Image Processing Techniques for Monitoring Lunar Surface Changes

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Abstract

The moon is the earths nearest neighbor; so it is no far to think that meteorites bombard it in the same rate that hit the earth. However, the moon has no atmosphere so an approaching meteorites could form craters when it hit lunar surface, this makes the Lunar surface perfect location to calculate the rate number of meteorites that reached its surface (and consequently the number on the earth surface) and studying the change on its surface due to meteorites impact.

This research is an attempt to find out whether is it possible to find the rate number of meteorites that hits lunar surface(earth surface as well) per year and detects impacts changes in the surface by applying change detection techniques on Lunar Orbiter4 mission in 1968 and Clementine mission in 1993 images for Gassendi and Palto caters.

Introduction

Aside from the Earth, we know more about the Moon than about any other object in the solar system (Hartmann, 1983). The sources of information's come from ground-based telescopic observations to satellite orbiters and Landers to human exploration and samples return. Since the end of 1950's , several nations have embarked upon an ambitious series of manned and unmanned exploration missions to the Moon as listed in table(1).

Table (1) Successful lunar exploration missions (Jeff, 2004)

Mission name	Dates	Goals and result
Luna 2,3,13	1959-1968	Lunar hard and soft landing, photography, soil physics.
Luna 4	1959	Lunar far side flyby, photography
Ranger 7 - 9	1964-1965	Lunar hard landing, photography
Luna 10,12,14,19	1966-1971	Lunar orbiter, gravity and magnetic field data, photography
Surveyor I, III, V-VII	1966-1968	Lunar soft landings, photography, soil physics and chemistry
Lunar orbiter 1-5	1966-1967	Global medium to high resolution Lunar photography
Apollo	1968-1969	Manned Lunar orbiters, photography
Luna 16, 20, 24	1970-1976	Unmanned Lunar sample return
Lunokhod1,2	1970, 1973	Lunar traverse vehicles, covered 20km and 30km each
Clementine	1994-2004	Lunar global multispectral mapping, topography, and gravity

The moon has no atmosphere, so meteor could hit lunar surface and form a crater. Historically, many lunar craters and other surface features have also been created through volcanic activity. By examining images obtained from space missions in different time, it may be possible notice any new surface features or craters have formed during the gap that separated the two missions.

If the entire lunar surface is examined using such comparison techniques, a large database of

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information could be created that would allow researches to document any changes in lunar surface.

The main goal of this research is to detect any change in specific lunar surface regions from space mission images for 25 years period (1968-1993) by applying different change detection methods.

Digital Change Detection Techniques

Change detection is a digital image analysis that is commonly used to detect changes or identify difference in the state of an object or phenomenon by observing it at different times (Singh, 1989, Howarth and Gregory, 1981).

There are many techniques for change detection. Manual change detection, write function memory, principle component analysis (PCA) change detection, image algebra (differences, ratio) and temporal data classification are the most common used methods (Mass, 1999, Jenson, 1996). The techniques used in this research are:

- **Manual Change detection**

can be performed manually using on-screen digitizing to identify area of change.

- **Image Difference (Image Subtraction)**

Involves mathematically combining images from different dates and can be achieved subtracted one image (date 1) from the other (date 2). The differences in area of no change will be very small (approaching zero) and area of change will have larger positive and negative values. Mathematically, this process can be given as [Singh, 89}:

$$CD_{ij} = DN_{ij}(t_2) - DN_{ij}(t_1) \quad ....(1)$$

Where CD_{ij} is the difference image, $DN_{ij}(t_2)$ and $DN_{ij}(t_1)$ are the second and first dated images. Absolute value to the difference image may be found as:

$$CD_{ij} = | DN_{ij}(t_2) - DN_{ij}(t_1) | \quad ...(2)$$

- **Image Ratio**

Image ratio involves computing the ratio of data from two images of different dates. This means that the value of each pixel in one image will be divided by corresponding pixel value in the other image (Howarth and Wickwave, 81).

$$CD_{ij} = DN_{ij}(t_2) / DN_{ij}(t_1) \quad ...(3)$$

In output image, pixel value equal one represent area have not changed, while pixel value greater or less than one means area of change. Pixel values may be quantized to 256 (8 bits) grey levels by :

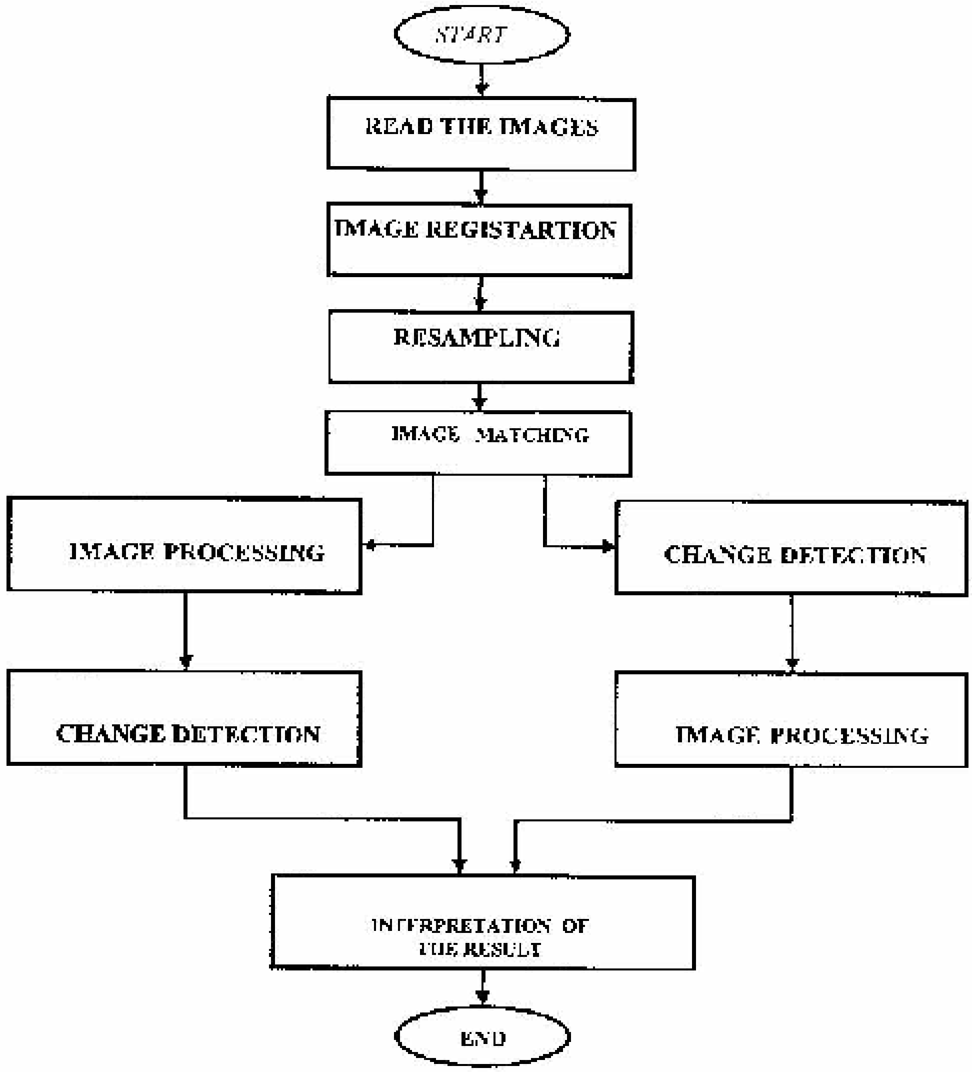
$$(CD_{ij})_r = \left(\frac{Max - CD_{ij}}{Max - Min}\right) x\, 255 \quad ...(4)$$

Where Max .and Min. is the maximum and minimum values in ratio image.

Practical Work

The core of this research include applying change detection techniques on Lunar Orbiter (1968) and Celementine (1993) space missions images to study the resultant change on Lunar surface during the period 1968-1993.

Craters Plato and Gassendi are selected as region of study. Plato is one of the most conspicuous craters on the Moon; it is about 95 Km in diameter, dark spot and prominently placed on the northern edge of Mare Imbrium. Gassendi, placed in the north of Mara Humorn. it is about 90 Km in diameter. It has a curious lop-sided appearance and its walls are quite high and complete except on the south where a gap is found. The work has been done according to the following fchart:



The first step in this work is to select suitable images for the study regions from lunar orbiters and Clementine space missions (see figures 1, 2, 3, 4). It is important to note that the original lunar orbiters images are exist as negative transparency and can be converting to digital form. While Clementine images are exist as digital form.

Figure (1) Lunar orbiter image of Gassendi crater

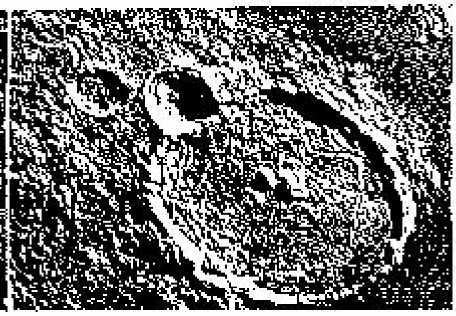


Figure (2) Clementin image of Gossendi crater

Figure (3) Lunar orbiter image of Plato crater

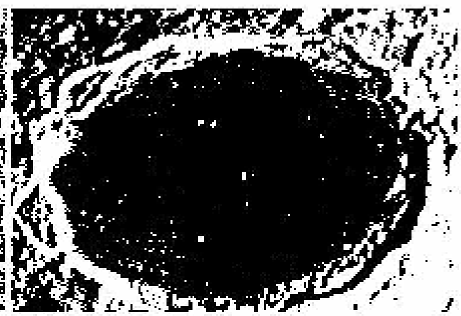


Figure (4) Clementine image of Plato crater

The main differences between the selected images are in terms of the spatial, radiometric and geometric aspects. These differences are due to time of acquisition, illumination and type of sensors, its height and speed. Hence, various image processing techniques have to be applied to manipulate and produce images that match each other to be digitally compared for any new surface features have developed from a meteor collision or other reasons.

Image Registration

Image registration has been performed for Gassendi only, by using ground control points (GCPs) between two images. Figure (5,6) shows Gassendi image before and after registration

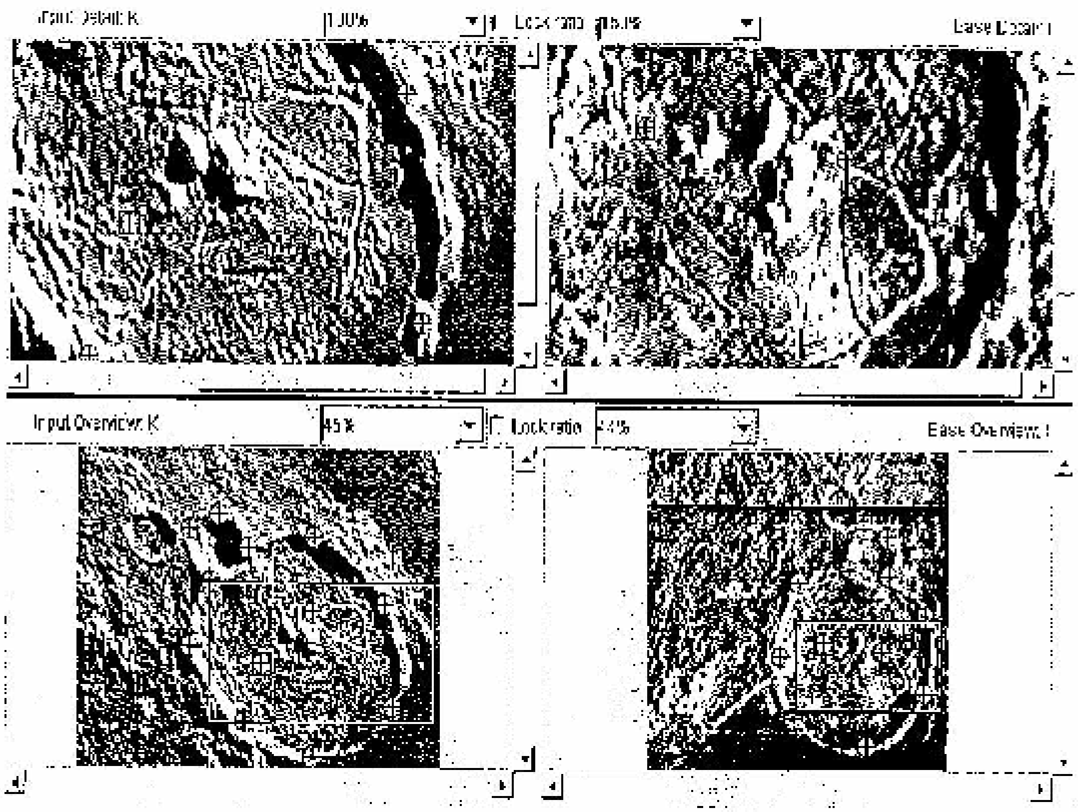
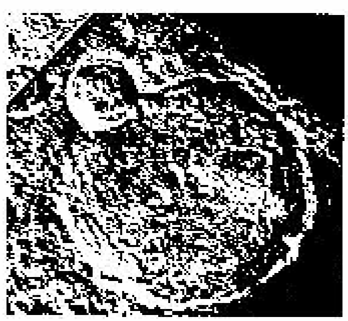


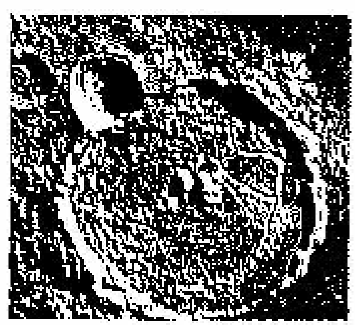
Figure (5) selection of GCPs on lunar and Clementine Gassendi images

(a) Lunar orbiter before registration

(b) Clementine Before registration



(c) Lunar Orbit after registration



(d) Clementine after registration

Figure.(6) Gassendi images before and after Registration.

Image Matching

For a given point in one image, a corresponding point may not exist due to occlusion, there may be more than one possible match due to repetitive patterns or a semi-transparent object surface, and the solution may be unstable with respect to noise due to poor texture so that accurate spatial matching of the images is important for effective change detection. When mismatching greater than one pixel, numerous errors will result at comparing results.

Normalized cross-correlation coefficient is used as matching criteria. By using this coefficient; it's possible to find corresponding pixels in the two images that match each other with minimum Root Mean Square error (RMS).

For Plato images the result gives a proper matching. The size of both images after matching process are (503×270 pixels) as shown in figures (7, 8). RMS error value for Gassendi images after matching process was more than one pixel that mean there is mismatching between images pixels. That mismatching may be due to the complex surface of Gassendi , so that only plato images have been used.

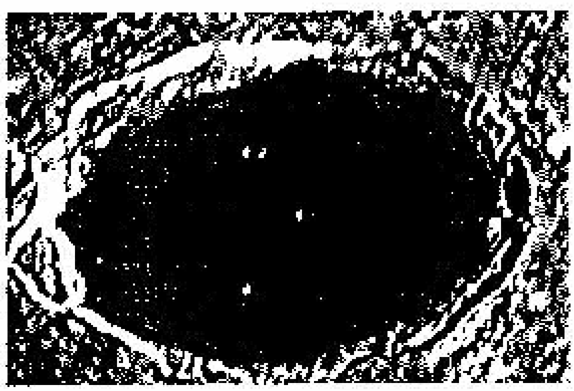


Figure (7) Lunar Orbit

Figure (8) Clementine image

Image Enhancement and Filtering

Some types of processing have to be used to enhance the images quality and appearance for easily interpretation. Two enhancement techniques have been applied these are: first technique is histogram matching or histogram equalization.

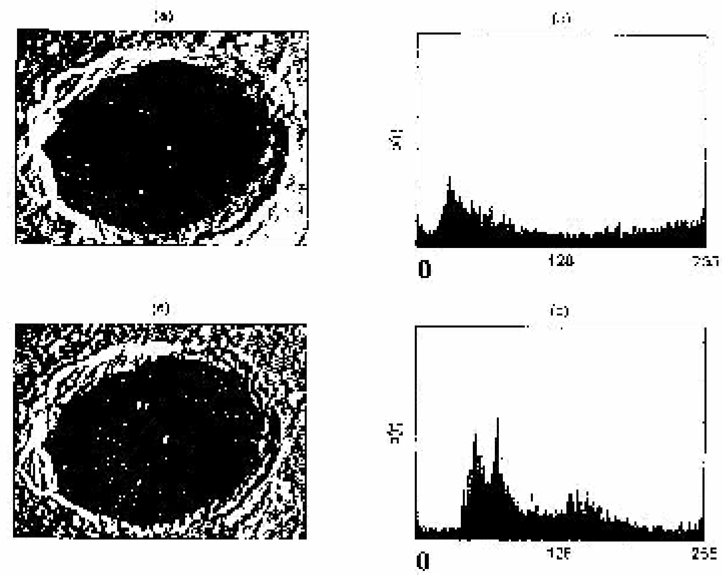


Figure (9) Raw Images (a) Clementine image (b) its histogram (c) Lunar image (d) its histogram

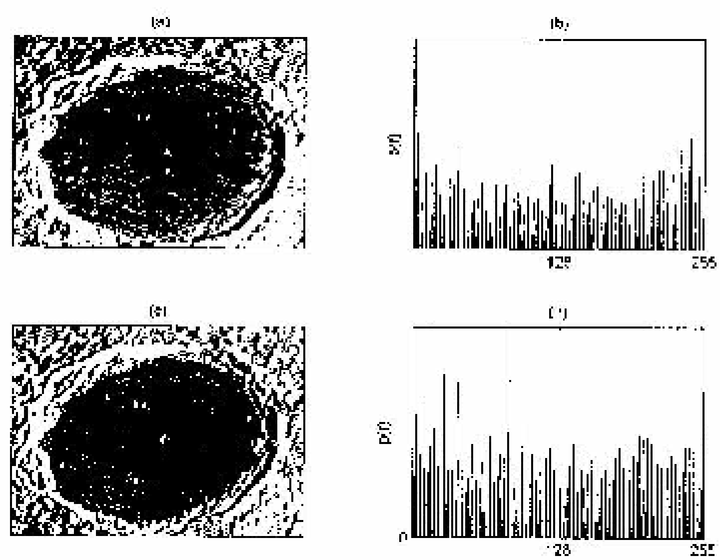


Figure (10) Images after applying Histogram Equalization (a) clementine image (b) its histogram (c) Lunar image (d) its histogram

Second technique is, Filtering which makes the smallest details appear in the images, these details may represent craterlet due to meteors impacts. Figures (11, 12, 13 and14) shows the effect of using some type of filters.

Figure (11) Raw Lunar image

Figure (12) Robert filter

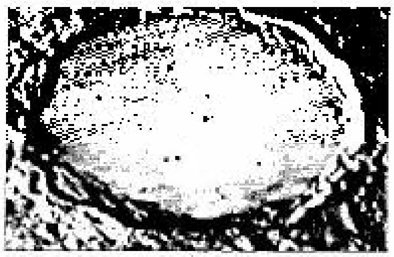


Figure (13) Laplac filter

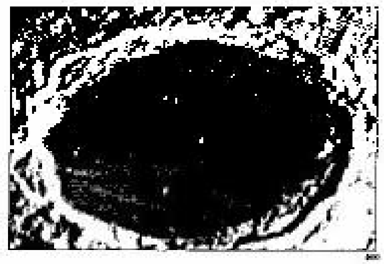


Figure (14) high- pass filter

Manual Change Detection

This process is conducted by divided the images in to blocks of specific size and compare the similar blocks in the two images, as shown in figure(15). From this comparison, any change can be identifying between the two images such as the number of craters in the study area

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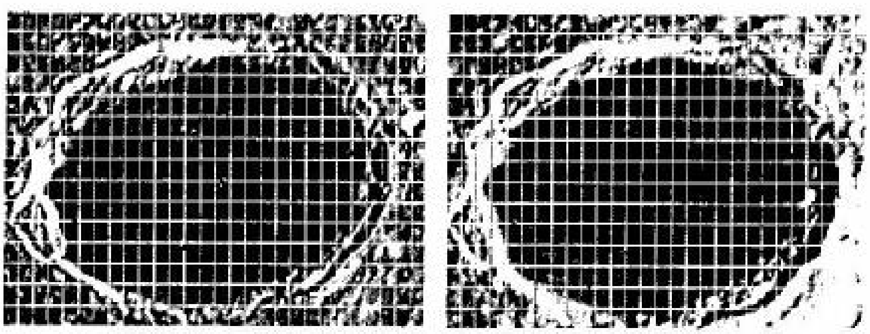

Figure (15) Manual Change Detection for raw images

Also enhanced images were used in this process. More information's can be obtained when enhanced images were used as it shown in fig.(16).

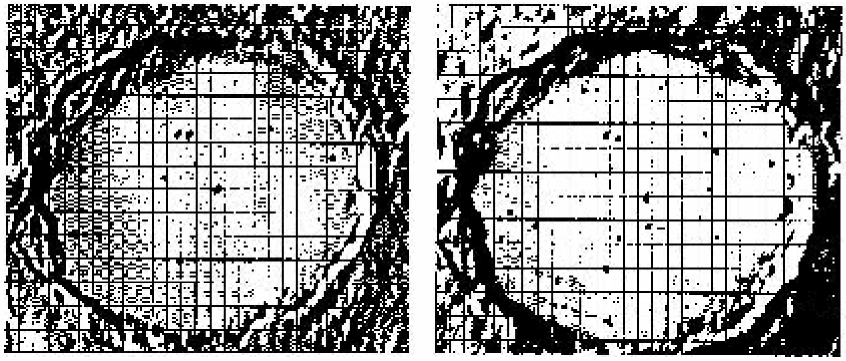

Figure (16) Manual Change Detection of enhanced images

Image Difference (Image Subtraction)

Image difference is the simplest change detection techniques. From the difference images, (fig 17-a) it can be noted that the shadows of the craterlets have bad effect on the output image. No improvement noticed on difference image when enhanced images were used as it shown in fig 17 b-c-d.

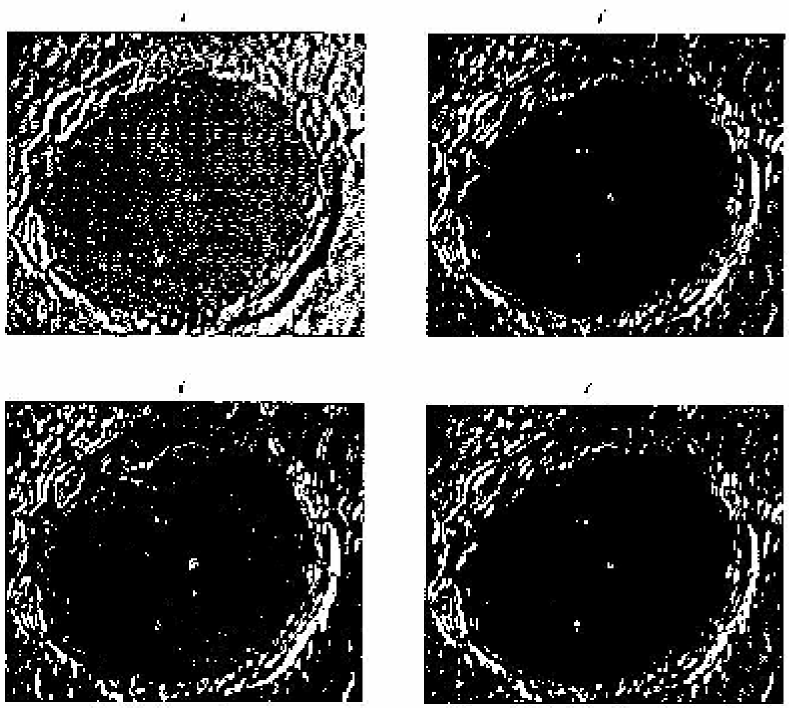

Figure (17) Difference images between Lunar and Clementine: (a) raw images (b) absolute difference image (c) absolute difference of histogram equalization images (d) absolute difference of Robert filter images .

One difficulty encountered in employing image subtraction technique is the selection of the appropriate threshold values that separate between the real and spurious change. The selection of threshold value depends on mean and standard deviation of the difference image. The suitable threshold was found to be in range 50 - 80.

Roberts, Lap lace, Hi-pass and low pass filters were used with various threshold values as it shown in figure (18).

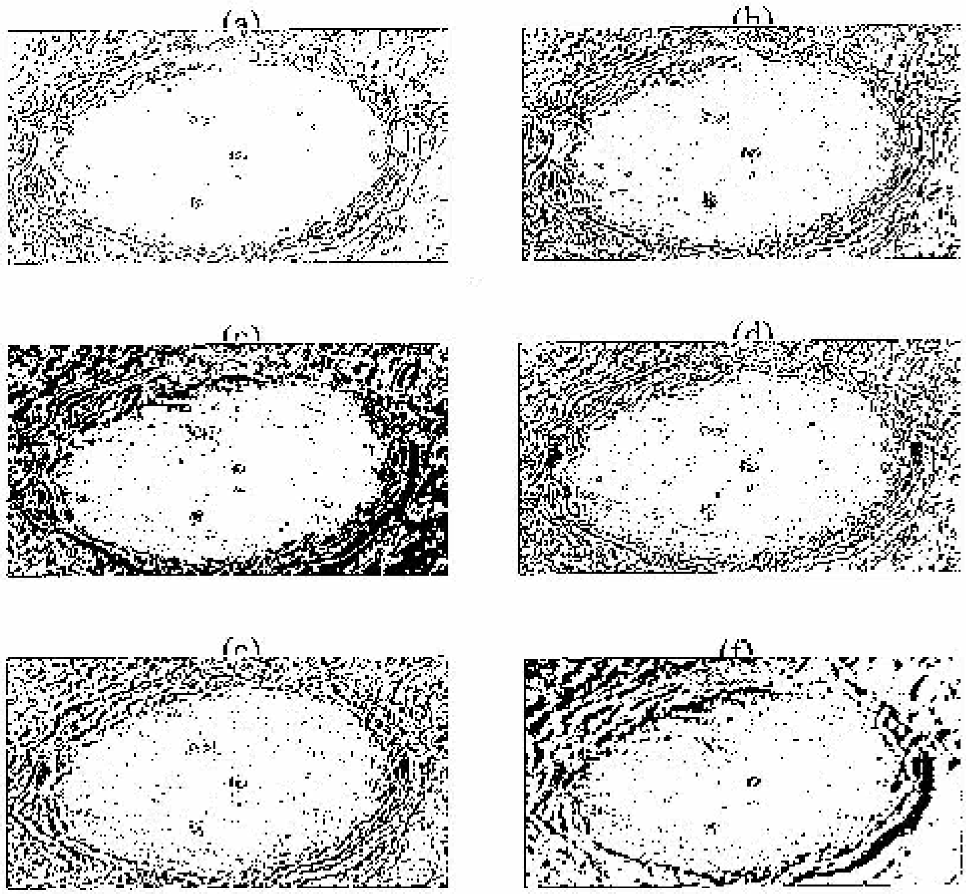

Figure (18) Filtered subtraction Image with Thresholds: (a)Laplacian filter with threshold 25 (b) Sobel filter with threshold 55 (c) Logarithm filter with threshold 55 and (d) Gaussian filter with threshold 25 and (e) Roberts filter with threshold 25 (f) Prewitt filter with threshold 25.

Image Ratio Technique

Sometimes the difference in images brightness values from similar surface materials may be caused by topographic conditions, shadow, or seasonal change in sunlight illumination angle and intensity, as we see in figure (19). Ratio images should be normalized with threshold value for visual interpretation, see figure (20).

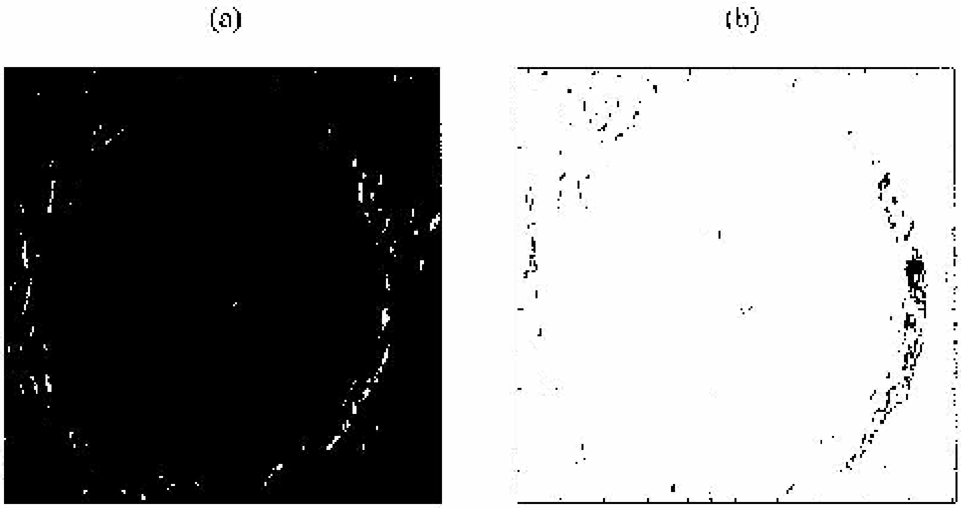

Figure (19) (a) Ratio image (b) ratio image after applying histogram equalization

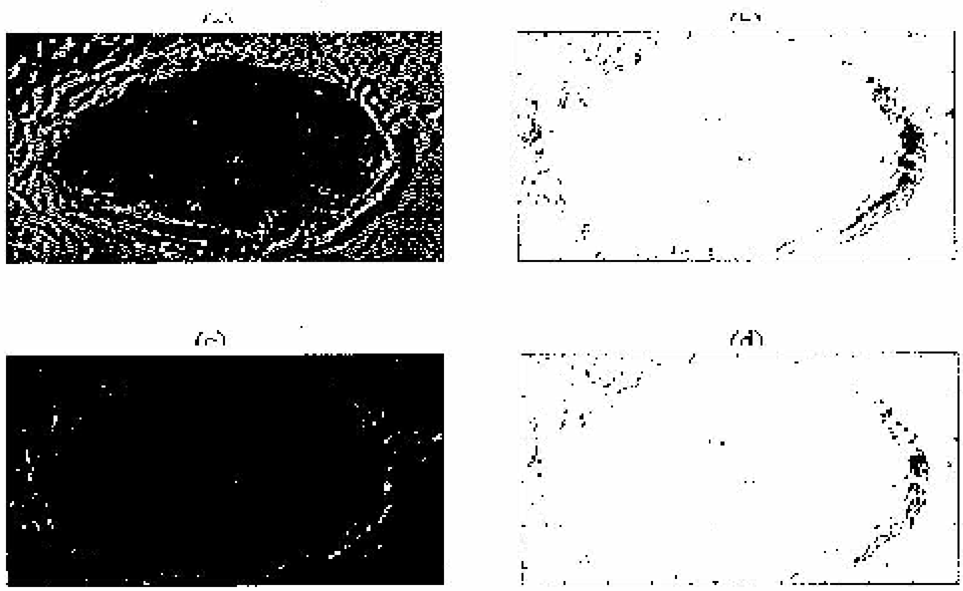

Figure (20) a- ratio image b- 8 bit quantized image c- ratio of quantized enhanced images d- ratio of quantized filter images

The results of applying change detection techniques can be summarized as shown in table (2).

Table (2) Number of Craters obtained from application of change detection techniques

Techniques	No. of small craters	No. of large craters
Manual Change Detection		8
Enhanced Manual Change Detection	30	13
Subtraction of lunar and clementine		12
Absolute difference of lunar and clementine		5
Absolute difference of histogram equalization of lunar and clementine		12
Difference image , threshold =50	13	10
Laplace filter , threshold =25	15	6
Ratio image	0	0
Histogram equalization for ratio image	0	0

Conclusions

There is many craters appeared in the output images, but the number of craters varied according to the used techniques and even for the same technique with different parameters. The important question is which represents the closest one to the real number. It is hard to answer this question because there are many factors contribute to final output images.

One main reason for having such difficulty is due to the fact that there is no available map of the lunar surface; and the old lunar maps that are available do not have very many details.

Other reasons for un-accurate results may be due to the used images. There are many differences between the two images such as:

1. Ground resolution: - Lunar Orbiter image used a camera that had ground resolution of 2 m, whereas the Clementine had ground resolution of 20 m.
2. Time of acquisition:- the images seemed be taken at different times of the day, as can be seen by the shadow effects.

Due to above reason and by using imagery with poor resolutions, it is hard to find the rate numbers of meteors and interpret the nature of change that occurred on lunar surface.

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