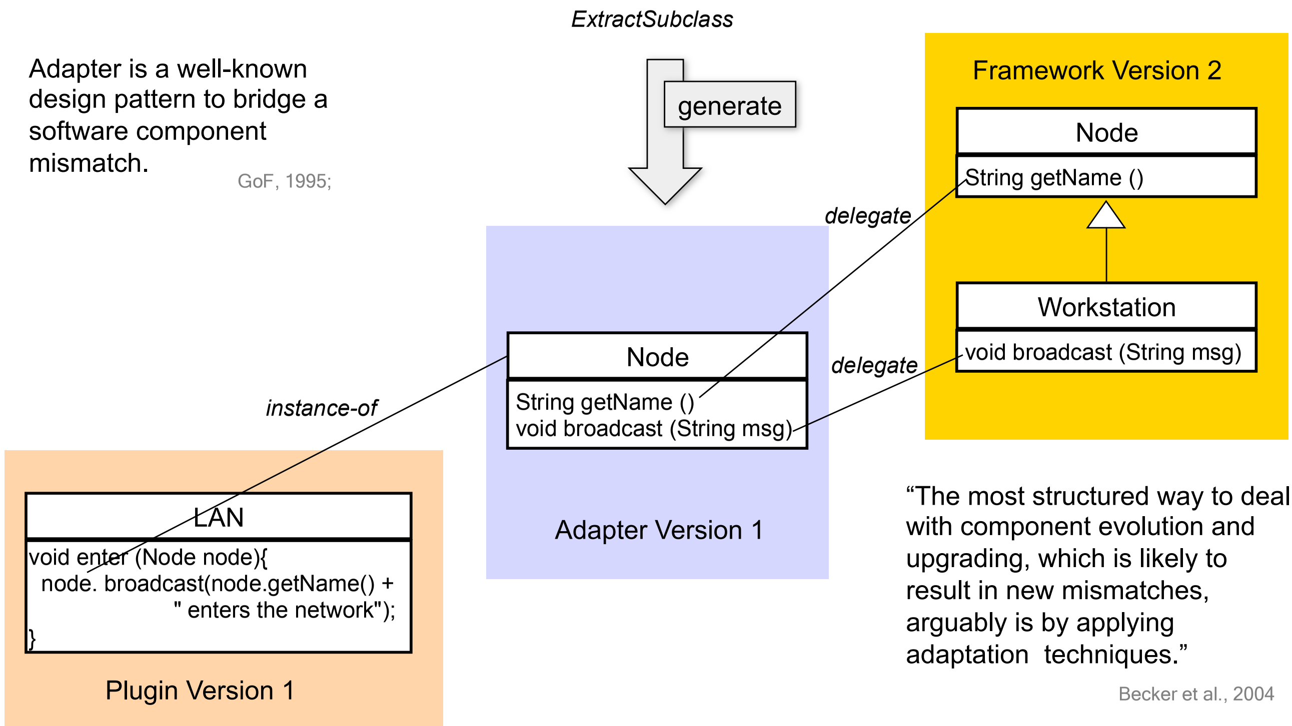
Refactorings comprise **75-97%** of application-breaking API changes.

Dig and Johnson, 2005; Dagenais and Robillard, 2008; Schäfer et al., 2008; Şavga et al., 2008;

Refactoring-Driven Adaptation

Adapter is a well-known design pattern to bridge a software component mismatch.

GoF, 1995;



"The most structured way to deal with component evolution and upgrading, which is likely to result in new mismatches, arguably is by applying adaptation techniques."

Becker et al., 2004

Comebacks: Refactoring Inverses on Adapters

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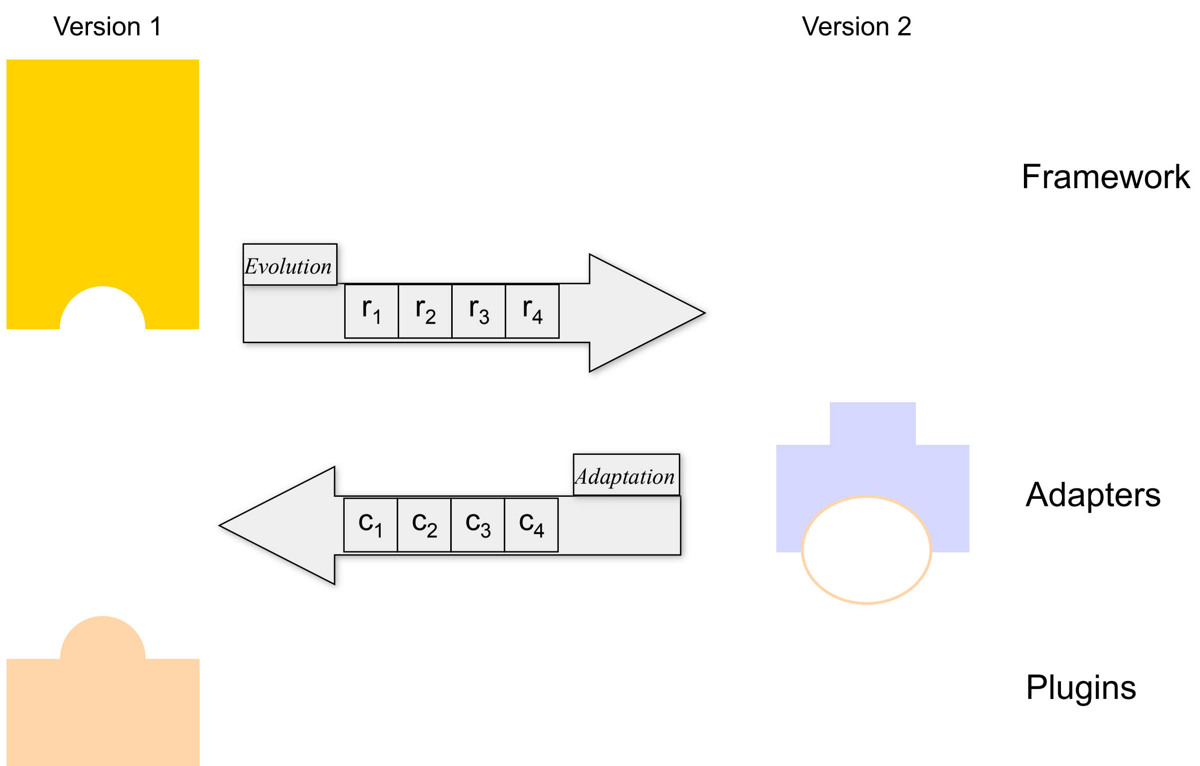

Comebacks: Refactoring Inverses on Adapters

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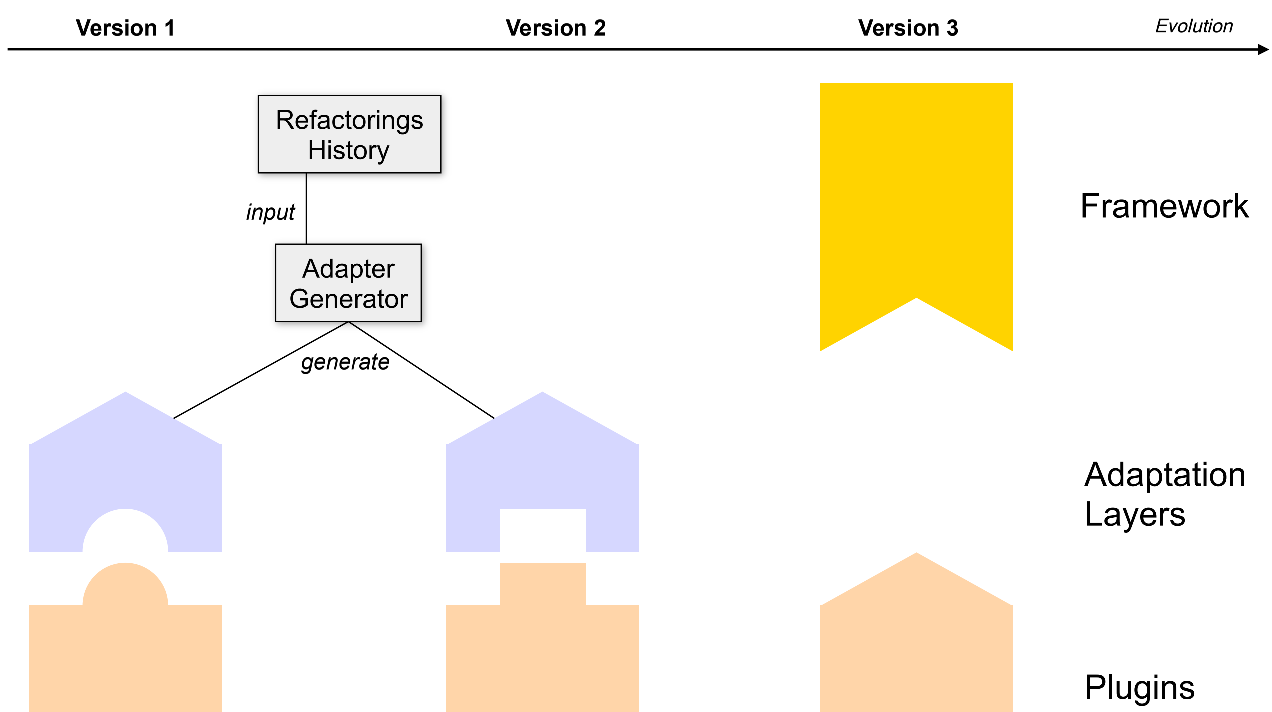
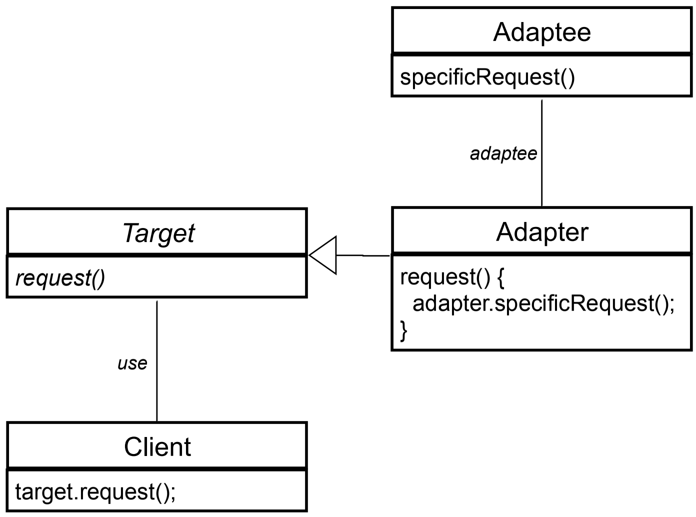
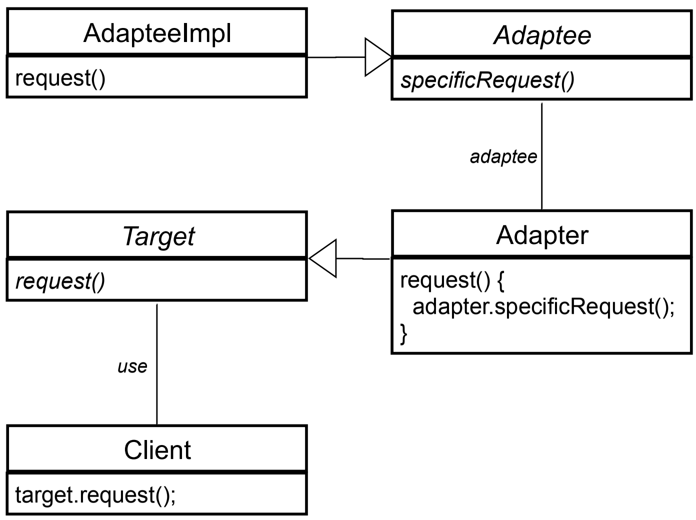


Adapter Design Pattern (Object Version)



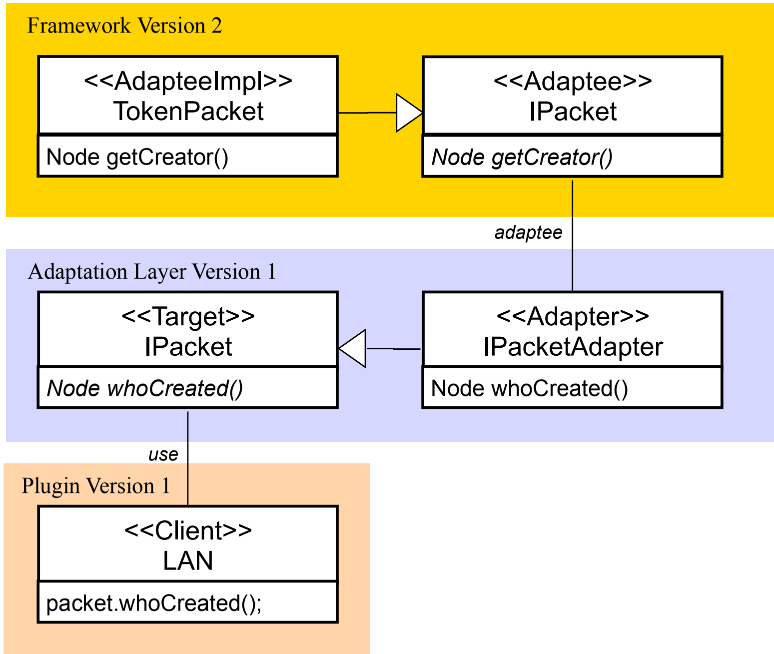
GoF, 1995

Refined Adapter Design Pattern (Object Version)

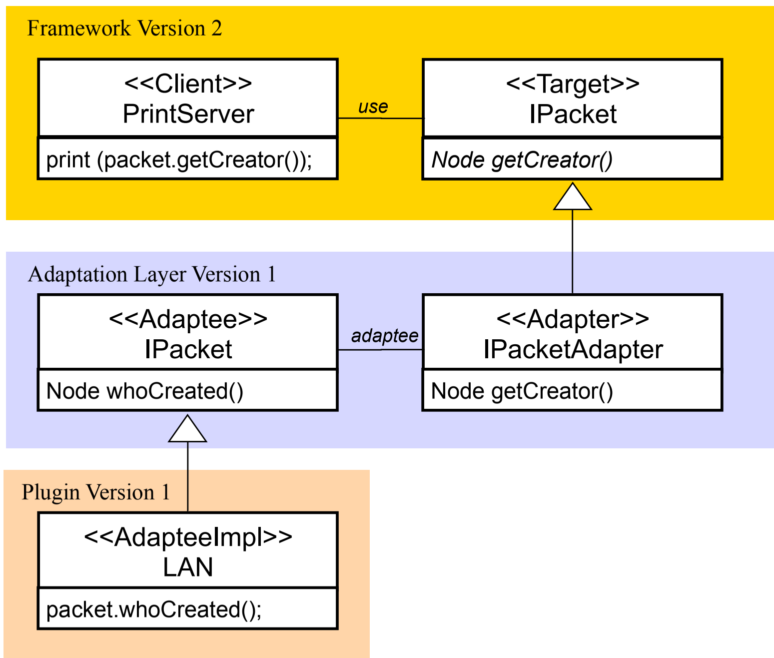


GoF, 1995

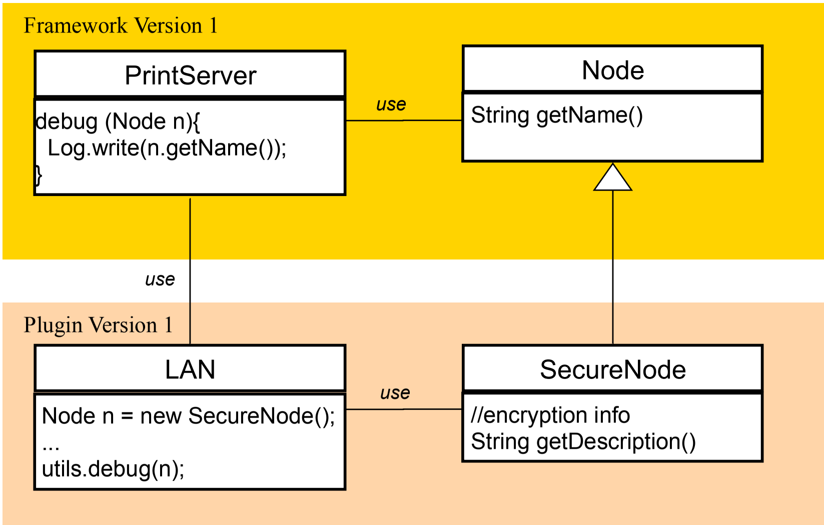
The Comeback! Black-Box Interface Adapter



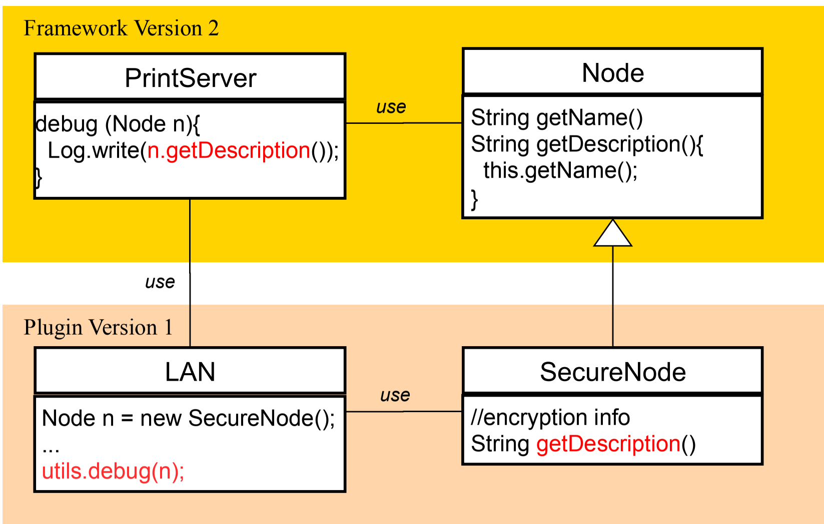
The Comeback! White-Box Interface Adapter



A White-Box Framework (Re-use by Inheritance)



Fragile Base Class Problem: Method Capture



Steyaert et al, 1996; Mikhajlov and Sekerinski , 1998

Method Capture Solved with Comback!White-Box Class Adapter

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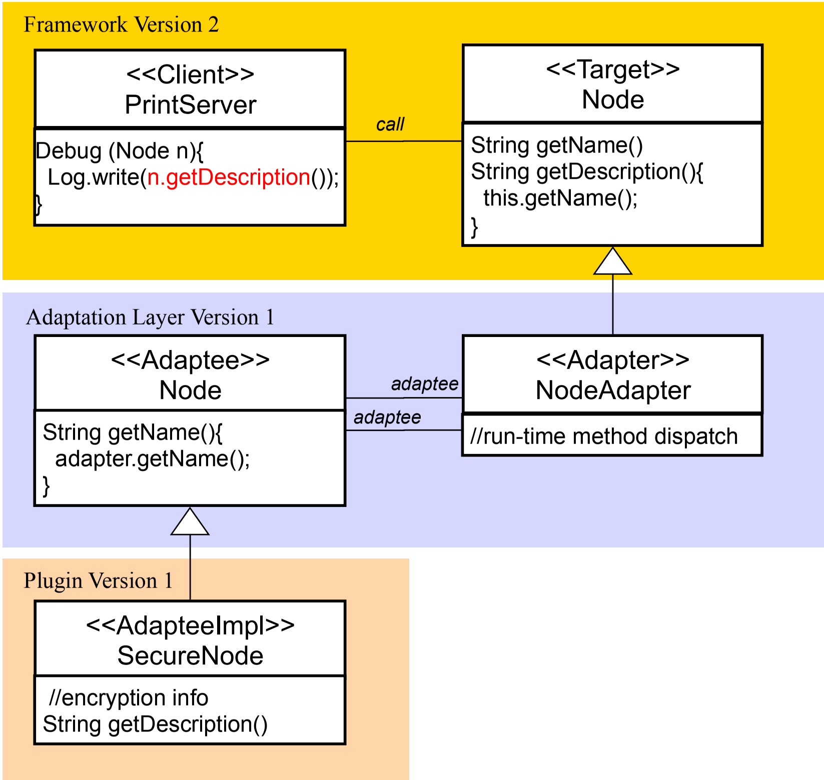

Exhaustive API Adaptation: Management of Adapters

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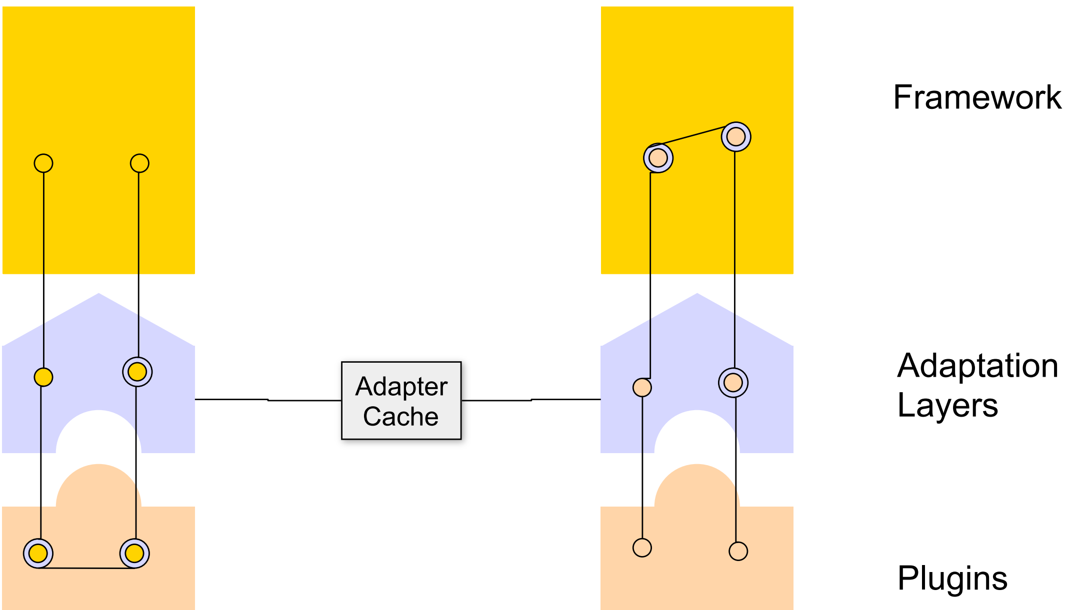
Call Framework -> Plugins

Call Plugins -> Framework



Framework<->Plugin Object Exchange

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Framework Version 1

```
public class PacketFactory{
  private Hashmap packetHistory;
    public Packet createPacket(PacketType type, INode creator){
        Packet pckt = new Packet(type);
        pckt.setCreator(creator);
        packetHistory.save(pckt);
        return pckt;
    }
}
```

Plugin Version 1

```
SecureNode node = new SecureNode();
PacketType pt = PacketFactory.getEncryptedPacketType();
…
Packet packet = PacketFactory.createPacket(pt,node);
```


Wrapping and Unwrapping of Parameter Objects in the Adaptation Layer

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New Framework

```
public class PacketFactory{
  private Hashmap packetHistory;
    public Packet createPacket(PacketType type, INode creator){
        Packet pckt = new Packet(type);
        pckt.setCreator(creator);
        packetHistory.save(pckt);
        return pckt;
    }
}
```

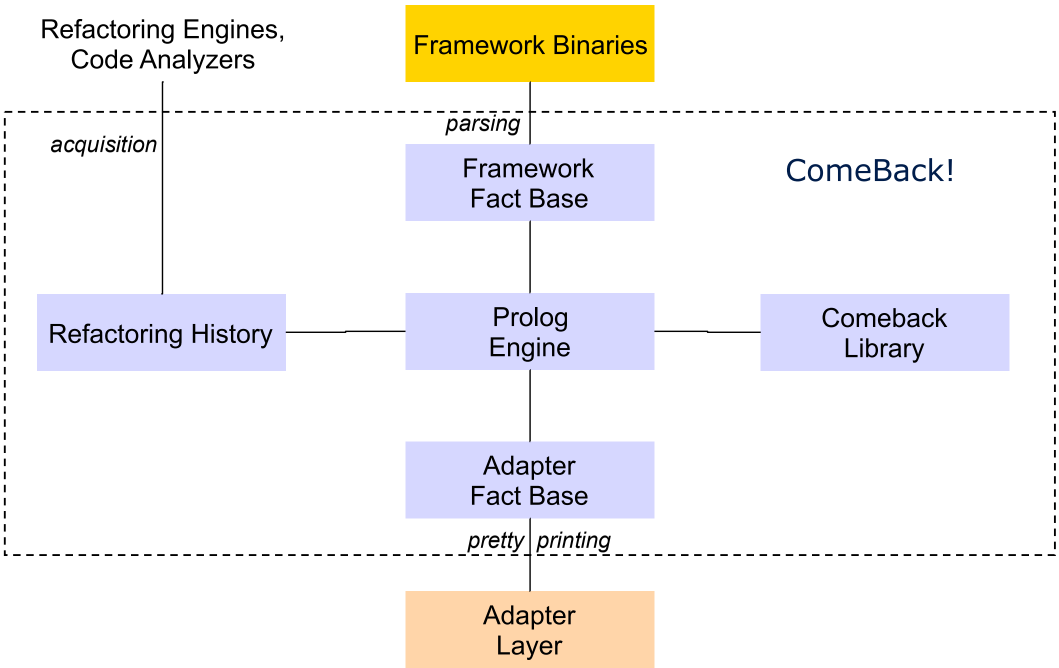
Adaptation Layer

unwrap
wrap
consult/update
adapter cache

Old Plugin

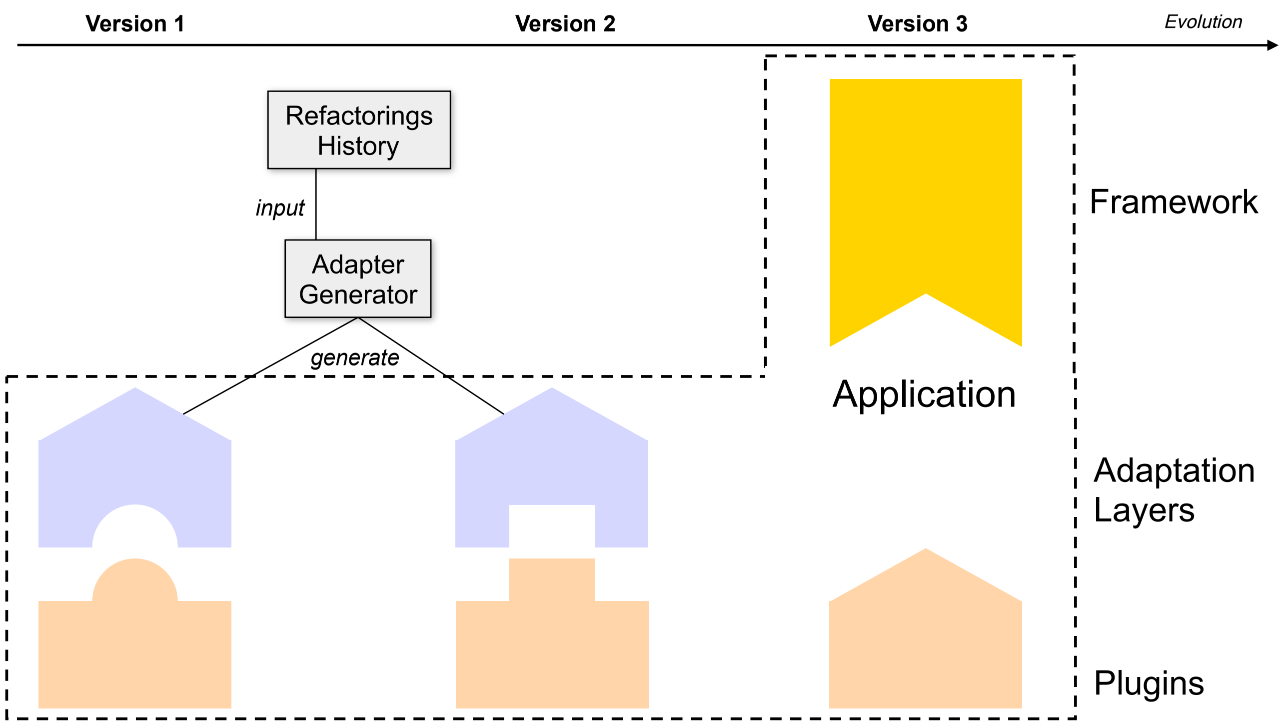
```
SecureNode node = new SecureNode();
PacketType pt = TypeFactory.getEncryptedPacketType();
…
Packet packet = PacketFactory.createPacket(pt,node);
```

Tool Validation: the ComeBack!



ComeBack! homepage: *http://comeback.sf.net*

Side-by-Side Plugin Execution



Case Studies

SalesPoint; JHotDraw

Java-based frameworks: SalesPoint and JHotDraw

- application-driven refactoring detection
- no backward compatibility concern but 85%
- comebacks specified and executed, remaining changes adapted manually

Effectiveness: all refactorings adapted

Performance: up to 6.5% overhead <=

- static optimizations
- run-time optimizations

Challenges and Limitations

Adapter pattern limitations

- no field refactorings
- no comebacks for refactorings implying *this*
- limited recovery of deleted methods

Object structure assumptions

- abusive reflective calls
- default serialization

Non-available refactoring info

- quering Eclipse refactoring log
- investigating the use of CVS

Intrusive Refactoring-Based Adaptation

CatchUp!: intrusively adapting plugins — Henkel and Diwan, 2005

- refactoring record-and-replay on application sources

\+ re-use of Eclipse refactoring info

\- requires plugin sources and implies new application release

ReBA: intrusively adapting frameworks — Dig at al., 2008

- compensating refactorings for combining old and new APIs

\+ preserve object identities; low performance overhead; recovering deleted implementation

\- no prove of soundess

\- (both): context-dependent (delete M and rename to M);
no white-box adaptation (accidental overriding possible);
Java-specific transformations

Conclusions

Comeback-based approach is rigorous and practical:

- refactorings treated as formal specification of syntactic change
- automatic and transparent API adaptation for most of application-breaking changes
- side-by-side plugin execution and fairly acceptable performance overhead (in tested applications)

At least, a short-term solution

Questions and Further Discussion

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Theorem 1. *CbAddClass is a comeback of AddClass.*

Proof. • Prop 1: *CbAddClass* is constructed using exactly one refactoring (*RemoveClass*) and, because it satisfies the preconditions of that refactoring (they are the same), behavior is preserved.

• Prop 2: The precondition of *RemoveClass* has to evaluate to true for the program changed by *AddClass*. Let the changed program be P'.

$$\begin{aligned} & P' \models (IsClass(class) \wedge \\ & (ClassReferences(class) = \emptyset) \wedge \\ & ((Subclasses(class) = \emptyset) \vee \\ & IsEmptyClass(class))) \\ \Leftrightarrow\ & (P' \models IsClass(class)) \wedge \\ & (P' \models (ClassReferences(class) = \emptyset)) \wedge \\ & ((P' \models (Subclasses(class) = \emptyset)) \vee \\ & (P' \models IsEmptyClass(class))) \\ \Leftrightarrow\ & \top \wedge \top \wedge (\top \vee \top) \Leftrightarrow \top \end{aligned}$$

The last derivation step is performed using the assertions transformed by the *post* of *AddClass*.

• Prop 3: The precondition of *AddClass* has to evaluate to true for the program changed by *AddClass* and *RemoveClass*. Let the changed program be P''.

$$\begin{aligned} & P'' \models (IsClass(superclass) \wedge \\ & \neg IsClass(class) \wedge \forall c \in subclasses. \\ & (IsClass(c) \wedge (Superclass(c) = superclass))) \\ \Leftrightarrow\ & (P'' \models IsClass(superclass)) \wedge \\ & (P'' \not\models IsClass(class)) \wedge \forall c \in subclasses. \\ & ((P'' \models IsClass(c)) \wedge \\ & (P'' \models (Superclass(c) = superclass))) \\ \Leftrightarrow\ & \top \wedge \top \wedge \top \wedge \top \Leftrightarrow \top \end{aligned}$$

The last derivation step is performed using the *post* of *AddClass* composed with the preconditions and *post* of *RemoveClass*.

□

CbPushDownMethod*(class, subclass, method)* is defined as a set of refactorings executed in two steps:

1. *AddMethod(class, method, Method(subclass, method)):* Add to the class *class* the method *method*, which is semantically equivalent to the method with the same name defined in *subclass*.
2. *RemoveMethod(subclass, method):* Remove *method* from *subclass*.

The precondition of *CbPushDownMethod*:

1. $IsClass(class) \wedge$
2. $IsClass(subclass) \wedge$
3. $(Superclass(subclass) = class) \wedge$
4. $(Superclass(Delegatee(subclass)) = Delegatee(class)) \wedge$
5. $DefinesSelector(subclass, method) \wedge$
6. $\neg DefinesSelector(class, method) \wedge$
7. $(\neg UnderstandsSelector(class, method) \vee (LookUpMethod(class, selector) \overset{\alpha}{\equiv} Method(subclass, method)))$

CbPushDownMethod: Proof

Theorem 2. *CbPushDownMethod is a comeback of PushDownMethod.*

Proof.
- Prop 1. For each used refactoring its precondition is satisfied. For *ChangeType*: type safeness property is preserved by assertions 1–4 of the *CbPushDownMethod* precondition. For *AddMethod*: the newly added method is not yet defined locally and is semantically equivalent to any overridden function (satisfied by assertions 5–7). For *RemoveMethod*: the *subclass* overrides a semantically equivalent *method* from *class* after executing *AddMethod* in the previous step, so *method* can be safely removed from *subclass*. Since the preconditions of all used refactorings are satisfied, behavior is preserved.
- Prop 2. The *post* of *PushDownMethod* (not shown) reflects the appearance of the method in the subclass and its removal from the superclass. It can be shown that the precondition of *CbPushDownMethod* is satisfied by the program changed by *PushDownMethod*.
- Prop 3. The assertions of the precondition of *PushDownMethod* ensure that: *class* and *subclass* exist; *method* is defined in *class* and not redefined in *subclass*; no private variables of *class* are accessed from *method*. The first two assertions are also assertions of the *CbPushDownMethod* precondition and are not changed (i.e., remain satisfied) after its execution. The definition of *method* in *class* and not in *subclass* is implied by the execution of *AddMethod* and *RemoveMethod*. The last assertion is satisfied by keeping the access mode of the delegation field protected (see Step 2 of *AddAdapter*).

□

CbExtractClass: Definition

CbExtractSubclass*(class, subclass, method)* is defined as:

1. *CbPushDownMethod(class, subclass, method)*
2. *CbAddClass(subclass, class, Subclasses(class))*

The precondition of *CbExtractSubclass* is a conjunction of the precondition of *CbPushDownMethod* and that of *CbAddClass* evaluated with regard to the *post* definition of *CbPushDownMethod*.

Theorem 3. *CbExtractSubclass is a comeback of ExtractSubclass.*

Proof. As *CbExtractSubclass* is defined as a sequence of two comebacks *CbPushDownMethod* and *CbAddClass*, its three comeback properties can be proven by induction on the previous two proofs. □

Creating Adaptation Layer: AddAdapter

AddAdapter(*class*)

1. *AddClass(Delegatee(class), Delegatee(Superclass(class)), ∅):* Create an empty class with the unique name returned by the renaming function. Its superclass name is the value of the renaming function for the *superclass* of *class*.
2. *AddInstanceVariable(class, DField(class), Delegatee(class)):* Add a (protected) delegation variable to the class.
3. $\forall v \in VariablesDefinedBy(class) \setminus \{DField(class)\}$. *MoveInstanceVariable(class, v, Delegatee(class)):* Move all but the delegation variable of *class* to the class created in step 1.
4. $\forall m \in \{d | DefinesSelector(class, d)\}$. *MoveMethod(class, m, DField(class), m):* Move all methods, defined in *class*, to the class of its delegation variable. For each method, *MoveMethod* creates a method in the original class, which forwards to the moved method.

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