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Fast Object Tracking By a Repeated Centre Approximation Method Based On Chromatic Processing

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Abstract: - An object tracking algorithm is presented which is particularly fast, computationally simple, and works well with both simple and complex object shapes. It is highly modular and easily adaptable to various applications. It is based on chromatic modulation methods and takes into account non-uniform illumination and external light fluctuations. The tracking ability of the proposed algorithm was tested with a CCD-based remote monitoring system in a clinical environment.

Key-Words: - object tracking, image tracking, chromatic processing, vision systems

1. Introduction

Developing robust computer vision algorithms for real-world applications is a major challenge today and will continue to be one for a long time. Most of existing vision-based systems designed for daytime in the visible spectrum range are built upon fundamental blocks like object detection, tracking and classification.

Original tentative of the vision community has been focused mostly on the development of robust vision algorithms associated with visible range sensors, which among other research fields, have been extended into special areas like medicine and military. This increased interest level in visible spectrum imagery was due in part to the low cost of visible range sensors, high image resolution and low image noise. Image sensing devices with high dynamic range and high sensitivity have started to appear in a growing number of applications ranging from military and automotive domains to home and office security applications.

In order to develop robust and accurate vision-based systems, not only existing methods and algorithms for the visible range should be adapted, but also entirely new algorithms are certainly required.

Accurate object segmentation and tracking under the constraint of low computational complexity presents a challenge. The aim of this work is to find solutions that are robust, simple, computationally feasible, modular and easily adaptable to various applications. The proposed algorithm uses the method of image matching to initially find the location of the feature to be tracked and then looks for the feature's edges, based on chromaticity differences, and computes its center of chromaticity weight. It takes into account non-uniform illumination and external light fluctuations which result in chromatic measurement errors and uses noise minimisation methods to improve the resolution of the tracked object.

The algorithm was tested with a CCD-based remote monitoring system which was tracking the movement of a number of neonatal babies in a clinical environment.

2. Chromatic Processing

Chromatic processing can be considered to be a form of heavily truncated Gabor transform [1]. In the Gabor transform a signal is considered to be formed from the summation of a series of Gaussians, in the same way that the Fourier series considers a signal to be a summation of sinusoids. The Gaussian and non-orthogonal nature of the Gabor processors makes the approach more reliable and powerful for analyzing finite duration signals than various forms of the Fourier transform. Chromatic systems interpret complex signals by applying a number (normally two or three) of Gaussian integrators to the signal. Suitable algorithms derived from color science are then applied to the output from the Gaussian processors to assist in the understanding of the signal parameters.

The human color system is a specific example of chromatic processing. Light is observed by three broad-band detectors (the cones) covering the visible part of the optical spectrum. By combining information from these three detectors a large range of colors can be discriminated.

Chromatic changes can be monitored by a number (n) of detectors with overlapping spectral responses. The output of each detector may then be expressed as [2]:

$$V_n = \int P(\lambda) R_n(\lambda) d\lambda \qquad (1)$$

where P(λ) is the spectral power distribution in the optical signal and $R_n(\lambda)$ is the wavelength responsivity of the n^{th} detector and λ is the wavelength. The colour model representing this mathematical formalism is generally called RGB and it is widely used in self-luminous display technologies.

Each detector output may also be intensity normalised according to:

$$u_n = \frac{V_n}{\sum_n V_T} \qquad (2)$$

and chromaticity maps may be formed in terms of the coordinates u_1, u_2, … $u_{(n-1)}$ (u_n becomes redundant since $\sum_n u_T = 1$).

The special case of n=3 leads to a two-dimensional chromaticity map (u_1:u_2) on which changes in optical signals may be traced. The special case when $R_1(\lambda)$, $R_2(\lambda)$, $R_3(\lambda)$ correspond to the responsivities of the human eye leads to the chromaticity map reducing to the CIE diagram of colour science [3,4].

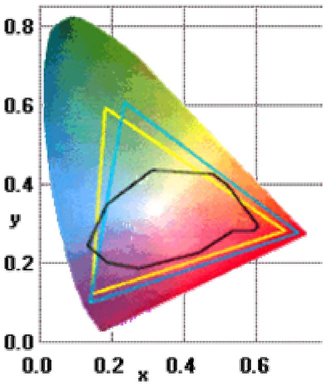

Fig. 1. The Lxy colour space

The colour model representing this mathematical formalism is called L_{XY} and provides the relative magnitudes of the tristimulus values (i.e. x=u_1; y=u_2; z=u_3). The Lxy colour space is shown in figure 1.

Although the above method of displaying chromatic information has proved the information compression capabilities of the chromatic approach, it does not easily lead to the identification of signal changes in terms of fundamental signal properties. An alternative approach to the processing of the signals from such chromatic detectors overcomes this limitation. For the tristimulus case (n=3) this approach utilizes three chromatic parameters, namely dominant wavelength (H), intensity (L) and degree of monochromaticity or spectral width (S) which are defined as follows:

$$H = 120\left[m_i + \left(\frac{V_i - V_{min}}{V_i + V_j - 2V_{min}}\right)\right] \qquad (3)$$

with m_i=0 for i=1, j=2, V_{min}=V_3,
with m_i=1 for i=2, j=3, V_{min}=V_1,
with m_i=2 for i=3, j=1, V_{min}=V_2

$$L = 100\left[\frac{V_{max} + V_{min}}{2}\right] \qquad (4)$$

$$S = 100\left[\frac{V_{max} - V_{min}}{200m_2 - m_3(V_{max} + V_{min})}\right] \qquad (5)$$

with m_2=0, m_3=-1 for L≤50 and m_2=m_3=1 for L>50. V_{min} and V_{max} are the minimum and maximum detector outputs.

For the special case of $R_n(\lambda)$ corresponding to the responsivities of the human eye, H, L and S become the Hue, Lightness and Saturation of colour science. The colour model representing this mathematical formalism is generally called HLS [5].

3. Experimental System

The remote monitoring system is computer based and is broken down into three distinct and important elements: a camera, a colour frame grabber card (C.F.G.), and a host personal computer.

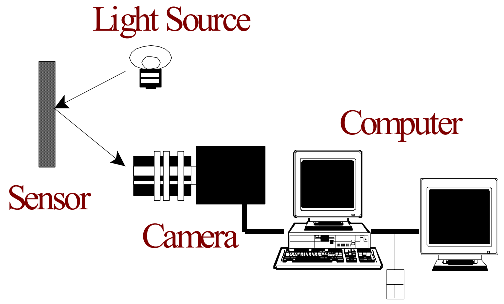

Fig. 2. Graphical illustration of the configuration of the remote monitoring system

The camera converts the spatially distributed optical information into analogue electric signals which are accepted by the colour frame grabber card (C.F.G.).

The signal is then digitised and stored in the card's frame memory. The C.F.G. card is the interface between the camera and the host personal computer which is used to access and programme the card's registers, frame memory, and buffers.

Figure 2 illustrates graphically the configuration of the system. Camera images were obtained with the remote monitoring system equipped with the VISIONplus AT CFG card and the PULNIX colour CCD camera. A white light source may be used depending on the application and the external lighting conditions.

4. Chromatic Calibration

The chromatic information received by the remote monitoring system depends on the lighting conditions of the surrounding environment. This means that the chromatic co-ordinates of an object under daylight conditions will be different than those under artificial light conditions. In the later case, alternative procedures are usually adopted and incorporated into the colour models of section II to allow for lightness adaptation.

The procedure presented in this paper is similar to the Von Kries transformation [6] with the difference being that instead of using a white colour (or greys of the same chromaticity) as a reference, any carefully selected colour can be used for the same purpose. In this procedure if a stimulus gives rise to the r,g, and b colour responses then the resulting responses will depend on r/r_c, g/g_c, b/b_c, where r_c, g_c, and b_c are the chromatic co-ordinates of the reference colour. For a stimulus in the state considered to have the same colour appearance as the same stimulus in a reference state it is necessary that:

$$\frac{r}{r_c} = \frac{r^{|}}{r^{|}_{c}}, \; \frac{g}{g_c} = \frac{g^{|}}{g^{|}_{c}}, \; \frac{b}{b_c} = \frac{b^{|}}{b^{|}_{c}} \qquad (6)$$

where $r^{|}_{c}$, $g^{|}_{c}$ and $b^{|}_{c}$ are the colour responses of the reference colour in the reference state. Hence

$$r^{|} = \left(\frac{r^{|}_{c}}{r_c}\right) r, \; g^{|} = \left(\frac{g^{|}_{c}}{g_c}\right) g, \; b^{|} = \left(\frac{b^{|}_{c}}{b_c}\right) b \qquad (7)$$

The resulting adapted variables $r^{|}$, $g^{|}$, $b^{|}$, obtained from (7), can then be used to calculate the L_{XY} tristimulus values as well as their HLS representation.

Hence, a calibration method for correcting the variations in RGB chromatic values was developed which concentrated on removing the RGB errors introduced by non-uniform illumination and external light fluctuations of the clinical environment. The algorithm for chromatic calibration was based upon the usage of reference chromatic values recorded under controlled laboratory lighting conditions, which in turn have been used as reference information for any further processing.

5. The Algorithm

After an image has been successfully segmented and objects of interest have been identified and represented, a tracking algorithm can be used to detect the movement of an object in the field of view. As the object of interest is already identified and located in the image frame, a tracking algorithm needs only to concentrate on the smaller object area. Unlike an object identification process, which is used only a few times in an application, an object tracking algorithm needs to continuously monitor the movement of an object in real time.

A particularly fast and at the same time computationally simple algorithm is then required to address these problems. The repeated centre approximation algorithm satisfies these conditions, works well with both simple and complex object shapes, and it is fast enough to allow real time tracking of an object.

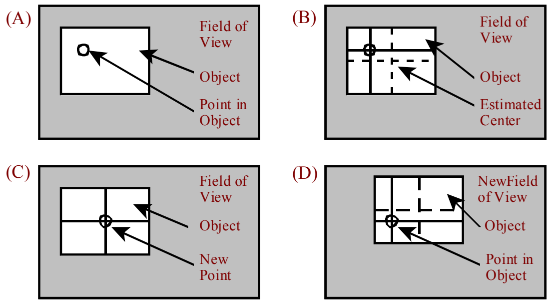

Fig. 3. Operation of the repeated centre approximation algorithm.

The chromaticity of the object to be tracked is assumed to be distinctly different from its background. This algorithm requires the coordinates of a point on the object to be tracked, which are provided by an object identification or description process, as shown in figure 3a. The chromatic coordinates of this point are evaluated and the method of chromatic calibration is performed to remove any chromatic measurement errors. The resulting chromatic values are then converted from the Lxy to the HLS color system. Starting from the position of this point, the algorithm uses a threshold value to locate the object boundary by scanning horizontally and vertically the image based on the Hue (H) objects property, as shown in figure 3b. The horizontal and vertical point distances from the boundary can be used to redefine the chromatic object centre, as shown if figure 3c. This method is then repeated with the newly evaluated chromatic centre coordinates as the starting point of the algorithm as shown in figure 3d.

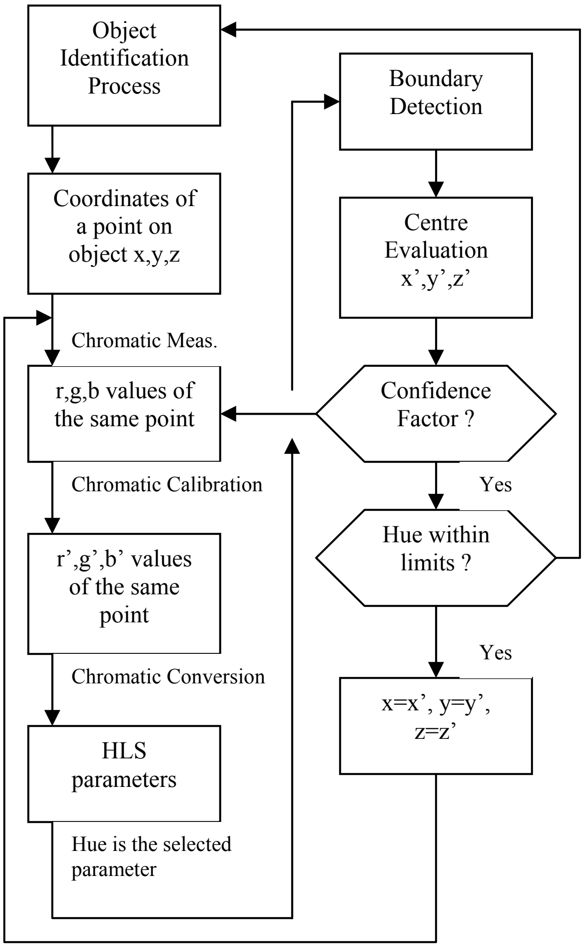

Fig. 4. Diagrammatic representation of the algorithm's operation.

Prior knowledge of the shape, texture and dimensions of an object can increase the execution speed of the repeated centre approximation algorithm and simplify its implementation. This is the case when a particular sensor element is to be tracked where shape, dimensions and color information are known parameters. In this case, a tracking confidence factor can be evaluated, defined as the ratio of the detected object attributes and the known object parameters. If the tracking confidence factor is below a preset threshold value then the chromatic measurement is rejected and reevaluated. Figure 4 shows graphically the operation of the proposed algorithm.

During the tracking process, the object's chromaticity may change above a preset threshold value and fall outside the tracking range. Then the object is said to be lost and the system has to restart the process of object identification to relocate it.

6. Improving Tracking

The proposed tracking algorithm may be further improved by using a number of digital filters as a pre-processing stage to this algorithm. Good candidate filters may include a de-interlace filter to allow a very fast moving object to be tracked and a gamma correction filter, adjusted to increase contrast around an objects boundary, to enhance the algorithmic process.

7. Conclusion

A fast object tracking algorithm is presented which is based on chromatic modulation techniques and it is best suited to daytime visible spectrum range applications. It is designed in such a way so it is easily adapted to a wide range of applications ranging from military and automotive domains to medical and security applications.

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