CCA Collective Ports Specification

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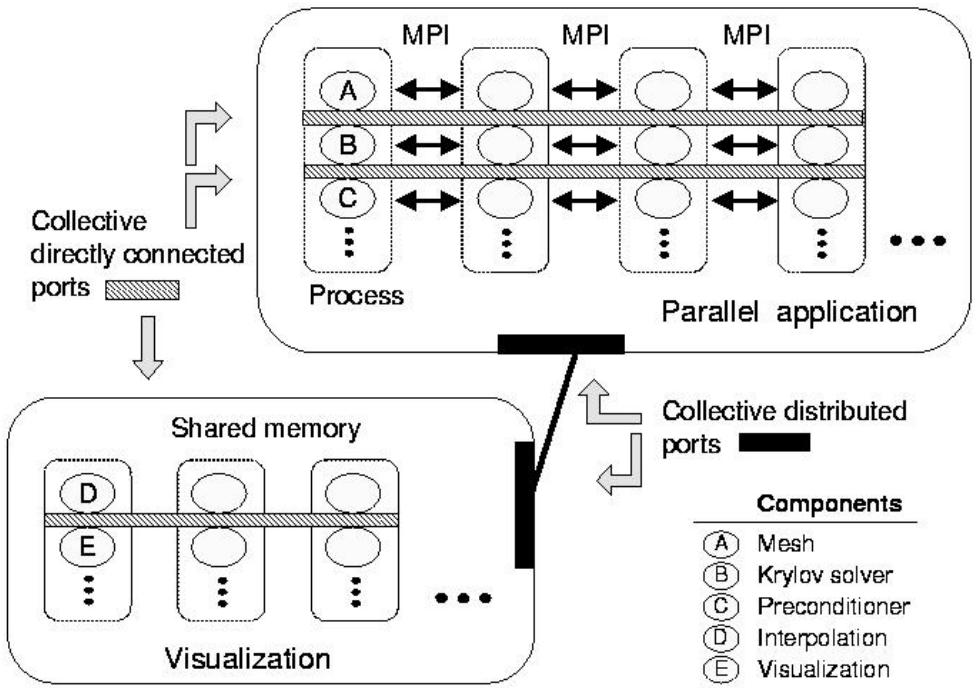
Collective Ports

- Extension of Basic Ports Model
  - ⇒ For Parallel Components, Distributed Data
- Extract & Assemble Subsets of Data Fields
  - ⇒ Online Visualization, Model Coupling
- Need Map of Data Layout / Decomposition
  - ⇒ Automate Data Collection (Hide Parallel Details)
  - ⇒ Support Interpolation or Re-Distribution of Data
  - ⇒ Improve Usability of Data (Data Semantics)

Arbitrary Data Distributions

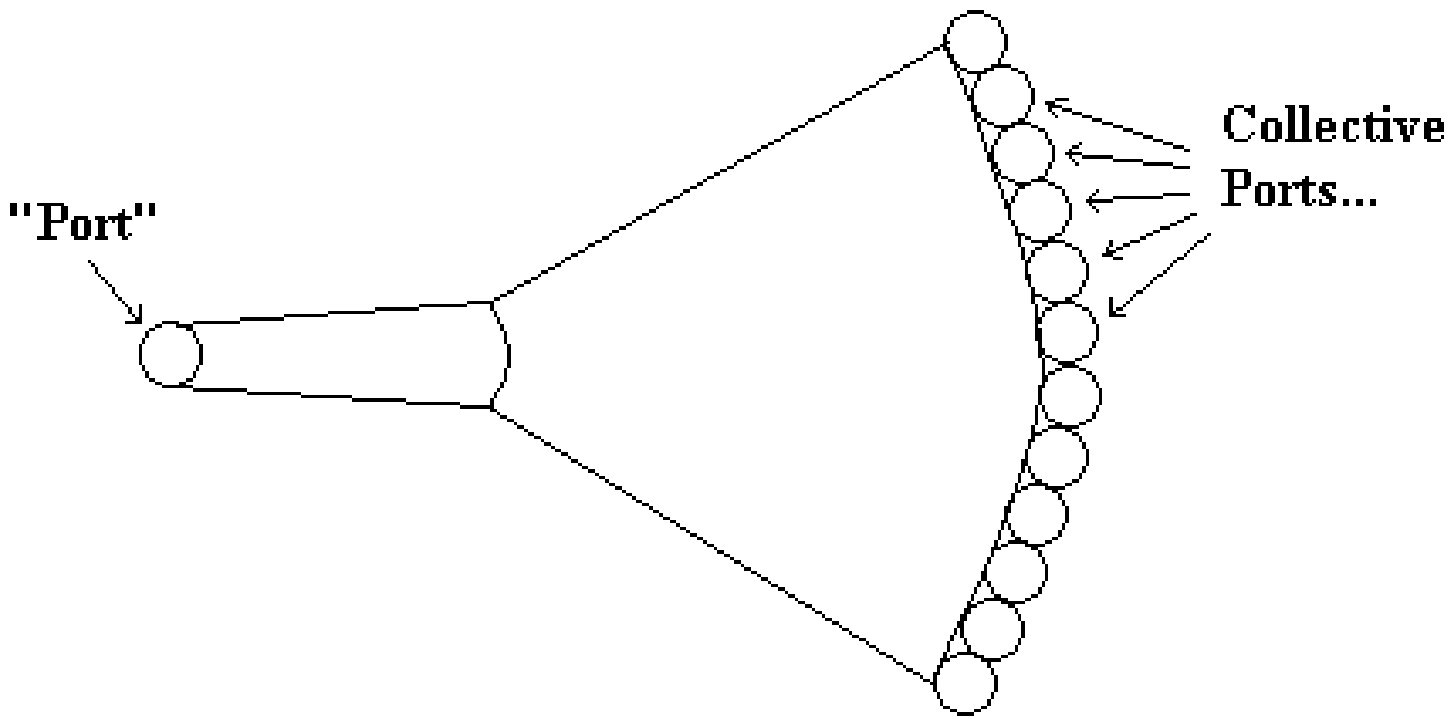
- Mixtures: NxN, 1xN, NxM, Dynamic

  ⇒ Varying Models: Distributed / Shared Memory



Two Views of a Collective Port

- Front-End View ~ Just Looks Like a “Port”
- Back-End View ~ Parallel Collection of Ports



Base Port Information

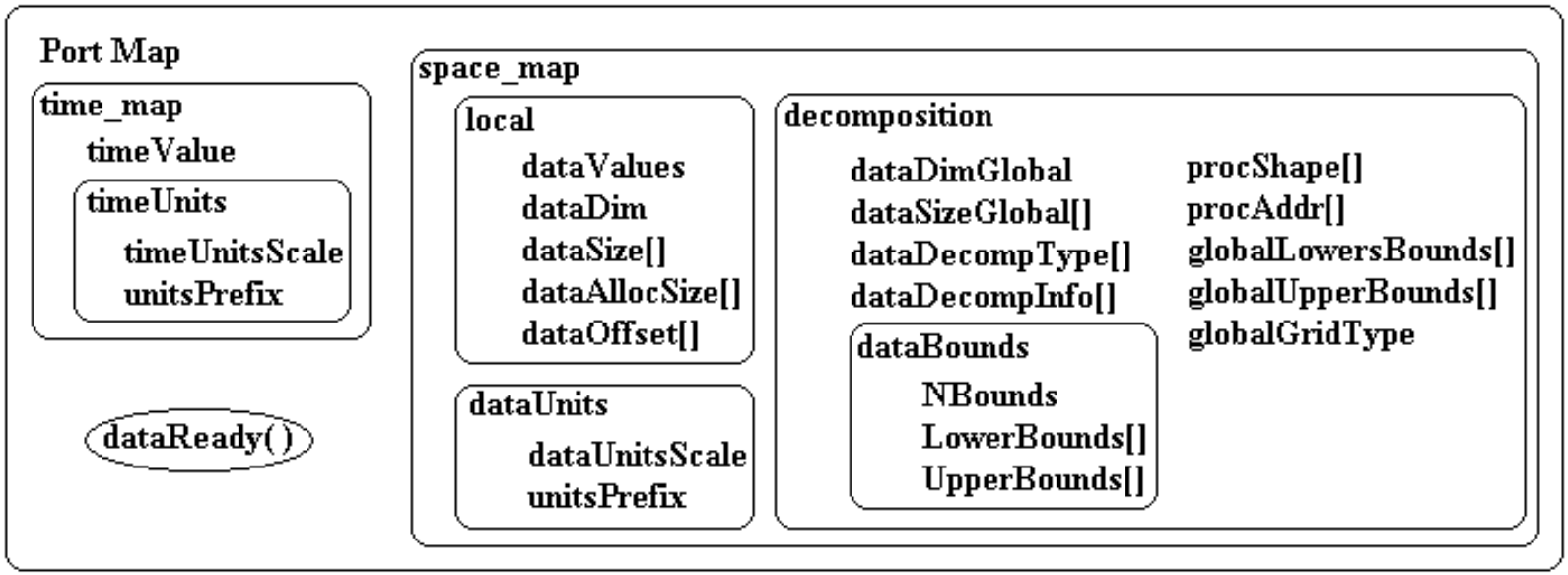
- ***Name*** ~ Semantic or Logical Description
- ***Data Type*** ~ Raw Data Format

$\Rightarrow$ For Generic Handling of Transfers

$\Rightarrow$ No Knowledge of Parallel Context Required

Collective Port Map

- ***Time Map*** ~ Time Scale of Data Snapshots
- ***Space Map*** ~ Spatial Organization of Data



Time Map

- Ports Produce Sequence of Data Snapshots
  - ⇒ Each Frame Has Associated "Time"…
    - → Explicit or Implied…
- Scientific Simulations
  - ⇒ Passage of Simulated Time, Time Steps
- Iterative Computations
  - ⇒ Simple Iteration Counts, Toward Convergence
- Static Data Sources
  - ⇒ Effective Time Scale of Zero.

Specifying Time Values

- Time Value with Units and Scale Factor

  ⇒ Immense Range of Times, High Precision, Good Redundancy for Convenience…

```
struct  time_map {
    float  timeValue;
    struct  timeUnits {
        enumerated  timeUnitsScale =
            { “seconds,” “minutes,” “hours,” “days,”
                “weeks,” “years,” “decades,” “centuries” };
        enumerated  unitsPrefix =
            { “pico,” “nano,” “micro,” “milli,” “centi,” “deci,”
                “deca,” “kilo,” “mega,” “giga,” “tera,” “peta” };
    };
};
```

When Can Data Be Extracted?

- Snapshots More Often Than Whole Iteration?
  - ⇒ Debugging, Sub-Steps of Computation…
- Component Must Choose Minimal Time Scale
  - ⇒ Nested Components?
- “Consistent” Data Snapshots?
  - ⇒ Application Must Define “When” & “Where”...

Instrument Computation

- Invoke ***dataReady***( ) Method for Port.
  - ⇒ Beginning or End of Primary Loops
  - ⇒ Other "Logical" Points in Computation…
- Bothersome and Intrusive…
  - ⇒ Though Simple and Direct!
- Convenient Hook for Non-Threaded Apps

What if the Time Scale is Dynamic?!

- Multi-Phase, Multi-Level or Non-Traditional
- Each Data Frame Needs Unique Time Map

  ⇒ Pass Optional "***struct time_map***" Argument to ***dataReady***( ) …
- Gives Sequence of Time Values

  ⇒ Use to Decode and Interpolate Data Frames (As Needed)

Spatial Mapping

- ***Local*** ~ Allocation & Layout of Local Data
  - ⇒ Some Information Obtainable Automatically…
- ***Decomposition*** ~ Context in Global Array
  - ⇒ Semantics of Locally-Stored Portion
  - ⇒ Maps Each Local Element to a Global Element
  - ⇒ Usually Only *Implied* By Data Usage…
- Full Specification of Both Required
  - ⇒ For Framework to Handle Extraction / Collection

Local Specification

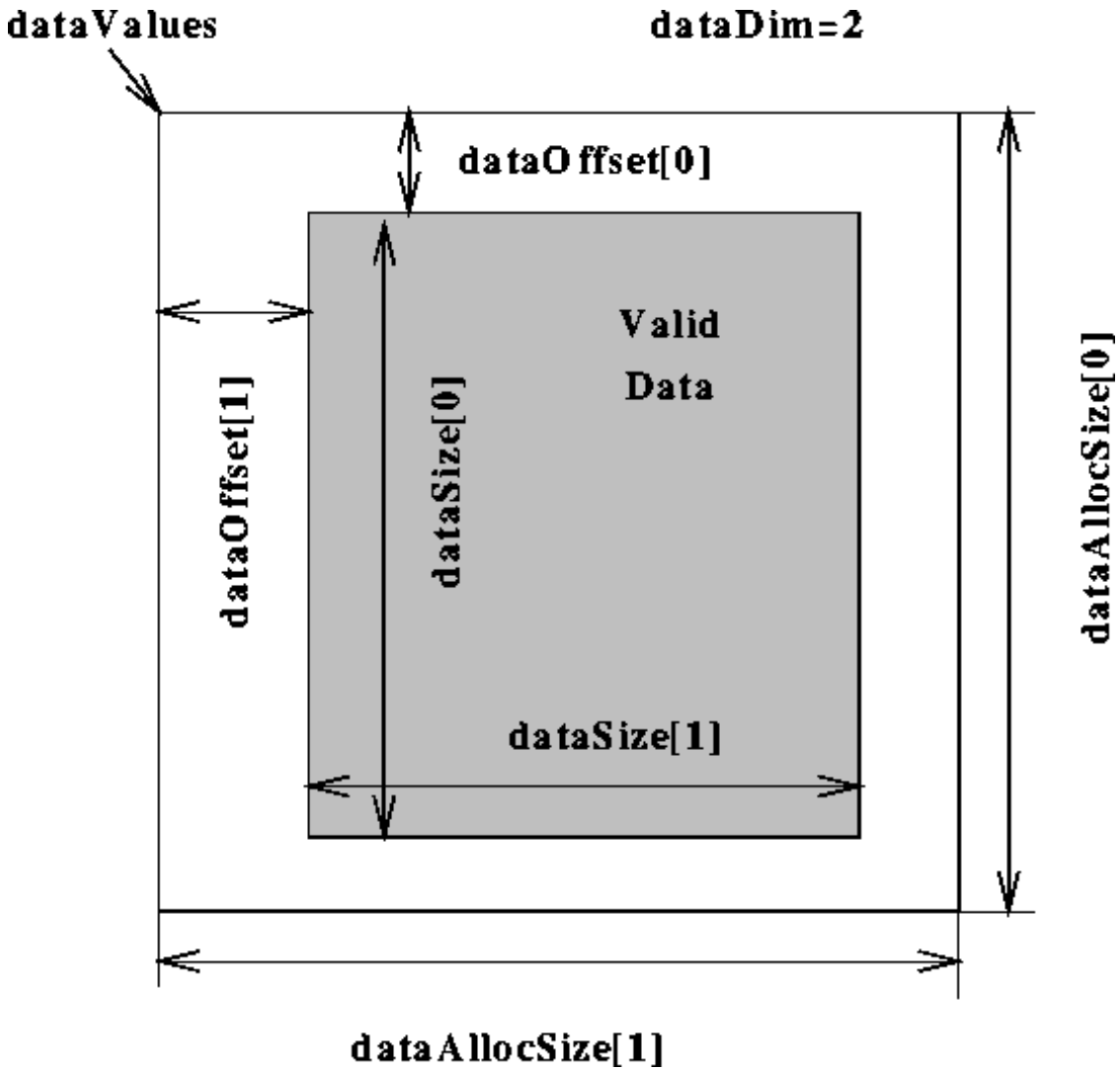
- For Locating Specific Local Data Elements
- Pointer to Actual ***dataValues***
- Local Array Size Information

  ⇒ ***dataDim***, ***dataSize***[ ]…
- Local Allocation Can Be Oversized!

  ⇒ Boundary Regions for Neighbor Communication

  ⇒ Only Use Portion of Larger Static Allocation
- So…. ***dataAllocSize***[ ] & ***dataOffset***[ ]…

Fully Specified Local Storage



Decomposition Specification

☙ Global Context of Local Data Elements ❧

- Global Array Size, Shape and Coordinates
- Decomposition Types for Each Axis
  - ⇒ With Detail Information
- Process / Thread Topology & Local Position
- Units of Actual Data

Global Array Size, Shape, Coords

- ***dataDimGlobal*** ~ Dimension of Global Array
- ***dataSizeGlobal***[ ] ~ Size Along Each Axis
- Coordinate Labels of Global Array

  ⇒ Identify Subregions for Collection

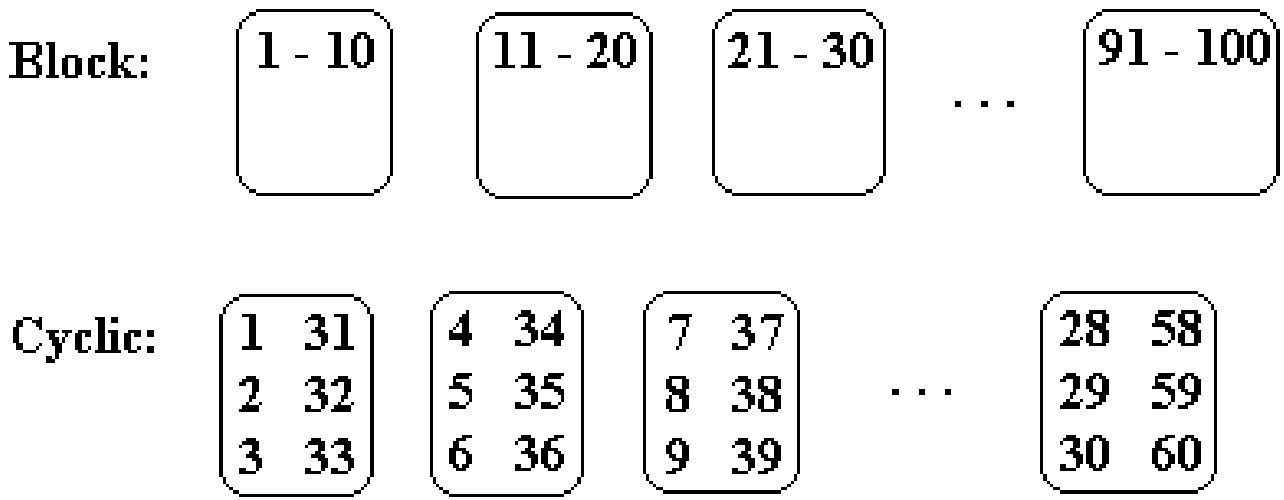
  ⇒ Frame of Reference for Sharing Data

  ⇒ ***globalLowerBounds***[ ] & ***globalUpperBounds***[ ]
- Global Grid Type

  ⇒ ***string globalGridType*** ~ polar, spectral, rect…

Decomposition Types

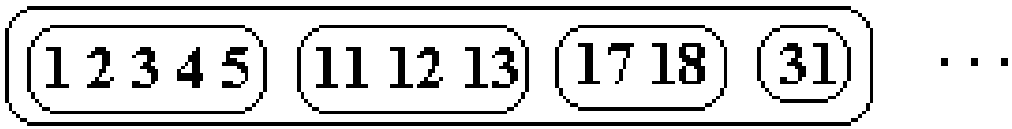
- ***enumerated dataDecompType***[ ]:
  - ⇒ "Standard" HPF-like Definitions
  - ⇒ ***Block, Cyclic, Collapse, Explicit***
- ***dataDecompInfo***[ ] ~ Detail for Block/Cyclic



Explicit Decompositions

- "Catch All" for Non-Standard Decompositions

  ⇒ Multiple Ranges Along Given Axis




```
struct  dataBounds[ dataDimGlobal ]  {
        int  NBounds;
        int  LowerBounds[ NBounds ];
        int  UpperBounds[ NBounds ];
};
```

Topology & Position

- ***procShape***[ ] ~ Organization of Parallel Tasks
  - ⇒ Number of Tasks Participating for Each Axis
- ***procAddr***[ ] ~ Local Task's Position
  - ⇒ Index Along Each Decomposition Axis
  - ⇒ Determines Local Portion of Global Array

Units of Actual Data

- Similar to Time Units…
- ***string dataUnitsScale*** ~ Units Description
  - ⇒ Immense Set of Possible Values
  - ⇒ Defined By Each Application Domain
- ***enumerated unitsPrefix*** ~ Same as Time
  - ⇒ “pico,” “nano,” … “tera,” “peta”

Dynamic Spatial Mappings

- Changing Decomposition or Grid
  - ⇒ E.g. Adaptive Mesh Refinement
- Optional "***struct space_map***" to ***dataReady***( )
  - ⇒ Just Like Dynamic Time Scale…
  - ⇒ Each Data Snapshot ~ Distinct Spatial Layout

Front-End Port...

- What the Outside World Sees…
- Includes:
  - ⇒ Time Map
    - → ***timeValue***, { ***timeUnitsScale***, ***unitsPrefix*** }
  - ⇒ Global Array Size
    - → ***globalLowerBounds***[ ], ***globalUpperBounds***[ ]
    - → ***globalGridType***
  - ⇒ Data Units
    - → ***dataUnitsScale***, ***unitsPrefix***
- Optional Subregion Bounds in ***getPort***()…

Particle-Based Data

- Non-Contiguous Data Distribution
  - ⇒ Specialized Collective Port Needed
  - ⇒ Replace ***decomposition*** with ***particle***…
  - ⇒ A ***particle*** Still Has:
    - → ***dataDimGlobal***
    - → ***globalLowerBounds***[ ] & ***globalUpperBounds***[ ]
    - → ***globalGridType***
  - ⇒ Describe Coordinate Space for Particles
  - ⇒ Subregion in Space Selects Particle Subsets

Particle Data Fields

- ***NFields*** ~ Number of Data Fields in Particle

  ⇒ Simple Data Fields/Arrays, No Decompositions

```
struct  partFields[ NFields ] {
        string  Name;
        enumerated  dataType = { . . . };
        int  dataDim;
        int  dataSize[ dataDim ];
};
```

Extracting Particle Data

- No Well-Defined /Accepted Particle Format

  ⇒ User-Defined Accessor Methods

- ***particleGet*( )** ~ Return Particle "Handle" List

  ⇒ User-Defined, (void *) pointers.

```
void  particleGet (
        int  regionLowerBounds[ dataDimGlobal ].
        int  regionUpperBounds[ dataDimGlobal ],
        void  *parts[ nparts ],
        int  coords[ nparts ][ dataDimGlobal ],
        int  *nparts );
```

Interpolation in Time & Space

- If Port's Data Not In Form Desired
  - ⇒ Either Temporally or Spatially (or Both!)…
- Visualization? No, Leave Data As Is…
- Model Coupling? A Necessity!
- Too Many Interpolation Techniques… :-Q
  - ⇒ Provide Hooks for User-Defined Methods
- Part of "Uses" Port Interface
  - ⇒ "Provider" Just Doesn't Wanna Know… :-)

Temporal Interpolation

- Goal: Process Sequence of Data Snapshots for Different Time Steps to Produce a New Snapshot for Some Other Target Time.

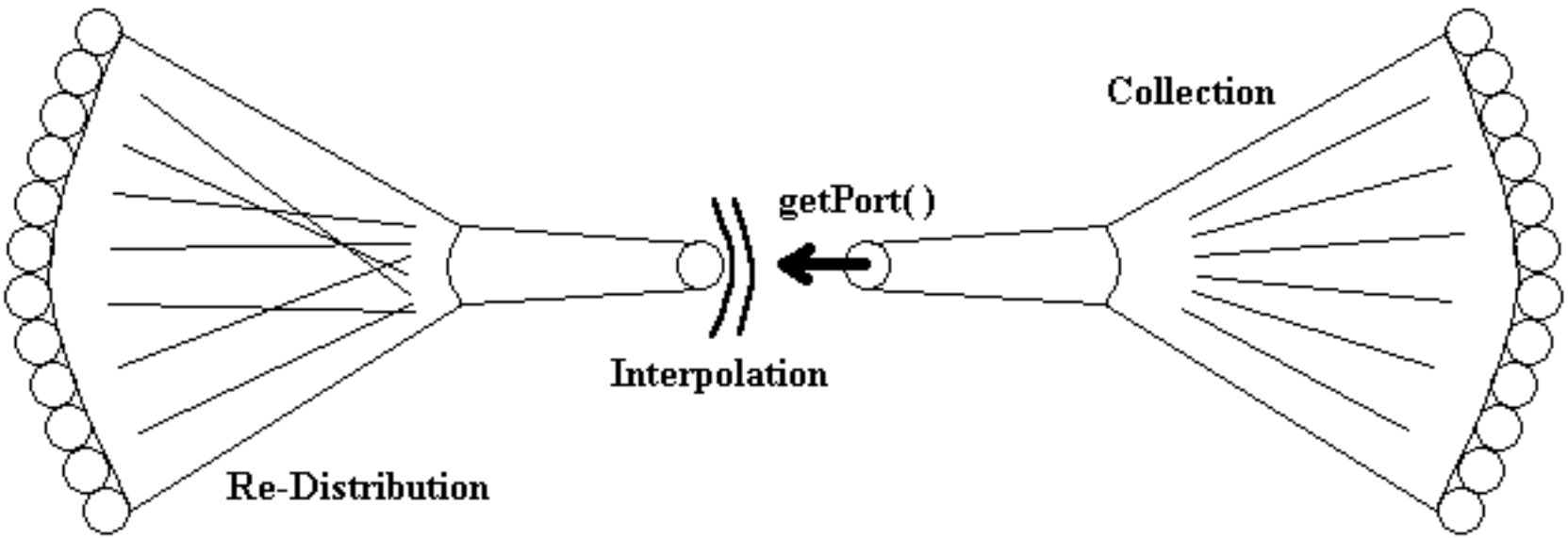
```
void dataInterpolateTime (
        struct space_map smap;
        struct time_map intimes[ nvals ];
        void *indata[ nvals ];
        int nvals;
        struct time_map outtime;
        void *outdata );
```

Spatial Interpolation

- Goal: Translate a Data Array into a Different Spatial Map.

```
void  dataInterpolateSpace (
        struct  space_map  insmap;
        void  *indata;
        struct  space_map  outsmap;
        void  *outdata );
```

Interpolation vs. Re-Distribution



Conclusion

- Some Portions of Collective Map Generalize
  - ⇒ Apply Equally Well to Serial Data
- Basic Port ~ Special Case of Collective
  - ⇒ Without Decomposition / Particle Specification
- To Integrate Into Basic Port Interface:
  - ⇒ ***time_map***
  - ⇒ ***space_map***: ***local***, ***global*** * and ***dataUnits***
  - ⇒ ***dataReady***( )

Oh Yeah, THE DEMO…

- "Viz" Side…
  - ⇒ Porting CUMULVS to Nexus / Globus
  - ⇒ Representative CUMULVS "Kernel" Works
- To Do Next:
  - ⇒ Finesse Nexus Model Into CUMULVS Comm
  - ⇒ Clean Up CUMULVS Message Handlers
- Next BIG Task:
  - ⇒Wrap CUMULVS for CCA ~ Interface to Ports