Concurrency

EECS 4315

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Counter Class

Problem

Implement the class `Counter` with

- attribute `value`,
- initialized to zero, and
- the methods `increment` and `decrement`.

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Question

Can multiple threads share a `Counter` object and use methods such as `increment` and `decrement` concurrently?

Answer

No, as before, if two threads invoke `increment` concurrently, the counter may only be incremented by one (rather than two).

Synchronized Methods

Methods such as `increment` should be executed atomically. This can be accomplished by declaring the method to be `synchronized`.

A lock is associated with every object. For threads to execute a synchronized method on such the object, first its lock needs to be acquired.

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A lock is associated with every object. For threads to execute a synchronized method on such the object, first its lock needs to be acquired.

```
public synchronized void increment()
{
  this.value++;
}
```

Resource Class

Problem

Implement the class **`Resource`** with

- attribute **`available`**,
- initialized to true, and
- the methods **`acquire`** and **`release`**.

Wait and Notify

The Object class contains the following three methods:

- `wait`: causes the current thread to wait until another thread wakes it up.
- `notify`: wakes up a single thread waiting on this object's lock; if there is more than one waiting, an arbitrary one is chosen; if there are none, nothing is done.
- `notifyAll`: wakes up all threads waiting on this objects lock.

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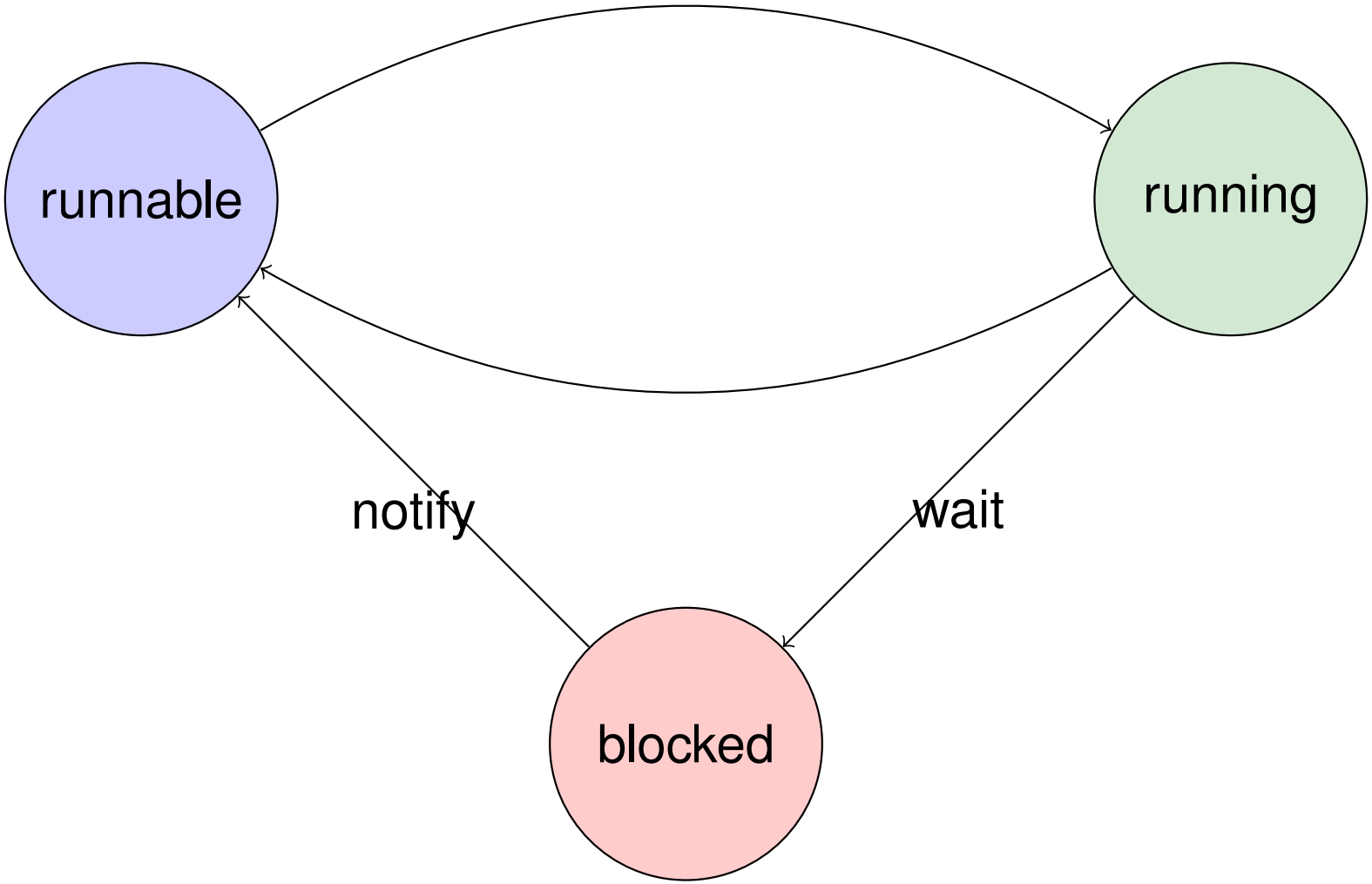
Since every class extends the class Object, these methods are available to every object.

States of a Thread



Counter Class

```
public class Counter extends Thread
{
  private int value;

  public Counter()
  {
    this.value = 0;
  }

  ...

}
```

Counter Class

```
public void run()
{
  this.value++;
}
```

```
0: aload_0
1: dup
2: getfield
5: iconst_1
6: iadd
7: putfield
10: return
```

Main Class

```
public class Main
{
  public static void main(String[] args)
  {
    Counter one = new Counter();
        Counter two = new Counter();
        one.start();
        two.start();
  }
}
```

```
0: new
3: dup
4: invokespecial
7: astore_1
8: new
```

```
11: dup
12: invokespecial
15: astore_2
16: aload_1
17: invokevirtual
```

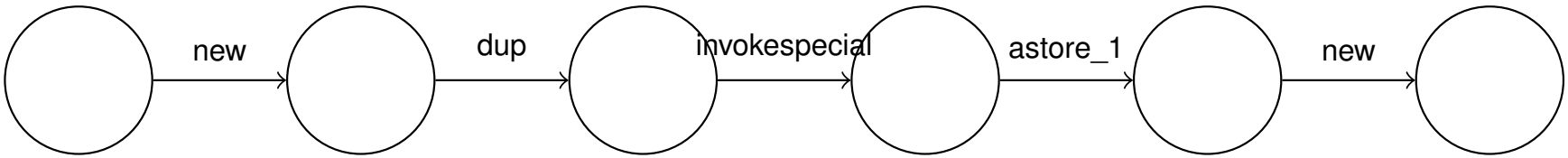
```
20: aload_2
21: invokevirt
24: return
```

State-Transition Diagram

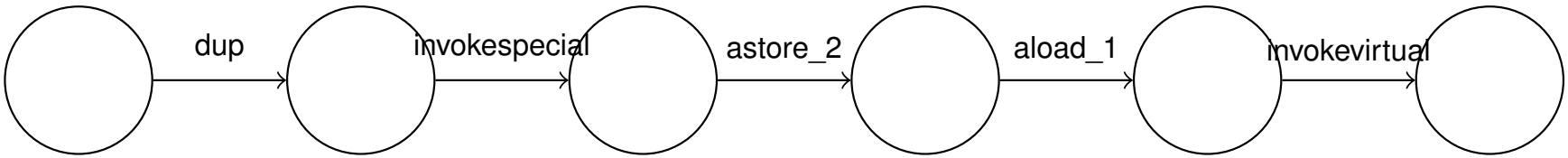
Question

Draw the corresponding state-transition diagram.

State-Transition Diagram



State-Transition Diagram



A Smaller Model

Combine the first ten transitions into one.

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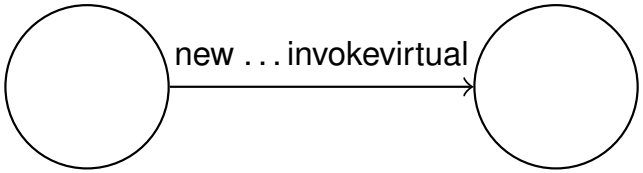

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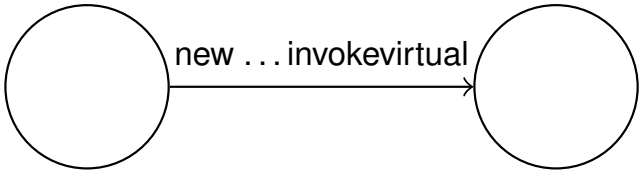
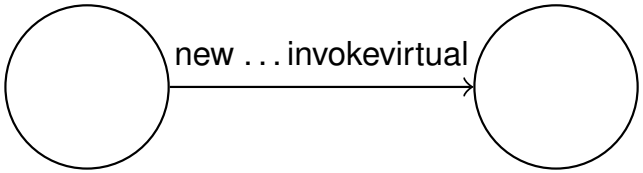


The actions of the labelled transition system are sequences of bytecode instructions.

State-Transition Diagram



Next instructions for the main thread:

```
20: aload_2
21: invokevirtual
24: return
```

Next instructions for the thread `one`:

```
0: aload_0
1: dup
2: getfield
5: iconst_1
6: iadd
7: putfield
```

State-Transition Diagram

Question

Can the bytecode instructions corresponding to the `run` invocation be modelled as a single transition?

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Answer

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State-Transition Diagram

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Can the bytecode instructions corresponding to the `run` invocation be modelled as a single transition?

Answer

Yes.

Question

Why?

Answer

Because the execution of this method does not impact the other threads.

Combining Bytecode Instructions

- We combine the first ten bytecode instructions since there is only one thread.
- We combine the bytecode instructions corresponding to the `run` invocation because those do not impact the other threads.

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General idea

Combine those bytecode instructions that do not impact other threads.

Combining Bytecode Instructions

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Given all the bytecode instructions, determine for a specific instruction whether it impacts other threads.

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Question

Give an algorithm that solves the problem.

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Impossible!

Proving Impossibility

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Which other problems cannot be solved?

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Answer

The halting problem: given code and input for that code, determine whether the code terminates.

Proving Impossibility

Problem

Given all the bytecode instructions, determine for a specific instruction whether it impacts other threads.

Question

Prove that the problem cannot be solved.

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General idea

Combine those bytecode instructions for which we can prove that they do not impact other threads.

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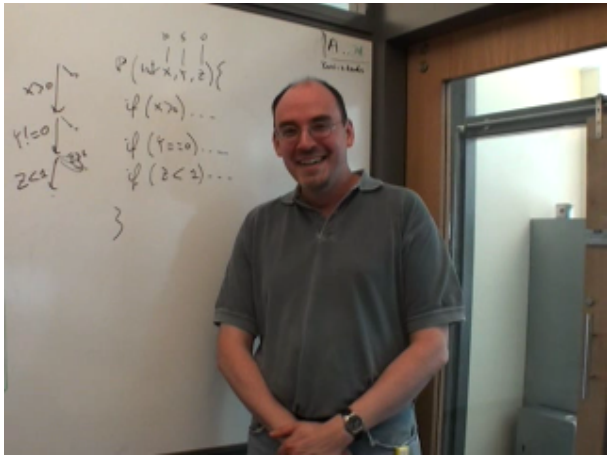
Examples of invisible actions

- Reading or writing an attribute that can be proved to be not shared.
- Reading or writing a local variable.
- ...

Patrice Godefroid

- Ph.D. degree in Computer Science from the University of Liege, Belgium
- Worked at Bell Laboratories.
- Currently at Microsoft Research.



Source: Patrice Godefroid