Parallel & Distributed: DIFFUSION LIMITED AGGREGATION (MPI)

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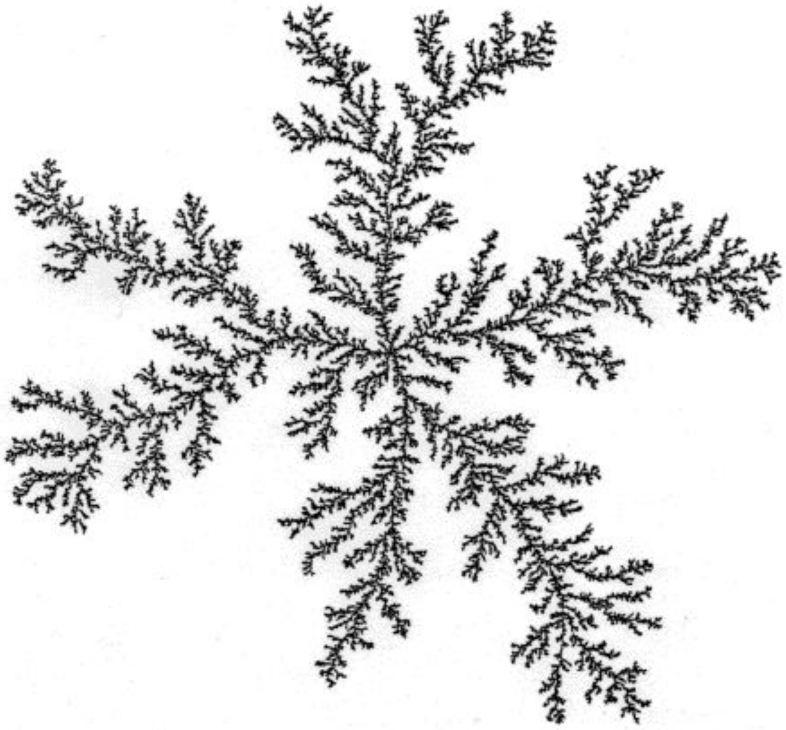
INTRODUCE
THE PROBLEM



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Time-independent Diffusion

In many situations, we may solely interested in the steady state, not much into the transient behaviours:

$$\nabla^2 c = 0 \, .$$

Reduce the problem into **solving time-independent Laplace equation**.

The concentration is no longer depends on the time variable, so by substituting the finite difference for the spatial derivatives into the **Laplace equation**:

$$c_{l,m} = \frac{1}{4}\left[c_{l+1,m} + c_{l-1,m} + c_{l,m+1} + c_{l,m-1}\right] \, , \ \forall (l,m) \quad .$$

(Time-independent Diffusion Equation)

Limited Diffusion Aggregation (1)

"Diffusion" because the particles forming the structure wander around randomly before attaching themselves ("Aggregating") to the structure. "Diffusion-limited" because the particles are in low concentrations so they don't come in contact with each other and *the structure grows one particle at a time rather then by chunks of particles.*

Algorithm 1 DLA algorithm

time-independent diffusion eq.: $\Delta c = 0$

loop till convergence:

1. Solve $\Delta c = 0$. Object be sink ($c = 0$).
2. Let object grow.

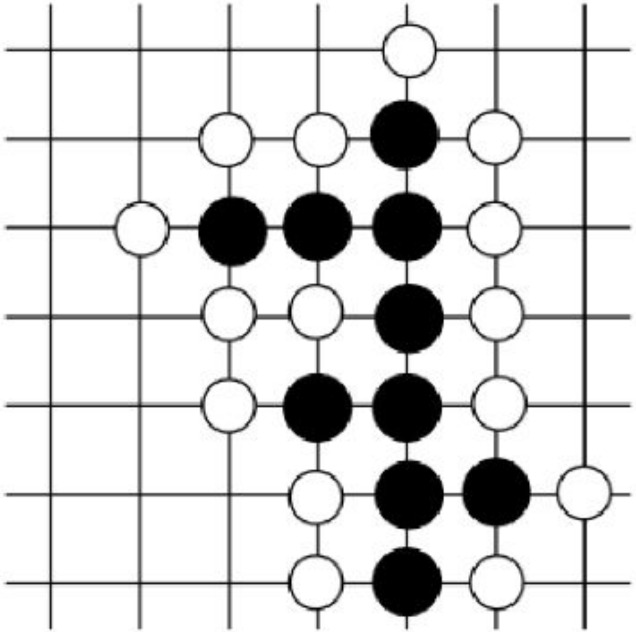

Figure 1: The object and possible growth sites.

Limited Diffusion Aggregation (2)

1. Determine growth candidates.
2. Determine growth probabilities.
3. Grow candidates.

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

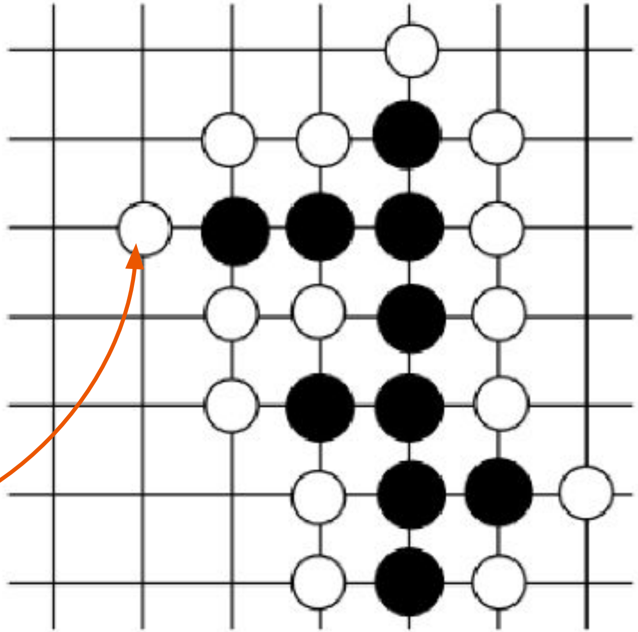

Figure 1: The object and possible growth sites.

ALGORITHMS WITH PARALLEL DESIGN

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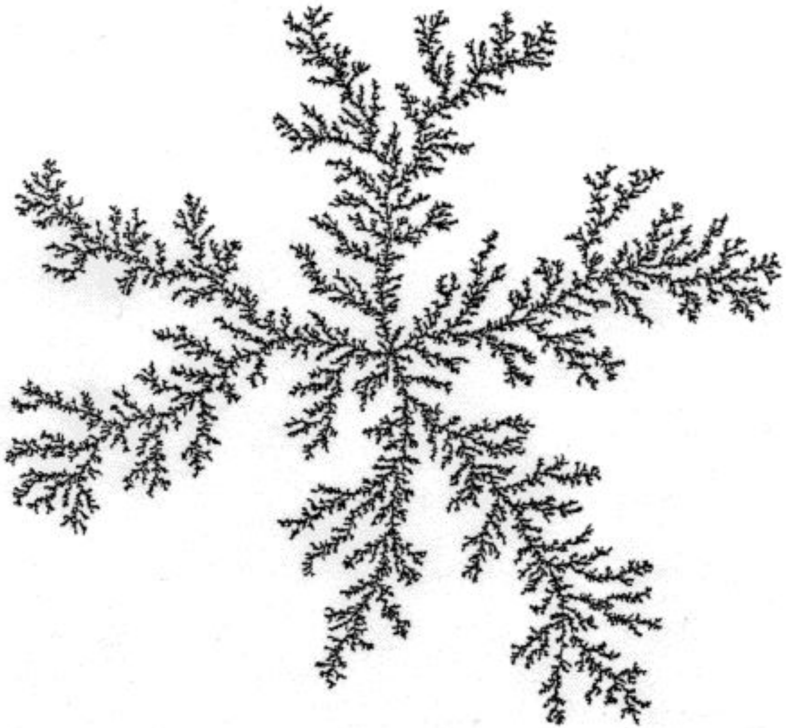


Successive Over Relaxation

```
/* Jacobi update, square domain, periodic in x, fixed */
/* upper and lower boundaries                         */
do {
   δ = 0
   for i=0 to max {
      for j=0 to max {
         if(c_ij is a source) c_ij^(n+1) = 1.0
         else if(c_ij is a sink) c_ij^(n+1) = 0.0
         else {
            /* periodic boundaries */
            west = (i==0) ? c_max-1,j^(n) : c_i-1,j^(n)
            east = (i==max) ? c_1,j^(n) : c_i+1,j^(n)
            /* fixed boundaries */
            south = (j==0) ? c0 : c_i,j-1^(n)
            north = (j==max) ? cL : c_i,j+1^(n)
            c_ij^(n+1) = 0.25 * (west + east + south + north)
         }
         /* stopping criterion */
         if(|c_ij^(n+1) - c_ij^(n)| > tolerance) δ = |c_ij^(n+1) - c_ij^(n)|
      }
   }
while (δ > tolerance)
```

SOR can be thought of as a smoothed version of Gauss-Seidel iterative method by using **momentum**.

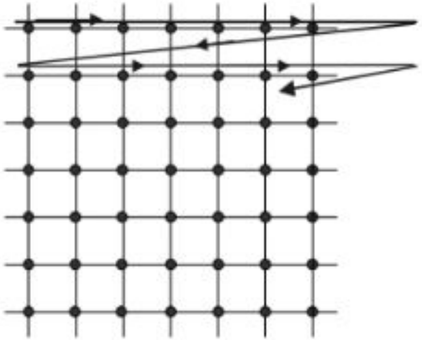
$$c_{l,m}^{(n+1)} = \frac{\omega}{4}\left[c_{l+1,m}^{(n)} + c_{l-1,m}^{(n+1)} + c_{l,m+1}^{(n)} + c_{l,m-1}^{(n+1)}\right] + \boxed{(1-\omega)\, c_{l,m}^{(n)}.}$$

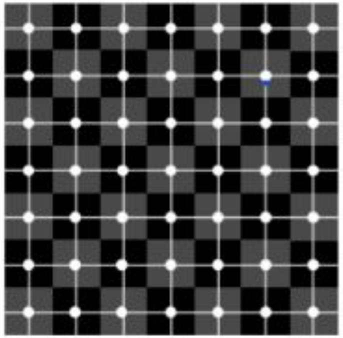
Red-black Ordering

❖ Each processor handles some row of the grid, with red-black ordering.

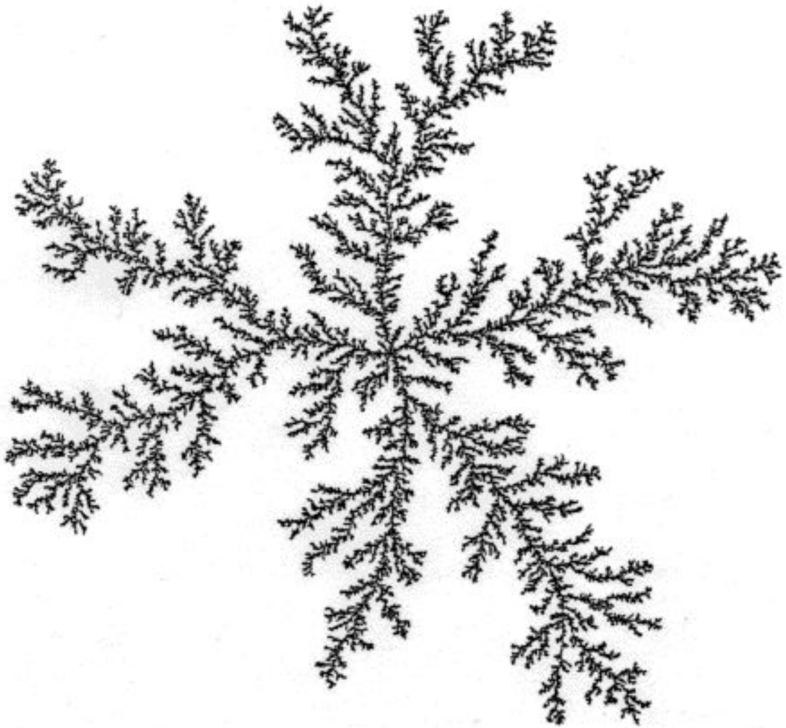
```
/* only the inner loop of the parallel Gauss-Seidel method with */
/* Red Black ordering */
   do {
      exchange boundary strips with neighboring processors;
      for all red grid points in this processor {
         update according to Gauss-Seidel iteration;
      }
      exchange boundary strips with neighboring processors;
      for all black grid points in this processor {
         update according to Gauss-Seidel iteration;
      }
      obtain the global maximum δ of all local δ_i values
   }
   while (δ > tolerance)
```

Algorithm 4: The pseudo code for parallel Gauss-Seidel iteration with red-black ordering.





EXPERIMENTS
AND RESULTS



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END

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