CS510 Languages and Low Level Programming: Portfolio submission, Topic 10

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Topic 10. Use practical case studies to evaluate and compare language design proposals.

With the lack of specific language for Low Level Programming, I picked two languages with Parallel Programming in mind (General C + MPI library, and Chapel - new domain specific language for parallel programming created by Cray). Even though domain is different it shows that language designed for a specific domain can drastically aid applications development. Parallel programming complexity is similar, if not greater than LLP, with many potential issues on the top of regular mistakes like concurrency issues such as race conditions, deadlocks etc. MPI - message passing interface is a well known standard for external parallel computing. Chapel is a modern high level language that hides all the intricacies of Message Passing. Chapel syntax is similar to Python, it is very expressive, safe, and has abstraction for many parallel programming approaches. Though Chapel is very different than C it uses C/MPI as an intermediate layer, i.e. first it compiles to C, hence the choice of comparison.

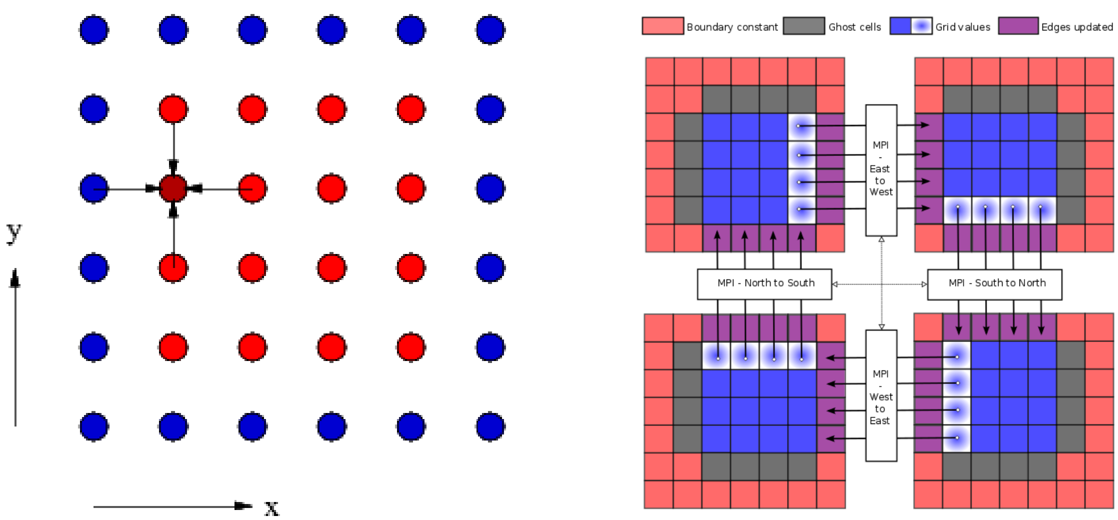
I Compare implementation of Jacobi-Laplace algorithm in C/MPI vs Chapel.

Problem Description

Jacobi-Laplace is a simple approach for solving Laplace equation with, used in many scientific applications, it is slow but highly parallelizable. Laplace equation : ${\phi^{t+1}}_{i,j} = \frac{1}{4}({\phi^t}_{i+1,j} + {\phi^t}_{i-1,j} + {\phi^t}_{i,j+1} + {\phi^t}_{i,j-1}), 0 < i, j < N$, i.e. current cell in a matrix is equal to a quarter of the sum of it's neighboring cells.

The main problem with external is matrix partitioning, and message passing when computing border elements (image on the right).

Figure 1: Element calculation on the left, MPI problem on the right (when matrix partitioned communication required among border layers)



Language Comparison, based upon Jacobi-Laplace implementation (included)

Table 1: Languages comparison

Types	C/MPI	Chapel
Complexity	High. It is quite a challenging task to do implement distributed Laplace in C/MPI, since matrix mapping to the network done manually, and all border communications are defined manually as well. The particular implementation I use as an example, divides matrix to 4 regions, each region is then sent to a remote CPU. It would be even more challenging to implement dynamic scalable matrix partitioning.	Low. As easy as implementing sequential version, just need to specify domain mapping. Chapel sequential and MPI implementations are almost identical, with one exception - matrix needs to be mapped to the distributed cluster. This is a natively supported operation in Chapel, short and concise. Unlike C doesn't require any math, or matrix offsets calculation. Code is simple and easy to read. Chapel includes multiple flexible partitioning schemes, and also allows custom defined schemes. The problem is mapped to the cluster automatically depending on the number of the available remote CPUs.
Typing	Weak. C allows unsafe type cast, any type can be converted to any other type C MPI interface, is limited to sending empty types (*void) so casting is required.	Strong. It is strong the sense that typing error are prevented at runtime with little implicit type conversion, and also utilizes static type checking. All border communication's are implicitly type checked during runtime.
Effort	High. Large ≈ 620 *lines* with comments	Low. Small ≈ 60 *lines* with comments
Performance	High. Area where C shines is performance. C implementation is up to x40 times faster.	Low. At this point of time Chapel suffers from performance issues. It is a new language, that is still undergoing major development, so intermediate C code produce by chapel compiler is far from being optimal. For example generated C code for the Laplace problem is $\approx 3K$ lines long
Abstraction	Low. Is one of the first "high level languages" is still very close to bare metal (No OOP, First order functions, Garbage Collection etc.)	High. Support most of the modern abstractions, and new abstractions for parallel programming, which makes conversion of sequential version of the algorithm trivial.
Expressiveness	Low. C is well known for being hard to understand - unclear syntax - subtle change in word ordering can cause unexpected behaviour, the same symbol used for multiple purposes.	High.
DS Features	Low. C is general purpose language, however it has been around long enough to have wide support and reach set of third party libraries, like MPI.	High. Chapel was specifically created for aiding Parallel Programming development easy, it supports most of the approaches out of the box (Shared Memory, Message Passing, Data parallelism).
Modularity	Medium.	High.
Simplicity	Medium.	High.
Optimization	High. C	High.

Both implementations are included to the submission. Files included:

- laplace-mpi.c - C/MPI
- chapel-distr.chpl - Chapel
- Makefile
- laplace-distr.c - Chapel Generated code (not to be compiled or executed).
- chpl-prep - Environment setup for running chapel applications.
- mpi-prep - Environment setup required for running MPI applications.
- mpihosts - Set of available hosts in the Linuxlab cluster.

Building and running

The code intended to be build on linuxlab machines.

```
make all
# MPI -
    source mpi-prep && mpirun -n 4 laplace-mpi  # number of remote procs must be 4 for
        this application
# Chapel
    source chpl-prep && ./laplace-distr -nl [number of remote procs] # number of
        procs can not exceed 20
```