FP6-513663

FLUID
FLUid Image Description and analysis

Instrument: Strep
Priority: IST FET OPEN

Plan for using and disseminating the knowledge 1

Due date of deliverable: 30/11/05
Actual submission date: 10/01/05
Start date of project: 01/12/04
Duration: 3 years

Organisation name of lead contractor for this deliverable: INRIA

Revision [1]

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<td>PP</td>
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Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)
Annex – Plan for using and disseminating the knowledge

1 – Exploitable knowledge and its use

A certain number of the studies initiated in the FLUID project constitute already important research progress with regard to computer vision or flow visualization. These first results have already begun to be published in renown and selective journals and conferences. They should benefit to any researcher of the fluid flow visualization community or to any research group willing to be involved in fluid flow analysis from image sequences. Among all the different valuable research activities one can particularly distinguish the following works:

- Variational Optical Flow Estimation for Particle Image Velocimetry (INRIA and CEMAGREF)
- A dense motion estimator dedicated to experimental fluid flow and its evaluation (INRIA)
- A low dimensional fluid motion estimator (INRIA)
- A stochastic technique for vorticity tracking. (INRIA)
- A method for non-smooth convex flow decomposition. (U. Mannheim)
- A discrete orthogonal decomposition technique for fluid motion Fields (U. Mannheim)

2 – Dissemination of knowledge

- According to the FLUID project work plan the following deliverables have been elaborated during this reporting period:

  - J. Carlier, D. Heitz and G. Arroyo “Report 1 on production and diffusion of data” deliverable 1.2
  - F. Becker, J. Yuan, C. Schnörr “Demonstrator on multiscale motion estimator”, deliverable 2.2
  - A. Cuzol, E. Memin, “Fluid motion segmentation”, deliverable no 3.1
  - E. Mémin, “Intermediate periodic activity report”, deliverable 6.1b
  - E. Mémin, “Periodic management report”, deliverable 6.2a
  - E. Mémin, “Periodic activity report”, deliverable 6.2b

- Several research articles related to the FLUID project have been accepted for publication in national and international refereed conferences and journals. Here is a list of these articles:


• A. Cuzol, E. Mémin. A stochastic filter for fluid motion tracking. Int. Conf. on Computer Vision (ICCV'05), Beijing, China, October 2005.


• A. Cuzol, E. Mémin. Vortex and source particles for fluid motion estimation. In 5th Int. Conf. on Scale-Space and PDE methods in Computer Vision (Scale-Space'05), Hofgeismar, Germany, 2005.


All these articles and deliverables are available on the FLUID web site: http://www.fluid.irisa.fr

The audiences related to these publications are indicated in the following table.
### Overview table

<table>
<thead>
<tr>
<th>Planned/actual Dates</th>
<th>Type</th>
<th>Type of audience</th>
<th>Countries addressed</th>
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As can be seen the publication of the studies performed within the FLUID project are composed of two first rank international journal of the domain of experimental fluid mechanics and several international conferences. These conferences, which belong either to the computer vision domain or to the fluid flow visualization domain, hold respectively in Beijing, Germany, USA and France. Two articles will appear also in a Spanish research journal.

- First research results of the FLUID project have been already well perceived by different institutions:
  
  - Jing Yuan received the best award student paper of the “Variational, Geometric and Level Set Methods in Computer Vision” workshop for his work on non-smooth convex flow decomposition.
  
  - Etienne Mémin received an unrestricted excellence grant from the society Dupont Science for his work on fluid flow motion estimation from image sequences.

- The proposal concerning a scientific transversal seminar in Schloss Dagstuhl in Germany on “Experimental fluid mechanics, computer vision and pattern recognition” has been accepted by the Schloss Dagstuhl Computer Science Foundation (http://www.dagstuhl.de/). The seminar will hold at the International Conference and Research Center at Dagstuhl castle, Germany, in spring 2007 (see: http://www.dagstuhl.de/07121/). A set of around 30 researchers of computer vision and fluid mechanics will be invited to give original talks. We expect this to be a major scientific event where consolidated findings and visionary ideas for the future will be discussed in a larger international context. This seminar is co-organized by the FLUID-coordinator Etienne Mémin, Christoph Schnörr (U
Mannheim), and two prominent figures from the field of experimental fluid mechanics.

2 – Publishable results

In this section we give a summary of the different studies of the FLUID project that have been published so far.


In this paper, the author presented an approach to parallel variational optical-flow computation by using an arbitrary partition of the image plane and iteratively solving related local variational problems associated with each subdomain. The approach is particularly suited for implementations on PC clusters because interprocess communication is minimized by restricting the exchange of data to a lower dimensional interface. Our mathematical formulation supports various generalizations to linear/nonlinear convex variational approaches, three-dimensional image sequences, spatiotemporal regularization, and unstructured geometries and triangulations. Results concerning the effects of interface preconditioning, as well as runtime and communication volume measurements on a PC cluster, are presented. Our approach provides a major step toward real-time two-dimensional image processing using off-the-shelf PC hardware and facilitates the efficient application of variational approaches to large-scale image processing problems.


In this paper a novel dense motion estimator technique dedicated to the measurement of velocity in fluid experimental flows through image sequences presented. Unlike most of the methods based on particle image velocimetry (PIV) approaches used in that context, the proposed technique is an extension of optical-flow schemes used in the computer vision community, which includes a specific enhancement for fluid mechanics applications. The method we propose enables to provide accurate dense motion fields. It includes an image based integrated version of the continuity equation. This model is associated to a regularization functional, which preserve divergence and vorticity blobs of the motion field. The method was applied on synthetic images and on real experiments carried out to allow a thorough comparison with a state-of-the-art PIV method in conditions of strong local free shears.
In this paper (in french) it is shown that the dedicated second order div-curl optical scheme allows to determine coherent information with a high resolution.

Cuzol, E. Mémin. A stochastic filter for fluid motion tracking. Int. Conf. on Computer Vision (ICCV'05), Beijing, China, October 2005.

In this paper a method for the tracking of fluid flow velocity fields is presented. The technique proposed is formalized within sequential Bayesian filter framework. The filter we propose here combines an Ito diffusion process coming from a stochastic formulation of the vorticity-velocity form of Navier-Stokes equation and discrete measurements extracted from an image sequence. The resulting tracker provides robust and consistent estimations of instantaneous motion fields along the whole image sequence. In order to handle a state space of reasonable dimension for the stochastic filtering problem, we represent the motion field as a combination of adapted basis functions. The used basis functions ensue from a mollification of Biot-Savart integral and a discretization of the vorticity and divergence maps of the fluid vector field. The efficiency of the method is demonstrated on a long real world sequence showing a vortex launch at tip of airplane wing.


In this paper we describe a new framework for the tracking of closed curves described through implicit surface modelling. The approach proposed here enables a continuous tracking along an image sequence of deformable object contours. Such an approach is formalized through the minimization of a global spatio-temporal continuous cost functional stemming from a Bayesian Maximum a posteriori estimation of a Gaussian probability distribution. The resulting minimization sequence consists in a forward integration of an evolution law followed by a backward integration of an adjoint evolution model. This latter pde include also a term related to the discrepancy between the curve evolution law and a noisy observation of the curve. The efficiency of the approach is demonstrated on image sequences showing deformable objects of different natures.


In this paper the authors presented a mathematical and computational feasibility study of the variational convex decomposition of 2D vector
fields into coherent structures and additively superposed flow textures. Such decompositions are of interest for the analysis of image sequences in experimental fluid dynamics and for highly non-rigid image flows in computer vision. Our work extends current research on image decomposition into structural and textural parts in a twofold way. Firstly, based on Gauss' integral theorem, we decompose flows into three components related to the flow's divergence, curl, and the boundary flow. To this end, we use proper operator discretizations that yield exact analogs of the basic continuous relations of vector analysis. Secondly, we decompose simultaneously both the divergence and the curl component into respective structural and textural parts. We show that the variational problem to achieve this decomposition together with necessary compatibility constraints can be reliably solved using a single convex second-order conic program.


The decomposition of motion vector fields into components of orthogonal subspaces is an important representation for both the analysis and the variational estimation of complex motions. Common finite differencing or finite element methods, however, do not preserve the basic identities of vector analysis. Therefore, we introduce in this paper the mimetic finite difference method for the estimation of fluid flows from image sequences. Using this discrete setting, we represent the motion components directly in terms of potential functions which are useful for motion pattern analysis. Additionally, we analyze well-posedness which has been lacking in previous work. Experimental results, including hard physical constraints like vanishing divergence of the flow, validate the theory.

- Cuzol, E. Mémin. Vortex and source particles for fluid motion estimation. In 5th Int. Conf. on Scale-Space and PDE methods in Computer Vision (Scale-Space'05), Hofgeismar, Germany, LNCS Vol. 3459, Springer, 2005.

In this paper we propose a new motion estimator for image sequences depicting fluid flows. The proposed estimator is based on the Helmholtz decomposition of vector fields. This decomposition consists in representing the velocity field as a sum of a divergence free component and a curl free component. The objective is to provide a low-dimensional parametric representation of optical flows by depicting them as a flow generated by a small number of vortex and source particles. Both components are approximated using a discretization of the vorticity and divergence maps through regularized Dirac measures. The resulting so called irrotational and solenoidal fields consist then in linear combinations of basis functions obtained through a convolution product of the Green kernel gradient and the vorticity map or the divergence map respectively. The coefficient values and the basis function parameters are obtained by minimization of a functional relying on an integrated version of mass conservation principle of fluid mechanics. Results are provided on real world sequences.
In this work the authors presented some comparative qualitative results of optic flow estimation in PIV and satellite fluid image sequence. This work has been done in the context of the FLUID Specific Targeted Research project – Contract No 513633 founded by the CEE. The main goal of this paper is to compare in a very basic way 3 optic flow estimation methods in the context of some fluid image sequence provided to us by AEROBIO-CEMAGREF and the "Laboratoire de Météorologie Dynamique de la Ecole Polytechnique" both partners of the FLUID project. In order to simplify the comparison and better understand the comparison results we have used just 2 images of each sequence, so no temporal smoothing or another 3D preprocessing have been performed. We have also implemented ourself in C language the 3 optic flow methods in order to better understand each method and to be sure about what are we doing. The organization of the paper is as follows: In section 1, we describe the optic flow methods we use for comparison purposes. In section 2 we present an invariant analysis of the methods. In section 3, we present the numerical experiments and finally in section 4 we present some conclusions and future works.

In this report we study a number of fluid optic flow sequences in the context of the FLUID Specific Targeted Research Project - Contract No 513633 founded by the EEC. The main goal of this report is to analyse the behaviour of classical computer vision optic flow techniques when we deal with fluid sequences. We use the optic flow sequences provided by other partners of the FLUID project.