Mean Radiant Temperature Simulation

CPSC 478 Final Project

Description

Mean Radiant Temperature (MRT) is an account of the incident radiation on a specific individual given the temperature of the surface and the angle factor from the individual to the surface. It plays an integral role in thermal comfort, but is hardly taken into account with current room heating and cooling systems. This simulation calculates the MRT acting on an individual given his position. MRT calculation uses the following formula:

$$MRT^4 = T_1^4 F_{p-1} + T_2^4 F_{p-2} + \ldots + T_n^4 F_{p-n}$$

Where MRT is mean radiant temperature, T_n is the temperature of a surface, and $F_{p\text{-}n}$ is the angle factor from the person to a surface.
The following simplifications had to be made:

- The character was simplified to a point (center point or character) in order to allow for direct calculation of angle factor. This is a larger issue with MRT implementation since the angle factor of a human is incredibly difficult to compute and varies from person to person.
- The angle factor calculation implemented was van Oosterom and Strackee's tetrahedral method which splits each surface into four areas at the surface's normal which intersects with the character point. The formula is as follows:
  $$\tan\left(\frac{1}{2}\Omega\right) = \frac{\left|\vec{a}\,\vec{b}\,\vec{c}\right|}{abc + \left(\vec{a}\cdot\vec{b}\right)c + \left(\vec{a}\cdot\vec{c}\right)b + \left(\vec{b}\cdot\vec{c}\right)a}$$
  where the numerator is the scalar triple product of the vectors from the character point to the vertices at the base of the tetrahedron (the surface).
- The surfaces were all considered to be black bodies, which is a regular assumption within MRT calculations for indoor environments.

This simulation was built using HTML, WebGL, css, and Javascript (using the three.js library).

Instructions

The simulation can be accessed at http://marcbielas.com/MRT-Simulation/

1. The user should input temperature in the unfolded room diagram. These temperatures will be used to calculate MRT. If the user does not input temperature values, the simulation will still run, and the percentage of MRT coming from surfaces will be shown, but the MRT value will not be calculated.
2. The user hits start to initiate the simulation. This also introduces a legend which includes the MRT calculation, wall temperatures from the user input, and the percentage of MRT coming from each surface.
3. The user can move an avatar by using the arrow keys on the keyboard. The user can also choose to switch the view from plan to perspective using the radio button. As the avatar moves, new MRT values and percentages are calculated
4. An extra option for sitting in the room is provided. This is important when calculating MRT due to the fact that rooms where MRT could be economically implemented should be rooms where occupants do not move around much (are seated). Seating reduces the y-position of the avatar centroid, which had the effect of increasing the percentage of MRT coming from the floor surface. When seating is enabled, the character does not move, if the user wishes to continue walking around, the sitting option must be switched to “No”.

Challenges

The two biggest challenges of this project were the calculation of solid angles within the room’s geometry (and therefore the calculation of MRT) and the complex geometry and animation of the character. The character’s legs and arms rotate while walking, and the torso and head bounce up and down to emulate natural rhythms.

Future Work

More research needs to be done in order to compute the MRT from complex room geometries and better model thermal comfort by including a consideration for conductive heating by floors.