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Temperature Distribution using Linear Equations

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ABSTRACT

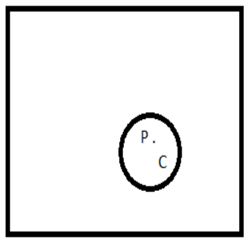
In this paper a methodology is proposed to predict temperature distribution from the limited number of the scattered measurement data.

I. Introduction

Consider the cross-section of long rectangular dam on a river. As you can imagine the boundaries of the dam are subject to three factors, the temperature of the air, temperature of the water and the temperature of the ground at its base. Engineers are interested in knowing the temperature distribution inside the dam in a specific period of time so they can determine the thermal stress to which the dam is subjected. Assuming the boundary temperature are held constant. During that specific period of time, the temperature inside the dam will reach certain equilibrium after some time has passed. Finding this equilibrium temperature distribution at different points on the plate is desirable, but extremely difficult.

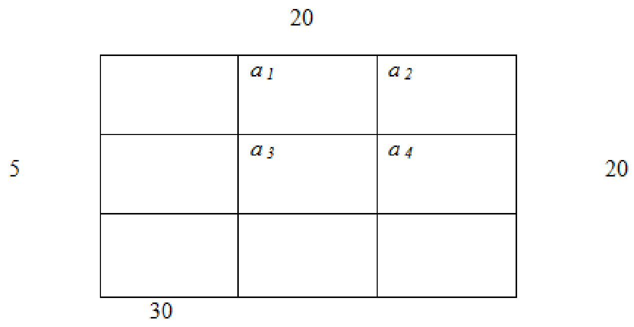
II. Mean value property

Consider a few points on the plate and approximate the temperature of these points. This approximation is based on a very important physical property called the mean value property.



Consider a plate has reached thermal equilibrium and P is a point on a plate and C is a circle centered at P fully contained in the plate then the temperature at P is the average value of the temperature function over C. In this paper, place a grid over the plate and concentrate only on the points. The grid is fashioned so that some grid points lie on the boundary of the plate, assume that the temperature at these points equals the external temperature.

III. Mathematical Model



We consider placing the grid on the square plate, as shown in the above figure. In the above figure, the number represents the temperature. There are 4 points inside the plate to consider the temperatures at these points are labelled a_1,a_2, a_3 and a_4. The discretized mean value property gives rise to the following 4 equations. The temperature of the 4 closed grid points are recorded clockwise in map order. Here we have taken a_1 equals the sum of 4 temperatures divided by 4 where

$a_1=(20+25+a_2+a_3)/4$
$a_2=(20+20+a_1+a_4)/4$
$a_3=(25+30+a_1+a_4)/4$
$a_4=(20+30+a_2+a_3)/4$

These four equations are equivalent to the following system of linear equations.

$4a_1-a_2-a_3=45$
$-a_1+4a_2-a_4=40$
$-a_1+4a_3-a_4=55$
$-a_2-a_3+4a_4=50$

A new system of equations could be solved. Now we write the system may be in matrix vector form.

Here $X=\begin{bmatrix}a_1\\a_2\\a_3\\a_4\end{bmatrix}$ $A=\begin{bmatrix}4&-1&-1&0\\-1&4&0&-1\\-1&0&4&-1\\0&-1&-1&4\end{bmatrix}$ $b=\begin{bmatrix}45\\40\\55\\50\end{bmatrix}$

X is called the vector of equilibrium temperatures. The solution for the above system is then $X=A^{-1}b$, in this A is invertible.

Compute the inverse of a square matrix.

Here we find $A^{-1}=\begin{bmatrix}7/24&1/12&1/12&1/24\\1/12&7/24&1/24&1/12\\1/12&1/24&7/24&1/12\\1/24&1/12&1/12&7/24\end{bmatrix}$

$X=A^{-1}b=\begin{bmatrix}23.125\\21.875\\25.625\\24.375\end{bmatrix}$

IV. Conclusion

The vector equilibrium temperature is
$a_1=23.125$, $a_2=21.875$, $a_3=25.625$, $a_4=24.375$

References

[1] A text book of B.Sc mathematics Vol-III, S.Chand Publications.