First-Class State Change in

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School of Computer Science

States and State Change

- Things all around us are changing state
  - Butterfly: Egg ➔ Caterpillar ➔ Chrysalis ➔ Imago

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  - You: Awake ➔➔ Asleep

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- In Programming, too
  - File: Open ➔ Closed

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  - Java Exception: Cause Not Set ➔ Cause Set

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- Different abilities depending on the state
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  - Java Exception: Cause Not Set → Cause Set
- Different abilities depending on the state
  - Butterfly can only fly as an Imago
  - read() only available in the Open state of File
- Error when the current state does not support the action

Describing Objects with State

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- An **Object Protocol** [Strom, Yemini '86] dictates an **order** on **method calls**:
  - Has a **finite number** of **abstract states** in which different method calls are valid;
  - Specifies **transitions** between abstract states that occur as a part of some method calls.

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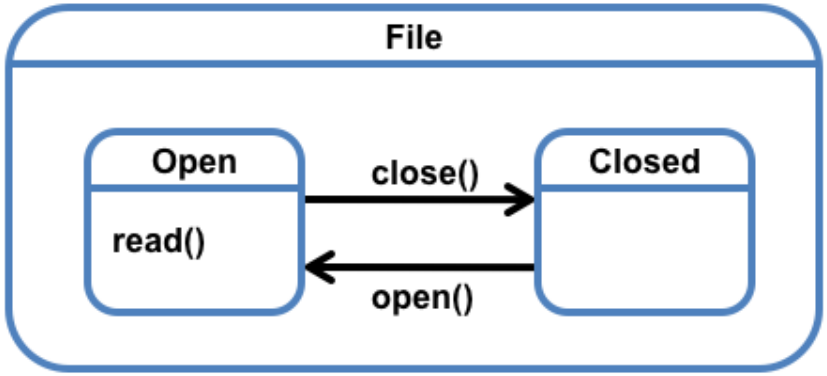
  - Specifies **transitions** between abstract states that occur as a part of some method calls.
- State Charts [Harel '87]: File
  - States: File, Open, Closed
  - Methods: read(), open(), closed()
  - Transitions: close(), open()



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Existing Support for States

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- States exists
  - In documentation

```
/** @throws IllegalStateException if task was already scheduled or
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private void sched(TimerTask task, long time, long period) { … }
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```
if (task.state != TimerTask.VIRGIN) throw new IllegalStateException(…);
```

- Problems
  - States from design are obfuscated
    - Code difficult to understand
  - If checks forgotten, results difficult to debug, e.g.
    - Non-specific **NullPointerException**
    - Data corruption (overwritten **TimerTask**)

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Common and Complex

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  - 7% of Java classes define object protocols
    - 3x as many as define generics
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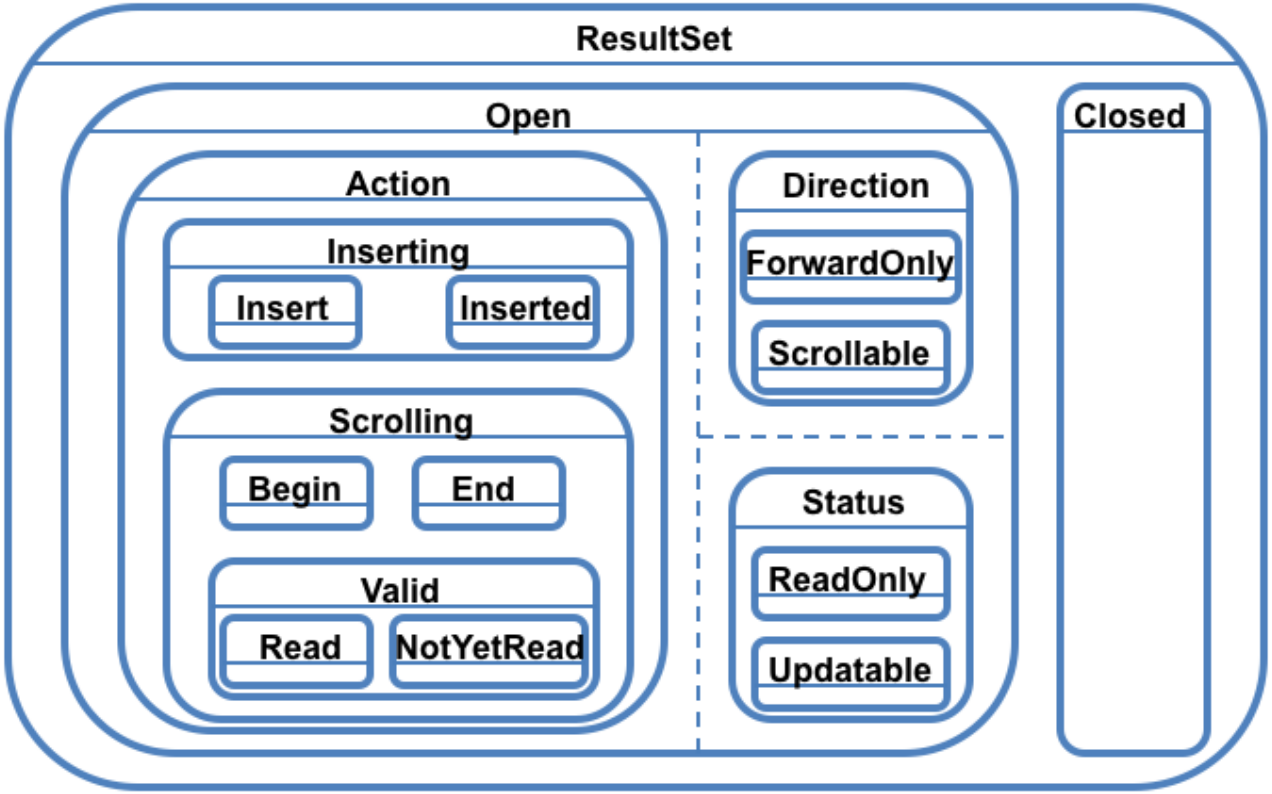

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Overview

- PLAID programming language
  - First class states and transitions

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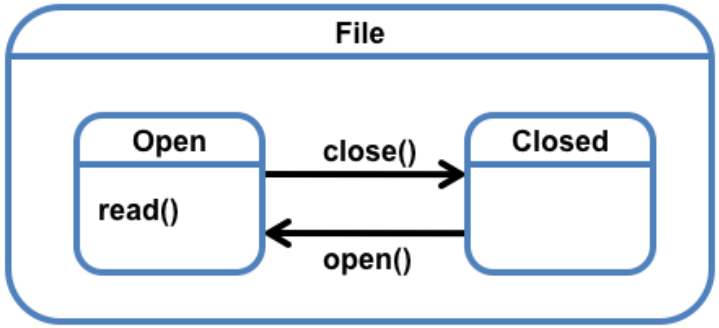
  - First class states and transitions
- Overview
  - Syntax and semantics of states and transitions
  - Trait-based reuse

Two Encodings of File



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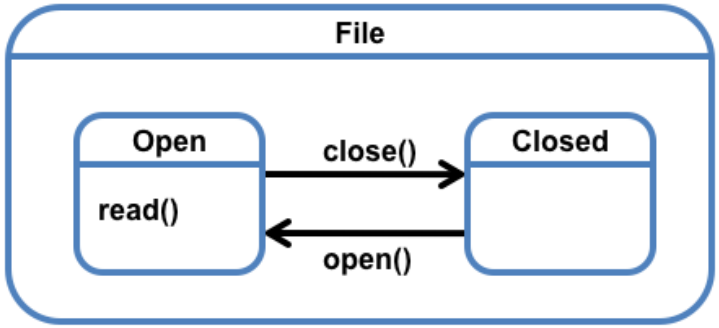
Two Encodings of File



1) States

```
class File {

  private FileResource filePtr = null;




}
```

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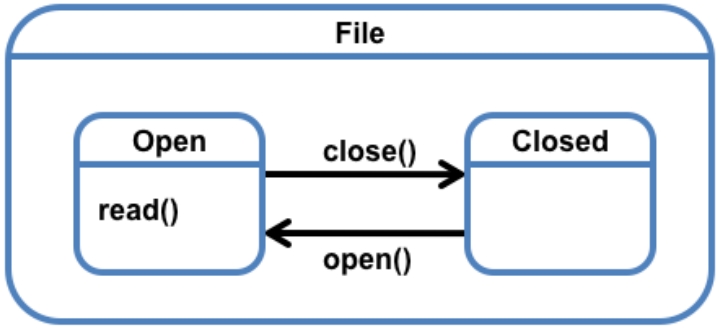


1) States

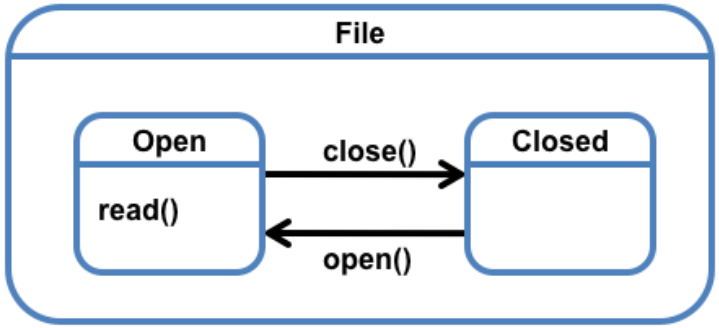
```
class File {

  private FileResource filePtr = null;

}
```

substate of file determined by **null**-ness of filePtr field

Two Encodings of File




```
class File {

  private FileResource filePtr = null;









}
```

1) States

```
state File {

}
```

```
state Open case of File {




}
```

```
state Closed case of File {




}
```

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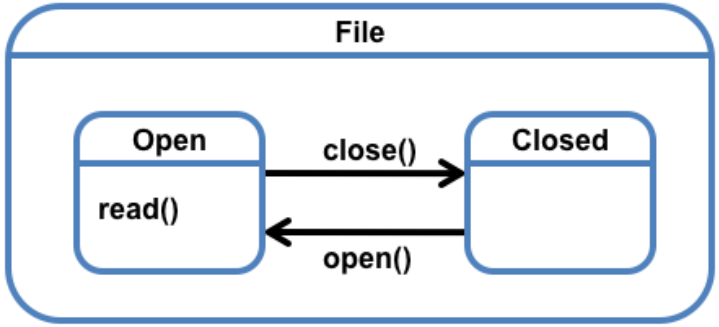


```
class File {

  private FileResource filePtr = null;
  pubic int read() {…}




  public void close() {…}
  public void open() {…}

}
```

2) Methods

```
state File {

}
```

```
state Open case of File {




}
```

```
state Closed case of File {




}
```

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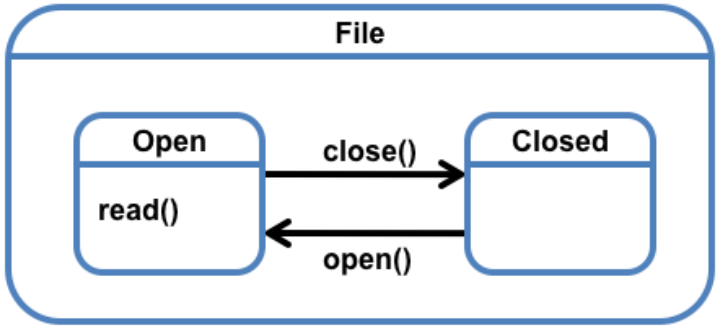


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2) Methods

```
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state Open case of File {

  method read() {…}
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```
state Closed case of File {
  method open() {…}


}
```

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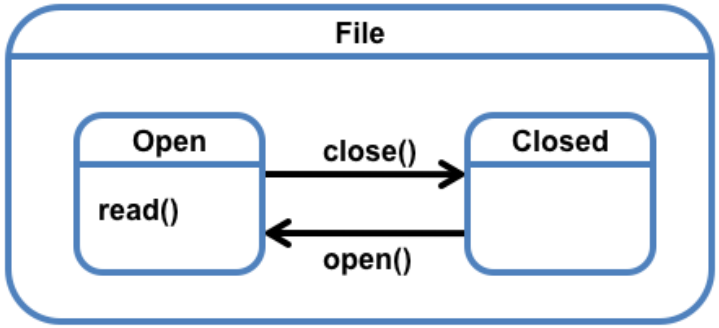


```
class File {

  private FileResource filePtr = null;
  pubic int read() {
    if (filePtr == null)
       throw new IOException
    else …
  }
  public void close() {…}
  public void open()
    { if (filePtr == null) {…} }
}
```

2) Methods

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state File {

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```
state Open case of File {

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state Closed case of File {
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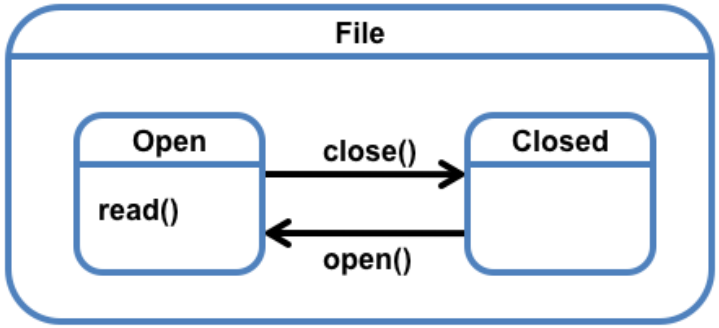


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class File {
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  }
  public void close() {…}
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}
```

3) Representation

```
state File {
  val filename;
}
```

```
state Open case of File {
  val filePtr;
  method read() {…}
  method close() {…}
}
```

```
state Closed case of File {
  method open() {…}


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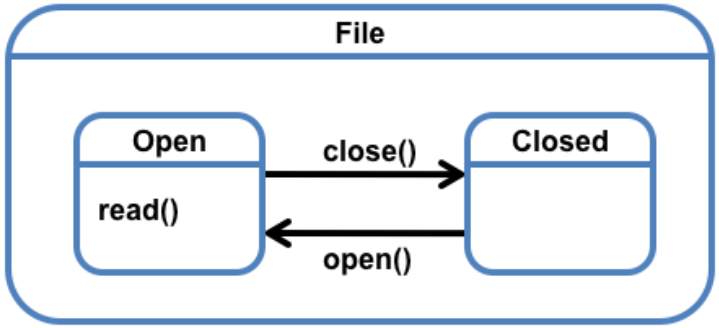


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  public void open()
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}
```

4) Transitions

```
state File {
  val filename;
}
```

```
state Open case of File {
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  method read() {…}
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state Closed case of File {
  method open() {…}


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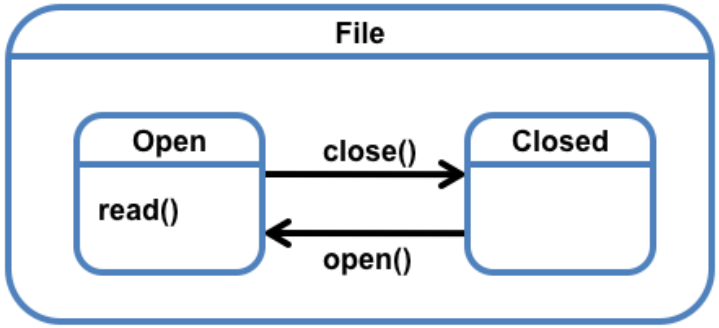


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}
```

4) Transitions

```
state File {
  val filename;
}
```

```
state Open case of File {
  val filePtr;
  method read() {…}
  method close() {…; this ← Closed;}
}
```

```
state Closed case of File {
  method open() {
     this ← Open { val filePtr = … };
  }
}
```

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Comparison

- PLAID encoding advantages:
  - Design salient in the code
  - Succinct: fewer explicit checks
  - Errors handled safely and informatively

Reuse and Composition

- **Goal**: flexibility of Traits [Ducasse '06] with benefits of protocols
  - Break protocols up into elemental protocols
  - Compose them

Reuse and Composition

- ReadStream = Position + Reader

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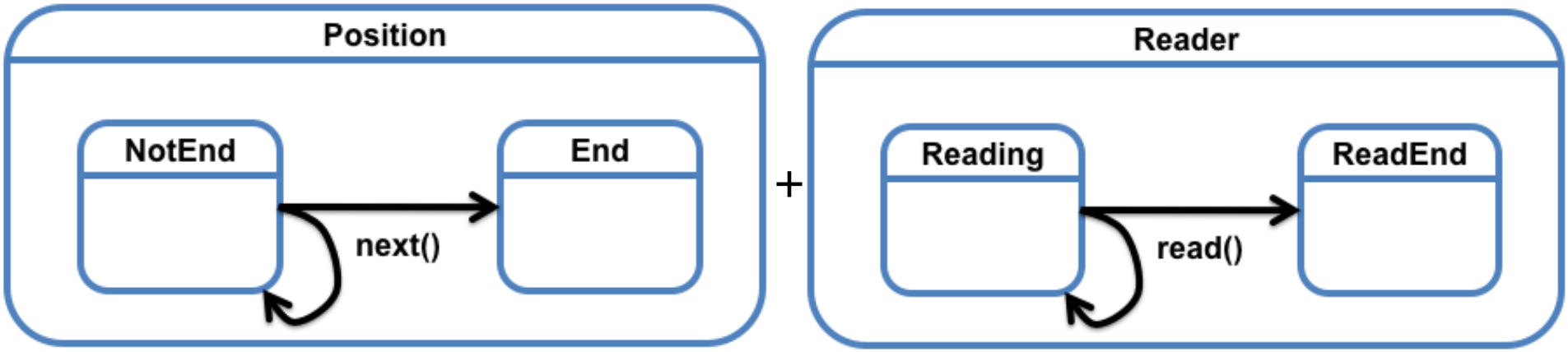
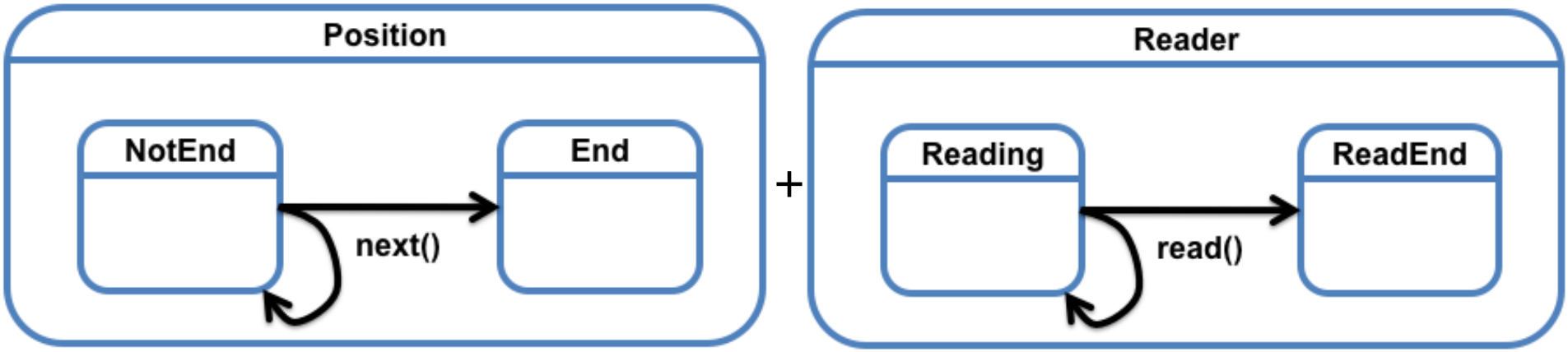


Reuse and Composition

- ReadStream = Position + Reader



Protocols in two separate **dimensions**

Reuse and Composition

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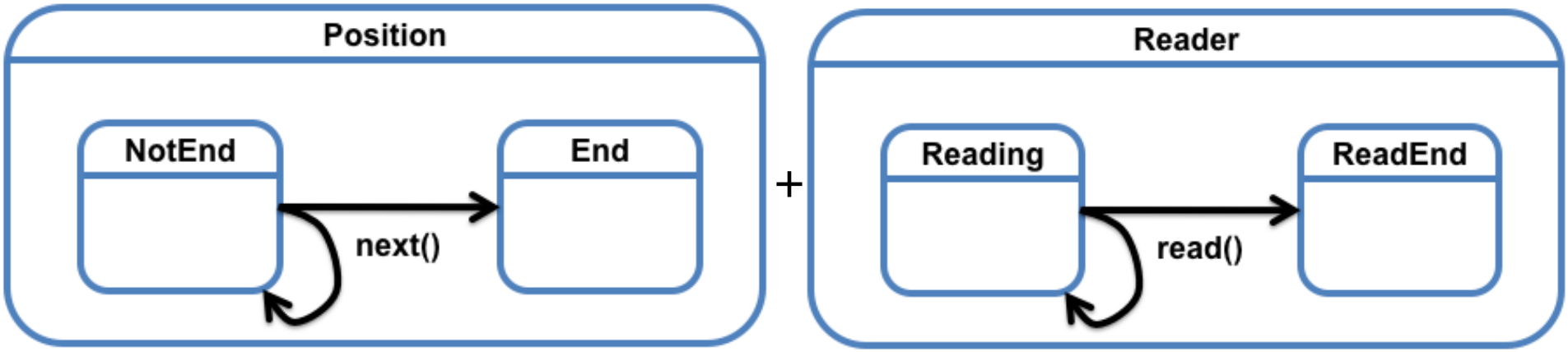


```
state Reading {
    method read() {
        /* read character */
        this.next();
    }
}
```

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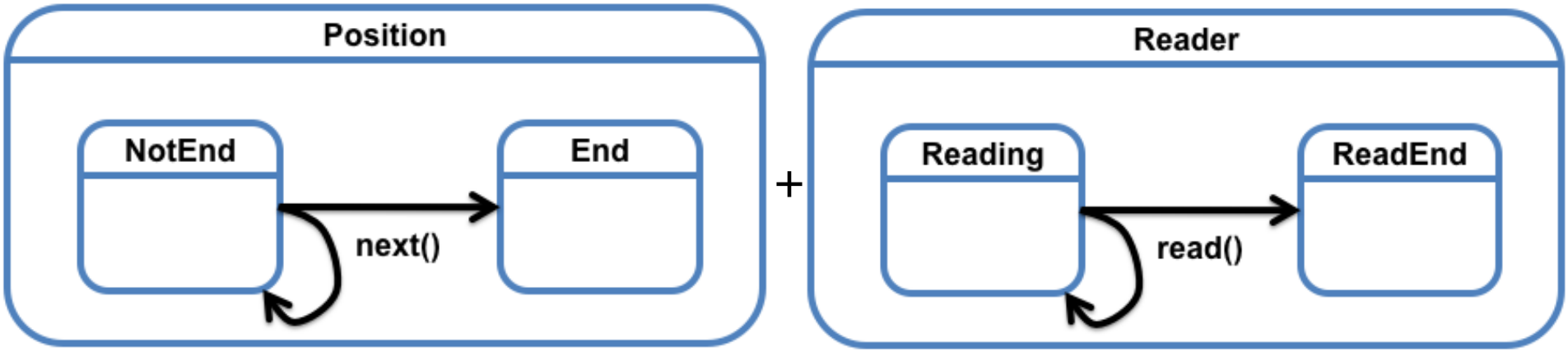


```
state NotEnd case of Position {
    method next() {
        /* move position forward */
        if (/* at the end */)
            { this ← End }
    }
}
```

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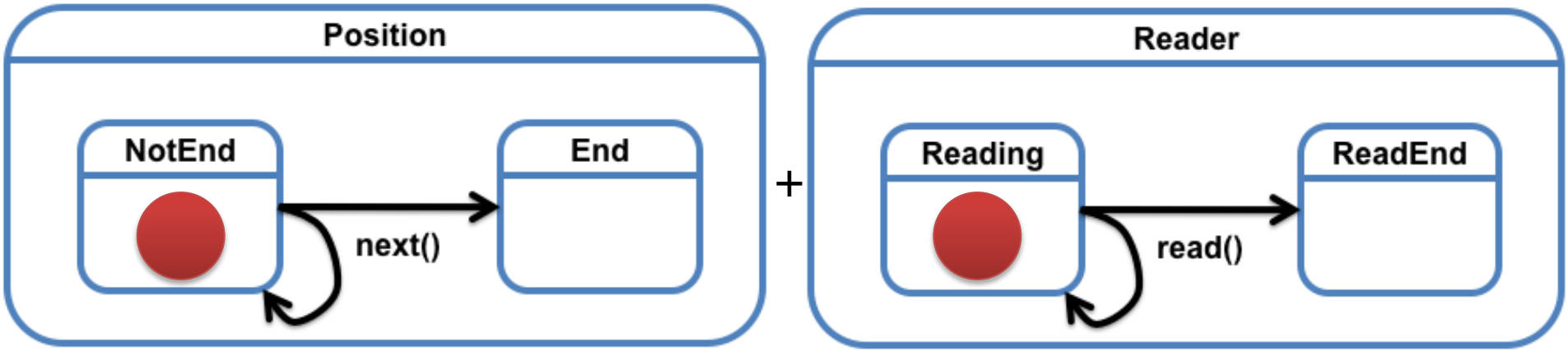


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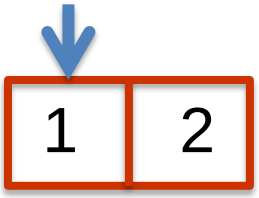

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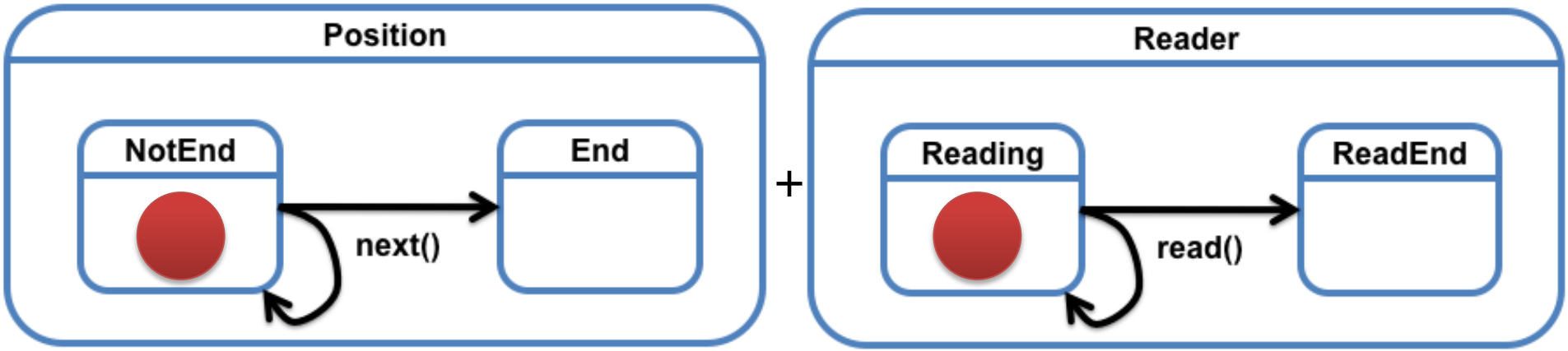


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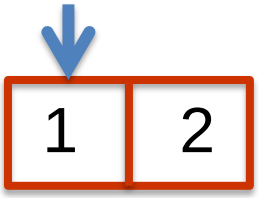

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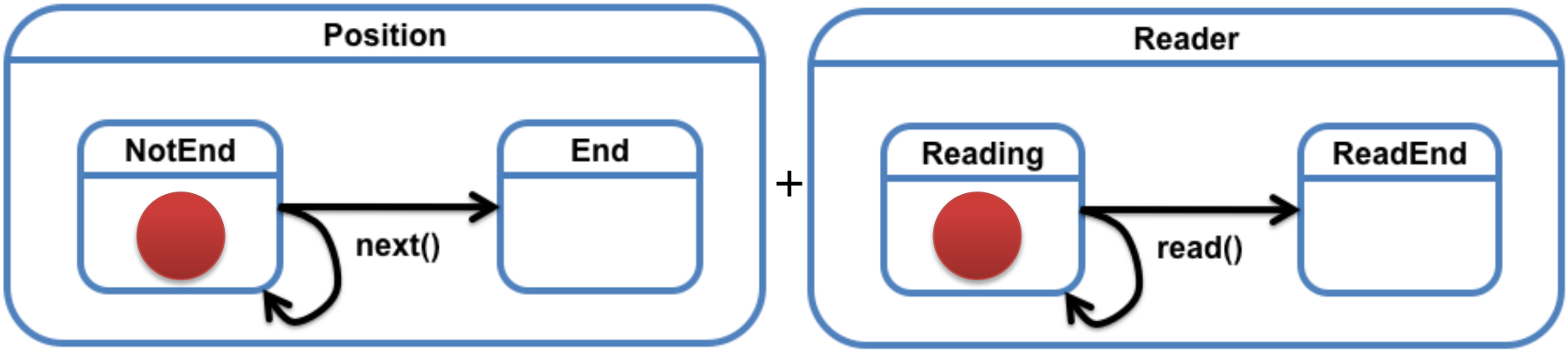


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rs.read(); //no state change
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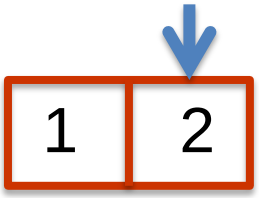

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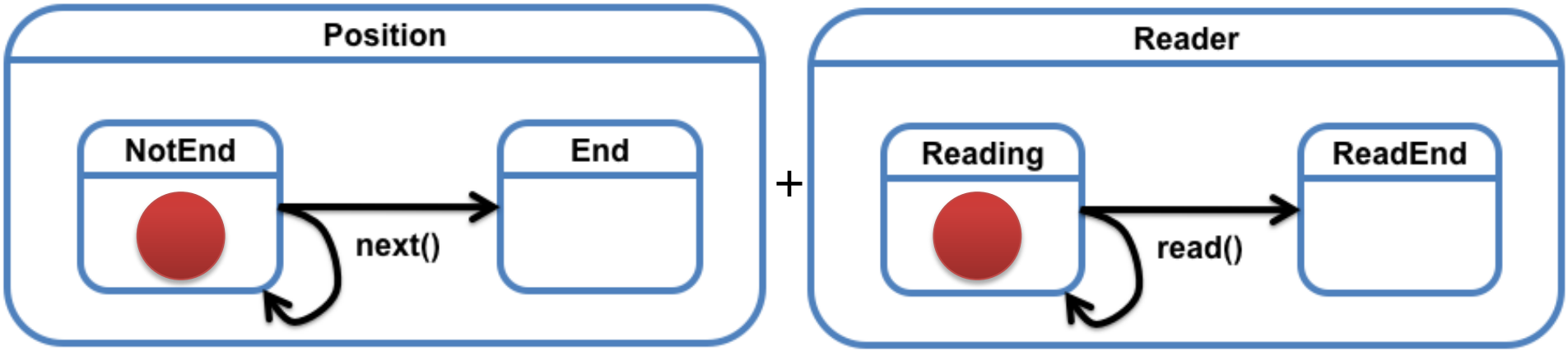


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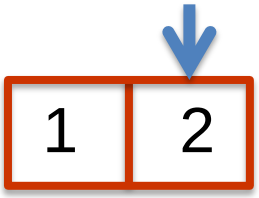

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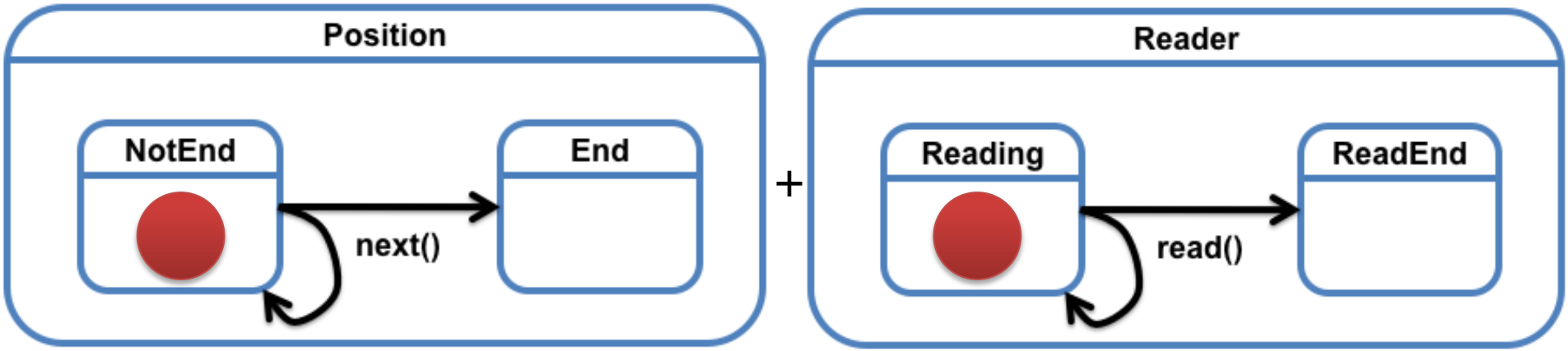
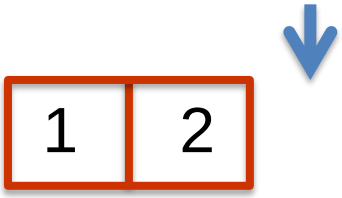



```
val rs = new Reading with
          NotEnd { val coll = [1,2]; … };
rs.read(); //no state change
rs.read(); // this ← End
```



No change in the Reader dimension!

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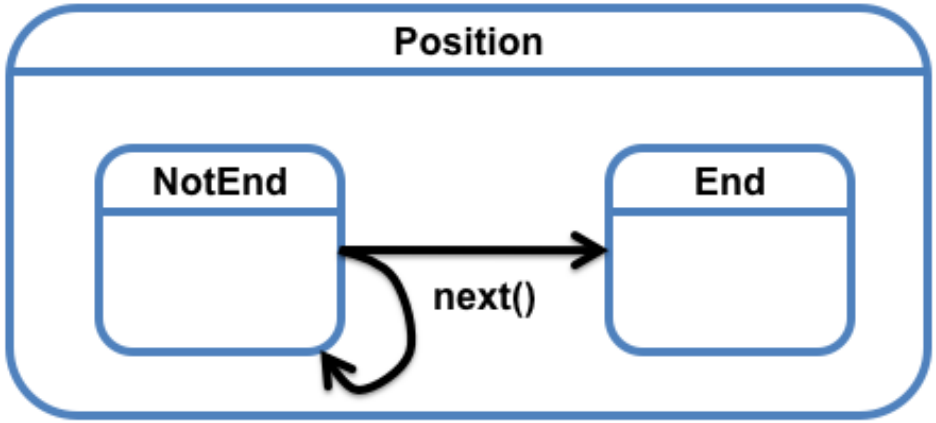
State Members



Solution:
State Members allow the incoming state to be determined dynamically

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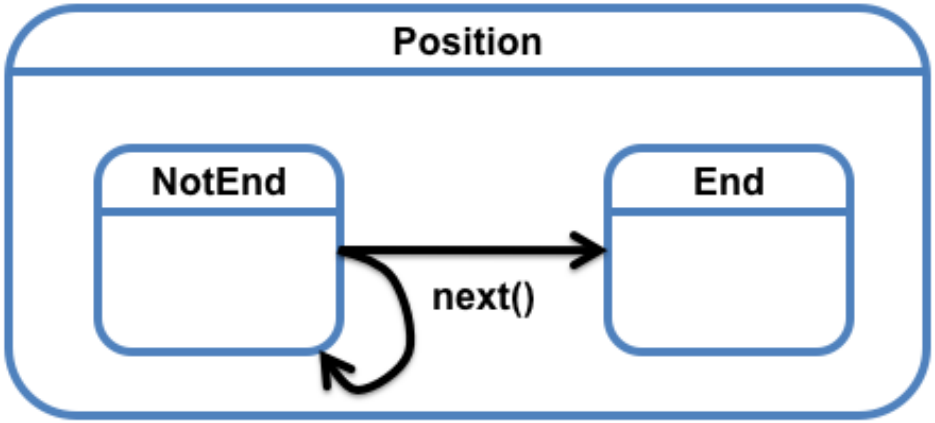
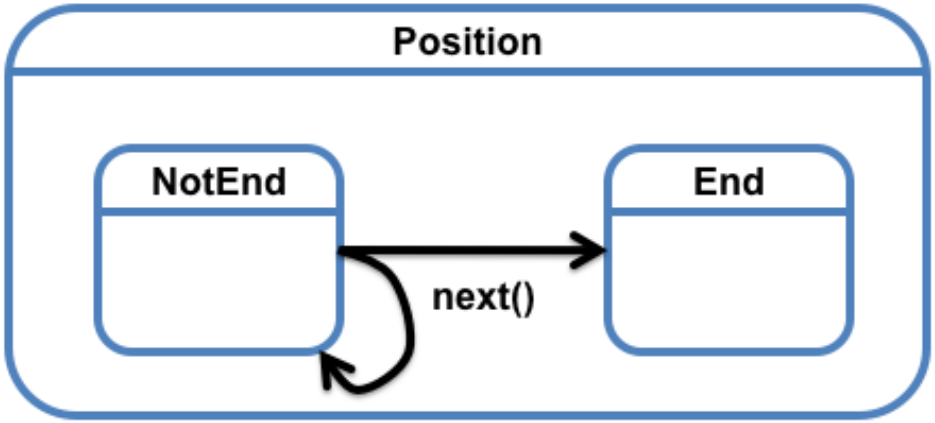
State Members




```
state Position {
   val endState = End;
   /* … */
}
```

Solution:
State Members allow the incoming state to be determined dynamically

State Members



Solution:
State Members allow the incoming state to be determined dynamically

```
state Position {
   val endState = End;
   /* … */
}
```

```
state NotEnd case of Position {
   method next() {
      /* … */
      if (/* at the end */)
         { this ← this.endState }
   }
}
```

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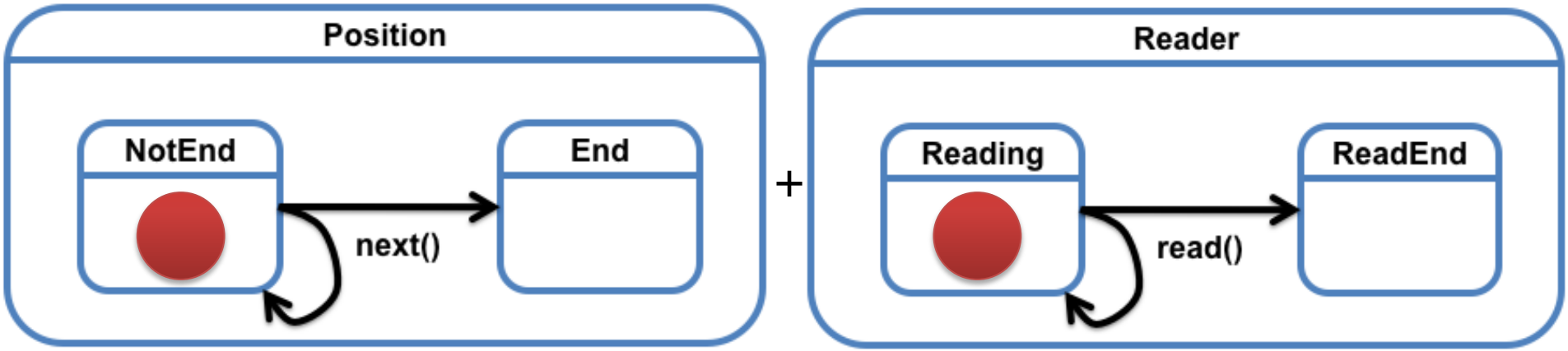
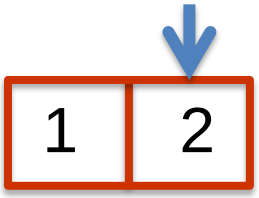
Reuse and Composition




```
val rs = new Reading with
  NotEnd { val coll = [1,2]; …;
    val endState = ReadEnd with End; };
rs.read(); //no state change
rs.read();
```



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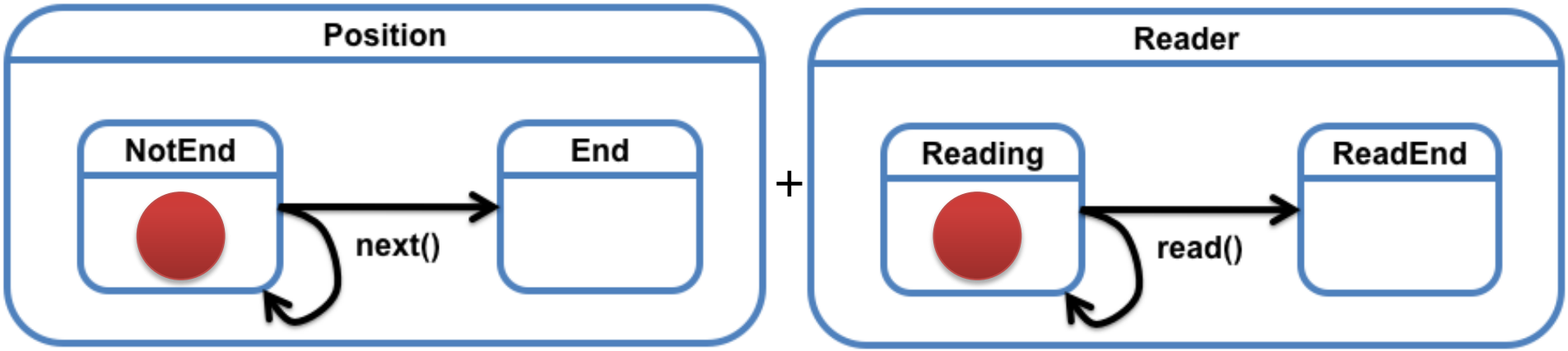


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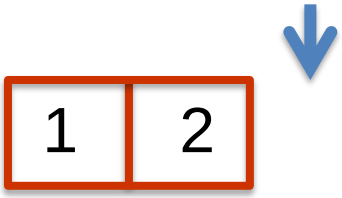

Both dimensions change together!

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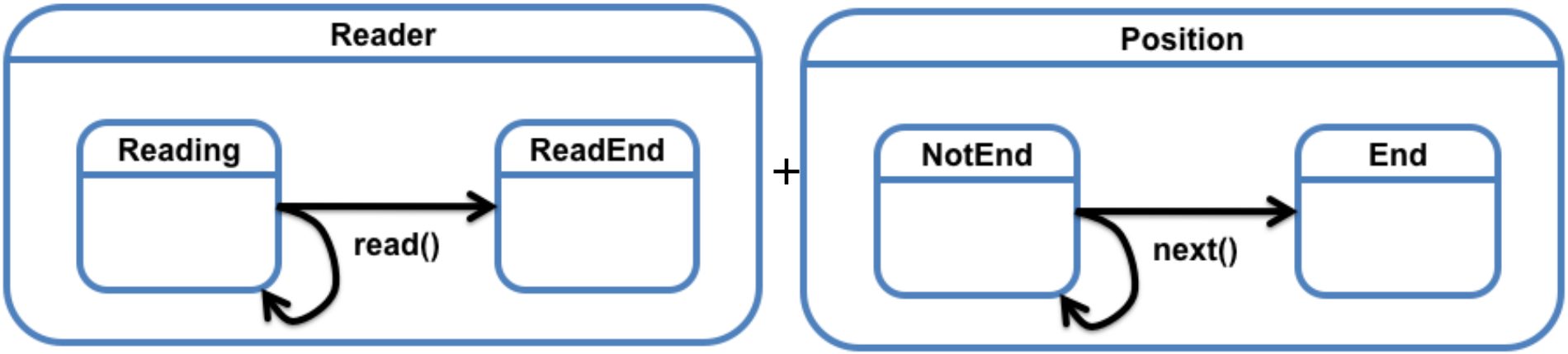
Reuse

- ReadStream = Reader + Position




```
state Reading {
   method read() {
      /* read character */
      this.next();
   }
}
```

```
state ReadStream = Position {
   val endState = ReadEnd with
                  End;
} with Reader
```

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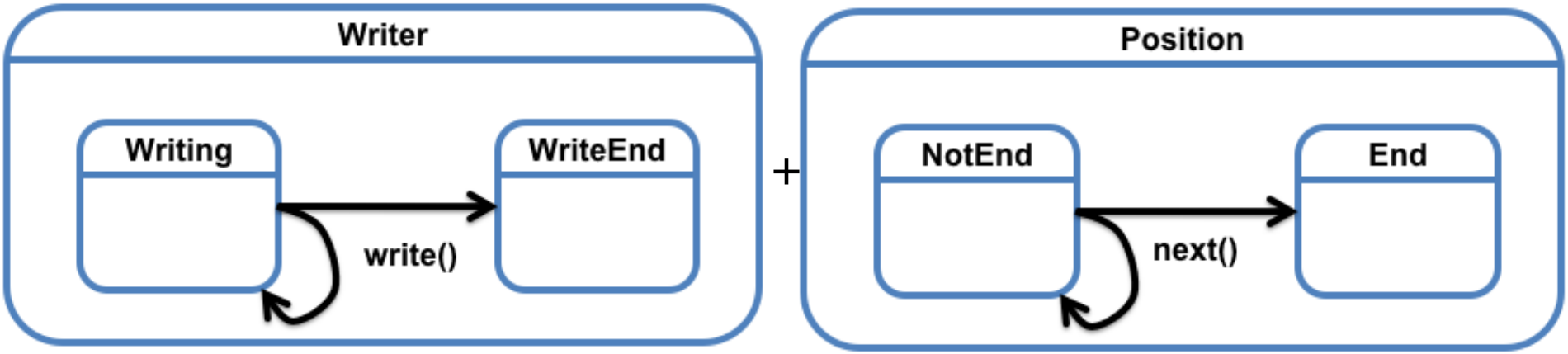
Reuse

- Reuse as a WriteStream = Writer + Position



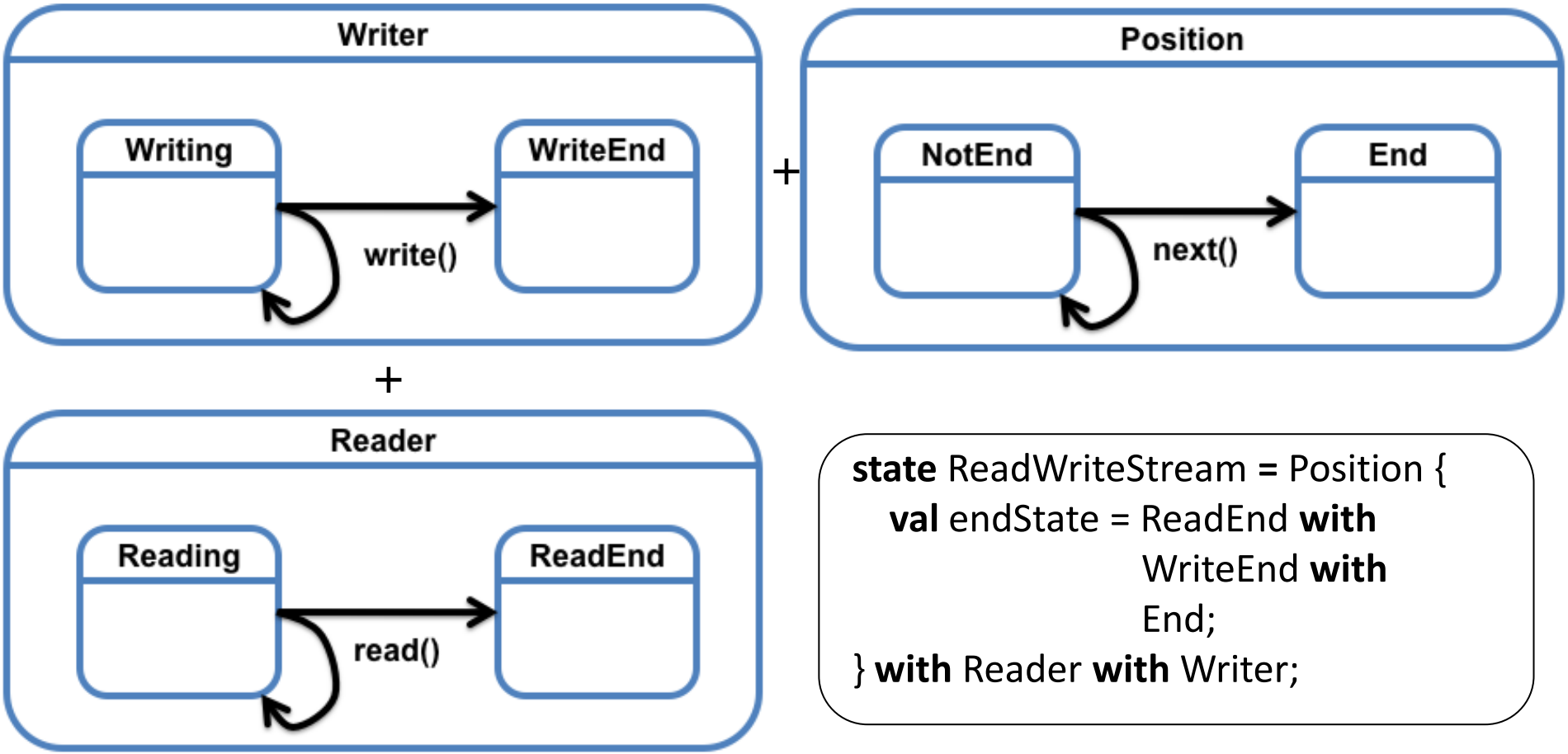

```
state Writing {
   method write() {
      /* write character */
      this.next();
   }
}
```

```
state WriteStream = Position {
   val endState = WriteEnd with
                  End;
} with Writer
```

PLAID

Reuse

- Or as a ReadWriteStream = Reader + Writer + Position




```
state ReadWriteStream = Position {
   val endState = ReadEnd with
                  WriteEnd with
                  End;
} with Reader with Writer;
```

PLAID

Conclusion

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Demo, 2pm Galleria III