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A Conclusion on Inheritance Anomaly

Why Inheritance Anomaly Is Not Worth Solving
Gramoli and Santosa, ICOOOLPS '14

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Inheritance Anomaly

- Inheritance of concurrent code breaks encapsulation [MY93]
- Solutions never adopted in mainstream languages → *Why?*

Our Observation

- Reasonable solution makes concurrency control more powerful
  - Complexity in checking Liskov-Wing substitutability
- Practitioners avoid the general problem by avoiding implementation inheritance [Gang of Four]

Example: Java Bounded Buffer

- **`put`**: Puts object into the buffer, suspends when full
- **`get`** (not shown): Retrieves object from buffer, suspends when empty

```
public class BBuf {
  protected int state;
  protected static final int EMPTY = 0;
  protected static final int PARTIAL = 1;
  protected static final int FULL = 3;
  public BBuf(int max) { ...
        state = EMPTY; }
  public synchronized void put(Object v)
        throws Exception {
        while (state==FULL) { wait(); }
        ...
        state = (current>=MAX? FULL : PARTIAL);
        notifyAll();
  } ...
}
```

Subclassing the Bounded Buffer

- **`get2`**: Retrieves 2objects from the buffer, suspends when full / only one

```
public class XBuf2 extends BBuf {
  protected static final int ONE = 4;
  public XBuf2(int max) { super(max) }
  ...
  public synchronized Object[] get2()
        throws Exception {
        while (state==EMPTY||state==ONE) { wait(); }
        ...
        state = (current<=0? EMPTY : PARTIAL);
        notifyAll();
        return ret;
  }
}
```

Subclassing the Bounded Buffer

- Requires redefinition of **`put, get.`**
- **No encapsulation**
- **No reusability**

```
public class XBuf2 extends BBuf {
  protected static final int ONE = 4;
  ...
  public synchronized void put(Object v)
        throws Exception {
        while (state==FULL) { wait(); }
        ...
        state = (current==1? ONE :
                (current>=MAX? FULL : PARTIAL));
        notifyAll();
  }
  ...
}
```

Inheritance Anomaly Solutions

- Increases the power of concurrency control
  - Ad-hoc constructs
  - Regular expressions
  - Temporal logic

- Solutions never adopted in mainstream languages → *Why?*

Too Much Power?

- JEEG as an example
- Elegant solution with temporal logic
- Deadlock introduced: superclass behavior *not preserved*

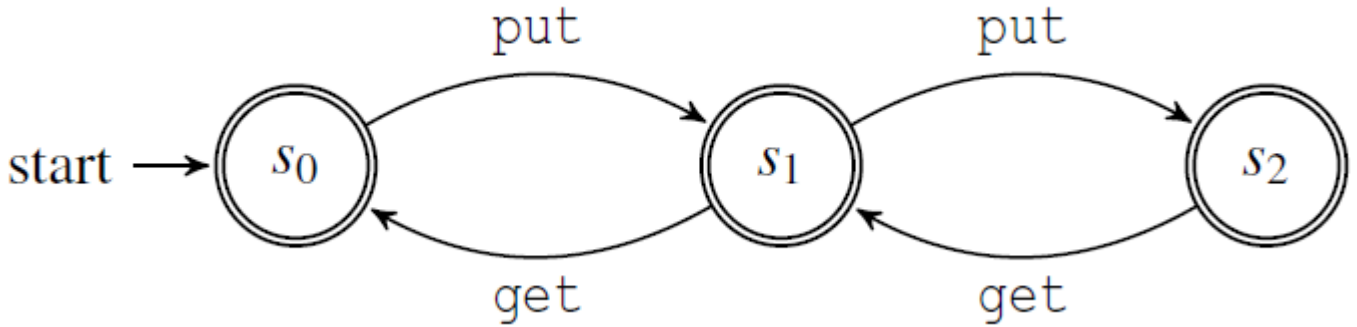
```
public class NewBBuf extends BBuf {
  sync {
       put: (super.putConstr) &&
              (Previous event==get);
       get: (super.getConstr) &&
              (Previous event==put);
  }
}
```

Formal Model of Concurrent Code Inheritance

- Based on NFA
- Not anomalous wrt. all three inheritance anomaly examples in [MY93]

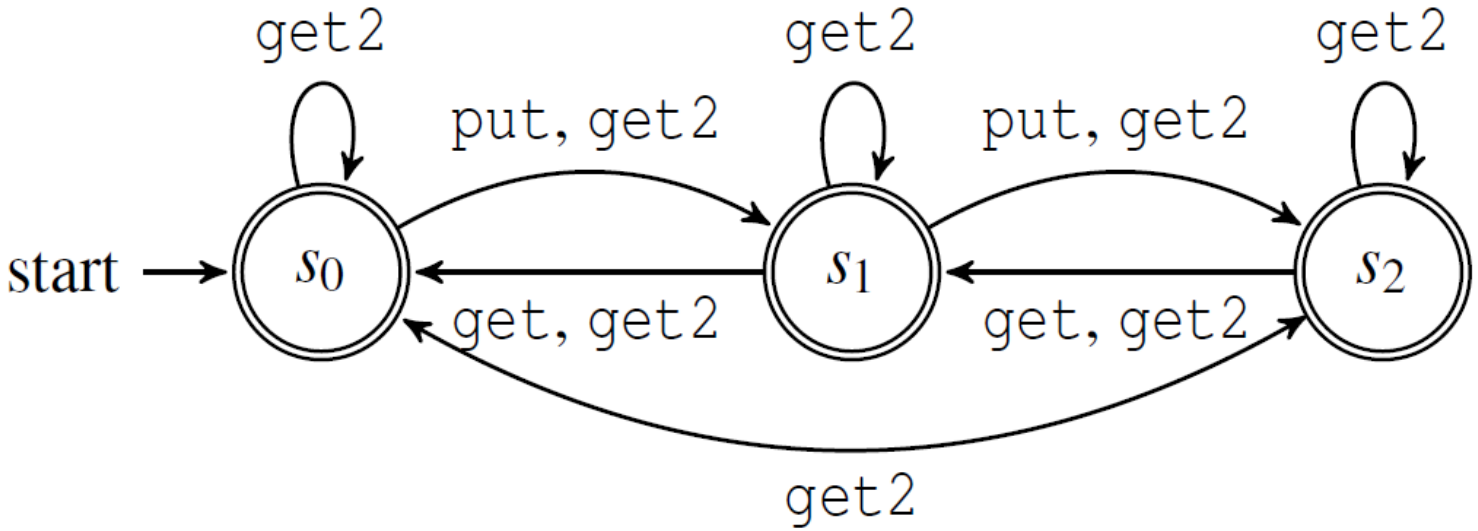
Formal Model of Concurrent Code Inheritance

- **Superclass behavior**
- Interface extension
- Behavior restriction



Formal Model of Concurrent Code Inheritance

- Superclass behavior
- **Interface extension**
- Behavior restriction



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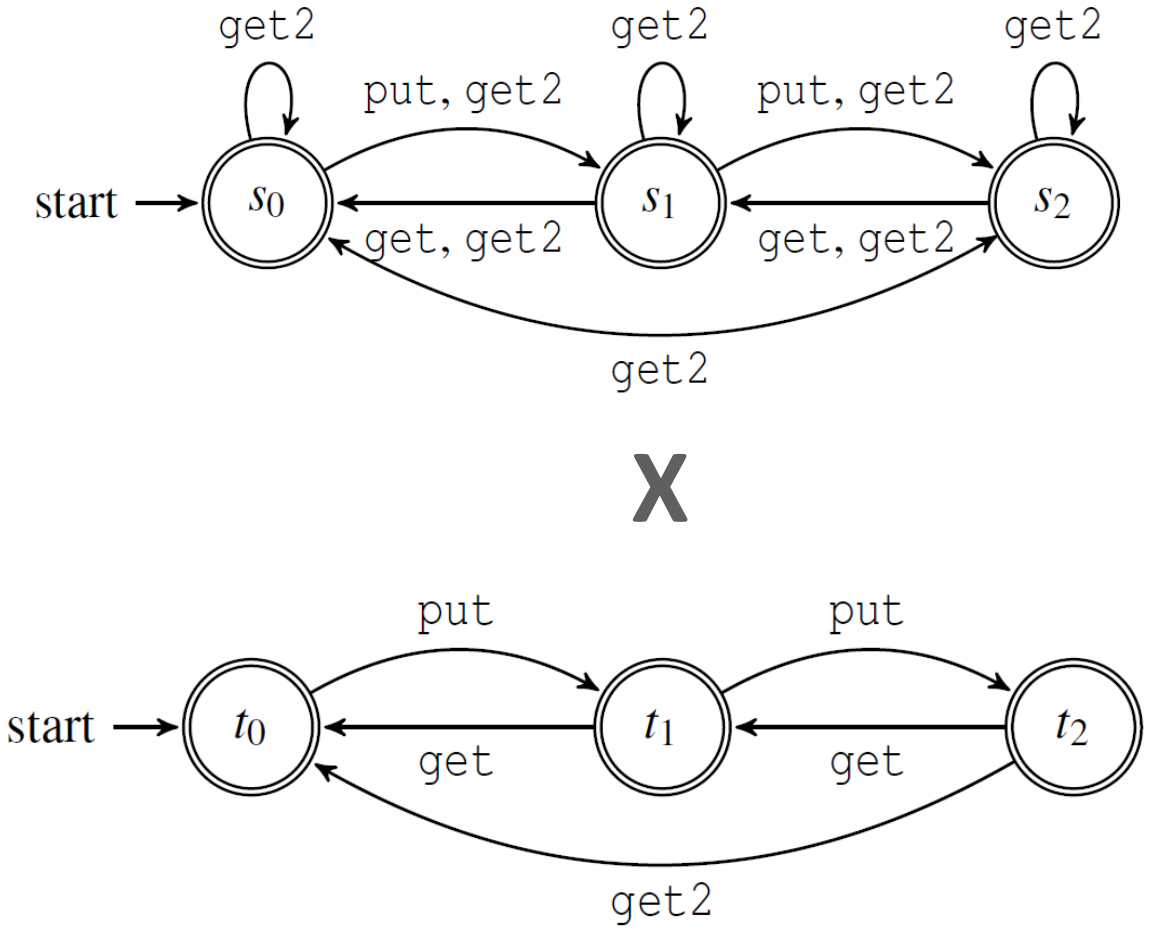

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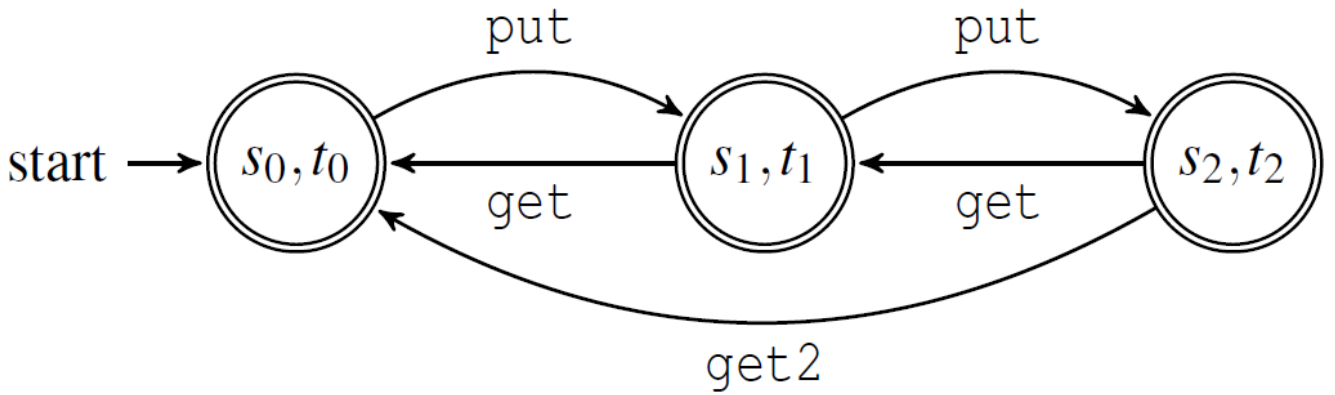
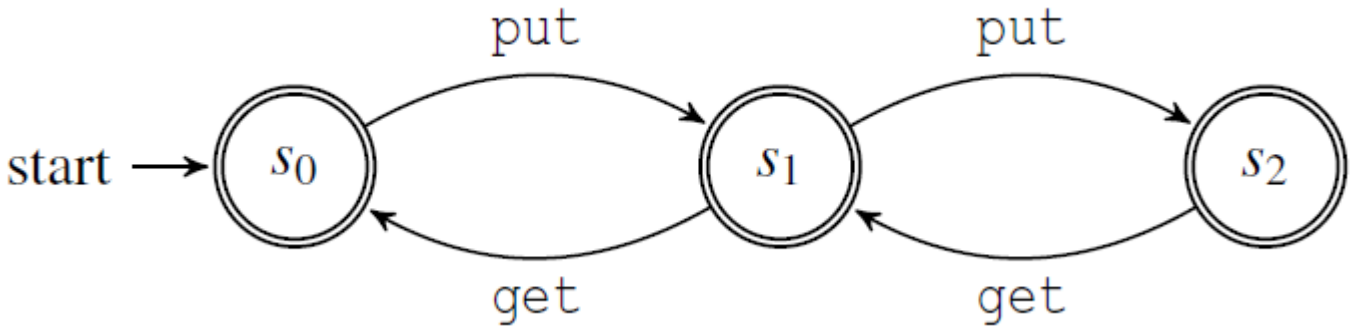


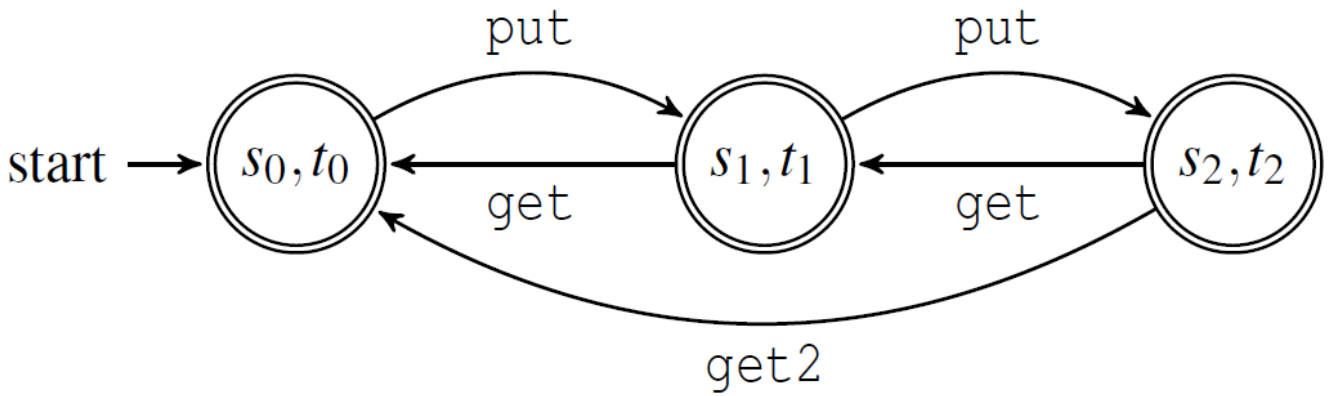
Anomaly Freedom

- A language is ***anomaly free*** iff any subtyping is implementable via ***incremental inheritance*** [CRR98]

- **Incremental inheritance:** Not redefining methods



SUPERTYPE

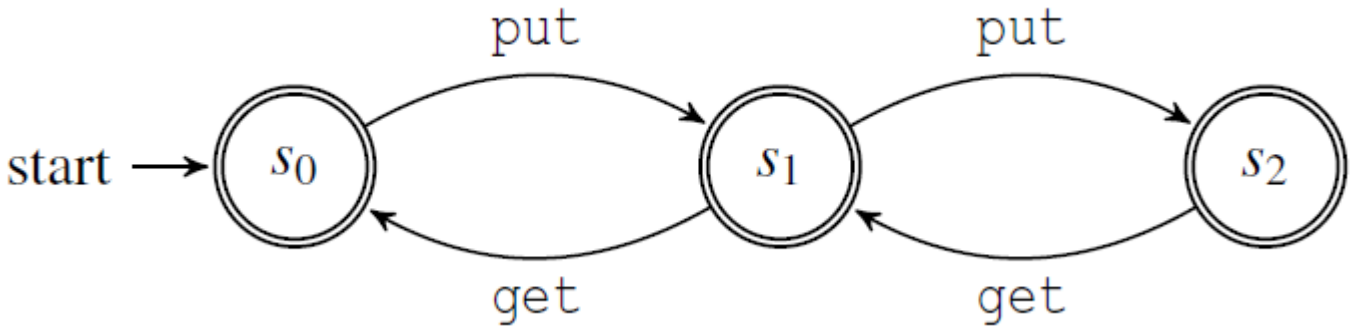


SUBTYPE

Problem of Anomaly Freedom (Theorem)

- In an anomaly free language, we need to model check to ensure ***behavior preservation*** (PSPACE hard)

- Behavior preservation [CRR98] ensures Liskov-Wing substitutability



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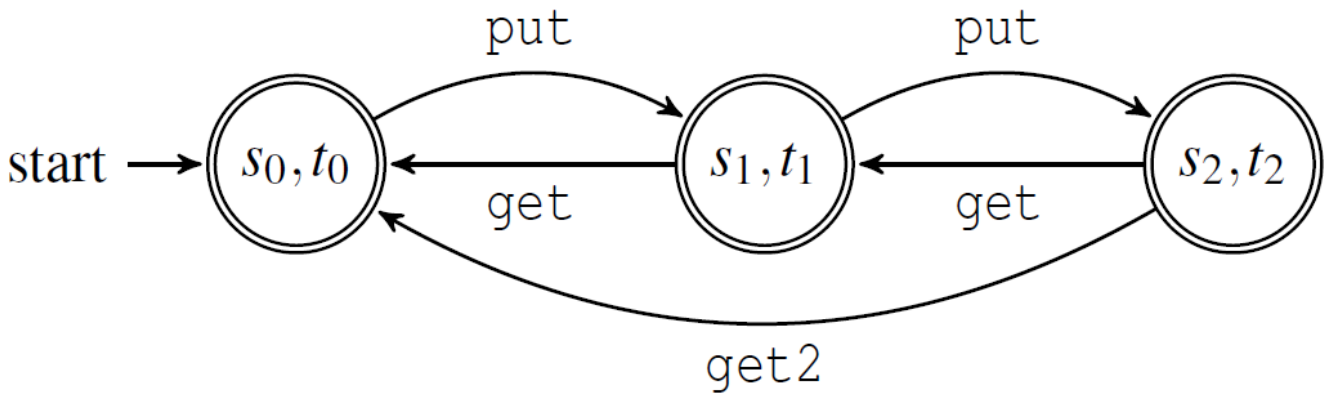

SUBTYPE

Inheritance Anomaly as Fragile Base Class Problem

- Tight coupling between subclass and superclass
- Fragile base class solved by programming practice: program to the interface [Gang of Four]
- As much as possible, we implement concurrency at the bottom of the inheritance hierarchy

Conclusion

- Should we still design the next anomaly-free language?
- Hard to ensure subclass objects substitute parent class objects
- For now, this is already tackled by avoiding implementation inheritance

References

- [MY93] S. Matsuoka and A. Yonezawa. Analysis of inheritance anomaly in object-oriented concurrent programming languages. In Research directions in concurrent object-oriented programming, pages 107–150. MIT Press, 1993.

- [CRR98] L. Crnogorac, A. S. Rao, and K. Ramamohanarao. Classifying inheritance mechanisms in concurrent object oriented programming. In 12th ECOOP, pages 571–600. Springer, 1998.

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