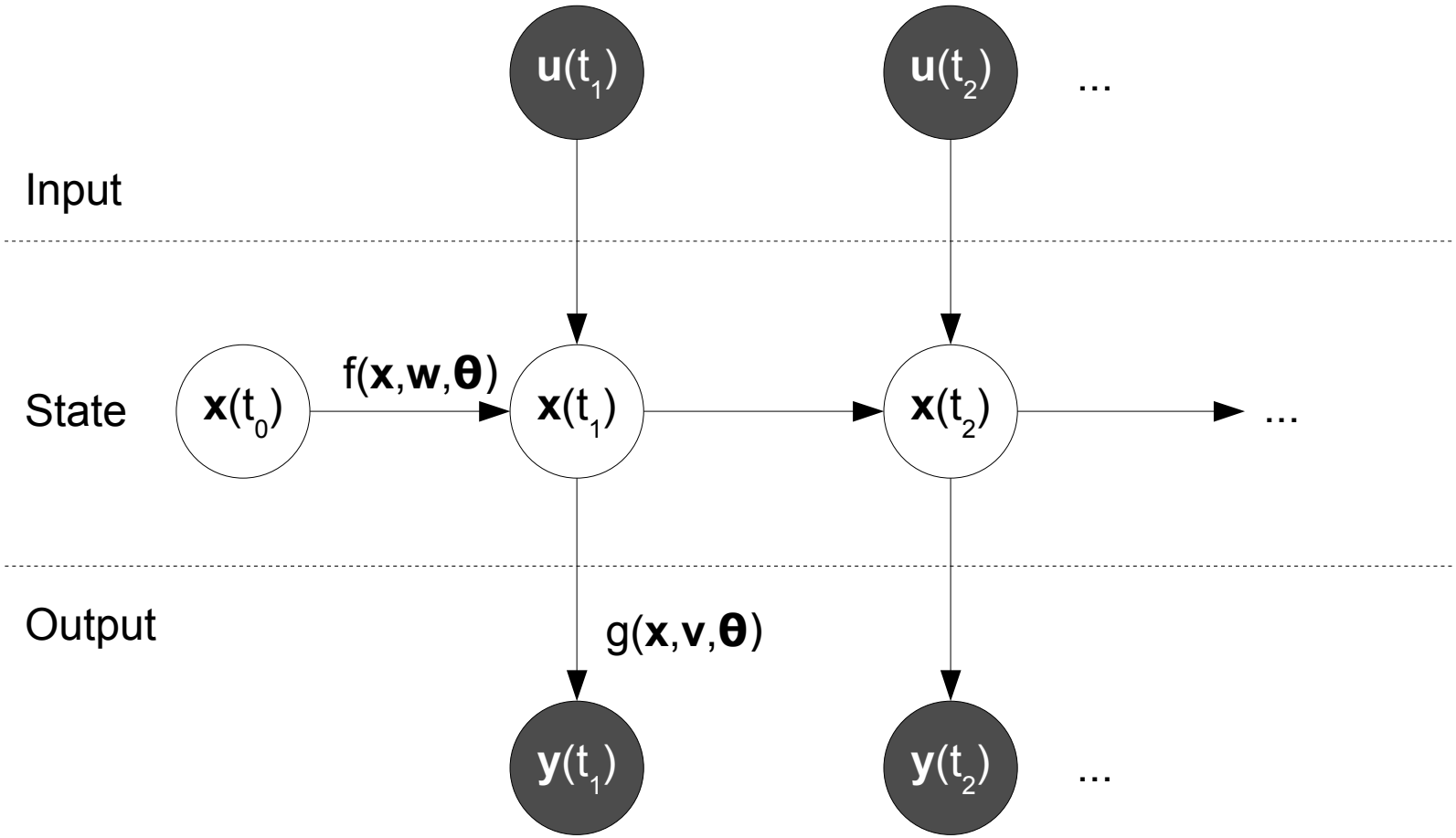
Parallel Computing with MPI

Lawrence Murray

Outline

- Motivation
- The Message Passing Interface (MPI)
- MPI implementations
- Computing resources
- Programming with MPI

Example: particle filtering



Motivation

- Synchronization
- Load balancing
- Resource management
- ...in all cases communication between nodes is required.

Message Passing Interface (MPI)

- Synchronous communication
  - `MPI_Send`, `MPI_Recv`
- Asynchronous communication
  - `MPI_Isend`, `MPI_Irecv`
- Collective communication
  - `MPI_Broadcast`, `MPI_Gather`, `MPI_Reduce`

MPI implementations

- MPICH www-unix.mcs.anl.gov/mpi/mpich/
- LAM/MPI www.lam-mpi.org
- Open MPI www.open-mpi.org
- MVAPICH2 mvapich.cse.ohio-state.edu/overview/mvapich2/

- The MPI interface is standard, so programming in all is identical.
- Booting and terminating nodes, and running jobs on the system, differs slightly.
- MPICH and LAM/MPI are now in maintenance mode, having merged to form the Open MPI project.
- Recommend Open MPI.

MPI implementation support

	DICE FC 5	DICE FC 6	Eddie
MPICH	✔	✔	✔
LAM/MPI	✔	✔	✔
Open MPI	✘	✔	✔
MVAPICH2	✘	✘	✔

- ANC compute servers still running FC 5.
- LAM configuration changed from FC 5 to FC 6.

Resources

	MPI	Dedicated	Hardware Homogeneity	Resource Reservation
Condor pool	✔	✘	✘	✔
Compute servers	✔	✔	✘	✘
Clusters	✔	✔	✔	?
Eddie	✔	✔	✔	✔

- Condor can run MPI jobs using the *parallel* universe, however, these can only be run on *dedicated* nodes. No nodes are configured as such.

Programming with MPI

- Single program, multiple data (SPMD)
  - Easy to program, easy to maintain.
  - Only as fast as slowest node.
- Multiple program, multiple data (MPMD), e.g. Master-worker setup
  - Master program packages and distributes batch jobs.
  - Worker programs process batch jobs.
  - Provides natural load balancing on heterogeneous system – faster nodes get more jobs than slower nodes.
  - More work to program, difficult to maintain, especially communication protocols.

Programming in C

```
int main(int argc, char **argv)
{
  char idstr[32], buff[128];
  int size, rank, i;

  MPI_Status stat;
  MPI_Init(&argc,&argv);
  MPI_Comm_size(MPI_COMM_WORLD,&size);
  MPI_Comm_rank(MPI_COMM_WORLD,&rank);

  if (rank == 0) {
    printf("We have %d processors\n", size);
    for(i = 1; i < size; i++) {
      sprintf(buff, "Hello %d", i);
      MPI_Send(buff, 128, MPI_CHAR, i, 0, MPI_COMM_WORLD);
    }
    for(i = 1; i < size; i++) {
      MPI_Recv(buff, 128, MPI_CHAR, i, 0, MPI_COMM_WORLD, &stat);
      printf("%s\n", buff);
    }
  } else {
    MPI_Recv(buff, 128, MPI_CHAR, 0, 0, MPI_COMM_WORLD, &stat);
    sprintf(idstr, "Processor %d ", rank);
    strcat(buff, idstr);
    strcat(buff, "reporting");
    MPI_Send(buff, 128, MPI_CHAR, 0, 0, MPI_COMM_WORLD);
  }

  MPI_Finalize();
}
```

Programming in C++

- Can use the C interface, but a nice C++ wrapper now available in Boost www.boost.org

Boost.MPI

- To be included for the first time in Boost v1.35, in the meantime can be obtained from CVS snapshot and installed locally.
- Advantage of Object Oriented interface...

Boost.Serialization

- ...but more importantly, supports object serialization with Boost.Serialization, which makes message passing much easier.
- Alleviates headaches of handling buffers and converting messages to primitive types.
- Can also make data storage and management a lot easier, serialize to files using the same interface.

Boost.uBLAS

- Supports serialization of vectors and matrices using Boost.Serialization, also in the CVS snapshot.
- Bindings to LAPACK etc.

Programming in C++ with Boost libraries

```
int main(int argc, char **argv)
{
  std::string str;
  std::stringstream buff;
  int size, rank, i;

  mpi::environment env(argc, argv);
  mpi::communicator world;
  size = world.size();
  rank = world.rank();

  if (rank == 0) {
    std::cout << "We have " << size << " processors" << std::endl;
    for(i = 1; i < size; i++) {
      buff << "Hello " << i;
      world.send(i, 0, buff.str());
    }
    for(i = 1; i < size; i++) {
      world.recv(mpi::any_source, mpi::any_tag, str);
      std::cout << str;
    }
  } else {
    world.recv(0, mpi::any_tag, stat);
    buff << "Processor " << rank << "reporting";
    world.send(0, 0, buff.str());
  }
}
```