**Literature Review for Fluid Flow rate measurement using Image Processing Techniques**

1. **Patents:**
2. **US 9226673 B2: METHODS, SYSTEMS AND COMPUTER PROGRAMI PRODUCTS FOR NON-INVASIVE DETERMINATION OF BLOODFLOW DISTRIBUTION USING SPECKLE IMAGING TECHNIQUES AND HEMODYNAMIC MODELING**

This patent aims at determining the velocity distribution of blood flow in principal vessels of the heart and quantifying the amount of blood passage through the tissue in the heart through Laser Speckle Contrast Imaging (LSCI). These objectives are achieved using the process described below. Initially, the portion of the heart under interest is illuminated using a coherent light source (I am guessing it is Laser). This is followed by taking at least 2 speckle images that are in sync with the beating of the heart. These images are then electronically analyzed, wherein the variation in the pixel intensities is measured with respect to time thus generating a LSCI. This will also provide a distribution of blood flow in the vessels of the heart. A velocity field for the blood flow in the relevant region of the heart is calculated. This in turn leads to the actually blood flow velocity in these regions. These velocities are then compared with the results obtained using the image processing.

**Similarities:** This technique is non-intrusive and is based on the basic concept of acquiring an image and then playing around with it to obtain the velocity distribution which is also aligned with our core idea at the moment. The non-intrusive feature is most suitable for the application since the blood flow is measured in the heart blood vessels. They have also aimed at velocity distribution determination, which is one of the factors we are looking at.

**Differences:** Most obviously, the application is not related to measurement of petrol/diesel in closed pipes. Moreover, the imaging technique used consists of a “coherent light source” such as lasers and related camera equipment. We are aiming to use the camera already present in the optical mouse, which is a modular and a non-expensive solution as compared to their technique. The usage of readily available image acquisition technique in the form of optical mouse continues to be our advantage.

1. **US 9759343 B2: FLOW METER USING A DYNAMIC BACKGROUND IMAGE**

The patent targets to determine the flow rate of a fluid inside a “drip chamber” using image processing techniques. A drip chamber is a vessel in which the fluid flows in a drop by drop fashion, most commonly seen in IVs of Saline Bottles in medical scenarios. The setup consists of a coupler, a support member, an image sensor and an image processor. A “field of view” is defined which are fixed coordinates inside the drip chamber which the image sensor will monitor. The processor along with the image sensor will capture the image, compare it with a “Dynamic” background and provide results about the flow rate of the drops flowing through the chamber.

**Similarities:** The patent uses a non-intrusive setup for image capturing and comparison with standard background to determine the flow rate.

**Differences:** We are not looking for drop-by-drop flow situation. Our flow condition in continuous flow. For image processing, the parameters are different. In this case, the droplet’s image is detected in a time interval and then the flow rate will be measured. In our case, we will have to ensure the formation of bubbles or any such tracers in the continuously flowing petrol/diesel so that we are able to track its movement.

1. **US9134726 B2: Intravenous flow rate controller**

The patent targets the issues arising in fluid administration due to tilting of the ‘Drip chamber’. To address these negative effects, in accordance with one embodiment of the present disclosure, a fluid delivery system that measures the flow volume of a fluid delivery system is disclosed, which includes an imaging apparatus that captures a first image of a drip chamber while a drop is falling therein and a second image of the drip chamber with no drop. Portions of each image that are in Substantially the same position in each image are subtracted. Detect Drop🡪Capture first image of drip chamber with drop🡪wait predetermined amount of time🡪capture second image of drip chamber without drop🡪remove image portions🡪calculate volume of drop.

**Similarities:** The patent focuses on measuring volume of fluid that drops through the drip chamber. It also pitches a non-intrusive technique so as to avoid any adulteration. It captures two images with a predetermined time to detect a drop and calculate its volume

**Differences:** It is not related to the specific situation about which we are proposing to work. It does not calculate the rate for the same type of liquid flow. The method is to capture an image with the drop and one without, while in our case we are proposing to determine the displacement of the particle which we have introduced by some obstruction.

1. **US10753779: Mass flow meter**

This patent claims to have developed a mass flow meter which measures the flow rate using one or more sensing elements that are exposed to a fluid flow in a pipe or conduit. The preferred combination of sensing elements comprises of two types: 1. A single curved azimuthal arm 2. Two i.e. one outer and one inner azimuthal arm. Each sensing element includes a torque transfer portion which extends through the flow pipe or conduit and a lever arm outside the pipe which engages a circumferential torque collecting ring. The ring, in turn, engages a fixed element or fin having a torque sensing device such as one or more strain gauges. Alternatively, flow and torque sensing may be achieved by an LVDT or servo-feedback system. As flow impinges upon the first and second curved azimuthal arms disposed in the flow stream, aerodynamic (viscous) drag is created and this force is carried by the torque transfer arms and the axial lever arms of the sensing elements to the torque collecting ring. The circumferential torque collecting ring or annulus thus applies force to the strain gauge(s). The output of the strain gauge(s), an LVDT or a servo-feedback system is conditioned and utilized to provide real time mass flow rate data. If desired, these data may be combined with a signal from a temperature sensor in the fluid flow to provide greater accuracy. The mass flow data may be accumulated (integrated) over time, if desired, to provide total mass flow per unit time.

**Similarities:** Not many similarities, but can be considered as an alternative to our idea.

**Differences:** It is not an application specific measuring device whereas we are specifically aiming for measuring flow of petrol/diesel. It is an intrusive technique and is subject to wear. The patent also considers torque generated by the flowing fluid which may add up to energy loss and consequently reduce the flow rate over long distances. This factor may not be a point of concern as we will be measuring the flow rate at such a point where the pipe is not subjected to bending.

1. **Research Papers:**
2. **DIGITAL IMAGE PROCESSING-BASED MASS FLOW RATE MEASUREMENT OF GAS/SOLID TWO-PHASE FLOW**

This paper focuses on flow rate measurement of a two-phase flow consisting of gas and suspended solid particles therein. The volumetric concentration of particles, there velocity and mass flow rate are calculated. The proposed technique uses Solid State Laser for illuminating the region of interest, a CCD camera for image acquisition and an image processing software. There are two kinds of images that are acquired here: (1) clear image (2) motion blurred images. The clear image is used for the analysis to obtain the volumetric concentration of particles in the gas flow. The motion blurred image is used to determine the velocity and thus the mass flow rate.

**Similarities:** The objective and applicability of this paper aligns with our proposed objective of measuring flow rate of continuously flowing fluid. Unlike previous examples, this is neither droplet flow, nor is it a medical application. The basic process also remains the same: Illumination 🡪 Image Acquisition 🡪 Processing the Image 🡪 Flow rate.

**Differences:** The technique makes use of a solid-state laser and a CCD camera. The camera inside a mouse is either LED or Laser Infrared Diode. (still have to investigate the details about this). We are not looking at a two-phase flow (mixture of gas and suspended particles). In all probabilities, we will encounter a single-phase flow of petrol/diesel. Due to the presence of particles, there is no need in their technique to have “tracers”, which we will need in our case (bubbles or likewise). Also, the need for illuminating the region of interest is one point that we need to discuss.

1. **A PIV-BASED FLOW METER**This paper investigates the different techniques that come under the header of Particle Image Velocimetry for determining the flow rate of a liquid flowing through a pipe. This technique isolates a plane normal to the direction of flow which is illuminated using a light source. The instantaneous velocity of the tracer particles is obtained to determine the flow rate of the fluid. Different techniques such as Planar 2D PIV, Stereo PIV for 3D measurements are discussed. The light source used is a Laser and the cameras used are CCD cameras. The images obtained from the camera were processed using Fast Fourier Transform based algorithms.

his data is then processed using a MATLAB script to determine the instantaneous streamwise velocity component of the tracer particles.

**Similarities:** Like the previous methods, this technique the basic method of illumination and data acquisition remains the same. This idea is essentially the same to our concept.

**Differences:** This technique also makes use of tracer particles for tracking the fluid flow. Also, as per the setup, CCD cameras are used, whereas we will use the readymade camera in the mouse.

1. **FLOW MEASUREMENTS IN SEWERS BASED ON IMAGE ANALYSIS: AUTOMATIC FLOW VELOCITY ALGORITHM (similar to: Image processing system for velocity measurements in natural convection flows)**

This paper focuses on flow rate measurement of sewer water using Image processing techniques. The surface water velocity is measured by video analysis using Feature point tracking technique. The source of illumination used in this case is infrared light. Due to the floating waste already present in the water, tracer particles are not required in this application. The small objects on the water surface appear as bright and dark spots which are then analyzed using image processing algorithms.

**Similarities:** Other than the objective of measuring flow rate, there are few similarities in the application described here.

**Differences:** The aim is to measure water flow rate in open channel large scale conditions. Our targeted application differs on both points. We are looking at closed conduit flow and the conditions (scale) are totally different as compared to flow of sewage water. Also, we are interested in image analysis, whereas this paper considers the use of videos to analyze the water velocity. Also, the velocity of water is measured only at the surface and not across the depth of the channel. The naturally present tracer particles in this application also deviates from our conditions of bubble formation and so on.

1. **Velocity field measurement by PIV technique:**

This paper proposes a non-intrusive technique to calculate the velocity field in the wake of a single bubble rising with a rectilinear path in a quiescent liquid. A spherical bubble is created through a capillary. The bubble rises through a glass column containing different solutions, thus presenting different viscosity and Reynolds number conditions. Each of these solutions is seeded with silvered tracer particles whose movement allows following the flow velocity field thanks to the PIV method. A high-speed camera is located far from the column in order to record the bubble position, size and velocity. This camera is also synchronized with the laser flash by a synchronizer processor.

**Similarities:** The technique proposed is essentially same as ours. The technique of PIV is used to determine velocity vectors in a 2d plane. It also uses a camera to detect displacement of a tracer particle (bubble).

**Differences:** The paper does not mention using this technique in the scenario of petrol pumps. It also uses a high-speed camera but is not attached to the column. Using the already available mouse camera is still a new idea.

1. **Wet Gas Flow Metering using PIV and Tracer Dilution**

This paper introduces a prototype wet gas flow metering system, named “Uletech”, for flow measurement. The “Uletech” Wet Gas Meter (UWGM) is based on the combination of particle recognition and the use of Laser Imaging Technology in the form of Particle Imaging Velocimetry (PIV). PIV uses tracer particles which follow the gas or liquid phase. The high-resolution digital laser cameras identify/recognize all the different sizes of particles (gas, oil and water) in a multiphase flow. The system comprises two cameras, laser source, optical arrangement, computer data acquisition system, synchronizer and MATLAB based software. The computer acquires image signals from the upstream and/or downstream cameras, and carries out the calculation of cross correlation between the two image frames so that the velocity of each pixel can be found.

**Similarities:** The technique used is essentially same.

**Differences:** The paper proposes to find velocity vectors for a multiphase (gas, oil and water) liquid. It also uses a MATLAB based software to process the images and find the velocities while using a readymade mouse camera is not considered.