

计算物理作业 n

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1 题目 1：太阳黑子数据处理

1.1 题目描述

Detecting periodicity: Download the file called sunspots.txt , which contains the observed number of sunspots on the Sun for each month since January 1749. Write a program to calculate the Fourier transform of the sunspot data and then make a graph of the magnitude squared $|c_k|^2$ of the Fourier coefficients as a function of k —also called the power spectrum of the sunspot signal. You should see that there is a noticeable peak in the power spectrum at a nonzero value of k . Find the approximate value of k to which the peak corresponds. What is the period of the sine wave with this value of k ?

1.2 程序描述

先使用 numpy(以下简称 np) 读取 sunspots.txt 文件，将其月份数据和对应的太阳黑子数数据分别存入两个数组中，随后用算法1分析得到其周期。

1.3 伪代码

高斯消去法的伪代码如下所示

Algorithm 1 FFT 分析太阳黑子周期

Sunspot data array: sunspot_data (monthly sunspot counts since January 1749) Period of the dominant sine wave in months: period_in_months

Step 1: Compute Fourier coefficients $\text{fft_coeffs} \leftarrow \text{FFT}(\text{sunspot_data})$ Perform Fourier transform to decompose the time series into frequency components.

Step 2: Compute frequencies associated with Fourier coefficients $\text{frequencies} \leftarrow \text{FFTFreq}(\text{len}(\text{sunspot_data}))$
1) Calculate the corresponding frequencies for each Fourier coefficient, assuming a sampling interval of 1 month.

Step 3: Compute the power spectrum $\text{power_spectrum} \leftarrow |\text{fft_coeffs}|^2$ The power spectrum quantifies the contribution of each frequency to the overall signal.

Step 4: Filter out zero-frequency components (DC component) $\text{nonzero_freqs} \leftarrow \text{frequencies}[\text{frequencies} > 0]$
 $\text{nonzero_power} \leftarrow \text{power_spectrum}[\text{frequencies} > 0]$ Exclude the zero frequency component to focus on periodic variations.

Step 5: Identify the peak in the power spectrum $\text{peak_index} \leftarrow \text{argmax}(\text{nonzero_power})$ Find the index of the highest peak in the power spectrum, indicating the dominant frequency.

Step 6: Find the corresponding frequency of the peak $\text{peak_frequency} \leftarrow \text{nonzero_freqs}[\text{peak_index}]$

Retrieve the frequency associated with the dominant peak.

Step 7: Calculate the period of the sine wave $\text{period_in_months} \leftarrow \frac{1}{\text{peak_frequency}}$ Convert the frequency to the period, representing the cycle length in months.

period_in_months Output the period of the dominant sine wave.

1.4 输入输出实例

原始数据如下图所示

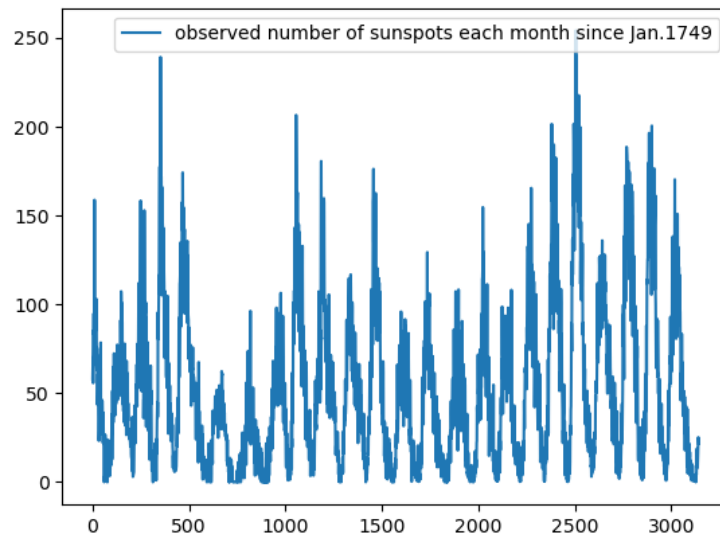


图 1: 太阳黑子数随月份变化关系

经过快速傅里叶变换得到结果如图所示

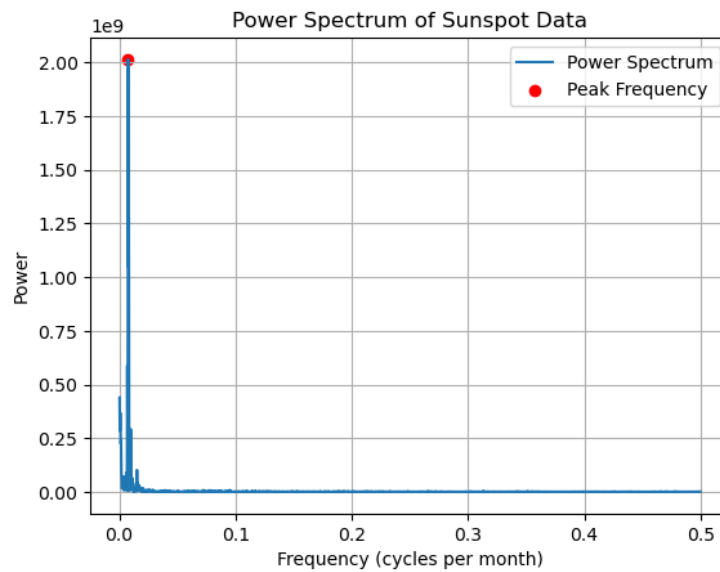


图 2: 快速傅里叶变换结果

因此得到结论为

```
17 # 输出结果
18 print(f"峰值频率为: {peak_frequency}")
19 print(f"峰值频率对应的周期 (以月为单位): {period_in_months} 个月")
20

[71]

... 峰值频率为: 0.007636016544702513
    峰值频率对应的周期 (以月为单位): 130.95833333333334 个月
```

图 3: 分析结论