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Separation of Different Vegetation Types in ASTER and Landsat Satellite Images Using Satellite-derived Vegetation Indices

Sharifeh Hazini and Mazlan Hashim*

Institute of Geospatial Science and Technology (INSTeG), Faculty of Geoinformation and Real State, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

*Corresponding author: mazlanhashim@utm.my

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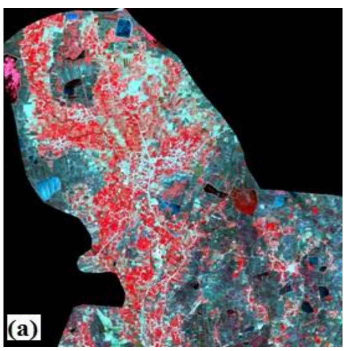
Graphical Abstract



Abstract

Separation of different vegetation types in satellite images is a critical issue in remote sensing. This is because of the close reflectance between different vegetation types that it makes difficult segregation of them in satellite images. In this study, to facilitate this problem, different satellite derived vegetation indices including: Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Enhanced Vegetation Index 2 (EVI2) were derived from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Landsat-5 TM data. The obtained NDVI, EVI, and EVI2 images were then analyzed and interpreted in order to evaluate their effectiveness to discriminate rice and citrus fields from ASTER and Landsat data. In doing so, the Density Slicing (DS) classification technique followed by the trial and error method was implemented. The results indicated that the accuracies of ASTER NDVI and ASTER EVI2 for citrus mapping are about 75% and 65%, while the accuracies of Landsat NDVI and Landsat EVI for rice mapping are about 60% and 65%, respectively. The achieved results demonstrated higher performance of ASTER NDVI for citrus mapping and Landsat EVI for rice mapping. The study concluded that it is difficult to detect and map rice fields from satellite images using satellite-derived indices with high accuracy. However, the citrus fields can be mapped with the higher accuracy using satellite-derived indices.

Keywords: ASTER; Landsat; NDVI; EVI; citrus; paddy rice

Abstrak

Pengasingan jenis tumbuh-tumbuhan yang berbeza dalam imej satelit adalah isu penting dalam penderiaan jauh. Ini adalah kerana pantulan rapat antara jenis tumbuh-tumbuhan yang berbeza yang membuat pemisahan sukar daripada mereka dalam imej satelit. Dalam kajian ini, untuk memudahkan masalah ini, indeks tumbuh-tumbuhan yang diambil dari satelit yang berlainan termasuk: Indeks Perbezaan Normalized tumbuh-tumbuhan (NDVI), Indeks Tumbuhan Disempurnakan (EVI), dan Enhanced Indeks Tumbuhan 2 (EVI2) berasal dari Advanced Spaceborne Pelepasan Haba dan Refleksi radiometer (ASTER) dan Landsat-5 data TM. EVI diperoleh, EVI2 dan gambar NDVI dianalisis dan ditafsirkan untuk menilai keupayaan mereka untuk melakukan diskriminasi beras dan limau bidang dari ASTER dan imej Landsat. Dengan berbuat demikian, Ketumpatan slicing (DS) teknik klasifikasi diikuti dengan kaedah percubaan dan kesilapan yang telah dilaksanakan. Keputusan menunjukkan bahawa ketepatan dari ASTER NDVI dan ASTER EVI2 untuk pemetaan sitrus adalah kira-kira 75% dan 65%, manakala ketepatan Landsat NDVI dan Landsat EVI untuk pemetaan beras kira-kira 60% dan 65% masing-masing. Hasil yang dicapai menunjukkan prestasi yang lebih tinggi dari ASTER NDVI untuk pemetaan jeruk dan Landsat EVI untuk pemetaan beras. Kajian ini membuat kesimpulan bahawa ia adalah sukar untuk mengesan dan peta sawah dari imej satelit menggunakan satelit indeks yang diturunkan dengan ketepatan yang tinggi. Tetapi, ladang limau dapat dipetakan dengan ketepatan yang lebih tinggi menggunakan indeks satelit yang diturunkan itu.

Kata kunci: ASTER; Landsat; NDVI; EVI; jeruk; padi

1.0 INTRODUCTION

Rice occupies about 11% of the global cropland area [16]. More than 50% of the world population rely on rice as a staple food [8]. Extensive rice cultivation, to meet the needs of an ever-increasing world population, has triggered the compound issue of insufficient food and environmental degradation [5]. In most developing countries, the required data are collected via traditional methods which are tedious, time consuming, and expensive [17]. Remote sensing should be considered as a proper alternative to conquest the limitations of traditional methods and recognized as an indispensable tool for the mapping agriculture fields on local, regional and global scales [5]. In recent years, increasing the accuracy of thematic maps produced through the process of image classification has become a popular research topic in remote sensing [14]. The ASTER and Landsat-5 TM satellite images are considered as good sources for this purpose on a regular basis because of their suitable spatial and spectral resolutions.

For vegetation detection and mapping, usually vegetation indices such as Normalized Difference Vegetation Index (NDVI) [15, 10, 27, 26, 6], Enhanced Vegetation Index (EVI) [7, 1, 13], Stabilized Vegetation Index (StVI) [21, 23, 20], Transformed difference vegetation index (TDVI)[29, 19], and Enhanced Vegetation Index 2 (EVI2) [3, 22, 25, 13] are used. This study investigated the application of different vegetation based satellite-derived indices including: NDVI, EVI, and EVI2 for detection and mapping citrus and paddy fields from the ASTER and Landsat-5 TM data. The density slicing technique followed by the trial and error method was used for this purpose.

2.0 MATERIALS AND METHODS

2.1 Study area

The study area, Simorgh city, is located in north of Iran between 30º 37′ N and 52º 53′ E of the Greenwich meridian and in average 51.2 meters above sea level (Figure 1). The climate is moderate with 17.7º Celsius mean yearly temperature, 621.5 millimeter sum of yearly rain, and 79 percent mean relative humidity [12]. This city is covered by 10.5 thousand hectares of agricultural lands. More than 90% of this agricultural land is allocated to rice and citrus production. Irrigated rice and citrus production is common in this region and considered as a key source of income for around 100% of inhabitants [2, 9].

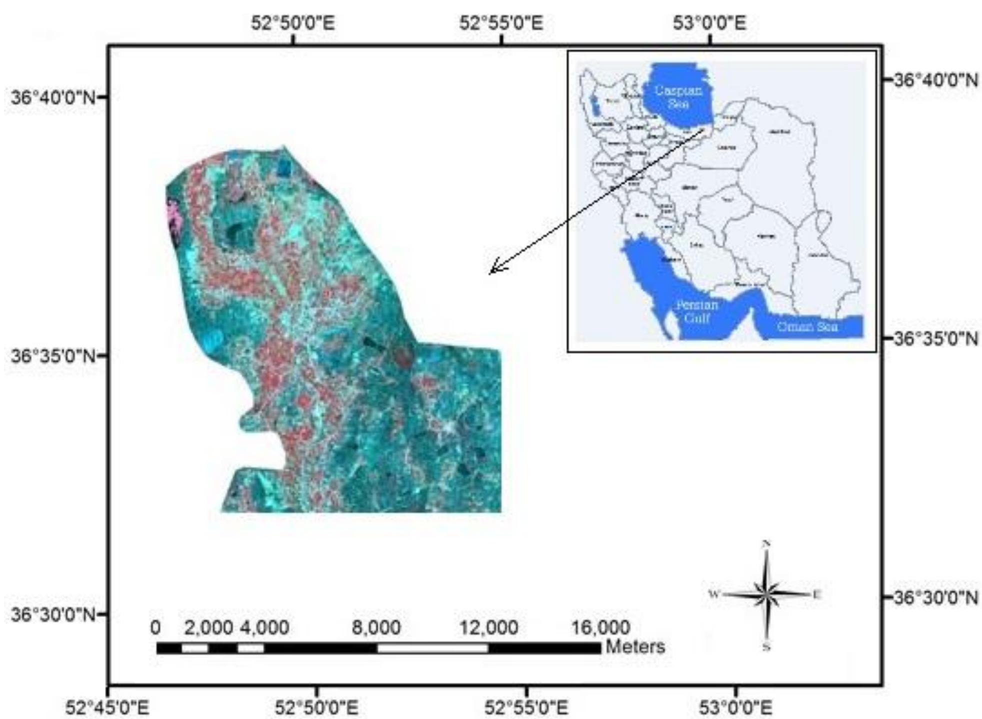


Figure 1 Location of the study area (resized ASTER image: 27 May 2010)

2.2 Dataset

ASTER Level-1B data acquired on 27 May 2010 and Landsat -5 TM data acquired on 22 July 2010 were obtained from the US-Geological Survey (USGS) Global Visualization Viewer and were utilized for mapping citrus trees and paddy fields in this study (Figure 2).

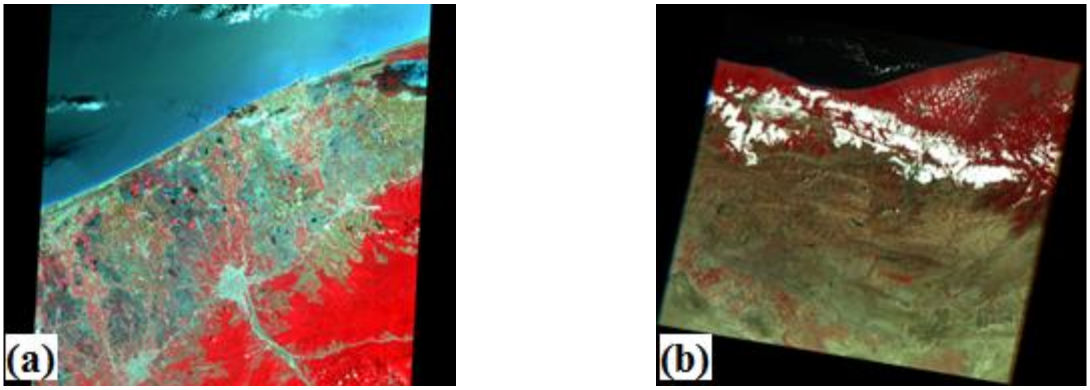


Figure 2 The datasets used in this study: (a) ASTER and (b) Landsat data

2.3 Methodology

The methods implemented in this study for citrus groves and paddy fields mapping is shown in Figure 3. The following tasks were performed: image pre-processing, NDVI, EVI, and EVI2 calculation, suitable threshold definition, mapping, and accuracy assessment.

2.3.1 Pre-processing

The pre-processing step includes co-registration, resampling, and atmospheric correction. The ASTER Level 1B data obtained from the USGS Global Visualization Viewer were pre-georeferenced to UTM WGS-86 Zone 39N, therefore was used as the reference for registration of Landsat-5 TM data. Using the image to image registration tool the images were co-registered with a root mean square error of about 0.3 pixel. Then, the satellite images were resampled to the size of the study area using the nearest neighbor method

Atmospheric correction is important for most remote sensing applications, where the radiation reflected by the targets can be modified by the atmosphere, mainly through scattering and absorption [24]. To eliminate the effects of atmospheric scattering and absorption in the satellite bands and to increase the accuracy of surface type classification, the Fast Line-of-sight Atmospheric Analysis of the Spectral Hypercubes (FLAASH) algorithm (Thome et al. 1998) was used in this study for atmospheric correction of the input imageries.

This algorithm contains the standard MODTRAN model atmospheres, which has standard column water vapour amounts for each model atmosphere. Moreover, scene and sensor information (solar zenith angle, satellite view angle and relative azimuth angle between the satellite and sun) and aerosol model are considered for running the algorithm.

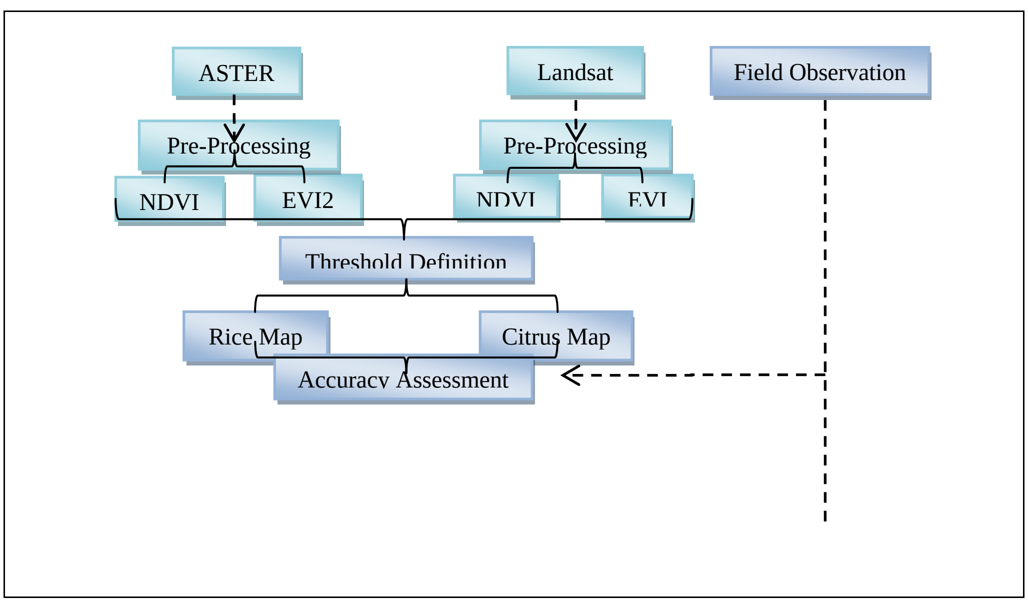


Figure 3 Research flowchart

Once the pre-processing step was done, the NDVI, EVI, and EVI2 indices were calculated from the ASTER and Landsat images. Then, using the Density Slicing (DS) classification technique and trial and error method the obtained indices were interpreted for citrus and rice field detection and mapping.

2.3.2 Normalized Difference Vegetation Index (NDVI)

NDVI is used in this study to extract citrus trees. NDVI as the ratio between measured reflectance in the red (R) and near infrared (NIR) spectral bands of the images for ASTER is calculated using the following formula [26].

$$\text{NDVI ASTER} = \frac{\text{band 3N} - \text{band 2}}{\text{band 3N} + \text{band 2}} \quad (1)$$

$$\text{NDVI Landsat} = \frac{\text{band 4} - \text{band 3}}{\text{band 4} + \text{band 3}} \quad (2)$$

2.3.3 Enhanced Vegetation Index (EVI and EVI2)

The EVI is used to identify rice paddies because of its higher sensitivity to canopy structural variation[11, 18, 4]. It is calculated as follows:

$$\text{EVI} = 2.5 * [\frac{(\text{NIR} - \text{VISR})}{(\text{NIR} + 6 * \text{VISR} - 7.5 * \text{VISB} + 1)}] \quad (3)$$

Recently, a 2-band variation of EVI (EVI2) was developed for sensors with no blue band, such as ASTER images. EVI2 has been reported to correspond well with the original EVI [13]. EVI2 was calculated for ASTER according to the following formula [13, 28]:

$$\text{EVI2} = 2.5 * [\frac{(\text{ASTER3N} - \text{ASTER2})}{(\text{ASTER3N} + 2.4 * \text{ASTER2} + 1)}] \quad (4)$$

2.3.4 Accuracy assessment

Statistical accuracy assessment of the resultant maps constitutes an important stage in remote sensing data classification. The accuracy of the generated maps was assessed quantitatively based on some ground truth points collect through field observation using Global Positioning System (GPS) instrument. Accuracy assessment of the thematic maps produced from the implementation of indices was performed based on overall accuracy calculation.

3.0 RESULTS AND DISCUSSION

The Aster and Landsat images after pre-processing steps including co-registration, resampling, and atmospheric correction are shown in Figure 4.

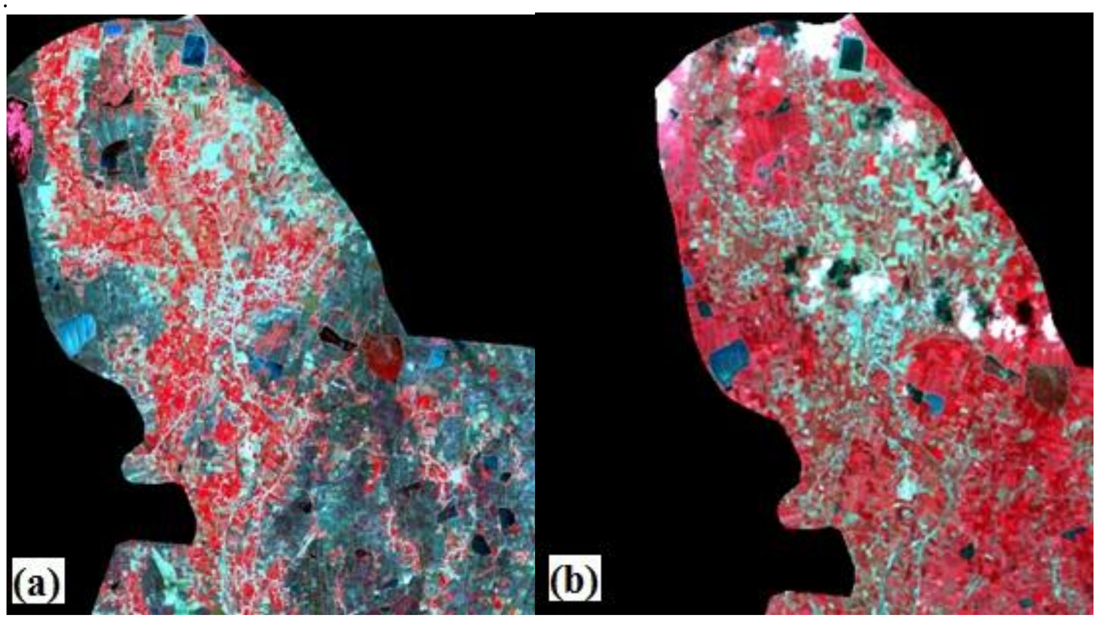


Figure 4 The dataset after pre-processing: (a) ASTER and (b) Landsat data

Once the pre-processing step was done, the NDVI, EVI indices were calculated from Landsat image and NDVI and EVI2 indices were calculated from the ASTER image. Then, the density slicing classification technique followed by the trial and error method was implemented to detect and map paddy rice and citrus fields in the study area. Because the acquisition time of the ASTER image was not suitable for rice mapping, thus this image was used for citrus mapping, and Landsat image was used for rice mapping. The citrus and paddy rice maps generated from ASTER and Landsat images are shown in Figure 5.

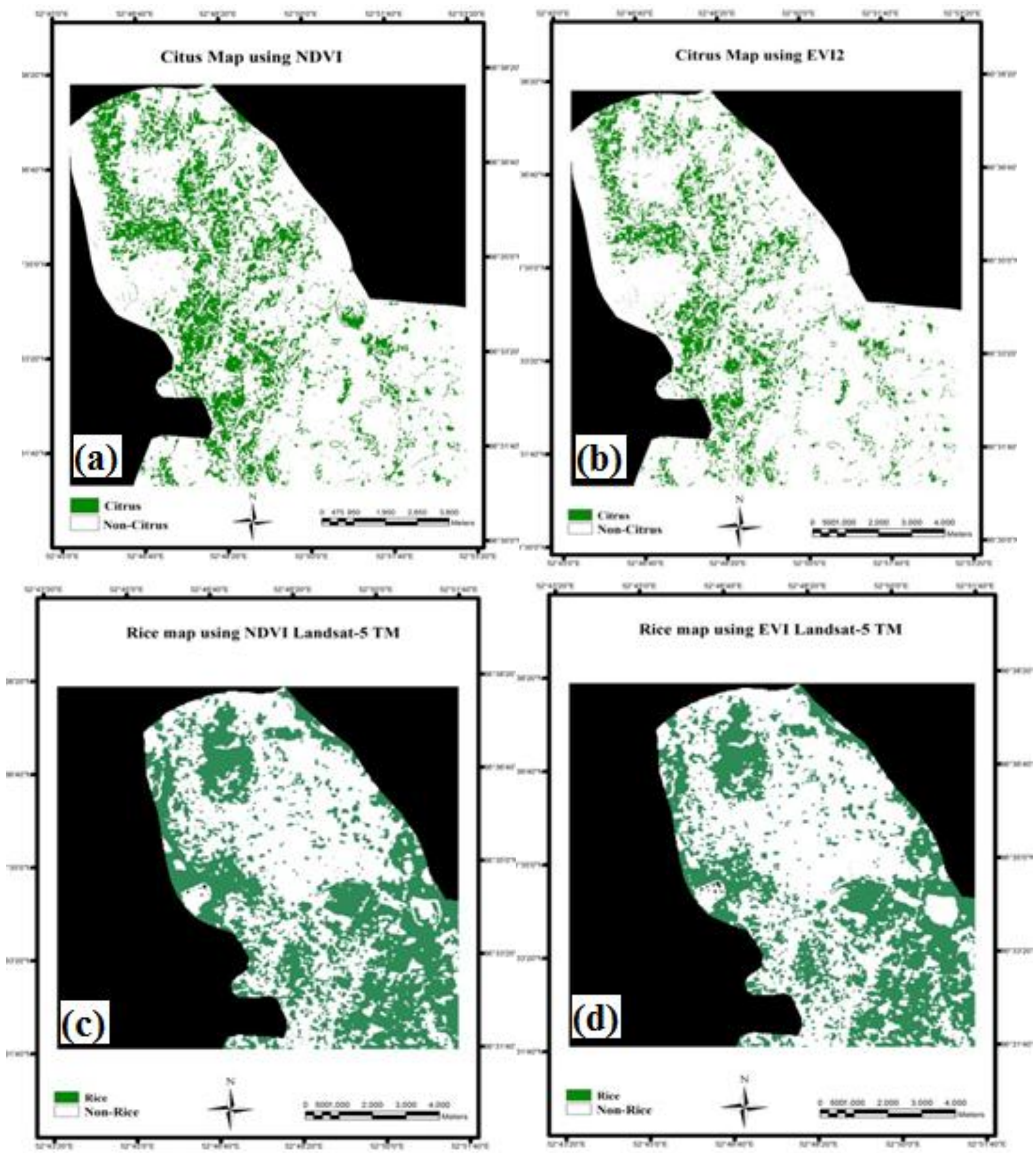


Figure 5 Citrus and rice maps generated using: (a) ASTER NDVI, (b) ASTER EVI2, (c) Landsat NDVI, and (d) Landsat EVI

In order to assess the accuracy of the generated maps, overall accuracy for each map was calculated. The results are summarized in Table 1.

The achieved results indicated that the overall accuracy of citrus maps generated from ASTER NDVI and ASTER EVI2 are 75% and 65%, respectively. It demonstrated higher applicability of ASTER NDVI for citrus mapping. Moreover, the results showed that the accuracy of Landsat NDVI and Landsat EVI for rice mapping is about 60% and 65% that indicated higher performance of Landsat EVI for this purpose. The results proved higher applicability of NDVI for citrus mapping; inverse, higher suitability of EVI for rice mapping. The study showed that even by acquiring the satellite image in suitable time, high accuracy rice fields mapping is very difficult. However, for citrus mapping, the accuracy could be higher.

Table 1 overall accuracy of produced map

Generated Maps	Overall Accuracy (%)
Citrus Map From ASTER NDVI	75
Citrus Map From ASTER EVI2	65
Rice Map From Landsat NDVI	60
Rice Map From Landsat EVI	65

4.0 CONCLUSIONS

In this study, the applicability of ASTER NDVI and EVI2 was investigated for citrus mapping, while the applicability of Landsat NDVI and EVI was investigated for rice detection and mapping in Simorgh, Iran. The accuracy of the generated maps was assessed based on field observation using GPS instrument. The achieved results indicated higher performance of ASTER NDVI than ASTER EVI2 for citrus mapping, while the accuracy of Landsat EVI was higher that Landsat NDVI for rice mapping. The study concluded that even by acquiring the satellite image in suitable time, it is difficult to detect and map rice fields with high accuracy. But for citrus mapping, the accuracy could be higher.

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