A Monte Carlo Method for thermal building simulation

Lukas Johannes Haarhoff

Presented in partial fulfillment
of the requirements for the degree
Master of Engineering in the faculty of
Engineering, the Built Environment
and Information Technology,
University of Pretoria.

2000

Abstract

Title: A Monte Carlo Method for thermal building simulation

Author: Lukas Johannes Haarhoff

Supervisor: Prof E H Mathews

Co-supervisor: Dr C Lombard

Department: Mechanical and Aeronautical Engineering

Degree: MIng (Mech)

Search terms: Monte Carlo model, stochastic model, deterministic model, building thermal simulation, temperature distribution, verification study, convolution, Chi-square test, constant weather, seasons.

A Monte Carlo method for finding an approximation of the building inside stochastic temperature distribution is given. Present simulation techniques are either over-simplified and uses only a deterministic method, or are highly complex stochastic models.

The development of a new method, easier to understand than a stochastic model, and at the same time giving a more general understanding of the problem than deterministic models is discussed. The method consists of a Monte Carlo approach, used in conjunction with a more traditional deterministic building thermal simulation model. Radiation and temperature data are simulated separately, then the combined effect is found with a numerical convolution integral.

Because the convolution integral is only strictly valid for independent variables, a verification study is also presented, using four different buildings and five different ventilation rates. Temperature and global radiation data measured at Irene over the five year period 1994 to 1998 was used. After analysis it was divided into four periods of constant weather, roughly coinciding with the seasons for this locale. Diffuse radiation was calculated from the global values since no measurements were available.

To measure the inside temperature distribution for five years, five different ventilation rates for the same four buildings was out of the timeframe of this study. Therefore the method was verified by comparison of results obtained with the new technique and results obtained by simulating every day for the same period.

Since the Chi-square test normally used to quantify the difference between distributions do not produce readily interpretable results in this instance, another test was developed and is described. From this it can be seen that the average predicted temperature error is 0.68°C, with a standard deviation of 1,37°C. The verification thus shows that by using the new Monte Carlo method a good approximation can be found for the inside temperature distribution by using only 4% of the days from the five year period.

Samevatting

Titel: A Monte Carlo Method for thermal building simulation

Outeur: Lukas Johannes Haarhoff

Leier: Prof E H Mathews

Mede-leier: Dr C Lombard

Departement: Meganiese en Lugvaartkundige Ingenieurswese

Graad: MIng (Meg)

Soek terme: Monte Carlo metode, stochastiese metode, deterministiese metode, gebou termiese simulasie, temperatuur verspreiding, verifikasie studie, konvolusie, Chi-kwadraat toets, konstante weer, seisoene.

'n Monte Carlo metode word gegee wat 'n benadering gee van die gebou binne stochastiese temperatuur verspreiding. Huidige metodes is òf oor-vereenvouding en gebruik net 'n deterministiese metode, òf is hoogs komplekse stochastiese metodes.

Die ontwikkeling van 'n nuwe metode wat is makliker om te verstaan as 'n stochastiese metode en tog 'n meer algemene begrip van die probleem gee word bespreek. Die metode gebruik 'n Monte Carlo benadering tesame met 'n meer traditionele deterministiese model. Radiasie en temperatuur data word afsonderlik gesimuleer, en dan word die gesamentlike effek gekry deur 'n numeriese konvolusie integraal te gebruik.

Omdat die konvolusie integraal slegs geldig is vir onafhanklike veranderlikes, word 'n verifikasie studie ook gegee. Die studie gebruik vier verskillende geboue en vyf ventilasie tempo's. Temperatuur en globale radiasie data gemeet by Irene oor die vyf-jaar periode van 1994 tot 1998 word gebruik. Na analiese word dit in vier periodes van konstante weer opgebreek, wat rofweg met die seisoene vir die meetstasie ooreenstem. Diffuse radiasie word uitgewerk van die globale waardes af aangesien geen metings beskikbaar was nie.

Dit sou buite die tydsbestek van die studie val om binne temperature te meet vir vyf jaar en vyf verskillende ventilasie tempo's vir dieselfde vier huise. Daarom is die metode geverifieer deur vergelyking van resultate soos deur die metode voorspel teen resultate verkry deur elke dag afsonderlik te simuleer vir dieselfde periode.

Aangesien die Chi-kwadraat toets wat gewoonlik gebruik word om die verskil tussen twee verspreidings weer te gee nie maklik interpreteerbare resultate vir die geval gegee het nie, is 'n ander toets ontwikkel en word ook hier beskryf. Hiervan kan gesien word dat die tempertuur met 'n gemiddelde fout van 0.68˚C voorspel is, en die standaard afwyking van die fout 1,37˚C is. Die verifikasie wys dus dat met die nuwe Monte Carlo metode 'n goeie benadering van die binne temperatuur verspreiding gekry kan word deur slegs 4% van die dae van die vyf jaar periode te gebruik.

Acknowledgements:

The author would like to thank the following people for their support, leadership and guidance. Without them this study would not have been possible.

Prof E.H. Mathews

Dr C. Lombard

Table of Contents