Specifications of Implemented Refactorings

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This document collects the pseudo-code specifications of all refactoring implemented in our engine. **Note:** This is work in progress; some specifications are missing, and not all implementations agree completely with the specifications.

1 Pseudocode Conventions

We give our specifications in generic, imperative pseudocode. Parameters and return values are informally typed, with syntax tree nodes having one of the types from Fig. 1. Additionally, we use an ML-like `option` type with constructors `None` and `Some` for functions that may or may not return a value.

Where convenient, we make use of ML-like lists, with list literals of the form $[1; 2; 3]$ and $|xs|$ indicating the length of list xs.

The names of refactorings are written in SMALL CAPS, whereas utility functions appear in `monospace`. A list of utility functions with brief descriptions is given in Fig. 2. An invocation of a refactoring is written with floor-brackets $\lfloor$LIKE THIS$\rfloor$() to indicate that any language extensions used in the output program produced by the refactoring should be eliminated before proceeding.

We write $A <: B$ to mean that type A extends or implements type B, and $m <: m'$ to mean that method m overrides method m'.

2 The Refactorings

2.1 Convert Anonymous to Local

This refactoring converts an anonymous class to a local class. Implemented in `TypePromotion/AnonymousClassToLocalClass.jrag`.

2.2 Convert Anonymous to Nested

This refactoring converts an anonymous class to a member class. Implemented in `TypePromotion/AnonymousClassToMemberClass.jrag`.

Note: the implementation additionally handles the case where A occurs in a field initialiser.

Algorithm 1 CONVERT ANONYMOUS TO LOCAL(A : *AnonymousClass*, n : *Name*) : *LocalClass*

Require: Java
Ensure: Java ∪ locked names

$c \leftarrow$ class instance expression containing A
$d \leftarrow$ [EXTRACT TEMP](c, `unCapitalise`(n))
$b \leftarrow$ enclosing body declaration of s
`lockNames`(b, n)
convert A to class named n, remove it from c
INSERT TYPE(b, A)
lock type access of c to A
INLINE TEMP(d)
return A

Algorithm 2 CONVERT ANONYMOUS TO NESTED(A : *AnonymousClass*) : *MemberType*

Require: Java
Ensure: Java

$L \leftarrow$ CONVERT ANONYMOUS TO LOCAL(A)
return CONVERT LOCAL TO MEMBER CLASS(L)

2.3 Convert Local to Member Class

This refactoring converts a local class to a member class. Implemented in `TypePromotion/LocalClassToMemberClass.jrag`.

TODO: provide specification of close over type variables and close over local variables (implemented in TypePromotion/CloseOverVariables.jrag)

2.4 Extract Class

This refactoring extracts some fields of a class into a newly created member class. Implemented in `ExtractClass/ExtractClass.jrag`.

This is only a bare-bones specification. The implementation additionally allows t encapsulate the extracted fields, and to move the wrapper class W to the toplevel.

2.5 Extract Constant

This refactoring extracts a constant expression into a field. Implemented in `ExtractTemp/ExtractConstant.jrag`.

An expression is extractible if its type is not `void`, it is not a reference to a type or package, and it is not the keyword `super`; furthermore, it is not on the right-hand side of a dot.

Algorithm 3 Convert Local to Member Class(L : *LocalClass*) : *MemberType*

Require: Java
Ensure: Java $\cup$ locked names, fresh variables

$A \leftarrow$ enclosing type of L
close L over type variables
close L over local variables
if L is in static context **then**
    make L static
end if
`lockNames`(`name`(L))
lock all names in L
remove L from its declaring method
Insert Type(A, L)

Algorithm 4 Extract Class(C : *Class*, *fs* : `list` *Field*, n : *Name*, *fn* : *Name*)

Require: Java
Ensure: Java $\cup$ locked dependencies, first-class array init

$v \leftarrow$ maximum visibility of any of the *fs*
$W \leftarrow$ new `static` class of name n with visibility v
Insert Type(C, W)
$w \leftarrow$ new field of type W and name *fn*, initialised to a new instance of W
Insert Field(C, w)
for all $f \in fs$ **do**
    assert f is not static
    for all uses v of f **do**
        qualify v with a locked access to w
    end for
    remove f
    Insert Field(W, f)
    if f has initialiser **then**
        lock flow dependencies of f
        $e \leftarrow$ initialiser of f
        remove initialiser of f
        add e as argument to initialisation of w
        $p \leftarrow$ new parameter of same name and type as f
        for all constructors *cd* of W **do**
            add copy of p as parameter of W
            add assignment from parameter to f to body of *cd*
        end for
    end if
end for

Algorithm 5 EXTRACT CONSTANT($e : \mathit{Expr}, n : \mathit{Name}$)

Require: Java

Ensure: Java $\cup$ locked dependencies

1: **assert** e is extractible
2: $A \leftarrow$ enclosing type of e
3: $t \leftarrow$ effective type of e
4: $f \leftarrow$ new `public static final` field of type t and name n
5: INSERT FIELD(A, f)
6: lock names, flow, and synchronisation of e
7: set initialiser of f to e
8: replace e with locked access to f

The *effective type* of an expression e is the same as the type of e, except when the type of e is an anonymous class, in which case the effective type is its superclass, or when the type of e is a captured type variable, in which case the effective type is its upper bound.

2.6 Extract Method

See ECOOP 2009 publication.

2.7 Extract Temp

This refactoring extracts an expression into a local variable. Implemented in `ExtractTemp/ExtractTemp.jrag`.

Algorithm 6 EXTRACT TEMP($e : \mathit{Expr}, n : \mathit{Name}$)

Require: Java

Ensure: Java

1: $t \leftarrow$ effective type of e
2: $v \leftarrow$ new local variable of type t and name n
3: $s \leftarrow$ enclosing statement of e
4: INSERT LOCAL VARIABLE(s, v)
5: EXTRACT ASSIGNMENT(v, e)
6: MERGE DECLARATION(v)

2.7.1 Insert Local Variable

The refactoring inserts a local variable before a given statement. Implemented in `ExtractTemp/IntroduceUnusedLocal.jrag`.

Algorithm 7 INSERT LOCAL VARIABLE(s : *Stmt*, v : *LocalVar*

Require: Java
Ensure: Java $\cup$ locked names

$b \leftarrow$ enclosing block of s
assert variable v can be introduced into block b
`lockNames`(b, n)
insert v before s

2.7.2 Extract Assignment

This refactoring extracts an expression into an assignment to a local variable. Implemented in `ExtractTemp/ExtractAssignment.jrag`.

Algorithm 8 EXTRACT ASSIGNMENT(v : *LocalVar*, e : *Expr*) : *Assignment*

Require: Java
Ensure: Java $\cup$ locked dependencies

assert e is extractible
$a \leftarrow$ new assignment from e to v
if e is in expression statement **then**
    replace e with a
else
    $s \leftarrow$ enclosing statement of e
    lock all names in e
    insert a before s
    replace e with locked access to v
end if
return a

2.7.3 Merge Variable Declaration

This refactoring merges a variable declaration with the assignment immediately following it, if that assignment is an assignment to the same variable. Implemented in `ExtractTemp/MergeVarDecl.jrag`.

2.8 Inline Constant

This refactoring inlines a constant field into all its uses. Implemented in `InlineTemp/InlineConstant.jrag`.

2.9 Inline Method

See ECOOP 2009 publication.

Algorithm 9 MERGE VARIABLE DECLARATION(v : *LocalVar*)

Require: Java $\setminus$ multi-declarations
Ensure: Java

```
if v has initialiser then
    return
end if
s ← statement following v
if s is assignment to v then
    make RHS of s the initialiser of v
    remove s
end if
```

Algorithm 10 INLINE CONSTANT(f : *Field*)

Require: Java $\setminus$ implicit assignment conversion
Ensure: Java

```
for all uses u of f do
    INLINE CONSTANT(u)
end for
REMOVE FIELD(f)
```

Algorithm 11 INLINE CONSTANT(u : *FieldAccess*)

Require: Java
Ensure: Java $\cup$ locked dependencies

```
f ← field accessed by u
assert f is final and static, and has an initialiser
e ← locked copy of the initialiser of f
assert if u is qualified, then its qualifier is a pure expression
replace u with e, discarding its qualifier if any
```

Algorithm 12 REMOVE FIELD(f : *Field*)

Require: Java
Ensure: Java

```
if f is not used and if it has an initialiser, it is pure then
    remove f
end if
```

2.10 Inline Temp

This refactoring inlines a local variable into all its uses. Implemented in `InlineTemp/InlineTemp.jrag`.

Algorithm 13 INLINE TEMP(d : *LocalVar*)

Require: Java
Ensure: Java

$a \leftarrow \lfloor$SPLIT DECLARATION$\rfloor(d)$
$\lfloor$INLINE ASSIGNMENT$\rfloor(a)$
$\lfloor$REMOVE DECL$\rfloor(v)$

Algorithm 14 SPLIT DECLARATION(d : *LocalVar*) : `option` *Assignment*

Require: Java $\setminus$ compound declarations
Ensure: Java $\cup$ locked names, first-class array init

if d has initialiser **then**
  $x \leftarrow$ variable declared in d
  $a \leftarrow$ new assignment from initialiser of d to x
  insert a as statement after d
  remove initialiser of d
  return `Some` a
else
  return `None`
end if

2.11 Introduce Factory

This refactoring introduces a static factory method as a replacement for a given constructor, and updates all uses of the constructor to use this method instead. Implemented in `IntroduceFactory/IntroduceFactory.jrag`.

We use `createFactoryMethod` (implemented in `util/ConstructorExt.jrag`) to create the factory method corresponding to constructor *cd* and insert it into the host type of *cd*. The factory method has the same signature as *cd*, but it has its own copies of all type variables of the host type used in *cd*.

2.12 Introduce Indirection

This refactoring creates a static method m' in type B that delegates to a method m in type A. Implemented in `IntroduceIndirection/IntroduceIndirection.jrag`.

TODO: implementation needs to be cleaned up

Algorithm 15 Inline Assignment(a : *Assignment*)

Require: Java $\setminus$ implicit assignment conversion
Ensure: Java $\cup$ locked dependencies

```
x ← LHS of a
assert x refers to local variable
U ← all u such that a is a reaching definition of u
for all u ∈ U do
    assert a is the only reaching definition of u
    assert u is not an lvalue
    assert u, a are in same body declaration
    replace u with a locked copy of the RHS of a
end for
if U ≠ ∅ then
    remove a
end if
```

Algorithm 16 Remove Decl(d : *LocalVar*)

Require: Java $\setminus$ compound declarations
Ensure: Java

```
if d is not used and has no initialiser then
    remove d
end if
```

Algorithm 17 Introduce Factory(cd : *ConstructorDecl*)

Require: Java
Ensure: Java $\cup$ locked names

```
f ← static factory method for cd
for all uses u of cd and its parameterised copies do
    if u is a class instance expression without anonymous class and it is not
    in f then
        replace u with a call to f
    end if
end for
```

Algorithm 18 INTRODUCE INDIRECTION(m : *Method*, B : *ClassOrInterface*)

Require: Java
Ensure: Java $\cup$ locked names, `return void`

assert B is non-library
$fn \leftarrow$ fresh method name
$m' \leftarrow$ copy of m with locked names and empty body
set name of m' to fn
$xs \leftarrow$ locked accesses to parameters of m'
set body of m' to `return` m`(`xs`);`
INSERT METHOD(`hostType`(m), m')
MAKE METHOD STATIC(m')
MOVE STATIC METHOD(m', B)

2.13 Introduce Parameter

This refactoring turns an expression into a parameter of the surrounding method. Implemented in `ChangeMethodSignature/IntroduceParameter.jrag`.

Algorithm 19 INTRODUCE PARAMETER(e : *Expr*, n : *Name*)

Require: Java
Ensure: Java $\cup$ locked names

assert n is a valid name
assert e is extractible and constant
assert e appears within a method m
assert m is not overridden by and does not override any other methods
assert m has no parameter or local variable n
`lockMethodCalls`(`name`(m))
$t \leftarrow$ effective type of e
$p \leftarrow$ new parameter of type t and name n
insert p as the first parameter of m
replace e with locked access to p
for all calls c to m **do**
    insert a locked copy of e as first argument of c
end for

2.14 Introduce Parameter Object

This refactoring wraps a set P of parameters of a method m into a single parameter n of type w, where w is a newly created wrapper class containing fields corresponding to all the parameters in P. Implemented in `IntroduceParameterObject/IntroduceParameterObjec`

Note that we need to perform the transformation for all relatives of m, *i.e.* for all methods r such that there exists a method m' with $m <:^* m'$ and $r <:^* m'$. We also lock all calls to methods of the same as m in the

Algorithm 20 INTRODUCE PARAMETER OBJECT(m : *Method*, P : `set` *Parameter*, w : `set` Name, n : `set` Name)

Require: Java \ variable arity parameters
Ensure: Java ∪ locked names

assert m has a body
assert the parameters in P are in contiguous positions $i, \ldots, i+k$
$W \leftarrow$ new class containing fields for all the P and a standard constructor to initialise them
INSERT TYPE(`hostType`(m), W)
`lockMethodCalls`(`name`(m))
for all relatives r of m **do**
    assert r has no parameter or local variable with name n
    $[p_1; \ldots; p_n] \leftarrow$ parameters of r
    $p \leftarrow$ new parameter of type W and name n
    replace parameters $p_i, \ldots, p_{i+k}$ with p
    for all $j \in \{i, \ldots, i+k\}$ **do**
        $v_j \leftarrow$ new variable of same name, type, and finality as p_j
        insert assignment from $p.f_j$ to v_j at beginning of m
    end for
    for all calls c to r **do**
        $[a_1; \ldots; a_n] \leftarrow$ arguments of c
        replace arguments $a_i, \ldots, a_{i+k}$ with `new` W`(`a_i`,...,`a_{i+k}`)`
    end for
end for

whole program; this ensures that if overloading resolution changes due to the transformation, the name binding framework will insert appropriate casts to rectify the situation.

2.15 Move Inner To Toplevel

This refactoring converts a member type to a toplevel type. Implemented in `TypePromotion/MoveMemberTypeToToplevel.jrag`.

Algorithm 21 MOVE MEMBER TYPE TO TOPLEVEL(M : *MemberType*)

Require: Java
Ensure: Java $\cup$ locked names

1: **if** M is not static **then**
2: $\lfloor$MAKE TYPE STATIC$\rfloor$(M)
3: **end if**
4: $p \leftarrow$ `hostPkg`(M)
5: lock all names in M
6: remove M from its host type
7: INSERT TYPE(p, M)

Algorithm 22 INSERT TYPE(p : *Package*, T : *ClassOrInterface*)

Require: Java
Ensure: Java $\cup$ locked names

1: **assert** no type or subpackage of same name as T in p
2: `lockNames`(`name`(T))
3: remove modifiers `static`, `private`, `protected` from T
4: insert T into p

2.16 Move Instance Method

This refactoring moves a method into a variable, which is either a parameter of that method or an accessible field. Implemented in `Move/MoveMethod.jrag`.

2.17 Move Members

In order to move Field, static methods, and member types, we simply lock all references to them, as well as all names contained in them, and (for fields) the flow dependencies of their initialiser, and then move them inside the AST.

2.18 Promote Temp to Field

This refactoring turns a local variable into a field. Implemented in `PromoteTempToField/PromoteTempToField.`

Algorithm 23 MAKE TYPE STATIC(M : *MemberType*)

Require: Java
Ensure: Java $\cup$ `with`, locked names

$[A_n; \ldots; A_1] \leftarrow$ enclosing types of M
for all $i \in \{1, \ldots, n\}$ **do**
  $f \leftarrow$ new field of type A_i with name `this$i`
  INSERT FIELD(M, f)
  for all constructors c of M **do**
    $p \leftarrow$ parameter of type A_i with name `this$i`
    assert no parameter or variable `this$i` in c
    insert p as first parameter of c
    if c is chaining **then**
      add `this$i` as first argument of chaining call
    else
      $a \leftarrow$ new assignment of p to f
      insert a after `super` call
    end if
  end for
end for
for all constructors c of M **do**
  for all non-chaining invocations u of c **do**
    $es \leftarrow$ enclosing instances of u
    assert $|es| = n$
    insert es as initial arguments to u
    discard qualifier of u, if any
  end for
end for
if M not in inner class **then**
  put modifier `static` on M
end if
for all non-`static` callables m of M **do**
  if m has a body **then**
    surround body of m by
    `with(this$n, ..., this$1, this) {...}`
  end if
end for

Algorithm 24 MOVE METHOD(m : *InstanceMethod*, v : *Variable*)

Require: Java
Ensure: Java ∪ locked names, `return void`, fresh variables, demand `final`

assert v is either a parameter of m or a field
$T \leftarrow$ type of v
assert T is a non-library class
assert m has a body and is not from library
$m' \leftarrow$ copy of m with `synchronized` removed and all names locked
$xs \leftarrow$ list of locked accesses to parameters of m
if v is a parameter **then**
  $i \leftarrow$ position of v in parameter list of m
  remove ith parameter from m'
  remove ith element of xs
else
  $i \leftarrow 0$
end if
$v' \leftarrow$ `final` local variable declaration with same name and type as v, initialised to `this`
insert v' as first statement into m'
lock all uses of v inside m' to v'
$qs \leftarrow []$
for all enclosing classes C of m **do**
  $p_C \leftarrow$ demand `final` parameter with fresh name, of type C
  make p_C the ith parameter of m'
  $e \leftarrow$ access to C`.this`
  insert e as ith element into xs
  $qs \leftarrow [\![p_C]\!] :: qs$
end for
wrap body of m' into `with(`qs`) {...}`
set body of m to `return` $[\![v]\!]$`.`$[\![m]\!]$`(`xs`);`
INSERT METHOD(T, m')
eliminate `with` statement in m'
INLINE TEMP(v')
for all p_C **do**
  REMOVE PARAMETER(p_C) **or** ID()
end for

Algorithm 25 PROMOTE TEMP TO FIELD(d : *LocalVar*)

Require: Java
Ensure: Java ∪ locked dependencies

```
⌊SPLIT DECLARATION⌋(d)
d' ← new private field of same type and name as d
make d' static if d is in static context
⌊INSERT FIELD⌋(hostType(d), d')
for all uses u of d do
    lock u onto d'
    lock reaching definitions of u
end for
REMOVE DECL(d)
```

Algorithm 26 INSERT FIELD(T : *ClassOrInterface*, d : *Field*)

Require: Java
Ensure: Java ∪ locked names

```
assert T has no local field with same name as d
assert d has no initialiser
assert if T is inner and d is static, then d is a constant
lockNames(name(d))
insert field d into T
```

2.19 Pull Up

This refactoring pulls up a method m from its host class B to the super class A. Implemented in `PullUp/PullUpMethod.jrag`.

Algorithm 27 PULL UP METHOD(m : *Method*)

Require: Java
Ensure: Java ∪ locked names

```
assert the host type of m B is a non-library class
assert the superclass A of B is also non-library
m' ← copy of m with locked names
translate type variables in m' from B to A
Insert Method(A, m')
remove m from B
```

TODO: explain translation of type variables; this is basically a right-inverse of the type variable substitution that happens when inheriting a method

Note that INSERT METHOD ensures that the inserted method is not called from anywhere.

2.20 Push Down

This refactoring pushes a method down to all subclasses of its defining class. Implemented in `PushDown/PushDownMethod.jrag`.

Algorithm 28 TRIVIALLY OVERRIDE(B : *Type*, m : *VirtualMethod*) : `option` *MethodCall*

Require: Java \ implicit method modifiers
Ensure: Java + locked names, `return void`

```
assert m is not final
if m not a member method of B then
  return None
end if
m′ ← copy of m with locked names
if m is abstract then
  insert method m′ into B
  return None
else
  xs ← list of locked accesses to parameters of m′
  c ← super.m(xs)
  set body of m′ to return c;
  insert method m′ into B
  return Some c
end if
```

Algorithm 29 REMOVE METHOD(m : *Method*)

Require: Java
Ensure: Java

```
assert (uses(m) ∪ calls(m)) \ below(m) = ∅
o ← {m′ | m <: m′}
if o ≠ ∅ ∧ ∀m′ ∈ o.m′ is abstract then
  for all types B that inherit m do
    MAKE TYPE ABSTRACT(B)
  end for
end if
remove m
```

2.21 Rename

This family of refactorings is used for renaming named program entities. Implemented in `Renaming/`.

Refactoring RENAME FIELD changes the name of a field f to n. It ensures that n is indeed a valid name and that the host type of f contains no other

Algorithm 30 MAKE METHOD ABSTRACT(m : *Method*)

Require: Java
Ensure: Java

```
assert calls(m) \ below(m) = ∅
for all types B that inherit m do
  MAKE TYPE ABSTRACT(B)
end for
make m abstract
```

Algorithm 31 MAKE TYPE ABSTRACT(T : *Type*)

Require: Java
Ensure: Java

```
if T is interface then
  return
end if
assert T is class and never instantiated
make T abstract
```

Algorithm 32 PUSH DOWN VIRTUAL METHOD(m : *VirtualMethod*)

Require: Java
Ensure: Java ∪ locked names

```
for all types B <: hostType(m) do
  c ← ⌊TRIVIALLY OVERRIDE⌋(B, m)
  if c ≠ None then
    INLINE METHOD(c)
  end if
end for
REMOVE METHOD(m)
    or MAKE METHOD ABSTRACT(m)
    or ID()
```

Algorithm 33 RENAME FIELD(f : *Field*, n : *Name*)

Require: Java
Ensure: Java ∪ locked names

```
assert n is a valid name
assert host type of f contains no other field of name n
lockNames({n, name(f)})
set name of f to n
```

field called n. It then globally locks all accesses to variables, types, or packages named either n or $\texttt{name}(f)$, and changes the name of f to n.

Algorithm 34 RENAME LOCAL(v : *Local*, n : *Name*)

Require: Java
Ensure: Java $\cup$ locked names

assert n is a valid name
assert enclosing block of v is neither contained in, nor contains the scope of another local named n
$\texttt{lockNames}(\texttt{block}(v), \{n, \texttt{name}(f)\})$
set name of v to n

Refactoring RENAME LOCAL changes the name of a local variable or parameter v to n. It ensures that n is indeed a valid name and that the renaming v to n will not violate the rule that scopes of local variables of the same name cannot be nested. It then again locks all accesses to variables, types, or packages named either n or $\texttt{name}(v)$, but only within the enclosing block of v, and changes the name of v to n.

2.22 Self-Encapsulate Field

This refactoring makes a field private, rerouting all accesses to it through getter and setter methods. Implemented in `SelfEncapsulateField/SelfEncapsulateField.jrag`.

Algorithm 35 SELF-ENCAPSULATE FIELD(f : *Field*)

Require: Java $\setminus$ abbreviated assignments
Ensure: Java $\cup$ locked names

create getter method g for f
if f is not `final`, create setter method s for it
for all all uses u of f and its substituted copies **do**
  if $u \notin \texttt{below}(g) \cup \texttt{below}(s)$ **then**
    if u is an rvalue **then**
      replace u with locked access to g
    else
      if f is not `final` **then**
        $q \leftarrow$ qualifier of u, if any
        $r \leftarrow$ RHS of assignment for which u is LHS
        replace u with locked access to s on argument r, qualified with q if applicable
      end if
    end if
  end if
end for

Node Type	Description
ClassOrInterface	either a class or an interface; is a *Type*
Field	field declaration
LocalVar	local variable declaration
MemberType	type declared inside another type; is a *Type*
Method	method declaration
MethodCall	method call
Package	package
Type	type declaration
VirtualMethod	non-`private` instance method; is a *Method*

Figure 1: Node Types

By "abbreviated assignment" we mean `x+=y` and friends, as well as increment and decrement expressions. The language restriction tries to expand these into normal assignments, but may fail if the data flow is too complicated. If it succeeds, every lvalue will appear on the left hand side of a (simple) assignment.

Note that even when f is final there may still be assignments to f from within constructors; we cannot encapsulate these assignments, so we skip them.

3 Node Types

See Fig. 1. We also use the non-node type *Name* to represent names.

4 Utility Functions

See Fig. 2.

Name	Description
`below`(n)	returns the set of all nodes below n in the syntax tree
`calls`(m)	returns all calls that may dynamically resolve to method m; can be a conservative over-approximation
`hostPkg`(e)	returns the package of the compilation unit containing e
`hostType`(e)	returns the closest enclosing type declaration around e
`lockMethodCalls`(n)	locks all calls to methods named n anywhere in the program
`lockNames`(n)	locks all names anywhere in the program that refer to a declaration with name n
`name`(e)	returns the name of program entity e
`uses`(m)	returns all calls that statically bind to method m

Figure 2: Utility Functions