FP6-513663

FLUID
FLUid Image Description and analysis

Instrument: Strep
Priority: IST FET OPEN

Periodic Activity report 3

Due date of deliverable: 30/11/07
Actual submission date: 20/12/07

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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**Publishable executive summary**

This interdisciplinary project, that we have entitled FLUID, aims at studying and developing new methods for the estimation, the analysis and the description of complex fluid flows from image sequences. We propose to devise novel image processing and computer vision methods by using sound methodological frameworks incorporating suitable physical models accounting for the observed phenomena. This domain of research encompasses a wide range of difficult issues and thus will have a significant impact on several scientific and application domains including meteorology, oceanography, and flow visualization in applied fluid mechanics. The first objective of our project consists in studying novel and efficient methods to estimate and analyse fluid motions from image sequences. The second objective is to guarantee the applicability of the developed techniques to a large range of fluid visualization applications. To that end, two specific areas are considered: meteorological applications and experimental fluid mechanics for industrial evaluation and control. From the application point of view the project particularly focus on 2D and 3D wind field estimation, and on 2D and 3D flow velocimetry for various experimental fluid mechanics.

The consortium includes five academic research groups and one industrial group as described below. All the research groups are experienced, internationally known groups. They have contributed to numerous collaborative projects in the past. Each of them brings complementary interests and recognized experience in order to successfully achieve the FLUID project goals.

- **INRIA** is the Project Leader. The Inria (French National Institute for Research in Computer Science and Control) team involved is the VISTA ("VIsion Spatio-Temporelle et Apprentissage") group located in Rennes (France). This group is specialized in statistical modelling for image sequence processing and especially for visual motion analysis. Studies concerning fluid motion analysis have been one of its main subjects of investigation for several years. Research work on that topic focuses mainly on fluid motion estimation problems and on specific structure detection and tracking with important applications in the meteorological domain (which were supported by contracts with Meteo-France and Eumetsat) to estimate low clouds motion or to detect and track convective situations.

- **The CVGPR Group of the Mannheim University (Germany)** is concerned with various aspects of mathematical modelling and optimization for image processing. They have particularly studied issues of representation and processing of image sequences using partial differential equations, and problems of image segmentation using statistical shape knowledge.

- **The AMI group of University of Las Palmas (Spain)** mainly explores the applications of the mathematical analysis to a number of computer vision problems. The topic addressed includes morphological multiscale analysis and studies on partial differential equations for image processing and computer vision problems.

- **The Cemagref (French National Institute for Research in Agricultural and Environmental Engineering) team involved is the AEROBIO group situated in Rennes (France).** It is involved in airflow research studies in the context of
high care environment for industrial processes and rooms (e.g. food industry). From a methodological point of view, the group is specialized in experimental and numerical study of turbulent shear flows with an emphasis on mixing layers. Their goal will be to provide images from well-controlled experimental flows with known physical properties and evolution. They also actively participate to the design of suitable physical models or constraints for fluid image processing.

- LA VISION is the industrial partner involved in WP1, WP2, WP4 and WP5. It is a German industrial company. It is specialized in the development of open PIV systems. Since a few years it has succeeded in becoming an inescapable reference in the domain of PIV visualization systems. Their task in the project consists to evaluate the new methods developed by the consortium against reference techniques used in the domain of flow visualization. It also plays a role of consultant in order to provide the consortium with real industrial needs and requirements.

- The LMD, CNRS (Laboratory of Dynamic Meteorology) is situated in Ecole Polytechnique, Palaiseau, and in Ecole Normale Supérieure and University of Paris 6, Paris. LMD is involved in the study of the atmosphere and atmospheric processes. It is a renowned research laboratory in dynamical meteorology. The LMD gathers researchers specialized in atmospheric numerical modelling, climate processes as well as specialists of atmosphere observation through satellite images for the monitoring or forecasting of meteorological or pollution events. There is presently a renewed interest for tracking the air parcels both for studies of atmospheric pollution and for more general problems of transports in the atmosphere, particularly concerning water vapour. Model based analyses are frequently used for reconstructing these trajectories, but they need to be validated against observation. LMD is responsible of providing relevant data of meteorological satellites, participates to the evaluation of the results of motions computed from these images, provides dynamical and physical constraints on the atmospheric fields, eventually deduced from models.

The FLUID project is divided in five technical workpackages:

- The first one is dedicated to the constitution of relevant benchmarks for the two targeted applications namely meteorology and experimental fluid mechanics. The different groups involved in this workpackage have selected several specific situations and different kind of representative data either for meteorological issues or for experimental fluid flows analysis. It must be outlined here that this project aims at devising general methodological framework for fluid flows measurement and analysis from image sequences. We have therefore paid attention to have a large and significant database of different types of images.

- The second workpackage aims at studying early processing tools for the estimation of multiscale motion estimation. During the project several local and global motion estimators have been developed.

- The goal of the third workpackage is to study methods for the temporal analysis of 2D fluid motion fields. The objective is here to propose methods for the tracking of representative structures of the observed fluid flows. The method proposed relies either on stochastic filtering or an optimal control strategy.

- The forth workpackage’s objective is to devise methods for the estimation of 3D fluid motion field. We focus on two different issues in this workpackage.
The first one concerns the estimation of the vertical velocity component of atmospheric layers at constant pressure. The second issue concerns the estimation of dense 3D velocity fields from volume image data.

- The fifth workpackage is devoted to the evaluation and comparison of the different methods produced during this project. The evaluation methodology has been defined during the different fluid meetings. Different preliminary comparisons have been already done for several types of situations.

A last workpackage has been defined for the management of the project. At the beginning of the project, we have launched a web site to facilitate the exchanges between the different partners. The web site’s address is http://fluid.irisa.fr. During the third year this web site have been maintained and complemented by several online demos. These demos aim at promoting the results that have been obtained within this project.

1 – Project objectives and major achievements during the reporting period

The first main objectives of the third years were to stabilize the approaches proposed for fluid motion estimation and analysis and to complete the study on 3D measurements. The purpose was also to conduct a final assessment of the methods proposed within the different workpackages. Several final demonstrators were scheduled in the different workpackages and for each workpackage final reports describing the different approaches developed have been submitted at the end of the project. The detailed objectives of this third year are listed below workpackages by workpackages.

- **In workpackage 1:** Additional meteorological and experimental data have been added to complete the data benchmarks. Some of these data have been selected and are now freely available on the web site.

- **In workpackage 2:** The objective was to provide a numerical study for the efficient implementation of fluid motion estimators. This includes aspects concerning domain decomposition and the design of multigrid solvers for the approach developed in this workpackage. A final report describing the different techniques proposed has been also submitted.

- **In workpackage 3:** The main purpose of this third year was to finalize the different tracker proposed during the two first years but also to analyze the potential of the different techniques developed. Two final demonstrators and a final report were scheduled for this workpackage at the end of the reporting period. A description and a methodological comparison of the technique proposed are presented in this final report. Several experimental results enable to outline the advantage and the deficiency of the proposed techniques for several applications.

- **In workpackage 4:** The goal was to complete the different the 3D motion estimators proposed in the second year of the project. Two different kinds of estimators have been designed for experimental fluid mechanics and atmospheric flows. These techniques use either satellite images and some derived products (altimetric classification maps) or volume of particles obtained from a tomographic reconstruction. Two demonstrators and a final report present a detailed description of these techniques.

- **In workpackage 5:** The purpose was here to present an evaluation as complete as possible of the different methods proposed in the project. The techniques developed within the different workpackages have been compared on the basis of experimental flows or on meteorological data bases. Three
different final reports gather the experimental evaluation of techniques developed in workpackages 2, 3 and 4.

All these objectives have been achieved and no delays in the planned time schedule have been occasioned. A lot of the studies done within the project have been published in international conferences and journals. Let us outline also that a scientific transversal seminar organized by Etienne Mémin and Christoph Schnoerr on “Experimental fluid mechanics, computer vision and pattern recognition” have been organized at the International Conference and Research Center at Dagstuhl castle, Germany, in March 2007 (see: http://www.dagstuhl.de/07121/).

2 – Workpackages progress of the period

WP1 (Data Acquisition):

- Several data packages have been selected during the two first years of the project. Some non-crucial meteorological data, which was not available during the two first years, has been added by the LMD to complement the database.
- The Cemagref made evolved the synthetic image sequence of the database towards more realistic luminance conditions. Hence, the signal to noise ratio was increased, simulating a reduction of the power of the virtual laser. In addition based on the feedback of the evaluation procedure, synthetic 3D image sequences have been improved. The DNS and LES of turbulent wake flows which have been used to generate synthetic image sequences have been published Journal of Turbulence [Parnaudeau-et-al-JoT07] and Physics of Fluids [Parnaudeau-et-al-PoF07].
- Two more data packages have been added by LaVision. The first one is an experimental LIF image sequence, the other one a full-volume particle image set for tomographic PIV processing. They are more precisely described below:
  - Package 9: Experimental volume PIV-data. This data package contains of two volumes computed by tomographic reconstruction (Tomographic-PIV). It is a Karman street behind a cylinder, which is positioned to the right of the volume, with the water flow going to the left.
  - Package 10: Experimental LIF images. The supplied sequence of 20 images has been recorded in water where another fluid with a certain fraction of carbonoxy snarf which is pH-sensitive. The images have been illuminated with a laser light sheet at 532 nm detected by two cameras having filters for two different wavelength ranges (image set SNARF-1 and SNARF-2). The ratio of the two intensities is proportional to the pH-value (set SNARF-pH).

Some of the data are now publicly available. They can be downloaded on the web site together with their description.

Deviations from the project work plan
No deviation from the initial work plan has been decided neither observed.

Deliverable List of WP1 during the reporting period

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WP2 (Physical Models and Early Processing)

Workpackage 2 is devoted to the design of early processing methods for image sequences depicting fluid phenomena. We list below the different research activities related to this workpackage during the reporting period.

- The AMI group of university of Las Palmas de Gran Canaria has developed a variational approach to accurately estimate simultaneously the velocity field and its derivatives directly from PIV image sequences. Instead of using standard finite difference schemes to estimate the flow derivatives, they are introduced as unknowns in the energy minimization problem. This approach is used to accurately estimate flow characteristics as the vorticity or the strain tensor this work has been published in the journal Experiments in Fluids [Alvarez-et-al-EIF07].

- The Vista group has worked on an improvement of the motion estimator dedicated to atmospheric layers. These improvements concern the definition of more accurate discretization schemes and also an improved version of the divergence vorticity form of the Shallow water momentum conservation law used. The data model used on pressure images has been also theoretically justified as an integrated form of the Shallow water mass conservation. This work has been done in collaboration with the LMD and has been published in the journal IEEE trans. on Geo-Sciences and Remote Sensing [Heas-et-al-GRS-07].

- The Cemagref worked on the influence of the regularization parameters - introduced to control the balance between the data term and the regularizer - and on the description of the dynamic range. Based on a dimensional analysis of the optical flow equations non dimensional regularization parameters were highlighted. A work is currently under progress to calibrate these parameters and model their behaviours as a function of the physical scales involved in the image sequences.

- The CVGPR group of the Mannheim University has studied domain decomposition techniques and efficient multigrid implementations of second order variational fluid motion estimators. This study relies on convex programming and duality. It is described in deliverable 2.5.

- The CVGPR has designed a technique for local motion estimation method with a joint estimation of an optimal estimation support windows. This technique enables to get rid of a sensitive parameter of local techniques and allows adapting the estimation support according to the spatial fluid flow image context.

- The CVGPR group has proposed a technique for the denoising of incompressible fluid flow vector fields. This work relies on stationary Navier-Stokes equation.

- La Vision and the CVGPR group have collaborated on the design of new objective function for the tomographic fluid volume reconstruction.

- La Vision collaborated with the CVGPR group for the study on local adaptive variational approach for vector field estimation. This technique allows estimating the size and the shape of the estimation support function.

Deviations from the project work plan

No deviation from the initial work plan has been decided neither observed.

Deliverable List of WP2 during the reporting period
WP3 (2D fluid motion analysis):
Workpackage 3 aims at proposing methods for analysing the 2D apparent motion of fluid phenomenon observed through an image sequence. The purpose is here to devise fluid motion segmentation models and tracking approaches of fluid structures. We list below the research activities that have been conducted within this workpackage during the reporting period.

- The VISTA group has investigated the use of so-called Ensemble Kalman filtering for fluid tracking problems. This kind of stochastic filters introduced has been popularized for the analysis of geophysical fluids. This technique consists in a suboptimal Monte-Carlo approximation of the filtering density driven by the Kalman filter update equation. We have proposed extension of this technique that combine sequential importance sampling and the propagation law of ensemble kalman filter. This technique leads to an ensemble Kalman filter with an improve robustness and lower computational cost. This study has been submitted to the IEEE transaction on Signal Processing [Papadakis-et-al-SP07]. Such improvement could be of great utility for geophysical forecasting numerical model based on this technique.

- The VISTA group has continued to work on the estimation of low order dynamical system based on POD Galerkin technique. The approach developed is formalized as an optimal control problem on the initial condition and on the dynamical system coefficients. The method has shown to significantly improve the results and the of state of the art methods. The final version of this technique constitutes the deliverable 3.4. A preliminary version of this work has been published in the Journal of Turbulence [Dadamo-et-al-JOT07]. This work has been conducted in collaboration with the group of Professor Artana from University of Buenos-Aires.

- The VISTA group has worked on the definition of assimilation strategy for the direct estimation of fluid velocity fields from images. In the proposed technique the measurements considered rely directly on the luminance function and not anymore on motion measurements or segmentation maps provided by external motion estimators. The resulting estimator allows us to recover very accurate fluid motion fields and enables to track very accurately closed curves and vorticity maps along an image sequence. The latter application constitutes the deliverable 3.3. These studies have been published in the IEEE conference on computer vision [Papadakis-Memin-ICCV07a, Papadakis-et-al-ICCV07b] and two journal papers have been submitted [Papadakis-Memin-JMIV07, Papadakis-Memin-SIS07]. This assimilation scheme has been also considered for the tracking of atmospheric layers from pressure images. Different dynamical models and measurements have been compared. This study has been submitted to the Tellus journal [Corpetti-et-al-Tellus07].

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<td>2.6</td>
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The AMI group has designed a Kalman filter technique to track a cloud trajectory. The trajectory of each cloud point is assumed to follow an affine motion model Kalman filter to track the trajectory across the time. This technique allows denoising noisy velocity measurement through a temporal integration. The approach could be useful for short time forecasting and the inspection of point trajectories on meteorological images.

**Deviations from the project work plan**
No deviation from the initial work plan has been decided neither observed.

**Deliverable List of WP3 during the reporting period**

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<td>30/11/07</td>
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**WP4 (3D fluid motion estimation):**
The purpose of workpackage 4 consists in proposing methods for the estimation of 3D motion vectors. The two targeted applications are experimental fluid flows observed through particle images and atmospheric flows observed from satellite images. This workpackage has been launch between month 9 and 12.

- The AMI group has developed a variational technique which takes into account the information of the different channels provided by the EUMETSAT satellite in order to estimate cloud layer motion. The proposed method provides a single vector flow estimation by combining the information of several channels. This technique and the corresponding software are described in a document entitled “Method for motion layers estimation (without physical coupling between layers)” and which can be downloaded from the fluid web site. The tracking of the cloud structure has been addressed through the Kalman filter technique developed in WP2. A study on the visualization of 3D atmospheric wind fields has been done in collaboration with the vista group. This work has been presented in the EUMETSAT Conference 2007 [Alvarez-et-al- Eumetsat07].
- The AMI group has worked on improvements of the variational methods for 3D motion estimation proposed during the second year of the project. The first amelioration consists in the inclusion of an incompressibility constraint within the energy formulation. The resulting constrained optimization is solved with a Lagrange multiplier strategy. A second improvement has consisted to implement a symmetric data model with respect to the two consecutive data volumes available. This technique has been compared to 3D correlation techniques. The modifications considered have shown to lead to improve results and to compete favorably with correlation techniques.
LaVision has further developed the technique of tomographic PIV, which is a 3D3C-flow measurement technique in a full volume. Different experimental tests have been performed in-house and in collaboration with other universities, and the results have been presented at three conferences. Some of the experimental data have been provided for the FLUID-partners for further processing.

LaVision has developed a new volumetric self-calibration technique for 3D particle image velocimetry techniques. A patent has been granted in Germany, and is submitted for other countries. This technique improves the vector field quality of Tomographic PIV and other 3D velocimetry methods significantly.

The VISTA group has proposed a motion estimator for 3D atmospheric motions. This estimator is expressed as the minimization of a global function including a data term and a spatio-temporal smoothness term. The data term relies on a shallow-water mass conservation model that includes boundary terms modelling mass variation at the layers surfaces frontiers. This study has been accepted for publication in the IEEE transaction on Geo-science and remote sensing [Heas-Memin-GRS07].

Deviations from the project work plan
No deviation from the initial work plan has been decided.

Deliverable List of WP4 during the reporting period

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WP5 (Evaluation):
The objective of this workpackage is to evaluate the different methods or frameworks proposed within this project.

The Cemagref and LMD provide first qualitative assessments of methods of workpackages 2, 3 and 4 for the meteorological data. These evaluations have been included in the deliverable 5.1, 5.2 and 5.3. The Cemagref in collaboration with INRIA proposed a thorough evaluation of the dynamic consistent correlation – variational approach proposed by INRIA group. This study on particle image sequences have been presented in PIV07 [Heitz-et-al-PIV07] and invited for publication in special issue of Experiments in Fluids [Heitz-et-al-2007].

Deviations from the project work plan
No deviation from the initial work plan has been decided.

Deliverable List of WP5 during the reporting period
The different tasks scheduled in the work plan for the project management have been done. No particular problem has been encountered with respect to the work program.

Two partners, namely La Vision and the University of Mannheim, have declared an increase of their efforts for the second year compared to what was scheduled originally in the work plan. The possibility of funding redistribution has been accepted by the different partners. The different groups will be authorized to use the grants planned for travelling and other expenses for labour costs. This redistribution cannot nevertheless exceed the global amount allocated to each of the partners at the beginning of the project. These amounts are listed in the annex of the document “Description of work”. The third payment will be done on the basis of what remains to be paid with a saving of money corresponding to the last payment of the European commission. The partners on their own grants will finance the additional labour costs.

During the reporting period two meetings of two days each have been organized:

- The sixth meeting took place in Dinard, France the 7 and 8 of June 2007. The Cemagref organized it. Several technical fruitful presentations and lectures have been given during this meeting.
- The closing meeting took place the 8 of November 2007 in Rennes. The consortium leader has organized this meeting. This meeting has been the occasion to dress review of all the different works that have been done during the whole FLUID project. A fruitful discussion on future extensions of this project occurred.

During these meetings the partners presented the different on going works and the works that have been achieved in each group the last six months before the meetings. The second meeting has been also devoted to the preparation of the second evaluation meeting.

The web site for the FLUID project has been maintained up to date. Its address is: http://fluid.irisa.fr. This web site provides to the project participants a convenient way to exchange documents, source codes or data. It gives also to the public a brief description of the project and of the different participants. All the published articles related to this project and all the deliverables are publicly available on this site.
The project timetable is shown below. No tasks have been delayed. The deliverables of the third period will be provided on due time.

4 – Other issues

Invitations

- Anne Cuzol has been hired as assistant professor in the University of South Brittany (Vannes)
- Long stay of N. Papadakis in Buenos-Aires where he worked with Prof. G. Artana on POD decomposition and data assimilation)
- Long stay of Patrick Heas in Buenos-Aires where he worked on the definition of physically sound regularization functional. This works is still on going and has been funded by INRIA.
- Patrick Heas has been hired by the Cemagref for a one year post-doctoral position at the end of its contract with INRIA.
- F.X. Le Dimet from the LJK (U. Grenoble) has participated to the PhD defense of Nicolas Papadakis.
- N. Papadakis has been invited to give a seminar talk in the Laboratory Joseph Kuntzmann in Grenoble.
- N. Papadakis gave a Talk at the Pompeu Fabra University, Barcelona
- N. Papadakis has been hired for 5 years on post-doc position at the Pompeu Fabra University, Barcelona
- E. Mémin has been invited to give a talk at the Argentinian Academy of Sciences.
• E. Mémin has been invited to give a talk at the University Louis Pasteur of Strasbourg.
• E. Mémin has been invited to give a talk at the Ecole Normale Supérieure de Cachan.
• D. Heitz has been invited to give a talk at the Ecole Normale Supérieure de Cachan.
• C. Baer from MeteoFrance Toulouse visited E. Mémin at IRISA, and gave a seminar on Particle filtering for measuring turbulent atmospheric winds.
• La Vision has deposited a patent on volumetric self-calibration technique for 3D particle image velocimetry techniques in Germany.

Symposium organization

Etienne Mémin and Christoph Schnörr have (co-) organized an international symposium on Experimental Fluid Mechanics, Computer Vision, and Pattern Recognition at Schloss Dagstuhl, Germany, Spring 2007, involving about 35 leading researchers involved in experimental fluid mechanics, fluid flows visualization and image analysis. This seminar has been a great success. It has allowed people of three different communities to share their point of view on close objectives concerning fluid flows analysis and the visualization/restitution of flow features. Dantec and La Vision have sponsored this meeting. A paper summarizing this seminar will be published in the journal “Experiments in Fluids”. The summaries of the different presentations are available on the Dagstuhl website: http://kathrin.dagstuhl.de/07121/Materials2/

Christoph Schnörr has Co-organized of the Annual Conference of the German Association for Pattern Recognition (DAGM).

Dominique Heitz has organized a national CNRS meeting on the Structure of Turbulence, with special sessions on Image and model based measurement techniques, Assimilation techniques. This meeting was initially scheduled in November 2007 but due to the social context of this period, the meeting has been postponed to January 2008 (28-29-30 January 2008). More information are available on the website of the meeting: http://gdr-turbulence.pmmh.espci.fr/Jan2008/jan2008.html

Collaboration between partners

• Karl Krissian has worked two weeks at IRISA in Rennes in January 2007. During his stay he collaborated with P. Heas and E. Memin on the visualization of 3D motion of atmospheric layers. This work has been presented at the Eumetsat conference in Amsterdam.
• Patrick Heas has actively collaborated with the Cemagref to define an optical-flow estimator embedding a collaborative scheme with correlation techniques. This work has been presented to the PIV conference in Rome. This work has been selected to be submitted to a special issue covering this conference in the journal Experiments in Fluids.
• A. Szantai and P. Lopes (CNRS) followed a 2-day training in Göttingen on the DaVis software from LaVision developed for motion measurements on experimental flows. They used and tested it on meteorological data.
• LaVision and Prof. Schnörr from Mannheim started collaboration on further improvement of the Tomographic PIV reconstruction technique. The project is now funded by DFG. DLR Göttingen is the third partner in the project providing experimental validation.
**Edition of a book**

- The reviewer suggested to publish a book covering the different researches investigated during the FLUID project. We definitely think it is a good idea, however the publication of such book raises the question of the community to which it is devoted. This question is fundamental with regards to its content and we have not been able for the moment to decide whether this book should be dedicated to the image community or to the fluid mechanics community. Instead of writing directly such book we have decided to organize the publications through different retrieval key words in the web site. The different final reports of each workpackage will also provide us the material and hindsight to edit this book.
Annex – Plan for using and disseminating the knowledge

1 – Exploitable knowledge and its use

As part of the FLUID project LaVision has considerably improved on its 3D Tomographic PIV technique (WP 4.2):

- Improvement of the technique especially by using volumetric self-calibration patent granted for volume self-calibration (in D, filed also internationally)
- Very positive response of the 3D Tomographic-PIV technique in the fluid dynamic community
- First sales of measurement systems
- Advantage compared to the (US-)competition
- Potential to include variational approach and physical laws (results of WP 2+3)

A new collaboration has started between LaVision and Chr. Schnörr, Uni. Mannheim and A. Schröder, DLR Göttingen concerning advanced tomographic reconstruction techniques, funded by DFG Germany.

Another subject of exploitation relates to the different optical flow techniques developed within FLUID for processing scalar (LIF, etc.) images (results of WP 2). LaVision plans to offer a special software package to analyze LIF images.

There is a promising potential of using combined correlation+optical-flow (e.g. Cemagref-INRIA) and variational correlation approach (Uni Mannheim) for 2D-PIV flow field measurements. Further work is needed to validate these approaches.

The Cemagref and INRIA groups have decided to propose to their respective general management boards the creation of a common and transversal research group on the study of fluid flows from image sequences. This group will focus on the study of geophysical flows and industrial flows for analysis and control purposes. We believe there is a huge potential of satellite fluid image analysis for environmental analysis in meteorology, oceanography and climatology but also to analyze accurately on long time range human activities evolution. This concerns questions of deforestation, monitoring of forest fires, desertification, impacts of repetitive natural disaster on lands, city growing etc. The question of flow control is also of major interest for industry and we believe that image analysis could bring in this context interesting solutions. All these research issues, which are of major interests for the society, are prolongations of the techniques proposed within the FLUID project.

The submission of another European project focusing on image analyses for 3D flows, flow control, geophysical flows and environmental applications is planned. We intend to submit a proposal with more ambitious objectives and an enlarge number of people involved. We believe these questions of analysing fluid flows from images are essential with respect to a great number of applications. The FLUID project was in that prospect a very interesting starting point that provides us some advances compared to international competition.
2 – Dissemination of knowledge

- According to the FLUID project work plan the following deliverables have been elaborated during this reporting period:
  
  - F. Becker and C. Schnörr Report on Motion Estimation Based on Convex Problem Decomposition, Deliverable 2.5
  - C. Schnörr, Final report on Motion estimation for fluid flows, Deliverable #2.6
  - N. Papadakis, E. Memin, N. Gengembre, Demonstrator on vorticity tracking method for fluid flows, deliverable #3.3
  - N. Papadakis, Juan D’adamo, Etienne Memin and Guillermo Artana, Demonstrator on turbulent structure characterization deliverable #3.4
  - E. Mémin, Final report on WP3: Representation, Tracking methodologies, and Characterization of fluid flows from images sequences. Deliverable #3.5
  - P. Heas E. Mémin Demonstrator on motion layer estimation method, deliverable #4.1
  - AMI group, Demonstrator on 3D fluid flow estimation methods, Deliverable #4.2
  - L. Alvarez, Final report on WP4: 3D estimation of fluid flows from images sequences. Deliverable 4.3
  - G. Arroyo, J. Carlier, D. Heitz, A. Szantai, Final report on the evaluation of the tasks of the workpackage 2, Deliverable #5.4
  - G. Arroyo, J. Carlier, D. Heitz, A. Szantai, Final report on the evaluation of the tasks of the workpackage 3, Deliverable #5.5
  - G. Arroyo, J. Carlier, D. Heitz, A. Szantai, Final report on the evaluation of the tasks of the workpackage 4, Deliverable #5.6
  - E. Mémin, “Periodic intermediate management report”, Deliverable 6.3a, 6.3b
  - E. Mémin, “Periodic activity report”, Deliverable 6.4c

- During the reporting period, several research articles related to the FLUID project have been accepted or submitted for publication in national and international refereed conferences and journals. Here is a list of these articles:

  **Journals**

  **Published/accepted:**


7. N. Papadakis and E. Mémin, A variational technique for time consistent tracking of curves and motion, accepted for publication under minor revisions International Journal on Mathematical Imaging and Vision (IJIV)


Under revision:


Submitted:


17. T. Corpetti, P. Heas, N. Papadakis and E. Mémin, Pressure image assimilation for atmospheric motion estimation, Tellus Series A: Dynamic meteorology and oceanography.


21. D. Heitz, P. Héas, V. Navaza, J. Carlier, E. Memin. Spatio-temporal correlation-variational approach for robust optical flow estimation. selected for the Special Issue on « PIV’07» in Experiments In Fluids..
23. B. Wiencke, Volume Self-Calibration for Stereo-PIV and Tomographic-PIV, Selected for the Special Issue on « PIV’07 » in Experiments In Fluids

In preparation:


Conferences

Published/accepted:

35. D. Heitz, P. Héas, V. Navaza, J. Carlier, E. Memin. Spatio-temporal correlation-variational approach for robust optical flow estimation. In *7th International Symposium on Particle Image Velocimetry (PIV’07)*, Sept. 2007 - has been selected for 'Special Issue of PIV’07’ in Exp. In Fluids.


Below we list the impact factor of the different journals publications or submissions related to this project


<table>
<thead>
<tr>
<th>Journal</th>
<th>Papers number</th>
<th>Impact factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Journal of Computer Vision (IJCV)</td>
<td>2</td>
<td>6.085</td>
</tr>
<tr>
<td>Journal of Turbulence</td>
<td>2</td>
<td>1.06</td>
</tr>
<tr>
<td>Experiments in Fluids</td>
<td>4</td>
<td>1.112</td>
</tr>
<tr>
<td>Journal on Mathematical Imaging and Vision.</td>
<td>2</td>
<td>1.767</td>
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<tr>
<td>IEEE Transactions on Geosciences and Remote Sensing</td>
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<tr>
<td>Measurement Science and Technology</td>
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<tr>
<td>SIAM J. Scientific Computing</td>
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<td>1.824</td>
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<td>Physics of fluids</td>
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<tr>
<td>Pure and Applied Geophysics</td>
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<td>Tellus Series A: Dynamic meteorology and oceanography</td>
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<td>Lecture notes on Computer Sciences</td>
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<tr>
<td>IEEE trans. On Signal processing</td>
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<tr>
<td>IEEE trans. On Pattern Analysis and Machine Intelligence</td>
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<td>Computer Vision and Image Understanding</td>
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<tr>
<td>Journal of Fluid Mechanics</td>
<td>1</td>
<td>1.85</td>
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<tr>
<td>SIAM Journ on Imaging Sciences</td>
<td>1</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

All these articles and deliverables are available on the FLUID web site: [http://www.fluid.irisa.fr](http://www.fluid.irisa.fr). These publications have been organized according to different keywords. They can be selected also by year or by authors.

As can be seen the publication of the studies performed within the FLUID project are composed of first rank international journal in Computer Vision, Experimental fluid mechanics, applied mathematics and Geosciences.

The works done within this project have been presented in several international conferences. These conferences focused either on Computer Vision, fluid flow visualization, or Geosciences and Meteorology issues.

- The FLUID project contributed to form 6 PhD students and 8 post-doctoral fellows. Among the PhD students, four of them have defended their PhD.
The scientific transversal seminar in Schloss Dagstuhl in Germany on “Experimental fluid mechanics, computer vision and pattern recognition” funded by the Schloss Dagstuhl Computer Science Foundation (http://www.dagstuhl.de/) held at the International Conference and Research Center at Dagstuhl castle, Germany, from the 18/03/2007 to the 23/03/2007 (see: http://www.dagstuhl.de/07121/). A set of around 30 researchers of computer vision and fluid mechanics has participated and gave original talks. This seminar has been organized by the FLUID-coordinator Etienne Mémin, Christoph Schnörr (U Mannheim), Jean-Paul Bonnet and Cam Troppea.