Abrupt Termination in Java

Reasons for abrupt termination

- continue (with or w/o label)  
  }  
  loop (current iteration)

- break (with or w/o label)     
  }  
  loop, switch, labelled block

- exception                     
  }  
  try-catch statement            
  (also: block, loop, method)

- return                        
  }  
  method                        
  (also: try-catch, block, loop)
Loop terminated by `break`

```java
while (true) {
    if (i==10) break;
    i++;
}
```
Abrupt Termination in Java: Examples

**try-catch-finally with exception**

```java
try {
    x = y / z;
} catch (ArithmeticException e) {
    x = 0;
} finally {
    z = z + 1;
}
```
New semantics for $\langle p \rangle F$:

$p$ terminates **normally (not abruptly)** and $F$ holds in the final state

There is no “return value” describing the reason for termination
Possible Contexts of an Abrupt Termination

- method
- block
- switch statement
- while, do-while, for loops
- try-catch-finally statement
Rule for while Loops

Symbolic execution of one loop iteration

\[ \Gamma \vdash \langle \text{if}(b)p \quad \text{while}(b)\{p\}\rangle F \]

\[ \Gamma \vdash \langle \text{while}(b)\{p\}\rangle F \]
Rule for while Loops

Symbolic execution of one loop iteration

\[ \Gamma \vdash \langle \text{if}(b)\ l_1:\{l_2: \{p'\} \} \text{ while}(b)\{p\} \rangle F \]

Construction of \( p' \):

\begin{align*}
\text{break} & \rightarrow \text{break } l_1 \\
\text{continue} & \rightarrow \text{break } l_2
\end{align*}
while (true) {
    if (i==10) break;
    i++;
}
Rule for while Loops: Example

```plaintext
while (true) {
  if (i==10) break;
  i++;
}
```

\[ \Gamma \vdash \langle \text{if(true)\{11: \{if(i==10) break 11; i++;\}\}} \text{while(true)\{p\}} \rangle F \]

\[ \Gamma \vdash \langle \text{while(true)\{if(i==10) break; i++;\}} \rangle F \]
Rule for Exception that is Caught

\[ \Gamma \vdash \text{instanceof}(\text{exc}, T) \quad \Gamma \vdash \langle \text{try}\{e=\text{exc}; \ q\}\text{finally}\{r\}\rangle F \]

\[ \Gamma \vdash \langle \text{try}\{\text{throw} \ \text{exc}; \ p\}\text{catch}(T \ e)\{q\}\text{finally}\{r\}\rangle F \]
try {throw exc; return 3;}
catch (Exception e) {return 4;}
finally {return 5;}

Rule for Exception that is Caught: Example
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```
try {throw exc; return 3;}
catch (Exception e) {return 4;}
finally {return 5;}
```

\[ \Gamma \vdash \text{instanceof}(\text{exc, Exception}) \]

\[ \Gamma \vdash \langle \text{try}\{\text{e=exc; return 4;\}}\text{finally}\{\text{return 5;\}} \rangle F \]

\[ \Gamma \vdash \langle \text{try}\{\text{throw exc; return 3;\}}
\text{ catch(\text{Exception e})\{return 4;\}}
\text{finally}\{\text{return 5;\}} \rangle F \]
Rule for Exception that is Caught: Example

\[ \Gamma \vdash \ldots \quad \Gamma \vdash \langle \text{try}\{e=\text{exc}; \text{return } 4;\}\text{finally}\{\text{return } 5;\}\rangle F \]

\[ \Gamma \vdash \langle \text{try}\{\text{throw exc; return } 3;\}\text{catch} (\text{Exception e})\{\text{return } 4;\}\text{finally}\{\text{return } 5;\}\rangle F \]
Rule for Exception that is Caught: Example

\[ \Gamma, e = \text{exc} \vdash \langle \text{try}\{\text{return } 4;\}\text{finally}\{\text{return } 5;\}\rangle F \]

\[ \Gamma \vdash \langle \text{try}\{e=\text{exc}; \text{return } 4;\}\text{finally}\{\text{return } 5;\}\rangle F \]

\[ \Gamma \vdash \langle \text{try}\{\text{throw } \text{exc}; \text{return } 3;\}\text{catch}(\text{Exception } e)\{\text{return } 4;\}\text{finally}\{\text{return } 5;\}\rangle F \]
Rule for Exception that is Caught: Example

\[ \Gamma, e = \text{exc} |- \langle \text{return } 5; \text{ return } 4; \rangle F \]

\[ \Gamma, e = \text{exc} |- \langle \text{try}\{\text{return } 4;\}\text{finally}\{\text{return } 5;\}\rangle F \]

\[ \Gamma |- \langle \text{try}\{e = \text{exc}; \text{return } 4;\}\text{finally}\{\text{return } 5;\}\rangle F \]

\[ \Gamma |- \langle \text{try}\{\text{throw exc; return } 3;\}\text{catch(Exception e)}\{\text{return } 4;\}\text{finally}\{\text{return } 5;\}\rangle F \]
Example

Proof obligation

```
while (true) {
    if (i==10) then break;
    i++;
}
```

terminates with $i = 10$ if started with $0 \leq i \leq 10$

Formal

$$0 \leq i, i \leq 10 \vdash \langle p \rangle i = 10$$
Example

```
while (true) {
    if (i==10) then
        break;
    i++;
}
```

```
\( n \leq 9, i = 10 - n \)
\( \vdash \langle p \rangle i = 10 \)
```

```
(\forall n)((n \leq 10 \wedge i = 10 - n) \rightarrow \langle p \rangle i = 10)
```

choice of induction hypothesis

```
0 \leq i, i \leq 10 \vdash \langle p \rangle i = 10
```

VerifiCard Workshop, Marseille, January 2002 – p.21