ABSTRACT
Accuracy in rendering sky/atmosphere color has long been neglected and reduced to fictitiously simplified methods such as uniform blue color, color gradation from zenith to horizon and static textured sky dome. These methods may save up a lot of CPU-computation time; nonetheless they lack the ability of working with arbitrarily complex atmospheric conditions. As the light itself is a fraction of the electromagnetic spectrum, we need a spectral-based solution to compute the resulting color of the sky. This is being the result of interaction processes between light and the atmosphere, namely absorption and scattering being wavelength-dependent. We present a fast yet accurate model for approximating full spectrum daylight for local atmospheric conditions based largely on radiative transfer works in atmospheric science. Our aim is to design an inexpensive model yet maintain the physical-based radiometry to a certain level without sacrificing accuracy and usability for outdoor computer graphic rendering. The proposed method expands and existing method developed by Preetham et al (1999) to consider observer altitude change. The coefficients used are also rebuilt in order to improve result for local atmosphere. In addition, tweaks are introduced to compensate for any shortcomings in the previous method.

KEYWORDS
Atmospheric attenuation, Spectral rendering, Local atmosphere.

1. Introduction
Previous works on rendering daylight sky are either too simplistic or too complicated. Doing this in real-time does present a delicate issue in balancing between accuracy and speed. In general, methods in rendering daylight sky can be categorized into two groups; classical and real-time. Our proposed model shares both group characteristics and can be considered as a hybrid. It draws strengths from classical group as in its accuracy and reduced complexity from real-time group. The model is intended for use in pc based real-time applications such as flight simulator where the aim is to create perceptually realistic rendering of the daylight sky.

The diagram below shows the desired output for our proposed model. To be considered as a successful daylight sky model, it has to capture various effects observed on daily skies. These effects are sunrise/sunset, whitening of sky near to horizon, brightening of circumsolar area of the sun, a dark/bluest region that divide two opposing bright regions, color distribution change as the sun traverses the sky and whitening of the sky as turbidity increase.
Figure 1: Examples of the desired rendered output. From top to bottom: morning, turbidity 2; evening, turbidity 2; overcast, turbidity 10. All images rendered using Preetham et al. [1] method at a fixed altitude and a single direction-facing west.

Images rendered above include the effect of aerial perspective, which causes blurring of distant objects such as mountains. Our intended model does not include the effect, as we will not be rendering terrain et cetera thus removing the needs to do so.

Figure 2: Actual images captured at increasing altitude. From left to right: altitude 500 feet; altitude 50000 feet; altitude 100000 feet.

We follow closely Preetham et al. [1] framework and add the effect of increasing altitude to it. Altitude play a major role in determining the condition of a sky as can be seen in Figure 2. As the altitude increase, the darkening of sky region near to zenith becomes more apparent. Nielsen [2] has proposed a solution to the stated problem but his model suffers from accuracy point of view. His model only considers scattering and further reduce computational time by doing the attenuation calculation at selected wavelengths only to represent RGB color triplets. Absorption is an important factor in attenuation process as ozone, one of the major absorbers; help preserve the rich blue color of the sky during high zenith angle of the sun. Color information is also lost as full spectrum calculation of the visible band will produce much more natural looking color rather than doing the attenuation at three wavelengths only (R, 650nm; G, 610nm; B, 475nm). Furthermore, Malaysian very humid atmosphere contains large amounts of water vapor; another one of the major absorbers; thus requiring absorption to be considered.

2. Methodology

The proposed solution for problems stated above is explained in steps below.

2.1 Generating sky spectral radiance distribution data

As we lack the actual measured data, we opt for a solar spectral model, SMARTS2 [3] to help produced approximated version of the required sky spectral radiance distribution data. The simulation is run with a combination of 145 sky patches, five angstrom turbidity values and five altitude values. This combination is chosen to ensure that our simulated data covers every local atmospheric state possible. SMARTS [3] input sheet is devised to imitate local atmospheric properties as close as possible.

The spectral radiance information is converted to Yxy color space before storing it in memory. This will reduce storage space needed, as we are only interested in color information rather than the full spectrum. This is done by following the standard procedure as advised by CIE using Standard Observer 2° and illuminant D65 (daylight). Conversion is done at selected wavelengths similar to Nielsen [2] but the amount of selected wavelengths is higher, covering all possible color in a visible band from violet to red light. This is unavoidable in order to ensure the simulation process is feasible, as full spectrum calculation requires higher computation power and time, which is impossible for real-time application.
2.2 Derivation of function from sky spectral distribution data

Real-time rendering prohibit the direct usage of SMARTS2-generated data. We are going to derive a function from the large data using fitting formula. This function will relate the spectral information of the queried sky patches by supplying insolation parameters such as turbidity.

We pick Perez et al.’s [4] formulation as it has been battle-tested and posses few enough variables to ensure the convergence of the optimization stage of the fitting process. The function is fitted using Levenberg-Marquardt non-linear least squares method and as a result, a linear function in turbidity and altitude was obtained successfully. The function described the five parameters in Perez et al. [4] formulation for luminance Y and chromaticity x and y for current sky patch.

2.2 Conversion from Yxy to RGB

Yxy color space can be converted to RGB by first calculating both X and Y in order to obtain complete tristimulus value of XYZ. RGB values in a particular set of primaries can be transformed to and from CIE XYZ by a 3x3-matrix transform. These are standard procedures and for further reading, we suggest [5].

3. Results/Discussion

At present, we only managed to complete the first step of the proposed methodology, due to a few programming glitches and misunderstanding. Effort has been taken to start tackling the rest of the proposed solution.

4. Conclusion

We managed to provide a solution for rendering daylight sky in real-time application purpose by extending Preetham et al. [1] works to include the effect of increasing altitude. We also take the effort to represent the local atmosphere as close as possible to ensure the rendered sky closely resemble Malaysian skies.

References


