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Multiphase Flow Control with Embedded System and Color Image Processing

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Abstract

In Oil and Gas Industry, Multiphase Flow of Oil, Gas and Water is present during exploration, transmission, refining process. Finding the content of oil, gas and water is very important for decision making of exploration, transmission and refining process. Using mechanical instruments is not very efficient, as they are bulky, expensive and not very accurate, so using electronic instruments with embedded system and sensors will capture the image of fluid and then converting that image to digital form. Once the image in digital form, we applied image processing technics of de-blurring to increase the accuracy and then calculating the pixels of oil, gas and water to find content profile. Installing these sensors at two points is used to find velocity profile of fluid. We have successfully fabricated multiphase flow metering (MFM) system using local resources. This system is designed to study the application of wire mesh tomography and for capturing image data of multiphase flow of fluids with the help of embedded system and used de-blurring algorithm of image processing, to increase accuracy of content profile and correlation technique was applied to find velocity profile, then with color image processing techniques, content profile of oil, gas and water was calculated to see that calculation of oil, gas and water are the same and verified as it was obtained from the image processing and de-blurring techniques. Results obtained were quite encouraging.

Keywords: Correlation, De-blurring, Embedded System, Flow Control, Image Processing, Multiphase

1. Introduction

Definition of multiphase flow metering is finding the content profile of each phase specially, in oil and gas industry, it is required because when oil fluid is excavated it contains oil, gas, water, sand and emulsions and at every stage content profile calculation has to be done[1]. At the well site, on pipelines, during oil gas separator stage, during

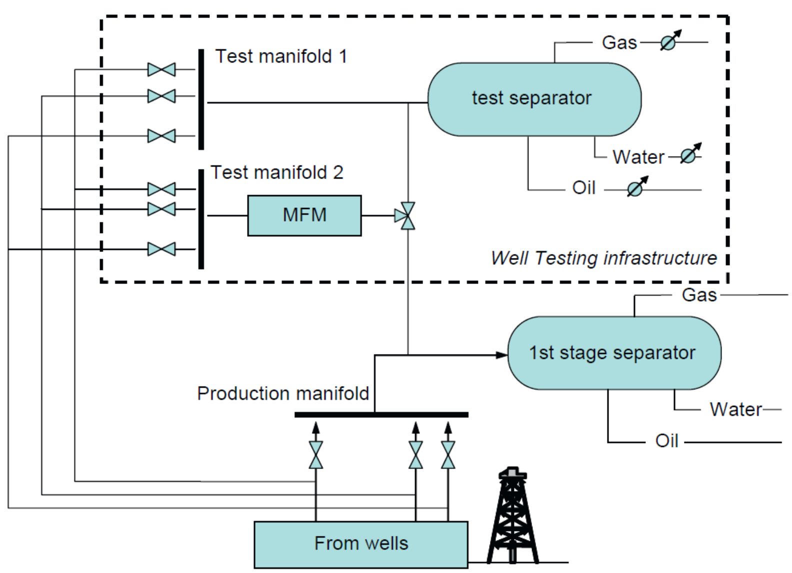

Figure 1. The integration of MFM in an existing well-testing infrastructure.

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refining process and during supply stage as shown in the Figure 1[2]. Also flow metering is required in power plants, nuclear rod bundle processing for the monitoring of bubbles in hard water heat exchanger[3]. Flow monitoring is also required in many processes like in food industry, pharmaceutical industry and also human blood flow needs to be monitored.

To find out the accuracy of Wire Mesh Tomography (WMT) for gas-liquid flow measurement in oil and gas industry and process industry, the experimental study focused on its measurement features has been carried out. The WMT principle is based on the dependency upon electrical conductivity of particular phase. The applied Wire Mesh Sensor (WMS) consists of two measuring planes, transmitter plane and the receiving plane as shown in Figure 2. Each plane has 8 × 8 crossing points with spatial resolution of 2.22 × 3.03 mm^2 and wire diameter of 0.125 mm. The conductivity level of each phase depends upon the chemical composition of each phase[4]. The data acquisition method used with the help of embedded system of PIC microcontroller, as the image acquired it was de-blurred, by regression algorithm and correlation was found between the different images so correlation can be helpful to find how much distance the fluid covered in given time so the velocity of fluid have been found out[5,6].

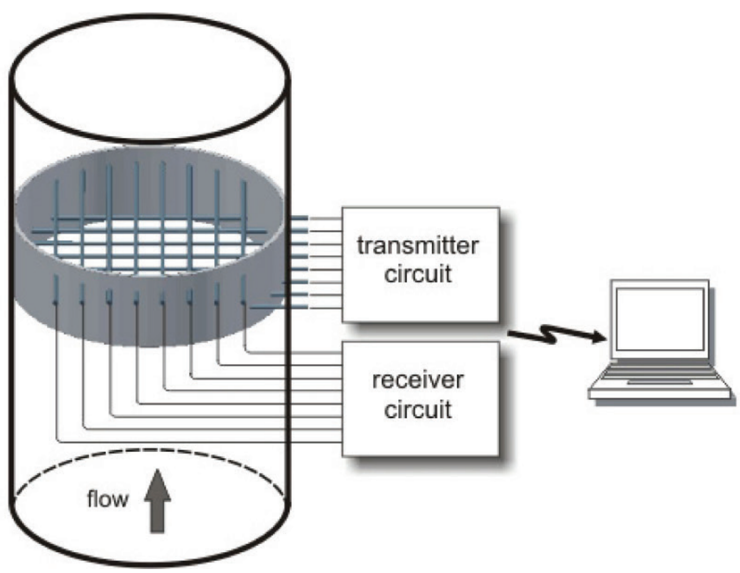
2. Wire Mesh Tomography

Industrial images mostly obtained are of the resolution of 360 x 400 pixels[7,8], which is a sufficient resolution for the processing and calculation, but higher resolution images can also be obtained[9,10]. Commercial cameras available in the market for industrial imaging are of the resolution of 100 MP, but in smart phones cameras available of 20 MP.

3. Image Digitization

Image digitization bridges the gap between the analogue world in which the scenes are obtained and the digital format of images which are to be processed, algorithms applied and digitally the image should be transmitted. Digitization involves two processes of sampling in time and space (Figure 4) and quantization in amplitude. Sampling involves selecting finite number of points within an interval, whereas quantization implies assigning an amplitude value. The result of the digitization process is the pixel array. Rectangular array values correspond to the intensities of pixel in case of monochrome image and color components in case of color images.

Sampling is the process of measuring the value of a 2D function at discrete intervals along the x and y axis. A system that has equal horizontal and vertical sampling



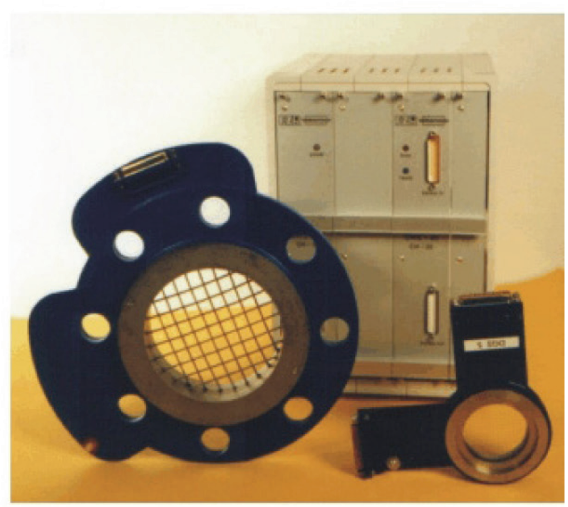


Figure 2. Applied Sensor Layout.

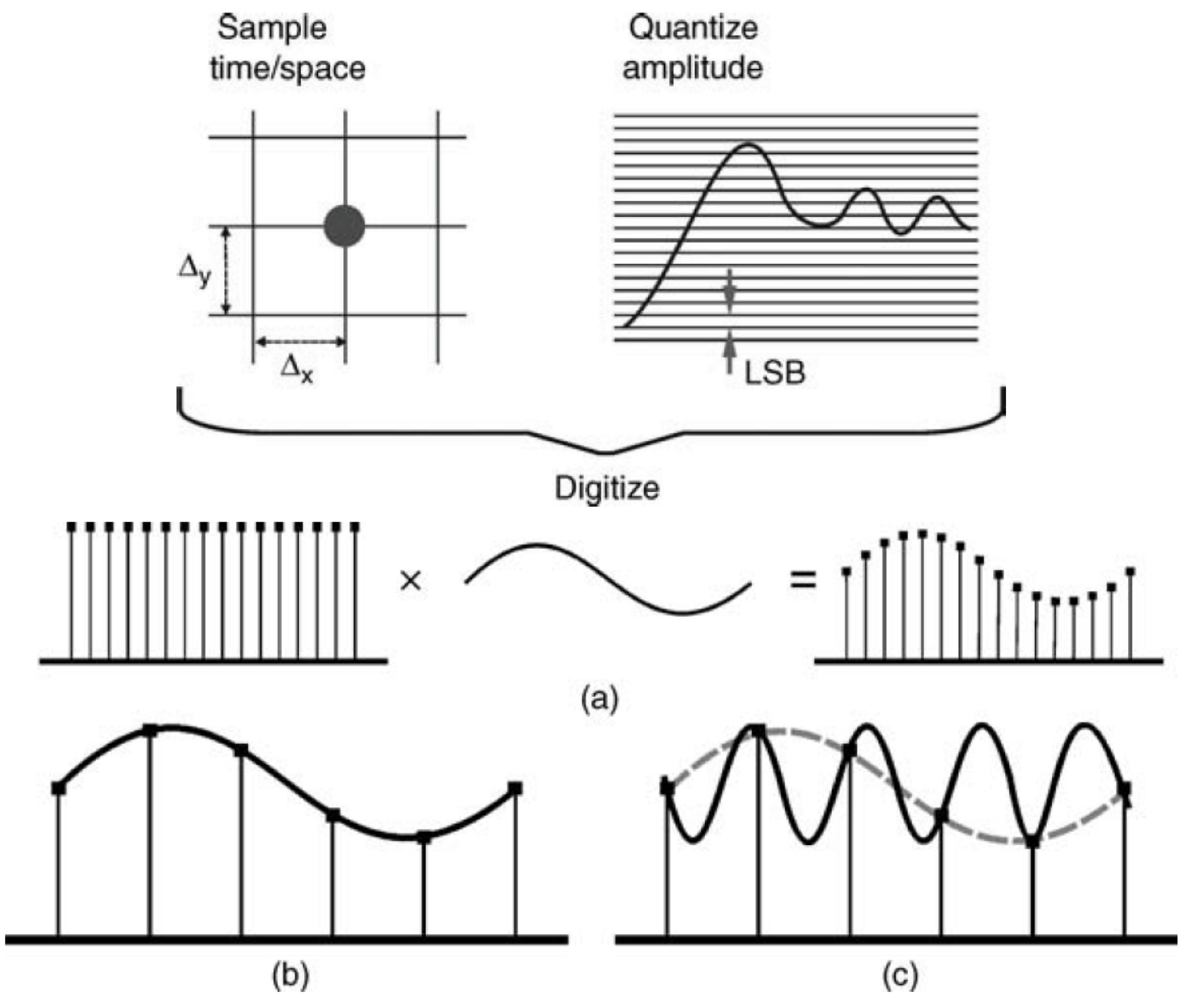


Figure 4. Digitization, sampling, quantization and aliasing explanation.

densities is said to have square sampling. Sampling rate should be double to the available frequency as specified by Nyquist Theorem if it is lower than it is called as under-sampling which creates the problem of aliasing as shown in Figure 4.

4. Regression Algorithm

4.1 Point Spread Function

Point spread function describes the response of an imaging system to a point source or a point object.

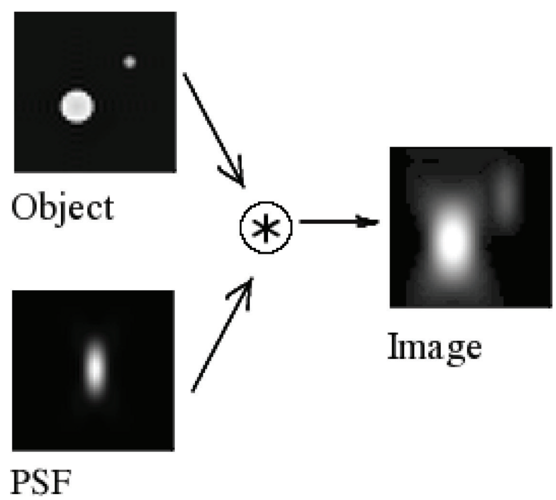


Figure 5. Example of point spread function.

Suppose,

Y : Degraded Image,

Λ : Original Image,

P : Point Spread Function,

*: Operation of Convolution.

Then

$$Y = \Lambda * P \tag{1}$$

Numerical values of Y, Λ and P can be considered as a measure of frequency at that point.

In the model (1),

$P = ((\ p(i,j)\ ))$, $p(i,j)$ = P[Photon emitted at *i* is seen at *j*].

$\Lambda = (\lambda_1, \ldots\ldots, \lambda_n)'$ λ_i = True pixel value at the *ith* point.

$Y = (y_1, \ldots\ldots, y_d)'$

y_j = Observed pixel value at the *jth* point.

4.2 Distribution of Observed Pixels

Notice that *yj* is nothing but the count of the photon seen at *j*. So *yj* has a Poisson distribution. In fact,

yj~ Poisson (*μj*)

Where

$$\mu j = \sum_{i=1}^{n} \lambda i\, p(i,j) \tag{2}$$

4.3 Distribution of Spread Function

The distribution of spread function varies from problem to problem. In our problem we have taken the Gaussian spread function which is given by:

$$p(i,j) = \exp\left(-\frac{d(i,j)2}{\sigma 2}\right) \tag{3}$$

Where *d* (*i, j*) = Distance between i and j.

4.4 Explanation of Regression Algorithm

Define the contribution of λ_i and *yj* as:

$$z(i,j) \sim \text{Poisson}\ (\lambda i\ p(i,j)) \tag{4}$$

then,

$$yj = \sum_{i=1}^{n} z(i,j) \quad 5)$$

and $\frac{\lambda i\ p(i,j)}{\sum_k \lambda k\ p(k,j)}$ 6)

is the proportion of yj emitted by i

If we know Λ then z (i,j) is emitted by:

$$\dot{z}(i,j) = \frac{yj\ \lambda i\ p(i,j)}{\sum_k \lambda k\ p(k,j)} \tag{7}$$

Given z (i,j), λi is estimated by:

$$\lambda i = \sum_{j=1}^{d} z(i,j) \tag{8}$$

So ultimately it gives an iterative procedure[11]:

$$\lambda i(t+1) = \lambda i(t) \sum_{j=1}^{d} \frac{yj\ \ p(i,j)}{\sum_k \lambda k\ p(k,j)} \tag{9}$$

Practically that regression algorithm has been implemented as shown below when:

PSF = Point Spread Function

SD = Standard Deviation

DAMPR is ten times of Standard Deviation.

Then finding limit and weight

NUMIT is number of iterations.

```
PSF = fspecial ('gaussian', 7, 10);
SD = 0.01;
g = imnoise (imfilter(f, PSF), 'gaussian', 0, SD^2);
DAMPAR = 10*SD;
LIM = ceil(size (PSF, 1)/2);
WEIGHT = zeros (size(g));
WEIGHT (LIM + 1: end - LIM, LIM + 1:end - LIM) = (1);
NUMIT = 5;
fr = deconvlucy (g, PSF, NUMIT, uint 8 (DAMPAR), (WEIGHT));
```

5. High Resolution Image Captured through WMT

High resolution image captured through WMT and it is shown in Figure 11.

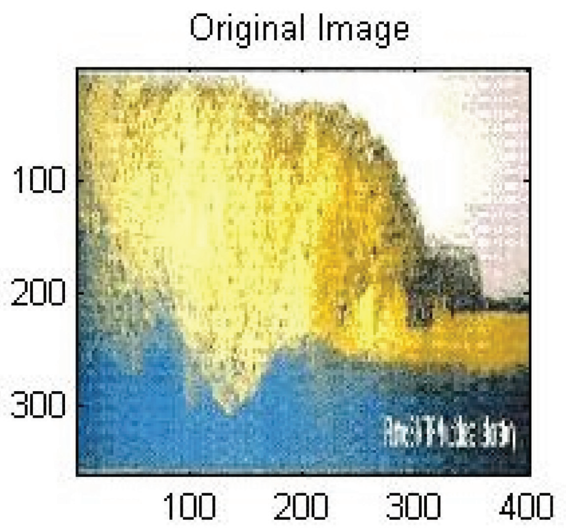


Figure 6. High resolution image captured through WMT.

Blurred image was de-blurred through iteration algorithm after 5 iterations, correlation was calculated and it is as shown in Figure 7.

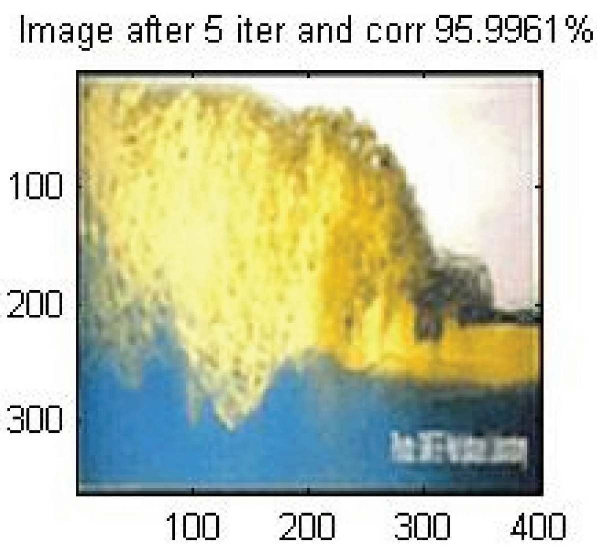


Figure 7. De-blurred image after 5 iterations and correlation with original image is 95.9961%.

Blurred image was de-blurred through iteration algorithm after 10 iterations, correlation was calculated and it is as shown in Figure 8.

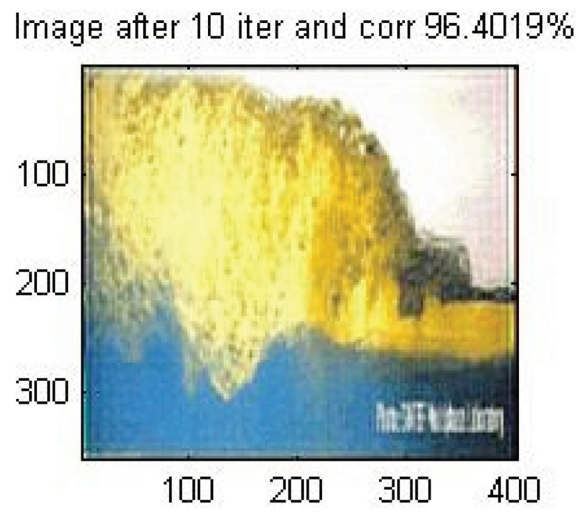


Figure 8. De-blurred image after 10 iterations and correlation with original image is 96.4019%.

Blurred image was de-blurred through iteration algorithm after 20 iterations, correlation was calculated and it is as shown in Figure 9.

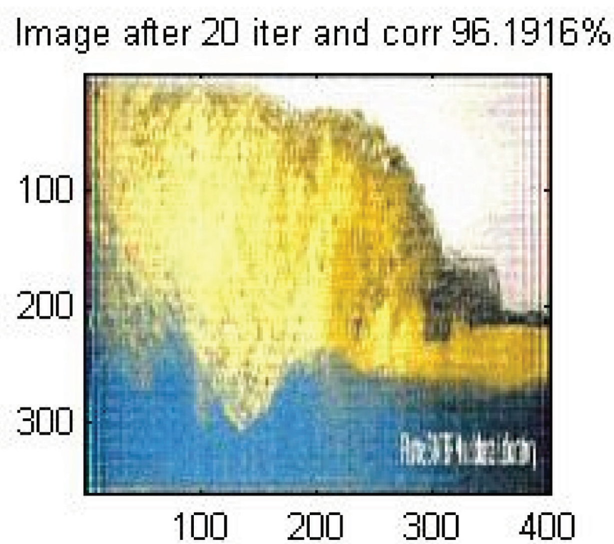


Figure 9. De-blurred image after 20 iterations and correlation with original image is 96.1916%.

Blurred image was de-blurred through iteration algorithm after 100 iterations, correlation was calculated and it is as shown in Figure 10.

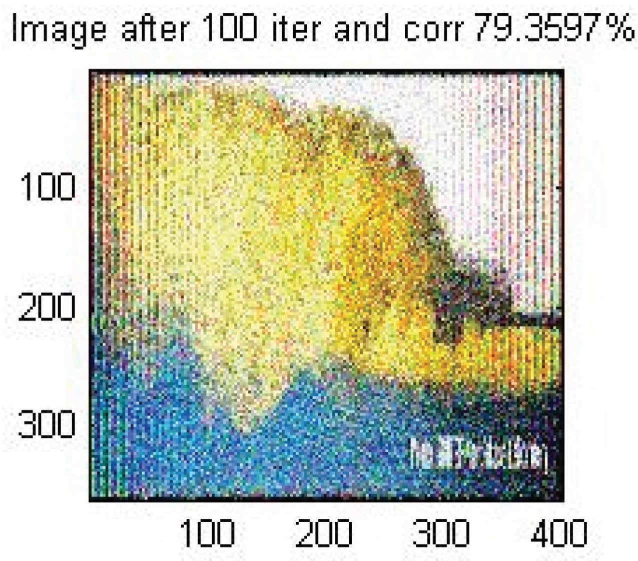


Figure 10. De-blurred image after 100 iterations and correlation with original image is 79.3597%.

Blurred image was de-blurred through iteration algorithm after 200 iterations, correlation was calculated and it is as shown in Figure 11.

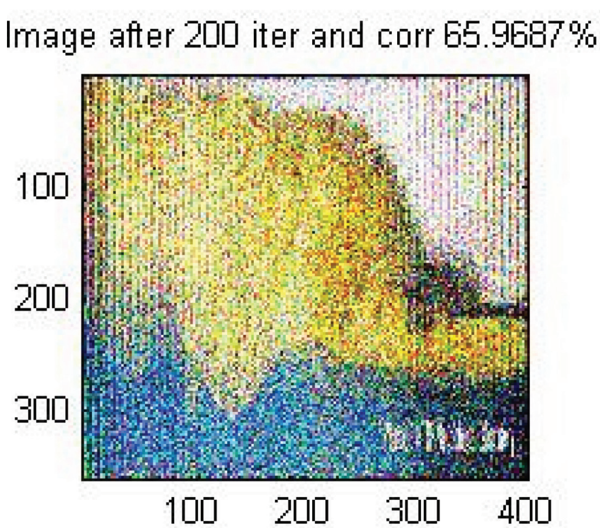


Figure 11. De-blurred image after 200 iterations and correlation with original image is 65.9687%.

Ten iterations are enough for the de-blurring and more rigorous iterations up-to 200 were used for experimentation and to prove that beyond 10 iterations are not useful and image obtained have total of 363*400 = 145200 pixels out of which;

Oil pixels = 53880 pixels.

Gas pixels = 46014 pixels.

Water pixels = 45306 pixels.

So the percentage of Oil is 37%, the percentage of Gas is 31% and percentage of water is 30%. In the setup fluid travelled 40.64 meters from source to destination in a time of 29.5 seconds so the velocity was 1.378 m/s, as per the data observed by Petrosult and Unimart.

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6. Indexed Color Image Processing Results

Indexing of color images can be done by rgb2ind function. Primary use of this function is to generate an indexed image based on an input true-color image. Multiphase flow control image is indexed through this function as shown below:

```
I = imread ('multiphase flow image square for segmentation.jpg');
n = 3;
[I2, map2] = rgb2ind (I,n, 'nodither');
figure, imshow (I)
figure, imshow (I2,hsv(3))
```

After indexing of image the results obtained is as shown in figure.

Image obtained have total of 363*400 = 145200 pixels out of which;

Oil pixels = 53880 pixels

Gas pixels = 46014 pixels

Water pixels = 45306 pixels

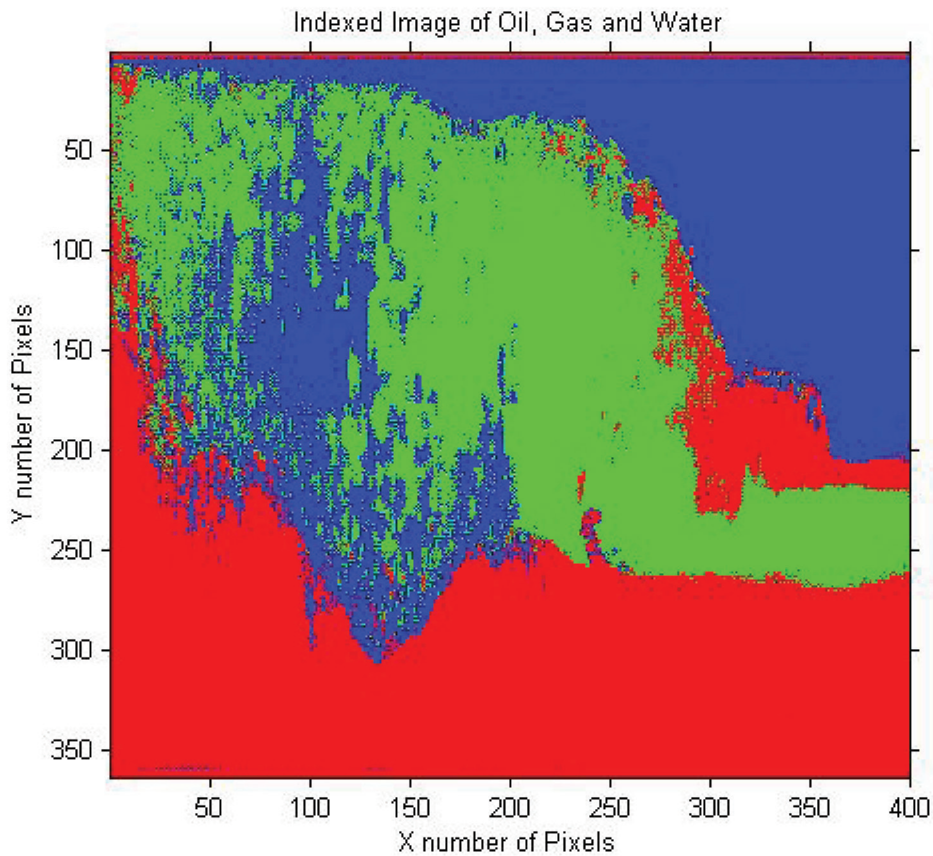

Figure 12. Indexed image for oil, gas and water.

So the percentage of Oil is 37%, the percentage of Gas is 31% and percentage of water is 30%.

Which proves that data obtained is correct.

7. Conclusion and Future Plan

Wire-mesh tomographic sensors are very useful for the measurement of content profile and velocity profile of the Multiphase Flow Control in the Oil and Gas Industry, Process Industry, Power Plants, Nuclear Plants and anywhere where Flow Control is the main focus. WMT used with Embedded System of microcontrollers that has been programmed very precisely for capturing images and images has been processed through advanced image processing techniques like de-blurring regression algorithm for the improvement of images so much more accurate content profile and velocity profile have been measured. Correlation finding technique is used to see that in how much time fluid travelled to other point in Plant so velocity profile has been measured, also color indexed image processing is required to verify the data and that is the verification and validation. In Multiphase Flow Control like in Oil and Gas Industry finding content profile and velocity profile is the requirement that has been automated through Embedded System and image processing techniques and advance techniques of Data Mining like cubing and Artificial Intelligence techniques are to be applied in further research work. Higher resolution and high voltage energizing will be applied for obtaining more accuracy. Industrial Automation for the control purposes is the need of the time that has been implemented through Embedded Systems.

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