

Analysis of Transit Method for Exosolar Planet Detection in Clustered Environment

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ABSTRACT

There has been curiosity among researchers to find exoplanets. Numerous techniques have been developed to find exoplanets. One of the most common techniques is Transit method which measures incoming flux of the star. Depending on the disturbances created in the flux, an exoplanet is detected. Transit method requires lots of computation power, as it requires taking reading at regular interval and then processing it. In computer field, the algorithms which require high computation power, are executed in parallel fashion. Clusters are commonly used to execute a high computation algorithm parallel. This paper explains transit method's execution in clustered environment and its complexities compared to sequential execution

Keyword's – Planet, FWHM

I. INTRODUCTION

There is vast number of researches going on the astronomical data [1]. This project is also based on the analysis of astronomical data. Here an available data from the sources issued by Astronomical resources is being analyzed to detect the presence of stars and individually identify each star and find its attributes.

Like our Solar system has a star called Sun, there are many other stars present in the universe [1]. Unlike Sun they might also have planets revolving around them. The stars being the source of light are bright and easily visible. On the other hand the other celestial body reflects the light of the stars nearby and hence is less bright.

Archival data for research work are available on the sites for astronomical researches [2]. One such image of a galaxy is used here to be analyzed in the initial phase. This image displays thousands of stars. The analyses to be done need some working environment so here IDL (Interactive data language) will be used. IDL, short for interactive data language is a programming language that is a popular data analysis language among scientists.

The work that is to be done in first phase is to identify the stars from the images and calculate their magnitudes of luminosity [1]. In the later phase this developed procedure is applied to a series of images. The images are taken over intervals for a particular location. The magnitudes obtained are compared to observe the variations among these stars. The observations also helps to identify if a star may be having celestial bodies revolving around them [1].

There has always been the greed of discoveries in the astronomical world. One such topic is extra solar planets [1].

An extra solar planet or exoplanet is a planet beyond solar system [3]. As of April 2008, 287 exoplanets have been detected. The first confirmed detections were made in 1990s; since 2000, more than 15 planets have been discovered every year [4]. It is estimated that at least 10% of sun-like stars have planets [4][5]. The discovery of extra solar planets sharpens the question of whether some might support extraterrestrial life.

Planets are extremely faint light sources compared to their parent stars. They usually have a less than a millionth of their parent star's brightness. In addition to the intrinsic difficulty of detecting such a faint light source, the parent star causes a glare that washes it out. For those reasons, current telescopes can only directly image exoplanets under exceptional circumstances. Specifically it may be possible when the planet is especially large (considerably larger than Jupiter [5]), widely separated from its parent star, and hot so it emits intense infrared radiation. The vast majority of known exoplanets have been discovered through indirect methods. One such method is transit method [6][7][8].

If a planet crosses (or transits) in front of its parent star, then the observed brightness of star drops by a small amount [8]. The amount by which the star dims depends on its size and on the size of the planet.

II. PROCEDURE

The Astronomical Data Pipeline reduction will include the following issues

- Determine the mean FWHM of stars in the field.
- Extracting stars from the field with accurate x, y pixel position of the image.

- Determine the median flux of all stars in a large square degree FOV Image, the total number of stars may vary from 1000 to 10000 or even more.
- Determine the magnitude of the extracted stars and normalizing the stars magnitudes with respect to the median flux determined by step1.
- Repeating the above 4 steps for a series of images observed in a single night and/or over several nights and determining the variations in the stars magnitudes during the period of observations.

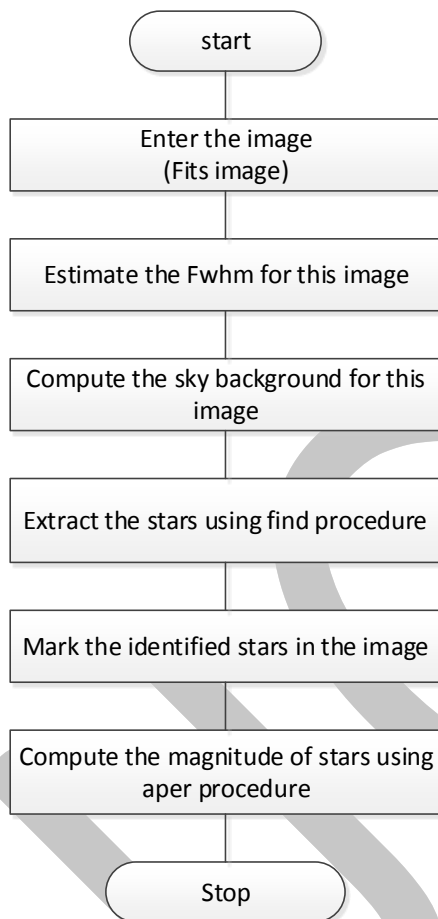


Fig. 1: Flow chart of transit method

A. Magnitudes

Optical astronomers almost always use something called the (astronomical) magnitude system to talk about several different kinds of measurements, such as the observed brightness (power fluxes, or energy received per unit time per unit area) of stars and the luminosity (total power output in EMR) of stars. The historical roots of the magnitude system go way back to the first star catalog, compiled by a Greek named Hipparchus some 2200 years ago. Hipparchus divided the stars into six brightness classes, and he called the stars that appeared brightest (to the naked eye, of course, there being no

telescopes back then) first magnitude stars, and the faintest visible stars the sixth magnitude stars.

Much later, when astronomers were able to make more exact measurements of the brightness of stars, they found that the Hipparchus magnitude scale was roughly logarithmic. That is, each magnitude step corresponded to a fixed brightness ratio or factor. The first magnitude stars are roughly 2.5 times as bright as the second magnitude stars, the second magnitude are roughly 2.5 times as bright as the third magnitude stars etc.

Based on the Hipparchus magnitude system, but using modern brightness measurements, astronomers decided to define a magnitude system where 5 magnitudes corresponds to exactly a factor of 100 in brightness or flux. Thus, each magnitude is exactly 100^{1/5} (which is equal to 10^{2/5}) or about 2.512 times as bright as the next.

$$m_1 - m_2 = -2.5 \log_{10} (f_1/f_2)$$

B. FWHM

A **full width at half maximum (FWHM)** is an expression of the extent of a function, given by the difference between the two extreme values of the independent variable at which the dependent variable is equal to half of its maximum value.

Now here we select a window which is less populated. By looking at image we can search for a star which is isolated and the area around is less populated.

Then we fit a Gaussian on that window. For that particular window there will be a Gaussian curve which will be having some maximum peak value. That is the stars maximum intensity.

Now we need to calculate the centroid position and the FWHM in this window. For a Gaussian distribution function the functional form of the curve is given by, Wherever Times is specified; Times Roman or Times New Roman may be used. If neither is available on your word processor, please use the font closest in appearance to Times. Avoid using bit-mapped fonts. True Type 1 or Open Type fonts are required. Please embed all fonts, in particular symbol fonts, as well, for math, etc.

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Here μ =mean and σ = standard deviation

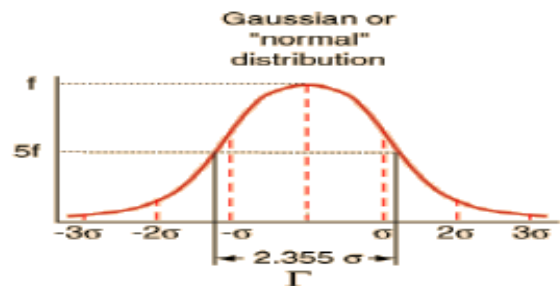


Fig. 2: Gaussian distribution

$$f(x) = C e^{(-x^2/2\sigma^2)}$$

Let $x = h$ at half the max height

$$0.5C = C e^{(-h^2/2\sigma^2)}$$

Taking log on both sides

$$\ln(0.5) = -h^2/2\sigma^2$$

$$h^2 = -2 \ln(0.5) \sigma^2 = 2 \ln 2 \sigma^2$$

The full width Half Maximum of the peak is

$$FWHM = \sqrt[2]{2 \ln 2} \sigma = 2.355 \sigma$$

C. NEED OF FWHM

Stars are point sources. However the image formed of stars by focusing through a lens is not a point but a blurred spot. Thus point sources emit light which is processed by the optical system, because of diffraction; this light is smeared out into some sort of blur spot over a finite area on the image plane rather than focus to a point. When this patch is scanned the distribution of intensities can be described by a mathematical function. This function is known as the point spread function (PSF) of the lens. It is the impulse response of the system whether it is optically perfect or not. In a well corrected system, apart from a multiplicative constant the PSF is the Airy irradiance distribution function centered in the Gaussian image point. The value of the spread function depends only on the displacement of that location from the particular image point on which the PSF is centered [10] [12].

For an object spread across an area or several pixels the object is no more just a point. We must therefore give a precise meaning to the term ‘co-ordinates’ or ‘position’. In order to determine the co-ordinate of the object, the center of area is chosen as the representative position. The center of area is estimated by the center of mass or centroid of the object. Also determining the position of a star by just taking best give the precision of measurement to one pixel. It is therefore highly preferable to determine the centre of mass or centroid.

When the image of space is taken, then it is seen that due to high luminosity bright stars can shadow faint neighbors. The stars those are bright are easily visible, but some of them are not.

So here we use PSF fitting to identify bright good stars. Each star is identified or scanned individually and its magnitude is calculated. All the stars above a threshold values are selected.

III. IMPLEMENTATION

The photometric data pipeline is actually a program that does the photometry of astronomical images and gives the desired

output. The input to this program is a series of image. For this work the input is the images of XO2 taken at intervals [10][11]. The total duration between the first and last image is approximately four and half hours.

IV. SYSTEM CONFIGURATION

Two kinds of homogenous clusters with different number of nodes were developed. Each node was having Pentium 4 processor with 2.40 GHz speed. Both were having 2-Level Cache one of 16 KB and other of 512 KB. Both clusters were equipped with 1 GB DDRAM and 40 GB hard disk. Each processor was connected with each other using 100 Mbps Ethernet.

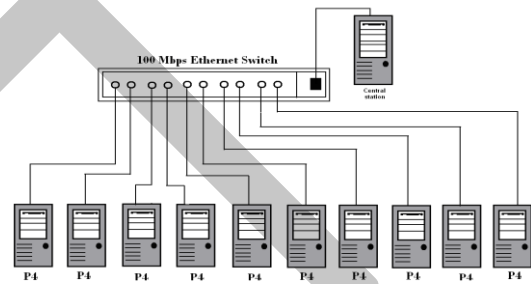


Fig. 3: The above image is that of the cluster that was configured for analysis of Transit method.

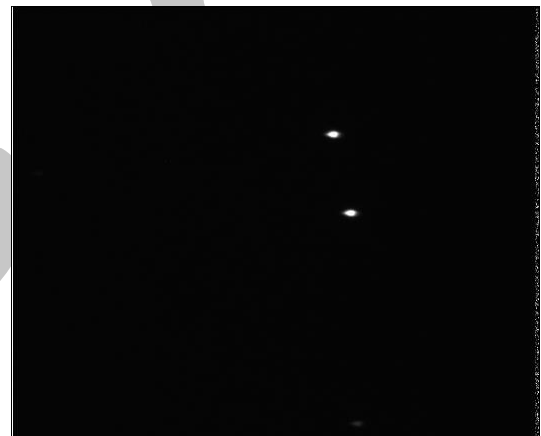


Fig. 4: FITs image of xo-2 galaxy

Above mentioned is the image obtained of xo-2 [11] galaxy from electron specification [12]

In conducting the experiment around 226 images (as shown above) were taken from [10]. In clustered environment the master node used to collect all the images and pass it on to 10 different slaves in the cluster. Each slave used this image and calculated the FWHN from the specific image and passed it on to the master. To avoid conflict among the FWHM each image was given an identification number in ascending order. So, as each cluster node calculated FWHM, it passed it on to the master node along with the id of the image as reference. Below mentioned is the graph of normalized magnitude vs frames.

Star	X	Y	Magnitude
0	676.3	534.7	10.549±0.002
1	641.7	709.1	10.579±0.002

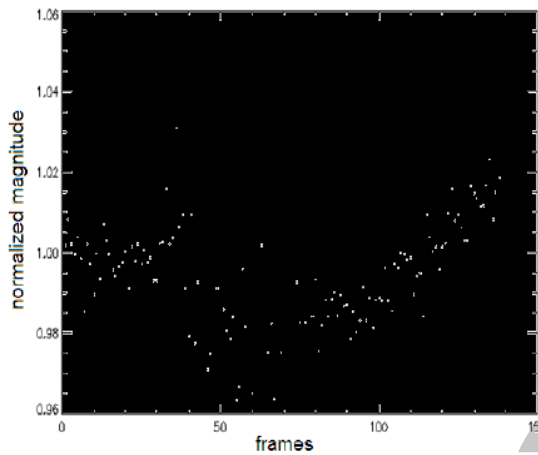


Fig. 5: Graph of normalized magnitude vs. number of frames

The above mentioned figure is graph of Normalized magnitude vs number of frames. This graph shows that there is an exoplanet (xo-2b) revolving in xo2.

V. RESULT AND CONCLUSION

The main purpose of this experiment was to find out the time taken for this transit method to get complete in Clustered environment. Theoretically, the time taken to complete this task should take 1/10th the original time, but on performing it; it took just 40% less time compared to non-clustered environment. The reason behind this is the high latency in transferring the images over the LAN. So, the total time taken is equal to

$$T_{Total}(t) = \sum (T_{ex}(n) + T_{Latency}(n))$$

Where n is number of nodes in cluster

VI. REFERENCES

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