Review of Research and Application of Fluid Flow Detection Based on Computer Vision

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ABSTRACT

As an important parameter in various industries such as metal processing, agriculture, and medicine, the measurement of liquid flow can not only help us ensure the quality of production, but also improve production efficiency. In recent years, the development of computer vision has driven the development of flow detection towards intelligence. As a non-contact, fast measurement, high degree of automation, and high-precision measurement method, image processing technology has gradually been applied to various industries. Many researchers have invested a lot of research work on flow measurement. The representative research and solutions are summarized for more than 20 years, and describes the six main methods used in the flow detection of each fluid. It includes the following aspects: obtaining the flow through the liquid level detection; measuring the volume change rate by detecting the contour of the droplet; detecting the flow through a water ruler; adding markers such as tracer particles and tracer fluid to the liquid; using the inter-frame displacement of the water surface texture method. The article points out that the accuracy of the flow measurement is mainly affected by the liquid environment, and there are still many problems in the selection of light sources and algorithm research, and the true non-contact has not been achieved. At the same time, the future research trends and development directions are given. Through a large number of literature reviews, a review of the detection of fluid flow is provided, which provides many ideas for the next topic of milk flow detection.

CCS CONCEPTS

• Computing methodologies • Computer graphics • Image manipulation • Image processing

KEYWORDS

Fluid flow, Image processing, Measurement method

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1 Introduction

Liquid flow is an important parameter in the fields of industry, agriculture, medicine, etc., especially in the fields of thermal power plants, petroleum, mining, metal processing, aviation, and mechanical design [1]. Now, it has expanded to biomedical field. The flow is an important parameter necessary for industrial process [2, 3], scientific experiment measurement [4] and various economic calculation. Due to the rapid development of modern technology, the measurement environment is becoming more and more complicated, and the requirements for accurate measurement are getting higher and higher [5]. The accurate measurement of liquid flow has been a symbol of historical processes from ancient times to the present. For example, the Egyptians used the Nile flow to predict the success of the year, the ancient Romans repaired the canal and used water to measure the flow [6]. Flow is also called as instantaneous flow, which refers to the amount of fluid flowing through an effective cross-section of a closed pipe or open channel per unit time. It is a key parameter that must be regulated in the fluid process in industrial processes and can be used to ensure stable production and product quality. Through the measurement of liquid flow, people can understand the flow process, complete the automatic control of product quality and energy management [7], so as to ensure product quality, improve manufacturing efficiency, and save energy. Due to the rapid development of process industry, energy metering, and urban utilities, the research on flow measurement is also continuously deepening. The flow rate changes in real time, so the detection of the flow rate is very complicated and difficult. The measured fluid is divided into three fluids with different physical characteristics: gas, liquid and mixed fluid. The conditions for measuring the flow rate are also complex and diverse. The temperature ranges from high to very low. The pressure range during measurement can be from high pressure to low pressure. The measured flow range is from small volume to large flow. The liquid flow state can be laminar, turbulent, etc. In general, there are different situations of viscosity. Therefore, in order to accurately measure the flow, this article analyzes the flow measurement methods of different objects under different conditions.

Vision detection technology was an emerging measurement technology developed in the past ten years. It used automatic control technology and the measurement can be controlled by computers with little manual intervention. With the continuous development of image processing technology, the application fields of visual inspection technology are increasing day by day, and continuous progress has been made in theoretical models. At present, it is widely used in military industry, civil industry and people's social life. Nowadays, there are many kinds of products in industrial production. Emphasis on real-time, online, non-contact monitoring to control the manufacturing process, ensure high production efficiency and product qualification rate, and greatly improve the requirements for manufacturing accuracy. Therefore, traditional detection methods are no longer suitable for modern production needs, and new product testing technologies are urgently needed to meet the requirements of modern production. The collected images are processed by algorithms such as grayscale, binarization and target detection, etc., which has good flexibility and meets the flexible production requirements of modern manufacturing. It can also implement non-contact online detection. Visual inspection has the advantages of non-contact, fast measurement speed, high degree of automation, high precision, etc. [8], and it is well matched with the development requirements of modern automation in the manufacturing industry. Combining the development of modern theory and technological advancement, visual inspection technology is becoming more and more mature and gradually entering the industrial field.

2 Research Progress of Fluid Flow Measurement Based on Computer Vision

As early as 1990, with the development of electronic computer technology, a large-scale surface flow field calculation method based on image processing was developed with laboratory image particle velocimetry as the starting point. In hardware device design and image processing algorithms, a breakthrough was also achieved. Computer vision systems generally include: (1) image acquisition; (2) pre-processing [9]. Image pre-processing was to make the characteristics of the image conform to the requirements of specific processing algorithms. Usually, the image was pre-processed after acquiring the image, including subsampling, contrast enhancement, smooth denoising, adjustment of scale or coordinate system, etc.; (3) feature extraction, extracting features such as color, shape, contour, etc. from the image. For example, Hough transform was used to obtain lines, edge operators are used to obtain edges, and critical point detection was used to obtain feature points; (4) detection and segmentation. In the step of image processing, the detection target might be obtained by segmenting the graphics for subsequent processing, such as threshold segmentation, target segmentation, etc.; (5) advanced processing. In this step, the size of the image data was generally small. If only the part of the object was detected by the target, then advanced processing methods include parameter estimation, prediction of motion trends, and classification. Preliminary research shows that computer vision technology had the advantages of remote monitoring, non-contact and non-interference, and had a good value prospect for fluid flow measurement. Therefore, in recent years, many scholars had carried out research on fluid flow measurement based on image processing. The research analysis is shown in Table 1. The flow detection process generally uses the methods of liquid level measurement, liquid droplet measurement, bubble measurement, water surface texture measurement, water ruler and adding markers to complete flow measurement.

2.1 Liquid Level Detection

The liquid flow can generally be obtained by measuring the liquid level height flowing into the container and using image processing to collect the liquid level height in real time to obtain the liquid flow. The liquid level generally refers to the surface height of the liquid in the transparent or non-transparent container. There were many existing liquid level detection methods, such as microwave detection method, ultrasonic detection method, photoelectric detection method, floating ball detection method, etc. [10]. But these methods were not suitable for transparent liquid containing foam or liquids such as steam and dust. The float type was not suitable for liquid level measurement of viscous liquids, and all methods were not suitable for liquid level detection of corrosive and high temperature liquids. The unique non-contact performance of the machine vision method effectively avoided these problems. It was still relatively rare to use digital image processing to analyze the liquid level. It was mainly used for industrial beer, oral liquid, and beverage level measurement. These liquid level detection systems had a stable detection environment, simple liquid level characteristics, uniform liquid color, and fast processor operation. The basic image processing flow for liquid level detection usually included the following steps: image acquisition, graying, image enhancement, image denoising, edge detection, and binarization. Accurately measuring the liquid level height not only needed to optimize the image acquisition environment and improve the quality of image acquisition, but also must continuously modify and improve the algorithms of image processing such as binarization, filtering, as well as the hardware of the detection link.

Table 1: Fluid Flow Measurement Based on Computer Vision.

	Method	Measurement environment	Light source	Influencing factors	Application
Liquid level	Boundary method, principle of liquid refraction	Experimental platform	LED	Image binarization, filtering algorithm	Drinks, molten iron and other liquids
Water level	Water Ruler	Natural environment, experimental platform	Auxiliary lighting equipment	Edge detection algorithm, water level recognition algorithm	River, pumping station, rainwater, oil and water mixture
Droplet	Static drop method, volume change rate	Experimental platform	White backlight	Image processing algorithm	Micro chemical industry, pipeline exit
Bubble	Inter-frame displacement	Experimental platform	LED	Bubble segmentation accuracy	Gas-liquid two-phase flow
Add marker	The flow velocity of the fluid is the speed of the marker	Natural environment, experimental platform	Highlighted halogen lamp or LED fill light, light intensity sensor	Moving target tracking is difficult, light source	River, open channel
Water surface texture	Velocity-area method	Natural environment	Natural light	Shooting angle, reflection noise	River

The image collection generally used a CCD camera to directly shoot at the liquid level position. For example, for the hot metal liquid level that was difficult to detect, researchers collected images of the pouring liquid level. For beverage level detection, urine level detection and transparent bottled liquid level detection, image acquisition was performed at the liquid level. The liquid level was obtained by directly using image processing algorithms. For example, Chen Guiping [11] directly performed algorithms such as median filtering, binarization, and edge detection on the images collected in the molten iron level detection. The effects of the area method and the boundary method on the extraction of the characteristic information of the liquid surface were compared. The results showed that the boundary method can obtain the liquid surface height, can also estimate the flow rate under the ladle, and had relatively strong anti-interference. However, the level of some liquids cannot be directly obtained through image processing algorithms, and certain media must be used. For example, in the beverage liquid level detection, Lu Peng et al. [12] used the beverage bottle cap as a matching template and set the coordinate origin at a certain position in the image of the bottle cap, which can effectively detect the position of the liquid level and overcome the measurement error caused by the left or right image of the beverage on the conveyor. In the process of measuring the urine flow, the researchers performed the urine flow measurement in a closed casing [13], and performed image processing on the scale lines at the upper and lower ends of the storage tank to obtain the liquid level. Huang Ling et al. [14] used the principle of liquid refraction to carry out liquid level detection on transparent bottled liquids. In the experiment, they choose a standard with a significant difference in color from the bottled liquid and is placed vertically behind the bottle. Under the illumination of the LED light source, the benchmark behind the bottle will "break" at the liquid level. The level is extracted by the difference between the gray value of the liquid level in the image and the rest of the area. This method has small detection errors and is not easily affected by liquid reflections, inverted image, etc., and is a feasible method. Yan Yan et al. [15] used a ruler for oil and water mixture flow detection. Place it on the side of the container wall, while taking the mixed solution out of the container, and use a video camera to record the stopwatch and ruler readings. This method was very convenient for flow measurement, and the measurement results were more accurate. The relative error was less than 1.2%, but there would also be errors caused by ruler readings and stopwatch readings, and this error would also decrease as the time interval increases. This method can be used for flow measurement of similar liquids. Because it is non-contact measurement, it will not cause interference with the measured liquid, and the measurement results are reliable.

2.2 Water Level Detection

Water security and water resources issues have extremely important impacts on social and economic development. Therefore, it is very urgent to establish an effective disaster prevention and water resource optimization management guarantee system. This requires us to be able to accurately monitor the water levels of rivers and reservoirs. Water level data will play an important role not only in disaster prevention and flood prevention, but also in other studies. In order to obtain the water level data, the method adopted by most researchers was to use a water ruler to perform image processing on it. The water level acquisition flowchart is shown in Figure 1.

The most direct method was to place the water ruler into the water and processed the image of the water ruler at the water surface interface. The edge detection algorithm was used to extract the outline of the water ruler and distinguish the water surface interface of the water ruler. The edge detection algorithm was the main algorithm for water level data collection. In the selection of the algorithm, Wang Ying [16] used Hough transform to identify the water level, and proposed a water level recognition algorithm based on the HSV (Hue Saturation, Value) color space to solve the problem of the water rule forming a reflection in the water. For the blurry image at night, an optimization algorithm based on Retinex was used. A defogging algorithm based on the dark primary color a priori was used for defogging in foggy and hazy days. Such a series of algorithmic processing improved the system's application range. Lu Zhenbang et al. [17] introduced a non-maximum suppression method in the edge detection algorithm to overcome the problem that traditional edge detection was prone to false edges, and had high stability and reliability.

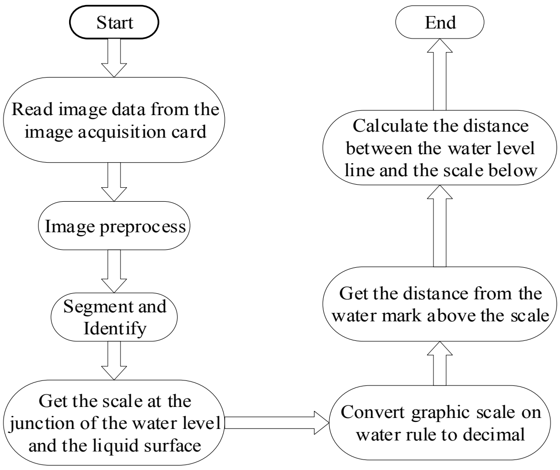

Figure 1: Water Level Detection Process.

The scale of the traditional water ruler was generally marked with Arabic numerals with small font size, which is difficult to be distinguished, and therefore causes inaccurate measurements. In order to solve this problem, Teng Cuifeng [18] proposed to use a new type of water level ruler, instead of the traditional Arabic numerals on the water ruler to represent the water level, and then use the image processing method to get the position of the scale at the junction between the water ruler and the water surface to get the water level height. This technology not only provided a new way of thinking for automated water level detection, but also greatly improved the accuracy of detection.

2.3 Drop Detection

The droplet method used a numerical method to obtain the surface tension and contact angle from the image contour of the droplet and a known density, and then calculated the volume of the droplet from the obtained contour line of the droplet to obtain the flow rate of the fluid. Rotenberg [19] first proposed the static droplet method, and the obtained Laplace arc was close to the contour of the droplet. Later, Takehiro et al. [20] proved the feasibility of the method through a large number of experiments, but the amount of calculation was large, and iteration would not converge. The Chinese Academy of Sciences simplified the method later, but the above-mentioned researches all deal with the droplet contour statically after acquiring the image, and during the flow measurement process, the droplets need to be processed dynamically in real time. Therefore, later a lot of research was done on the processing speed of droplets. In the flow measurement process of micro-chemical technology, Ye Xinxin [21] used the image processing algorithm to obtain the droplet profile to calculate the droplet volume at a specific time, and then calculated the flow rate. At the same time, the coordinate rotation algorithm, Newton-Raphson algorithm and genetic algorithm were analyzed, which proved that Newton-Raphson algorithm has a good effect in practical applications. The flow measurement accuracy of this method was 0.5ml/h, and the relative error was 2.37%. Lu Jiangang et al. [22] used camera to continuously shoot the droplets at the outlet of the pipeline. Pre-processing algorithm is used to obtain the binary image of the droplets, the contour fitting line of the binary image is obtained by the droplet contour detection algorithm, the droplet volume is calculated by the droplet volume integration algorithm, and then the volume change rate algorithm is used to obtain the volume change rate of the droplet, through the change rate of volume, the liquid flow in the pipeline can be calculated in real time. This method is also suitable for liquid flow measurement in a single pipe or multiple pipes at the same time, especially for micro flow measurement in micro pipes.

2.4 Bubble Detection

Multiphase flow is an important research area and has received widespread attention in industrial processes such as petroleum, chemical, metallurgy, water supply, medicine, and environmental processes [23]. Multiphase flow was usually divided into continuous phase and dispersed phase. Bubble measurement was an important subject to be studied in gas-liquid two-phase flow [24]. With the rapid development of computer vision, image processing technology played an extremely important role in the scientific research of bubbles [25]. Non-contact image processing technology made it easier to recognize the flow structure of multiphase flow. The bubble picture was collected by the camera, and the physical parameters and spatial distribution of the bubble were obtained after image processing. It had the advantages of no interference, transient and full field visualization. S. Di Bari from Ireland, R. Mosdorf from Poland, Dong Feng from Tianjin University in China, Zhu Rong from Chongqing University, etc. had all done a lot of research on the air bubble parameters in water using image processing technology. R. Mosdorf et al. [26] used a laser transistor sensor to record pressure fluctuations and signals in real time, and then measured the movement of the bubbles with high-speed camera and image processing technology. The motion rate and acceleration were calculated from the difference between the center coordinates of the two frames of the picture. R. Krishna et al. [27] used four cylindrical bubble column equipment with inner diameters of 0.051cm, 0.1cm, 0.174cm, and 0.063cm, and used medical syringes and ladles to inject bubbles respectively, and analyzed the rising speed of single bubbles and bubble groups. The authors found that the rising speed of independent bubbles was in good agreement with the David-Taylor formula and Collins formula. When calculating the rising speed of bubble groups under turbulent mixing conditions, the researchers had obtained their own fitting expressions. Zhu X et al. [28] used a water tank in which the radius, aspect ratio, and velocity of the microbubbles varied linearly with height. As the height increases, the bubble velocity decreases and then increases. At the same time, the bubble radius and aspect ratio appear bifurcation.

The previous image measurement technology can only observe the two-dimensional information of the bubbles [29], and there was no way to obtain the three-dimensional distribution data of the entire bubbles. Li Qinghao et al. [30] used the three-dimensional measurement method. This new method was based on the principle of light field imaging. The three-dimensional reconstruction steps are shown in Figure 2. A light field camera was used to record the light field data of gas-liquid two-phase flow field, and the light field measurement imaging technology was used to obtain the full-focus image and refocus image sequence of bubbles in the two-phase flow field. By using image processing such as binary segmentation on the total focus image, the projection of the bubbles on the depth was obtained, and the resolution evaluation of the refocused graphic sequence was performed to obtain the depth data of the bubbles. Using the obtained bubble projection and depth data, complete the 3D reconstruction of the bubble, and then further summarize the variables such as the size distribution, spatial position, and gas content of the bubble group. At relatively large airflow velocities, the bubble overlap was more obvious, and the accuracy of the measurement results depended to a large extent on the accuracy of bubble segmentation. Therefore, it is necessary to optimize the overlapped bubble segmentation algorithm to improve the overlap bubble identification accuracy and precision of segmentation.

The measurement of two-phase flow and the measurement of void ratio were also inseparable. The void ratio was the ratio of the cross-sectional area occupied by the gas and the total flow area when the two-phase flow flows in the pipeline [31]. For the flow measurement, an algorithm can be used to obtain the porosity of the cross section of the pipe, the mass air content can be obtained according to the measured temperature and pressure values, and finally the flow measurement result can be obtained by the flow relationship.

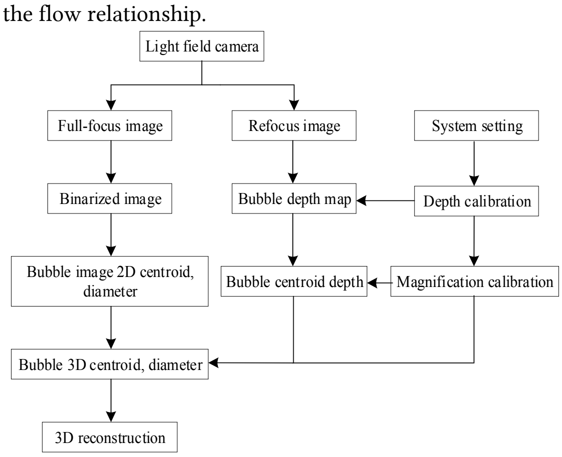

Figure 2: Bubble 3D Reconstruction Flowchart.

2.5 Adding Markers

In liquid flow measurement, the flow rate can also be measured by adding markers. Transient velocity distribution of the flow field was indirectly measured by the displacement of the incorporated tracer particles, tracer fluid, fluorescent particles and other markers within a known relatively short time interval [32]. The marker must have a high flow followability, so that its movement can truly reflect the movement of the flow field. The requirements for high-quality markers were: (1) the weight should be as large as possible in accordance with the liquid in the experiment; (2) the size should be small enough; (3) the shape should be as round as possible, and the size distribution should be as balanced as possible; (4) have very high light scattering efficiency. Generally, hollow microbeads or metal oxide particles were used in the liquid test, smoke or dust particles were used in the gas test, and fluorescent particles were used in the micro-pipe environment [33-35]. After adding the markers, image processing was required to detect moving targets and to obtain basic features such as the color, shape, and contours of the markers. The step after target detection was target tracking. Target tracking was to dynamically estimate the target's motion using the data of the information source without knowing the target's motion information beforehand to complete the determination of the target position and motion trend. Moving target tracking had extremely important practicality in various fields such as industrial process control, traffic monitoring, modern medical research, astronomical detection, and navigation systems. Object tracking was a very popular research topic in the fields of computer vision, image processing and pattern recognition [36, 37]. Determining the target position was the main purpose of target tracking and can be obtained by image matching algorithms. The matching tracking algorithm mainly included region matching, contour matching, and feature matching.

ADP (acoustic Doppler profilers) / ADCP (acoustic Doppler current profilers) was usually used for single-point or multi-point profile measurement of river flow velocity measurement. However, the contact of the instrument with the water body will interfere with the measured flow field, and the time and labor costs were relatively high, especially when the terrain was dangerous or floods was impossible to perform the test, and the problem of field measurement was largely solved by image processing of the added marker. Based on this, researchers had carried out a large number of experiments to verify the feasibility and measurement accuracy of the image processing method in the case of adding markers, and to gradually improve the software and hardware of the problems encountered during the experiment. For example, M. Jodeau et al. [38] used particles made of corn starch as artificial tracer particles, and measured the high-speed flow field of mountain streams when the reservoir was drained. J.D. Cretin et al. [39] detailed the application of upstream foam as tracer particles in river flow measurement. Bradley et al. [40] used leaves as tracer particles to measure the velocity of rivers. It can be seen that researchers attach great importance to the use of image processing technology to measure the flow velocity of rivers, but were limited by various conditions. So far, in domestic hydrological field measurements, in domestic hydrological field measurement, especially in mountain river monitoring, the research of flow velocity measurement system using image processing was not extensive.

2.5.1 Using Lead Fish as a Marker. Some researchers [41] studied the use of lead fish for automatic river flow measurement, using a current measurement system consisting of cable channels, motors, lead fish, control cabinets, etc., to measure the water depth and velocity of the river. During the measurement process, three cameras were used. One was used to monitor the running status of lead fish, and the other two were placed on both sides of the river to automatically measure the width of the river surface through online image analysis. Then, the cable car was controlled by the PLC, and the lead fish equipped with the flow meter was driven out of the water surface to measure the water depth and flow velocity, and then calculate the instantaneous flow of the river water. The image processing included binarization, filtering, Hough transform and so on. The measurement error was less than 0.8%, and the running time was less than 1 second, which achieved satisfactory results.

2.5.2 Using Tracer Particals as Markers. Although the above method had small measurement error, the operation was complicated and cumbersome, and the equipment cost was relatively high. Next, L. Xu, Z. Zhang, X. Yan, X. Wang [42] put a biodegradable tracer particle into the measured river in the current measurement. The camera took photos of the water surface, then took frames at fixed time intervals, calculated the maximum likelihood displacement of the first frame image relative to the second frame image, and then obtained the instantaneous speed of the water surface from the displacement and time interval. River flow was the product of the average velocity of the water surface and its corresponding area.

2.5.3 Using Tracer Fluid as a Marker. The marker added by Gong Jiaguo et al. [43] when measuring the hydrological flow field on the slope was the tracer fluid, and the flow velocity was calculated using the tracer displacement distance and time interval. Wang Wenhai, Wu Junqi, et al. [44] selected marker that was less dense than water. Because the inertial force of the uniform flow condition did not work, the speed of the measured marker was the velocity of the water flow. In the experiment, using a ruler and recording the position of the two-frame image ruler with a camera, the displacement of the marker could be calculated. And if the time interval between two frames of image was known, then the marker, that was, the speed of the water flow, was known. And it was verified that this method can also be used to study non-uniform or non-constant flow.

2.5.4 Using Other Substances as Marker. In addition, G. Li [45] had used natural floating objects in water or artificial buoys as markers to measure mountain river flow velocity. The camera was used to calibrate the marker, and the image processing algorithm was used to detect and track the target, and then the distance and time of the floating object were obtained. During the automatic calibration of the camera, the automatic determination of the spatial resolution was a difficult point. At the same time, there may be incomplete target detection at low flow rates, and tracking of moving targets during floods was also difficult. In this regard, researchers need to further improve. When measuring the open channel flow in a mine, Wei Jianwen, Yu Yanwen et al. [46] used a CCD camera to collect image information of a float with a mark. After image processing, the distance between the plane where the marker was located and the camera was calculated, and further obtain the specific height of the water level, calculate the open channel flow. The study also found that the influence of light sources on image quality and even the entire visual system can reach more than 30%, which played an important role in the flow measurement process. Selecting an appropriate light source was also a focus of research.

2.6 Water Surface Texture

Some researchers conducted flow measurement by tracking the texture of the water surface (such as ripples, bubbles, etc.) under natural light. For example, Li Wei, Liao Qian, et al. [47] used industrial cameras to continuously shoot the measured river sections when measuring and calculating the flow field on the river surface, and continuously adjusted the camera frame rate according to the actual flow velocity of the river channel to ensure the surface texture of the river channel only changed in displacement that between two frames, but did not change in morphology. The experiment was carried out in a natural environment. Due to the complicated terrain on the site, the experiment proved that the camera needs to be tilted. Because of the need to ensure the sharpness of the image, the inclination of the camera and the river needs to be greater than 20 degrees. Six ground control points were set on the stones on both sides of the river to measure their relative physical coordinates. There was no need to add tracer particles in the experiment, the algorithm used the water surface texture for the next analysis. Compared with traditional ADP/ADCP and other measurement methods, it had obvious advantages, such as convenience, easy installation, non-contact, high efficiency and high accuracy. Researchers have further proved that the enhancement of image quality and calculation accuracy was important to increase the shooting angle and avoid reflection noise. Research showed that this method was completely suitable for measuring the velocity of mountain rivers.

3 Main Issues and Future Development Trends

3.1 Current Major Technical Issues

Although researchers have carried out a lot of research work and improvement and optimization of image processing technology, the stability of the measurement object, the non-contact nature of the computer vision system, the obtained image quality, and the image processing algorithm are still the main problems in the flow measurement using image processing. Therefore, the key issues to consider when using image processing to measure fluid flow include: 1) the flow measurement environment is complex, and during the experiment, it is generally affected by the flow regime and environmental complexity under the field conditions, such as abnormal high-velocity environments such as floods and dikes, as well as the measurement of large-scale river flows with very low flow rates and large areas of passing water, and the effects of liquid color. 2) the selection of the light source will have a significant impact on the quality of the image, as well as issues regarding the angle of illumination and color. Many researchers have shown that the important factor affecting the image quality of machine vision systems is the light source, and the influence of the light source on the experimental data can reach more than 30%. 3) in the two-phase flow where the bubble is used to calculate the flow rate, when the gas velocity is large, the phenomenon of bubble overlap is more significant, so the accuracy of the measurement result has a great relationship with the accuracy of bubble segmentation. 4) the tilt angle during shooting will affect the distant pixel sharpness. After a large forward calibration, the image quality is reduced again, causing a large calculation error. 5) the non-contact requirements required by modern industry have not been realized, and media such as tracer particles or tracers need to be added for flow measurement. 6) the errors caused by the complicated measurement environment, human factors and the image processing algorithm itself are relatively large.

3.2 Research Focus and Development Trend

Research on measuring fluid flow using image processing to achieve real-time, online, non-contact detection required by modern industry is of great significance to improve production efficiency and product qualification rate, and increase product accuracy. It provides a useful method for the next step of measuring milk flow. Based on the problems in the above flow measurement process, when using image processing for fluid flow measurement, it is necessary to select a suitable light source, improve the quality of image acquisition, real-time transmission of data information, and high-precision processing algorithms to improve production reliability for modern industries. At present, the key points to be urgently addressed are: 1) Under different experimental conditions, it is necessary to correlate the relationship between the measured value and the influencing factors, so as to establish a more accurate mathematical model and improve the measurement accuracy. 2) Use a higher resolution CCD camera and increase the tilt angle of the shot. Studies have shown that increasing the shooting angle and avoiding reflection noise have a crucial impact on enhancing image quality and improving calculation accuracy. 3) According to the environment of different monitoring points, design more different water level identification algorithms to meet the requirements of environmental diversity of monitoring points. 4) Other light sources can be selected in the experiment. The main characteristics to be considered when selecting machine vision light sources are brightness, uniform distribution of light sources, spectral characteristics, service life, and contrast. 5) The current detection method still needs to manually select the tracking target when the first frame image is acquired, so it can be considered to use the target recognition algorithm to achieve automatic selection. 6) The overlapping bubble segmentation algorithm needs to be improved to improve the accuracy of segmented bubble identification and segmentation accuracy. 7) The filtering algorithm for image processing can be further improved, and the image binarization method also needs to be improved. For example, a reasonable thresold needs to be obtained during image preprocessing so that the binarized image can better display the characteristics of boundary. Alternatively, the local area approach can be used.

4 Conclusions

This article summarized the seven main methods of flow detection using image processing methods for different fluids. The system based on image processing and flow measurement mainly includes image capture, image preprocessing, and image processing algorithms. The flow is obtained by measuring the liquid level, add tracer particles, fluorescent particles, tracer fluid to the fluid, or process the volume and velocity of droplets or bubbles through image analysis to accurately obtain the instantaneous velocity of the fluid, and then calculate the fluid flow. Compared with flow measure using flowmeters and sensors, the use of image processing technology for fluid flow detection has the advantages of non-contact, fast measurement speed, high degree of automation, high measurement accuracy, etc., and has gradually replaced traditional technical means. However, due to errors in the ruler readings and stopwatch readings, the effects of light sources, the proportion of gas in the gas-liquid two-phase flow, and the measurement accuracy, as well as the limitations of vision theory, image processing software and hardware technologies, etc., existing image processing and flow measurement technologies are still incomplete. In terms of detection speed, accuracy, degree of automation, and reliability, it still cannot meet the needs of actual production. Therefore, in-depth research remains to be done to provide better ideas for fluid flow measurement in the future. And inspired the subject milk flow detection. Due to the non-transparency of milk, air bubbles cannot be used as targets for feature matching. However, the milk will not fill the pipe during milking, and the texture feature can be used for target matching algorithm and frame difference method to obtain real-time flow.

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