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Analysis of Liquid Viscosity by Image Processing Techniques

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Abstract

Objective: In this paper, a technique is proposed for measurement of viscosity using the principle of dispersion of incident light with variation of liquid viscosity. The objective of the proposed technique is to design a non contact technique to analyze the characteristics of dispersed image using image processing for the light incident on liquid whose viscosity is to be measured. **Methods:** A camera is used to capture the background image of the refracted image. This captured image is processed by techniques like thresholding, filtering, and histogram to arrive at a quantified relation between viscosity and histogram values. To establish the relation an artificial neural network model is designed. Proposed neural network is trained by levenburg Marquardt Algorithm, once trained it is tested with the real time system conditions. **Findings:** Once the neural network is designed, tests are conducted. Several samples of liquid are used with varying viscosity. From the obtained results it is clear that the proposed technique is able to measure viscosity accurately with a root mean percentage of error 2.01%. **Application:** From the obtained results it is clear that the proposed viscosity measurement technique can be used for measurement of liquid viscosity, even in dynamic flow conditions.

Keywords: Image Processing, LabVIEW, Liquid Viscosity, Refraction

1. Introduction

Characteristics of liquid are often considered to be a very important parameter while designing any process. One such parameter is the viscosity of liquid. Viscosity of liquid affects the rate of flow of liquid. Higher the viscosity more is the friction established with the surface and less the flow rate. On the other side, lower viscosity liquid will have a free flow with less friction. Thus in a process like liquid level process or liquid flow processes the liquid viscosity should be considered while design of controller, actuator, etc.

Measurement of liquid viscosity can be carried by using several ways. Few techniques are discussed after a survey of presently available techniques. In[1], reported a technique for measurement of lubricant viscosity using shear rheometer. Boundary slip and friction between solid-liquid interfaces is considered for evaluation of the device. Lagrangian approach is used to compute the shear rate of the dissipative parameters for measurement of viscosity[2]. In[3] a technique for measuring the viscosity of liquid is reported using the principle of variation of refractive indices with specific density of liquid. Measurement of liquid viscosity by analyzing the characteristic of a vibrating wire is reported in[4,5]. Rotational viscometer is used for measuring the viscosity of solid particles in[6]. Paper[7], discusses the use of falling ball type viscometer for measurement of liquid viscosity. Design and implementation of interferometer for measurement of liquid viscosity is reported in[8]. Paper[9] reports a technique of viscosity measurement by computing the rate of change of liquid flow on a cantilever beam by measuring the strain changes. Micro-crevice viscosity developed using the principle of interferential and parallel plate viscosimeter is reported in paper[10]. Analysis of effect of viscosity of liquid used in Liquid Crystal Display (LCD) is reported using the capacitance voltage characteristics and transmittance-voltage characteristics[11]. Principle of Diamagnetic levitation is used to analyze the fluid property

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like viscosity in micro-cavities[12,13]. In[14] frequency response characteristics of QCM crystal are analyzed to determine the viscosity of liquid. Analysis of viscous property of liquid is carried on using properties of fluids for propagation of wave[15]. Analysis of fluid viscosity in a micro channel using microscope is reported in[16]. Analysis of refraction angle is performed for computing the viscosity of liquid flowing inside a tube[17]. Paper[18] discusses the technique for measurement of viscosity of silicone liquid by electro-optical principles. Design of acoustic resonator sensors are used for measurement of viscosity is reported[19] analysis of design and performance issues is also reported. Paper[20,21] discusses the analysis of viscosity using the adsorption property. From the survey of reported work it is very clear that most of the techniques are contact type. Contact type of viscosity measurement will lead to disturbance in flow profile and hence will not be suitable for use in flow/ liquid level process.

In view of the above reasons a non-contact technique is proposed using image processing technique for analysis of liquid viscosity. The technique uses the principle of measuring the rate of particle dispersion for computing viscosity of liquid. Dispersion of particle is found using image processing technique on captured image. Based on the deviation computed using image processing techniques.

The paper is organized as follows: after introduction in Section 1, followed by discussion on experimental setup used is given in Section 2. Section 3 discusses the problems associated and following which is solution in Section 4. Section 5 reports the results obtained by the proposed technique and its analysis.

2. Experimental Setup (Figure 1)

To perform the task of measuring liquid viscosity, an apparatus is designed as shown in the figure. It consists of an apparatus where the laser light is incident on a tube containing liquid, whose viscosity is to be measured. Figure 2 shows how the laser light will be incident of the source liquid whose liquid is under measure.

3. Problem Statement

Once the monochromatic laser light is incident on the liquid source it gets refracted (snells law) because of the change in refractive index between air and liquid medium. The refracted wave is collected on the background as shown in Figure 3.

Figure 1. Experimental setup

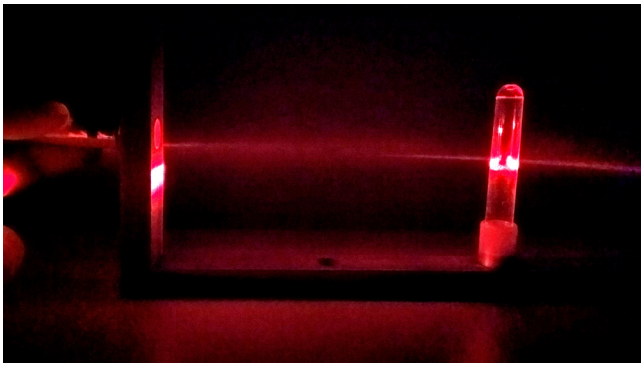

Figure 2. Experimental setup under test

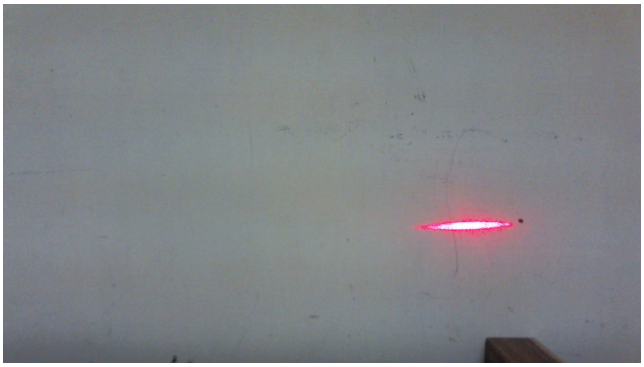

Figure 3. Image of captured light source because of refraction by plain water.

Similar experimentation is carried on with varying the liquid viscosity. Since the viscosity of liquid is proportional with the refractive indices of liquid. The incident laser light would get refracted with different angle and size. To understand the behavior of dispersed light, tests are conducted with different liquid of varying viscosity. Images obtained are as shown in Figure 4–6.

From the above images (Figure 3-9) it is clear that the light incident on the liquid would disperse/refract in different form depending on the viscosity of liquid used.

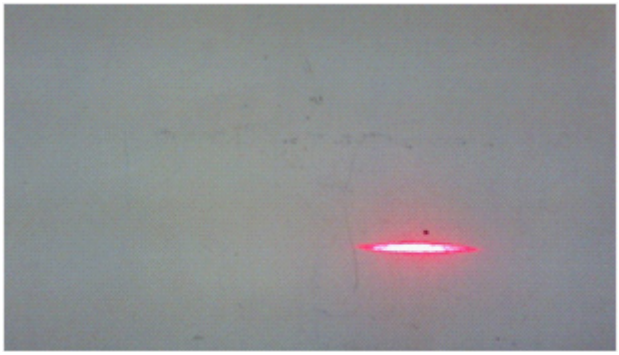

Figure 4. Image obtained for water added with 25% sugar solution

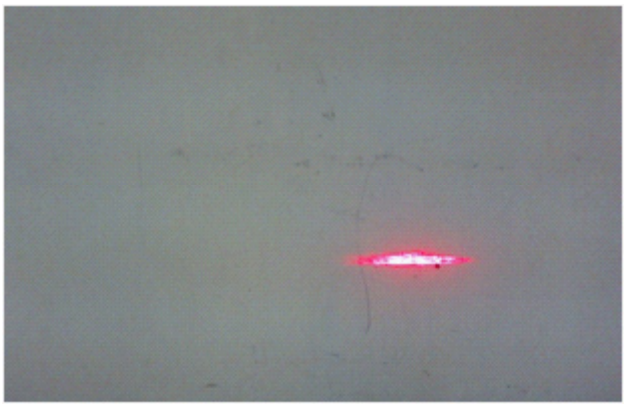

Figure 5. Image obtained for water added with 50% sugar solution

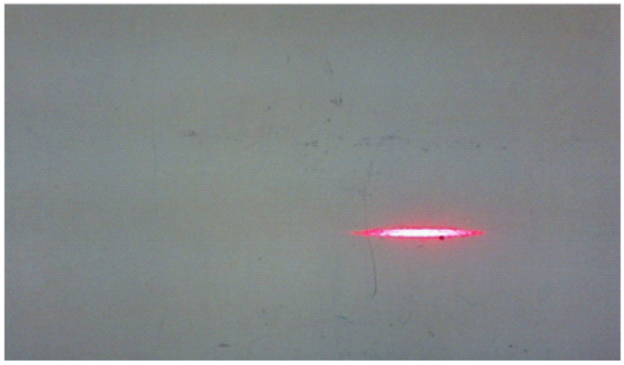

Figure 6. Image obtained for water added with 75% sugar solution

Problem statement: From the above, it is clear that the objective of the proposed technique is:

1. To compare the image produced by varying viscosity of liquid to analyze the effect of viscosity.
2. Compute the viscosity of liquid under test based on the analysis.

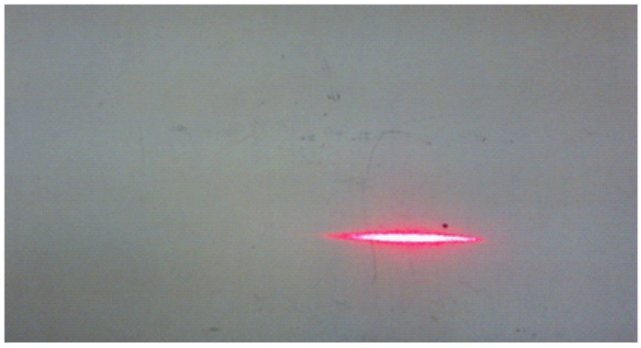

Figure 7. Image obtained for 10% glycerin solution

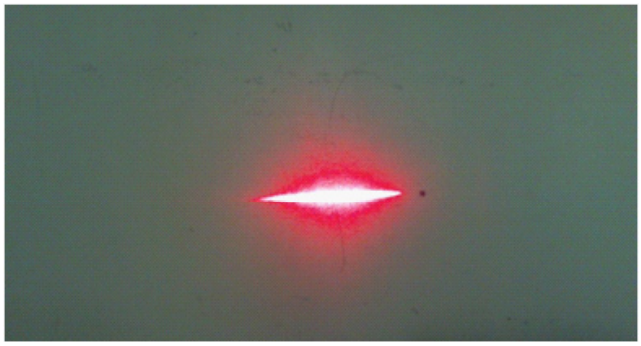

Figure 8. Image obtained for 40% glycerin solution

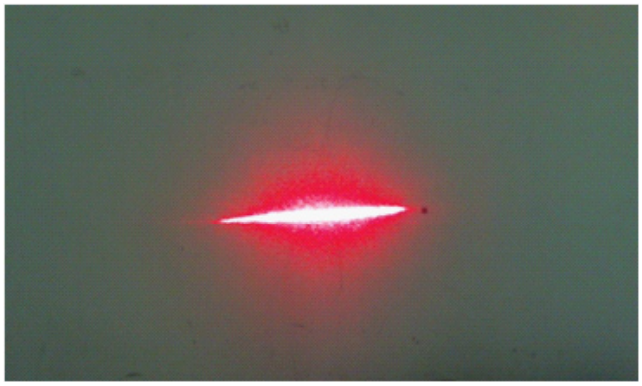

Figure 9. Image obtained for 70% glycerin solution

4. Problem Solution

To achieve the objectives discussed, an image processing algorithm is designed. Image produced by the refracted laser light is acquired on to PC by a high resolution camera. The obtained image is processed so as to compute the viscosity of liquid. The process followed for the said purpose can be described using a flow chart shown in Figure 10. For the purpose of analysis LabVIEW toolbox is used.

A: Acquire image

The first step towards achieving the objective is to acquire the image captured from the camera to the PC. In the proposed work LabVIEW platform is used for this purpose. The image is captured using the VISA terminal as the connectivity between Camera and PC is through USB port. VISA is programmed to capture the image from the camera once the trigger button is initialized. The trigger button is operated manually, can also be initialized using a timer.

B: ROI

Region of interest selection is an operation carried on the image captured from the camera. In this operation the section of image is selected which is to be processed for obtaining information.

In the proposed technique a coordinate based selection of ROI is used. In this technique the rectangular region is selected by assiging the (x,y) coordinates. This operation is carried on to reduce processing of unwanted data. The image obtained after ROI is as shown in Figure 11.

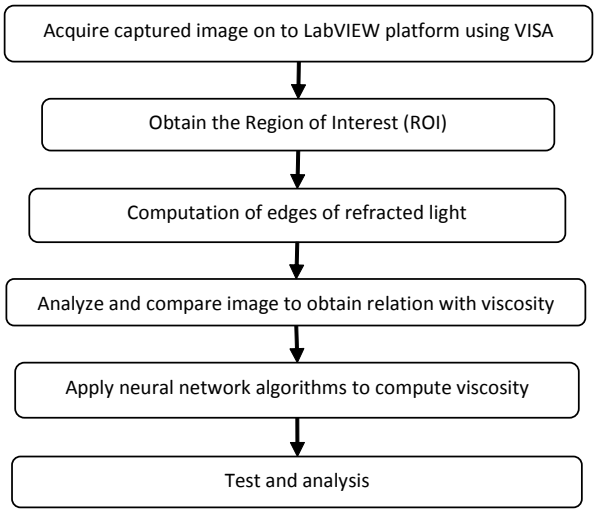

Figure 10. Block diagram of proposed image processing technique

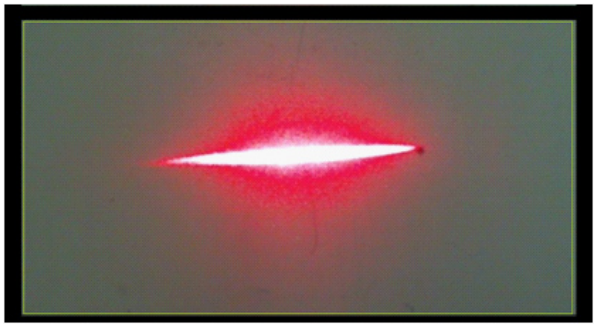

Figure 11. Image after ROI

C: Computation of Edges

In this stage the refracted light image is obtained interms of coordinates, edges, and contour. For this primarily the image is converted to a grey scale using the conversion palette. The converted image is as shown in Figure 12. Next step is to detect the edge for this operation a thresholding operation is carried to find the edges. Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene. Hough Transform is applied for detection of edges in the proposed work[22,23]. Output obtained is as shown in Figure 13. The edges and its coordinates can be identified using edge detection. To identify the contour a histogram technique is used. Histogram is defined by a function of intensity level in all pixel of given region (for an 8 bit image, intensity level will be in between 0 to 255). Two different kinds of histograms are obtained for color images. Namely,

- Intensity histogram
- Individual color channel histograms

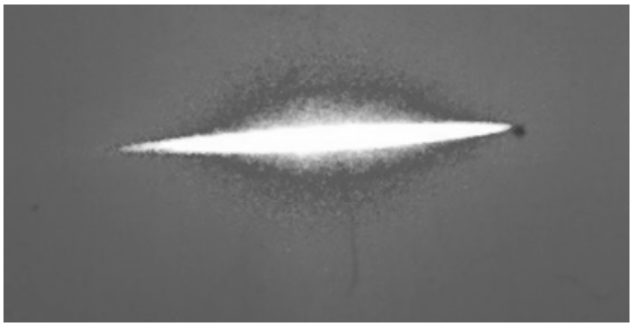

Figure 12. Grey scale converted image

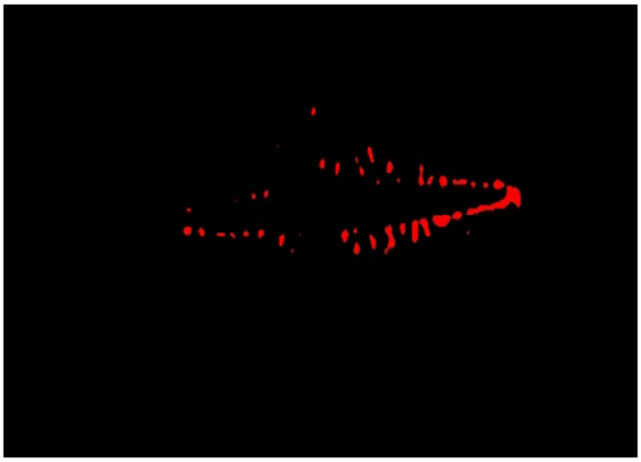

Figure 13. View after thresholding

Intensity histogram technique is used here. An inbuilt H-component function in LabVIEW is used to create histogram function for acquired image. In this process, image is converted into an N vectors of two dimensions which are bin position and its corresponding normalized frequency.

D: Computation of Viscosity using Neural Network

Once histogram is created for images, it is trained to obtain the viscosity of liquid. For this a neural network approach is used. The neural network function acts as a mapping function between the image and viscosity.

The first step in developing a neural network is to create a database for its training, testing, and validation. The output matrix obtained from the histogram of a particular image is created used as input data for the neural network. Target data will be viscosity of liquid. Training base is considered of 60%, test base of 20%, and validation base of 20%, number of layers is chosen as two. Training is carried on using Levenberg-Marquardt Algorithm (LMA). Figure. 14 and 15 shows the regression and plot fit curve of the trained neural network.

5. Results and Analysis

Once the neural network based image processing technique is completed. It is tested for evaluating its performance. For testing the proposed technique is analysed with liquids of varying viscosity. The result obtained from the proposed technique is tabulated in the Table 1

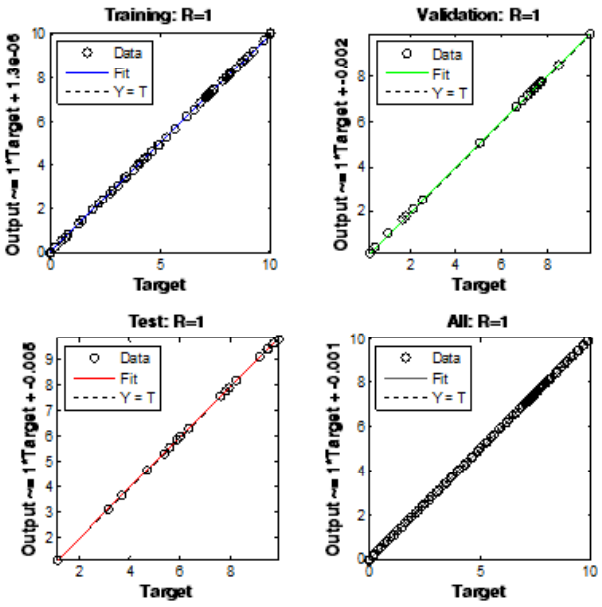

Figure 14. Plot of Regression of ANN

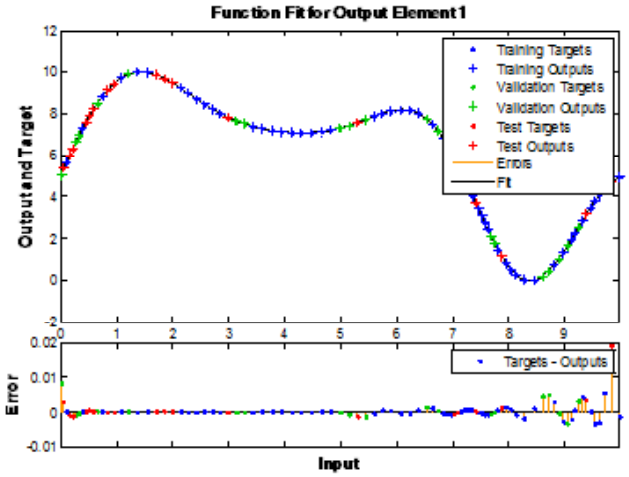

Figure 15. Plot fit of proposed ANN

Table 1. Viscosity measured by proposed system

Actual viscosity in cP	Measured viscosity in cP	% error
1.0	1.01	–1.00
1.2	1.13	5.83
1.5	1.53	–2.00
2.7	2.77	–2.59
4.0	3.76	6.00
9.3	9.32	–0.22
13.8	13.89	–0.65
28.0	28.2	–0.71
42.5	42.0	1.18
66.0	66.04	–0.06
74.8	74.4	0.53
92.0	91.1	0.98
118.0	117.2	0.68
127.0	126.4	0.47
149.7	155.0	–3.54
170.0	167.2	1.65
227.0	226.4	0.26
312.0	310.4	0.51
390.0	390.2	–0.05
466.2	466.0	0.04
626.0	628.4	–0.38
701.1	700.2	0.13
893.0	892.8	0.02
1021.0	1022.2	–0.12
1298.0	1298.5	–0.04
1490.0	1488.0	0.13

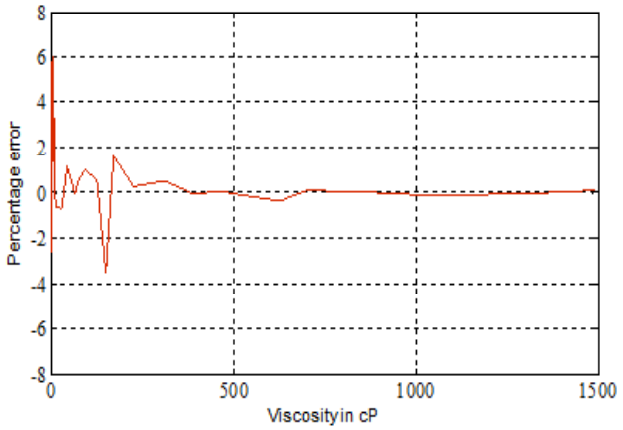

Figure 16. Plot of percentage error obtained

along with the viscosity obtained from available standard viscometer at a temperature of 25 °C.

As shown by Figure 16 and Table 1, it is clear that the proposed viscosity measuring technique is able to measure the viscosity of the liquid accurately.

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