Defining a High-Level Programming Model for Emerging NVRAM Technologies

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Outline

- Introduce Non-Volatile Random Access Memory (NVRAM)
  - Describe features of existing NVRAM frameworks
  - Explain the limitations of existing NVRAM frameworks
- Propose new NVRAM programming model for managed languages
- Partially apply model to Java and show initial results
- Describe Future Work

Non-Volatile Random-Access Memory (NVRAM)

- Non-Volatile Random-Access Memory (NVRAM) is soon to become available
  - Byte-addressable durable storage
  - Performance is within an order of magnitude of DRAM
  - Capacity is much higher than DRAM
  - Much faster than traditional block-based storage offerings
- Enterprise Applications will use NVRAM
  - Better performance
  - Removes separation between application working memory and storage

Using NVRAM Today

- Measures still must be taken to ensure crash-consistency
  - Volatile data must be written back from caches
  - Fences must be inserted to ensure a specific ordering of persistence stores
- Current frameworks expect the programmer to manage all operations needed for crash consistency
  - Allocation into NVRAM
  - Cache writebacks
  - Fences

Limitations of Existing NVRAM Frameworks

- Low-level model does not match the level of abstraction expected by managed language users
- Easy to introduce bugs
- At odds with automatic memory management support
- Existing libraries must be modified to be crash consistent
- Difficult for the compiler to perform optimizations

Goals for New NVRAM Programming Model

1. Require minimal markings by programmer
2. Libraries and other pre-existing codes should not need to be changed to work correctly in a durable program
3. Failure-atomic support should be provided and need only minimal markings

- More details in paper

Requirements for NVRAM Programming Model

- Specific enough for consistent behavior
- General enough to give implementors flexibility

❶ Only objects directly addressed at recovery time should require markings
  - We call these objects the *durable root set*
  - The runtime should dynamically ensure all objects reachable from the durable root set are in NVRAM
  - May require moving objects at runtime to NVRAM

❷ Failure-atomic regions should only need markings to delimit the code region
  - Runtime should automatically provide needed logging

❸ Outside of failure-atomic regions, stores to recoverable memory should complete in sequential order

- More details in paper

Applying Model to Java

- We only describe the beginning of applying our model's requirements to Java
  - Identifying Durable Roots
  - Modifying Behavior of JVM Bytecodes
- Identifying Durable Roots
  - Annotate select static fields with new `@durable_root` annotation
  - All objects reachable from this annotation must be durable
  - All stores to objects reachable from this annotation must be performed durably and in sequential order

Modifying JVM Bytecodes

Modifying Behavior of JVM Bytecodes

- `putfield`(O, F, V)
  - Original: Store value V into field F of object O

Modified → when O is durable:

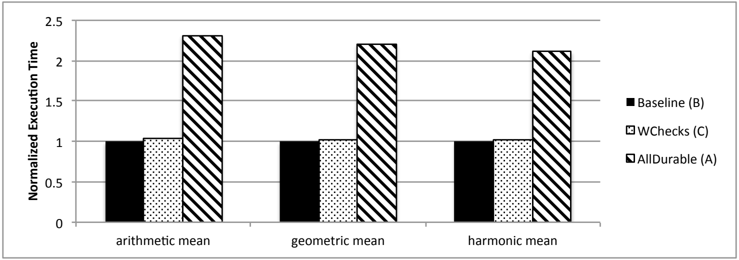
1: Ensure V and its transitive closure is durable, moving objects to NVRAM if necessary
2: Store V into $O.F$
3: Write back store to NVRAM
4: Insert fence after writeback to ensure sequential ordering

- `putstatic` and {`a,b,c,d,f,i,l,s`}`astore` are also modified in similar ways
- More details in paper

Evaluation

- Intention of evaluation is to present an initial approximation of our model's overhead in Java
- Implement changes on Maxine VM version 2.0.5
  - Modify only baseline compiler (T1X)
  - Disable use of optimizing compiler
- Do not use NVRAM, but do insert all necessary cache writebacks and fences
  - Writebacks and fences are the main overhead of NVRAM
- Three Configurations
  - *Baseline (B)*: unmodified JVM
  - *WChecks (C)*: modified JVM, but no durable roots
  - *AllDurable (A)*: modified JVM and all objects are durable

Initial Results



- Run DaCapo Benchmarks
- *WChecks* does not have significant overheads
- *AllDurable* is over twice as slow as *Baseline*
  - Gap may be wider in reality

Future Work

- Fully define NVRAM programming model extension for Java
  - If also defined for JVM, then can be incorporated into many languages
- Determine the runtime support necessary to dynamically move objects between volatile and non-volatile memory
- Determine the runtime support necessary for failure-atomic regions
- Introduce compiler optimizations to minimize the overheads introduced by our model

Conclusion

Paper Contributions:

- Describes how existing NVRAM frameworks are not a good match for managed languages
- Describes what goals a NVRAM programming model for managed languages should meet
- Proposes a new NVRAM programming model which is intuitive for programmers and a good fit for manged languages
- Explains how the initial steps of how Java can be modified to implement our NVRAM programming model

- I have a poster in the following session