An Image Processing System for Quantitatively Analyzing Two-Dimensional Fluid Velocity-Field Image

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ABSTRACT

The quantitative analysis of 2D fluid velocity field plays an important role in the investigation of fluid mechanics and other areas. In this paper a new system for analyzing 2D fluid image is presented. The 2D flow visualization image is input through a TV camera, and then followed by a set of processes to extract the velocity information, finally the principal parameters of the flow field are computed and displayed. In this system the control strategy is mixed bottom-up and top-down and the knowledge of the fluid mechanics is introduced on several levels to improve the performance of the system. For this reason, it is more efficient and has more powerful functions than the conventional ones by reducing the human intervention.

KEYWORDS: image processing, flow visualization, velocity field, line feature extraction, velocity direction determination

1. Introduction

The quantitative analysis of the 2D fluid flow plays an important role both in the investigation of the flow mechanism, and in many application areas, such as machinery, chemical processing, hydraulics, etc. [1]. The hot-wire anemometer and laser Doppler anemometer are advanced instruments for the measurement of dynamic flow velocity. Although the accuracy of them is high enough, only one or a few velocities can be measured at one time. In the case of some complicated fluid flow, such as unsteady flow field, velocity distribution of the whole flow can not be measured by the above instruments instantaneously. In order to study the whole dynamic flow, we must measure the velocities simultaneously. Flow visualization techniques provide useful information about the behavior of the whole flow field, but they are not usually intended to provide quantitative velocity data. Recent developments of image processing techniques has been promoted in the flow measurement. Some researchers applied the speckle method to the measure of the fluid velocity in the 70's and 80's [2]. In the early 80's Kensaku Imaichi, Kazuo Ohmi and et al. developed some new systems for computing some of the principal physical variables of fluid by combining the flow visualization and image processing techniques [3, 4]. These techniques take the advantage of measuring the whole 2D flow field at the same time, whether steady or unsteady. In comparison with the point by point measurement, it is a tremendous progress, but there is a tedious and time consuming input procedure with too much man-made intervention in the above system, because the tracer pathlines are input by the manual operation on the digitizing tablet.

In this paper, a new flow image analysis system for 2D dynamic flow is presented. The main goal of the research described here is to develop a more efficient and flexible system in this domain. There are two important problems to be considered. First, although there are a lot of image processing techniques [6, 7], most of them have to be modified or improved in order to fit the requirements for the quantitative analysis of the flow velocity-field. In some steps, we have to develop some new schems for our system such as the direction determination, etc. Second, it is necessary to represent the domain-specific knowledge in some way, so this knowledge can be used during the analysis to make the system more efficient and robust. The control strategy of this system is mainly bottom-up as shown in the major block diagram (see Fig. 1). The control proceeds from the noisy grey-level image to line structures and finally to the descriptions—the physical parameters of the fluid flow. The data flow is passed from the low level to the higher one under the image driven mode. But in some steps, the image processing procedure is model-directed, i.e., top-down; knowledge of the geometry and the fluid mechanics has directed the analysis to improve the accuracy and reliability here. To sum up, this system involves the control of a large and complex image processing tasks. To achieve a more automatic and powerful system, we use the mixed bottom-up and top-down control strtegies here. In the next sections we will give some details of several important steps of this system.

2. Pathline Enhancement and Feature Image Extraction

It is difficult to extract the pathlines directly because some pathlines in the image are degraded by noise and interference. Therefore some preprocessings must be undertaken before extracting the pathlines.

2.1. Preprocessing