Logging and Debugging

Lecture 25

Motivation

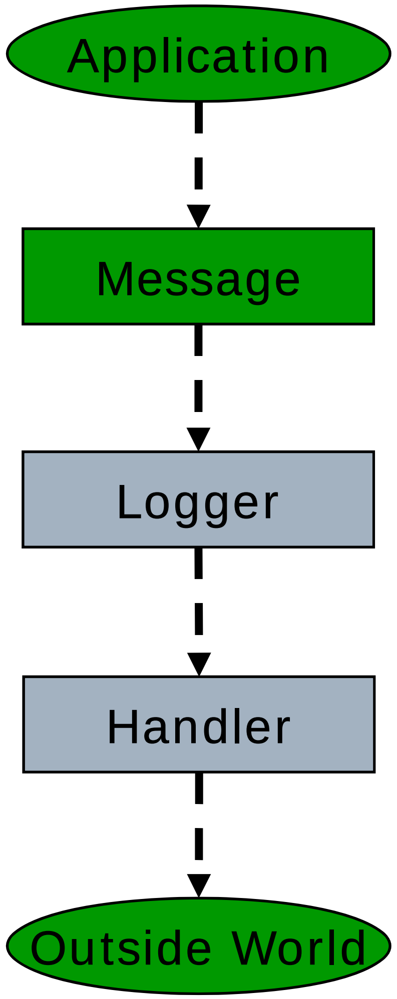
- Ever had one of these to deal with?
  - JUnit red bar
  - a java.lang.NullPointerException exception
  - any unexpected and wrong behavior
- What do you do?
  - Stare at the code until you figure it out
  - Make random changes and try again
  - Ask someone for help
  - Insert many System.out.println()'s
- Problems with the last approach
  - Cluttered code ends up in deployment
  - If problems re-emerge, re-add the println's?
    "If the trace is useful now, it will be useful later"
- Better approaches, indicative of experience:
  - Use a real logging facility to save tracing information
  - Use a debugger to interactively inspect execution

Logging

- General framework for recording (during execution):
  - System information
  - Error messages
  - Fine-grain tracing output
- See java.util.logging
- Common in enterprise-scale, industrial-strength applications; uncommon in small programs
  - "Programming in the large"
- Flexibility and Customizability
  - Support for many output devices and formats
  - Dynamic control over output (no recompilation)

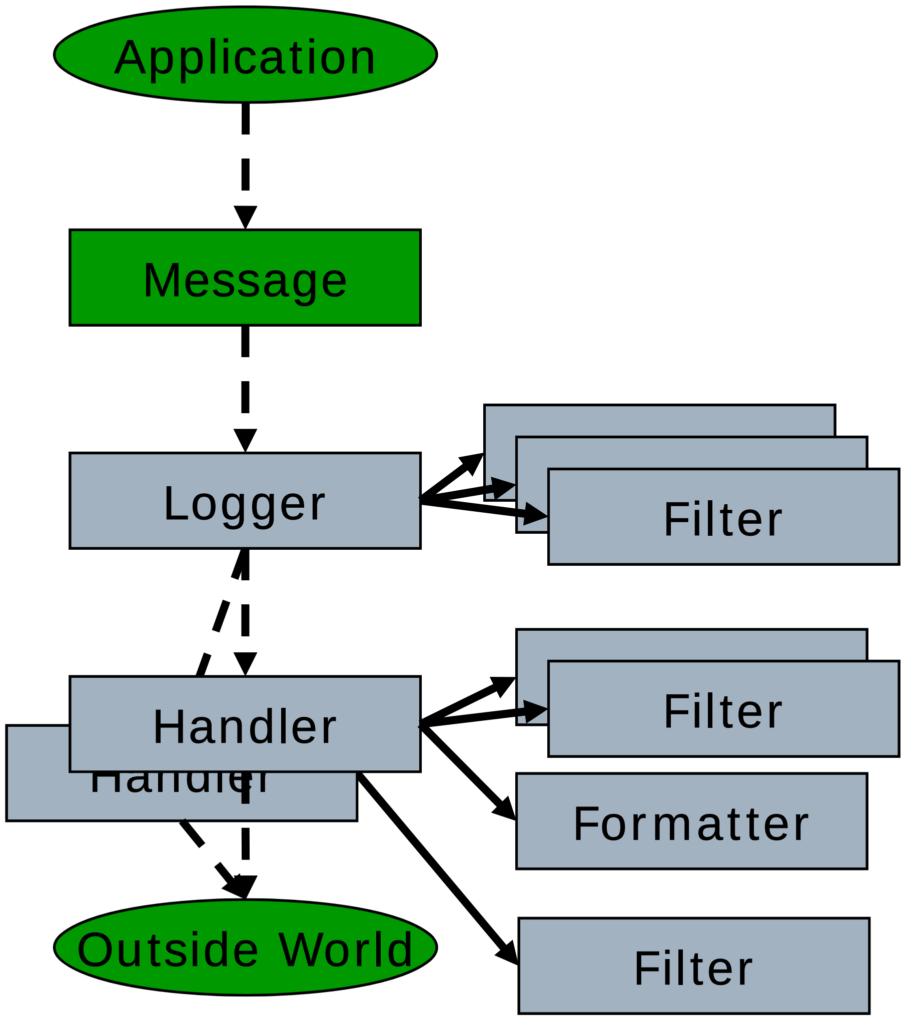
Taxonomy of java.util.logging

- Message
  - A string and a level of importance
- Logger
  - Client-side view of logging functionality
- Handler
  - Performs output
  - Different classes for sending to different destinations:
    - ConsoleHandler, FileHandler, SocketHandler



Extended Taxonomy

- Logger can have multiple Handlers
  - Or none (more later)
- Filters
  - Optional for Loggers and Handlers
  - Fine control for squelching messages
  - Control usually done through *levels*
- Formatters
  - What output looks like
  - SimpleFormatter, XMLFormatter
- Defaults (no Filters, SimpleFormatter) usually sufficient



Message Levels

- Logger discards messages *below* a certain level

  ```
  void setLevel(Level newLevel);
  ```

  - Default configuration shows INFO and higher:

    ```
    myLogger.setLevel(Level.INFO);
    ```

  - Handlers have similar controls
- 7 Levels, which are totally ordered:
  - For an end-user (ie suitable for general consumption)
    - SEVERE
    - WARNING
    - INFO
  - For a sys. admin (ie technical sytems information)
    - CONFIG
  - For a developer (ie can assume familiarity with code)
    - FINE
    - FINER
    - FINEST

Usage Guidelines

- SEVERE: significant or complete loss of some function
  `"Power lost - running on backup"`
  - Failure of application
  - Absence of a configuration file that completely debilitates the application (there is no good fall back)
- WARNING: problem adversely affecting operations
  `"Database connection lost, retrying..."`
- INFO: event within normal operation
  `"Startup complete"`
- FINE: significant events explaining flow/state of system
  `"Loading graphics package"`
  - Object creation
- FINER: major flow-of-control points in execution
  `"Building pie chart"`
  - Method entry/exit, or throwing exception
- FINEST: low-level debug tracing
  `"Starting bubble sort: value = "  + size`
  - Intraprocedural tracing

Logger Creation

- Each Logger instance has a String name
- Created through a static factory, getLogger
  - Guarantees only one instance per name is created

    ```
    static Logger getLogger(String Name);
    ```
  - Can be cached in a field, or called in each method

    ```
    class Student {
      private static final Logger logger =
       Logger.getLogger(Student.class.getName());
      . . .
    }
    ```
- Usual practice: 1 Logger / class in a package
  - Named following fully-qualified class name
    - Eg “edu.osu.cse.421.Student”

Logger Methods

- Basic method for adding a message

  ```
  void log(Level level, String msg);
  ```

  - Example

  ```
  logger.log(Level.FINEST, “Found target at
     position ” + i);
  ```

- Convenience methods for each level
  - severe, warning, info, config, fine, finer, finest
  - Example

  ```
  logger.info(“Configuration complete”);
  ```

- Convenience methods for some events
  - entering, exiting, throwing
  - Associated log message has level FINER
  - Two string parameters: class name, method name
  - Example

  ```
  logger.entering(“Student”, “getValue”);
  logger.entering(getClass().getName(),
     “getValue”);
  ```

Example Code

```
package edu.osu.cse.421;
class Student {
  private static final Logger logger =
    Logger.getLogger(Student.class.getName());

  public boolean myMethod(int p1, Object p2) {
    logger.entering(getClass().getName(), "myMethod");
    logger.log(Level.FINER, "First argument: " + p1);
    logger.log(Level.FINER, "Second argument: " + p2);

    //Method body

    logger.exiting(getClass().getName(), "myMethod");
    logger.log(Level.FINER, "Returning: " + result);
    return result;
  }
}
```

Bad Practice: Logger.global

- Logger provides a convenience static field global
  - A globally visible logger
  - Does not need to be explicitly constructed
  - Simplifies quick and easy logging
- It might be tempting to
  - replace: System.out.println(s);
  - with: Logger.global.info(s);
- But benefit over println is marginal

Performance Consideration

- Entering/Exiting methods overloaded

  ```
  void entering (String, String, Object[]);
  ```

  - Used to display value of parameters (and possibly **this** object too)
- Concern: Stringifying these objects can be expensive
- Solution: Short-circuit check whether message level is too fine to matter anyway

  ```
  boolean isLoggable(Level level)
  ```

  - Returns true if and only if level messages would be passed on by logger
  - Handler might still filter them out of course

Example Code

```
package edu.osu.cse.421;
class Student {
  private static final Logger logger =
    Logger.getLogger(Student.class.getName());

  public boolean myMethod(int p1, Object p2) {
    if (logger.isLoggable(Level.FINER)) {
      logger.entering(getClass().getName(), "myMethod",
                      new Object[]{Integer.valueOf(p1), p2});
    }

    // Method body

    if (logger.isLoggable(Level.FINER)) {
       logger.exiting(getClass().getName(), "myMethod",
                      Boolean.valueOf(result));
    }
    return result;
  }
}
```

Handlers

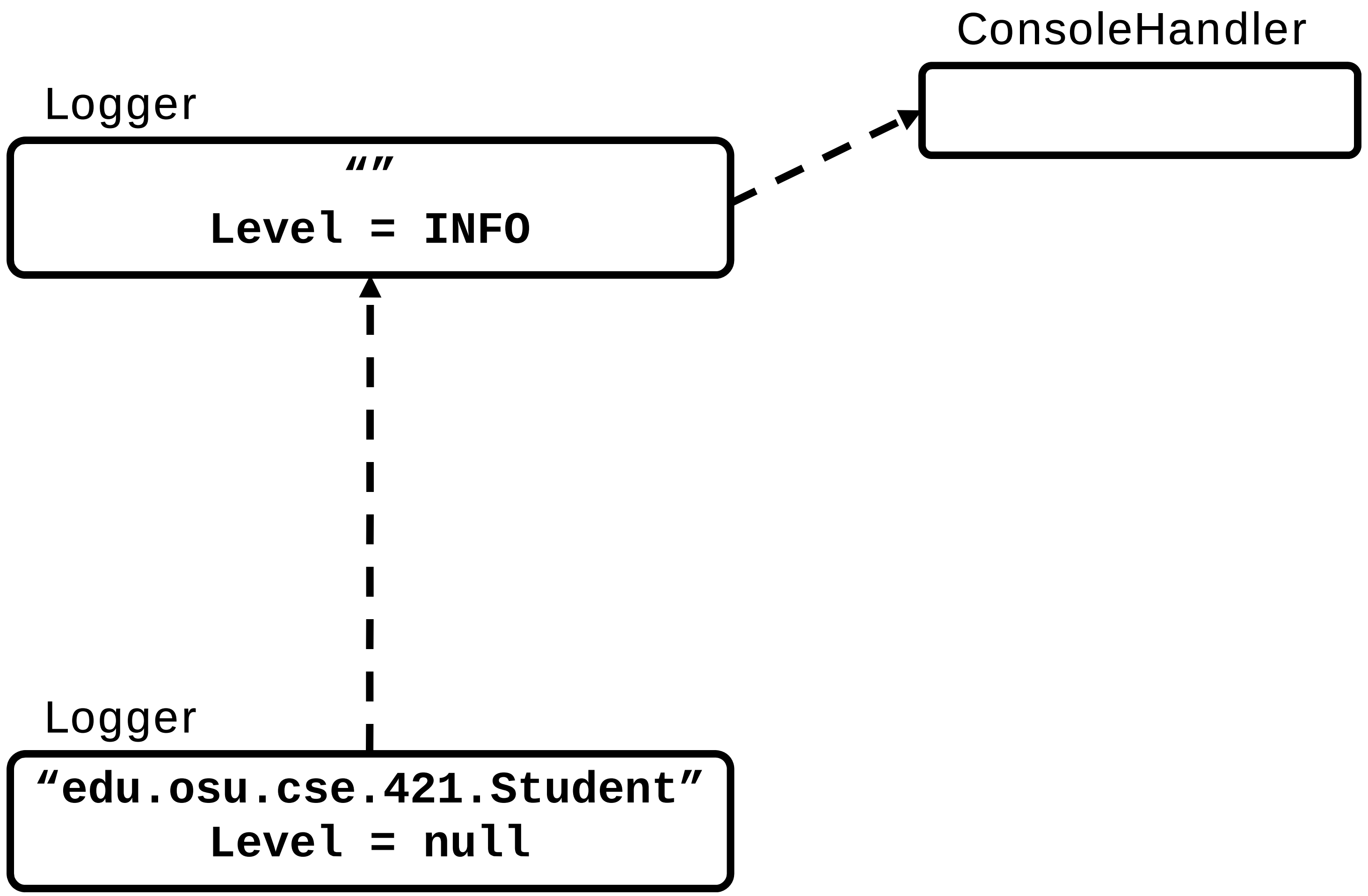
- Recall:
  - Handlers do the work of publishing messages to a device/destination
  - One Logger can have multiple Handlers
- Predefined Handlers in java.util.logging:
  - ConsoleHandler, FileHandler, StreamHandler, SocketHandler
- Default configuration uses ConsoleHandler
  - Output goes to screen
- To associate a Handler with a Logger
  - Use Logger method addHandler()

```
FileHandler h = new FileHandler(“test.log”);
logger.addHandler(h);
```

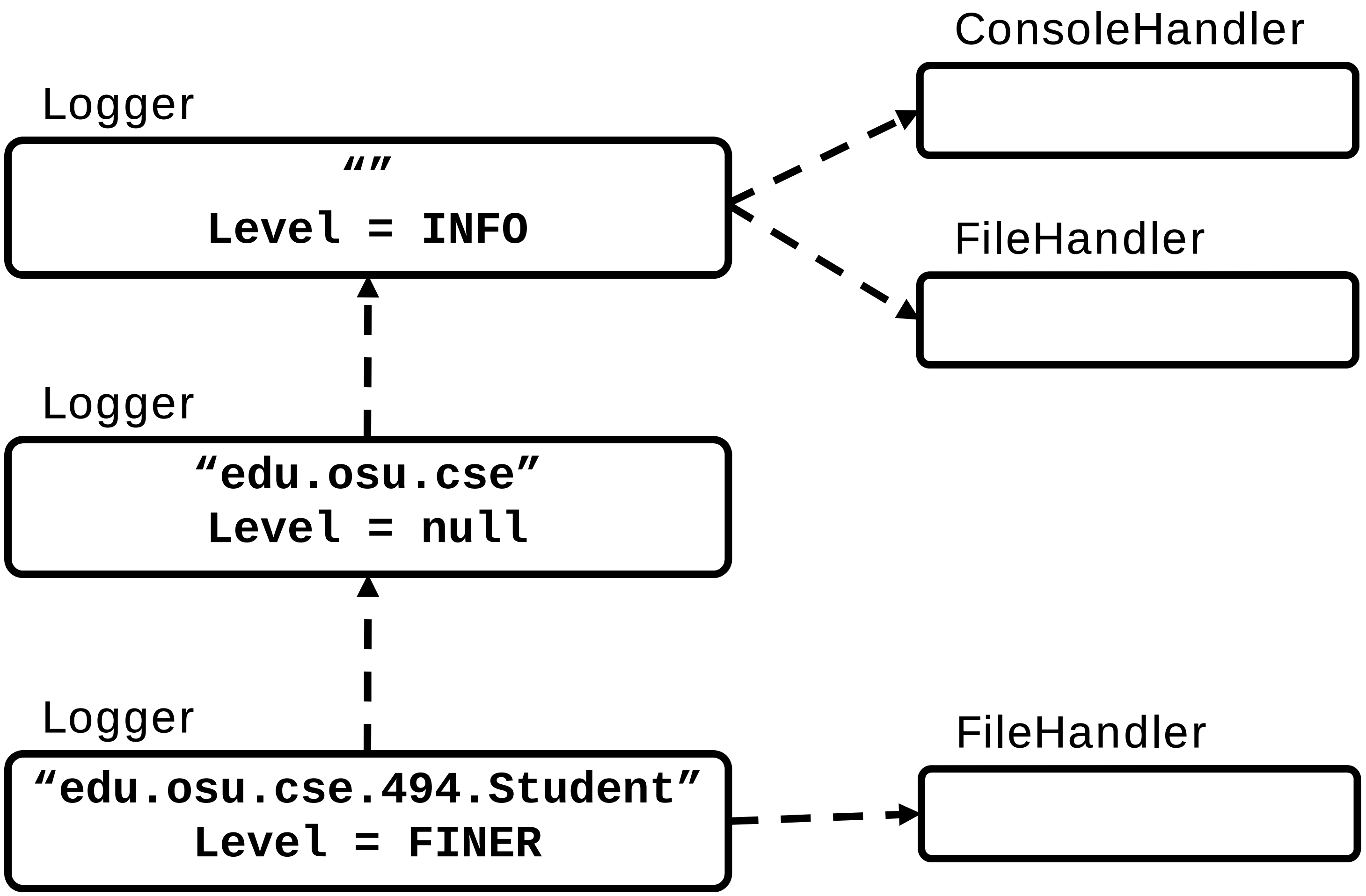
Logging Hierarchy

- Every logger has a parent logger
  - Follows naming scheme
    - “edu.osu.cse.421”, if it exists, is parent of “edu.osu.cse.421.Student”
  - Default logging level is null
    - Receives parent’s logging level
- When message meets logger’s level
  - Passed along to associated handlers
  - Passed up to parent’s handlers
    - Ignores parent’s logging level
- Root logger
  - Named “” (the empty string)
  - By default, has level INFO, and has 1 handler (a ConsoleHandler)

Logging Hierarchy: Default



Logging Hierarchy: General



Logger Organization: Alternative

- One logger/class simplifies controlling output based on *structural* concerns
- A different segmentation would be based on *functional* concerns
- Example
  - AppLog: General application events
  - SQLLog: SQL-related processing activities
  - ThreadLog: Events related to managing the thread pool
  - RequestLog: Requests into the system, including the time to fulfill the request
  - DbConnectLog: Events related to managing the database connection pool

Eclipse Support

- Lots of boiler-plate code
- Approach 1: Modify method body template
  - Window > Preferences > Java > Code Style > Code Templates > Method Body
- Approach 2: Create new code template
  - Window > Preferences > Java
  - Editor > Templates > New
    - Name: logger
    - Pattern: private static final Logger logger = Logger.getLogger(${enclosing_type}.class.getName());
  - Now you can type "logger" inside any class, then use content-assist to fill in the rest

Configuration

- Default set in an external properties file
  - ${JDK_HOME}/jre/lib/logging.properties
- Defaults can be overridden
  - Provide a new file, eg mylog.prop
  - Run program with command-line argument
    - -Djava.util.logging.config.file=mylog.prop

Example Properties File

```
# Specify the handlers to create in the root logger
# (all loggers are children of the root logger)
# The following creates two handlers
handlers = java.util.logging.ConsoleHandler,
    java.util.logging.FileHandler

# Set the default logging level for the root logger
.level = ALL

# Set the default logging level for new ConsoleHandler instances
java.util.logging.ConsoleHandler.level = INFO

# Set the default logging level for new FileHandler instances
java.util.logging.FileHandler.level = ALL

# Set the default formatter for new ConsoleHandler instances
java.util.logging.ConsoleHandler.formatter =
    java.util.logging.SimpleFormatter

# Set the default logging level for the logger named edu.osu.cse.494
edu.osu.cse.494.level = ALL
```

Debugging

- Debuggers give us a way to stop a program and examine its contents
- Breakpoint: A stop sign
  - Whenever execution reaches that point, it stops
- Viewing state
  - Examine value of variables, fields, memory
    - A good toString method helps!
  - Watch certain variables or expressions
  - Change the value of variables
- Advancing execution
  - Step-into/over/return to take a small step forward (into next method / one line / out of method)
  - Resume to continue (until next breakpoint)

To Ponder

We could, for instance, begin with cleaning up our language by no longer calling a bug a bug but by calling it an error. It is much more honest because it squarely puts the blame where it belongs, viz. with the programmer who made the error. The animistic metaphor of the bug that maliciously sneaked in while the programmer was not looking is intellectually dishonest as it disguises that the error is the programmer's own creation.

E. W. Dijkstra (EWD 1036), “On the cruelty of really teaching computer science”

Summary

- Logging components from java.util.logging
  - Messages, Loggers, Handlers
  - (Also Filters and Formatters)
- Message Levels
  - End-users: SEVERE, WARNING, INFO
  - Administrators: CONFIG
  - Developers: FINE, FINER, FINEST
- Logger
  - Creation with static factory
  - Basic methods (log, info/fine/etc, entering/etc)
  - Eclipse support for boiler-plate code
- Configuration with external properties file
- Debugging in Eclipse