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VISION SYSTEM FOR RELATIVE MOTION ESTIMATION FROM OPTICAL FLOW

This paper talks about the vision systems that allow the receipt of information on relative object motion in real time. It is shown, that the algorithms solving a wide range of practical problems by definition of relative movement can be generated on the basis of the known algorithms of an optical flow calculation. Works in the field of an optical flow calculation have been conducted for more than 30 years. Last decade these methods were used in a wide range of applied problems due to increase of computers computing capacity and the occurrence of specialized graphic processors. There are many articles that have been written on the subject of optical flow methods. There are also widely available libraries with an open code, in which the ready applications of the most popular optical flow methods could be found (for example, OpenCV, LTI-Lib, VXL). Methods of an optical flow appear to be useful for segmentation of images, and also for detection of obstacles from moving objects.

Key words: *robotic vision, software package, segmentation of images, optical flow, OpenCV.*

Introduction

Despite the growing efficiency of computers, it is prudent to see how the optical flow method can be widely used in different applications but with minimal computing expenses and sustained data accuracy and calculating stability. In order to reduce computing expenses restrictions to the way optical flow calculated and processed may be imposed.

Important questions to be answered are:

– accuracy of calculations at a low image resolution;

– selection of an optical flow method for specific targets regarding the optimal parameters values;

– algorithms' construction where parameters can be adjusted depending on changing conditions.

The work paper set out to address the following tasks:

– calculation and interpretation of an optical flow using Lucas-Kanade method on pyramids of images given plain -parallel camera movement as well as movement under an angle;

– determination of how calculation accuracy depended on resulting values of algorithm parameters in various applications;

– identification of how all algorithms functioned together when a single task was performed in real time.

Results of researches

During VS creation the following two basic methods were used in order to determine relative movement on an optical flow:

– COTS technology in configuration of hardware and software parts of the system;

– the VS system was also formed as a component of information system of mobile devices, inside of which there was programmed an ability to integrate with local and global navigation.

A sparsed optical flow method has been used to achieve maximum efficiency and to decrease computing expenses. The optical flow is not applied throughout the picture, but only at feature points.

Any algorithm based on a sparsed optical flow method entails three stages:

– identification of feature points of the image;

– definition of the vectors where feature points are displaced;

– segmentation of the resulting vector field and its interpretation.

These stages would be called processing levels of initial visual data. Besides these traditional operations, the following algorithms were added: algorithms that allow selecting areas of interest in a video camera's view, algorithms that can statistically calculate statistical vectors' displacement and finally, algorithms that can automatically change the parameters of visual data inputs.

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The functions from OpenCV library were used to completely implement the low level of video data processing. An approach identifying feature points was selected in order to keep the system working in real time and also to be able to address any new issues at a low level from the known optical flow methods. There is a possibility of effective processing of image points by regions of interest. These regions are set by special masks (based on priority of information or as a result of analyzing images from previous video sequence) which are formed by algorithms of top level.

Let each point of the image be characterized by the function of intensity I (x, y). For the further combination angular points are then selected as feature points. Harris's [6] modified algorithm which reacts to angles is applied to their allocation. Angle in this case is a local distinctive area (location) of the image where the change of intensity function I is maximized simultaneously in both directions x and y. An equation for Harris's detector:

$$R_I(x,y) = \det(G(x,y)) - k(\mathrm{tr}(G(x,y)))^2 = \\ = \lambda_1\lambda_2 - k(\lambda_1+\lambda_2)^2. \quad (1)$$

Where G – covariance matrix of derivatives function I(x,y) (Hessian's functions I of second order):

$$G = \begin{vmatrix} \left(\frac{\partial I}{\partial x}\right) & \frac{\partial I}{\partial x}\frac{\partial I}{\partial y} \\ \frac{\partial I}{\partial x}\,\frac{\partial I}{\partial y} & \left(\frac{\partial I}{\partial y}\right)^2 \end{vmatrix}. \quad (2)$$

λ_i – Hessian own values, and k - empirical value is usually taken out from the interval [0.04, 0.06]. – R_I is called an angle sensitivity function. If its value is negative, then the found location is an edge; if its value is higher than the positively set threshold, then the location is an angle. Locations with positive values lower than the threshold are considered monotonous. Parameter k sets operator's sensitivity in that higher the parameter value, the fewer number of angles will be found. Derivatives (according to numerical methods) are in a vicinity of points; therefore high-frequency filtration has already been embedded in the algorithm. Local function maxima are picked out because several neighboring angle points yield maximum values for the angle sensitivity function R_I.

From now the definition of Gauss pyramid of images will be used. Gauss pyramid of images is a number of images with resolution consistently decreasing by 2. The initial image lays in the pyramid basis. The operation of images' combination calculates vectors fields that translate feature points of the first image into those of the second image. When optical flow is calculated in a traditional way, it would be ideal to compare all points of the image. However, not all points are unique, not all of them are feature points that could be exactly applied to the points from the second image, for example, points found in monotonous areas where brightness of image is the same. This is the reason why optical flow algorithm to such points is not applicable. For image combination, i.e. displacement vector identification, Lucas-Kanade method is used, where minimization condition states that vector displacement:

$$\vec{v}_{opt} \approx G^{-1}\vec{b}. \quad (3)$$

The formula (3), the basic formula of Lucas-Kanade optical flow, states that the vector which fully correlates a point of the first image to that of the second could be found with a margin error. To reduce the error the given method is applied iteratively, i.e. the found vector becomes an input parameter into the algorithm to produce a new more exact vector.

The process is repeated until the desired accuracy lever or number of iterations is achieved. Optical flow methods have an essential weakness: they can be applied at small (1-3 pixels) displacement of objects. In order for the algorithm to work with larger displacements, it is applied to the Gauss pyramid of the initial image. First, the vectors at the top level of the pyramid are calculated; the process is repeated until the margin of error sufficient for the application at lower level is reached.

These steps are performed for all levels. A vector of an optical flow is resulted at the final stage. This algorithm even given all its advantages has an essential drawback: small errors in calculations at top levels of the pyramid tend to accumulate and increase.

In the OpenCV implementation depending on flags, the pyramid of images can be constructed in advance, or the function of finding an optical flow would call it before the calculation begins. The size of a pyramid is chosen based on a rough estimate of visible plain-parallel displacement of an image (or from the prior information, or from a previously calculated vector). Two times as many displacements are found with every new level of a pyramid.

If the feature point of the first image appears closed on the second or falls out of the image area, there are two approaches to address this situation: either such point is marked as the one for which a conformity is not found or the algorithm would substitute the point with another with similar features to yield a false vector i.e. an optic flow vector that does not correspond to the true objects' movement on the scene. False vectors would be filtered at the next stage of the algorithm.

Depending on the application, vectors' filtration may be more challenging than the actual determination of optical flow. Undoubtedly, accuracy and stability of the solution for a specific task is depended on optical flow vectors' segmentation. Also at that stage an image comparisons in a camera objective (the so-called visible image) to the real movement of the camera (objects relevant to the camera) is made; and the resulting data would serve for subsequent calibration of algorithms.

At a described stage of research, the relative movements, in which the visible movement was either plain-parallel or the movement of camera's sensor plain under a constant angle to the surface's plain, were considered. Finding an average vector for an optical flow of such camera movement is not that difficult. It is the vector whose coordinates equal to the sum of corresponding coordinates of all vectors divided by the number of vectors (given corrections of camera movements under an angle).

The filtration of false vectors of optical flow is better conducted based on direction or length, keeping those, whose directions or lengths lay within the acceptable for the average vector's margin of error. The resulting filtration data could be used iteratively: first, find an average vector, then, reject vectors considerably deviating from the average vector's directions or lengths, finally, find a new average vector, reject, and reduce the error. Thus, the accuracy of average vector's calculation as it relates to the plain-parallel movement rises. Since restrictions to the camera movement are imposed a priory, comparing an average vector to the real world metric, movement parameters could be obtained.

Top-level algorithms set out the functionality for the system itself beginning from the visual data collection and ending with the results about a certain relative movement.

Conclusion

The initial a priori data for the algorithms are:

– location and characteristics of attainable visual fields (resolution, zoom, responsiveness of the visual data channels);

– location specifics and images' contours of the observed objects (in order to form masks and necessary resolution for the level of Gauss pyramid;

– possibility to obtain additional data about observed objects.

In this work paper it has been shown through a number of experiments that the rational use of well-known low-level optical flow algorithms could solve a wide range of tasks where an estimate of parameters of relative objects movement is needed .Thus, the following issues with the optical flow analysis have been addressed:

– big volume of processed data;

– texture variability (structure of a underlying surface);

– the errors in feature points correspondences.

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СИСТЕМА ТЕХНИЧЕСКОГО ЗРЕНИЯ ОТНОСИТЕЛЬНОЙ ОЦЕНКИ ДВИЖЕНИЯ В ОПТИЧЕСКОМ ПОТОКЕ

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Эта статья рассказывает о системах технического зрения, которые позволяют получать информацию об относительном движении объекта в режиме реального времени. Показано, что алгоритмы, необходимые для решения широкого круга практических задач по определению относительного движения могут быть получены на основе известных алгоритмов расчета оптических потоков. Работы в области оптического расчета потока были проведены на протяжении последних 30 лет. В последние десятилетия эти методы были использованы в широком кругу прикладных задач в связи с увеличением вычислительной мощности компьютеров и появление специализированных графических процессоров. Существует большое количество публикаций, которые были написаны на данную тему. Существуют также широко доступные библиотеки с открытым кодом, такие как OpenCV, LTI-Lib, VXL. Методы оптического потока оказываются полезными для сегментации изображений, а также для обнаружения препятствий от движущихся объектов.

Ключевые слова: робототехническое зрение, программный пакет, сегментация изображений, оптический поток.

СИСТЕМА ТЕХНІЧНОГО ЗОРУ ВІДНОСНОЇ ОЦІНКИ РУХУ В ОПТИЧНОМУ ПОТОЦІ

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Ця стаття розказує про системи технічного зору, які дозволяють одержувати інформацію про відносний рух об'єкту в режимі реального часу. Показано, що алгоритми необхідні для вирішення широкого круга практичних задач за визначенням відносного руху можуть бути одержані на основі відомих алгоритмів розрахунку оптичних потоків. Роботи в області оптичного розрахунку потоку були проведені на протязі останніх 30 років. В останні десятиріччя ці методи були використані в широкому крузі прикладних задач у зв'язку із збільшенням обчислювальної потужності комп'ютерів і появою спеціалізованих графічних процесорів. Існує велика кількість публікацій, які були написані на дану тему. Існують також широко доступні бібліотеки з відкритим кодом, такі як OpenCV, LTI-Lib, VXL. Методи оптичного потоку виявляються корисними для сегментації зображень, а також для виявлення перешкод від об'єктів, що рухаються.

Ключові слова: робототехнічний зір, програмний пакет, сегментація зображень, оптичний потік.

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