Chapel: Background

Chapel's Origins

- **HPCS**: High Productivity Computing Systems
  - Overall goal: Raise high-end user productivity by 10x

    Productivity = Performance + Programmability + Portability + Robustness
- **Phase II:** Cray, IBM, Sun (July 2003 – June 2006)
  - Goal: Propose new productive system architectures
  - Each vendor created a new programming language
    - **Cray:** Chapel
    - **IBM:** X10
    - **Sun:** Fortress
- **Phase III:** Cray, IBM (July 2006 –)
  - Goal: Develop the systems proposed in phase II
  - Each vendor implemented a compiler for their language
    - Sun also continued their Fortress effort without HPCS funding

Outline

- Chapel's Context
- Chapel's Motivating Themes
  1. General parallel programming
  2. *Global-view* abstractions
  3. *Multiresolution* design
  4. Control over locality/affinity
  5. Reduce gap between mainstream & HPC languages

1) General Parallel Programming

With a unified set of concepts...

...express any parallelism desired in a user's program

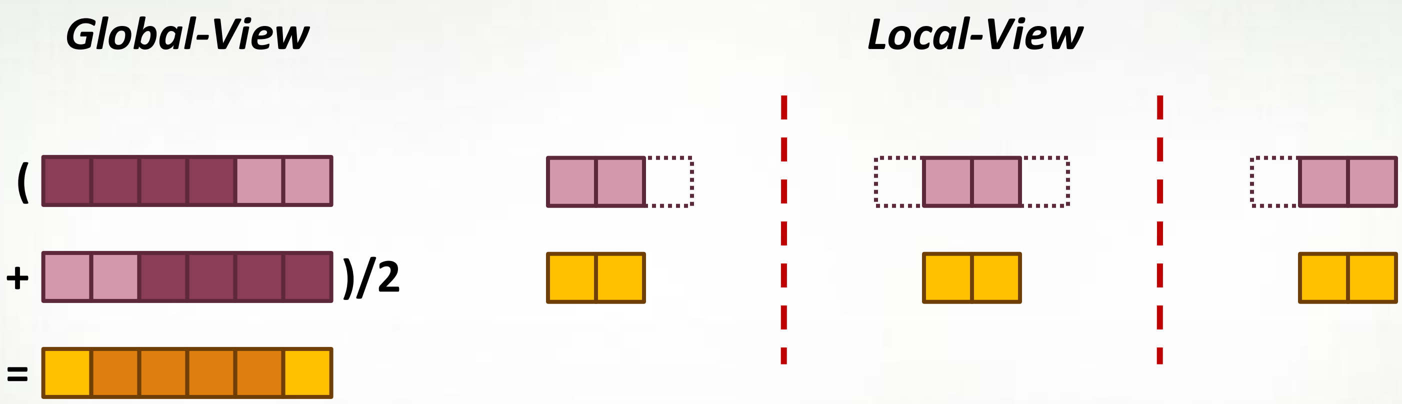
- **Styles:** data-parallel, task-parallel, concurrency, nested, …
- **Levels:** model, function, loop, statement, expression

...target all parallelism available in the hardware

- **Systems:** multicore desktops, clusters, HPC systems, …
- **Levels:** machines, nodes, cores, instructions

2) Global-View Abstractions

In pictures: “Apply a 3-Point Stencil to a vector”



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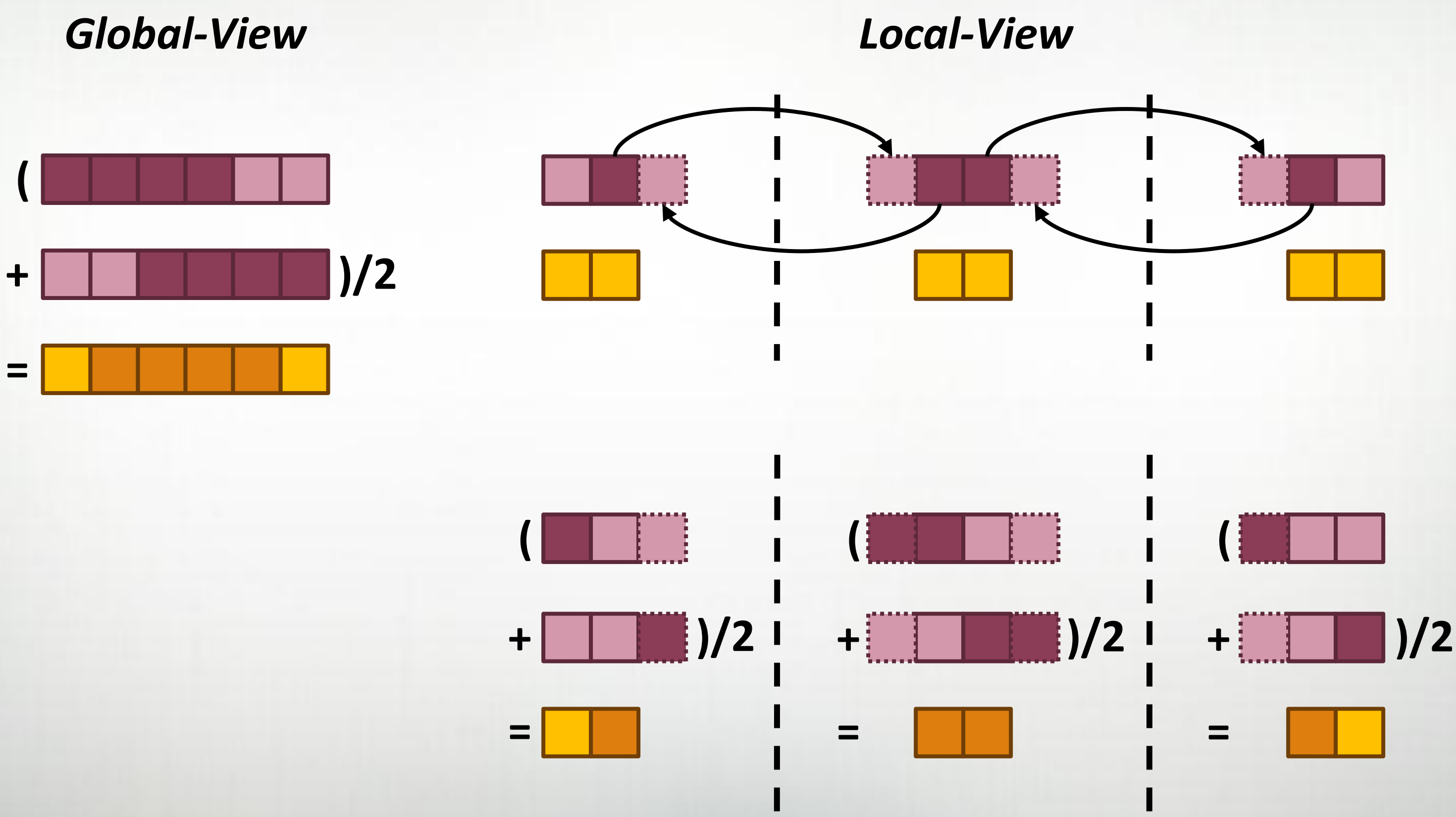

2) Global-View Abstractions

In code: "Apply a 3-Point Stencil to a vector"

Global-View

```
proc main() {
  var n = 1000;
  var A, B: [1..n] real;

  forall i in 2..n-1 do
    B[i] = (A[i-1] + A[i+1])/2;
}
```

Local-View (SPMD)

```
proc main() {
  var n = 1000;
  var p = numProcs(),
      me = myProc(),
      myN = n/p,
  var A, B: [0..myN+1] real;

  if (me < p-1) {
    send(me+1, A[myN]);
    recv(me+1, A[myN+1]);
  }
  if (me > 0) {
    send(me-1, A[1]);
    recv(me-1, A[0]);
  }
  forall i in 1..myN do
    B[i] = (A[i-1] + A[i+1])/2;
}
```

Bug: Refers to uninitialized values at ends of A

2) Global-View Abstractions

In code: “Apply a 3-Point Stencil to a vector”

Global-View

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  var n = 1000;
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  forall i in 2..n-1 do
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}
```

Communication becomes geometrically more complex for higher-dimensional arrays

Local-View (SPMD)

```
proc main() {
  var n = 1000;
  var p = numProcs(),
      me = myProc(),
      myN = n/p,
      iLo = 1,
      iHi = myN;
  var A, B: [0..myN+1] real;

  if (me < p-1) {
    send(me+1, A[myN]);
    recv(me+1, A[myN+1]);
  } else
    myHi = myN-1;
  if (me > 0) {
    send(me-1, A[1]);
    recv(me-1, A[0]);
  } else
    myLo = 2;
  forall i in iLo..iHi do
    B[i] = (A[i-1] + A[i+1])/2;
}
```

Assumes p divides n

2) Classifying Current Programming Models

	System	Data Model	Control Model
Communication Libraries	MPI/MPI-2	Local-View	Local-View
	SHMEM, ARMCI, GASNet	Local-View	SPMD
Shared Memory	OpenMP, Pthreads	Global-View (trivially)	Global-View (trivially)
PGAS Languages	Co-Array Fortran	Local-View	SPMD
	UPC	Global-View	SPMD
	Titanium	Local-View	SPMD
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HPCS Languages	Chapel	Global-View	Global-View
	X10 (IBM)	Global-View	Global-View
	Fortress (Sun)	Global-View	Global-View

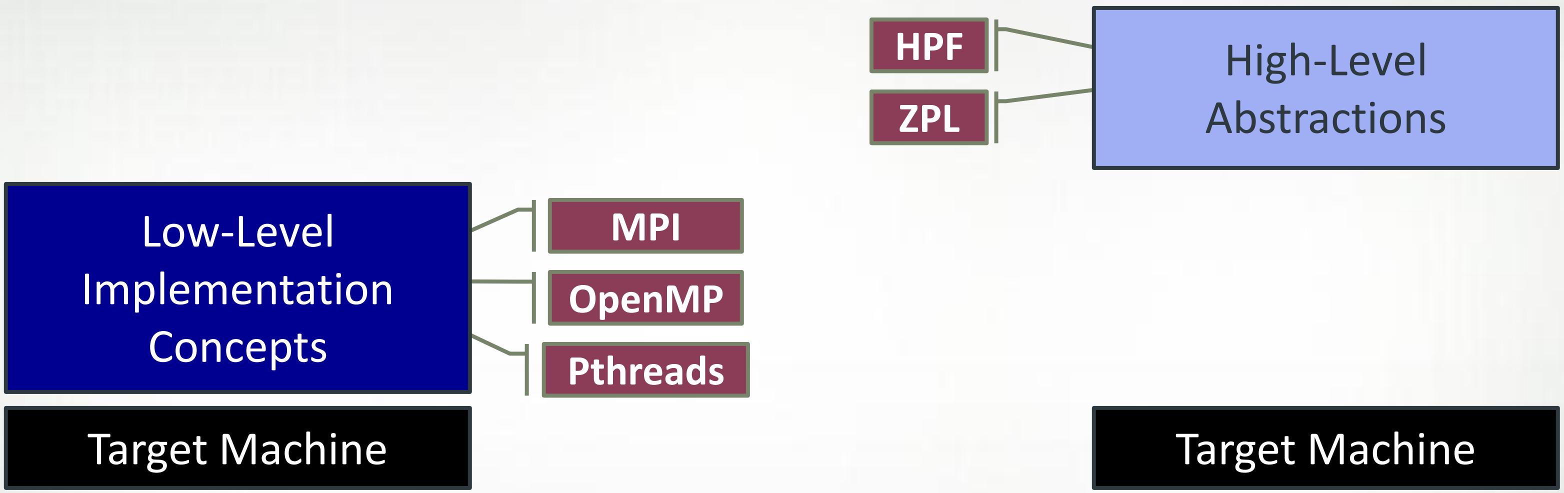
2) Global-View Programming: A Final Note

- A language may support both global- and local-view programming — in particular, Chapel does

```
proc main() {
  coforall loc in Locales do
    on loc do
      MySPMDProgram(loc.id, Locales.numElements);
}

proc MySPMDProgram(me, p) {
  ...
}
```

3) Multiresolution Language Design: Motivation



"Why is everything so difficult?"
"Why don't my programs port trivially?"

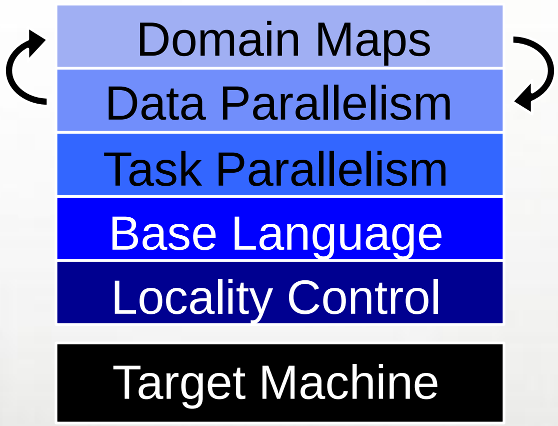
"Why don't I have more control?"

3) Multiresolution Language Design

Multiresolution Design: Support multiple tiers of features

- higher levels for programmability, productivity
- lower levels for performance, control
- build the higher-level concepts in terms of the lower

Chapel language concepts



- separate concerns appropriately for clean design

4) Locality/Affinity Control

Facts of Life:

- Scalable architectures package memory near processors
- Remote accesses take longer than local accesses

Therefore:

- Placement of data relative to computation affects scalability
- Give programmers control of data and task placement

Note:

- As core counts grow, locality will matter more on desktops
- GPUs and accelerators already expose node-level locality

5) Reduce Gap Between HPC & Mainstream Languages

Consider:

- Students graduate with training in Java, Matlab, Perl, Python
- Yet HPC programming is dominated by Fortran, C/C++, MPI

We'd like to narrow this gulf with Chapel:

- to leverage advances in modern language design
- to better utilize the skills of the entry-level workforce...
- ...while not ostracizing the traditional HPC programmer
  - e.g., support object-oriented programming, but make it optional

Questions?