SPECIALIZED PROJECT REPORT

STUDYING AND DEVELOPING DISTRIBUTED BARRIER ALGORITHMS USING THE HYBRID PROGRAMMING MODEL COMBINING MPI-3 AND C++11

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   2.2 MPI-3
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1.1 Motivation

1.1.1 HPC and its Applications

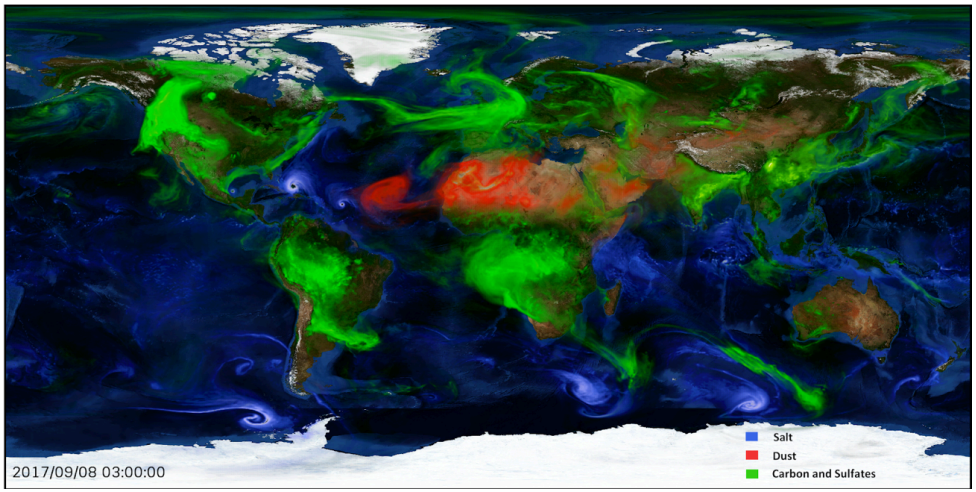

Figure 1: Weather Simulation [1]

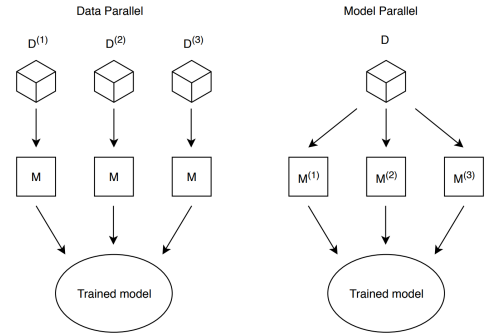

Fig. 2. Parallelism in Distributed Machine Learning. Data parallelism trains multiple instances of the same model on different subsets of the training dataset, while model parallelism distributes parallel paths of a single model to multiple nodes.

Figure 2: Distributed Machine Learning [2]

1.1 Motivation

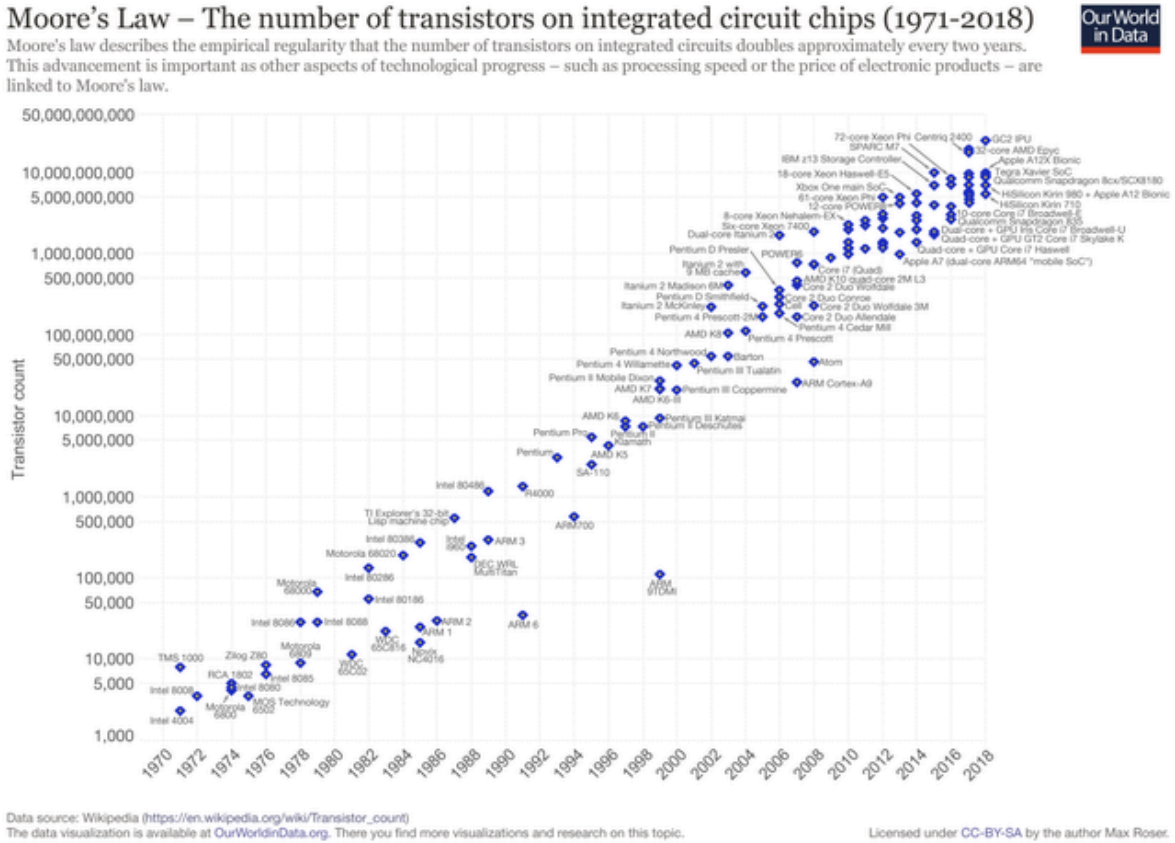

Figure 3: Moore's Law [3]

1.1 Motivation

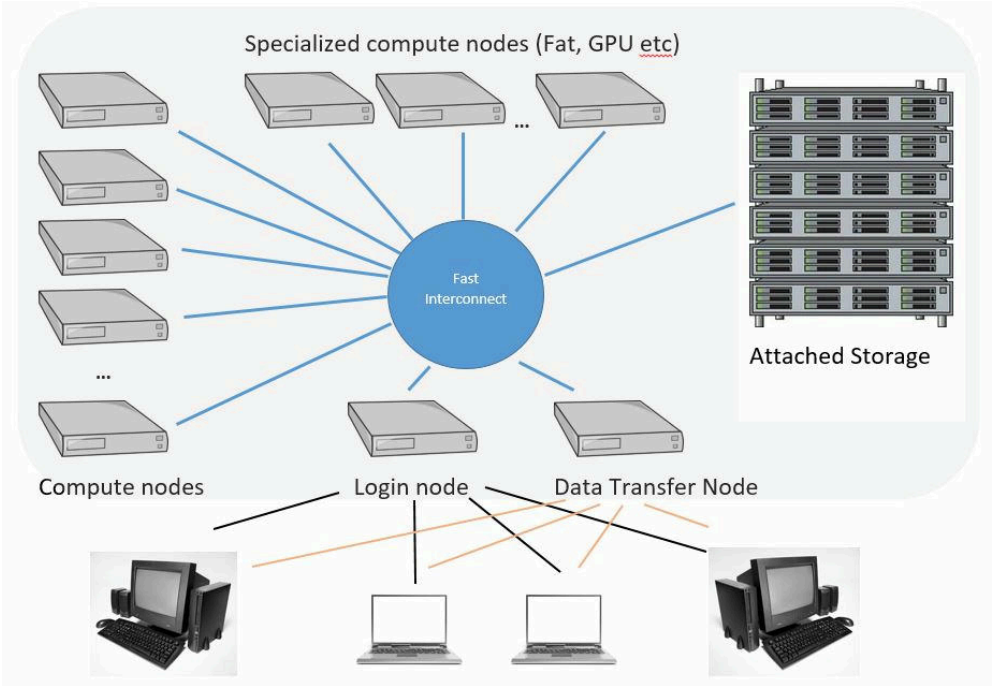

Figure 4: Multiple Computing Nodes connect to each other to form a HPC Cluster [4]

- Nodes are connected via a very fast network (Infiniband, Ethernet, etc.)

1.1 Motivation

1.1.2 MPI-3

- MPI is a standard for message-passing between nodes in a distributed system
- MPI is optimized for communication between nodes
- Multiple implementations of MPI are available (OpenMPI, MPICH, MVAPICH, etc.)
- Multiple programming languages support MPI (C, Fortran, etc.)

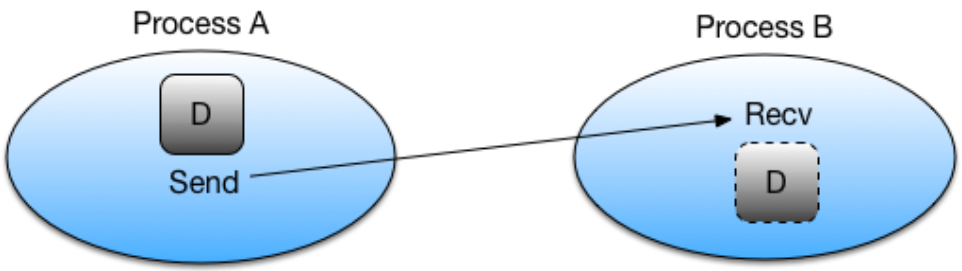

Figure 5: Live program communicating with each other using MPI [5]

1.1 Motivation

1.1.3 C++11

- C++11 is a standard for the C++ programming language released in 2011
- C++11 provides support for multithreading and parallel programming
- C++11 provides native support for multithreading

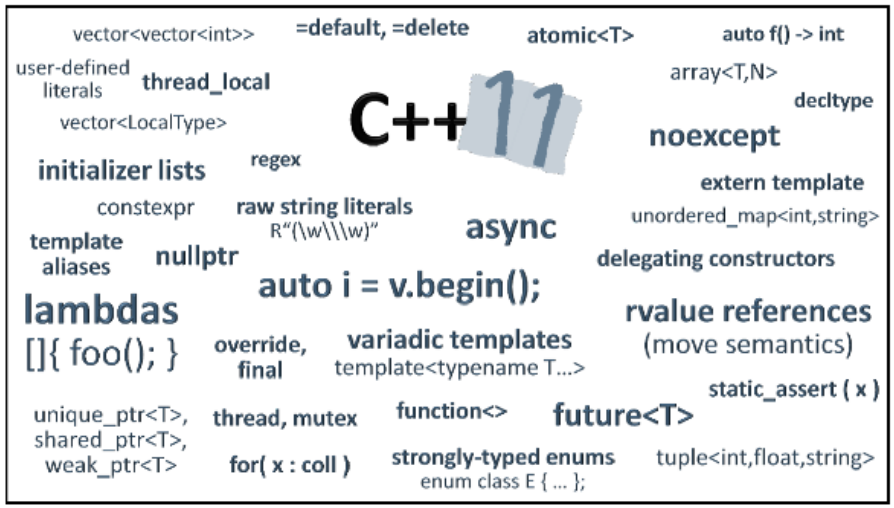

Figure 6: Features introduced in C++11 [6]

1.1 Motivation

1.1.4 The Paper

- Quaranta et al [7] proposed to combine MPI-3 and C++11 (hybrid model)
- Only implements a simple barrier algorithm using the hybrid model

→ Implement and benchmark more complex barrier algorithms using the hybrid model

1.2 Objectives

- Research and familiarize with the MPI-3 and C++11 programming model ✓
- Research about many barrier algorithms ✓
- Implement a simple barrier algorithm using MPI-3 ✓

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2.1 Barrier Algorithm

What is a Barrier Algorithm?

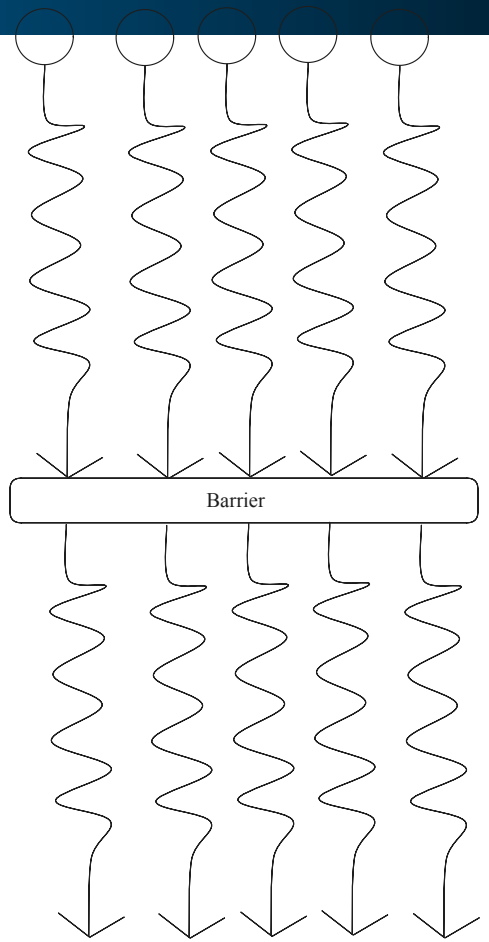


Figure 7: Barrier Algorithm

2.2 MPI-3

Traditional Message Passing

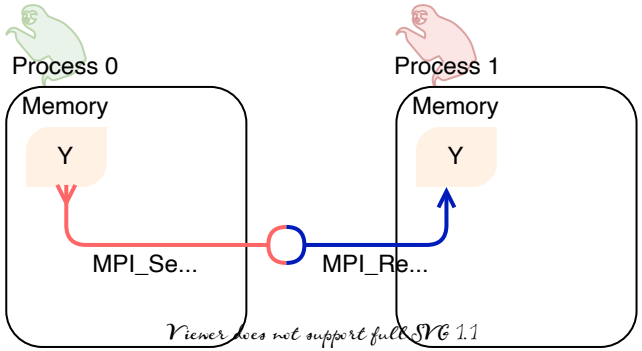


Figure 8: Point-to-point communication [5]

- Point-to-point
- Explicit send and receive

One-sided Communication

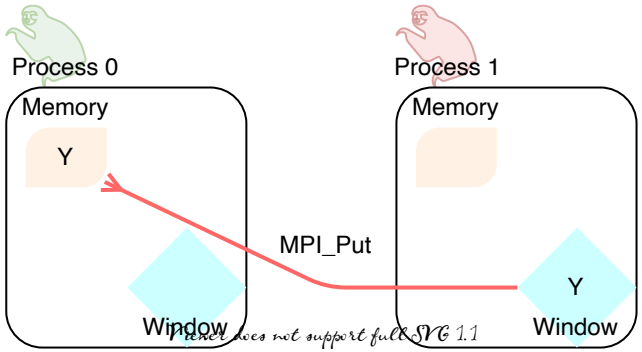


Figure 9: One-sided Communication [5]

- Remote Memory Access
- Handshake is implicit

2.2 MPI-3

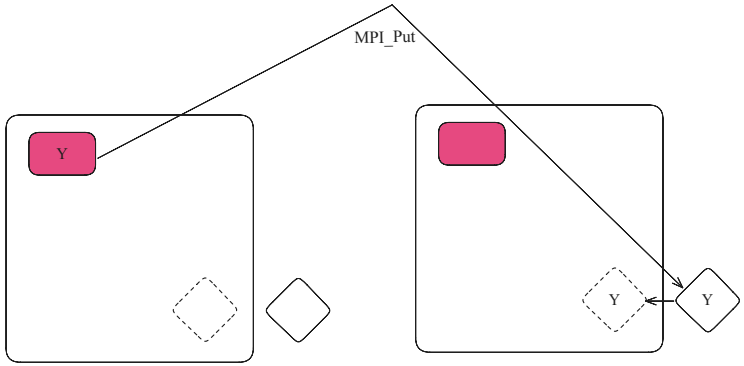
2.2.1 One-sided Communication

- Introduced in MPI-2
- Share mechanism:
  - Declare a window of memory to be shared
  - read/write without explicit send/receive
- Simple operations:
  - MPI_Put
  - MPI_Get
  - MPI_Accumulate
- Atomic operations:
  - MPI_Get_accumulate
  - MPI_Fetch_and_op
  - MPI_Compare_and_swap

2.2 MPI-3

2.2.2 New Features in MPI-3

Separate Memory



Unified Memory

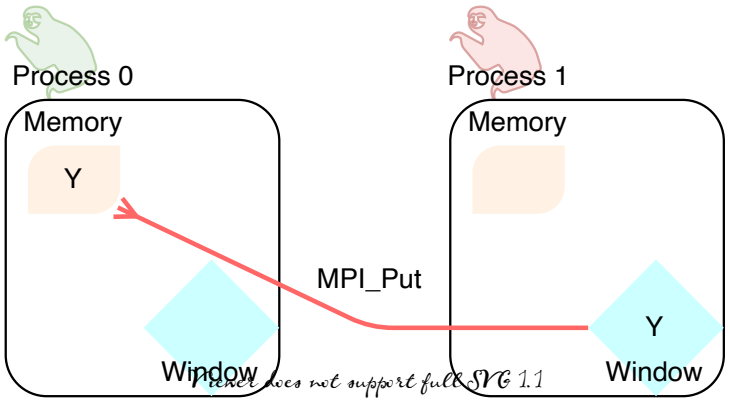


Figure 11: One-sided Communication [5]

2.3 C++11

- Introduced in 2011
- Support for multithreading and parallel programming within a single node
- Can use **shared memory** to communicate instead of **message passing**

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3.1 The MPI-3 C++11 Paper

- Quaranta et al [7] proposed a hybrid model of MPI-3 and C++11

3.2 Other Barrier Algorithms

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5.3.1 Plan

5.3.2 Timeline

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[6] "Technical CPP Blog." Accessed: Jan. 01, 2025. [Online]. Available: https://www.cyberplusindia.com/blog/index.php/category/technical/cpp/

[7] L. Quaranta and L. Maddegedara, "A Novel MPI+MPI Hybrid Approach Combining MPI-3 Shared Memory Windows and C11/C++11 Memory Model," *Journal of Parallel and Distributed Computing*, vol. 157, pp. 125–144, Nov. 2021, doi: 10.1016/j.jpdc.2021.06.008.

`bibliography-as-footnote`

Bibliography

Tổng thời lượng thuyết trình: nhóm 1 người = 10p (bao gồm cả demo)

1. Introduction (2p)
    1. Motivation (1.5p)
    2. Objectives (0.5p)
2. Background (1.5p)
    1. Vai trò của thuật toán Barrier trong xử lý đa luồng (0.2p)
    2. MPI: One-sided Communication dùng RMA (1p)
    3. C++11(?)
3. Related Works (1.5p)
4. Algorithm + Implementation (2p)
5. Conclusion (accomplishments + future works) (2.5p)

total = 2 + 1.5 + 1.5 + 2 + 0.2 + 2.5 = 9.5p

Bibliography

1. Ứng dụng của HPC và nhu cầu của parallel computing (15s)

- HPC dung de giai quyet cac van de kho tinh toan, nhu weather simulation, distributed machine learning
- Du lieu cang ngay cang lon, doi hoi toc do tinh toan va xu ly nhanh hon
- Tuy nhien, theo dinh luat Moore, chi phi cua viec tang toc do cua 1 CPU cang ngay cang cao
- Vi vay cac chuong trinh can duoc lap trinh de co the chay song song tren nhieu

may tinh

- Ma da nhac den xu ly song song thi khong the khong nhac den cac van de lien quan den

dong bo giua cac tien trinh, vi du nhu dong bo hang rao

- Giai thuat dong bo hang rao, hay con goi la Barrier Algorithm, la nhung giai thuat

Bibliography

nham den viec chan, cac tien trinh song song dung lai o mot thoi diem nao do trong chuong trinh de giao tiep, hoac thuc hien mot cong viec nao do, truoc khi den giai doan tiep theo cua giai thuat

2. HPC Cluster và Computing Node (15s)
3. Message Passing Interface (MPI) và vai trò của nó trong việc giao tiếp giữa các Compute Nodes (15s)
4. Giao tiếp bên trong 1 compute node phiên bản C++11 và hỗ trợ lập trình đa luồng của nó (20s)
5. Nhắc (5s):

- MPI hiện tại chỉ đang được tối ưu cho việc giao tiếp giữa nhiều Nodes
- C++11 multithread thì tối ưu để giao tiếp giữa các luồng xử lý trong 1 Node

6. Paper Hybrid MPI-3 và C++11