D The functional programming language nobody is talking about

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D is a functional programming language

What makes D a functional programming language

C the functional programming language

- D is a $\approx$ superset of C
- C is a functional programming language

Proof by example

High order functions

```
1  int apply(int(*fun)(int), int value) {
2    return (*fun)(value);
3  }
4
5  int addOne(int a) {
6    return a + 1;
7  }
8
9  int main() {
10   return apply(&addOne, 1);
11 }
```

High order functions

```
1  int addOne(int a) {
2    return a + 1;
3  }
4
5  int addTwo(int a) {
6    return a + 2;
7  }
8
9  int (*apply(int value))(int) {
10   return value == 1
11     ? &addOne
12     : &addTwo;
13 }
14
```

High order functions

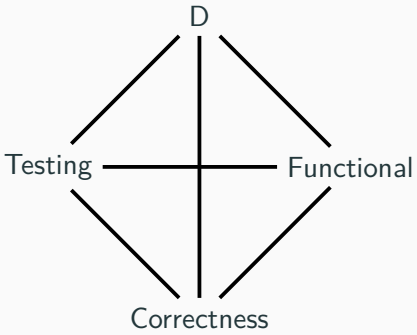
```
1  int apply(int function(int) pure fun
2      , int value) pure
3  {
4    return fun(value);
5  }
6
7  int addOne(int a) pure {
8    return a + 1;
9  }
10
11 int main() {
12   return apply(&addOne, 1);
13 }
```

High order functions

```
1  int addOne(int a) pure {
2    return a + 1;
3  }
4
5  int addTwo(int a) pure {
6    return a + 2;
7  }
8
9  int function(int) pure apply(int value) pure {
10   return value == 1
11     ? &addOne
12     : &addTwo;
13 }
14
```

Why should you care

Why should you care about D



Why should you care

```
1  void main() {
2    File("rng2.d", "r")
3      .byLineCopy
4      .map!(l => l.splitter(" "))
5      .joiner
6      .map!(w => w.strip())
7      .filter!(w => !w.empty)
8      .array
9      .sort
10     .uniq
11     .count
12     .writeln;
13 }
```

Ranges Ranges Ranges

Ranges Ranges Ranges

A thing `foreach` can iterate

Ranges

```
1  struct Range {
2    int from;
3    int to;
4
5    @property int front() {
6      return this.from;
7    }
8
9    @property bool empty() const {
10     return this.from >= this.to;
11   }
12
13   void popFront() {
14     ++this.from;
15   }
16 }
```

Ranges

```
1 unittest {
2   foreach(it; Range(0, 10)) {
3     writeln(it); // 0, 1, 2, 3, ... , 9
4   }
5 }
```

Ranges

```d
unittest {
  foreach(it; Range(0, 10)) {
    writeln(it); // 0, 1, 2, 3, ... , 9
  }
}
```

```d
unittest {
  for(auto __r = Range(0, 10); !__r.empty; __r.popFront()) {
    auto it = __r.front;

    writeln(it);
  }
}
```

Range types

- Input Range

Range types

- Input Range
- Forwared Range
  - `save()`
- Bidirectional Range
  - `back`
  - `popBack`
- Random Access Range
  - `[]`
- Infinite Range
  - `enum empty = false;`

Ranges types, practically

```
1    import std.array : array;
2
3    int[] a = Range(0, 10).array;
```

Ranges

```
1  struct Map(alias fun) {
2    Range range;
3
4    @property int front() {
5      return fun(this.range.front);
6    }
7
8    @property bool empty() const {
9      return this.range.empty;
10   }
11
12   void popFront() {
13     this.range.popFront();
14   }
15 }
```

Ranges

```
1 Map!fun map(alias fun)(Range r) {
2   return Map!fun(r);
3 }
4
5 unittest {
6   auto tt = Range(0, 10).map!(it => it * 2);
7   assert(tt.equal([0, 2, 4, 6, 8, 10, 12, 14, 16, 18]));
8 }
```

Ranges

```
1  struct Map2(alias fun, R) {
2    R range;
3
4    @property int front() {
5      return fun(this.range.front);
6    }
7
8    @property bool empty() const {
9      return this.range.empty;
10   }
11
12   void popFront() {
13     this.range.popFront();
14   }
15 }
```

Ranges

```
1  Map2!(fun,R) map2(alias fun, R)(R r) {
2    return Map2!(fun,R)(r);
3  }
4
5  unittest {
6    import std.range : iota;
7
8    auto tt = iota(0, 10).map2!(it => it * 2);
9    assert(tt.equal([0, 2, 4, 6, 8, 10, 12, 14, 16, 18]));
10 }
```

Uniform functional call syntax (UFCS)

```
1  int theSame(int a) {
2    return a;
3  }
4
5  int fun2(int a) {
6    return a;
7  }
8
9  unittest {
10   fun2(theSame(10));
11   10.theSame().fun2();
12 }
```

Ranges

```
1  void main() {
2    File("rng2.d", "r")
3      .byLineCopy
4      .map!(l => l.splitter(" "))
5      .joiner
6      .map!(w => w.strip())
7      .filter!(w => !w.empty)
8      .array
9      .sort
10     .uniq
11     .count
12     .writeln;
13 }
```

Testing

Testing

Not tests = wrong

Testing in D

- D has in-build unittesting
- `unittest { }`
- D has in-build test coverage analysis
- 100% is a terrible metric, but still the best we have

Coverage analysis

```
1  int fun(bool b) {
2    return b ? 1 : 0;
3  }
4
5  unittest {
6    assert(fun(true) == 1);
7    assert(fun(false) == 0);
8  }
```

dmd -main -cov -unittest -run cov.d

Coverage analysis

```
1   |int fun(bool b) {
2  4|  return b ? 1 : 0;
3   |}
4   |
5   |unittest {
6  1|  assert(fun(true) == 1);
7  1|  assert(fun(false) == 0);
8   |}
```

Coverage analysis

```
1  int fun2(bool b) {
2    return b
3      ? 1
4      : 0;
5  }
6
7  unittest {
8    assert(fun2(true) == 1);
9    assert(fun2(false) == 0);
10 }
```

Coverage analysis

```
1   |int fun2(bool b) {
2  2|   return b
3  1|     ? 1
4  1|     : 0;
5   |}
6   |
7   |unittest {
8  1|   assert(fun2(true) == 1);
9  1|   assert(fun2(false) == 0);
10  |}
```

Coverage analysis

```
1 bool complexCondition(int a, int b) {
2   return a == 10 && b == 20 || a > 20 || b < 5 ? true : false;
3 }
4
5 unittest {
6   assert(complexCondition(1,2));
7 }
```

Coverage analysis

```
1   |bool complexCondition(int a, int b) {
2  4|   return a == 10 && b == 20 || a > 20 || b < 5 ? true : false
       ;
3   |}
4   |
5   |unittest {
6  1|   assert(complexCondition(1,2));
7   |}
```

Coverage analysis

```
 1  |bool complexCondition2(int a, int b) {
 2 3|  return a == 10
 3 1|       && b == 20
 4 2|       || a > 20
 5 2|       || b < 5
 6 2|    ? true
 7 1|    : false;
 8  |}
 9  |
10  |unittest {
11 1|  assert( complexCondition2(1,2));
12 1|  assert( complexCondition2(10,20));
13 1|  assert(!complexCondition2(1,50));
14  |}
```

Exceptions

Elephant in the Room

Elephant in the Room

```
1  struct Exp {
2    @property int front() {
3      throw new Exception("");
4    }
5
6    @property bool empty() {
7      return false;
8    }
9
10   void popFront() { }
11 }
12
13 unittest {
14   Exp e;
15   assertThrown(e.map!(i => 2).array);
16 }
```

handle Exceptions

```
1    Exp e;
2    int[] r = e
3      .handle!(Exception, RangePrimitive.front, (e, r) => 0)
4      .take(2)
5      .map!(i => i * 2)
6      .array;
```

try catch

```
1   string s = "12,1337z32,54,2,7,9,1z,6,8";
2
3   int[] i = s.splitter(",")
4     .map!(n => {
5       try {
6         return to!int(n).nullable();
7       } catch(Exception e) {
8         return Nullable!(int).init;
9       }
10    }())
11    .filter!(n => !n.isNull)
12    .map!(n => n.get())
13    .array;
```

try catch nullable

```
1   Nullable!int parse(string s) nothrow {
2     try {
3       return to!int(s).nullable();
4     } catch(Exception e) {
5       return Nullable!(int).init;
6     }
7   }
8
9   string s = "12,1337z32,54,2,7,9,1z,6,8";
10
11  int[] i = s.splitter(",")
12    .map!(n => parse(n))
13    .filter!(n => !n.isNull)
14    .map!(n => n.get())
15    .array;
```

State

State

- Most programs are not just input, map, output
- Most programs have some sort of state

State: The model

```
1  struct Group {
2    long id;
3    string name;
4    long[] members;
5  }
6
7  struct State {
8    Group[] groups;
9  }
```

State: `createGroup`

```
State createGroup(State old
    , string name)
{
  Group ng = Group
    ( old.groups.empty
      ? 1
      : old.groups
        .map!(g => g.id)
      .maxElement
    , name
    , []
    );
  old.groups ~= ng;
  return old;
}
```

State: `findGroup`

```
1  Nullable!(const(long)) findGroup(
2      ref const(State) old
3      , string name)
4  {
5    auto f = old.groups
6      .find!(g => g.name == name);
7
8    return f.empty
9      ? typeof(return).init
10     : nullable(f.front.id);
11 }
```

State: addMember

```
State addMember(State old
    , long groupId
    , long memId)
{
  auto g = old.groups
    .countUntil!(g => g.id == groupId);

  enforce(g != -1, "Group not found");
  old.groups[g].members ~= memId;
  old.groups[g].members = old.groups[g]
    .members.sort.uniq.array;
  return old;
}
```

State: Usage

```
1 unittest {
2   State s;
3   s = s.createGroup("D_Users");
4
5   Nullable!(const(long)) gId = s
6     .findGroup("D_Users");
7
8   s = s.addMember(gId.get(), 1);
9 }
```

State Two: `createGroup`

```
State createGroup(ref const State old
    , string name)
{
  Group ng = Group
    ( old.groups.empty
      ? 1
      : old.groups
        .map!(g => g.id)
      .maxElement
    , name
    , []
    );

  State neu = old.deepCopy();
  neu.groups ~= ng;
  return neu;
```

State Two: `addMember`

```
State addMember(ref const State old
    , long groupId, long memId)
{
  auto g = old.groups
    .countUntil!(g => g.id == groupId);
  enforce(g != -1, "Group not found");

  State neu = old.deepCopy();
  neu.groups[g].members ~= memId;
  neu.groups[g].members = neu.groups[g]
    .members.sort.uniq.array;
  return neu;
}
```

State Two: `deepCopy` 1/2

```
1  auto deepCopy(T)(ref const(T) old) {
2    alias UQ = Unqual!T;
3    static if(isBasicType!UQ) {
4      return cast()old;
5    } else static if(isArray!UQ) {
6      alias ET = Unqual!(ElementEncodingType!T);
7      ET[] ret;
8      foreach(ref it; old) {
9        ret ~= deepCopy!(ET)(it);
10     }
11     return ret;
```

State Two: `deepCopy` 2/2

```
1     } else static if(is(T == struct)) {
2       Unqual!T ret;
3       foreach(mem; FieldNameTuple!T) {
4         __traits(getMember, ret, mem) =
5           deepCopy(__traits(getMember, old, mem));
6       }
7       return ret;
8     } else {
9       static assert(false, T.stringof);
10    }
11  }
```

Commercial break

Symmetry Investments

Conclusion

Takeaways

- `if` statements considered harmful
- learn phobos/std by heart
- when you think exception `goto` Nullable
- no tests = bugs

The End

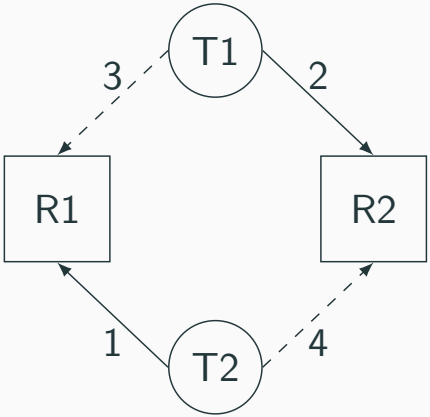
Encore

Dead lock free multi Mutex Systems

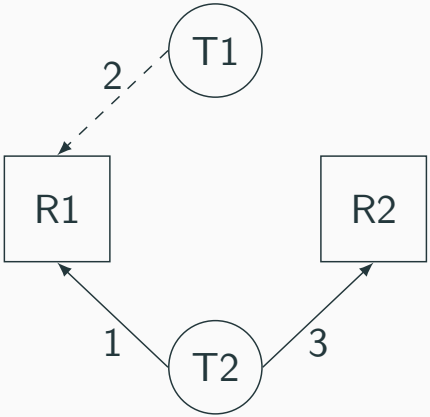
Deadlock Recipe:

- Mutual exclusion
- Hold and wait
- No preemption
- Circular wait

Anti Dead lock: Un-sorted



Anti Dead lock: Sorted



Anti Dead lock

```
1  struct State {
2    Data[] data;
3    Mutex[long] mutexes;
4
5    void action(ActionData ad
6        , long[] mutexIds)
7    {
```

Anti Dead lock

```
1  struct State {
2    Data[] data;
3    Mutex[long] mutexes;
4
5    void action(ActionData ad
6        , long[] mutexIds)
7    {
8      mutexIds
9        .sort
10       .each!(it => this.mutexes[id].lock());
11
12     //
13     // perform action
14     //
```

Out of Slides