Writing Better Charm Programs More Easily Using Charj

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What’s the matter with Charm?

Opaque semantics

What does this Charm code do?

```
w.compute();
x.compute();
y.compute();
z.compute();
```

Opaque semantics

What does this Charm code do?

```
w.compute(); // local method
x.compute(); // entry method
y.compute(); // sync entry method
z.compute(); // array broadcast
```

Opaque semantics

What does this Charm code do?

```
w.compute(); // blocking, local
x.compute(); // nonblocking, entry
y.compute(); // blocking, entry
z.compute(); // n invocations
```

Non-local semantic information

```
// A sync, expedited entry method
void foo::twist() { ... }

// A local method
void foo::shout() { ... }
```

Non-local semantic information

```
int n; // readonly variable
...
n = 17; // Ok if we’re in a
        // mainchare constructor.
        // Silent bug otherwise.
```

Stop repeating yourself

```
// foo.ci
entry void twist();

// foo.h
void twist();

// foo.cc
void foo::twist() { ... }
```

Limited Scope for Checking & Optimizations

- Most of your code is only seen by a C++ compiler
- No way to do lots of simple things:
  - observe messaging behavior
  - enforce Charm semantics
  - instrument or modify method implementations
- Moving more stuff into the translator sort of works (e.g. SDAG, accelerated entry methods), but it’s difficult, inflexible, and not very powerful.

Charj

Charm programs, but more productive

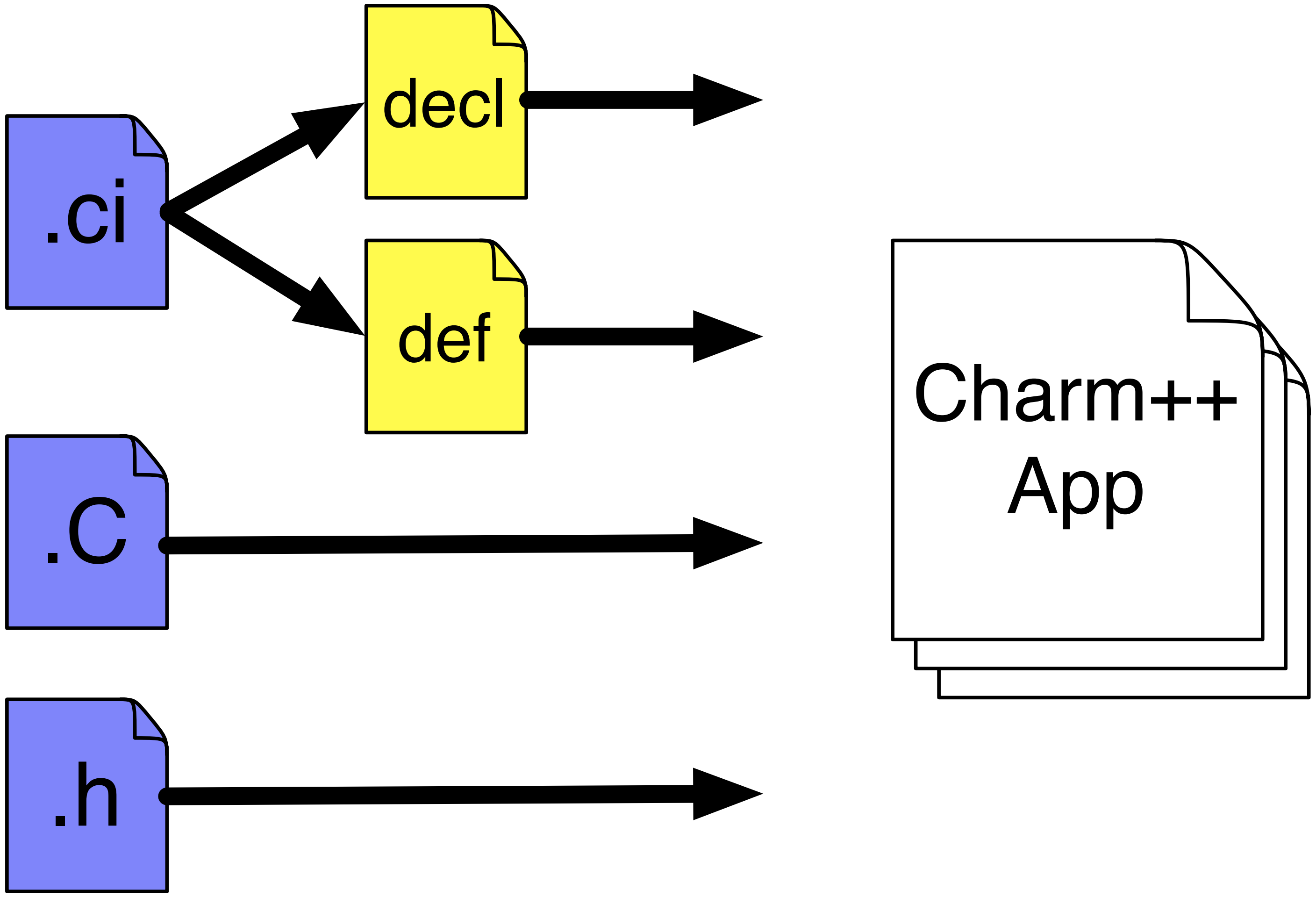
- Make syntax more meaningful
- Avoid boilerplate/automatic code
- Provide optimizations that are impossible at the library level
- Provide more safety
- Facilitate DSLs and “Little Languages”

Charj Infrastructure

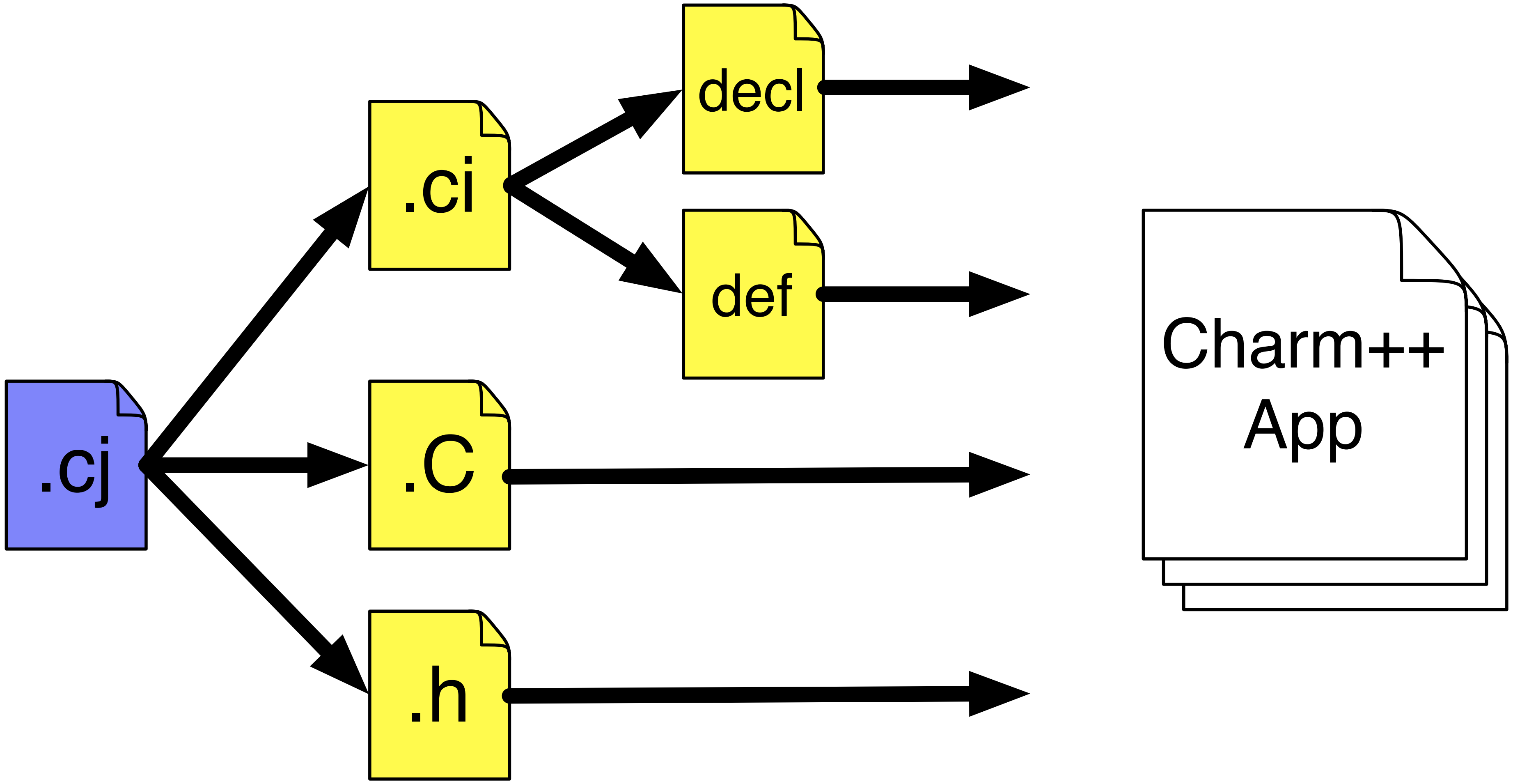
Technology

- ANTLR to lex, parse, and manipulate AST
- Simple Java/C#/D-inspired syntax
- Charj-specific libraries for things like arrays, ranges
- Translated to C++

Charm Translation/Compilation



Charj Translation/Compilation



Writing Clearer Programs

Charm-specific Syntax

- Use ‘@’ to indicate proxy operations/remote invocation

```
workerProxy.do_work(x, y, z,
       CkCallback(CkIndex_Manager::report_back));


vs


workerProxy@do_work(x, y, z, @Mananger.report_back);
```

Reductions in Charm

```
Worker::do_reduction() {
    int contribution = 1;
    contribute(1*sizeof(int), &contribution,
        CkReduction::sum_int);
}

Worker::reduction_done(CkReductionMsg* m) {
    int result = *((int*)m->getData());
    // ...
 }
```

Typed Reductions in Charj

```
Worker::do_reduction() {
    int contribution = 1;
    contribute(contribution, Reduction.sum);
}

Worker::reduction_done(int result) {
    // ...
}
```

Applying Simple Analysis

Packing and Unpacking

- Packing and unpacking data structures in Charm is mostly boilerplate

```
class Point3d {
    double x, y, z;
    void pup(PUP::er& p) { p|x; p|y; p|z; }
}
```

- Why should you have to write this code?
- What if you’re only going to use some of the class’s data on the receiving end?

Example: Computing Local Finite Element Solutions

```
class Element {
    // Geometry data
    vector coordinates, neighbors, normals;
    // Physics Data
    quadrature_info q;
    matrix basis, jacobian, boundary_data, cohesive_data;
}
smoothRegion(Element e, ... {...}
refineRegion(Element e, ...) {...}
coarsenRegion(Element e, ...) {...}
solveRegion(Element e, ...) {...}
```

How do we write entry methods?

```
smoothRegion(Element e, ...) // uses a subset of geom. data
refineRegion(Element e, ...) // a different subset of geom. data
solveRegion(Element e, ...) // uses a subset of phys. data
```

It would be wasteful to pack all that unneeded data

```
smoothRegion(SmoothMessage)
refineRegion(RefineMessage)
coarsenRegion(CoarsenMessage)
solveRegion(SolveMessage)
```

Lots of boring packing/unpacking code.

Creating Custom Pack/Unpack Code

```
entry void smoothRegion(Element e) {
    for each neighbor in e.neighbors
        if can_smooth(neighbor)
            ...
}
```

Creating Custom Pack/Unpack Code

```
entry void smoothRegion(Element e) {
    for each neighbor in e.neighbors
        if can_smooth(neighbor)
            ...
}
```

- identify all possible reads to *e* (being conservative)
- generate a custom method to pack/unpack only what is needed for this particular entry method
- fall back on full pack/unpack code where needed

Improving Charm’s “Little Languages”

MSA: Globally Addressable Arrays

```
// arr is an MSA array
for (int i=0; i<x_dim; ++i) {
    for (int j=0; j<y_dim; ++j) {
        update(arr[i][j]);
    }
}
```

MSA: Globally Addressable Arrays

```
// arr is an MSA array
for (int i=my_x; i < my_x+tile_x; ++i) {
    for (int j=my_y; j < my_y+tile_y; ++j) {
        update(arr[i][j]);
    }
}

// Inside arr[i][j], we need to check if the array element is
// local, and fetch it if needed.
```

This access may be local or non-local

MSA: Globally Addressable Arrays

```
// A higher-performance approach
arr.ensure_region_local(my_x, my_y, my_x+tile_x, my_y+tile_y);
for (int i=my_x; i < my_x+tile_x; ++i) {
    for (int j=my_y; j < my_y+tile_y; ++j) {
        update(arr.unsafe_read(i, j));
    }
}

// Faster, but also uglier.
```

MSA: Globally Addressable Arrays

```
for (int i=my_x; i < my_x+tile_x; ++i) {
    for (int j=my_y; j < my_y+tile_y; ++j) {
        update(arr[i][j]);
    }
}

// What we want: simple, natural expression
// without sacrificing efficiency.
```

Opportunities for Improvement

- Embed SDAG in any method
- Enforce readability and writability rules in accelerated entry methods
- Easy embedding of DSLs in Charm apps
  - DivCon, a DSL devoted to divide-and-conquer problems
- Better, smarter threading support

It is possible to write simpler, more expressive programs without giving up performance.