The Tasks with Effects Model for Safe Concurrency

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- Parallel Computing
- Compilers
- Computer Security
- Operating Systems
- Programming Languages

Tasks with Effects (TWE)

- Objects are associated with regions
- Effects are write or read operations on regions
- Running tasks have exclusive access to regions

Deterministic Parallel Java

```
class Image {
    region Top, Bottom;
    int[] topHalf in Top;
    int[] bottomHalf in Bottom;
    void increaseContrastTop() writes Top { // write topHalf }
    void increaseContrastBottom() writes Bottom { // write bottomHalf }
    void increaseContrast() writes Top, Bottom {
        cobegin {
            this.increaseContrastTop();
            this.increaseContrastBottom();
        }
    }
}
```

- Data race freedom
- Atomicity
- Deadlock freedom
- Determinism

Lack of flexibility :-(

Tasks With Effects Java (simplified)

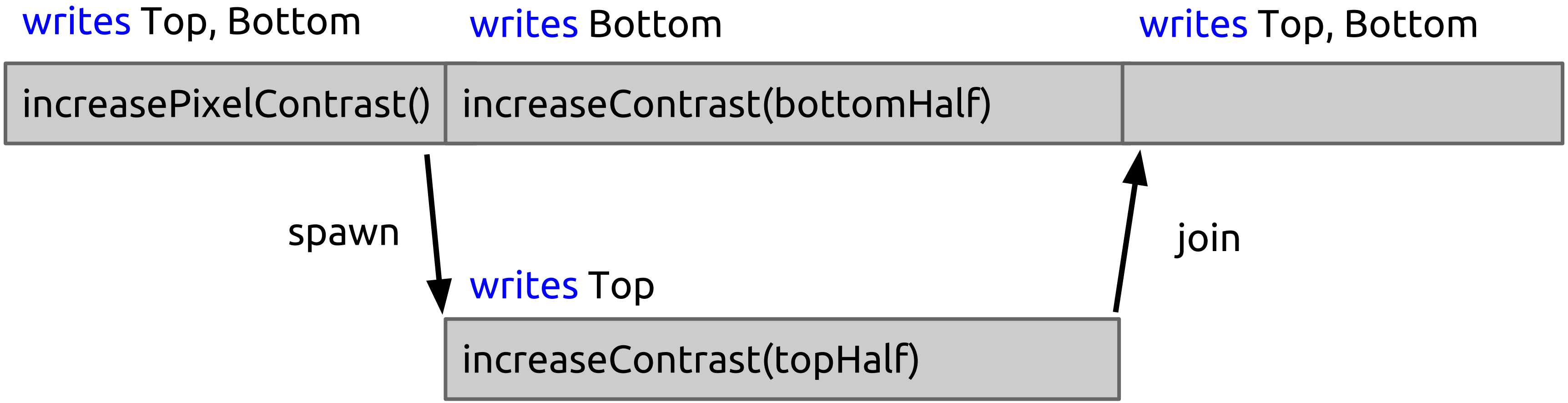
```
abstract class Task<type TRet, TArg, effect E>
{
    // code to be run when task is executed
    public abstract TRet run(TArg arg) effect E;
    // start task
    public SpawnedTaskFuture<TRet> spawn(TArg arg);
}

class SpawnedTaskFuture<type TRet, effect E>
{
    // await completion of task and get return value
    public TRet join();
}
```

Tasks With Effects Java

```
class Image {
    region Top, Bottom;
    int[] topHalf in Top;
    int[] bottomHalf in Bottom;
    public void increasePixelContrast() writes Top, Bottom {
        SpawnedTaskFuture<Void, writes Top> f = increaseContrast(topHalf).spawn(null);
        increaseContrast(bottomHalf).run(null);
        f.join();
    }
    private Task<Void, Void, writes R> increaseContrast(final int[] in R pixels) pure {
        return new Task<Void,Void, writes R>(){
            public Void run(Void _){ // modify pixels }
}   }   }
```

Effect Transfer in TWEJava



writes Top, Bottom

increasePixelContrast()

writes Bottom

increaseContrast(bottomHalf)

writes Top, Bottom

spawn

writes Top

increaseContrast(topHalf)

join

Flexibility? Not really...

Tasks With Effects Java (complete)

```
abstract class Task<type TRet, TArg, effect E> {
        // code to be run when task is executed
        public abstract TRet run(TArg arg) effect E;
        // execute a task at some point in the future without effect transfer
        public final TaskFuture<TRet> executeLater(TArg arg);
        // spawn a subtask of the current task, with effect transfer
        public final SpawnedTaskFuture<TRet, effect E> spawn(TArg arg);
}
class TaskFuture<type TReturn> {
        // await completion and get return value without effect transfer
        public TReturn getValue();
        // check if task is done without blocking
        public boolean isDone();
}
class SpawnedTaskFuture<type TReturn, effect E> extends TaskFuture<TReturn>{
        // await completion and get return value with effect transfer
        public TReturn join();
}
```

Parallel Control Flow with TWEJava

```
class Scientist {
    region Lab, Auditorium;
    Work research in Lab;
    Work teaching in Auditorium;

    public void doJob() writes Lab, Auditorium {
        TaskFuture researching = new Task<ResearchPaper, Work, writes Lab>() {

            public ResearchPaper run(Work research) { research.justDoIt();
                                                      return new ResearchPaper(research); }

        }.spawn(research);

        while ( !researching.isDone() ) {

            new Task<Void, Work, writes Auditorium>() {

                public Void run(Work teaching) { teaching.justDoIt(); return null; }

            }.spawn(teaching).join();
        }

        publish(writing.join());
}   }
```

Flexibility!

Security properties

- Data race freedom

  Exclusive access to regions
- ~~Atomicity~~

  Can break if a task does create new tasks or waits for other tasks.
- ~~Deadlock freedom~~

  Can happen since there are locks on regions.
- ~~Determinism~~

  Only limited control over task scheduling and termination.

@Deterministic

- Can be used to enforce determinism
- Only allows **spawn()** and **join()**

Limited to Fork-Join parallelism!

Regions are a burden

```
class Zoo {
    region Water, Jungle, Desert;
    Animal fish in Water;
    Animal monkey in Jungle;
    Animal tiger in Jungle;
    Animal camel in Desert;

    private void feed(Animal animal) effect E { // feed animal };

    public void feedAnimals(){
        // parallelizable (more or less)
        feed(fish); feed(monkey); feed(tiger); feed(camel);
    }
}
```

What is a smart way of defining regions?

Regions are a burden

```
class Zoo {
    region Water;
    Animal fish in Water;
    Animal monkey in Water;
    Animal tiger in Water;
    Animal camel in Water;

    private void feed(Animal animal) effect E { // feed animal };

    public void feedAnimals() {
        // not parallelizable :-(
        feed(fish); feed(monkey); feed(tiger); feed(camel);
    }
}
```

Multiple objects in same region hinders parallelization!

Regions are a burden

```
class Zoo {
        region Fish, Monkey, Tiger, Camel;
        Animal fish in Fish;
        Animal monkey in Monkey;
        Animal tiger in Tiger;
        Animal camel in Camel;

        private void feed(Animal animal) effect E { // feed animal };

        public void feedAnimals() {
                // parallelizable :-)
                feed(fish); feed(monkey); feed(tiger); feed(camel);
        }
}
```

In practice: Just put every object in its own region.

Regions are a burden

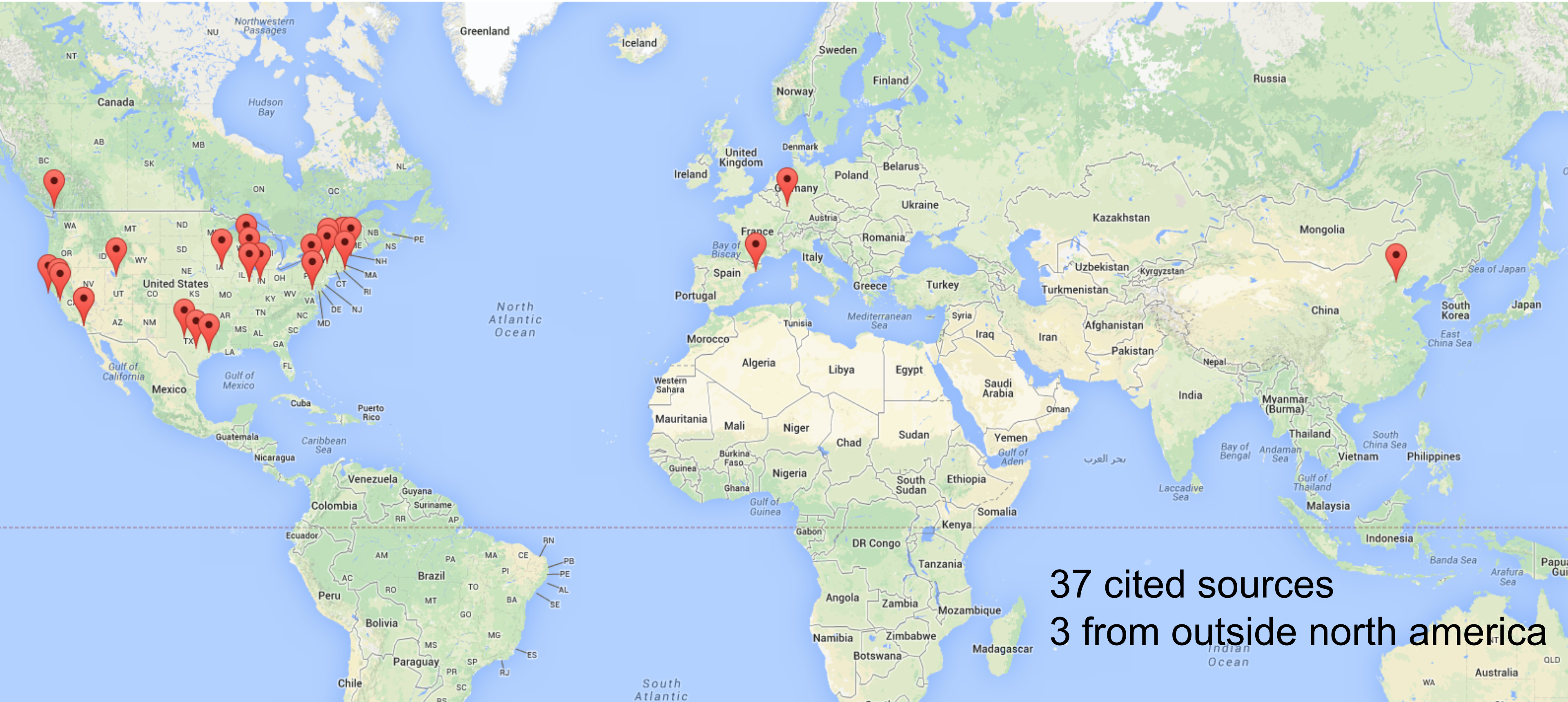
```
class Zoo {
    Animal fish inHisOwnRegion;
    Animal monkey inHisOwnRegion;
    Animal tiger inHisOwnRegion;
    Animal camel inHisOwnRegion;

    private void feed(Animal animal) effect E { // feed animal };

    public void feedAnimals() {
        // parallelizable :-)
        feed(fish); feed(monkey); feed(tiger); feed(camel);
    }
}
```

How about a keyword?

Location of sources



37 cited sources
3 from outside north america

Questions?