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Report

Summary of PIV'97–Fukui and New Directions in PIV Development

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***Abstract*:** This article is a summary of The Second International Workshop on PIV'97-Fukui, which was held from 8 July to 11 July, 1997, in Fukui, Japan, and describes interesting topics presented there. The first and second workshops originated in Fukui, Japan, sponsored by the Japan Society of Visualization and the Center for Cooperative Research in Science and Technology, Fukui University. The participants exchanged new information and deepened their friendship among them. A lot of important and new directions in PIV development were discussed in the workshop. Some of them are summarized in the last part of this article. The Third Workshop chaired by Prof. Adrian will be held in Santa Barbara, USA, and the forth will be held in Europe.

***Keywords*:** particle imaging velocimetry (PIV), flow visualization, image processing, velocity measurement, fluid engineering.

1. Introduction

It has been known well that PIV (particle imaging velocimetry) can measure the whole flow field simultaneously for two-dimensional or three-dimensional flows. This merit has successfully promoted wider applications in universities and industries all over the world. The Visualization Society of Japan (VSJ) organized both the first and the second international workshops on PIV in Fukui, Japan, in 1995 and 1997, sponsored together with the Center for Cooperative Research in Science and Technology, Fukui University. Both conferences were chaired by Prof. Toshio Kobayashi at the University of Tokyo, and the secretary general was Prof. Fujio Yamamoto at Fukui University. The organizing committee of the second workshop consisted of 15 people from Japan and 16 people from the other countries.

The supporting academic societies are as follows: Atomic Energy Society of Japan, Japan Iron and Steel Institute of Japan, the Japan Society of Aeronautical and Space Sciences, the Japan Society of Fluid Mechanics, the Japan Society of Mechanical Engineers, the Japan Society of Multiphase Flow, the Society of Heating, Engineering of Japan, the Japan Society of Aeronautical and Space Sciences, the Society of Instrument and Control Engineers, and the Society of Powder Technology.

The purpose of the conference was to develop and promote wide usage of the PIV techniques in the following four aspects: 1) measurement accuracy improvement in temporal and spatial resolution, 2) new PIV systems and new algorithms, 3) new application, and 4) post-processing of data to extract other physical information from velocity field. The workshop provided tremendous opportunities to learn what have been achieved in PIV and to discuss future direction of PIV.

2. Summary of PIV'97 -Fukui

"Call for Papers" was distributed widely through the members of the organizing committee and the magazines of the supporting societies. Abstracts of 40 papers were submitted for the first review. After notification of acceptance, the authors were asked to submit their full-length papers for the second review. Each full paper was reviewed by two reviewers. Finally 33 papers were selected and the revised papers were published in the

proceedings. Four papers were written as keynote papers to present new research aspects. About 1/3 of the papers were recommended for the Journal of Visualization.

The workshop was executed in such a way that each paper was presented at the oral session and afterwards at the poster session for sufficient discussion and information exchange. Enlarged copies of each paper were pasted on the panel, which was prepared by the local executive committee beforehand. The speakers and the participants gathered in front of the panels during the poster session in the afternoon followed by the oral presentation session and the opinions were exchanged. This system received good evaluation from many participants because it provided opportunities to participants, particularly Japanese participants to discuss and exchange questions and answers.

The registration was started at 3 p.m. on the first day, 8 July. The welcome party was held at six o'clock in the evening. Opening remarks were addressed by the secretary general using some viewgraphs on the over-head-projector. About seventy people gathered to the welcome party to deepen their friendship, and enjoyed Japanese and European food and drink in happy atmosphere. Fukui is famous for good "Sashimi" i.e. slice of raw fish.

On the second day, 9 July, the workshop started at 9 a.m. followed by the chairman's address. Prof. Y. A. Hassan at Texas A&M University, U.S.A., made a keynote speech entitled "Three-dimensional bubbly flow measurement using PIV". After coffee break, the session were conducted on three-dimensional bubbly flow measurement with the PIV methods including cross-correlation method, holographic method, and simultaneous measurement of velocity and temperature using thermo-sensitive liquid crystals. Researches concerning three-dimensional measurement techniques were reported in the afternoon. The afternoon sessions also presented PTV algorithms using GA based on Affine transformation, a new technique of velocity, gradient tensor available to measure fluid flow distortion of rotation, shearing, expansion beside translation, and a method using brightness difference for evaluating spatio-temporal similarity. Successively, PIV equipment exhibition and poster session were opened simultaneously during the coffee break in a big convention hall.

The last speaker of the day, Prof. Adrian at Illinois University, U.S.A., made a keynote speech entitled "Stereoscopic PIV applications to the study of turbulence". He told that holographic PIV for the measurement of three-dimensional turbulence was not adequate for the disposal of time series of data. Stereoscopic PIV based on video images from two CCD cameras could obtain the same level of time and spatial resolution properly, and was rather valuable for turbulence visualization. Active panel discussions were opened to this keynote lecture.

In the morning of the third day, 10 July, the velocity field of the flow in a mixer, the velocity fields of the flow in the Darrieus rotor and the flow around delta wing, and relative velocity field of the rotation wing cars were reported as PIV applications in the first session. A new cross-correlation method using Delaunay tessellation, a statistical approach to velocity field measurement, a moving least square algorithm coupled with Navier-Stokes flow solver, and an evaluating method of fluid flow using both PIV data and fluid dynamic equations were proposed in the second session. In the afternoon, Lagrangian measurements by PTV and the measurement of the flow field with minute flow rate were reported. The last presentation of the day was given as a keynote speech by Prof. W. Merzkirch at Essen University, Germany. He proposed a PIV method by evaluating similarity of brightness distribution based on the minimum quadratic difference, and reported the results of application to the simultaneous measurement of the velocities of both bubbles and liquid in a gas liquid two-phase flow.

The talks and the discussions concerning the measurement accuracy and standardization were concentrated on the fourth day, 11 of July, including small particle following behavior in oscillatory flows, vorticity extraction from PIV data, feasibility and usability on the shifting for PIV, the PIV using photo-conductor plastic hologram, spatial frequency filtering technique for double- or multiple- exposed PIV images, accuracy of PIV data, particle mask correlation method and an analysis of noise in PIV images. In the last session, there was an introduction about standard images for PIV proposed by a research group in the Visualization Society of Japan. It was opened to an active panel discussion. Everybody can challenge to apply his own PIV algorithm using the standard images distributed on the Internet (http://sap.gen.u-tokyo.ac.jp/).

The welcome banquet for participants and guests of the support group was held in the convention hall in the evening of the third day. The banquet was opened with the bamboo flute performance by Dr. Koji Okamoto at the University of Tokyo. His performance was outstanding and received warm applause. The chairman of the Visualization Society of Japan, Dr. Hiroshi Tanaka gave a warm welcome speech, hoping to build up friendship among the participants and to exchange new information through the two workshops for development and promotion of the PIV technology. Next, the president of Fukui University, Dr. Shinpei Kojima talked about Fukui University and Fukui area, which is rich in nature and famous for textile and glasses industries. Then on behalf of participants, Prof. Merzkirch expressed his appreciation for kind hospitality.

The steering committee was opened in the evening of the second day and decided Prof. Adrian as the chairman of the next workshop. In the closing ceremony, he announced that the third workshop would be held in 1999 in Santa Barbara, U.S.A.

Last but not lest, on behalf of the workshop organizing committee, We would like to express our sincere appreciation for financial support given by the Japan Ministry of Education, Fukui-city, the Foundation of Fukui Prefecture Association of Industrial Technology, Kusakabe-Griffis Academic and Cultural Exchange Fund, many Companies, and Fukui University.

3. New Directions in PIV

PIV has been quite promising as a flow measurement tool over LDV and others because some advantages in instantaneous whole field measurement are recognized generally in practical use. The applicability of PIV to various flow phenomena has been advanced, but demands for PIV application in practical use are becoming higher than the current capability of the present systems. In this section, some new directions in PIV are addressed and discussed briefly.

3.1 Expanding Application

More fundamental and practical researches have been expected to solve environmental and energy problems. Although PIV gives information of flow velocity, it can also extract other information such as vorticity, temperature or density through solving the governing equations of continuity, momentum and energy. It is desirable to apply the PIV to wider natural and artificial fields such as meteorology, global sea water flow, micro-flow structure analysis for electronics and bio-fluid, blood flow in brain and blood vessel, micro-gravity flow in space, and so on. From a viewpoint of academic research, fields of such applications are classified into multi-phase flow, slow flow, high speed flow, rheology, life science, medical science, bio-chemistry, and so on.

3.2 Hybrid CEFD

In order to extract other physical information through PIV data of velocity, first of all a lot of velocity data should be obtained. Some groups are challenging to obtain more than one million velocity vectors in 3-D space by HPIV. Innovation of optical system is a key point. Other groups are developing new hybrid systems of experimental PIV and numerical CFD, named "hybrid CEFD", where PIV is limited to so called PTV (Particle Tracking Velocimetry) because PTV cannot obtain so many velocity vectors at particle positions. Hybrid CEFD has been originated first from the need to fill-up vacant data at grid points using some interpolation techniques, and is now developed so that the particle velocity data should satisfy the fundamental equations. Since there are many discussions on supplementing insufficient and limited imaging data of lighting, spatio-temporal recording and hybrid CEFD are expected to become a breakthrough in the analysis of a whole flow field.

3.3 Intelligent PIV System

Another direction is expected to be development of a new artificial intelligent PIV (AI PIV) system. When an AI-PIV system is introduced for practical use, such a system can be used easily as a user-friendly measurement tool. Some researchers have already applied fuzzy and GA techniques to PIV algorithms as an intelligent theory, but their total system cannot reach the level of intelligent system. The conventional PIV system works as a programmed control, but the AI-PIV system will be able to work as AI processes, which can learn, judge, and interact with a user and give a lot of useful information with CG display.

4. Concluding Remarks

This article summarized the Second International Workshop on PIV'97-Fukui, and introduced interesting topics presented at the workshop. Some new directions in PIV development were addressed briefly in the last part. The authors wish that the Third Workshop on PIV'99, which will be held in Santa Barbara, U.S.A., and be chaired by Prof. Adrian, will be successful.

Authors' Profiles

Fujio Yamamoto : He obtained his degree of Dr. of Engineering in mechanical engineering at Osaka University, Japan, 1979 and now works as a professor at Fukui University. His research interests are in fluid engineering. He has developed some techniques for PIV and flow visualization, and applied them to measurement of multiphase flows concerned with practical use in environmental and energy aspects. He has developed a new technique for measuring flow velocities of gas- and liquid phase separately using PIV and analyzed the micro-structure of two-phase flow from both sides of experiment and numerical simulation.

Toshio Kobayashi : He received his Ph.D. in Mechanical Engineering Department at the University of Tokyo in 1970. Since his completion of Ph.D. program, he has been a faculty member of Institute of Industrial Science, University of Tokyo, and currently is professor. His research interests are numerical analysis of turbulence, especially large eddy simulation (LES), and particle imaging velocimetry(PIV). He serves as President of Japan Society of Computational Fluid Dynamics, Director of the Japan Society of Mechanical Engineers, and Director of Japan Society for Computational Engineering and Science.