Concurrency Abstractions in C#

Concurrency
• critical factor in behavior/performance
• affects semantics of all other constructs
• advantages of language vs. library
  • compiler analysis/optimization
  • clarity of syntax
• asynchronous communication
  • occurs at various levels
  • requires language support

Basic Constructs – Asynchronous Methods

Syntax:

```csharp
async postEvent (EventInfo data) {
    // method body using data
}
```

• calls to async methods return “immediately”
• method body scheduled for execution in another thread
• no return result
• similar to sending message/event
Basic Constructs - Chords

Example:

```csharp
public class Buffer {
    public string Get() & public async Put (string s) {
        return s;
    }
}
```

- illustrates a single chord with two methods
- chord body is executed only when all methods in the chord have been called
- non-async method call implicitly blocked/queued until chord complete
- async method calls are queued until matched (caller not blocked)
- at most one non-async method per chord
- non-deterministic selection of method calls matched by chord
- chord body executes in thread of non-async caller (unless all methods in chord are async methods, in which case a new thread is created)

Executing Chords

- Invocation queues (one per method)
- Methods: [a], [b], [c], ...
- Bitmaps (one per chord)
- execute [a,b] chord
- execute [b,c] chord
“Counting” via Methods

```java
class Token {
    public Token (int initial_tokens) {
        for (int i=0; i < initial_tokens; i++) Release();
    }
    public int Grab (int id) & public async Release() {
        return id;
    }
}
```

- allows clients to Grab and Release a limited number of tokens
- argument on Grab returned to client

Recording “State” via Methods

```java
public class OneCell {
    public OneCell () {empty();}
    public void Put(object o) & private async empty () {
        contains (o);
    }
    public object Get () & private async contains (object o) {
        empty();
        returns o;
    }
}
```

- methods empty and contains are declared private
- methods empty and contains “carries” the state of the cell
Reader-Write Example

```java
class ReaderWriter
{
    ReaderWriter () { idle(); } 

    public void Shared () & async idle () { s(1); } 
    public void Shared() & async s(int n) { s(n+1); } 
    public void ReleaseShared() & async s(int n) {
        if (n == 1) idle(); else s(n-1); }
    public void Exclusive() & async idle () {} 
    public void ReleaseExclusive() { idle(); }
}
```

Active Object (Actor): Base Class

```java
public abstract class ActiveObject {
    protected bool done;

    abstract protected void ProcessMessage();

    public ActiveObject () {
        done = false;
        mainLoop(); }

    async mainLoop () {
        while ( !done ) { ProcessMessage(); } }
}
```

- actor: thread per object; repeatedly processes received messages
- note: thread created by call to async mainLoop()
- abstract class creates basic actor infrastructure/pattern
Active Object (Actor): Event Example

```java
public class StockServer : ActiveObject {
    private ArrayList clients = new ArrayList();

    public async AddClient (Client c)
    & override protected void ProcessMessage() { clients.Add(c); }

    public async WireQuote (Quote q)
    & override protected void ProcessMessage() {
        foreach (Client c in clients) { c.UpdateQuote(q); }
    }

    public async CloseDown()
    & override protected void ProcessMessage() { done = true; }
}
```

• message reception/processing driven by `ProcessMessage` invocations in `mainLoop`

Implementation Outline

<table>
<thead>
<tr>
<th>chord</th>
<th>bitmap, one bit for each method in the chord</th>
</tr>
</thead>
<tbody>
<tr>
<td>async method with argument(s) of type m</td>
<td>mQ: to hold message (e.g., intQ)</td>
</tr>
<tr>
<td>async method with no arguments</td>
<td>voidQ: a counter</td>
</tr>
<tr>
<td>synchronous method</td>
<td>threadQ: for blocking caller threads</td>
</tr>
</tbody>
</table>
### Performance

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Test</th>
<th>operations/sec (thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>polyphonic</td>
</tr>
<tr>
<td>single processor</td>
<td>ping pong</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>bounded buffer</td>
<td>682</td>
</tr>
<tr>
<td></td>
<td>(1 prod/1 cons)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bounded buffer</td>
<td>423</td>
</tr>
<tr>
<td></td>
<td>(2 prod/2 cons)</td>
<td></td>
</tr>
<tr>
<td>dual processor</td>
<td>ping pong</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>bounded buffer</td>
<td>288</td>
</tr>
<tr>
<td></td>
<td>(1 prod/1 cons)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bounded buffer</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>(2 prod/2 cons)</td>
<td></td>
</tr>
</tbody>
</table>

### Syntactic Extension

```java
public class ReaderWriter {
    async idle();
    async s(int);

    ReaderWriter() { idle(); }

    public void Shared()
        when idle() { s(1); }
        when s(int n) { s(n+1); }

    public void ReleaseShared()
        when s(int n) { if (n == 1) idle(); else s(n-1); }

    public void Exclusive()
        when idle() {}

    public void ReleaseExclusive() { idle(); }
}
```