

# Parallel Numerics

## Exercise 8: Stationary Methods

### 1) Stationary Methods Revisited

To solve the equation system  $Ax = b$  stationary methods split up the matrix  $A$  into  $A = M - N$ :

$$\begin{aligned}Ax &= b \\(M - N)x &= b \\Mx &= Nx + b \\Mx^{(n+1)} &= Nx^{(n)} + b\end{aligned}$$

- i) Give the Richardson, Jacobi and Gauß–Seidel method using matrix notation.
- ii) Give the Richardson, Jacobi and Gauß–Seidel method in pseudo code and identify GAX-PYs, SAXPYs, ...
- iii) For the weighted relaxation schemes, one scales the iteration rule above with a factor  $\omega$  and adds the trivial iteration  $x^{(n+1)} = x^{(n)}$ . Derive the  $\omega - JAC$  and SOR (Successive-Over-Relaxation) scheme in matrix notation.

### 2) Residual–based Notation

The residual is defined as

$$r = b - Ax$$

- i) Give the Richardson, Jacobi and Gauß–Seidel method using the residual.
- ii) Give the  $\omega - JAC$  and SOR scheme using the residual.
- iii) Give a scetch of the data dependendy graph for both computing the residual and updating the solution according to the Jacobi and the GS scheme. (To simplify matters: Assume that  $A$  is tridiagonal)
- iv) Which parallel algorithms for matrix vector products do you know (already)?

### 3) SOR Implementation

In this section, we want to implement the SOR. As simplification for the following algorithms we assume that the iteration index  $k$  is always running from 0 to a maximum number  $k_{stop}$ . With the definitions

$$\alpha_i := \frac{\omega}{a_{ii}} \quad \text{for } i = 1, \dots, n \quad \text{and} \quad b_{ij} := \begin{cases} -a_{ij} & \text{for } i \neq j \\ \frac{1-\omega}{\omega} a_{ii} & \text{for } i = j \end{cases}$$

a serial algorithm for the SOR method can be given as follows:

```
for k = 0 to kstop
  for i = 1 to n
    s := di
    for j = 1 to n
      s := s + bijxj
    xi := αis
```

 (\*)

A parallel algorithm can be implemented in a similar way: The  $b_{ij}$  are distributed columnwise on  $p$  processors in a cyclic way (cp. the Parallel Gauss Elimination, Exercise 6). Every processor calculates only a part of the sum in (\*). Following, the  $x_i$  are calculated successively on different processors after receiving the parts of the sum from the other processors. Suitable communication is necessary. The parallel algorithm has the following shape:

```
for k = 0 to kstop
  for i = 1 to n
    a := ∑j∈mycolumns bijxj
    if i ∈ mycolumns
      Get a from all other processors and calculate s := ∑p a
      xi := αi(s + di)
```

Implement the serial and parallel algorithm! On which processor do you find the solution  $x$  after running the parallel algorithm? Can you observe a speedup?