Exceptions: implementation and implications

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Issues

- Since exceptions are for exceptional situations, they shouldn't happen often
  - Should be "free" except when used
- Want to minimize the indirect impact of exceptions
- Will assume a simple exception model, a.l.a. Modula-3, Java

An example

f

```
TRY
  g();
EXCEPT
  e1 => <C1>;
 |e2 => <C2>;
END
g();
```

g

```
TRY
  h();
EXCEPT
  e1 => <C3>;
END;
```

h

```
IF (cond)
  RAISE e1;
ELSE
  RAISE e2;
END;
```

When a handler is not found in a routine

f

```
TRY
  TRY
    g();
  EXCEPT
    e1 => <C1>;
   |e2 => <C2>;
  END
  g();
EXCEPT
  ELSE => <C6>
END
```

g

```
TRY
  TRY
    h();
  EXCEPT
    e1 => <C3>;
  END;
EXCEPT
  ELSE => <C5>
END
```

h

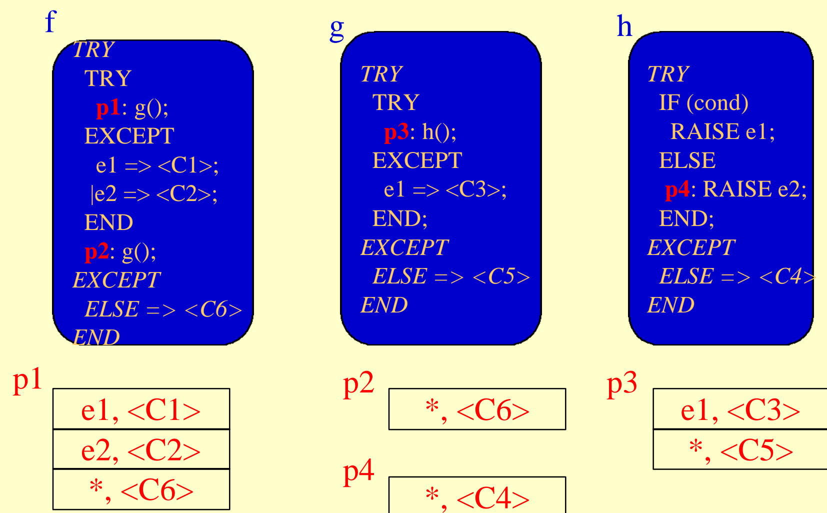
```
TRY
  IF (cond)
    RAISE e1;
  ELSE
    RAISE e2;
  END;
EXCEPT
  ELSE => <C4>
END
```

What do <C4>, <C5>, and <C6> do?

Implementing exceptions

- In each scope, we know statically, what exceptions are handled
  - May have a "handler" for the "ELSE" exception too
- Make a table mapping exceptions to exception handlers for each scope

An Example



An exception is raised

Path: p1, p3, p4

Observation: can use return address to locate exception table

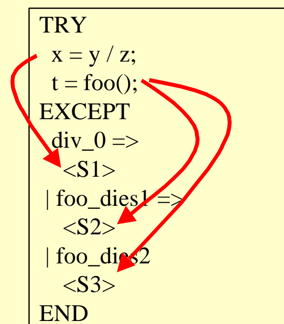
	Stack	
f		Exception table entry: <C2> (i.e., e2's exception handler)
g	return: p1	Exception table entry: <C5> (i.e., reraise)
h	return: p3	Exception table entry: <C4> (i.e., reraise)

Important properties of the technique

- Tables are built at compile time
  - no run-time overhead
- When an exception is raised, look for handler one activation record at a time
  - some handlers will reraise the exception
  - may need to unwind the stack

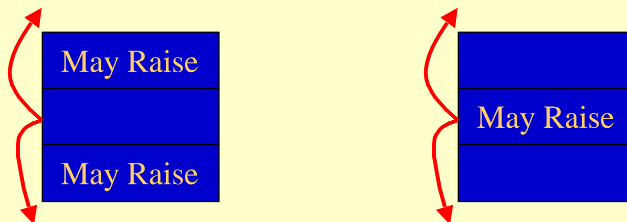
How exceptions affect the control flow in the program

- A program analysis must assume worst case about raising of exceptions



Implications

- Optimizations cannot easily move code around instructions that may cause an exception
- Optimizations cannot easily move code that causes exceptions



Analysis to reduce pollution due to exceptions

- Can analyze programs to see what
  - statements will not raise an exception
    - e.g., if (d != 0) t = n/d;
    - e.g., if (p != NULL) *p = 0;
  - exceptions will be raised by each statement
    - E.g., foo can only raise foo_dies1 but never foo_dies2

Checked exceptions

- Checked exceptions alleviate this analysis
  - All "checked" exceptions that may be raised by a call have to be in the "throws" clause of callees
    - e.g., foo() throws {foo_dies1, foo_dies2} {...}
  - All exceptions in M-3 are checked. Some exceptions in Java are not checked

Other issues with exceptions

- If an exception causes a return from a function must invoke whatever cleanups are registered for that function
  - e.g., destructors for local variables
- Must register cleanups in exception-tables

Discussion

- Are implicit exceptions a good idea?
  - for div/0, *p, ... ?
  - for out of memory errors?
- Comparison of exception handling to “return” code
  - Return code typically restricts one to success/no success. More expressiveness in exceptions
  - Exceptions cannot be ignored
  - ...?

Summary

- The direct costs of exception handling are low
  - Tables built at compile time remove run-time overhead except when an exception is raised
- Indirect costs of exception handling may be high
  - Control-flow edges can severely restrict optimizations

Next two lectures

- First lecture: Continuations
  - Readings: See class web page for pointers
- Second lecture: Implementation of continuations