Generation of Concurrency Control Code using Discrete-Event Systems Theory

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Motivation

- Optimal usage of today's Multi-core systems requires parallel executable Software
- Efficient and correct concurrent source code is hard to write and debug

→ facilitate development of concurrent source code

Introduction

- Automatic generation of concurrency control code
  - Input
    - Source code without concurrency control
    - Informal specification of the desired concurrent behaviour
  - Output
    - Source code with concurrency controls

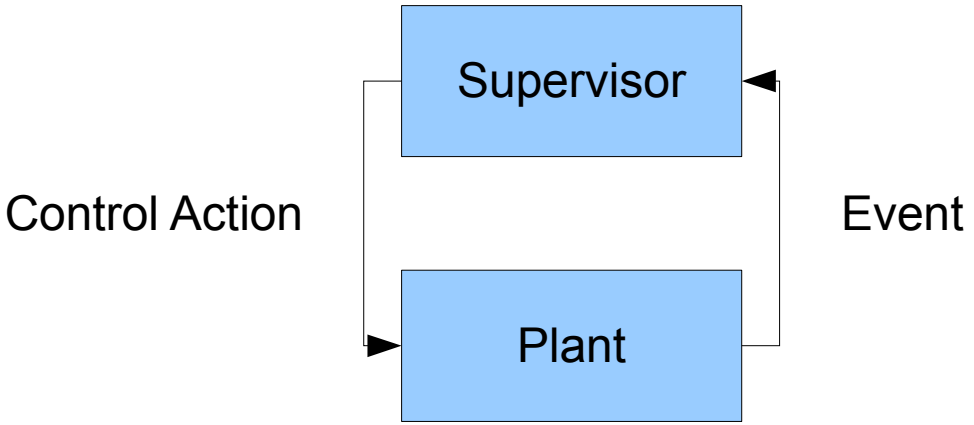
Introduction

- Aims
  - No Deadlocks
  - No Starvation
  - Minimally restrictive

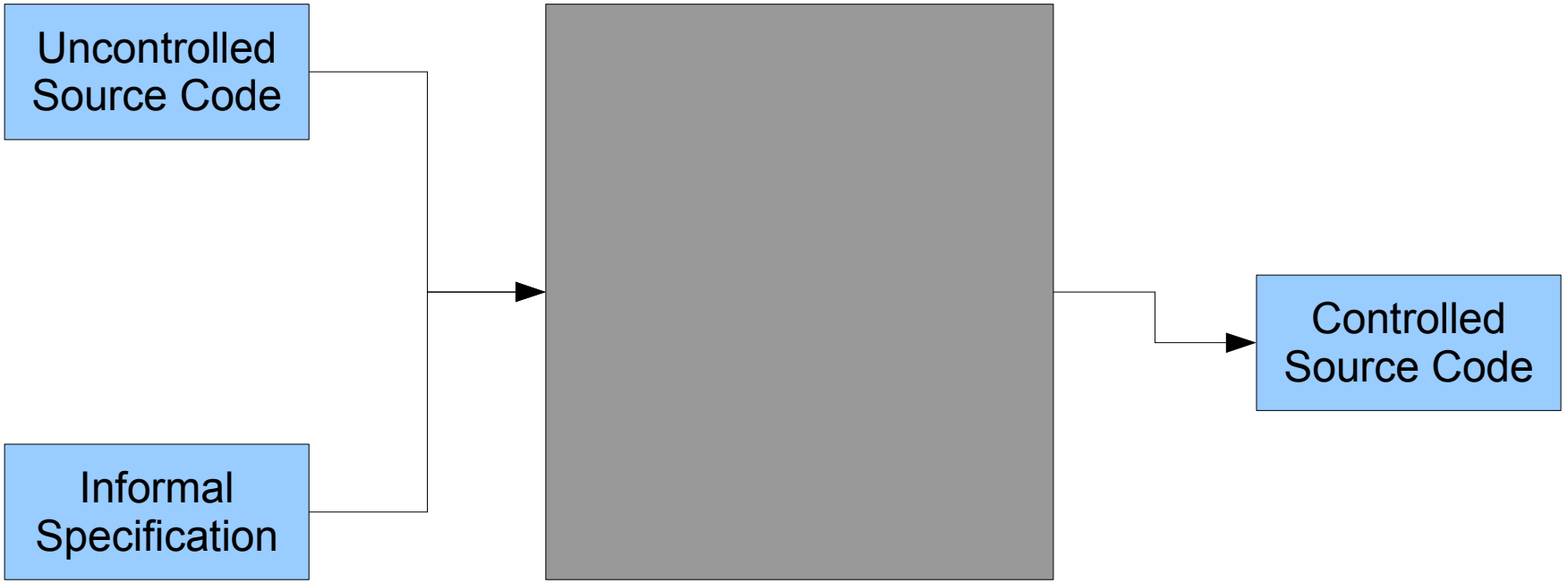
→ using control theory (Discrete-event System)

DES - Supervisor-Plant

- System(Plant) modelled as a finite-state automaton (FSA)
  - Transitions in FSA are called events
    - Events can be controllable or uncontrollable
- Supervisor modelled as a FSA
  - Enables or disables controllable events



Process Overview



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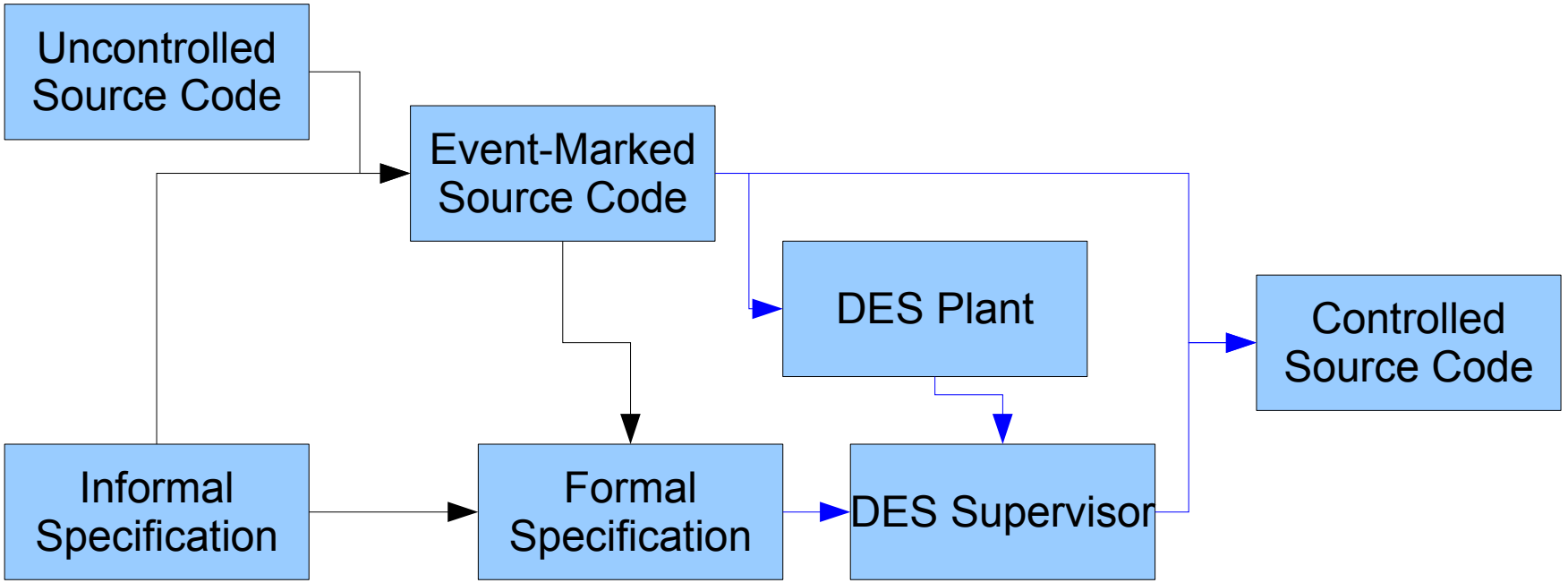
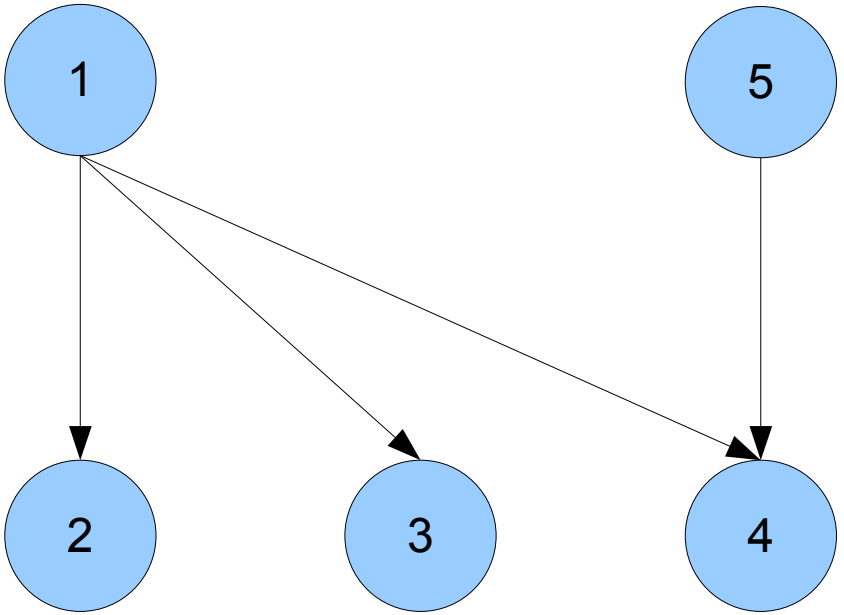


Relevant Events

- Find relevant events for concurrency control
  - Example
    - Enter/Exit Critical Section → relevant
    - Accessing shared variable → non-relevant
- Mark events in the source code
- Differentiate controllable and uncontrollable events

Example

- 5 Threads with dependencies
  - 1 → 2,3,4
  - 5 → 4



Code example for Thread 3:

```
public void run() {
    // relevant event: T3-start
    System.out.println(id);
    doWork();
}
```

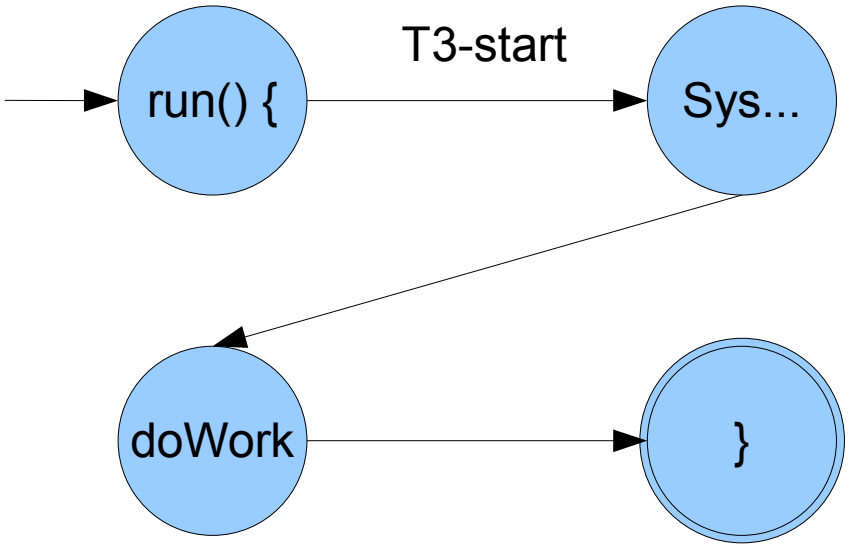
DES Plant

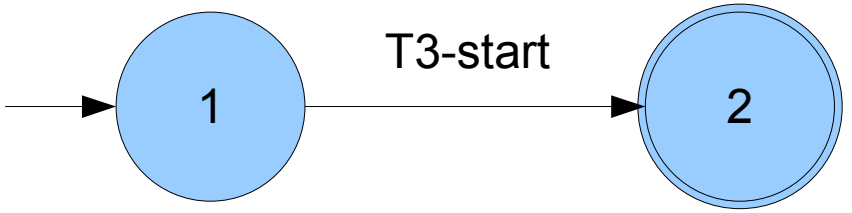
- Build a Finite-state automaton (FSA) representing all possible event sequences for each Thread
  - Build control-flow graph(CFG) from source code
  - Reduce CFG
    - All relevant events remain
    - All non-relevant events important for CFG structure remain

Example

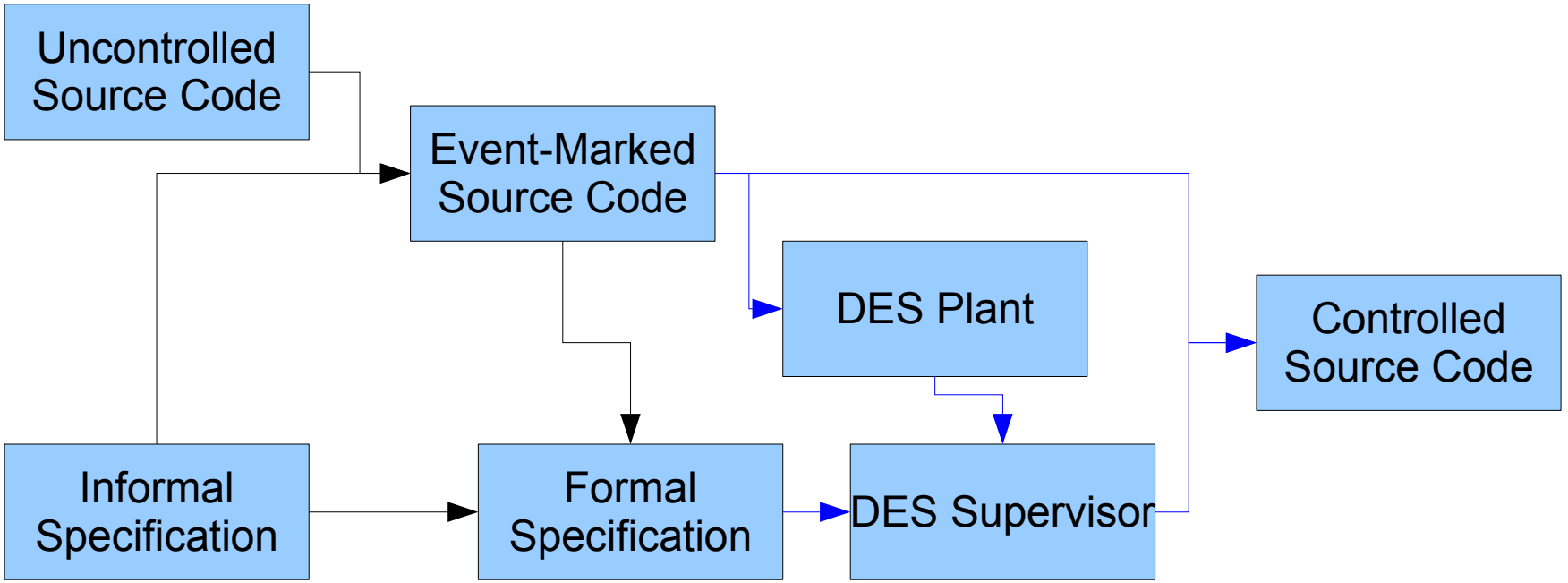
Code example for Thread 3:

```
public void run() {
    // relevant event: T3-start
    System.out.println(id);
    doWork();
}
```





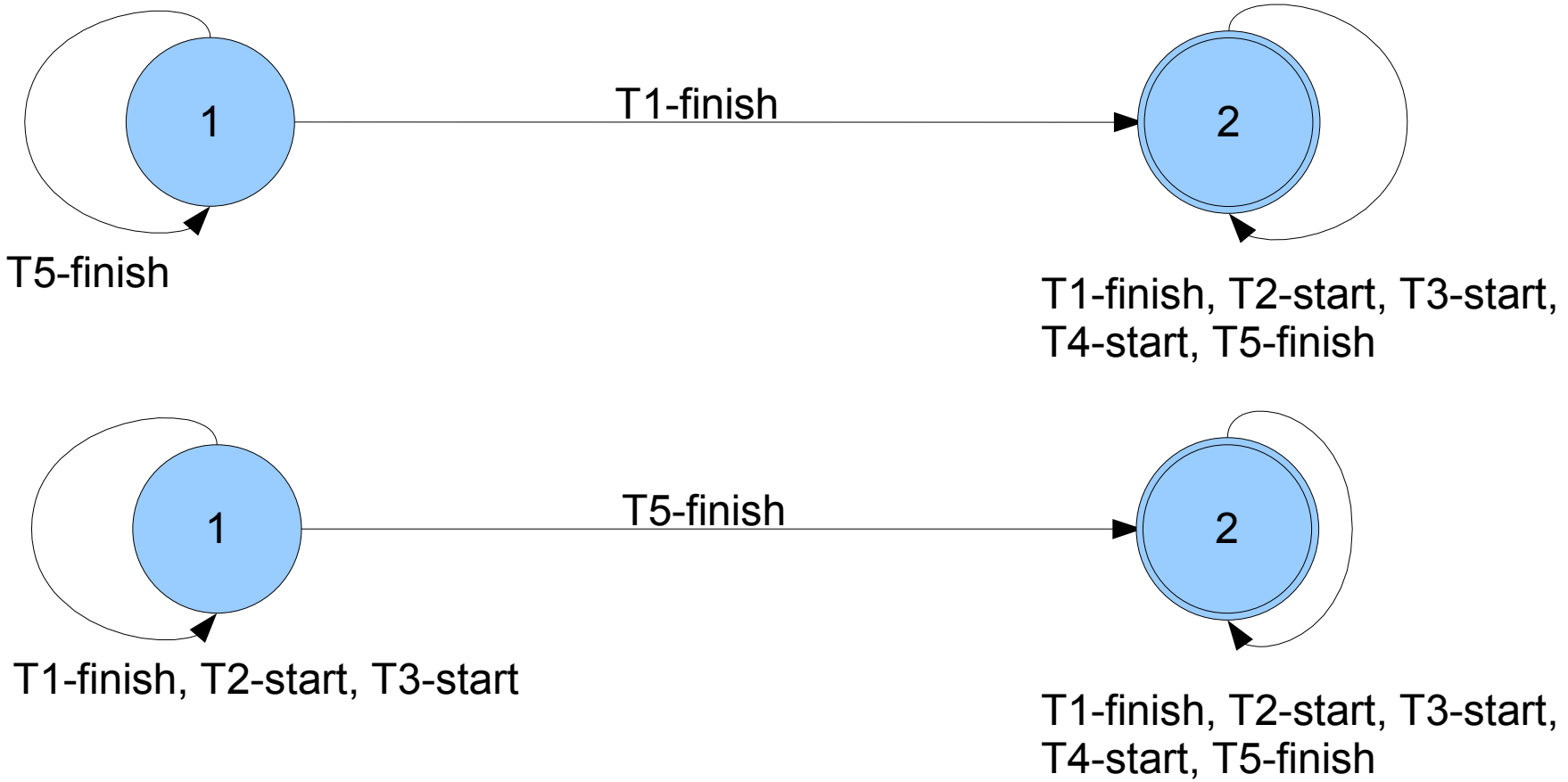
Process Overview



Formal Specification

- Specifies the allowed subset of event sequences
  - FSA for each restriction
  - Only restrictive

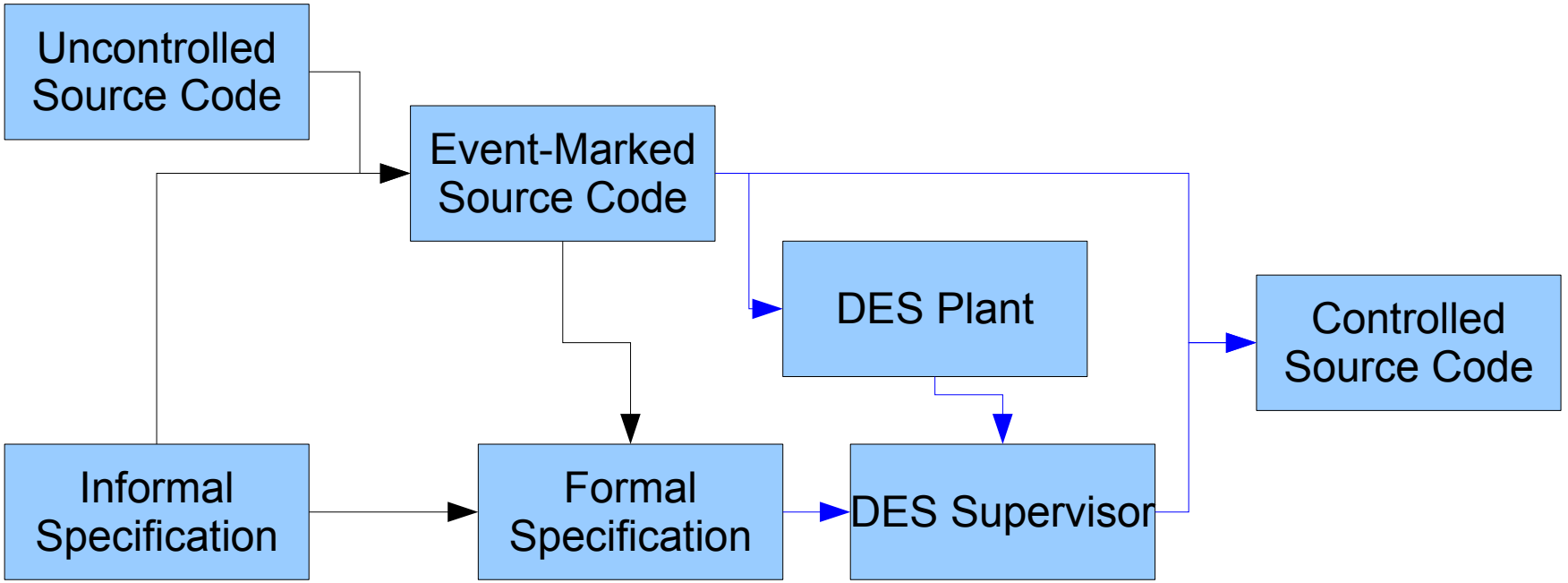
Example


1
T1-finish
2
T5-finish
T1-finish, T2-start, T3-start,
T4-start, T5-finish
1
T5-finish
2
T1-finish, T2-start, T3-start
T1-finish, T2-start, T3-start,
T4-start, T5-finish

DES Supervisor

- Only one supervisor (simplification)
- Different FSA's need to be combined into a monolithic specification
  - Scalability issue

Process Overview



Code Generation

- Supervisor needs to block non allowed controllable events
  - Generates a Semaphore for each controllable event set to the initial state
  - Supervisor state changing function enables/disables controllable events

Example – Thread 3

```
//relevant event: T3start
while (true) {
    if(Synchronizer.stateChangeTest("T3start",
    Synchronizer.T3start))
        break;
    Synchronizer.T3start.acquireUninterruptibly();
    Synchronizer.T3start.release();
}
```

Example – Supervisor I

```
public static synchronized Boolean stateChangeTest(String event,
Semaphore eventBlocker) {
    if (!(eventBlocker == null)) {
        if (!eventBlocker.tryAcquire()) {
            return false;
        }
        eventBlocker.release();
    }
    changeSupervisorState(event);
    return true;
}
```

Example – Supervisor II

```
private static void changeSupervisorState(String event) {
    if (event.equals("T1finish")) {
        switch(Synchronizer.stateTracker) {
        case(0):
            Synchronizer.T3start.release();
            Synchronizer.T2start.release();
            Synchronizer.stateTracker = 1;
        break;
        case(1):
        ...
```

Verification

- Discrete-event theory is proven correct and non blocking
- Formal proof for algorithm is still needed
- Modelchecker (Java Pathfinder)

- Input not reliable!

Limitations

- No dynamic threads generation allowed
- Monolithic supervisor not very efficient
- Starvation not properly addressed

Conclusion

- DES theory can be applied to concurrency
- Chosen FSA-based version of DES not expressive enough
- Further work needed

Questions

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