Implementation of Real-Time Java using KURT

Dinesh Selvarajan

Project Defense
Master of Science (Computer Engineering)
University of Kansas
Oct 21, 2003

Committee
Dr. Jerry James (Chair)
Dr. Douglas Niehaus
Dr. John Gauch

Talk Content

- Need for Real-Time Java (RTJ)
- Implementation
  - RTJ library
  - Driving example
- Evaluation
- Conclusion
- Future Work

Need for RTJ

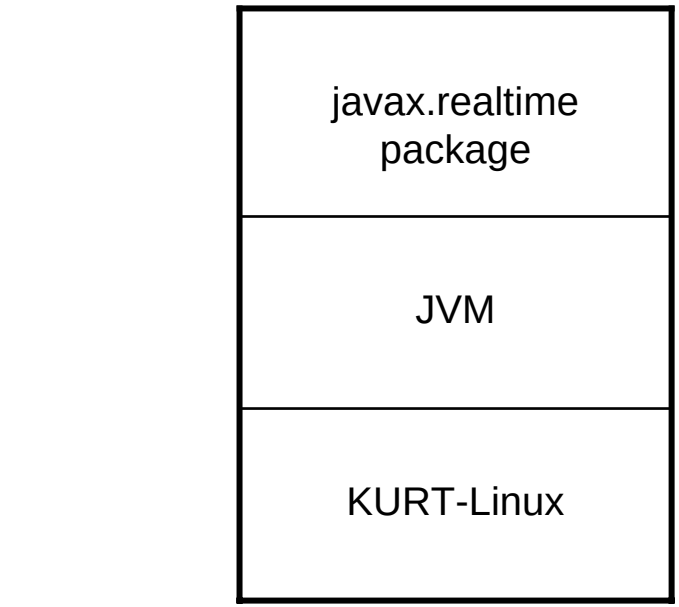
- Enable Java for real-time systems
- What is real-time?
- Proven predictable behavior
- Useful in military, aerospace and commercial process control systems
- Java does not suit time-aware systems
- Real-Time Specification for Java (RTSJ) – from Real-Time Java Expert Group

Basic Differences – RT & non-RT

- High resolution timers (micro- and nanosecond precision)
- Scheduling of events is guaranteed to take place at the exact time specified

Framework

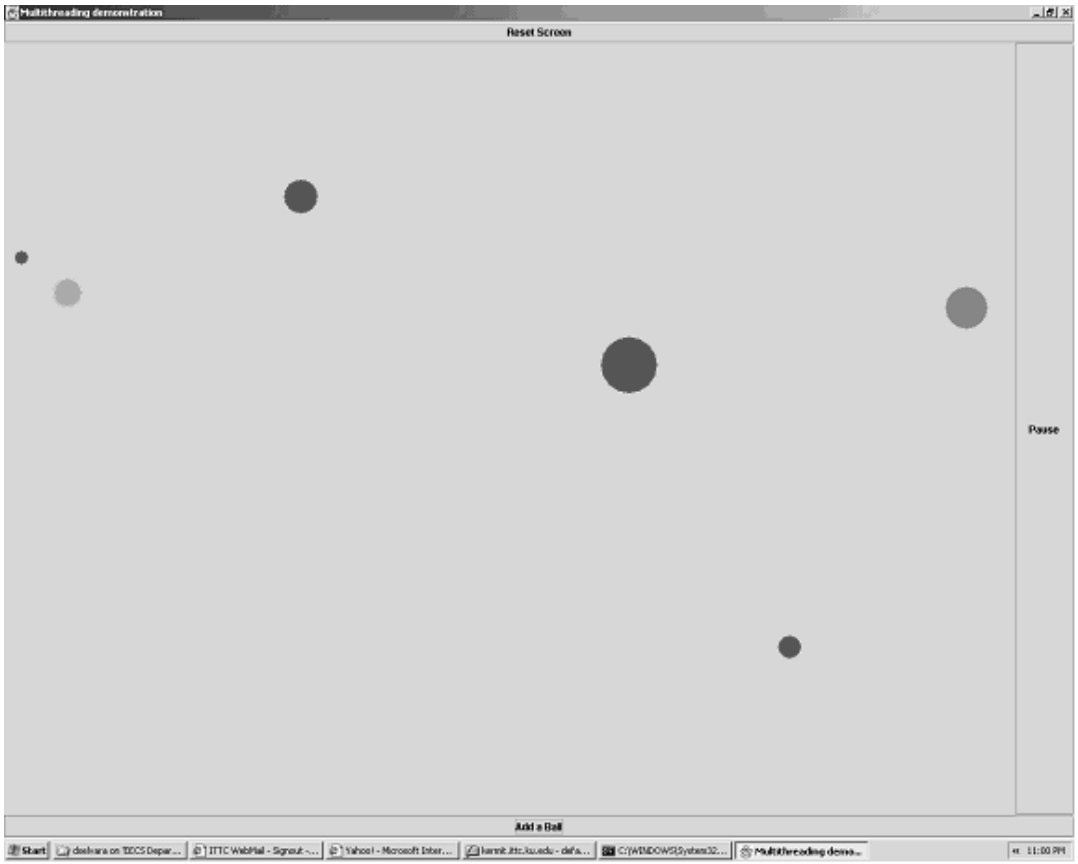
- JVM 1.4.1
- Real-time Operating System (RTOS) – KURT Linux
- RTJ Library
- Driving example



Areas of focus

- Under the javax.realtime package,
  - Real-time Clocks
    - HighResolutionTime
    - AbsoluteTime
    - RelativeTime
    - RationalTime
  - Real-time Timers
    - OneShotTimer
    - PeriodicTimer
  - Real-time Threads
    - RealtimeThread
  - Real-time Scheduling
    - Scheduler
- Communicate with the RTOS (KURT) through native calls linked by Java Native Interface (JNI)

Bouncing Ball



RT threads & Scheduling

- Native calls – directly interact with KURT
- Using JNI
- Make threads real-time
- Schedule those threads
  - Explicit Plan Schedule
  - Dynamic Scheduling

Data Streams with JNI

- Timing and schedule of the threads need to be checked using high-precision timers
- DSUI – tool to collect instrumentation data during execution
- DSUI made possible using JNI
- Instrumentation points – family, events and counters (contained in namespace file)
  - APPLICATION (family) 5
  - EVENT_OPEN 5
  - EVENT_START 4
  - EVENT_SUBMIT_SCHED 3
  - EVENT_SUSPEND 2
  - EVENT_WAKEUP 1
  - EVENT_EXIT 0

Customized JVM

- JVM spawns nine threads
- System threads that are non-deterministic
  - Garbage Collector (GC)
    - Finalizer thread
    - Reference Handler thread
  - Signal Dispatcher thread
  - Compile Thread
- Needs to be removed for testing

Results

```
testbed55 [6] # java Bounce2 10
kurtdev is: 20
Real-time ID# (as assigned by KURT) are:
ball1: 255
ball2: 254
ball3: 253
ball4: 252
ball5: 251
ball6: 250
ball7: 249
ball8: 248
ball9: 247
```

Results (cont…)

DSUI Output Log (xml format):

```
...
<ENTITY number="1" time_stamp="6791678943066" tag="0" type="Event">
<EVENT  name="EVENT_OPEN" family="APPLICATION" id="69" />
</ENTITY>
<ENTITY number="2" time_stamp="6791679225486" tag="0" type="Counter">
<COUNTER name="COUNTER_BOUNCE_SPEED_CONST" family="APPLICATION" id="64"
    count="10" first_updatetime="6791679167887"
    last_updatetime="6791679167887"/>
</ENTITY>
<ENTITY number="3" time_stamp="6838384115559" tag="0" type="Event">
<EVENT  name="EVENT_START" family="APPLICATION" id="68" />
</ENTITY>
<ENTITY number="4" time_stamp="6838384832808" tag="0" type="Event">
<EVENT  name="EVENT_SUBMIT_SCHED" family="APPLICATION" id="67" />
</ENTITY>
<ENTITY number="5" time_stamp="6838384854671" tag="0" type="Event">
<EVENT  name="EVENT_SUSPEND" family="APPLICATION" id="66" />
</ENTITY>
<ENTITY number="6" time_stamp="6838399036229" tag="0" type="Event">
<EVENT  name="EVENT_WAKEUP" family="APPLICATION" id="65" />
</ENTITY>
...
```

Results (cont…)

Status of the running real-time threads:

- `kurt_status` program provided by KURT – lists all the current real-time processes and their status:

```
...
handled late    dropped invalid wdog    baddog1 baddog2 baddog3
1316    504     0       0       0       0       0       0
rt_id   pid      woken     missed    rt_susp     aborts nonrt_susp   switches
  247 10890          3          0          4          0          0          0
  248 10889         19          0         20          0          0          0
  249 10888         30          0         31          0          0          0
  250 10887         47          0         48          0          0          0
  251 10886         63          0         64          0          0          0
  252 10885         98          0         99          0          0          0
  253 10884        151          0        152          0          0          0
  254 10883        195          0        196          1          0          0
  255 10882        416          0        417          0          0          0
...
```

Results (cont…)

Scheduling of events – timing information, based on timestamp counters:
(Processor speed = 1399.380 MHz; which means 1399380000 cycles per second)

Timestamp counter of the wakeup events	Diff. bet. 2 wakeup events	Diff. in milliseconds = (diff./cycles per second)* 1000	Deviation (in ms) from the expected 10ms
6838399036229			
6838413029334	13993105	9.9995	0.0004
6838427395794	14366460	10.2663	0.266
6838441011820	13616026	9.7300	0.269
6838455003761	13991941	9.9986	0.0013

Conclusion

- javax.realtime package is built
- Gaps in Java have been bridged
- Widens the scope of Java
- Limitations
  - Overhead due to JNI
  - Not for hard real-time systems
- Other commercial versions of RTJ – not freely available to all

Other Challenges

- Memory Management
- Garbage Collection (GC)
- Contribute to unpredictable behavior

Other Challenges (cont…)

- Memory Management
  - JVM allocates memory from heap
  - Does not use a specific allocation algorithm – leads to non-deterministic results
  - Solution – create No Heap Real-Time (NHRT) threads
  - Dynamic checking (at every read & write) – so that NHRT threads do not access any location into the GC heap
  - Limitation – overhead due to this kind of dynamic checking for memory access for the NHRT threads

Other Challenges (cont…)

- Garbage Collector (GC)
  - GC acts unpredictably
  - NHRT threads should be made to preempt GC
  - Wider perspective – Sun's Java HotSpot uses a compacting mark & sweep algorithm for GC
  - Objects are grouped into following generations:
    - Nurseries
    - Older generation
  - for Nurseries – generational copying collector
  - for Older generation – mark-compact collection algorithm

Thanks for your (real) time!