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Motion Estimation of Elver by Lucas and Kanade Optical Flow

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مقدمة __ قد يساعد تحليل حركة بعض الحيوانات الحية على فهم الأخطار التي تهدد هذه الانواع، ولكنه في بعض الأحيان من الصعب تقنيًا. هذا ينطبق بشكل خاص على علماء الأحياء الذين يدرسون الأسماك المهاجرة في حوض آدور. هنا، نقوم بالبحث في إمكانية استخدام رؤية الكمبيوتر للتتبع التلقائي واكتساب المعرفة حول سلوك هجرة اسماك الانقليس الصغيرة. لهذا الغرض، يتم وضع علامة لونية على عينة من هذه الاسماك، ومن ثم إدخالها في تجارب تحاكي المد والجزر في المتوسط. يتم جمع الملاحظات في تسلسلات من الفيديو. للحصول على معلومات حول سلوك الأسماك، يمكن للمرء ان يتتبع هذه الحركة من خلال خوارزميات التدفق البصري. تتناول هذه المقالة مهمة تقدير حركة اسماك الانقليس الصغيرة بواسطة خوارزمية لوكاس & كندي. تظهر النتائج الأولية أنه يمكن للمرء تقدير السرعة وايضا سلوك السباحة، مما يؤدي في نهاية المطاف إلى معلومات حيوية عن الحيوانات.
الكلمات الدالة: سمك الانقليس. تحليل الحركة. الطرق التفاضلية. تتبع، سلوك السباحة، لوكاس وكناد

*Abstract*__ Motion analysis of living animals might help to understand the dangers that threaten the species, but it is sometimes technically challenging. This is particularly true for biologists who study migrating fishes of the basin of Adour. Here, we investigate the use of computer vision for automatic tracking and acquisition of knowledge about the migratory behavior of elvers. For that purpose, some elvers are color-marked, then introduced into an experimental medium reproducing tidal condition. Observations are collected in video sequences. To get information about fish behavior, one can track their motion by optical flow methods. This article addresses the task of estimating the motion of elvers by the algorithm of Lucas & Kanade. Preliminary results show that one can estimate the velocity but also the swimming behavior, hence eventually leading to energetic information about the animals.
Keywords: elver, Motion analysis, Differential methods, Tracking, Swimming behavior, Lucas and Kanade

INTRODUCTION

In computer vision and image processing, motion estimation is of increasing interest because of the large number of applications: object tracking (military, video-surveillance, robotics), complex behavioral analysis (modeling of human body motions, meteorology), medical analysis (cardiac contraction follow-up, infarction detection) [1].

In biology, tracking the motion of animals sometimes poses technical problems, related to the characteristics of species and stages of development. For example, the European elver (Anguilla anguilla) has a complex life cycle, with reproduction in the sea of Sargasso, a larval phase that crosses the Atlantic Ocean and a juvenile stage, the elver, which goes up the estuaries to grow in the river [2]. For this ascent, elvers swim following rising tidal water currents and descend to the substrate at tide. However, it has been shown that this estuarine migration is optional, with some individuals renouncing rivers and settling in the estuary, or even at sea [3]. A better understanding of the determinism of estuarine migration is of crucial interest for this endangered species, because individuals settling downstream give more males, while those colonizing upstream, especially females. To study the estuarine migration of elvers, it is possible to reproduce the tidal water currents in the laboratory and observe the swimming behavior of individuals. The major difficulties concern the animal itself, which is transparent, and moves mainly at night or at very low light intensity. To follow elvers, each individual is tagged with VIE Tag (Visible Implant Elastomer) [4]. This marking consists in implanting under the skin a tip of colored elastomer, visible under UV. Tracking individuals is done on video recordings but it is a tedious job because currently not automated. The parameters that interest biologists are mainly the motion direction of elvers (with or against the water current) and their velocity. Any measure to assess energy expenditure is also sought, as elvers do not eat during migration, and their energy status could play an important role in the migration potential. Motion estimation is the study of the displacement of each pixel in a moving image or region to obtain velocity vectors, assuming that light intensity is conserved during displacement. Apparent motion from changes in the intensity spatial distribution is called optical flow. The original optical flow estimation method proposed by Horn and Schunck [5] has led to multiple methods that can be classified into four main categories: differential methods, frequency methods, block matching methods and parametric motion model methods (for a panorama of methods, see [6]). In this work, we have chosen differential methods for their many advantages. These methods are at first robustness and precision, while being easy to implement. Because of its differential nature, the optical flow equation also allows a sub-pixellic estimation of the motion. Finally, the measurement of the motion only requires a local calculation of the spatio-temporal derivatives of the sequence as explained in a recent study [7].

The main disadvantage of differential methods is their foundation based on constant light intensity assumptions, and small displacements. During larger trips, however, it is possible to solve the problem by multi-resolution iterative approaches. In this case, we do not only process the image sequence at its acquisition resolution, but we build from each frame, a pyramid of images successively filtered and subsampled [8][9]. The relevance of such an approach requires, however, that the images at the coarsest levels of the pyramid should not be too degraded by the lowering of the resolution. The purpose of this preliminary work is to use differential methods to estimate the motion of elver, determine the direction of their motion and assess their velocity.

The article is structured as follows: section 2 presents the principles of motion estimation to compute a velocity vector field. Then we present the results. Finally, we end with a conclusion and perspective.

MOTION ESTIMATION

Principle

Motion estimation techniques consist in measuring the optical flow represented by the variations of the luminance between two images. The principle is based on the assumption of the conservation of the luminous intensity of a pixel along the trajectory of the motion [5]. In a sequence of digital images, it can be represented by its luminance function I(x,y,t) where the luminous intensity I is conserved between two images successive at times t and t+dt. it's written in the general form:

$$I(x + dx, y + dy, t + dt) - I(x, y, t) \approx 0 \qquad (1)$$

Applying the Taylor formula to order 1 and dividing by dt, the equation (1) leads to:

$$\frac{dI}{dt} = \frac{\partial I}{\partial x}\frac{dx}{dt} + \frac{\partial I}{\partial y}\frac{dy}{dt} + \frac{\partial I}{\partial t} \quad (2)$$

Assuming that the light intensity does not vary with time, we have:

$$\frac{dI}{dt} = 0$$

If we note $I_x = \frac{\partial I}{\partial x}$, $I_y = \frac{\partial I}{\partial y}$ and $t_x = \frac{\partial I}{\partial t}$,the 3 components of the gradient according to (x, y, t) and $u = \frac{dx}{dt}$, $v = \frac{\partial y}{\partial t}$, the two velocity components along the directions (x, y), the optical flow equation can be summed up as follows:

$$I_x u + I_y v + I_t = 0 \quad (3)$$

This equation is called the motion constraint equation. In order to find a unique solution for the two components of the velocity V= (u, v), we need two independent equations, which is not the case, because the only equation (3) does not make it possible to uniquely determine the optical flow. We are in the presence of an ill-posed problem hence the need for the use of additional constraints to estimate the motion. Depending on the type of constraint used, different methods are obtained, the two main ones being Horn & Schunck and Lucas & Kanade.

Lucas and Kanade Algorithm

Their method is based on a local regularization of the velocity field {lucas1981iterative. They assume that the optical flow equation remains constant in small regions Ω of the image. This is expressed by:

$$min_{u,v} \sum_{P\in\Omega} W^2(P)\left[I_x(p)u + I_y(p)v + I_t(p)\right]^2 \quad (4)$$

where W(p) is a window function (weighting) to give more influence to the center of the neighborhood rather than to its periphery. Applying the least squares method, we find:

$$\begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} \sum W^2 I_X^2 & \sum W^2 I_x I_y \\ \sum W^2 I_x I_y & \sum W^2 I_y^2 \end{bmatrix}^{-1} \begin{bmatrix} -\sum W^2 I_x I_t \\ -\sum W^2 I_y I_t \end{bmatrix} \quad (5)$$

These local differential methods are interesting because each calculation on a small window is independent of the others. The results are also less sensitive to noise and allow the calculation of local motions, in particular using a pyramidal implementation.

Results

First of all, in order to determine the basics of swimming behavior of elvers (sense and velocity), we start by explaining the results obtained with the local method of Lucas & Kanade that meets the first need of biologists. To apply these algorithms, we use two successive images. This is illustrated in Fig. 1. The original image (a) has four marked elvers: the first two are at the bottom left in the image, one with a short orange marking (close) coded OOS, and the second with a double orange marking and long red (spaced) coded ORL; the third is in the middle of the image with a long green double marking (GGL code), and the fourth is on the right in the image with a double green and short blue marking (GBC code); image (b) corresponds to the next instant. The direction of the water current in this sequence goes from the right to the left of the image.

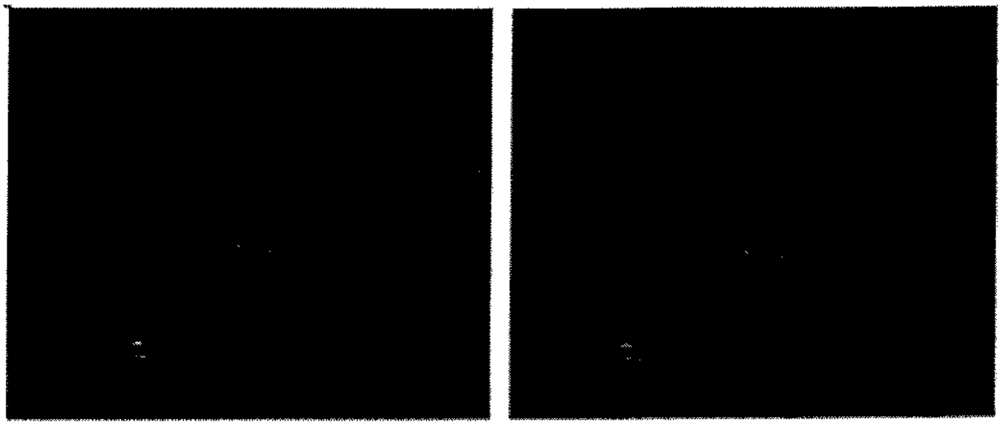
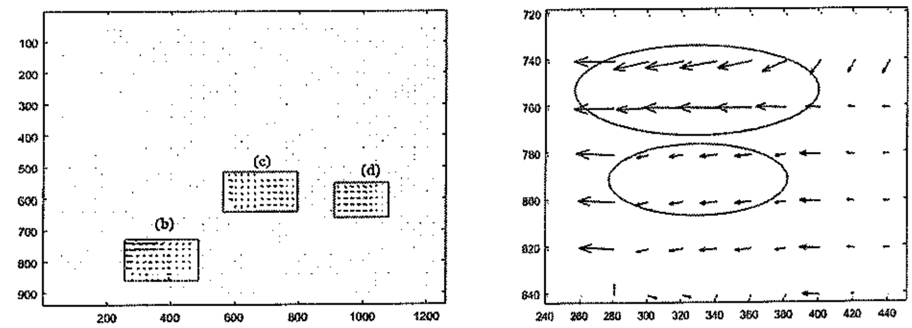


Figure 1 - Two successive images: (a) at the instant t and (b) at the instant t+dt.

Results with Lucas & Kanade

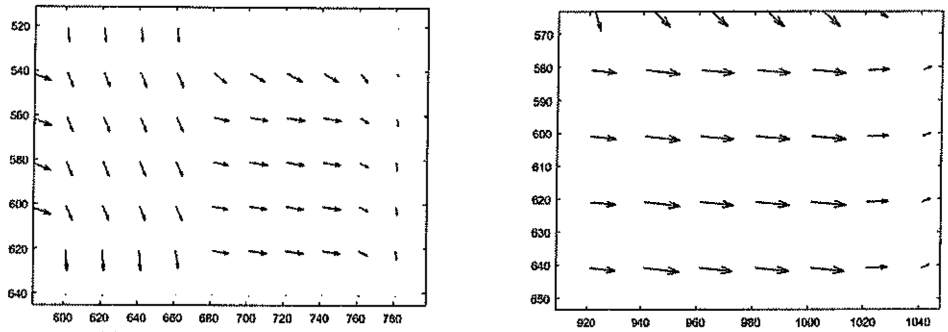
The differential method of Lucas & Kanade is interesting because each calculation on a small window is independent of the others. In the algorithm we use small windows of size 40X40 pixels. In Fig. 2(a), we notice in each window that the arrows have a general orientation corresponding to the direction of motion of the elvers.

To better visualize the velocity vector fields, we chose and enlarged three zones (b), (c), (d). Fig. 2(b) shows the area (b). There are two different sizes of arrows, which reflect the presence of two individuals. These two elvers move to the left of the image, the one characterized by the larger arrows swimming faster than the other. In the figure 2 (c) the size of the arrows is identical which means the presence of a single elver that moves to the lower right side of the image. Similarly, in the figure 2(d), we see that the arrows are identical revealing a single elver moving to the right. As a result, we can distinguish the mean velocity of different elvers.



(a) complete picture

(b) Zoom on zone b



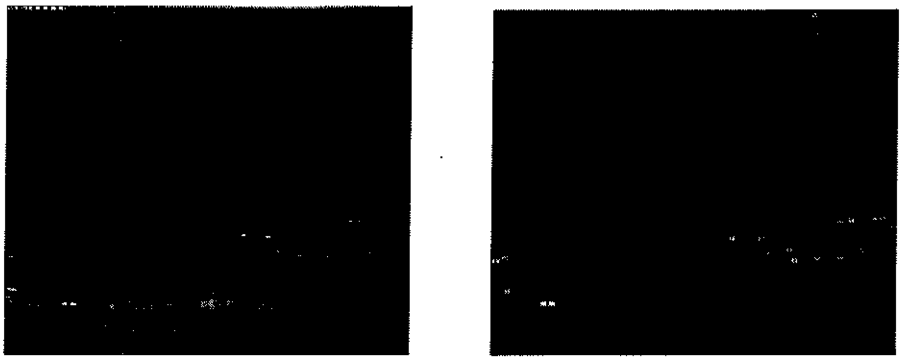
(c) Zoom on zone c (d) Zoom on zone d

Figure 2- Vector-velocity field by the Lucas & Kanade algorithm.

Calculating the velocity of elvers

To calculate the velocity of elvers, we chose a sequence of 6 images with a shift between each pair of successive images of 14 images, Fig.3(a). The principle of our algorithm is based on two phases. The first is to detect elvers in the video sequence and to calculate the centers of gravity of bounding boxes, Fig. 3(b). In the second phase, the Lucas & Kanade algorithm is used to estimate the velocity vector field in each center of gravity and calculate the velocity V of each elver thanks to the following equation: $\|\vec{V}\| = \sqrt{u^2 + v^2}$

The results obtained in Fig. 3(c) make it possible to distinguish two different velocities: elvers in the direction of the water current swim with a weak undulation and consequently they have a low velocity field. On the other hand, elvers going against the direction of flow swim with a strong undulation and the field of velocities is more important.



(a) Sequence of 6 superimposed images (b) Bounding boxes and centers of gravity

(c) velocity $\|\vec{V}\|$ calculated in pixels/frame (d) Zoom on the rectangle of the figure (c)

Figure 3 Calculate the velocity of elvers

In order to observe the waving of the elvers swimming [11], we calculate the two angles of undulation by the relation:

$$\theta = arctan(\frac{v}{u}).$$

On the results of Fig. 4, we note two undulations different from elvers in the direction of the water current: if the swim is against the water current, a significant shift occurs between the two angles of undulation [11] [12]. On the other hand, with the direction of water current, the two angles are very similar.

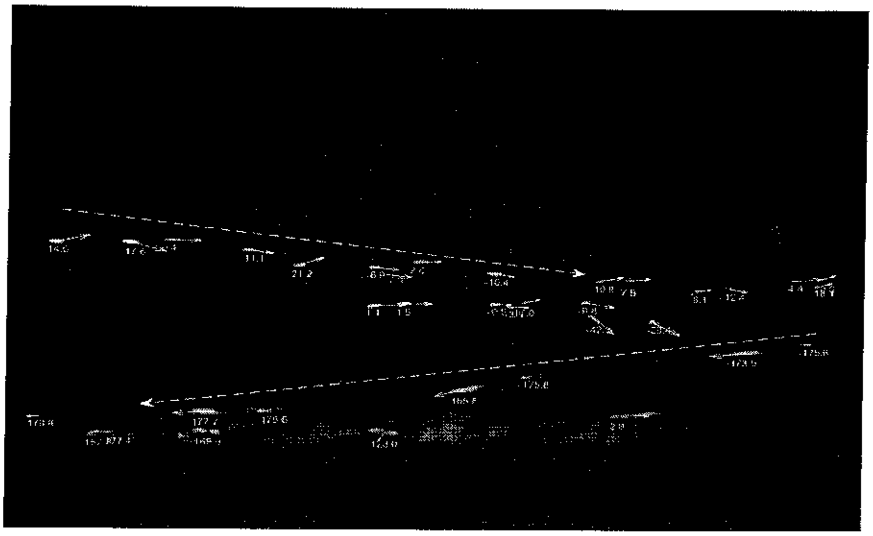


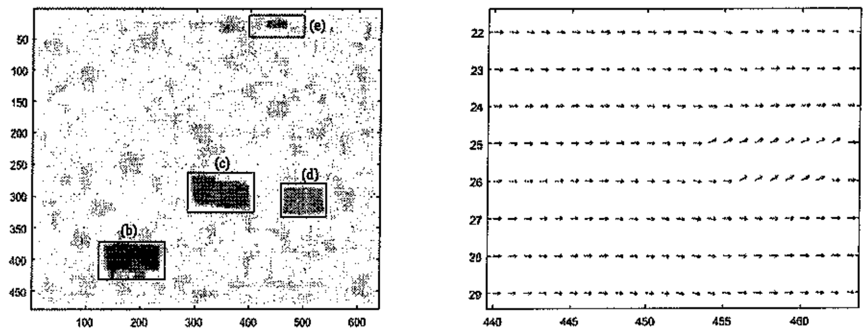
Figure 4- The θ angles of the undulating of elvers; two different swimming sense (WC ⟵ and AC⟶)

Pyramidal implantation

A pyramidal implementation of the Lucas & Kanade algorithm has been implemented with iterative refinement at each level. The main steps of this pyramid algorithm are:

- A Gaussian pyramid is formed up to a n=3 level, filtering the image with a Gaussian mask, then scaled by a factor of 0.5.
- The size of the integration window is maintained at Ω=20X20 and the number of iterations is i=10.
- The Lucas \& Kanade algorithm is executed first at the highest level of the pyramid using an initial zero estimate of the vector field.
- The optical flow, calculated at the top level of the pyramid (L=n), is then scaled by a factor of 2 and propagated to the lower level (L=n-1), as the initial value for calculate the optical flow at the lower level. This process continues to the lowest level (L=0).

Large motions can be correctly estimated with a small window of integration thanks to this approach; the problem of limitation of displacements with the classical method can thus be solved. Fig. 5(a) shows the four elvers already detected previously (b, c and d) and in addition, a new elver (zone e) which moves near the surface of the water. This unlabeled elver was not detected by the main algorithms. Fig. 5 (b) shows its weak passage to the right side of the image in the direction of the water current.



(a) the direction of the water current goes from right to left: ← (b) Zoom on the chosen area(e)

Figure 5- pyramidal of Lucas & Kanade.

CONCLUSION ET PERSPECTIVE

The differential methods of Lucas & Kanade are used in this article. The flow obtained by the Lucas & Kanade local method makes it possible to determine the motion direction of the elvers because the arrows of the vector-velocity field take the average orientation of the applied window. The application of the Lucas & Kanade algorithm to the centre of gravity of each elver also allows to obtain a superimposed sequence on which it is possible to calculate the velocity of displacement. The procedure of iterative refinement by a multi-resolution structure makes it possible to estimate the small incremental motions of elvers, undetectable by the general differential methods. This result reflects a more accurate optical flow and suggests the possibility of detecting and tracking unmarked elvers. The elvers adopt different swimming strategies (with or against the water current), with more or less high velocity. In order to better understand these different migration tactics and their energy costs, biologists hope to couple these measures of velocity and range of motion with the weight loss of elvers and their metabolism. Finally, the ultimate goal of this project is the automation of these measures in order to reduce the working time of the observer. For that purpose, we have in perspective, thanks to the fusion of the results obtained by the main phases of processing, of build a tool allowing the automatic tracking of elvers integrating sense of swimming, velocity and undulation energy.

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