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ASSESSING THE RELATIONSHIP OF LAND USE LAND COVER ON SURFACE TEMPERATURE IN CITY OF SHAH ALAM, MALAYSIA USING LANDSAT-8 OLI

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ABSTRACT

The purpose of this paper is to investigate the relationship between land use and land cover (LULC) and land surface temperature in city of Shah Alam using remotely sensed data. Extracting Land Surface Temperature (LST) is a best indicator to analyse urban heat island phenomenon. Landsat-8 data data and remote sensing techniques were used to analyse LULC classification and its relationship with the LST. The objective of this study is to determine the relationship of LULC and LST over Shah Alam area. LULC classification and LST was extracted and computed using Landsat-8 data. The obtained results showed that different LULCs have different LST due to their spatial characteristics. Shah Alam was experiencing LST in the range of 26.5 to 33.8 ºC. The presence of green trees also influenced the surrounding LST.

Keywords: remote sensing; land surface temperature; land use land cover; Landsat-8.

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1. INTRODUCTION

1.1. Introduction

Urban heat island (UHI) is a reflection of topographical changes due to man-made alterations to the urban surfaces. Surrounding surface temperature is affected by development and urbanisation process [1]. The process of urbanisation has elevated the surface temperature known as urban heat island phenomenon. In any city development, trees are cut down to allocate commercial development, route design, industrial sectors, and urban development [2]. Green areas normally will reduce the amount of heat by absorbing heat during the day, and will release away through the evaporation process [3]. Changes of land cover will significantly modified surface properties like heat conductivity, heat capacity, roughness length and water substances. In addition, the major effects of land cover change also will influence the thermal stratification and amount of evaporation. These will definitely alter the atmospheric boundary layer humidity and temperature [4-5]. The smallest change of land cover gives an impact to the weather. Hence, it impacts the urban climate condition significantly. Earlier studies have investigated the issues of the relative warmth of cities by estimating the air temperature by referring to the land-based observations of weather stations and used scheduled measurements of temperature using static weather station at localised locations [6-10]. These methods can consume high costing and restricted in area coverage [11]. Satellite remote sensing and geographical information system (GIS) technologies has been well accepted to examine the land use land cover (LULC) changes, environmental identification and monitoring as well as hydrology purposes [12-15]. The benefit of using remote sensing data is highly on the availability of high resolution and consistent measurements of earth surface conditions. There were implemented a new combination method of monitoring the UHI from different intensity and on different scale, which enabled a spatial examination of the city's UHI and its thermal coverage characteristics. Thermal remote sensing of satellite sensors are acceptable techniques for universal studies including global measurement such as regional and local observations. Thermal infrared remote sensing also has been a technology to study the thermal characteristic of land surface characteristic. Many numbers of algorithms have been developed by researchers to extract land surface temperature [15]. Landsat-8 data has two extra thermal bands that have an ability to measure temperature by converting digital number (DN) value to temperature. Recently, a number of algorithms have been developed to convert satellite data into surface temperature. Procedure to derive the surface temperature as used in requires conversion of DN to spectral radiance and conversion of the spectral radiance to temperature which is the exact units for temperature is Kelvin (K) [16].

1.2. Objective and Study Area

The purpose of this study is to identify the effect and relationship of LULC surface alteration or modifications have on towards the land surface temperature. The major hypothesis that can be made, higher temperatures value in the surface significantly can be lowered down by increase the vegetative landscape or green area cover. The selected study area was area within the city of Shah Alam, capital city of Selangor, Peninsular Malaysia. Shah Alam is located on latitude 3°5’00”N and 101°32’00”E (Fig. 1). Air temperatures are consistent throughout the year between 23.2 and 31.9 °C. The city is warmest in the month of March, and experiences heavy rains and showers during the month of November. The methodology for this study involves four (4) phases: 1) data acquisition 2) data processing which includes image subset the multispectral and thermal infrared bands and image classification, and 3) LST retrieval and 4) data validation. The LST is calculated using Planck’s equation.

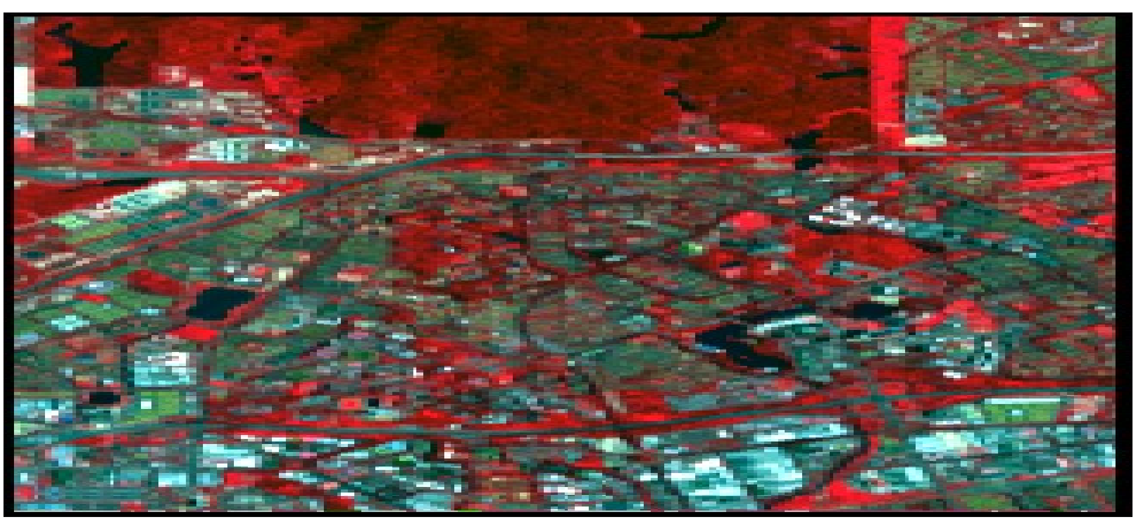

Fig.1. Location of Shah Alam, Selangor (source: Google Earth)

2. METHODOLOGY

2.1. Landsat-8 Data Acquisition

Landsat-8 imagery was acquired on 24th November 2016 to generate the LST and LULC maps. Landsat-8 has 11 bands where band 10 and band 11 are two new bands to detect thermal information with spatial resolution of 100m. As for multispectral bands, 30m. spatial resolution is suitable for classifying LULC of the study area. Maximum likelihood classification was adopted to classify LULC over Shah Alam where land use/land cover was divided into 6 classes; which are water, industrial, cleared land, residential and commercial, forests and agricultural land.

2.2. Derivation of Normalize Difference Vegetation Index

Normalize Difference Vegetation Index (NDVI) is an index of plant "greenness" or photosynthetic activity and calculated as a ratio between measured reflectivity in the red and near infrared portions of the electromagnetic spectrum [16]. NDVI is computed using the following equation.

$$NDVI = (NIR-RED)/(NIR+RED) \quad (1)$$

2.3. Land Surface Temperature Calculation

Land surface temperature (LST) is the main factor used to determine energy exchange and surface radiation. To estimate the LST from the Landsat-8 thermal infrared band data, digital number (DN) of sensors were converted to spectral radiance using the equation below

$$\text{Spectral radiance} = Ml \times Qcal + Al - Qi \quad (2)$$

where Ml is band specific multiplicative rescaling factor, Qcal is the band 10 image, Al is the band specific additive rescaling factor and Qi is the correction for band 10 [13]. Spectral radiance then converted to brightness temperature using equation below

$$TB = K2/\text{Log}\ \{(K1/\text{Radiance}) + 1\} \quad (3)$$

where TB is the effective at satellite brightness temperature, K1 = 666.09 (thermal conversion constant) and K2 = 1282.71 (thermal conversion constant)

$$e = 0.004Pv + 0.986 \quad (4)$$

where e = emissivity values and Pv = (NDVI - NDVImin)/(NDVImax - NDVImin)

$$LST = BT / 1 + w * (BT / p) * \ln (e) \quad (5)$$

where BT = brightness temperature and w = wavelength of emitted radiance (11.5µm), p = h * c /s (1.438 * 10ˆ-2m K), h = Plank's constant (6.6268 * 10ˆ-34Js), s = Boltzmann constant (1.38 * 10ˆ-23Js), c = Velocity of light (2.998 * 10ˆ8 m/s) and e = emissivity.

2.4. In-Situ LST Measurement

In this study, LST in-situ measurement of was carried out using random sample points of different LULC classes using the Raytek non-contact infrared thermometer.

Fig.2. In-situ LST measurement on the field

3. RESULTS AND DISCUSSION

3.1. Land Use Land Cover (LULC) Map

The overall classification accuracy for supervised classification is 91.8%, while the overall kappa statistics is 0.88. The imagery was classified into 6 classes; water, industrial, cleared land, residential and commercial, forests and agricultural area as in Fig. 3. Table 1 shows the producers and users accuracy of each classes.

Table 1. Error matrix of classification

Class Name	Producers Accuracy (%)	Users Accuracy (%)
Water body	95.1	92.7
Industrial area	90.1	94.1
Cleared Land	98.8	98.8
Residential and Commercial	77.8	63.6
Forest	87.5	83.6
Agricultural area	91.0	89.1

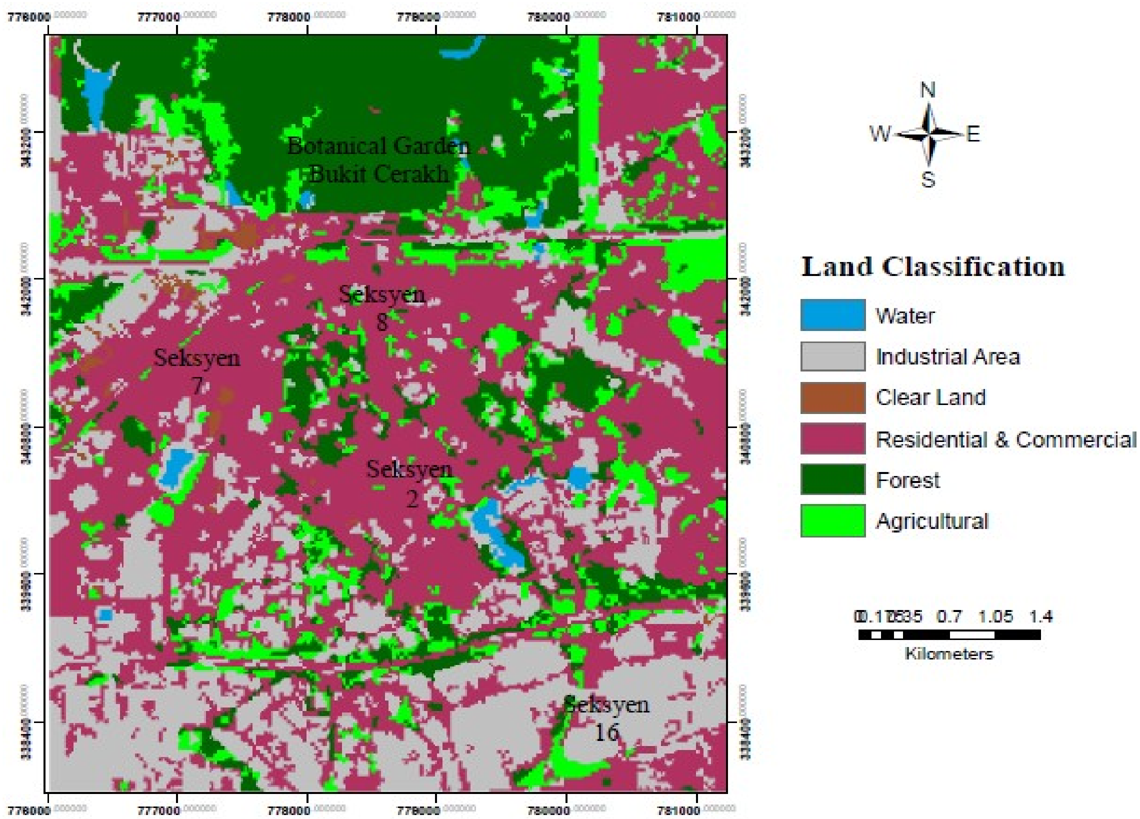

Fig.3. Land use land cover map of Shah Alam city

Table 2 shows 42% of LULC in Shah Alam covered by residential and commercial. Currently, Shah Alam is experiencing rapid urban development especially in housing and commercial development. Industrial area covers 25% of total study area. While, the percentage of water bodies and cleared land in Shah Alam was the lowest with 1% for both classes respectively as in Table 2.

Table 2. Land use classes and area in percentage

Land Use Class	Area (ha)	Percentage (%)
Water	32.7	1
Industrial Area	804.4	25
Clear Land	27.0	1
Residential & Commercial	1381.8	42
Forest	673.7	21
Agricultural	346.8	10

3.2. Land Surface Temperature (LST)

Fig. 4 shows the LST spatial distribution of Shah Alam city derived from Landsat-8 thermal bands. The reddish colour region indicated that the area have warmer temperature reading, while the bluish colour region indicated the colder temperature reading. The highest temperature value at the study area not exceeded 34ºC. It can be observed from the map, the LST values are estimated in the range of 26.5ºC to 33.8 ºC. In addition, it also can be observed that Section 16 of Shah Alam area exhibit highest temperature (38ºC) which mainly due to the industrial activities. On the other hand, the lowest temperature value of 26.5ºC was observed at the Bukit Cherakah Botanical Garden. This is due to the presence of green area and vegetative substances which reduced the surrounding temperature values.

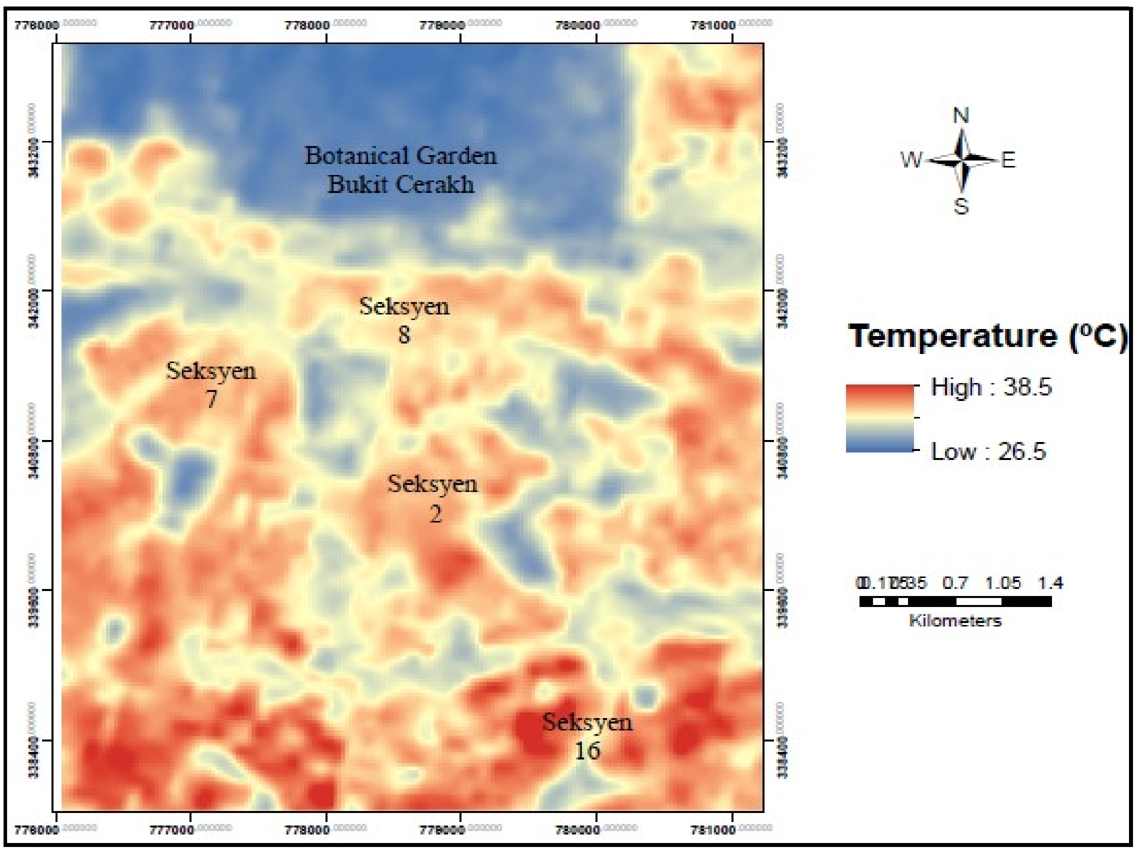

Fig.4. LST map of Shah Alam derived from Landsat-8

3.3. Relationship between LULC, LST and NDVI

The minimum and maximum LST were 27.8 ºC and 33.8 ºC respectively. The mean LST values over various LULC types range from high to low are as follows: industrial area, residential and commercial, clear land, agriculture and forest as in Table 3.

Table 3. Land use mean temperature

LULC Class	Mean LST (°C)
Water	29.5
Industrial Area	35.5
Clear Land	31.3
Residential and Commercial	32.4
Forest	27.8
Agriculture	28.5

Transect line was purposely created across variety LULC classes to show different LULC experiencing different LST as derived using Landsat-8 thermal bands. The highest peak temperature can be seen over the industrial area (grey colour), while the lowest peak temperature through the forested area (dark green).

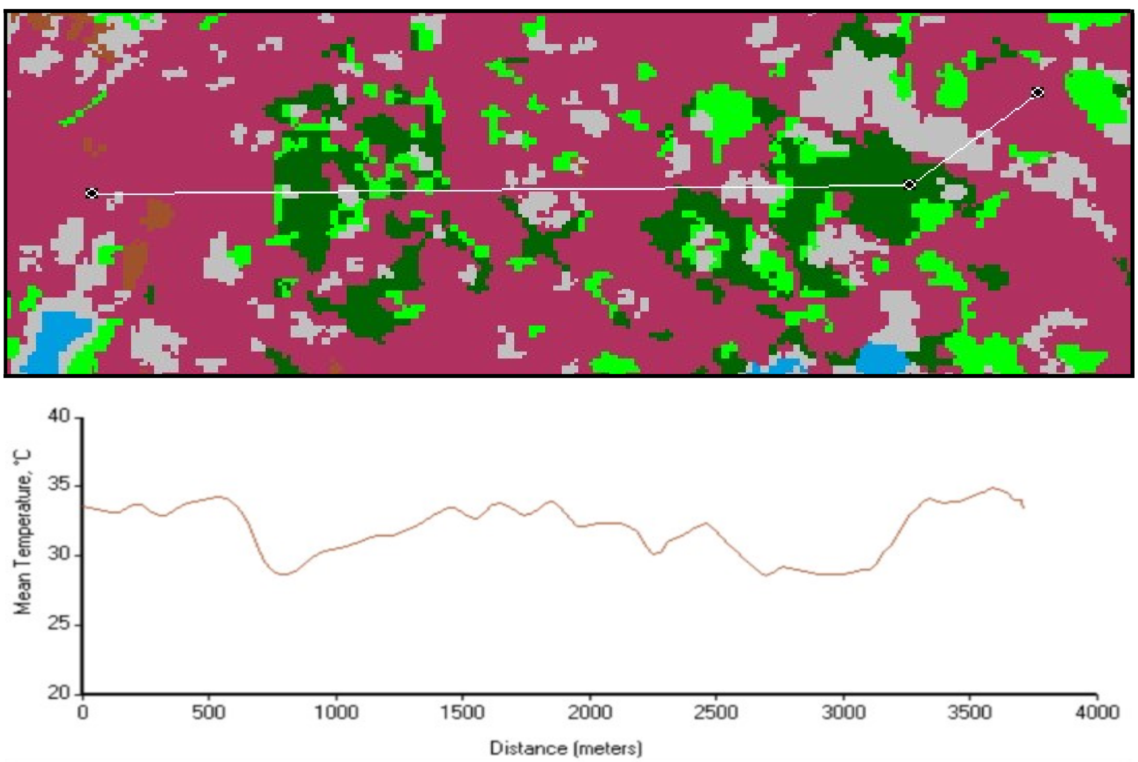

Fig.5. Transect line of LST across different LULC

Higher values (positive integers) signify a larger difference reflected between the red and near infrared radiation recorded by the sensor represent active vegetation. Low NDVI values mean there is little difference between the red and NIR signals. This happens when there is just very little NIR light reflectance.

Table 5. Land use area and the percentage

Land Use Class	Mean NDVI
Water	-0.05
Industrial	0.04
Clear land	0.13
Residential and Commercial	0.21
Forest	0.35
Agricultural	0.48

Approximately 100 random points have been selected from the LST and NDVI images for identifying the relationship between NDVI and LST. Based from Fig. 7, LST and NDVI was negatively correlated where areas with less dense of vegetation are experiencing higher LST value.

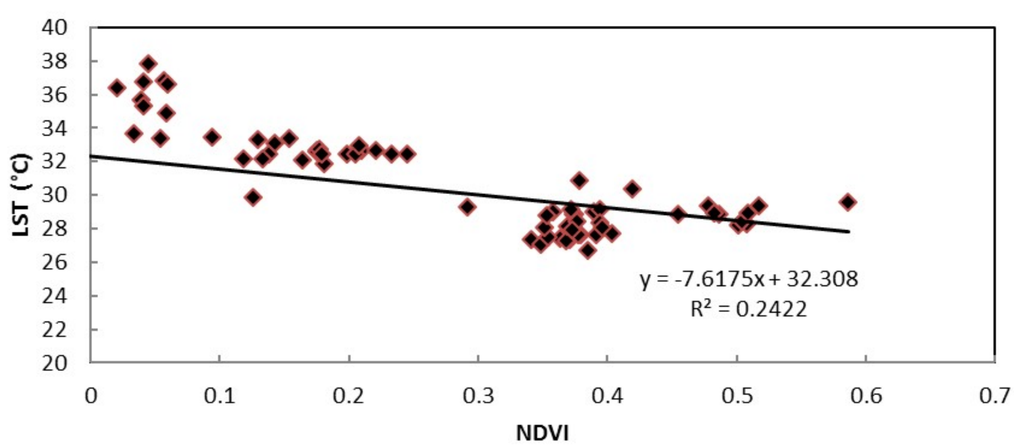

Fig.6. Linear regression graph between LST and NDVI

3.4. Validation of LST

Approximately 18 random points was manually collected by using non-contact thermometer where 3 points for each land use class. Generally, the locations were selected and measured were based on the characteristics of the features and visibility in the Landsat-8 image. The LST values measured on the site was highly correlated with the LST derived using Landsat-8 with R2 value of 0.96. In general, the closer value of R2 to 1, the better the model fits your data.

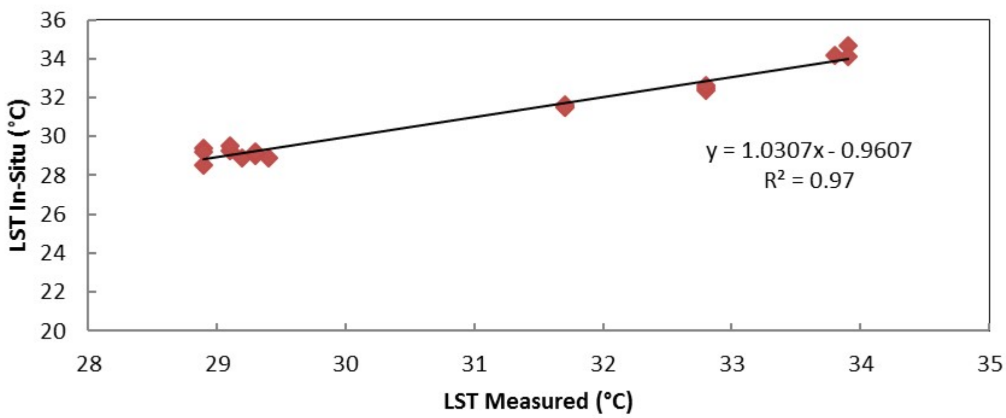

Fig.7. Linear regression graph between in-situ and measured LST

4. CONCLUSION

In this study, the relationship between LULC and LST in Shah Alam area were examined. The LULC were classified into six classes which are water bodies, forest, and agricultural, industrial, residential and clear land. Over the years, due to rapid development vegetation and cultivated land are likely to decline and substitute for commercialize area. Remote sensing technique can be the most effective techniques for LST assessment of the different LULC. The temperature surrounding is related to the types of LULC. Industial areas have the highest temperature which can lead to the urban heat island phenomena. There were strong relationships between LULC and LST and green areas or trees within an urban area will significantly reduce the surface temperature. This study can be applied by urban planners to plan appropriate strategies to minimize the effect of urban heat island within the Malaysian cities.

5. ACKNOWLEDGEMENTS

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