

# ERCIM "Alain Bensoussan" Fellowship Programme

## Scientific Report

October 2, 2010

Research Fellow: Dr. Annette Stahl  
Visited Location: Department of Engineering Cybernetics  
Norwegian University of Science and Technology  
7491 Trondheim, NORWAY  
Fellowship Duration: 26th of October 2009 to 25th of October 2010  
Scientific Contact: Prof. Ole Morten Aamo

### I - Scientific activity:

During my fellowship, I collaborated with Prof. Ole Morten Aamo and Ass. Prof. Øyvind Stavdahl. One of the objective of the project was the development and investigation of methods for a computer based video sequence analysis in order to detect a certain kind of General Movements (GM) observed in the motion performed by infants with the aim to determine the risk to have Cerebral Palsy. Cerebral Palsy is a perinatally acquired non-progressive condition of functional impairment of the brain which is associated with a motor impairment affecting mobility and posture of the child.

To develop a robust method for the classification of movement patterns of the infants from video data we applied and combined several mathematical and computer vision based techniques.

Within the first part of the project we developed the mathematical framework – which exploited variational methods along with appropriate optimisation techniques – in order to extract motion information of infants from video recordings. This work was inspired by previous works and discussions about the combination of control applications to human motion estimation approaches. The resulting variational formulation incorporates physical prior knowledge by giving preference to motion fields that satisfy appropriate equations of motion. Although the developed framework is flexible, we employed a particular equation from fluid mechanics as physical prior knowledge in this study. The finally obtained control based formulation evaluates the entire spatio-temporal information of the provided image sequences to estimate the apparent motion in the sequences. We performed numerical experiments on synthetic and real image sequences. The comparison of our results with other well-known methods demonstrated the ability of the optimal control formulation to reliable determine the image motion from video and image sequences. In particular for highly noisy image sequences we observed an improved performance compared to standard optical flow approaches.

In the second part we intended to exploit the motion information that can be extracted by standard optical flow approaches from the video recordings of the infants to detect certain motion patterns which absence indicate the presents of a motor impairment. A promising approach is based on a wavelet analysis of motion trajectories extracted from all parts of the human body. A filtered set of features is used to construct feature vectors that are suitable for the training and

the subsequent classification of unclassified data. Finally we employed the developed method to the provided test video sequences and evaluated the performance of this approach in comparison with previously developed methods.

## II - Publications during my fellowship:

1. *Title:* Image Motion Estimation using Optimal Flow Control  
*Authors:* Annette Stahl and Ole Morten Aamo  
*Abstract:* In this paper we present an optimal control approach for image motion estimation in an exploitative and novel way. The variational formulation incorporates physical prior knowledge by giving preference to motion fields that satisfy appropriate equations of motion. Although the framework presented is flexible, we employ the Burgers equation from fluid mechanics as physical prior knowledge in this study. Our control based formulation evaluates entire spatio-temporal image sequences of moving objects. In order to explore the capability of the algorithm to obtain desired image motion estimations, we perform numerical experiments on synthetic and real image sequences. The comparison of our results with other well-known methods demonstrates the ability of the optical control formulation to determine image motion from video and image sequences, and indicates improved performance.  
*Proceedings of the International Conference on Informatics in Control, Automation and Robotics (ICINCO), Madeira, June 2010, Vol. 3: 14-21*
2. *Title:* A new Framework for Motion Estimation in Image Sequences using Optimal Flow Control  
*Authors:* Annette Stahl and Ole Morten Aamo  
*Abstract:* Application of tools from optimal flow control to the field of computer vision and image sequence processing, has recently led to a new and promising research direction. We present an approach to image motion estimation that uses an optimal flow control formulation subject to a physical constraint. Motion fields are forced to satisfy appropriate equations of motion. Although the framework presented is flexible with respect to selection of equations of motion, we employ the Burgers equation from fluid mechanics as physical prior knowledge in this study. To solve the resulting time-dependent optimisation problem we introduce an iterative method to uncouple the derived state and adjoint equations. We perform numerical experiments on synthetic and real image sequences and compare our results with other well-known methods to demonstrate performance of the optimal control formulation in determining image motion from video and image sequences. The results indicate improved performance.  
*Informatics in Control, Automation and Robotics, Lecture Notes in Electrical Engineering (LNEE), Springer Verlag, 2010, to appear*
3. *Title:* An Optical Flow Based Method to Predict Infantile Cerebral Palsy  
*Authors:* Annette Stahl, Christian Schellewald, Harald Kirkerød, Øyvind Stavadahl, and Ole Morten Aamo  
*Abstract:* Cerebral palsy (CP) is a perinatally acquired non-progressive condition of functional impairment of the brain and is associated with a motor impairment affecting mobility and posture. Therefore, it is desired to start the rehabilitation process of the affected child as early as possible. Automatic and accurate prediction of CP would be a welcomed tool to assist in diagnosis and decision-making for an appropriate treatment of the patient. During the early infancy distinct motion pattern occur in a frequent manner and last long

enough to be observed properly in video recordings of the infant. In this paper we present a medical application of optical flow and statistical pattern recognition based methods to predict CP. We extract motion information from video recordings of young infants using a total variation related optical flow method. By using wavelet based analysis features from motion trajectories of points initiated on a regular grid were extracted and classified using a support vector machine (SVM).

*Journal IEEE Transactions on Neural Systems and Rehabilitation Engineering, 2010, in preparation*

### **III - Attended Conference:**

I presented a paper at the *International Conference on Informatics in Control, Automation and Robotics (ICINCO) in Madeira, Portugal on June 2010* with the Title: "Image Motion Estimation using Optimal Flow Control". Within this conference I was session chair for the Signal Processing, Systems Modeling and Control session.

### **IV - Research Exchange Programme (12 month scheme):**

*First Research Exchange Institute:*

Institute for Computer Graphics and Vision (ICG) at the Graz University of Technology, Austria.

Exchange period: 11th to 20th January 2010

Research topics: Computer Graphics, Visualisation, Medical Computer Vision, Object Recognition, Object Reconstruction, Robotics, Virtual Reality and Augmented Reality.

I presented my research work to the ICG group and discussed several aspects and details of the optical flow computations with the members of the group. The stay provided me with the opportunity to get a short introduction into high performance computing with Graphics Processing Units (GPUs) for computer vision problems.

During the visit in Graz Prof. Christa Einspieler from the Institute of Physiology, Center for Physiological Medicine of the Medical University of Graz agreed to a personal meeting. She provided me with information about Cerebral Palsy and insights concerning the motion patterns one expects from healthy infants. Together with Heinz F.R. Prechtel she developed the General Movement Assessment method to predict Cerebral Palsy of infants.

*Second Research Exchange Institute:*

Image group at the department of Computer Science at the University of Copenhagen DIKU in Denmark.

Exchange period: 8th to 12th February 2010

Fields of expertise: Image Processing, Computer Vision, Robotics, Statistics, Computer Graphics, High Performance Computing, and Data Collection.

I presented some details of the optimal control work and had the opportunity to individually meet with many of the researchers of this group resulting in inspiring discussions.