Specifying the Java Collections Framework in JavaDL

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Outline

1. Motivation
2. Specification by example
3. Interface specification
4. Using specifications
5. A "new" method contract rule
6. Demo
7. Conclusion

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1. *No sources of the JDK library available in KeY*
   $\Rightarrow$ *symbolical execution of library calls fail*
2. *For native methods sources not even exist*

Why specifying the Java Collections Framework?

- JCF used in many projects
- Case study

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Specification by example
Normal case

Example Method

```
SomeLibrary.copy(java.lang.Object[] src, java.lang.Object[] dest)
```

Precondition

```
src != null & src.<created> = TRUE &
dest != null & dest.<created> = TRUE &
src.length = dest.length &
\forall int i; ( (0 <= i & i < src.length) ->
arrayStoreValid(dest, src[i]) )
```

Postcondition

```
\forall int i; ( (0 <= i & i < src.length) -> dest[i] = src[i] )
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Modifies

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dest[0 .. src.length]
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Specification by example

Exceptional case

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```
src.length = dest.length &
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Postcondition

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exc = null ->
\forall int i; ( (0 <= i & i < src.length) -> dest[i] = src[i] )
&
exc != null ->
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    ( src != null & dest != null ) ->
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General Concept for specifying methods

Precondition

Nearly all the time "`true`"

Postcondition

Let ϕ_N be the postcondition for normal behaviour
Let ψ_{Exc_i} $(1 \leq i \leq n, n \in N)$ be the condition where the exception Exc_i is thrown
Let ϕ_{Exc_i} be the postcondition that holds after Exc_i has been thrown
Then the postcondition should look like this:

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\begin{array}{l}
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Model functions

Problem

Method behaviour is described by attribute changes

But:

Interfaces don't contain any attributes

Solution

Introduce some function symbols for storing necessary information ("model functions")

E.g. `\nonRigid[Location] int _size(java.util.List)` for remembering a Lists actual size

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Interface specification

Example

Method to be specified

`s = myList.size()@java.util.List;`

with `s` $\sqsubseteq$ `jint` and `myList` $\sqsubseteq$ `java.util.List`

Precondition

`true`

Postcondition

```
\if (_size(myList) <= java.lang.Integer.MAX_VALUE)
\then (s = _size(myList))
\else (s = java.lang.Integer.MAX_VALUE)
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Modifies

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Problems with model functions

Introducing model methods yields to two additional problems.

1. How to initialize a model function?

Answer

Write a method contract for the <init> function of the appropriate class

2. Symbolical execution <–> use of method contracts

Solution

Never use both for the same object in one proof
and assure correctness by

- Proof obligation inserts new non rigid predicate
- check in preconditions of contracts for it

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Using specification
Libraries

Loading of contracts

The Library mechanism of KeY is used to load the contracts, i.e. the specifications are stored in KeY-files

Application of Contracts

Applying contracts within a proof is done via the `MethodContractRule`

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Using specifications

Let `S`, `T` be types with $\texttt{S} \sqsubseteq \texttt{T}$
Let $\texttt{obj} \in \texttt{S}$

Method call vs. method body statement

- Method call

  $$\texttt{obj.m(}\mathit{params}\texttt{)}$$

  will be expanded to
- Method body statement

  $$\texttt{obj.m(}\mathit{params}\texttt{)@T}$$

  where `T` specifies where to find the implementation of `m(`*params*`)`

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Using specifications

Behavioral subtyping

Let `S, T` be types with `S` $\sqsubseteq$ `T`

Let `obj.m(`*params*`)@T` be a method body statement with `obj` $\in$ `S`

Which contracts are available?

Contracts written for Method `m(`*params*`)` in type `T` or a supertype

Which contracts should be available?

Contracts written for Method `m(`*params*`)` in type `S` or a supertype

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- `MethodContractRule` available only on method body statement
  $\Rightarrow$ Possible huge proof split up (e.g. `java.util.List` has many subtypes), hence same proof has to be done n times

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Adapt `MethodContractRule` to use method call

- Used specifications must be proven

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Let Exc_1 to $Exc_k (1 \leq k \leq n)$ be caught by a program

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Let ψ_{Exc_i} $(1 \leq i \leq n, n \in N)$ be the condition where the exception Exc_i is thrown
Let ϕ_{Exc_i} be the postcondition that holds after Exc_i has been thrown

Let Exc_1 to $Exc_k (1 \leq k \leq n)$ be caught by a program

A "new" method contract rule

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A "new" method contract rule

Then the contract that should be applied is

Precondition

$\bigwedge_{k<i\leq n}$ `!`ψ_{Exc_i}

Postcondition

(`exc = null ->` ϕ_N) `&`
`exc != null ->`
`(`
    ($\bigvee_{1\leq i\leq k}$ Exc_i`::instance(exc) = TRUE`) `&`
    $\bigwedge_{1\leq i\leq k}$(`!`$\psi_{Exc_i}$ `->` Exc_i`::instance(exc) = FALSE`) `&`
    $\bigwedge_{1\leq i\leq k}$(Exc_i`::instance(exc) = TRUE ->` ϕ_{Exc_i})
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( exc = null -> φ_N ) &
exc != null ->
(
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    ⋀_{1≤i≤k}( !ψ_{Exc_i} -> Exc_i::instance(exc) = FALSE ) &
    ⋀_{1≤i≤k}( Exc_i::instance(exc) = TRUE -> φ_{Exc_i} )
)
```

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)

Demo

Demo

Proving the contract of a simple method
`containsNullElements(java.util.List)`

Conclusion

- Method contracts are capable of specifying library behaviour
- For interfaces: use of model functions necessary
- Need for thinking about the method contract rule

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Tanks for your attention

Combining contracts

Assume 2 contracts given for one method
Let ϕ_1 be the precondition of the first and ϕ_2 the precondition of the second
Let ψ_1 be the postcondition of the first and ψ_2 the postcondition of the second
Let M_1 be the modifier set of the first and M_2 the modifier set of the second

Then a valid contract for the method is

Precondition

ϕ_1 `|` ϕ_2

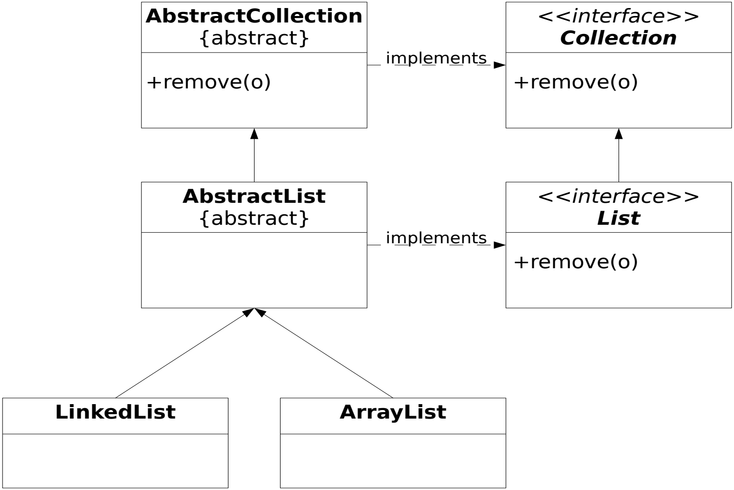
Postcondition

`(` ϕ_1`@pre ->` ψ_1 `) & (` ϕ_2`@pre ->` ψ_2 `)`

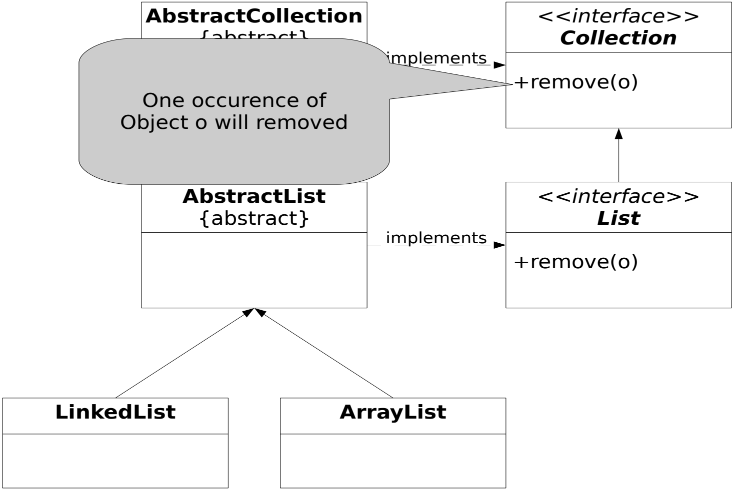
Modifies

$M_1 \cup M_2$

Behavioral subtyping



Behavioral subtyping



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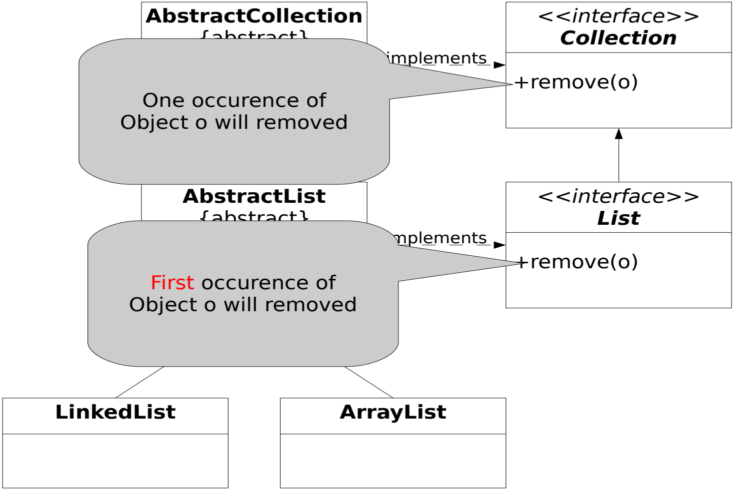

Behavioral subtyping