PRELIMINARY STUDIES OF FOURIER ANALYSIS FOR SOME CLIMATE DATA THAT INFLUENCES HEAT TRANSFER IN BUILDING ENVELOPE

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JANUARY 2007

PRELIMINARY STUDIES OF FOURIER ANALYSIS FOR SOME CLIMATE DATA THAT INFLUENCES HEAT TRANSFER IN BUILDING ENVELOPE

BY:

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JANUARY 2007

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Tuan / Puan

TAJUK PROJEK : PRELIMINARY STUDIES OF FOURIER ANALYSIS FOR SOME CLIMATE DATA THAT INFLUENCES HEAT TRANSFER BEHAVIOUR !N BUILDING ENVELOPE

Dengan hormatnya perkara di atas adalah dirujuk.

Sukacita dimaklumkan bahawa cadangan penyelidikan yang telah dikemukakan oleh tuan/puan bersama Encik Zainazlan Bin Md Zain telah diluluskan.

Tempoh projek penyelidikan ini ialah 12 bulan iaitu bermula **1 Julai 2005** hingga **30 Jun 2006.**

ii. Walaubagaimanapun, adalah dimaklumkan bahawa kos yang diluluskan adalah sebanyak **RM 8,000.00** sahaja. Diharapkan perkara ini tidak mematahkan semangat tuan/puan untuk menjalankan penyelidikan dan diharapkan kos tersebut dapat membantu pihak tuan/puan memulakan projek.

iii Tuan/puan juga perlu **mengemukakan semula keperluan kewangan J-Series mengikut jumlah peruntukan yang telah diluluskan.** Pembiayaan pembentangan kertas kerja dan perjalanan ke luar negara dihadkan kepada RM 2,000.00 sahaja. Permohonan peralatan penyelidikan adalah dicadangkan dari Fakulti/ Cawangan masing-masing.

iv ^uan/^uar! ^er'u memhe'aniakap. 50% Harioada oeran oenvelidikan vanQ telah diluluskan bagi projek tuan/puan dalam tempoh **6 bulan** pertama projek berjalan. Sehubungan itu , pihak IRDC akan memantau penggunaan geran penyelidikan tuan/puan untuk memastikan 50% daripada jumlah geran yang diluluskan telah dibelanjakan sehingga bulan **Disember 2005.**

v. Semua pembelian peralatan yang kosnya melebihi RM500.00 satu item perlu menggunakan Pesanan Jabatan Universiti Teknologi MARA (LO). Pihak tuan/puan juga dikehendaki mematuhi peraturan penerimaan peralatan. Panduan penerimaan peralatan baru dan pengurusannya , dilampirkan.

vi. Semua peraiatan / kelengkapan penyelidikan yang dibeli adalah menjadi hak milik fakulti. Semua peraiatan / kelengkapan hendaklah diserahkan kepada pihak fakulti setelah tamat penyelidikan untuk kegunaan bersama.

vii. Seperti yang tuan/puan sedia maklum tuan/puan perlu membentangkan kertas kerja di Seminar Hasil Penyelidikan IRDC setelah projek tamat dijalankan nanti.

viii. Kertas kerja boleh dibentangkan di seminar selain daripada yang dianjurkan oleh IRDC setelah 75% deraf awal laporan akhir projek dihantar ke IRDC untuk semakan. Walau bagaimanapun , tuan/puan perlu membuat permohonan kepada pihak kami.

ix. Pihak tuan/puan dikehendaki mengemukakan **Laporan Kemajuan** kepada IRDC 3 kali setiap tahun iaitu pada bulan April , Ogos dan Disember sepanjang penyelidikan tuan/puan berjalan. **Laporan Akhir** perlu dihantar sebaik sahaja projek penyelidikan disiapkan. Format menulis laporan akhir boleh diperolehi di Institut Penyelidikan , Pembangunan dan Pengkomersilan.

Sekian, terima kasih.

'SELAMAT MENJALANKAN PENYELIDIKAN'

Yang benar

PROF. DRAZNIZAIN AHMED
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Ilsue

Tarikh : 24 Januari 2007

No Fail Projek: 600-IRDC/ST 5/3/1007

Penolong Naib Canselor (Penyelidikan)
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Ybhg. Prof,

LAPORAN AKHIR PENYELIDIKAN "PRELIMINARY STUDIES OF FOURIER ANALYSIS FOR SOME CLIMATE DATA THAT INFLUENCES HEAT TRANSFER IN BUILDING ENVELOPE "

Merujuk kepada perkara di atas, bersama-sama ini disertakan 3 (tiga) naskah laporan akhir penyelidikan bertajuk "Preliminary Studies Of Fourier Analysis For Some Climate Data That Influences Heat Transfer In Building Envelope".

Sekian, terima kasih.

Yang benar,

PROF MADYA MASRIAH HJ AWANG
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PENGHARGAAN

Setinggi-tinggi penghargaan dan ribuan terima kasih kepada semua pihak yang terlibat secara langsung atau tidak langsung bagi menjayakan projek ini dan seterusnya dapat menyiapkan laporan projek dengan sempurna.

Di antaranya

Prof Dr Azni Zain Ahmed
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ABSTRACT

Energy utilization in buildings continues to increase as quality of life increases. Buildings are built in an environment and the climate surrounding a building is a factor that will influence the amount of energy for the building services. The higher the thermal stress due to the external condition, the higher the energy needs to provide the same building service. This paper discusses the different types of analyses of climate for Subang. The climate data were calculated using the monthly hourly averaged. Then the least squares method and fast Fourier transform via MATLAB were explored in order to get some important information.

Overall, the temperature distribution, solar radiation, relative humidity distribution, rainfall distribution, wind-speed distribution and pressure distribution were presented. The least square polynomial of degree four and ten were chosen to represent the climate data. The least square error and the norm of the residual for these two polynomials were the smallest among other polynomials. The coefficients of determination were also calculated. The Fast Fourier Transform (FFT) from MATLAB toolbox was also used to disclose the pattern of the climate data. The FFT shows the Fourier coefficient on the complex plane. A peridogram of power versus frequency and a peridogram of power versus period were obtained for the climate data via MATLAB.

These studies reveal the patterns that need to be considered for optimum energy utilization in buildings.

CHAPTER 1

INTRODUCTION

1.1 Preliminary

Generally, people are concerned about the possibility of global climate change and its effect to their life. Due to this, there are an increasing number of studies and analyses of distribution and pattern of climate data. The analysts want to determine either the changes of increasing or decreasing in climate data has great value of influence to the global life.

A major challenge when dealing with climate data is in analyzing and interpreting any possible hidden information to the user. This information visualization allows users to get some important information and focus on items of interest. For a closer overview to the distribution and pattern of climate data, approximation methods are helpful that provide a means to display as much of the necessary information as possible.

This project paper has three objectives. The first objective is to analyze some climate parameters in Subang. The second objective is to study time domain analysis via least square method. The third objective is to analyze the climate data using frequency domain analysis. These analyses are done by MATLAB.

1.2 Rational of the Study

There are patterns in the climate conditions. Recognizing the patterns and understanding the phenomena will enable the efficient management of the climate modifying process such as air conditioning in building space. A building is a climate modifier. The energy utilized in a building is dependent on the climate condition surrounding the building.

Fourier transform provides a good study on the repetitive or cyclic phenomena of the climate data. Climate data that will be analyzed using Fourier Transform will be solar radiation, relative humidity, rain, wind and pressure. It is hoped that this study will give the general pattern and provide the opening for further studies on the weather data derivatives.

1.3 Scope of the Study

Climate data can be in the form of temperature, solar radiation, rain, relative humidity, wind, pressure and other phenomena. In this study we analyze the temperature, solar radiation, rainfall, relative humidity, wind-speed and pressure for Subang. The tool that we used in this study is MATLAB.

CHAPTER 2

LITERATURE REVIEW

2.1 Temperature

Temperature is a measure of the average kinetic energy of the particles in a sample of matter (Temperature, 2005). In other words, temperature of an object can be described as the sensation of warmth or coldness felt from contact with it. Temperature can also be written as a property which governs the transfer of thermal energy, or heat, between one system and another (Temperature, 2005).

" Being a country closed to the .equator, Malaysia has uniform temperature throughout the year (Climate, 2006). The highest average monthly temperature was recorded in April and May in most places and December and January shows the lowest value of average monthly temperature (Climate, 2006).

Analyses of temperature data produce significant information in our life. Through a detailed study of temperature data, the climate change scenario (especially for temperature) and its implication towards human, animal and plant life can be determined. The climate change scenario describes a future in which the gradual rising temperature accelerates the rate of warming, increasing the sea levels, floods in mountainous regions,

droughts occur in coastal and agriculture areas and thinning artic ice (Shearer, A.W., 2005). The temperature data in climate model also has its important role. Alnaser, W.E. and Merzaa, M.K. (2005) stated that climate model concerning of monthly and yearly average temperature variations is significance as air temperature is an important factor to estimate the added energy ($E_{greenhouse}$) from the greenhouse gasses.

The measurements of surface temperature were recorded daily at hundreds of locations over a long time. The easiest way of obtaining daily scenario temperature data is to simply apply monthly scenario changes to a daily-observed station weather record (Barrow, E.M. & Lee, R.J., 2000). For the purpose of synthesizing daily temperature data corresponding to a particular climate change scenario, a stochastic weather generator can be applied (Barrow, E.M. & Lee, R.J., 2000). This is done in order to observe and analyze the temperature data so that a warming pattern in Earth's temperature variation can be analyzed. It has been proved that the increasing of average temperature year by year has been affected with the increase of the greenhouse effect gasses emissions due to the industrialization (Wesker, E., 1996).

The historical climate change analysis is also based on temperature data, which can be used as a point of reference for cyclic average Earth's temperature variation (Global Warming, 2000). Besides that, the analysis of temperature data and its results are very useful to forecast the future temperature pattern as well as the climate changes due to changes in temperature data. The climate model are possible to predict and summarize the potential consequences of climate change such as tendency for drought in some

regions and higher rainfall in others and also the potential for crop distribution to change due to the hotter and drier conditions (Global Warming, 2000). A historical weather record can be used to construct analogue scenario for the future such as to identify extreme conditions (drought or flood) and the consequent impacts (Barrow, E.M. & Lee, R.J., 2000).

2.2 Solar Radiation

Solar radiation is the energy from the sun transferred to the earth's surface and sun is the source energy. The earth revolves round the sun in an elliptical orbit. The earth will receive 7 percent more radiation in January than in July. (CP Arora, 2000). This happened because the position of the earth which is closest to the sun on January and remotest from it on July which is about 3.3 percent farther away. The rate at which solar radiation strikes earth's upper atmosphere is expressed as the solar constant.

Being a country closed to the equator, Malaysia received quite an ample quantity of sunshine and thus solar radiation. Solar radiation is very much related to temperature. If the temperature is higher, then the amount of solar radiation will be higher. As we know solar radiation does not exist in early morning and night. On the average, Malaysia receives about six hours of radiation per day. Due to the amount of solar radiation that we received, it is important to study on solar radiation pattern.

The demand of solar radiation data is high as it is uses in many aspects and application of life. Chuah et al. (1984) listed various types of uses of solar radiation data. Information such as the availability, seasonal and geographical distribution of total, direct, diffuse radiation are important in the design and performance prediction of solar energy system. In addition, it is also useful for atmospheric science studies and meteorological forecasting.

There are several methods in analyzing and interpreting solar radiation data. One of the methods is by using statistical approaches. Rehman, Shafiqur, et al. (2000) studied the spatial variation in Saudi Arabia using geostatistical techniques. Besides, Ianetz, et al. (2000) presented a method based on analysis approach that can be applied to characterize and differentiate sites with regards to their potential for solar energy conversion systems. This statistical method had been demonstrated by applying it to three sites located in southern Israel.

However in Riyadh, the ASHRAE clear sky model seem to be the method in analyzing and interpreting solar radiation data. Al-Sanea, et all, (2004) applied the ASHRAE model to calculate the monthly average hourly global solar radiation in Riyadh on a horizontal surface. The calculation from the model is compared with measurements for Riyadh, Saudi Arabia. ASHRAE model also can be used to determine the beam, diffuse and ground reflected solar radiation components separately. This solar model is beneficial in such a way that this model can be made as an integral part of the entire heat-transfer analysis model in order to contribute for the boundary conditions.

On the contrary, Flor et. al, (2004) explained the calculation of the incident total solar radiation in all type of surface either in open urban environments or inside building. This methodology is relevant for problems related to solar access, solar gains and day lighting. Certainly, solar radiation is the main contributor to heat gains in buildings, especially in residential buildings where internal gains are very low.

Solar Radiation data is essential in order for the design and assessment of future solar radiation profile prediction. Solar radiation information is needed in variety of applications and areas including agriculture, water resources, day lighting, architectural design and climate change studies (Power,H.C, 2001). For these reasons, solar radiation data play an important role in many aspects of life.

2.3 Relative Humidity

Relative humidity is a term of percentage that describes the quantity of water vapor that exists in a gaseous mixture of air and water (Humidity, 2006). Relative humidity can be used as an indicator of precipitation, dew or fog in weather forecasts and reports.

Overall, the mean monthly relative humidity in Malaysia is in the range from 70% to 90%) from month to month. In Peninsular Malaysia, the minimum range of mean relative humidity varies from a low 84% in February to a high of only 88% in November

(Climate, 2006). In January and February, it is observed that all states in Peninsular Malaysia are experiencing minimum relative humidity except for Kelantan and Terengganu. These two states show the minimum relative humidity in March. However, the maximum relative humidity is generally found in November (Climate, 2006).

Analysis of relative humidity data produces significant information in our life using various methods. Alnaser, W.E. and Merzaa, M.K. (2005) performed regression methods including polynomial and sinusoidal models to fit the data in modeling the average yearly and average monthly variations to obtain the coefficients of determination (R). A companson with similar studies from nearby countries was done between Kingdom of Bahrain, Oman and Kuwait.

Guan, L. et al. (2005) reported that there is a strong linear correlation between hourly variations of dry bulb temperature and relative humidity based on a statistical analysis of 10 years historical hourly climatic data in Australia. It is observed that when dry bulb temperature increases, the relative humidity generally tends to decrease.

2.4 Rainfall

Rain is a form of precipitation includes sleet, snow, hail and dew (Rain, 2006). Falling water drops from clouds to Earth's surface form rain. Rain has important role in hydrologic cycle in which moisture from the oceans evaporates, condenses into clouds, precipitates back to earth, and eventually returns to oceans via streams and rivers to

repeat the cycle again (Rain, 2006). Water vapor that respires from plants and evaporates also join other water molecules in condensing into clouds but in a small amount. The amount of rainfall is expressed as the depth of water that collects on a flat surface and measured by a rain gauge (Rain, 2006).

In general, most places in the Malaysia received average to much above average amount of rainfall. Combination of pattern of seasonal wind flow with the local topographic features determines the rainfall distribution patterns over the country. Heavy rain spells mostly occurs in the exposed areas like the east coast of Peninsular Malaysia, Western Sarawak and the northeast coast of Sabah during the northeast monsoon season (Climate, 2006).

Several studies have been carried out based on rainfall data in terms of timing and volume. Ceballos, A. et al. (2004) analyzed the trends in rainfall and the behavior of dry spells in Mediterranean. The relationship between annual rainfall, the length and frequency of dry spells and the annual variability of these has been studied. They also found that there is no relationship between total annual rainfall with an increment in intra-annual variability in rainfall and a very pronounced occurrence of dry periods.

In a study carried out in a typical Mediterranean semi-arid area in Spain, Lazaro, R. et al. (2001) analyzed a rainfall time-series (1967-1997) for implications on vegetation using statistical methods. They found that all types of rainfall, in terms of volume, timing

and intensity, have consequences for the composition, density and distribution of vegetation.

2.5 Wind-Speed

Wind is the roughly horizontal movement of air caused by uneven heating of the Earth's surface (Wind,2006). Wind can be classified into global winds, upper-level winds, synoptic-scale winds and Mesoscale winds. Wind speed usually measured by anemometer.

In general, wind flow in Malaysia is light and variable. However, the wind flow patterns experiences some uniform periodic changes in certain period (Climate, 2006). Therefore, four seasons can be distinguished, namely, the southwest monsoon, northeast monsoon and two shorter intermonsoon seasons (Climate, 2006).

The studies of wind data is high has been done in various part of the world. Nfaoui, H. et al. (1996) developed an autoregressive model to stimulate hourly average wind speed based on twelve years of hourly average wind speed data. They studied the wind behavior by doing comparisons between generated and real series of data. Then, this model was used to generate reference monthly data in order to build up a reference yearly average wind speed data in Tangiers (Morocco). Blanchard, M. and Desrochers, G. (1984) used the Box-Jenkins method to build up a new model and a new generator of hourly wind speeds. They proved that hourly wind speed data is sufficient to reproduce

the main statistical characteristics such as monthly mean, standard deviation and high hourly autocorrelation of wind speed.

2.6 Pressure

Pressure (symbol: *p)* is the force per unit area applied on a surface in a direction perpendicular to that surface (Pressure, 2006). Pascal (Pa) is the SI unit for pressure and equal to one newton per square metre (N-m" or kg-m" -s"). Some meteorologists prefer the hectopascal (hPa) for atmospheric air pressure. Atmospheric pressure is the pressure above any area in the Earth's atmosphere caused by the weight of air (Pressure, 2006).

Several previous studies have been carried out based on pressure data. Guan, L. et al. (2005) reported that the final change of pressure due to changing temperatures is dependent on the product of new air density and temperature. The study is based on a statistical analysis of 10 years historical hourly climatic data in Australia. It is observed that an increment in temperature will lead to the decrement in pressure. They also found that the change in pressure is fairly small with a wide range of variation in temperature.

2.7 Time Domain Analysis

Coefficient of determination, also known, as the r-squared value is one of the measurements to indicate the quality of the curve fit. It was proven that r value was widely used in many researches of variety fields. El-Metwally, M. (2004) used