

and

$$A = \begin{bmatrix} a_1 & -c_1 & & & \\ -b_2 & \ddots & \ddots & & \\ & \ddots & \ddots & \ddots & \\ & & & -b_N & c_{N-1} \\ & & & & a_N \end{bmatrix} \quad \begin{aligned} a_i &= 1 + \frac{h^2}{2} q_i \\ b_i &= \frac{1}{2} [1 + \frac{h}{2} p_i] \\ c_i &= \frac{1}{2} [1 - \frac{h}{2} p_i] \end{aligned}$$

Note that $a_i > 0$, and also $b_i > 0$ and $c_i > 0$ if h is small enough.

This is a nonsymmetric *tridiagonal* system to solve for y . We will show how to change it to a symmetric positive definite tridiagonal system, so that we may use *band Cholesky* to solve it.

Choose $D = \text{diag}(1, \sqrt{\frac{c_1}{b_2}}, \sqrt{\frac{c_1 c_2}{b_2 b_3}}, \dots, \sqrt{\frac{c_1 c_2 \dots c_{N-1}}{b_2 b_3 \dots b_N}})$. Then we may change $Ay = b$ to $(DAD^{-1})(Dy) = Db$ or $\bar{A}\bar{y} = \bar{b}$, where

$$\bar{A} = \begin{bmatrix} a_1 & -\sqrt{c_1 b_2} & & & \\ -\sqrt{c_1 b_2} & a_2 & -\sqrt{c_2 b_3} & & \\ & -\sqrt{c_2 b_3} & \ddots & \ddots & \\ & & \ddots & \ddots & -\sqrt{c_{N-1} b_N} \\ & & & -\sqrt{c_{N-1} b_N} & a_N \end{bmatrix}.$$

It is easy to see that \bar{A} is symmetric, and it has the same eigenvalues as A because A and $\bar{A} = DAD^{-1}$ are *similar*. (See section 4.2 in Chapter 4 for details.) We will use the next theorem to show it is also positive definite.

THEOREM 2.9. Gershgorin. *Let B be an arbitrary matrix. Then the eigenvalues λ of B are located in the union of the n disks*

$$|\lambda - b_{kk}| \leq \sum_{j \neq k} |b_{kj}|.$$

Proof. Given λ and $x \neq 0$ such that $Bx = \lambda x$, let $1 = \|x\|_\infty = x_k$ by scaling x if necessary. Then $\sum_{j=1}^N b_{kj} x_j = \lambda x_k = \lambda$, so $\lambda - b_{kk} = \sum_{j \neq k} b_{kj} x_j$, implying

$$|\lambda - b_{kk}| \leq \sum_{j \neq k} |b_{kj} x_j| \leq \sum_{j \neq k} |b_{kj}| \quad \square$$

Now if h is so small that for all i , $|\frac{h}{2} p_i| < 1$, then

$$|b_i| + |c_i| = \frac{1}{2} \left(1 + \frac{h}{2} p_i \right) + \frac{1}{2} \left(1 - \frac{h}{2} p_i \right) = 1 < 1 + \frac{h^2}{2} q \leq 1 + \frac{h^2}{2} q_i = a_i.$$

Therefore all eigenvalues of A lie inside the disks centered at $1 + h^2 q_i / 2 \geq 1 + h^2 q / 2$ with radius 1; in particular, they must all have positive real parts. Since \bar{A} is symmetric, its eigenvalues are real and hence positive, so \bar{A} is positive definite. Its smallest eigenvalue is bounded below by $gh^2/2$. Thus, it can be

Applied Numerical Linear Algebra

IM Harris



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