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# Tridiagonal Matrix Algorithm (Thomas Algorithm)

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# 1 TRIDIAGONAL MATRIX ALGORITHM [THOMAS ALGORITHM]

A tridiagonal linear system is one of the form

$$\begin{bmatrix} b_1 & c_1 & & & \\ a_1 & b_2 & c_2 & & \\ & a_2 & \ddots & \ddots & \\ & & \ddots & \ddots & c_{n-2} \\ & & & a_{n-2} & b_{n-1} & c_{n-1} \\ & & & & a_{n-1} & b_n \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{n-1} \\ x_n \end{bmatrix} = \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_{n-1} \\ d_n \end{bmatrix}$$

We can define the  $\mathbf{x}$  and  $\mathbf{d}$  vectors as

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{n-1} \\ x_n \end{bmatrix}, \quad \mathbf{d} = \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_{n-1} \\ d_n \end{bmatrix}$$

and the  $n \times n$  **tridiagonal matrix**<sup>1</sup>,  $\mathbf{A}$ , as

$$\mathbf{A} = \begin{bmatrix} b_1 & c_1 & & & \\ a_1 & b_2 & c_2 & & \\ & a_2 & \ddots & \ddots & \\ & & \ddots & \ddots & c_{n-2} \\ & & & a_{n-2} & b_{n-1} & c_{n-1} \\ & & & & a_{n-1} & b_n \end{bmatrix} \quad (1)$$

Now we can write the tridiagonal linear system as

$$\mathbf{Ax} = \mathbf{d} \quad (2)$$

where  $\mathbf{A} \in \mathbb{R}^{n \times n}$  and  $\mathbf{x}, \mathbf{d} \in \mathbb{R}^n$ .

The **tridiagonal matrix algorithm** (also known as the **Thomas algorithm**) is an algorithm that can efficiently solve the tridiagonal linear system (given by Eq. (2)) for  $\mathbf{x}$ . This algorithm uses three vectors,  $\mathbf{a}$ ,  $\mathbf{b}$ , and  $\mathbf{c}$ , which we define as [1]

$$\mathbf{a} = \begin{bmatrix} a_1 \\ \vdots \\ a_{n-1} \end{bmatrix}, \quad \mathbf{b} = \begin{bmatrix} b_1 \\ \vdots \\ b_n \end{bmatrix}, \quad \mathbf{c} = \begin{bmatrix} c_1 \\ \vdots \\ c_{n-1} \end{bmatrix}$$

<sup>1</sup> In many references, a tridiagonal matrix is defined with the convention

$$\mathbf{A} = \begin{bmatrix} a_1 & b_1 & & & \\ c_1 & a_2 & b_2 & & \\ & c_2 & \ddots & \ddots & \\ & & \ddots & \ddots & b_{n-2} \\ & & & c_{n-2} & a_{n-1} & b_{n-1} \\ & & & & c_{n-1} & a_n \end{bmatrix}$$

When dealing with the tridiagonal matrix algorithm, a convention similar to the one in Eq. (1) is used almost exclusively. However, the convention that most sources have has the  $a_i$ 's ranging from  $a_2$  to  $a_n$ , which is inconvenient from a programming standpoint; therefore, I defined them here as ranging from  $a_1$  to  $a_{n-1}$ . This convention is also reflected in Algorithm 1.

The tridiagonal matrix algorithm is shown below [1–3].

### Algorithm 1: tridiagonal

Tridiagonal matrix algorithm (Thomas algorithm).

#### Given:

- $\mathbf{A} \in \mathbb{R}^{n \times n}$  - tridiagonal matrix
- $\mathbf{d} \in \mathbb{R}^n$  - vector

#### Note:

- $\mathbf{A}$  and  $\mathbf{d}$  define the tridiagonal linear system  $\mathbf{Ax} = \mathbf{d}$ .

#### Procedure:

1. Determine  $n$  (where  $\mathbf{A} \in \mathbb{R}^{n \times n}$ ).
2. Preallocate vectors of size  $n \times 1$  to store  $\mathbf{b}$  and  $\mathbf{x}$ .
3. Preallocate vectors of size  $(n - 1) \times 1$  to store  $\mathbf{a}$  and  $\mathbf{c}$ .
4. Extract  $\mathbf{a}$  from  $\mathbf{A}$ .

```

for  $i = 2$  to  $n$ 
     $a_{i-1} = A_{i,i-1}$ 
end

```

5. Extract  $\mathbf{b}$  from  $\mathbf{A}$ .

```

for  $i = 1$  to  $n$ 
     $b_i = A_{i,i}$ 
end

```

6. Extract  $\mathbf{c}$  from  $\mathbf{A}$ .

```

for  $i = 2$  to  $n$ 
     $c_{i-1} = A_{i-1,i}$ 
end

```

7. Forward elimination.

```

for  $i = 1$  to  $n$ 
     $w = a_{i-1}/b_{i-1}$ 
     $b_i = b_i - wc_{i-1}$ 
     $d_i = d_i - wd_{i-1}$ 
end

```

8. Backward substitution.

```

for  $i = n - 1$  to  $1$  by  $-1$ 
     $x_i = (d_i - c_i x_{i+1}) / b_i$ 
end

```

**Return:**

- $\mathbf{x} \in \mathbb{R}^n$  - solution of the tridiagonal linear system  $\mathbf{Ax} = \mathbf{d}$

## REFERENCES

- [1] James Hateley. *Linear Systems of Equations and Direct Solvers*. MATH 3620 Course Reader (Vanderbilt University). 2019.
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