Java's Volatile Keyword

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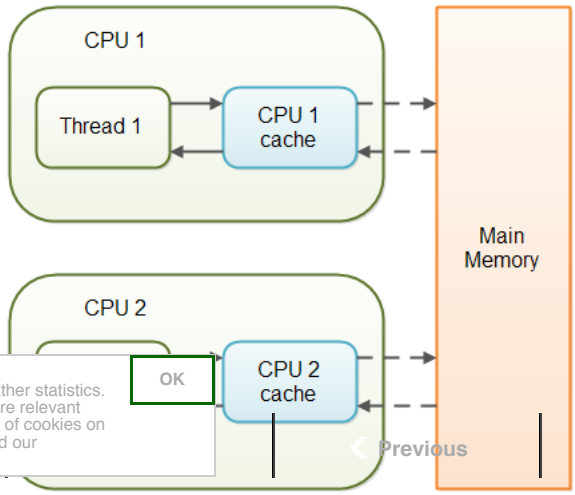
The Java `volatile` keyword is used to mark a Java variable as "being stored in main memory". More pr
that means, that every read of a volatile variable will be read from the computer's main memory, and not
the CPU cache, and that every write to a volatile variable will be written to main memory, and not just to t
cache.

Actually, since Java 5 the `volatile` keyword guarantees more than just that volatile variables are writte
and read from main memory. I will explain that in the following sections.

Java volatile Guarantees Variable Visibility

The Java `volatile` keyword guarantees visibility of changes to variables across threads. This may sour
abstract, so let me elaborate.

In a multithreaded application where the threads operate on non-volatile variables, each thread may copy
variables from main memory into a CPU cache while working on them, for performance reasons. If your
computer contains more than one CPU, each thread may run on a different CPU. That means, that each
may copy the variables into the CPU cache of different CPUs. This diagram illustrates such a situation:



Previous Next

With non-volatile variables there are no guarantees about when the Java Virtual Machine (JVM) reads da
main memory into CPU caches, or writes data from CPU caches to main memory. Let me explain what pr
that can cause with an example:

Imagine a situation in which two or more threads have access to a shared object which contains a counte
variable declared like this:


```
public class SharedObject {

    public int counter = 0;

}
```

Thread 1 could read a shared `counter` variable with the value 0 into its CPU cache, increment it to 1 an write the changed value back into main memory. Thread 2 could then read the same `counter` variable fr main memory where the value of the variable is still 0, into its own CPU cache. Thread 2 could then also increment the counter to 1, and also not write it back to main memory. Thread 1 and Thread 2 are now practically out of sync. The real value of the shared `counter` variable should have been 2, but each of th threads has the value 1 for the variable in their CPU caches, and in main memory the value is still 0. It is mess! Even if the threads eventually write their value for the shared `counter` variable back to main mem the value will be wrong.

By declaring the shared `counter` variable `volatile` the JVM guarantees that every read of the variable always be read from main memory, and that all writes to the variable will always be written back to main memory. Here is how the `volatile` declaration looks:

```
public class SharedObject {

    public volatile int counter = 0;

}
```

In some cases simply declaring a variable volatile may be enough to assure that multiple threads accessi variable see the latest written value. I will get back to which cases volatile is sufficient later.

In the situation with the two threads reading and writing the same variable, simply declaring the variable v is not enough. Thread 1 may read the `counter` value 0 into a CPU register in CPU 1. At the same time (after) Thread 2 may read the `counter` value 0 into a CPU register in CPU 2. Both threads have read the directly from main memory. Now both variables increase the value and writes the value back to main mer They both increment their register version of `counter` to 1, and both write the value 1 back to main mem The value should have been 2 after two increments.

The problem with multiple threads that do not see the latest value of a variable because that value has nc been written back to main memory by another thread, is called a "visibility" problem. The updates of one t are not visible to other threads.

The Java volatile Guarantee

Since Java 5 the `volatile` keyword guarantees more than just the reading and writing of a variable fron to main memory. Actually, the `volatile` keyword guarantees this:

- If Thread A writes to a volatile variable and Thread B subsequently reads the same volatile variable all variables visible to Thread A before writing the volatile variable, will also be visible to Thread B.
- The reading and writing instructions of volatile variables cannot be reordered by the JVM (the JVM r reorder instructions for performance reasons as long as the JVM detects no change in program beh from the reordering). Instructions before and after can be reordered, but the volatile read or write ca mixed with these instructions. Whatever instructions follow a read or write of a volatile variable are guaranteed to happen after the read or write.

Look at this example:

```
Thread A:
    sharedObject.nonVolatile = 123;
    sharedObject.counter     = sharedObject.counter + 1;

Thread B:
    int counter     = sharedObject.counter;
    int nonVolatile = sharedObject.nonVolatile;
```

Since Thread A writes the non-volatile variable `sharedObject.nonVolatile` before writing to the vola `sharedObject.counter`, then both `sharedObject.nonVolatile` and `sharedObject.counter` a written to main memory.

Since Thread B starts by reading the volatile `sharedObject.counter`, then both the `sharedObject.counter` and `sharedObject.nonVolatile` are read in from main memory.

The reading and writing of the non-volatile variable cannot be reordered to happen before or after the rea and writing of the volatile variable.

When is volatile Enough?

As I have mentioned earlier, if two threads are both reading and writing to a shared variable, then using th `volatile` keyword for that is not enough. You need to use **synchronization** in that case to guarantee th reading and writing of the variable is atomic.

But in case one thread reads and writes the value of a volatile variable, and other threads only read the v then the reading threads are guaranteed to see the latest value written to the volatile variable. Without ma the variable volatile, this would not be guaranteed.

Performance Considerations of volatile

Reading and writing of volatile variables causes the variable to be read or written to main memory. Readi
and writing to main memory is more expensive than accessing the CPU cache. Accessing volatile variabl
prevent instruction reordering which is a normal performance enhancement technique. Thus, you should
use volatile variables when you really need to enforce visibility of variables.

Next: Java ThreadLocal