The Chapel Memory Consistency Model

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The Memory Consistency Model Effort

- Philosophically:
  - The memory model already exists
  - We're just writing it down
Philosophy of the MCM Effort

- The memory model already exists
  - in example programs
  - in developer's minds
- We're just writing it down
Outline

- Example Constructions
- Learning from History
- The Model
Example Constructions
Sequential programs work in *program order*:

```plaintext
var x: int;
x = 1;
x = 2;
writeln(x);
```

should always output 2.

**Note:**
- CHARM++, OpenSHMEM don't follow this rule
- UPC, C, Java, Fortran do
Task constructs create additional dependencies:

```plaintext
var x:int;
x = 50;
coforall i in 1..4 {
    writeln(x + i);
}
```

should always output a permutation of

51 52 53 54

in other words, x is always 50 in each task.
Design Goal 3

Remote memory has the same memory consistency rules as local memory:

```java
var x: int;
on Locales[1] {
x = 1;
x = 2;
writeln(x);
}
```

should always output 2.

Enables separation of algorithm from data layout.
The memory model should not inhibit common optimizations:

```plaintext
var x: int = 0;
cobegin ref(x) {
  { while x==0 { /*wait*/} }
  { x = 1; }
}
```

Has *undefined behavior* since there is a *data race* on variable x. Probably won't terminate.

In other words, the programmer must identify variables used to synchronize tasks. Need:

```plaintext
var x: atomic int;  or
var x: sync int;
```
Learning from History
Defining Racy Program Behavior

● Some specifications tried to define behavior for racy programs
  → inhibits optimization
  → usually wrong

● Java
  ● circa 1996
  ● fixed now

● UPC
  ● attempted fix
Impossible Implementation

- *shared strict* variables can synchronize processes
  - each *shared strict* variable must be atomic
- any type can be *shared strict*
  - a *shared strict* variable could be 64KB!
- but RDMA can't possible be atomic for a 64KB type!
- and *shared strict* casts to local ptr → no locks!
  - in practice, *shared strict* only works for small types
SC for DRF: The Big House

C11, C++11, Java, UPC, Fortran 2008
Start with C++11 MCM

- At a high level: sequentially consistent behavior for data race free programs

- other things are possible with order= arguments for atomic operations
  - relaxed
  - acquire
  - release ...
Enhance for Chapel

- local and remote data have same rules
- task constructs (e.g. cobegin) influence \textit{program order}
- planned support for explicit \textit{unordered} operations
Questions?

```
var x: int;

x = 1;
x = 2;
writeln(x);
→ 2
```

```
var x: int;
x = 50;
coforall i in 1..4 {
  writeln(x + i);
}
→ permutation of 51 52 53 54
```

```
var x: int;
on Locales[1] {
  x = 1;
x = 2;
  writeln(x);
}
→ 2
```

```
var x: int = 0;
cobegin ref(x) {
  { while x==0 {} }
  { x = 1; }
}
→ undefined behavior
```
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