Technical Report

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Abstract

The Climate Calculation Module contains functionality for interpolating tabulated climate data and calculating solar radiation onto surfaces with given orientation and inclination. This report lists the equations implemented and the programming interface of the library.

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1 Introduction

Climatic data is needed for building physics and building energy simulation software. Besides the support for different climate data formats and reading of tabulated values, simulation programs need to implement interpolation methods, support for continuous (e.g. measured) or cyclic data. Further, solar radiation calculation is central to any building energy simulation software, and the calculation of the direct and diffuse radiation onto surfaces with arbitrary orienation and inclination.

In order to avoid implementing the same functionality in several simulation programs, this library has been developed. It is currently being used by the simulation software DELPHIN, THERAKLES and NANDRAD of the Institut für Bauklimatik of the Technische Universität Dresden, Germany. The library reads climate data files from weather files in C6B or EPW format. A format description of the C6B format is given in ....

1.1 Interpolation rules

Climatic data is provided for measured time intervals, typically with hourly frequency. When a simulation program requests climate data between time points, the climate data is interpolated between sampling points, using linear interpolation:

$$\alpha = \frac{t - t_i}{t_{i+1} - t_i}$$
$$v\left(t\right) = \left(1 - \alpha\right) v_i + \alpha v_{i+1}$$

2 Solar Radiation Calculation

The solar short wave radiation calculation expects climatic data for the direct radiation in the sun's normal direction and diffuse radiation onto a horizontal surface.

Note: Often, experimental data includes global radiation and diffuse radiation onto horizontal surfaces, whereby diffuse radiation is measured using sun blocking rings. The direct radiation onto the horizontal surface is then computed as the difference between global and diffuse radiation. When storing the direct radiation in the sun's normal direction in weather files, a sun position calculation is needed. Hereby, differences parameters and model complexity can lead to different normal radiation data. When applying a different sun position and radiation calculation to compute back the direct radiation on horizontal surfaces, it is possible that hereby different direct solar radiation values are obtained.

2.1 Sun Position Calculation

The first step in calculation solar radiation is the calculation of the sun's position. Hereby, it is important to remember that the solar radiation data was measured at a specific longitude and latitude L.

2.1.1 True time correction/local mean time

Since the location of the measurement location/building location can be different from that of the local time zone's center, a correction has to be applied such that 12 pm is indeed the time where the sun is in the zenit. Equations are taken from Kologirou - Solar Engineering.

Longitude of the selected time zone (tz):

$$l_{tz} = 15\text{deg}\ tz$$

and difference between this longitude and the longitude of the building:

$$\delta_{long} = l_{tz} - l_{ccm}$$

Time shift Δt_{long} to be applied is then the longitude difference times 4 minutes (24*60/360=4):

$$\Delta t_{long} = -\delta_{long} 4\text{min}$$

Local mean time (lmt) is then:

$$t_{lmt} = t + \Delta t_{long}$$

Example: Dresden, Germany, longitude 13.768°, time zone UIT+1, located west of the reference meridian for UIT +1, hence solar noon will be a little bit later than 12 pm:

$$l_{tz} = 15 \cdot 1 = 15$$
$$\delta_{long} = 15 - 13.768 = 1.232°$$
$$\Delta t_{long} = 4\text{min} \cdot 1.232 = 4.928\text{min}$$

Solar noon will be reached in Dresden around 5 minutes past 12 pm.

2.1.2 Apparent solar time calculation

Correction of day length due to eccentricity and earth's orbit around sun, using $t_d = t \cdot 1\text{d}/\left(3600 \cdot 24\text{s}\right)$ time in days:

$$B = 2\pi \frac{t_d - 81}{365}$$
$$\Delta t_{exc} = \left(9.87 \sin 2B - 7.53 \cos B - 1.5 \sin B\right) \text{min}$$

2.1.3 Declination and elevation angle of the sun

The declination δ of the sun is computed using the equations from ASHRAE handbook:

$$\delta = 23.45° \sin 2\pi \frac{t_d + 284}{365}$$

Hour angle $\Omega \in [-180°, 180°]$ is

$$t_h = t_d - [t_d]$$
$$\Omega = 2\pi \left(t_d - 0.5\right)$$

and elevation angle h is given by:

$$\sin h = \sin L \cdot \sin \delta + \cos L \cdot \cos \delta \cdot \cos \Omega$$

2.1.4 Azimuth angle

The azimuth angle is

$$\tan a = \frac{\sin 2\pi t_d \cdot \cos \delta}{\sin L \cdot \cos 2\pi t_d \cdot \delta + \sin \delta \cdot \cos L}$$