Chares are reactive

- The way we described Charm++ so far, a chare is a reactive entity:
  - If it gets this method invocation, it does this action,
  - If it gets that method invocation then it does that action
  - But what does it do?
  - In typical programs, chares have a *life-cycle*
- How to express the life-cycle of a chare in code?
  - Only when it exists
    - i.e. some chars may be truly reactive, and the programmer does not know the life cycle
  - But when it exists, its form is:
    - Computations depend on remote method invocations, and completion of other local computations
    - A DAG (Directed Acyclic Graph)!

Structured Dagger (sdag)

The *when* construct

- sdag code is written in the .ci file
- It is like a script, with a simple/narrow language
- Important: The *when* construct
  - Declare the actions to perform when a method invocation is received
  - In sequence, it acts like a blocking receive

```
entry void someMethod() {
        when entryMethod1(parameters) { block1  }
        when entryMethod2(parameters) {  block2  }
        block3
};
```

Structured Dagger

The *serial* construct

- The ***serial*** construct
  - A sequencial block of C++ code in the .ci file
  - The keyword ***serial*** means that the code block will be executed without interruption/preemption, like an entry method
  - Syntax: ***serial <optionalString> {/*C++ code*/ }***
  - The ***<optionalString>*** is used for identifying the ***serial*** for performance analysis
  - Serial blocks can access all members of the class they belong to
- Examples:

```
entry void method1(parameters) {
   when E(a)
    serial
      { thisProxy.invokeMethod(10, a);
           callSomeFunction(); }
…
};
```

```
entry void method2(parameters) {
   serial "setValue" {
      value = 10;
   }
};
```

Structured Dagger

The *when* construct

```
entry void someMethod() {
    serial { /* block1 */ }
    when entryMethod1(parameters) serial { /* block2 */ }
    when entryMethod2(parameters) serial { /* block3 */ }
};
```

- Sequence (implicit.. No construct name)
- Sequentially execute:

1. /* block1 */
2. Wait for `entryMethod1` to arrive, if it has not, return control back to the Charm++ scheduler, otherwise, execute `/* block2 */`
3. Wait for `entryMethod2` to arrive, if it has not, return control back to the Charm++ scheduler, otherwise, execute `/* block3 */`

Structured Dagger

The *when* construct

- Execute *"further code"* when ***myMethod*** arrives

```
when myMethod(int param1, int param2)
   /* further code */
```

- Execute *"further code"* whenM1 and *M2* arrive

```
When M1(int param1, int param2), M2(bool param3)

          /* further code */
```

Structured Dagger

Boilerplate

- Structured Dagger can be used in any entry method (except for a constructor)
    - Can be used in a *`mainchare`* , *`chare`* , or *`array`*
- For any class that has Structured Dagger in it you must insert:
    - The Structured Dagger macro: *`[ClassName]_SDAG_CODE`*

Structured Dagger

Boilerplate

The .ci file:

```
[mainchare,chare,array] MyFoo {
    …
    entry void method(parameters) {
        // … structured dagger code here …
    };
    …
}
```

The .cpp file:

```
class MyFoo : public CBase MyFoo {
    MyFoo_SDAG_Code/* insert SDAG macro */
public:
    MyFoo() { }
};
```

Structured Dagger

The *when* construct

- What is the sequence?

```
when myMethod1(int param1, int param2) {
   when myMethod2(bool param3),
         myMethod3(int size, int arr[size]) /* sdag block1 */
   when myMethod4(bool param4) /* sdag block2 */
}
```

- Sequence:
  - Wait for *`myMethod1`* , upon arrival execute body of *`myMethod1`*
  - Wait for *`myMethod2`* and *`myMethod3`* , upon arrival of both, execute *`/* sdag block1 */`*
  - Wait for *`myMethod4`* , upon arrival execute *`/* sdag block2 */`*
- Question: if *`myMethod4`* arrives first what will happen?

Structured Dagger

The *when* construct: refnum

- The *when* clause can wait on a certain reference number
- If a reference number is specified for a *when* , the first parameter for the *when* must be the reference number
- Semantic: the *when* will “block” until a message arrives with that reference number

```
when method1[100](int ref, bool param1)
    /* sdag block */

serial {
   proxy.method1(200, false); /* will not be delivered to the when */
   proxy.method1(100, true); /* will be delivered to the when */
}
```

Structured Dagger

The *if-then-else* construct

- The *if-then-else* construct:
  - Same as the typical C if-then-else semantics and syntax

```
if (thisIndex.x == 10) {
    when method1[block](int ref, bool someVal) /* code block1 */
} else {
    when method2(int payload) serial {
        //... some C++ code
    }
}
```

Structured Dagger

The *for* construct

- The *for* construct:
  - Defines a sequenced *for* loop (like a sequential C for loop)
  - Once the body for the *i*th iteration completes, the *i* + 1 iteration is started

```
for (iter = 0; iter < maxIter; ++iter) {
   when recvLeft[iter](int num, int len, double data[len])
      serial { computeKernel(LEFT, data); }
   when recvRight[iter](int num, int len, double data[len])
      serial { computeKernel(RIGHT, data); }
}
```

- *iter* must be defined in the class as a member

```
class Foo : public CBase Foo {
   public: int iter;
};
```

Structured Dagger

The *while* construct

- The *while* construct:
  - Defines a sequenced *while* loop (like a sequential C while loop)

```
while (i < numNeighbors) {
  when recvData(int len, double data[len]) {
    serial {
      /* do something */
    }
    when method1() /* block1 */
    when method2() /* block2 */
  }
  serial { i++; }
}
```

Structured Dagger

The *overlap* construct

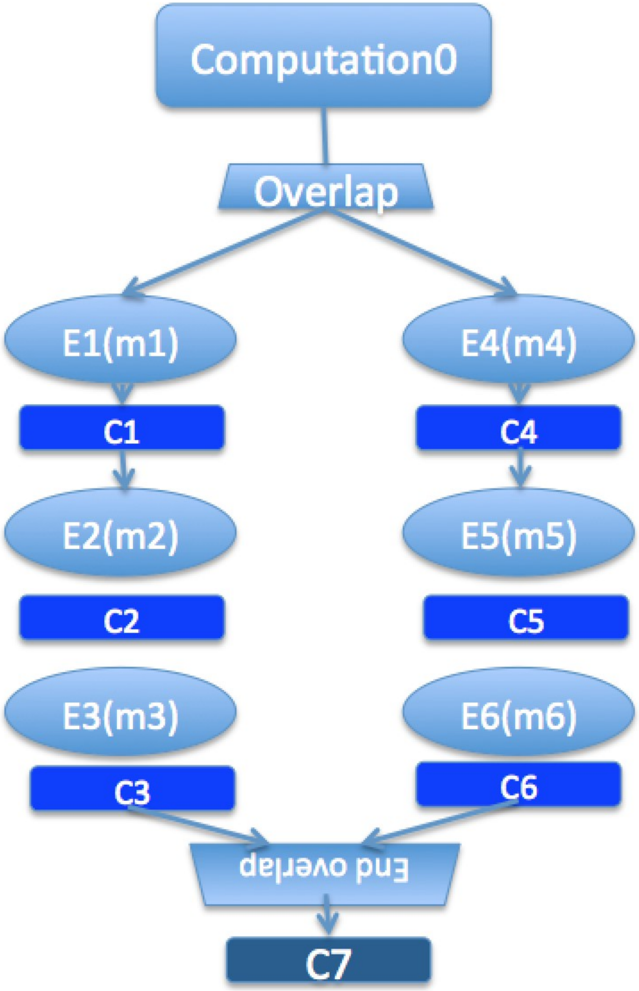
- The `overlap` construct:
  - By default, Structured Dagger defines a sequence that is followed sequentially
  - `overlap` allows multiple independent clauses to execute in any order
  - Any constructs in the body of an `overlap` can happen in any order
  - An `overlap` finishes in sequence when all the statements in it are executed
  - Syntax `overlap { /* sdag constructs */ }`

What are the possible execution sequences?

```
serial { /* block1 */ }
overlap {
   serial { /* block2 */ }
   when entryMethod1[100](int ref num, bool param1) /* block3 */
   when entryMethod2(char myChar) /* block4 */
}
serial { /* block5 */ }
```

Illustration of a long "overlap"

- Overlap can be used to get back some of the asynchrony within a chare
  - ➢ But it is constrained
  - ➢ Makes for more disciplined programming,
    - with fewer race conditions



Structured Dagger

The *forall* construct

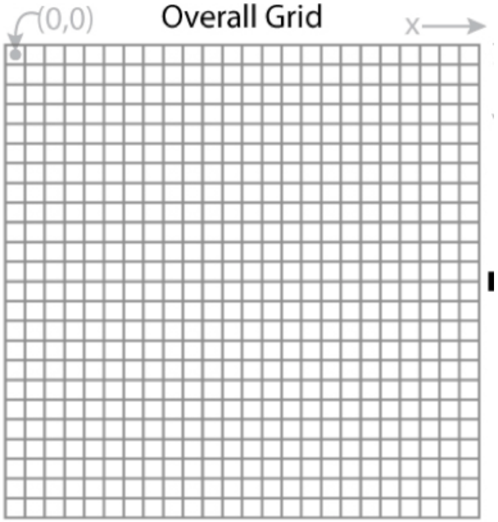
- The *forall* construct:
  - Has “do-all” semantics: iterations may execute an any order
  - Syntax:

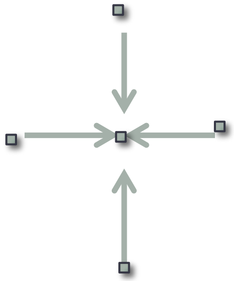
    `forall [<ident>] (<min> : <max>, <stride>) <body>`
  - The range from *<min>* to *<max>* is inclusive

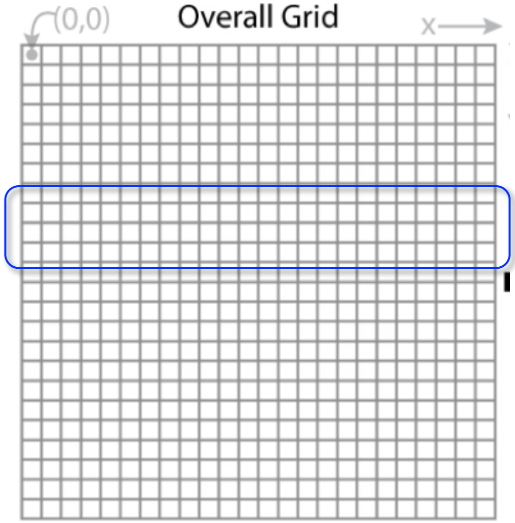
```
forall [block] (0 : numBlocks – 1, 1) {
    when method1[block](int ref, bool someVal) /* code block1 */
}
```

- Assume *block* is declared in the class as *public: int block;*

5-point Stencil

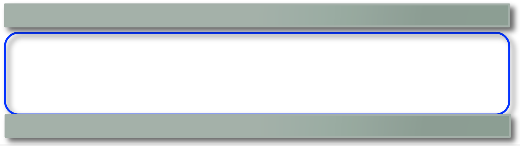






1-D decomposition: each chare object owns a strip

Need to exchange top and bottom boundaries



Jacobi: .ci file

```
mainmodule jacobi1d {
    readonly CProxy Main mainProxy;
    readonly int blockDimX;
    readonly int numChares;

    mainchare Main {
        entry Main(CkArgMsg *m);
    };
    array [1D] Jacobi {
        entry Jacobi(void);
        entry void recvGhosts(int iter, int dir, int size, double gh[size]);
        entry [reductiontarget] void isConverged(bool result);
        entry void run() {
            // ... main loop (next slide) ...
        };
    };
};
```

```
while (!converged) {
  serial "send_to_neighbors" {
    iter++;            top = (thisIndex+1)%numChares; bottom = …;
    thisProxy(top).recvGhosts(iter, BOTTOM, arrayDimY, &value[1][1]);
    thisProxy(bottom).recvGhosts(iter, TOP, arrayDimY, &value[blockDimX][1]); }
  for(imsg = 0; imsg < neighbors; imsg++)
    when recvGhosts[iter] (int iter, int dir, int size, double gh[size])
       serial "update_boundary" {
       int row = (dir == TOP) ? 0 : blockDimX+1;
       for(int j=0; j<size; j++)  value[row][j+1] = gh[j];  }

  serial "do_work" {
    conv = check_and_compute();    // conv: a boolean indicating local convergence
    CkCallback cb =  CkCallback(CkReductionTarget(Jacobi, isConverged), thisProxy);
    Contribute(sizeof(bool), &conv, CkReduction::logical_and, cb); }
  when isConverged(bool result) serial "check_converge" {
    converged = result; if (result && thisIndex == 0) CkExit(); }
}
```

```
while (!converged) {
  serial "send_to_neighbors" {
    iter++;              top = (thisIndex+1)%numChares; bottom = …;
    thisProxy(top).recvGhosts(iter, BOTTOM, arrayDimY, &value[1][1]);
    thisProxy(bottom).recvGhosts(iter, TOP, arrayDimY, &value[blockDimX][1]); }
  for(imsg = 0; imsg < neighbors; imsg++)
    when recvGhosts[iter] (int iter, int dir, int size, double gh[size])
       serial "update_boundary" {
       int row = (dir == TOP) ? 0 : blockDimX+1;
       for(int j=0; j<size; j++)  value[row][j+1] = gh[j];  }

  serial "do_work" {
    conv = check_and_compute();    // conv: a boolean indicating local convergence
    CkCallback cb =  CkCallback(CkReductionTarget(Jacobi, isConverged), thisProxy);
    Contribute(sizeof(bool), &conv, CkReduction::logical_and, cb); }
  when isConverged(bool result) serial "check_converge" {
    converged = result; if (result && thisIndex == 0) CkExit(); }
  if (iter % LBPERIOD == 0) {serial "start_lb" { AtSync();} when ResumeFromSync() {}}
}
```

```
while (!converged) {
  serial "send_to_neighbors" { //… send to neighbors..}

  for(imsg = 0; imsg < neighbors; imsg++)
    when recvGhosts[iter] (int iter, int dir, int size, double gh[size])
      serial "update_boundary" {
      int row = (dir == TOP) ? 0 : blockDimX+1;
      for(int j=0; j<size; j++)  value[row][j+1] = gh[j];  }

  serial "do_work" {
    conv = check_and_compute();    // conv: a boolean indicating local convergence
    if (iter%5==1) serial "send_converge" {
      CkCallback cb =  CkCallback(CkReductionTarget(Jacobi, isConverged), thisProxy);
      Contribute(sizeof(bool), &conv, CkReduction::logical_and, cb); }
  if (iter%5==4)
    when isConverged(bool result) serial "check_converge" {
      converged = result; if (result && thisIndex == 0) CkExit(); }
}
```