Parallel Diffusion Limited Aggregation:

Parallel and Distributed Programming

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DLA Algorithm

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Main function of C code using MPI

03 Initialization
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05 Growth
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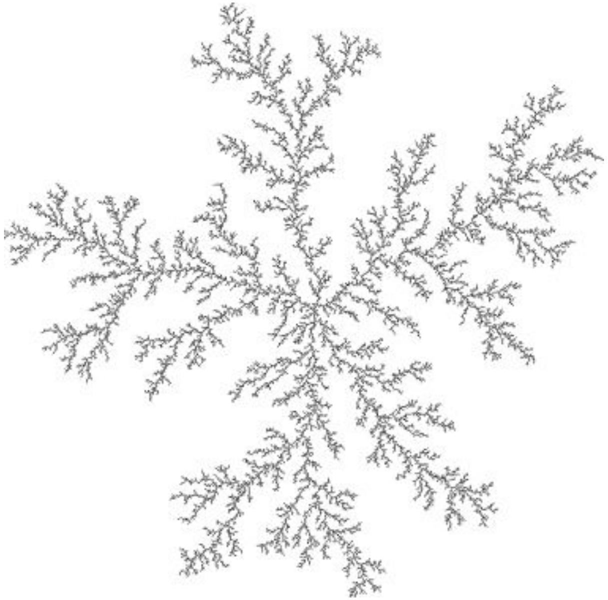
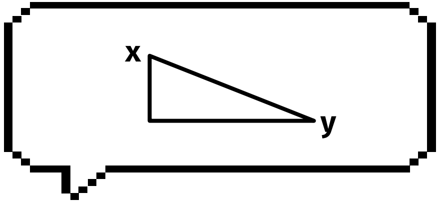
DLA

Diffusion Limited Aggregation (DLA) is a model for non-equilibrium growth, where growth is determined by diffusing particles





01

Algorithm

DLA Algorithm

Basic Algorithm

- Solve Laplace equation to get distribution of nutrients, assume that the object is a sink (i.e. c = 0 on the object)
- Let the object grow
- Go back to first step

The first step in above algorithm is done by a parallel SOR iteration

Simulation

Boundary Condition

X-direction and
Y-direction

Object Initialization

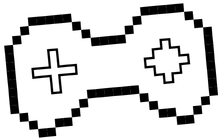
Where Object start
to grow

Hyperparams

Parameter in
experiment

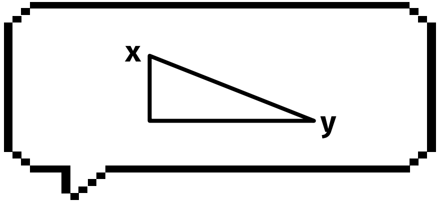
Boundary Condition and Object Init

- Periodic boundary conditions in x-direction
- Fixed value for the upper and lower boundary in y-direction
- The object start at the bottom center of the grid



Hyperparams

	Value
Number of Iteration	800 & 2000
Size of grid	200 x 200
Tolerance value for convergence	0.001
Omega	1.9
Upper and Lower boundary	C0 = 1 cN = 0



02

Main Function

Main Function in C using MPI

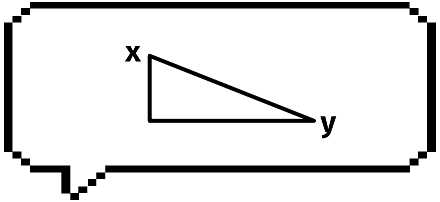
```c
    KhoiTao(C_old, C_current, O, candidates);

    for (k = 0; k < iter; k++)
    {
        SOR();
        for (i = 0; i < Np; ++i)
            for (j = 0; j < N; ++j)
                *(C_old + i * N + j) = *(C_current + i * N + j);
        growth();
    }

    float *C_current_global;
    int *O_global;
    // print
    if (rank == 0)
    {
        C_current_global = (float *)malloc(N * N * sizeof(float));
        O_global = (int *)malloc(N * N * sizeof(int));
    }
    MPI_Gather(C_current, Np * N, MPI_FLOAT, C_current_global, Np * N, MPI_FLOAT, 0, MPI_COMM_WORLD);
    MPI_Gather(O, Np * N, MPI_INT, O_global, Np * N, MPI_INT, 0, MPI_COMM_WORLD);
```

Initialization

SOR Iteration

Grow Step

Gather to Root



03

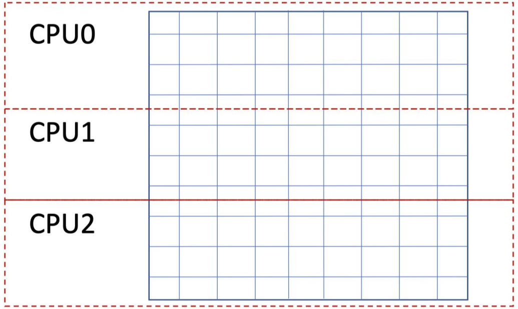
Initialization

How we initialize the data

Initialization

- Each CPU : Initialize independently

→ No need to distribute Input data from Root to all other CPUs




```
    // C  Initialization
    for (i = 0; i < Np; ++i)
        for (j = 0; j < N; ++j)
        {
            *(C_current + i * N + j) = 0;
            *(C_old + i * N + j) = 0;
            *(O + i * N + j) = 0;
        }

    // Object Initialization
    if (rank == size - 1)
        *(O + (Np - 1) * N + N / 2) = 1;
```

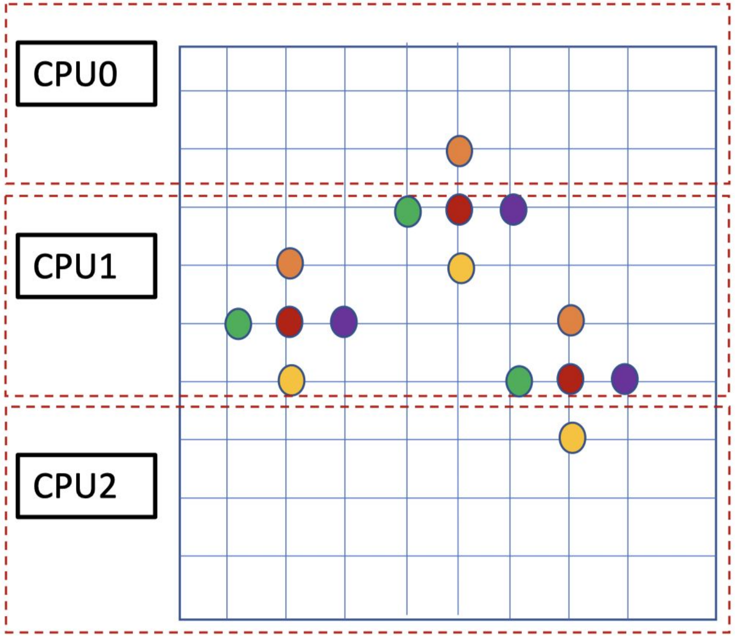
04

SOR Iteration

Use Successive Over Relaxation method to solve Laplace Equation

Communication

- Color the computational grid as a checkerboard, with red and black grid points.
- First update all red points and next update all black points
- Communicate **C_above** and **C_below**

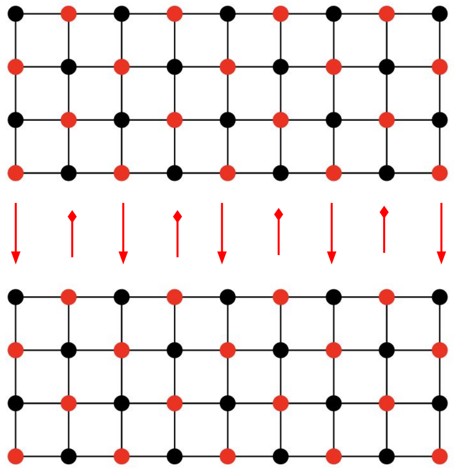


Communication

- Color the computational grid as a checkerboard, with red and black grid points.
- Communicate **C_above** and **C_below**

CPU (n+1) send up data to **C_above** of CPU (n)

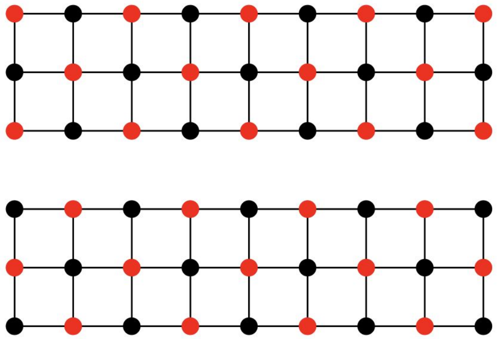
CPU (n) send down data to **C_below** of CPU (n)



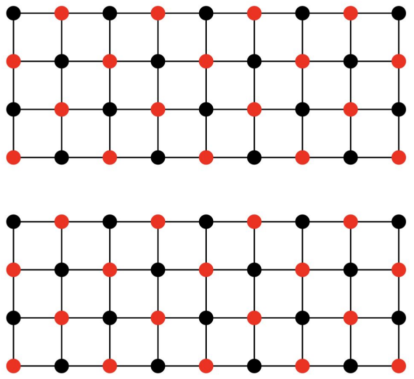
Red Turn

Communication

```c
// He so cho tung Np khac nhau
dieu_chinh = (Np * rank + 1 + r) % 2;

// Send down
if (rank != size - 1)
    MPI_Send(C_current + (Np - 1) * N + (dieu_chinh + Np) % 2, 1, everytwice, rank + 1, 0, MPI_COMM_WORLD);

// Send up
if (rank != 0)
    MPI_Send(C_current + 1 - dieu_chinh, 1, everytwice, rank - 1, 1, MPI_COMM_WORLD);

// Receive from below
if (rank != size - 1)
    MPI_Recv(C_below, (N + 1) / 2, MPI_FLOAT, rank + 1, 1, MPI_COMM_WORLD, &status);
else
{
    for (i = 0; i < (N + 1) / 2; ++i)
        C_below[i] = cN;
}

// Receive from above
if (rank != 0)
    MPI_Recv(C_above, (N + 1) / 2, MPI_FLOAT, rank - 1, 0, MPI_COMM_WORLD, &status);
else
{
    for (i = 0; i < (N + 1) / 2; ++i)
        C_above[i] = c0;
}
```



Odd Np



Even Np

Calculation

```c
  // ignore object position
  if (*(O + i * N + j) == 1)
      continue;

  // ignore half of the grid
  if ((rank * Np + i + j) % 2 == r)
      continue;

  left = (j == 0) ? *(C_current + i * N + (N - 1)) : *(C_current + i * N + j - 1);
  right = (j == N - 1) ? *(C_current + i * N) : *(C_current + i * N + j + 1);
  up = (i == 0) ? *(C_above + j / 2) : *(C_current + (i - 1) * N + j);
  down = (i == Np - 1) ? *(C_below + j / 2) : *(C_current + (i + 1) * N + j);

  *(C_current + i * N + j) = (1 - omega) * *(C_current + i * N + j) + omega * (left + right + up + down) / 4;

  *alpha = fmax(*alpha, fabs(*(C_current + i * N + j) - *(C_old + i * N + j)));
```

Communication

```
      MPI_Allreduce(alpha, &global_alpha, 1, MPI_FLOAT, MPI_MAX, MPI_COMM_WORLD);
  } while (global_alpha > tol);
```

```
  MPI_Datatype everytwice;
  MPI_Type_vector((N + 1) / 2, 1, 2, MPI_FLOAT, &everytwice);
  MPI_Type_commit(&everytwice);
```

05

Growth

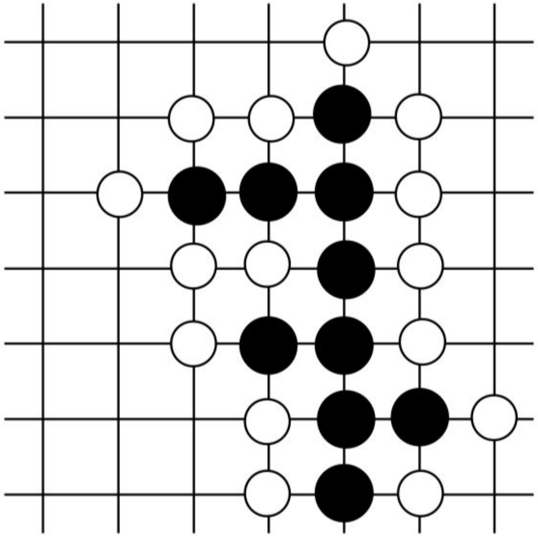
Grow the Object

Growth

- Growing object requires 3 steps:
  - Determine growth candidates
  - Determine growth probabilities
  - Grow

Calculation of the growth probabilities requires a global communication

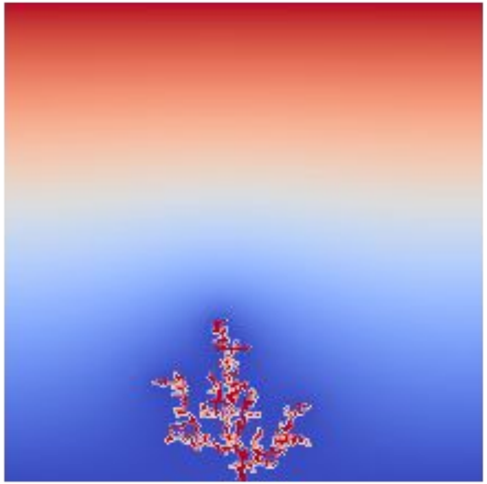
$$p_g\left((i,j)\in\circ\rightarrow(i,j)\in\bullet\right)=\frac{\left(c_{i,j}\right)^{\eta}}{\sum\limits_{(i,j)\in\circ}\left(c_{i,j}\right)^{\eta}}.$$



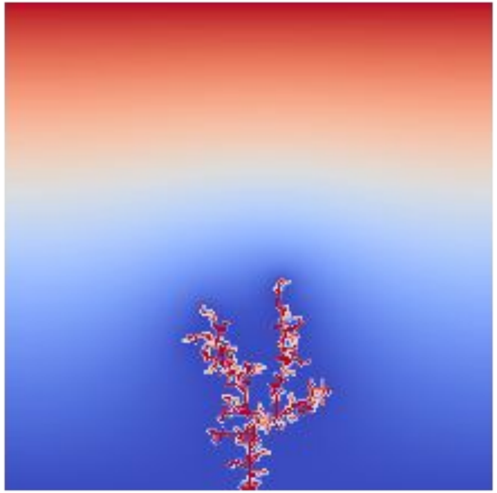
Growth

```c
    // calculate candidates and nutri
    for (i = 0; i < Np; i++)
    {
        for (j = 0; j < N; j++)
        {
            if (*(O + i * N + j) == 1)
            {
                continue;
            }

            left = (j == 0) ? 0 : *(O + i * N + j - 1);
            right = (j == N - 1) ? 0 : *(O + i * N + j + 1);
            up = (i == 0) ? *(O_above + j) : *(O + (i - 1) * N + j);
            down = (i == Np - 1) ? *(O_below + j) : *(O + (i + 1) * N + j);

            if ((left == 1 || right == 1 || up == 1 || down == 1))
            {
                *(candidates + i * N + j) = 1;
                *nutri += *(C_current + i * N + j);
            }
            else
                *(candidates + i * N + j) = 0;
        }
    }

    // Reduce
    MPI_Allreduce(nutri, &global_nutri, 1, MPI_FLOAT, MPI_SUM, MPI_COMM_WORLD);
```

Some Results

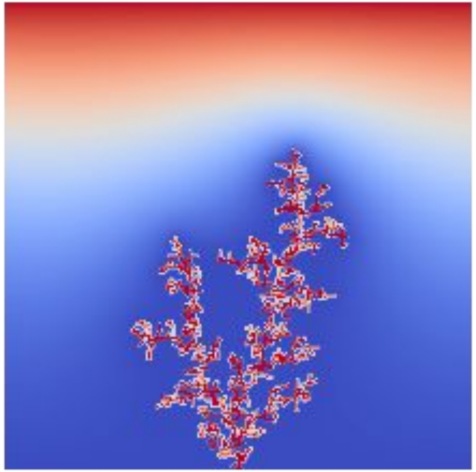


800 step serial

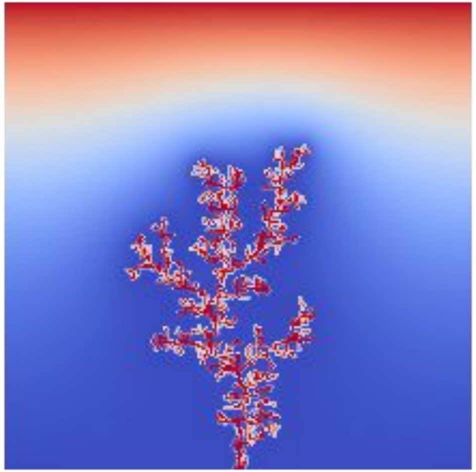


800 step parallel

Some Results



2000 step serial



2000 step parallel

THE END!

Thank you for listening