Handling Errors

Hochschule für Technik
und Wirtschaft Berlin

University of Applied Sciences

Main concepts to be covered

- Defensive programming.
  - Anticipating that things could go wrong.
- Exception handling and throwing.
- Error reporting.
- Simple file processing.

Typical error situations

- Incorrect implementation.
  - Does not meet the specification.
- Inappropriate object request.
  - E.g., invalid index.
- Inconsistent or inappropriate object state.
  - E.g. arising through class extension.

Not always programmer error

- Errors often arise from the environment:
  - Incorrect URL entered.
  - Network interruption.
- File processing is particular error-prone:
  - Missing files.
  - Lack of appropriate permissions.
  - Disk full.

Defensive programming

- Client-server interaction.
  - Should a server assume that clients are well-behaved?
  - Or should it assume that clients are potentially hostile?
- Significant differences in implementation required.

Issues to be addressed

- How much checking by a server on method calls?
- How to report errors?
- How can a client anticipate failure?
- How should a client deal with failure?

An example

- Create an `AddressBook` object.
- Try to remove an entry.
- A runtime error results.
  - Whose 'fault' is this?

Argument values

- Arguments represent a major ‘vulnerability’ for a server object.
  - Constructor arguments initialize state.
  - Method arguments often contribute to behavior.
- Argument checking is one defensive measure.

Checking the key

```
public void removeDetails(String key)
{
    if(keyInUse(key)) {
        ContactDetails details = book.get(key);
        book.remove(details.getName());
        book.remove(details.getPhone());
        numberOfEntries--;
    }
}
```

Server error reporting

- How to report illegal arguments?
  - To the user?
    - Is there a human user?
    - Can they solve the problem?
  - To the client object?
    - Return a diagnostic value.
    - *Throw an exception.*

Returning a diagnostic value

```
public boolean removeDetails(String key)
{
    if(keyInUse(key)) {
        ContactDetails details = book.get(key);
        book.remove(details.getName());
        book.remove(details.getPhone());
        numberOfEntries--;
        return true;
    }
    else {
        return false;
    }
}
```

Client can check for success

```
if(contacts.removeDetails("…")) {
    // Entry successfully removed.
    // Continue as normal.
    …
}
else {
    // The removal failed.
    // Attempt a recovery, if possible.
    …
}
```

Potential client responses

- Test the return value.
  - Attempt recovery on error.
  - Avoid program failure.
- Ignore the return value.
  - Cannot be prevented.
  - Likely to lead to program failure.
- ‘Exceptions’ are preferable.

Exception-throwing principles

- A special language feature.
- No ‘special’ return value needed.
- Errors cannot be ignored in the client.
  - The normal flow-of-control is interrupted.
- Specific recovery actions are encouraged.

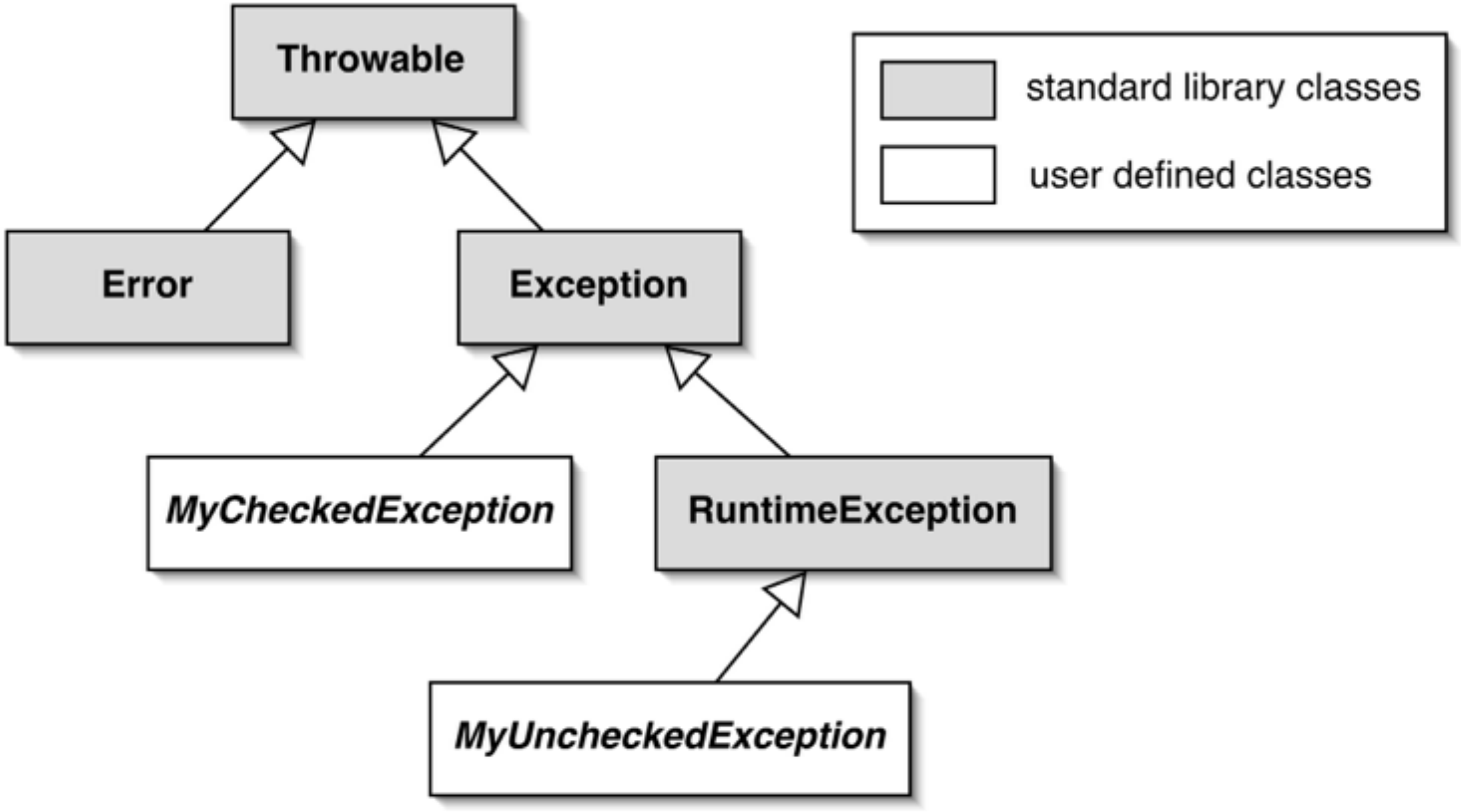
Throwing an exception

```
/**
 * Look up a name or phone number and return the
 * corresponding contact details.
 * @param key The name or number to be looked up.
 * @return The details corresponding to the key,
 *         or null if there are none matching.
 * @throws IllegalArgumentException if
 *         the key is invalid.
 */
public ContactDetails getDetails(String key)
{
    if(key == null) {
        throw new IllegalArgumentException(
                         "null key in getDetails");
    }
    return book.get(key);
}
```

Throwing an exception

- An exception object is constructed:
  - `new ExceptionType("...")`
- The exception object is thrown:
  - `throw ...`
- Javadoc documentation:
  - `@throws ExceptionType reason`

The exception class hierarchy



Throwable

Error

Exception

MyCheckedException

RuntimeException

MyUncheckedException

▨ standard library classes

□ user defined classes

Exception categories

- Checked exceptions
  - Subclass of **`Exception`**
  - Use for anticipated failures.
  - Where recovery may be possible.
- Unchecked exceptions
  - Subclass of **`RuntimeException`**
  - Use for unanticipated failures.
  - Where recovery is unlikely.

The effect of an exception

- The throwing method finishes prematurely.
- No return value is returned.
- Control does not return to the client’s point of call.
    - So the client cannot carry on regardless.
- A client may ‘catch’ an exception.

Unchecked exceptions

- Use of these is ‘unchecked’ by the compiler.
- Cause program termination if not caught.
  - This is the normal practice.
- **`IllegalArgumentException`** is a typical example.

Argument checking

```
public ContactDetails getDetails(String key)
{
    if(key == null) {
        throw new IllegalArgumentException(
                        "null key in getDetails");
    }
    if(key.trim().length() == 0) {
        throw new IllegalArgumentException(
                    "Empty key passed to getDetails");
    }
    return book.get(key);
}
```

Preventing object creation

```
public ContactDetails(String name, String phone, String address)
{
    if(name == null) {
        name = "";
    }
    if(phone == null) {
        phone = "";
    }
    if(address == null) {
        address = "";
    }

    this.name = name.trim();
    this.phone = phone.trim();
    this.address = address.trim();

    if(this.name.length() == 0 && this.phone.length() == 0) {
        throw new IllegalStateException(
                "Either the name or phone must not be blank.");
    }
}
```

Exception handling

- Checked exceptions are meant to be caught and responded to.
- The compiler ensures that their use is tightly controlled.
  - In both server and client objects.
- Used properly, failures may be recoverable.

The throws clause

- Methods throwing a checked exception must include a throws clause:

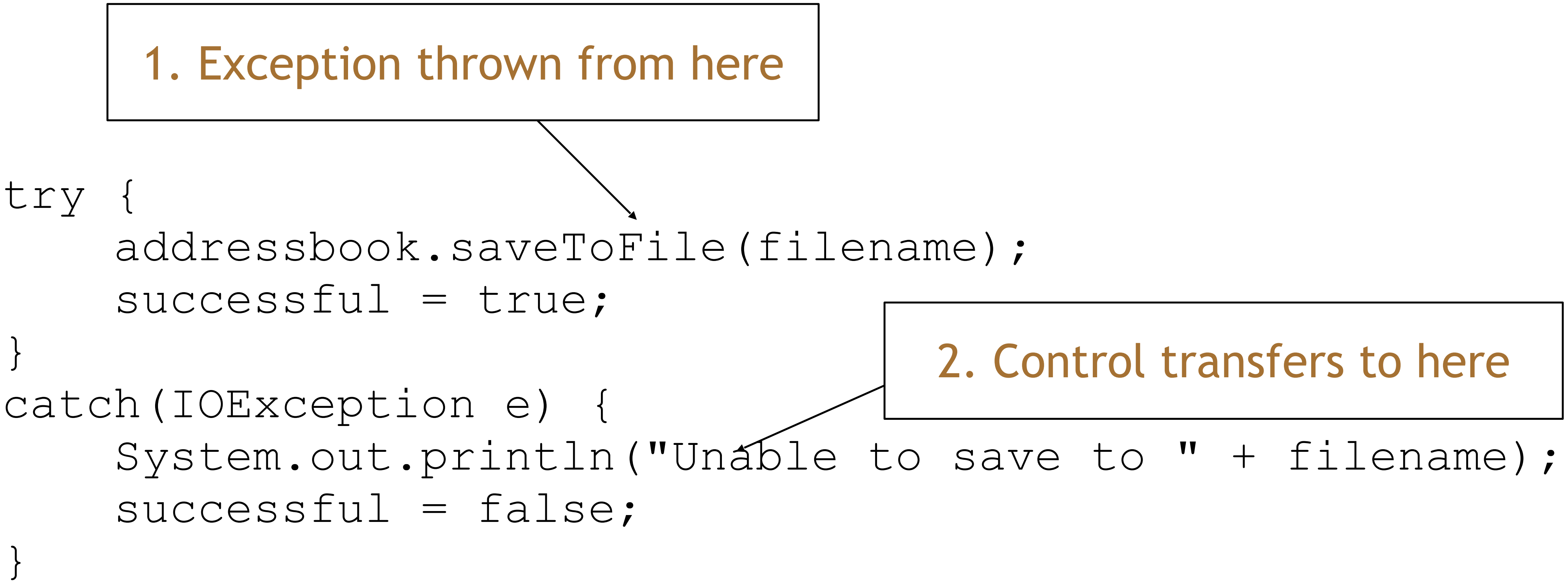
```
public void saveToFile(String destinationFile)
    throws IOException
```

The try statement

- Clients catching an exception must protect the call with a try statement:

```
try {
      Protect one or more statements here.
}
catch(Exception e) {
      Report and recover from the exception here.
}
```

The try statement



1. Exception thrown from here

2. Control transfers to here

```
try {
    addressbook.saveToFile(filename);
    successful = true;
}
catch(IOException e) {
    System.out.println("Unable to save to " + filename);
    successful = false;
}
```

Catching multiple exceptions

```
try {
    ...
    ref.process();
    ...
}
catch(EOFException e) {
    // Take action on an end-of-file exception.
    ...
}
catch(FileNotFoundException e) {
    // Take action on a file-not-found exception.
    ...
}
```

Multi-catch – a Java 7 feature

```
try {
    ...
    ref.process();
    ...
}
catch(EOFException | FileNotFoundException e) {
    // Take action appropriate to both types
    // of exception.
    ...
}
```

The finally clause

```
try {
        Protect one or more statements here.
}
catch(Exception e) {
        Report and recover from the exception here.
}
finally {
        Perform any actions here common to whether or
        not an exception is thrown.
}
```

The finally clause

- A finally clause is executed even if a return statement is executed in the try or catch clauses.
- A uncaught or *propagated* exception still exits via the finally clause.

Defining new exceptions

- Extend **`RuntimeException`** for an unchecked or **`Exception`** for a checked exception.
- Define new types to give better diagnostic information.
  - Include reporting and/or recovery information.

```
public class NoMatchingDetailsException extends Exception
{
    private String key;

    public NoMatchingDetailsException(String key)
    {
        this.key = key;
    }

    public String getKey()
    {
        return key;
    }

    public String toString()
    {
        return "No details matching '" + key +
               "' were found.";
    }
}
```

Assertions

- Used for *internal* consistency checks.
  - E.g. object state following mutation.
- Used during development and normally removed in production version.
  - E.g. via a compile-time option.
- Java has an *assert statement*.

Java Assertion Statement

- Two forms available:
  - `assert` *boolean-expression*
  - `assert` *boolean-expression* `:` *expression*
- The *boolean-expression* expresses something that should be true at this point.
- An `AssertionError` is thrown if the expression evaluates to false.

Assert Statement

```
public void removeDetails(String key)
{
    if(key == null){
        throw new IllegalArgumentException("...");
    }
    if(keyInUse(key)) {
        ContactDetails details = book.get(key);
        book.remove(details.getName());
        book.remove(details.getPhone());
        numberOfEntries--;
    }
    assert !keyInUse(key);
    assert consistentSize() :
           "Inconsistent book size in removeDetails";
}
```

Guidelines for Assertions

- They are *not* an alternative to throwing exceptions.
- Use for internal checks.
- Remove from production code.
- Don’t include normal functionality:

```
// Incorrect use:
assert book.remove(name) != null;
```

Error recovery

- Clients should take note of error notifications.
  - Check return values.
  - Don’t ‘ignore’ exceptions.
- Include code to attempt recovery.
  - Will often require a loop.

Attempting recovery

```
// Try to save the address book.
boolean successful = false;
int attempts = 0;
do {
    try {
        contacts.saveToFile(filename);
        successful = true;
    }
    catch(IOException e) {
        System.out.println("Unable to save to " + filename);
        attempts++;
        if(attempts < MAX_ATTEMPTS) {
            filename = an alternative file name;
        }
    }
} while(!successful && attempts < MAX_ATTEMPTS);

if(!successful) {
    Report the problem and give up;
}
```

Error avoidance

- Clients can often use server query methods to avoid errors.
  - More robust clients mean servers can be more trusting.
  - Unchecked exceptions can be used.
  - Simplifies client logic.
- May increase client-server coupling.

Avoiding an exception

```
// Use the correct method to put details
// in the contacts list.
if(contacts.keyInUse(details.getName() ||
        contacts.keyInUse(details.getPhone()) {
    contacts.changeDetails(details);
}
else {
    contacts.addDetails(details);
}
```

The `addDetails` method could now throw an *unchecked* exception.

Review

- Runtime errors arise for many reasons.
  - An inappropriate client call to a server object.
  - A server unable to fulfill a request.
  - Programming error in client and/or server.

Review

- Runtime errors often lead to program failure.
- Defensive programming anticipates errors – in both client and server.
- Exceptions provide a reporting and recovery mechanism.