COMP 322: Fundamentals of Parallel Programming

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Lecture 25: Dataflow Programming and Data-Driven Futures

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Acknowledgments for Today's Lecture

- Lecture 24 handout
- Slides from Prof. Guang Gao, U.Delaware
  - Topic-III-2-dataflow.pptx
- Sagnak Tasirlar. Scheduling macro-dataflow programs on task-parallel runtime systems. M.S. Thesis, Department of Computer Science, Rice University, May 2011 (expected).

Announcements

- HW5 submission deadline is 5pm TODAY

Dataflow Computing

- **Basic idea: replace machine instructions by a small set of dataflow operators**

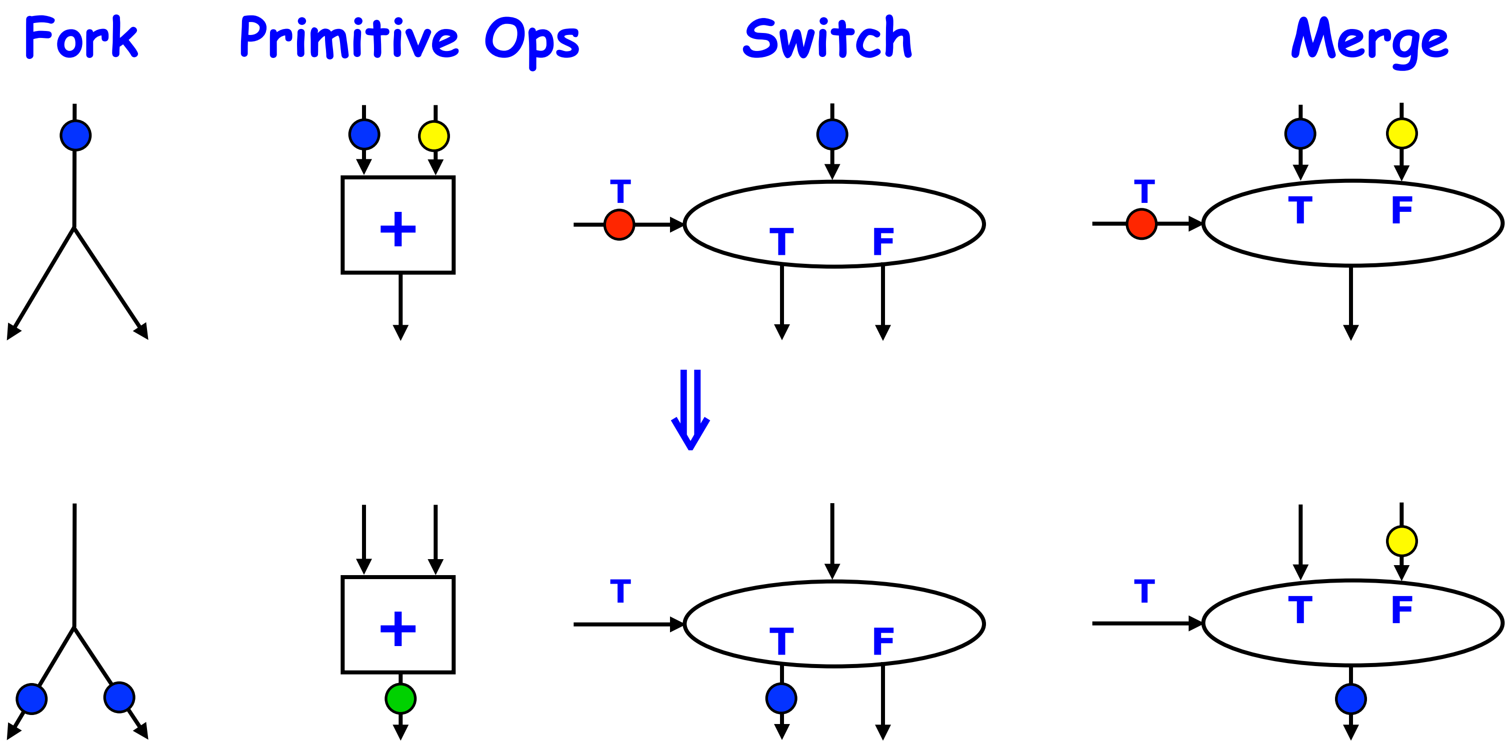
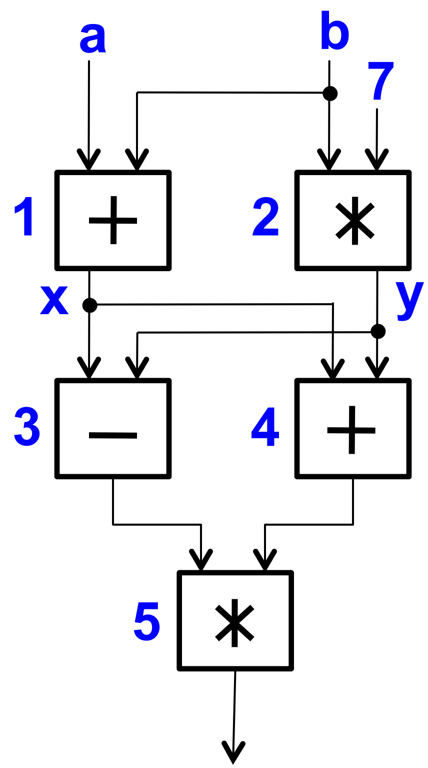


Figure 1: Example instruction sequence and its dataflow graph

```
x = a + b;
y = b * 7;
z = (x-y) * (x+y);
```



An operator executes when all its input tokens are present; copies of the result token are distributed to the destination operators.

No separate control flow

Extending Futures with Dataflow Principles: HJ Data-Driven Futures (DDFs)

ddfA = new DataDrivenFuture()

- Allocate an instance of a DDF object (container)

async await(ddfA, ddfB, …) <Stmt>

- Create a new async task to start executing **Stmt** after all of **ddfA, ddfB, …** become *available*
- Task is said to be *enabled* when **ddfA, ddfB, …** become available

ddfA.put(V)

- Store object V in **ddfA**, thereby making **ddfA** available
- Single-assignment rule: at most one put is permitted on a given DDF

ddfA.get()

- Return value stored in **ddfA**
- Can only be performed by async's that contain **ddfA** in their await clause (no blocking is necessary)

Figure 2: Example Habanero Java code fragment with Data-Driven Futures

```
DataDrivenFuture left = new DataDrivenFuture();
DataDrivenFuture right = new DataDrivenFuture();
finish {
    async left.put(leftBuilder()); // Task1
    async right.put(rightBuilder()); // Task2
    async await ( left ) leftReader(left); // Task3
    async await ( right ) rightReader(right); // Task4
    async await ( left, right )
                 bothReader( left, right); // Task5
}
```

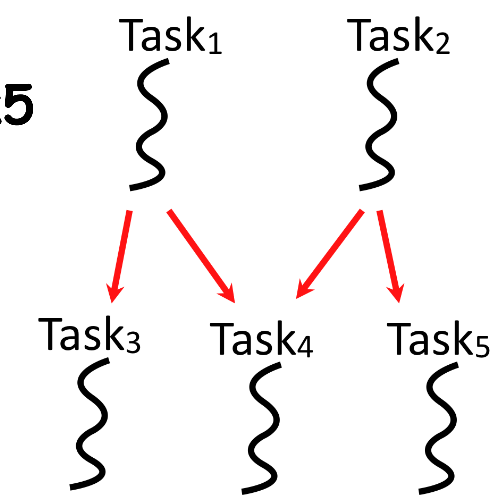
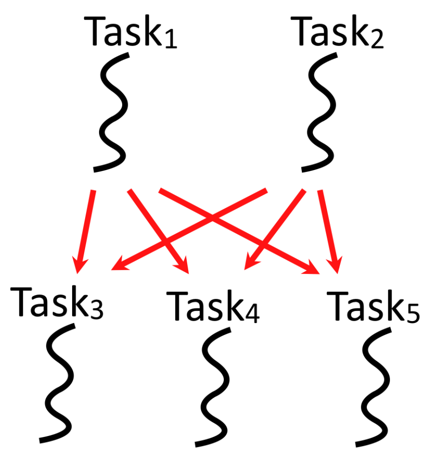


Figure 3: A finish-async version of the example in Figure 2

```
// Assume that left and right are fields in this object
finish {
    async left = put(leftBuilder()); // Task1
    async right = put(rightBuilder()); // Task2
}
finish {
    async leftReader(left); // Task3
    async rightReader(right); // Task4
    async bothReader( left, right); // Task5
}
```



Two Exception cases for DDFs

- Case 1: If two put's are attempted on the same DDF, an exception is thrown because of the violation of the single-assignment rule

- Case 2: If a *get* is attempted by a task on a DDF that was not in the task's await list, then an exception is thrown because DDF's do not support blocking gets.

Differences between Futures and DDFs

- Consumer task blocks on get() for each future that it reads, where as async-await does not start execution till all DDFs are available
- Producer task can only write to a single future object, where as a DDF task can write to multiple DDF objects
- The choice of which future object to write to is tied to a future task at creation time, where as the choice of output DDF can be deferred to any point with a DDF task
- Future tasks cannot deadlock, but it is possible for a DDF task to never be enabled, if one of its input DDFs never becomes available. This can be viewed as a special case of deadlock.
  - This deadlock case is resolved by ensuring that each finish construct moves past the end-finish when all enabled async tasks in its scope have terminated, thereby ignoring any remaining non-enabled async tasks.

Implementing Future Tasks using DDFs

- Future version

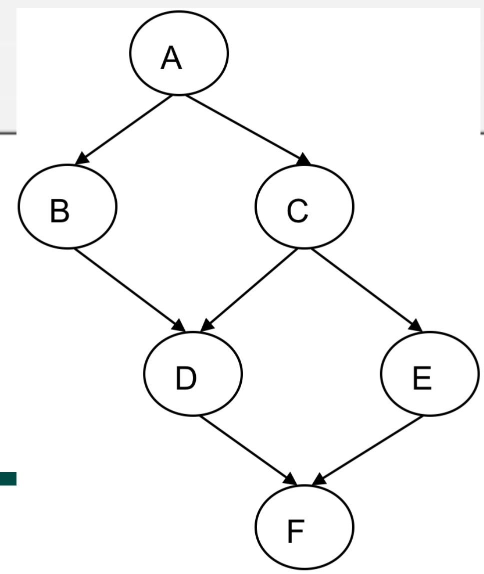
```
final future<int> f = async<int> { return g(); };
. . .
int local = f.get();
```

- DDF version

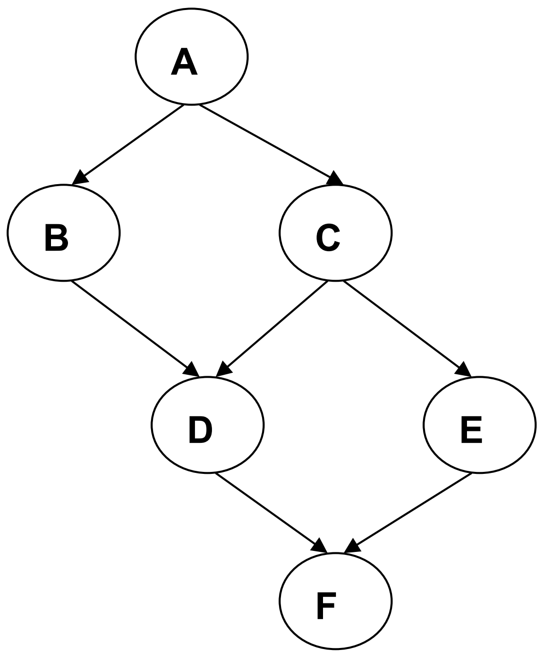
```
DataDrivenFuture f = new DataDrivenFuture();
async { f.put(g()) };
 . . .
async await (f) { int local = f.get(); };
```

Listing 1: use of DDFs with empty objects

```
finish {
  DataDrivenFuture ddfA = new DataDrivenFuture();
  DataDrivenFuture ddfB = new DataDrivenFuture();
  DataDrivenFuture ddfC = new DataDrivenFuture();
  DataDrivenFuture ddfD = new DataDrivenFuture();
  DataDrivenFuture ddfE = new DataDrivenFuture();
  async { . . . ; ddfA.put(""); } // Task A
  async await(ddfA) { . . . ;  ddfB.put(""); } // Task B
  async await(ddfA) { . . . ;  ddfC.put(""); } // Task C
  async await(ddfB,ddfC) { . . . ;  ddfD.put(""); } // Task D
  async await(ddfC) { . . . ;  ddfE.put(""); } // Task E
  async await(ddfD,ddfE) { . . . } // Task F
} // finish
```



Using Future Tasks to generate Computation Graph CG3 from Homework 2



Computation Graph CG3

```
// NOTE: return statement is optional
   when return type is void

final future<void> A = async<void>
   { . . . ; return;}

final future<void> B = async<void>
   { A.get(); . . . ; return;}

final future<void> C = async<void>
   { A.get(); . . . ; return;}

final future<void> D = async<void>
   { B.get(); C.get(); . . . ; return;}

final future<void> E = async<void>
   { C.get(); . . . ; return;}

final future<void> F = async<void>
   { D.get(); E.get(); . . . ; return;}
```