The Tasks with Effects Model for Safe Concurrency

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

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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 :-(
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  writes Bottom  writes Top, Bottom

increasePixelContrast()  increaseContrast(bottomHalf)  

spawn  writes Top  join

increaseContrast(topHalf)

Flexibility? Not really...
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());
    }
}
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?