Tools for porting programs to a new parallel programming language

(Feb. 3, 2011)

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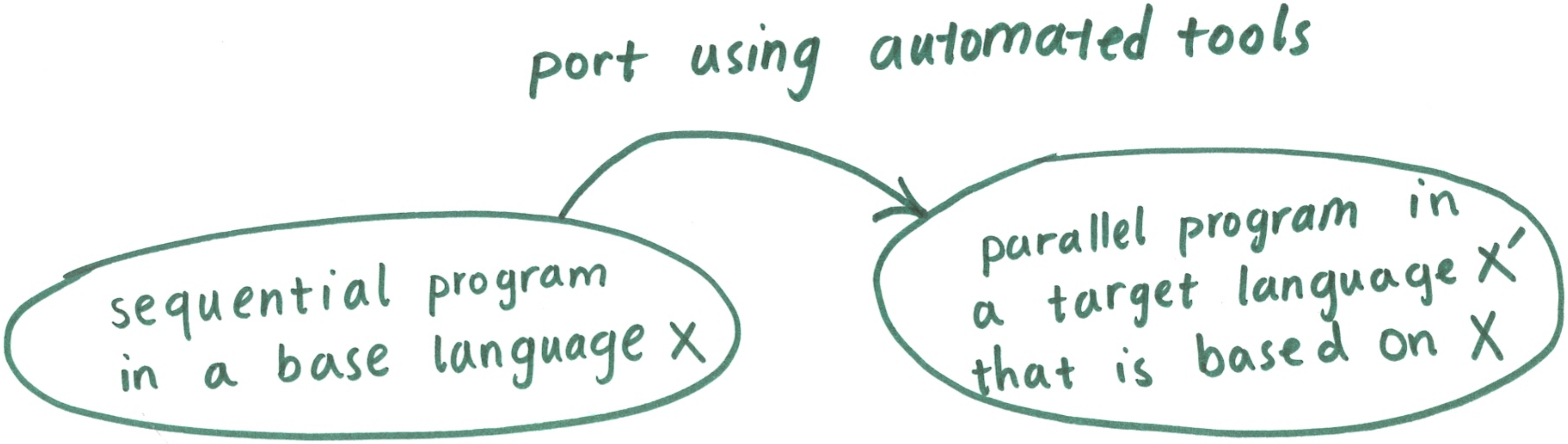


Some parallel programming environments are based on sequential ones.

DPJ

Intel Array Building Block

Microsoft PLINQ

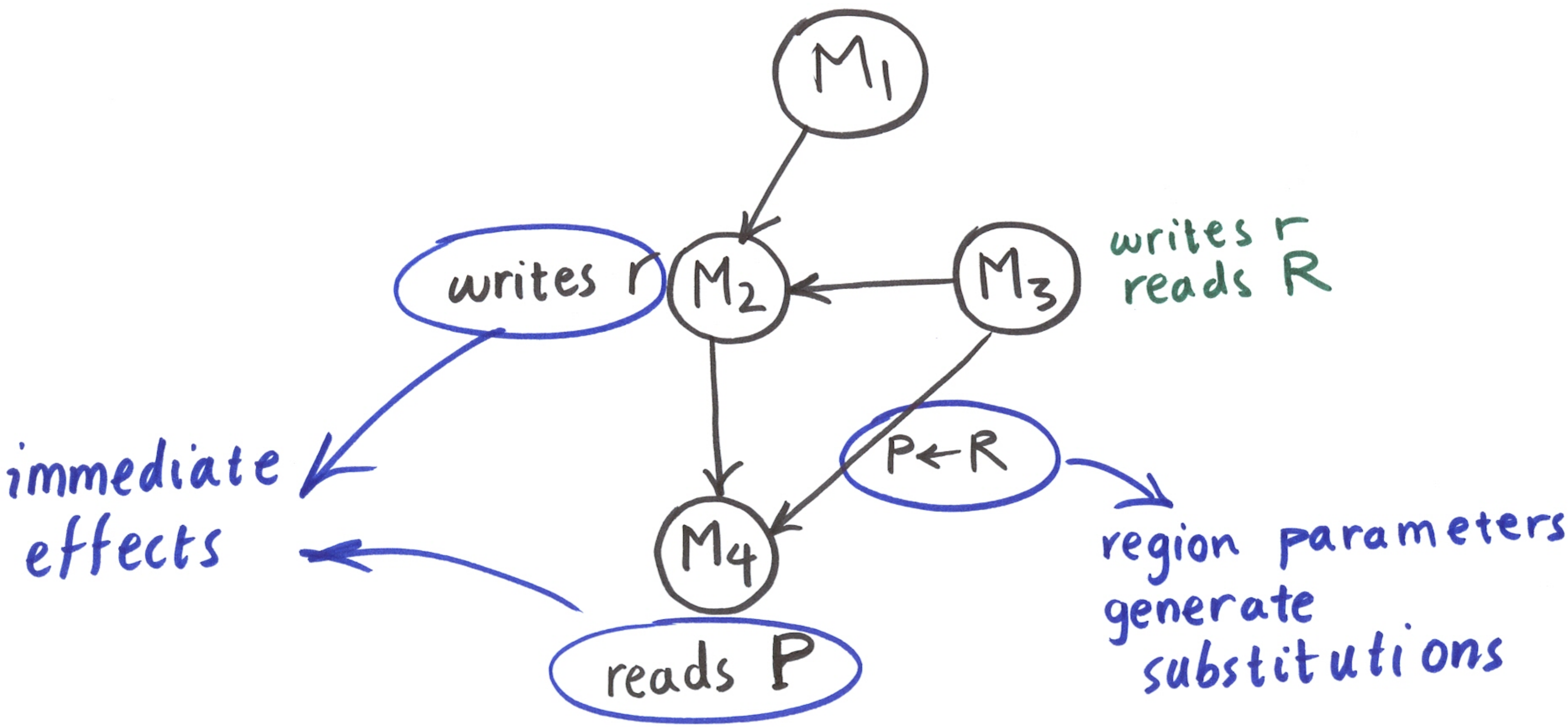
PLINQ extends LINQ

```
IEnumerable<T> data = ...;

var q = data.AsParallel().Where(x => p(x)).
                 Orderby(x => k(x)).
                 Select(x => f(x));

foreach (var e in q) a(e);
```

DPJ has region, RPL, region parameter and effects.

```
                                   region parameter
class Node<region P>{
    region L, R;                           RPL
    double mass in P;
    Node<P:L> left in P:L;
    Node<P:R> right in P:R;
    void setMassForTree(double mass)
effects →  writes P, P:L:*, P:R:* {
        this.mass = mass;
        if (left != null) left.setMassForTree(mass);
        if (right != null) right.setMassForTree(mass);
}
```

It is difficult for programmers or the compiler to infer the effects.



constraint graph

DPJizer infers effects better than programmers.

writes P, P:L:*, P:R:*	instead of	writes P:*
writes P	instead of	reads P, writes P

```
class Tree {
    Body<[i]/π1>[]#i/i bodies;

    void computegrav() {
        foreach (int j in 0, bodies.length) {
            HGStruct<[j]/π2> hg = new HGStruct<[j]/π3>();
            bodies[j].hackgrav(hg);
        }
    }
}

class Body<region BR> {
    Vector<BR/π4> vel in BR = new Vector<BR/π5>();

    void hackgrav(HGStruct<BR/π6> hg) {
        vel.<π̄11>SETV(hg.acc0);
    }
}
```

```
class Vector<region VR> {
    double[]<VR/π7>#k/k elts in VR = new double[3]<VR/π8>#l/l;

    <region SR> void SETV(Vector<SR/π9> u) {
        for (int m = 0; m < 3; m++) {
            elts[m] = u.elts[m];
        }
    }
}
class HGStruct<region HR> {
    Vector<HR/π10> acc0 in HR;
}
```

Region inclusion constraints are derived from subtyping rules.

double[]$\langle \pi_7 \rangle$#k elts in VR = new double[3]$\langle \pi_8 \rangle$#l;	$\pi_8 \subseteq \pi_7$
vel.$\langle \pi_{11} \rangle$SETV(hg.acc∅);	$VR[VR \leftarrow \pi_{10}][HR \leftarrow \pi_6] \subseteq VR[VR \leftarrow \pi_9][VR \leftarrow \pi_4][SR \leftarrow \pi_{11}]$
bodies[j].hackgrav(hg);	$HR[HR \leftarrow \pi_2] \subseteq HR[HR \leftarrow \pi_6][BR \leftarrow \pi_1][i \leftarrow j]$
HGStruct$\langle \pi_2 \rangle$hg = new HGStruct$\langle \pi_3 \rangle$();	$\pi_3 \subseteq \pi_2$
Vector$\langle \pi_4 \rangle$ vel in BR = new Vector$\langle \pi_5 \rangle$();	$\pi_5 \subseteq \pi_4$

Parallel statements generate disjointness constraints.

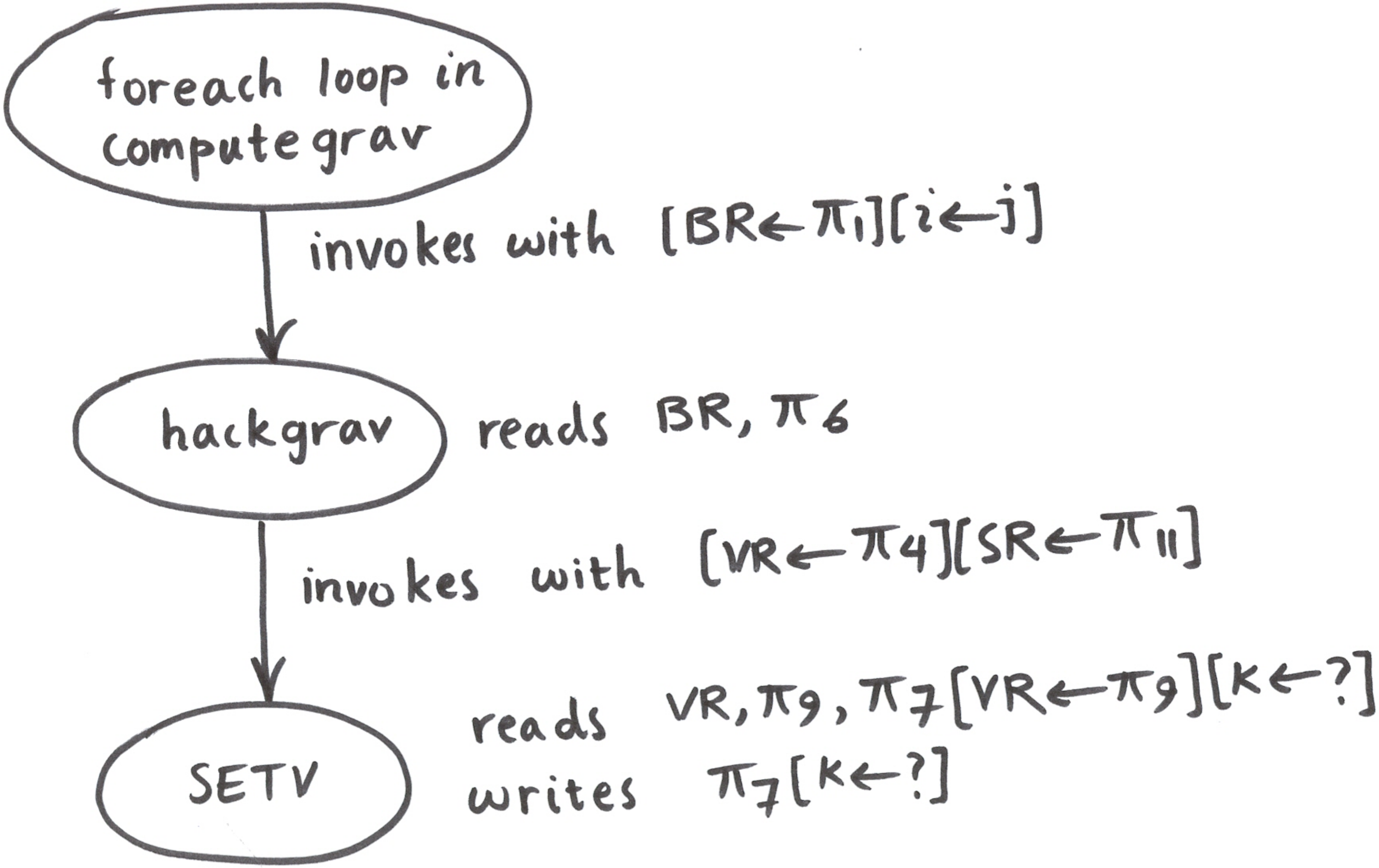
```
foreach ( int j in 0, bodies.length) {
    HGStruct<π2> hg = new HGStruct<π3>();
    bodies[j].hackgrav(hg);
}
```

$$\mathcal{E}(hackgrav)[BR \leftarrow \pi_1][i \leftarrow j][j \leftarrow a]$$

$$\#$$

$$\mathcal{E}(hackgrav)[BR \leftarrow \pi_1][i \leftarrow j][j \leftarrow b]$$

Write effects should be disjoint from each other, and read effects should be disjoint from write effects.



The index variable of the foreach loop should differentiate the write effects.

writes $\pi_7[K \leftarrow ?][VR \leftarrow \pi_4][SR \leftarrow \pi_{11}][BR \leftarrow \pi_1][i \leftarrow j]$

$\pi_7 = VR$ $\pi_4 = BR$ $\pi_1 = [i]$

Read effects should be disjoint from write effects.

reads $\pi_9[VR \leftarrow \pi_4][SR \leftarrow \pi_{11}][BR \leftarrow \pi_1][i \leftarrow j]$

$\pi_9 = VR$ OR $\pi_9 = SR,\ \pi_{11} = BR$

Region inclusion constraints determine the rest of variables.

$\pi_1 = [i]$, $\pi_4 = BR$, $\pi_7 = VR$, $\pi_9 = SR$, $\pi_{11} = BR$

$\pi_8 \subseteq \pi_7$	$\pi_8 = VR$
$VR[VR \leftarrow \pi_{10}][HR \leftarrow \pi_6] \subseteq VR[VR \leftarrow \pi_9][VR \leftarrow \pi_4][SR \leftarrow \pi_{11}]$	$\pi_6 = BR$, $\pi_{10} = HR$
$HR[HR \leftarrow \pi_2] \subseteq HR[HR \leftarrow \pi_6][BR \leftarrow \pi_1][i \leftarrow j]$	$\pi_2 = [j]$
$\pi_3 \subseteq \pi_2$	$\pi_3 = [j]$
$\pi_5 \subseteq \pi_4$	$\pi_5 = BR$

This work is funded by Microsoft and Intel through UPCRC and by NSF grants.

The DPJ homepage is http://dpj.cs.illinois.edu