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Application of Digital Image Processing for Shape Characterization of Sand Particles

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Abstract **- This part of research work is focused on defining sand particles shape using Digital Image Processing (DIP). Sand particles shape can be defined using geometrical structures which involves mathematics and its derivatives. Shape descriptor is utilized to define exactly the sand particles shape. It describes the region or boundary of sand particles. So study of sand shape using digital image processing with Fourier analysis gives an exact particles shape. This research utilizes nondestructive automation technique online or off-line based on using image processing. It is revealed that total 21 different shape of sand particles were identified each having different measures. Sand shapes were analyzed and processed using Charge Coupled Devices (CCD) camera, image processing Matrox Imaging Library (MIL) Software and in MatLab 6.5 platform. This new way of vision which cannot be revealed by eye can characterize particles shape easily. Research in shape similarity has a lot of challenges, some solutions and, and for same in use in different application.**

Keyword **– Digital Image, Processing, Processing, Analysis.**

I. INTRODUCTION

Shape can be categorized in different ways, but image processing technique is easiest and precise way of classifying. The analysis and effect of shape of sediments can be effectively predicted in some precision level. It will be a huge asset for any researcher involved in shape characterization.

It is often very rigorous to define the shape of an object. A little research has only been explored in shape feature extraction of sediments. So it's new and difficult to fully characterize sand particles. So only a generalized assumption is made to define them. It's easy to recognize shape visually but very hard to convey the representational or description about shape. Sediments are solid object having 3-dimensional different views. So it's cumbersome to exactly define all sediment shape types, so only a generalization of distinctly separable shape of particles can be characterized.

II. MATERIALS AND METHODS

Different techniques are utilized to clearly distinguish the shape of sand particles. Sand particles shapes were characterized taking from different spots. During the research different material and processes were used to give the research output more effectively.

2.1 *Digital Image Processing*

Sand Shape feature extraction and measurement is of great concern in sediment and material handling, sediment management, comminuting, constructing and in other various fields. Digital image processing technology has become an efficient and cost effective technology, so shape of the particles has been explores using this techniques with concrete results. The shape of sediment particles directly affects different system. The essence of development of this digital technology has great significance in determining critical coarse shape and size properties: flatness ratio, elongation ratio, flat and elongated ratio, gradation, angularity and surface texture also.

This research works includes development of image acquisition system that captures images of sediments instantaneously and in still mode. An ideal image capturing dark room was set up with all image processing software and cameras. Matrox Imaging Library and Magnus Pro software was used to process captured image. Acquisition system was developed to capture still images in different angles and processed with synchronized Matrox Imaging Library, MatLab and MagnusPro software for feature analysis.

2.2 *Image Analysis*

Sand particles are digitally photographed using CCD camera and analyzed using MIL, Magnus Pro and Matlab image processing software using axial dimensions. Still online image captured at an angle of 90^0 and resized the image and background elimination was done to clearly extract all the information of the particle. The image then was converted to gray level image. The image then filtered and segmented to extract the feature in 2 dimensions. The image was processed using different image processing features like Particle skeletonization obtained by finding locus or focal reference as a centre to determine the particle geometrical spherical maximal Particle inscribed about its sphere or disc, Image enhancement, Image is digitally photographed using Sony XC-HR70 charge coupled device camera and Matrox Imaging Library (MIL) software. It's a gray scale camera and captured using light emitting diode as light sources in Machine Vision Lab of Kathmandu University, Dhulikhel, Nepal.

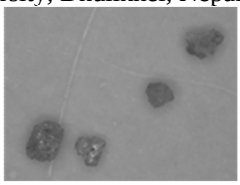
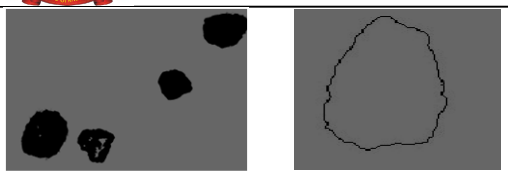


Fig.1. Sand particles image captured by CCD camera

Background elimination and single sand particle extraction was performed using MIL software. Cropping, edge detection and skeletonization features of software were explored to define a single particle as a reference.



(a) (b)

Fig.2. (a) Background elimination, (b) single particle extraction with skeletonized edge

Center of gravity (CG) defines the center point of particle that makes the particle analysis easier. It helps as a classifier and helps to fix the coordinate reference and girding lines to analyze particles. This particle is chosen as a reference particle to make Fourier analysis with its descriptor. Sobel method was used to find out center of Gravity using MIL platform as shown in figure 3.

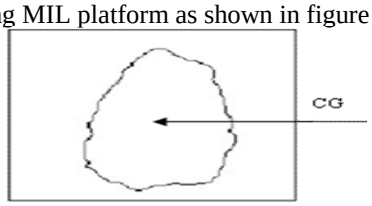


Fig.3. Skeletonization and CG of a single particle

2.2 *Fourier Method*

Complex Fourier transform descriptor is utilized to characterize particles more efficiently. Fourier descriptor requires number of descriptors to be chosen. In general, it is found that 15 descriptors are usually sufficient to describe particles shape complexity (Sonka et al. 1993). In the case of a sand particle however, 3 terms have been found to be enough to quantify the approximate morphology. Standard shapes were used to extract features of the descriptors. Three standard shapes involve circle, square and triangle while others are its measures like elongation, flatness, irregularity and asymmetry. . It is a complex equation and has real and imaginary part and is governed by boundary descriptor points and expressed mathematically as complex function:

$$x_m + iy_m = \sum_{n=-N/2+1}^{+N/2} (a_n + ib_n)\left[\cos\left(\frac{2\pi nm}{M}\right) + i\sin\left(\frac{2\pi nm}{M}\right)\right] \quad (1)$$

Where x, y are coordinates describing the particle
N is the total number of descriptors
n is the descriptor number
M is the total number of points describing the particle
m is the index number of a point on the particle
a, b are coefficients for each descriptor
i denotes an imaginary number

Complex Fourier transform and its descriptors are based on above reference particle. Different shapes were quantified using standard shapes circle based on radius, elongation, triangle, square and asymmetry. The lower order descriptors were chosen to n= -1 to -4. The equation has complex nature and describes the particle morphology. It has greater coefficient describing larger features with n=0, -1,-2and –3 used for morphological study of sand particles and done by using descriptors as 0 for radius, -1 for elongation, -2 for triangularity, -3 for squareness,+1 for asymmetry, +2 for second order elongation, +3 for second order triangularity.

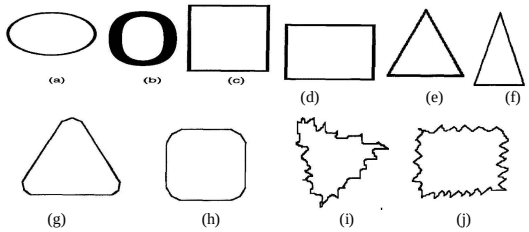
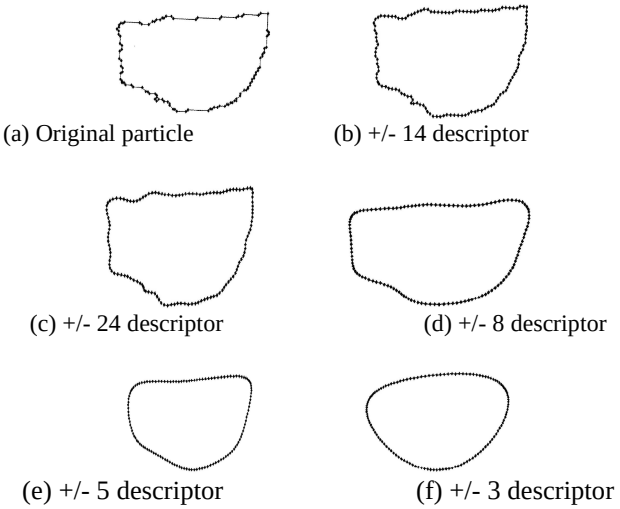


Fig.4. Descriptor and sand shapes

Analysis was done using above the standard shapes. Above fig 4 represents different signature or reference of descriptors provided by complex Fourier transform descriptor function. Figs. 4(a) to (f) particular features or “Signature Descriptors” may be obtained. Descriptors n=O, -1, -2 and -3 give Radius (a similar measure to particle size), Elongation (i.e. aspect ratio), Triangularity and Squareness features, respectively. Descriptor n=+l gives a measure of Asymmetry or irregularity, such that the square, rectangle, oval and equilateral triangle (i.e. all “regular” shapes with their centres of gravity equidistant from any corners) have values of 0.00, whilst the isosceles triangle and the roughened equilateral triangle and square both have non-zero values. Descriptor is a “second order” elongation term and a second order triangularity term.

2.3 *Analysis of Shape of Sand*

The software calculates the number of particles captured by CCD camera and after that complex Fourier Descriptor analysis is done to extract the shape of particles. The literature discusses and presents techniques to characterize particles shape. A MIL application with MatLab 1.5 platform inbuilt program was used to determine the Fourier descriptors for each sand particles. In order for the Fast Fourier Transform (FFT) to be correctly carried out for each sand particle, its perimeter is required to be broken into steps of equal length. Therefore, the length of each sand perimeter was assessed and this was broken into 128 equal lengths to produce 128 new coordinates. In order to reproduce sand in the space domain from the FFT, both the real and imaginary elements of the frequency domain must be maintained as separate - i.e. both the magnitude and the phase angle are required. Fig. 5 shows a typical profile of a sand particle as reconstructed using Fourier descriptors in this manner. Fig 5(a) gives the original profile as output by the image analysis programmed whilst Figs 5(b) to (f) show the effect of reducing the information by suppressing greater numbers of the higher order descriptors. The fine detail is increasingly lost but the overall morphology is retained. The data for this was output to a text file for each sand type. The coefficients were further analyzed using a spreadsheet to produce statistical data. The x, y coordinates are taken as real and imaginary for the complex Fourier analysis.



(a) Original particle (b) +/- 14 descriptor

(c) +/- 24 descriptor (d) +/- 8 descriptor

(e) +/- 5 descriptor (f) +/- 3 descriptor

Fig.5. The effect of reconstruction of a particle from complex Fourier descriptors using successively fewer descriptors

III. Result and Discussion

According to result generated by image processing by shape descriptors Fourier transform , shape of sand can be categorized according to its radius (circle), elongation, triangularity, squareness and asymmetry. Bulk of sand were tested by using this characterization technique and found that with 10 different descriptors and reconstruction of the derivates total 21 different kinds of particles were identified. Radius (circle) descriptor based identified shape of sand are practically and realistically described by other name rather than descriptors, which is very rigorous to define. Circle and its radius define roundness and sphericity of the particle. According to result generated by shape descriptors Fourier transform, shape of sand can be categorized according to its Radius (circle), Elongation, Triangularity, Squareness and Asymmetry. Bulk of sand were tested by using this characterization technique and found that with 10 different descriptors and reconstruction of the derivates total 21 different kinds of particles were identified.

Radius (circle) descriptor based identified shape of sand are practically and realistically described by other name rather than descriptors, which is very rigorous to define. To convey the result in an effective and simple way following are the sand particles shape identified and commonly used shapes;

Roundness/ Descriptor	Well circle rounded (a)	Rounded (b)	Sub rounded (c)	Out rounded angular (d)	Low Angular rounded (e)	High Angular (f)
Circle with high sphericity descriptor (+/- 5)	1	1	1	1	1	1
Circle with low low sphericity descriptor (+/- 3)	2	2	2	2	2	2

Table 1: Figure and terms of Roundness of sand shape particles

According to elongation, squarness and triangularity sand shape can be termed as;			
Elongation (E)	1	2	3
Square(S)	1	2	3
Triangular(irregular)(T)	1	2	3

Table 2: Figure of elongation, square and triangular irregular shape of sands

Basic standard shapes of particle are circle, square and triangular. According to these features complex Fourier descriptor has given extended different shape features extraction. Total 21 numbers of complex shapes are defined by above table 1 and table 2. To convey the result appropriately, particles shape were describe separately by below table 3;

Sand shape table	Sand type index	sand shape specific name
Table2 (a(1)	1	Well rounded with high sphericity
Table2 (a(2)	2	Well rounded with low sphericity
Table2 (b(1)	3	Rounded with high sphericity
Table2 (b(2)	4	Rounded with low sphericity
Table2 (c(1)	5	Sub rounded with high sphericity
Table 2(c(2)	6	Sub rounded with lowsphericity
Table 2 (d(1)	7	Rounded angular with high sphericity
Table 2(d(2)	8	Rounded angular with lowsphericity
Table 2 (e(1)	9	Low Angular with high sphericity
Table 2 (e(2)	10	Low Angular with low sphericity
Table 2 (f(1)	11	High Angular with high sphericity
Table 2 (f(2)	12	High Angular with low sphericity
Table 3 (E(1)	13	Slight Elongation (E)
Table 3 (E(2)	14	Moderate Elongation (E)
Table 3 (E(3)	15	High Elongation (E)
Table 3(S(1)	16	slight Square(S)
Table 3(S(2)	17	moderate Square(S)
Table 3(S(3)	18	High Square(S)
Table3 (T(1)	19	slight Triangular(irregular)(T)
Table3 (T(2)	20	moderate Triangular(irregular)(T)
Table3 (T(3)	21	high Triangular(irregular)(T)

Table 3: Sand shape particle description

IV. Conclusions

It can be found that sand particles shape can be easily characterize using digital imaging and processing. Different techniques are available but this process of characterizing particles is simple, realistic and more concise in nature. Complex Fourier Transform involves complex equation and it has real and imaginary part which gives the exact particles dimension in exact way and helps to extract particles shape. Particles shape plays important role in different field which helps to find out different important factors. The result of studies shows different morphological signature or shape differently depending on the type of sand. This research produces a qualitative and quantitative data to diagnosis the problem inherent to sand shape problem failure in an automated way which can guide a new vision to design and diagnosis the problem. It has characterized sand particles in 21 different shape morphology with the help of digital image processing. This process is one of the genuine works to solve problem inherent to particle shape. Applying this process will help various researches to give outlet to the problem related to

particles shape and procedures of particles shape determination and analysis.

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