Eclipse Concurrency in Action

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 | February, 2005 | Burlingame, California

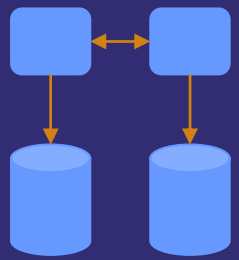
What are we going to cover?

1) Principles of concurrency
2) Concurrency in eclipse
3) Concurrency and the user interface
4) Concurrency and the workspace
5) Concurrency in the large

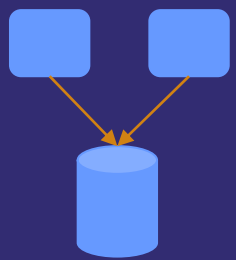
Part 1: Principles of concurrency

- Concurrency ideal: each thread is completely independent
- Concurrency is reduced and programming challenges arise when threads become entangled in either space or time
  - Space: when threads share physical resources such as memory, devices
  - Time: when threads have temporal dependencies (x must run before y)
- Goal: minimize dependencies between threads, and carefully handle the places where threads intersect

Dominant concurrency models



- Message passing
  - No shared state between threads
  - All interaction through asynchronous communication
  - Typically employs observer pattern and event queues
  - Eliminates tangling in space but increases tangling in time



- Shared state
  - Multiple threads operating on and competing for shared resources
  - Threads typically communicate via shared state
  - Most common model, looks easy to implement, but error prone
  - Manage thread interaction with locks

Pop quiz: Is this code thread safe?

```
List list = new ArrayList();
class One implements Runnable {
  public void run() {
    for (int i = 0; i < 10; i++)
      list.add(new Integer(i));
    for (int i = 0; i < 5; i++)
      list.remove(new Integer(i));
  }
}
class Two implements Runnable {
  public void run() {
    for (Iterator it = list.iterator(); it.hasNext();)
      System.out.println(it.next());
  }
}
public void doit() {
  new Thread(new One()).start();
  new Thread(new Two()).start();
}
```


Pop quiz (part 2): Is this good enough?

```
List list = Collections.synchronizedList(new ArrayList());
class One implements Runnable {
  public void run() {
    for (int i = 0; i < 10; i++)
      list.add(new Integer(i));
    for (int i = 0; i < 5; i++)
      list.remove(new Integer(i));
  }
}
class Two implements Runnable {
  public void run() {
    for (Iterator it = list.iterator(); it.hasNext();)
      System.out.println(it.next());
  }
}
public void doit() {
  new Thread(new One()).start();
  new Thread(new Two()).start();
}
```


Pop quiz (part 3): And now?

```
List list = Collections.synchronizedList(new ArrayList());
class One implements Runnable {
  public void run() {
    for (int i = 0; i < 10; i++)
      list.add(new Integer(i));
    for (int i = 0; i < 5; i++)
      list.remove(new Integer(i));
  }
}
class Two implements Runnable {
  public void run() {
    Object[] els = list.toArray(new Object[list.size()]);
    for (int i = 0; i < els.length; i++)
      System.out.println(elements[i]);
  }
}
…
```


Pop quiz: Synchronized solution

```
List list = Collections.synchronizedList(new ArrayList());
class One implements Runnable {
  public void run() {
    for (int i = 0; i < 10; i++)
      list.add(new Integer(i));
    for (int i = 0; i < 5; i++)
      list.remove(new Integer(i));
  }
}
class Two implements Runnable {
  public void run() {
    Object[] els = list.toArray(new Object[0]);
    for (int i = 0; i < els.length; i++)
      System.out.println(els[i]);
  }
}
…
```


Pop quiz: Copy on write solution

```
ArrayList list = new ArrayList();
class One implements Runnable {
  public void run() {
    ArrayList list2 = (ArrayList)list.clone();
    for (int i = 0; i < 10; i++)
      list2.add(new Integer(i));
    for (int i = 0; i < 5; i++)
      list2.remove(new Integer(i));
    list = list2;
  }
}
class Two implements Runnable {
  public void run() {
    for (Iterator it = list.iterator(); it.hasNext();)
      System.out.println(it.next());
  }
}
…
```


The lesson about shared state

- Coordinating access to shared state is a very tricky business
- Techniques for managing shared state include:
  - Make state immutable
  - Copy on write
  - Synchronize
- Synchronization introduces the possibility of deadlock
- Asynchronous message passing avoids these pitfalls but is not always possible

Part 2: Concurrency in Eclipse

- Job API: org.eclipse.core.runtime.jobs
- Job: a unit of work scheduled to run asynchronously
- Why not just java.lang.Thread?
  - Lighter weight: uses a shared thread pool
  - GUI integration: progress and cancelation
  - Priorities and mutual exclusion
  - Richer scheduling: run now, run later, run repeatedly
  - Job listeners can find out when jobs start, finish

Hello jobs world

```
class HelloJob extends Job {
  public HelloJob(String name) {
   super(name);
  }
  protected IStatus run(IProgressMonitor monitor) {
   System.out.println("Hello from " + getName());
   return Status.OK_STATUS;
  }
}
public void doit() {
  new HelloJob("Job1").schedule();
  new HelloJob("Job2").schedule();
}
```


Hello job output

- Result:

```
Hello from Job1
Hello from Job2
```

- Or perhaps:

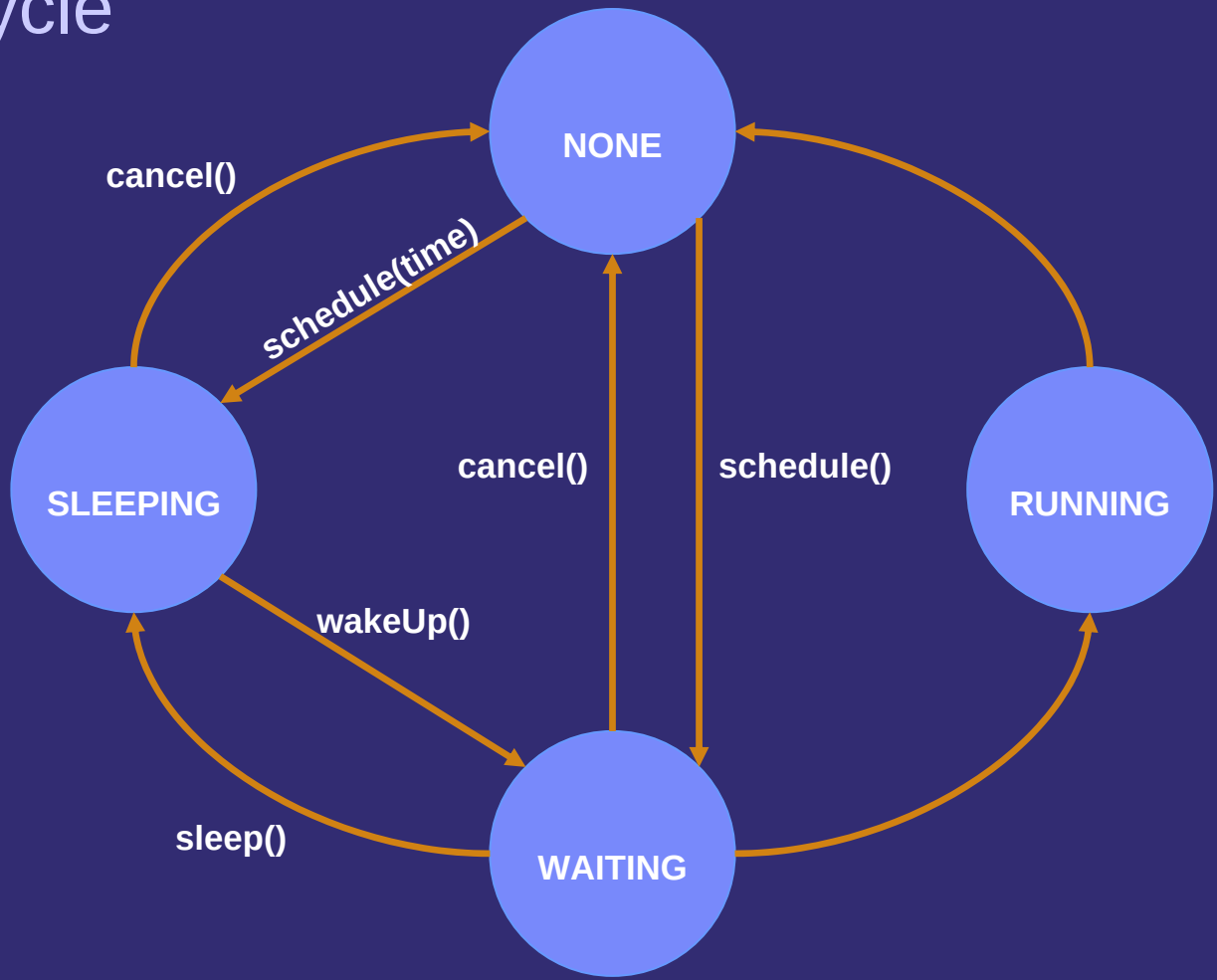
```
Hello from Job2
Hello from Job1
```

- In simple form, jobs offer no guarantees about execution time
- Multiple jobs can run at the same time

Job states

- A job instance can only be in one state at a given time
  - NONE: Job has not been scheduled or has finished running
  - WAITING: Job is queued to run as soon as possible
  - SLEEPING: Job should be run at some time in the future
  - RUNNING: Job is currently running
- Find out job state using Job.getState(); only predictable when called from the job's own thread
- Various job methods can be used to alter the state of a job
- Jobs are reusable; often a singleton instance is used

Job lifecycle

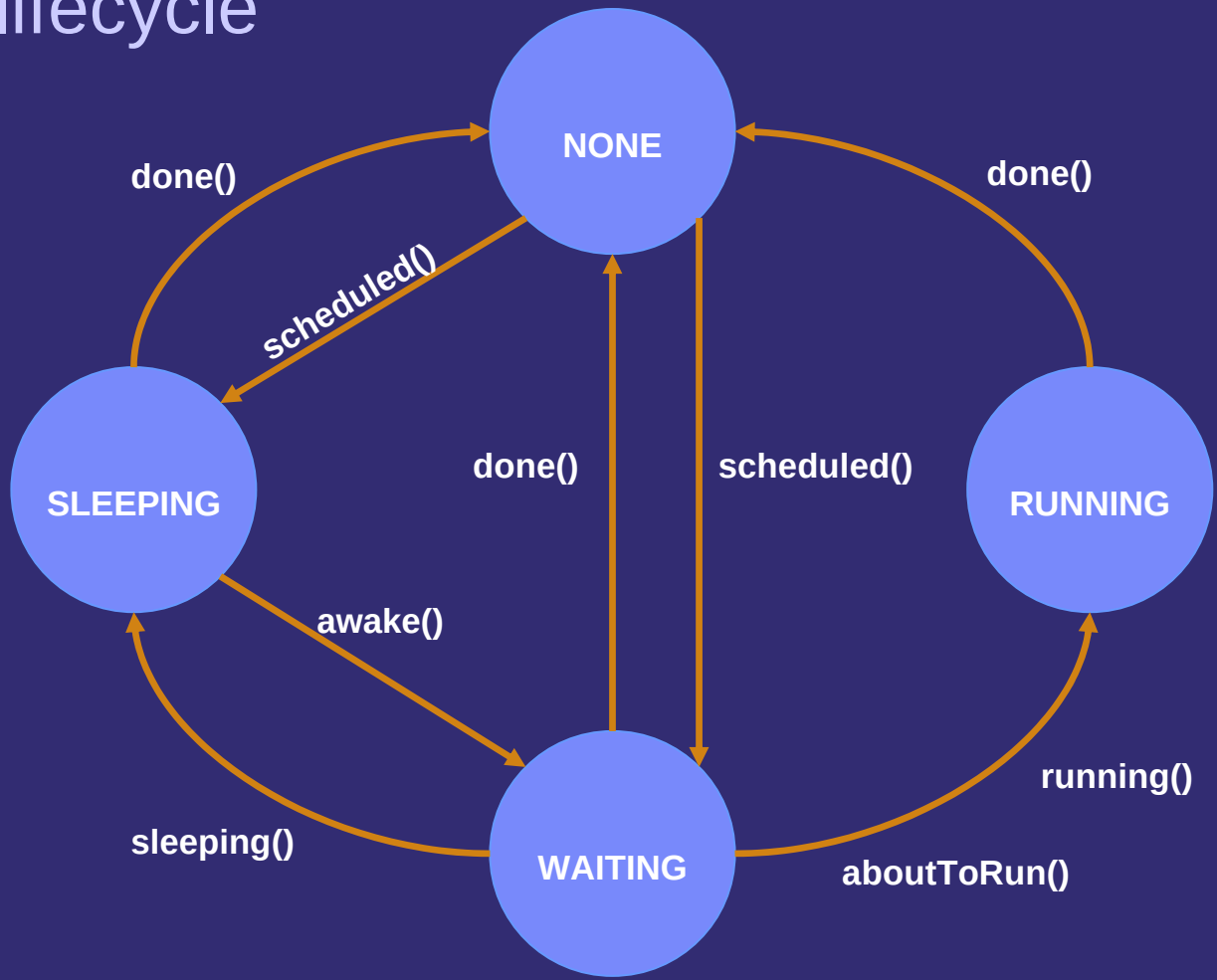


Job Listeners

- Anyone can add a listener to a particular job to keep track of its life cycle (Job.addJobChangeListener(…))
- In rare cases listen directly to job manager to track state of all jobs (IJobManager.addJobChangeListener(…))

```
class MyJobListener extends JobChangeAdapter {
 public void done(IJobChangeEvent event) {
   System.out.println("Done: " + event.getJob());
 }
}
```


Listener lifecycle



Job scheduling

- Job priorities are used as a hint about how soon the job should be run (interactive, short, long, build, decorate)
- Job priority is unrelated to Thread priority
- Can schedule a job to run now or run later
- Scheduling a job that is already running will cause it to be rescheduled as soon as it completes
- Can override shouldRun() or shouldSchedule() to make last minute decisions about whether to run or rerun a job

Exercise: A job creation view

- Create a subclass of AbstractJobView
- Implement the runJob() method to create and schedule jobs
- Call runJobBody() convenience method from the job's run method
- Print job status by calling setStatus(String)

Scheduling Rules

- Allow you to avoid certain jobs running at the same time
  - Example: Can't copy a file while deleting it

```
public interface ISchedulingRule {
 public boolean contains(ISchedulingRule rule);
 public boolean isConflicting(ISchedulingRule rule);
}
```

- isConflicting() method specifies if your rule can run at same time as others
- contains() method specifies if a rule is a subset of another rule

Scheduling Rules (continued)

- Scheduling rules can also be used outside of jobs
- Prevents a block of code from running concurrently with any job or other block using that rule

```
IJobManager jobMan = Platform.getJobManager();
final ISchedulingRule rule = new MySchedulingRule();
try {
 jobMan.beginRule(rule, null);
 // do some work
} finally {
 jobMan.endRule(rule);
}
```


MultiRule

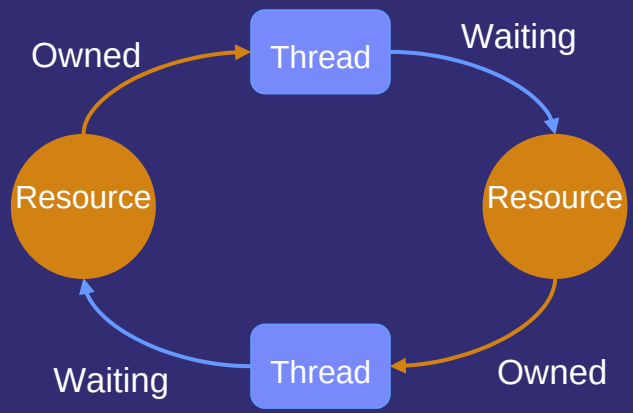
- At any given time, a single thread can only own one rule
- Topmost scheduling rule must be all-inclusive
  - Could use highest node in hierarchy
    - This inhibits concurrency
  - What if you need several unrelated rules?
- Need a means to combine two of more rules
  - MultiRule aggregates rules
    - MultiRule.combine(rule1, rule2)
    - MultiRule.combine(rules);

Locks

- ILock: re-entrant lock, similar to Java object monitors
- Acquires are granted in FIFO order
- Aware of syncExec: carries over to UI thread
- Deadlock reporting and recovery
  - Not a magic bullet!!
  - Intended as a programming aid

The necessary conditions for deadlock

- Mutual exclusion: resource held by a single thread
- Non-preemptible: resource can't be taken away
- Hold and wait: Each thread holds a resource and waits for another
- Circular wait: Waiting threads form a circle



Eliminating deadlock

- Avoid mutual exclusion
  - Use non-locking read operations as much as possible
  - Copy on write to avoid locking entirely
- Avoid hold and wait:
  - ISchedulingRule: allows jobs to specify requirements before they even start (two phase locking)
  - Impossible to hold a rule and be waiting for a rule
  - Avoid holding locks while client code is called
  - Avoid syncExec and use asyncExec where possible
- Avoid circular wait
  - Always acquire locks in a consistent order
- Preemption:
  - If all else fails, preempt the thread that introduced deadlock and report error in log

Pop quiz: deadlock?

```
class Deadlock extends Job {
  Deadlock() {super("Deadlock");}
  public synchronized IStatus run(IProgressMonitor pm) {
   Display display = window.getShell().getDisplay();
   display.syncExec(new Runnable() {
     public void run() {
       block();
     }
   });
   return Status.OK_STATUS;
  }
  public synchronized void block() {
  }
}
```


Solving deadlock with ILock

```
class NoDeadlock extends Job {
  ILock lock = Platform.getJobManager().newLock();
  public IStatus run(IProgressMonitor monitor) {
    lock.acquire();
    Display display = window.getShell().getDisplay();
    display.syncExec(new Runnable() {
      public void run() {
        block();
      }
    });
    lock.release();
    return Status.OK_STATUS;
  }
  public void block() {
    lock.acquire();
    lock.release();
  }
}
```


Party 3: Concurrency and the UI

- Topics to cover:
  - Progress and cancelation
  - User Jobs
  - Scheduling Rules
  - Job Configuration
  - Interaction with the UI thread
- Exercises involving a simple plug-in that:
  - Backups up one or more projects to a Backup project
    - Backup path is /Backups/<project name>/<backup key>/…
  - Restores a project from the backups

Exercise: Backup and restore plug-in

- Load the provided plug-in into your workspace
- Launch a run-time Eclipse
- Import the provided test plug-ins
- Perform some backups and restores
- How was the progress feedback?

Progress and cancelation

- Long running operations need to have:
  - Visual feedback of progress
    - Busy cursor
    - Graphical progress bar
    - Textual task/subtask descriptions
  - Ability to cancel
- Abstraction required between reporting and showing of progress
  - Using IProgressMonitor API for reporting progress
  - UI mechanisms for displaying progress

IProgressMonitor

- API features
  - reports progress and supports cancelation
  - Can be nested within other monitors
- How do we get a progress monitor?

```
public void doIt(IProgressMonitor monitor) {
  monitor.beginTask("Starting something big", 100);
  monitor.subTask("Doing the first part");

  doPartOne(new SubProgressMonitor(monitor, 40));

  if (monitor.isCanceled()) return;

  monitor.subTask("Doing the second part");
  // Do stuff
  monitor.worked(60);

  monitor.done();
}
```


Obtaining an IProgressMonitor

- IRunnableContext/IRunnableWithProgress
  - APIs for providing a progress monitor
  - Clients implements IRunnableWithProgress
- Context provided by
  - ProgressMonitorDialog
    - Show progress to the user using a dialog
    - Supports cancelation
  - IProgressService
    - run
      - Similar behavior to ProgressMonitorDialog
    - busyCursorWhile
      - Shows a busy cursor for a short time before opening a dialog

Progress services

```
IRunnableWithProgress runnable = new IRunnableWithProgress() {
  public void run(IProgressMonitor monitor) {
    doIt(monitor);
  }
};

IWorkbench workbench = PlatformUI.getWorkbench()
IRunnableContext context = workbench.getProgressService();

IRunnableContext context = new ProgressMonitorDialog(getShell());

context.run(true /* fork */, true /* cancelable */, runnable);

IProgressService service = workbench.getProgressService();
service.busyCursorWhile(runnable);
```


Exercise: Add progress and cancelation

- Convert the BackupAction and RestoreAction to use one of the previously mentioned progress services.
  - Wrap the appropriate method calls in the run methods
  - Wrap CoreException in InvocationTargetException
    - Why not just prompt at that point?
  - Push the monitor down to the IResource API calls
- How is progress and cancelation now?

Reporting progress from jobs

- Jobs also use a progress monitor
- Execution characteristics differ from other progress services
  - Executed asynchronously
  - Job specific progress feedback
  - Handling of errors returned from Job.run()
- There are several “types” of job progress
  - System jobs do not show progress anywhere
    - Job.setSystem(true)
    - Other jobs are shown in the progress view and status line
  - User jobs present a progress dialog
    - Option to run in the background (once or always)
    - Job.setUser(true);

Exercise: Convert to jobs

- Convert the BackupAction and RestoreAction to use Jobs
  - Don’t forget to schedule the job
  - Try it out.
    - How was the user experience?
    - Try setting the job to be a user job: Job.setUser(true)
    - How does it look now?
  - Error handling?
    - Return the status of the CoreException for now (see next slide)
- Was converting to a Job easy?
  - Why (or why not)?

Error handling

- The run method of a Job returns a status
  - ERROR – user is prompted with the error
  - WARNING, INFO – logged
- Jobs should create a new status object when errors occur
  - Tempting to return the status of a CoreException
  - Stack trace would then be lost
- Should exceptions terminate the job
  - Decision made on a case by case basis
  - If not, exceptions should be accumulated and a MultiStatus returned

Job feedback

- For long-running operations, the user wants to know
  - What is the operation doing?
  - Is the operation done?
  - Did the operation succeed?
  - What were the results?
- There are two mechanisms provided for background job feedback
  - A site associated with an originating or associated view
    - IWorkbenchSiteProgressService
  - The Progress view
- Can also use custom approaches
  - the synchronize view italicizes resources that are currently being operated on

Feedback in an associated view

- IWorkbenchSiteProgressService
  - Associated with a part (e.g. view)

```
part.getSite().getAdapter(IWorkbenchSiteProgressService.class);
```

  - schedule(job, delay, busyCursor)
    - schedule jobs through the service to get busy feedback (italic title) and job-busy cursor
  - showBusyForFamily(family)
    - Show busy whenever a job of the given family is running
  - warnOfContentChange()
    - Bold view title to indicate the contents of the view have changed

The Progress view

- The Progress view is where job progress is shown
- Job properties are used to configure the view
- Properties defined in IProgressConstants
  - KEEP_PROPERTY – keep all finished jobs in the progress view
  - KEEPONE_PROPERTY – keep only the last job in the view
  - ICON_PROPERTY – the icon that appears with the job in the view
    - URL or ImageDescriptor
  - ACTION_PROPERTY – action for job's hyperlink
  - PROPERTY_IN_DIALOG – set by progress service to indicate whether the progress dialog is visible or not
- For KEEP and KEEPONE, the text of the returned status is used as the hyperlink text

Exercise: Add properties to Backup/Restore

- Schedule the jobs through the site progress service
- Add the KEEP and ICON properties to the Backup/Restore
  - ProjectAction.getImageDescriptor() - example image
- Add an ACTION property that shows the ConsoleView
  - Use a subclass of org.eclipse.jface.Action
  - Override the run method
  - Invoke ConsoleView.showView()
- Output to Console
  - Add calls to ConsoleView.writeLine(String) to appropriate places
  - Will need to be in UI thread
    - Display.getDefault().asyncExec(new Runnable(…

Updating UI from a job

- All UI updates must be performed from the UI thread
- Low-level means of updating UI (SWT
  - Display.syncExec(Runnable) - synchronous
  - Display.asyncExec(Runnable) – asynchronous
- Higher-level
  - UIJob – asynchronous with return status
  - WorkbenchJob (extends UIJob) – won't start jobs after workbench shutdown

Considerations when updating UI

- Do minimal amount of work in the UI thread
- Batch updates whenever possible
  - Reduces Job/syncExec overhead
  - Reduces UI “disco-ball” effect
  - How often does the user need to see feedback?

Exercise: Batching updates

- Load and try out the Delta2Console example
- This code runs an asyncExec for each change
- Convert this example to use a WorkbenchJob to update the console
- How do we add batching?
- How do we know when to dispatch?
  - After a certain number of outputs
  - After a certain amount of time?
- How do we ensure that no output is lost?
- How do we handle errors?

Part 4: Concurrency and the workspace

- Changes made in 3.0 to make the workspace more concurrency-friendly
- How to run jobs that modify resources
- How the workspace uses jobs

Resource scheduling

- Eclipse resources are thread-safe
  - Can “lock” at individual resource level
  - Operations on resources obtain appropriate scheduling rules
- We can perform resource operations without worrying about it
- Why do we need to provide the job with a scheduling rule?
  - Job only runs when all rules are available
    - Reduced overhead
  - Operation is performed as an atomic unit on the resources
- What rules do we need for Backup and Restore?

Resource scheduling rule factory

- If we want to modify a resource, we need to get the proper rule
- The rules required to perform resource operations may vary
  - Some resource changes are linked to other resources
    - (I.e. changes to a link affect the .project file)
  - Repository provider may have additional requirements
    - operations may modify meta-files
  - Future requirements
- To Modify a project, we need to get the modify rule
  - ResourcesPlugin.getWorkspace().getRuleFactory().modifyRule(project)
- There are similar factories for other operation types
  - Create, copy, move, delete, validateEdit, etc

Workspace changes and builds

- What happens after a resource is modified?
  - Change notification sent to listeners
  - Auto-build is started
- What if several resources are modified by a single operation?
  - Don’t want to send notification and a start a build for each
- Several mechanisms provided to batch changes
  - IWorkspace.run methods
    - ResourcesPlugin.getWorkspace().
    - run(IWorkspaceRunnable, ISchedulingRule, int, IProgressMonitor)
  - WorkspaceJob
- Auto-build is postponed and change notifications are batched
  - POST_CHANGE notifications occur periodically within an operation

Background builds and change notifications

- Workspace builds occur in the background
  - All workspace modifications are blocked during a build
  - To improve responsiveness, builds will yield to blocked jobs
    - Using Job.isBlocking()
  - Yield point is determined by the active builder
    - Will occur at a point where the builder can easily resume
- Change notification also occurs in the background
  - Again, workspace modifications are blocked
  - Within a POST_CHANGE resource change listener:
    - workspace modifications are not allowed
    - Scheduling rules cannot be obtained

Exercise: Workspace considerations

- Do we need change batching?
  - Make the job a WorkspaceJob
- Do we need scheduling rules?
  - What is happening without any additional rules?
    - Each resource operation obtains the most specific rule possible
    - This leaves lots of opportunity for conflicting modifications
- Would like to add rules to ensure atomicity
  - What is needed for Restore?
  - What is needed for Backup?

Part 5: Concurrency in the large

- Best practices and principles for creating large-scale concurrent applications built on Eclipse
- Techniques for making a large existing application concurrent
- Wrap up

Designing concurrent/responsive applications

- Clearly separate the bulk of application logic from presentation (GUI) code
- GUI code always runs in UI thread – no worries about concurrency and thread safety of data structures
- Build API walls around pieces of application logic
- APIs must be prepared to be called concurrently in any thread
- APIs must specify “concurrency requirements” – locks needed, assumptions about calling thread, etc
- Don’t hold locks while calling into API, or when core code calls out

Making an existing application responsive

- Step 0 - If you make no changes, you will be ok (even slightly better)
- Step 1 - Revisit locks to reduce contention with background jobs
- Step 2 – Move long read only operations to background
- Step 3 – Move long writing operations to background

Step 0 – What if I do nothing?

- Backwards compatibility: no worse than Eclipse 2.1
- Blockage will always be reported to the user
- The UI is kept alive (painting) at all costs
- Cancelation is now always possible (even during deadlock)
- Lack of responsiveness in one component can kill responsiveness gains in other components

Step 1 - Revisit locks to reduce contention

- Identify where threads can become tangled
- Remove locks where possible
- Fine-grained locks to increase concurrency
- Lock for shorter periods of time
- Use scheduling rules to lock specific resources

Step 2 – Move read-only operations to background

- Less risk in moving read-only operations into background
- Can often be done with little or no contention
- Watch for assumptions about UI thread and thread safety
- Examples: searching, indexing, decoration, repository view
- Make sure things running silently in the background don't interrupt user tasks

Step 3 – Move writing operations to background

- Identify the big win operations – what common tasks will the user want to be able to perform in the background?
- Trade-off is added complexity of code versus important responsiveness gains
- Need to be aware of concurrency requirements of code you're calling: locks acquired, etc
- Be aware of deadlock risks and know avoidance strategies

References and resources

- Examples plug-in (dev.eclipse.org) org.eclipse.ui.examples.jobs
- *GUI Bloopers*, Jeff Johnson – Chapter 7: Responsiveness Bloopers
- *Concurrent Programming in Java*, Doug Lea
- *Modern Operating Systems*, Andrew S. Tanenbaum

Questions?