5.5. Mathematical Description of Auxiliary Tools

5.5.1. TRNSHD

The integrated tool for calculating solar sunlit and distribution factors is based on TRNSHD (Hiller, 2000). The code has been completely revised and adapted to the needs of TRNSYS 17. In addition, the 2D polygon clipping procedure which calculates the shading effect of a set of arbitrary polygons on a receiving polygon has be replaced by the GPC library Version 2.23 from Alan Murta, University of Manchester,UK is applied (http://www.cs.man.ac.uk/~toby/gpc/). Also, the beam radiation shading is no longer solved by hourly calculation for a given location but by discretisation of the half hemisphere. The approach has several advantages:

- pure geometric sunlit factors
- independent from building location
- only one calculation for both beam and diffuse radiation
- less data

Sky division model based on Tregenza

The sky is represented by a hemisphere where the building is placed in its center. The celestial hemisphere is subdivided into patches. The Tregenza-based sky division scheme divides the hemisphere vertically into 7 superimposed horizontal rows, each representing a differential altitude of 12°, with the hemisphere topped at its zenith by a circular segment having a half-cone angle of 6°. Each horizontal row is then divided into rectangular segments based on the Tregenza convention for a total of 144 rectangular and 1 circular segments. A scaling factor is used to increase the number of direct solar positions. (Bourgeois, 2008). Besides a medium resolution of 577 patches a high resolution of 2305 patches is available.
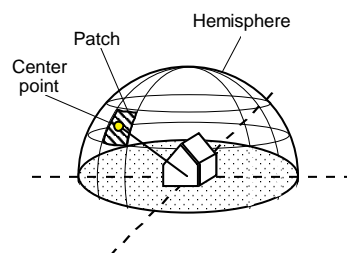

Figure 5.5.1-1: Discretization of the celestrial hemisphere

Solar sunlit factors of external windows

Each center point of a patch is defined as a sun position. The portion of external surfaces sunlit by beam radiation for each sun position is determined by projection and 2D polygon clipping. The fraction of each patch sunlit by beam radiation is given by:

$$f_{beam,ex} = \frac{A_{sunlit}}{A_{total}}$$

where A_{sunlit} is the sunlit area and A_{total} is the total area of an external window.

For solving the diffuse radiation shading it is assumed that the patches are rather small and far away. Thus, the diffuse radiation leaving each patch can be treated as parallel radiation with the direction from its center point to the center of the hemisphere. In the current version the diffuse radiation is assumed to be isotropic. Therefore, the diffuse fraction of an external window can be determined by:

$$f_{dfu,ex} = \frac{\sum_{k=1}^{n} \cos\alpha_k \cdot \Delta\omega_k \cdot f_{beam,k}}{\sum_{k=1}^{n} \cos\alpha_k \cdot \Delta\omega_k}$$

$$\Delta\omega_k = \sin\theta_{Z,k} \cdot \Delta\theta_Z \cdot \Delta\gamma$$

where n is the number of patches where the external window is sunlit, αk is the angle between the surface normal vector and the sun vector of patch k, $\theta Z,k$ is the zenith angle of patch k, $f_{beam,k}$ is the "beam" sunlit fraction of patch k, $\Delta\omega k$ is the increment of the solid angle of patch k, $\Delta\gamma k$ is the increment of the solar azimuth angle, $\Delta\theta Z$ is the increment of the solar zenith angle of patch.

All calculated sunlit fractions are written to an external file, the so-called **SH**ading **M**atrix file (*.SHM), which is read in by the multizone building model at the start of the simulation.
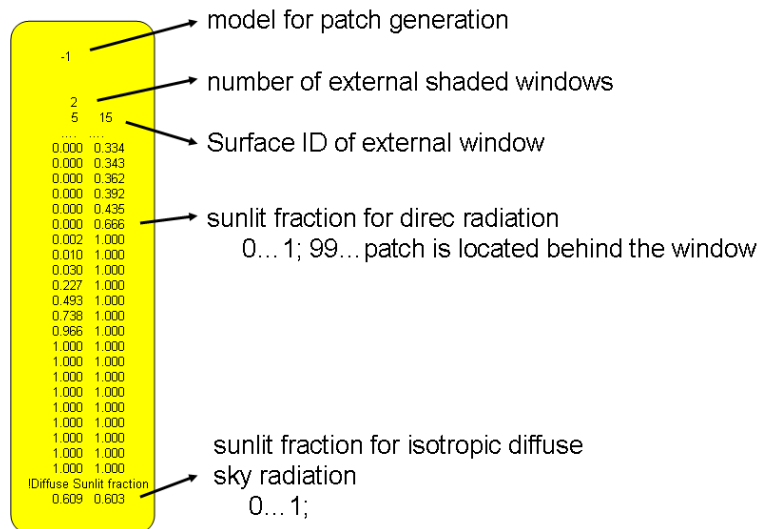

Figure 5.5.1-2: Example of a SHading Matrix file (*.SHM)

Solar beam distribution factors of external windows

In addition to sunlit fractions of external windows, TRNSHD can calculate the beam sunlit fractions of the window that strike each inside surface of the zone (not airnode!). The performed calculation steps are similar those for external shading. All sunlit inside surfaces are projected onto the plane of the window and clipped against the remaining sunlit parts of the window obtained from the external shading calculations. In the current version the beam distribution factor calculation is restricted to external windows only.

The calculated distribution factors are also written to one external file for each zone, the so-called **In**S**olation **M**atrix file (*_xxx.ISM), which is read in by the multizone building model at the start of the simulation.
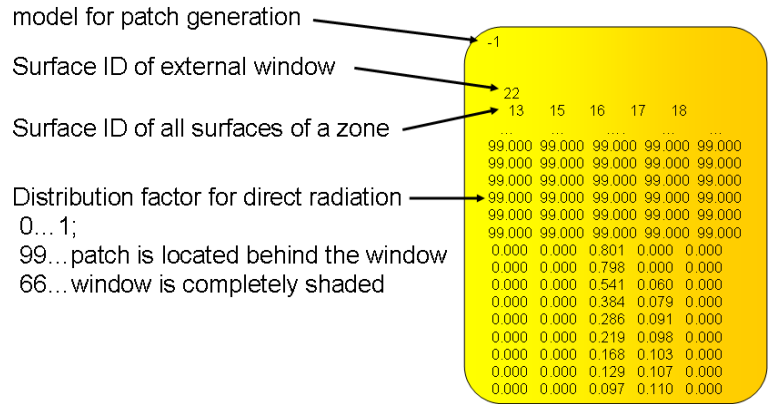

Figure 5.5.1-3: Example of a zone **In**S**olation **M**atrix file (*_xxx.ISM)

Model limitations

- Zones have to be closed and convex volumes.
- Surfaces have to be planar polygons described by an ordered list of vertices.
- Surfaces aren't allowed to have holes.
- Windows must be subsurfaces of walls.
- Building surfaces must have an outward normal vector.
- No reflection is taken into account.

References

Bourgeois D, Reinhart CF, Ward G, "A Standard Daylight Coefficient Model for DynamicDaylighting Simulations" Building Research & Information 36:1 pp. 68 – 82, 2008

Hiller, M. D.E., Beckman, W.A, Mitchell, J.W. 2000. TRNSHD – a program for shading and insolation calculations. Building and Environment 35, p.633 - 644.

Murta, A. - GPC library Version 2.23, University of Manchester,UK
http://www.cs.man.ac.uk/~toby/gpc/