Dynamic Memory Management

Current practice
- DO-178B and DO-278 provided no guidance
- Just say no!
- but the following are being used:
  - stack allocation
  - object pooling

Future
- DO-332 provides guidance
- Perhaps, but how?
Is DMM Necessary?

What is the computational complexity?

- State Machine: no
- Push Down Automaton: limited
- Turing Machine: yes

Examples

- Brake control
- Path retracing
- Object recognition
New Standards

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<th>EUROCAE</th>
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<tr>
<td>ED-12C</td>
<td>DO-178C</td>
<td>Software Considerations in Airborne Systems and Equipment</td>
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<td>ED-94C</td>
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<td>Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and AirTrafficManagement (CNS/ATM) Systems</td>
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* RTCA titles are identical except for the references to other standards.
Dynamic Memory Vulnerabilities

1. Ambiguous reference (reallocate live object)
2. Fragmentation starvation
3. Deallocation starvation (memory leak)
4. Premature deallocation (dangling reference)
5. Indeterministic allocation or deallocation
6. Lost update or stale reference (due to moving objects)
7. Heap memory exhaustion
Dynamic Memory Safety Objectives

1. Unique Allocation
2. Fragmentation Avoidance
3. Timely Deallocation
4. Reference Consistency
5. Deterministic Execution
6. Atomic Move
7. Sufficient Memory
## Memory Management Techniques

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**AC** = application code, **MMI** = memory management infrastructure, **N/A** = not applicable, and **?** = difficult to ensure by either **AC** or **MMI**.
Deterministic Garbage Collection

Saves development time

- No need to release objects explicitly
- Fewer memory errors
- Can easily track heap usage

Implements safety

- Reduces the danger of memory leaks
- Prevents premature object deallocation
- Does not interfere with realtime response

But what about Realtime?
Qualifying a Garbage Collector

Not possible for all collector

- Must be deterministic; no unbound steps
- Must assume maximum memory use
- Must consider allocation rate

Work Based Collector

- No root scan and compaction (unbound)
- Mark and sweep steps on fixed size blocks
- Automatically tracks allocation rate
Conventional Garbage Collection

GC can interrupt execution for long periods of time:

Problem

long, unpredictable pauses during execution
No heap threads can interrupt garbage collector:

Thread:

rt1
rt2
GC
User 1
User 2
...

time

The application must be split into a realtime and a nonrealtime part.
Realtime Garbage Collection

Paced garbage collector

• Run GC at a high priority
• Runs at given interval, for given duration (Scheduling!)
• Programmer must provide both maximum memory use and maximum allocation rate

Slack garbage collector

• Run GC at lower priority than realtime tasks
• Runs when processor cycles are available (Scheduling!)
• Programmer must provide both maximum memory use and maximum allocation rate
All Java Threads are realtime threads

- GC work is performed at allocation time
- GC work must be sufficient to recycle enough memory before free memory is exhausted
- Execution time of all allocations must be bound
Realtime Garbage Collection

Work based garbage collector

- No GC thread (not schedule!)
- GC borrows application thread
- Need only determine maximum memory use
- No read barriers needed
- Low latency

Also need priority inversion avoidance, realtime scheduling, and other concepts that the Real Java (RTSJ) has taken from Ada.
Real-Specification for Java

Conventional Java + deterministic GC != Realtime Java

Also need Real-Time Specification for Java

- priority inversion avoidance,
- realtime scheduling, and
- other concepts taken from Ada.
Example Period Task on LinuxRT

Period  200.00us, 7500 iterations
  • min = 167.90us (84%)
  • max = 231.80us (116%)
  • average = 199.99us
  • standard deviation = 965ns (0%)

Execution
  • both calculation & allocation in each release
  • 2–4 us
Conclusion

Generate state machines if you can, but deterministic garbage collection is the best solution for complex safety-critical programs.

Not just any Java implementation will do!