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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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M. A-Megeed Salem / B. Meffert

Wavelet-based Image Segmentation for Traffic Monitoring Systems

ABSTRACT

Multiresolution representation of images has gathered significant attention in recent years. In part this was due to its representation of the information encoded in an image in different scales and the simplification of the later processing. However, it has not been widely used for segmentation of time sequence images. In this work we introduce different variants of a multiresolution algorithm based on the 3D wavelet transform to extract the regions of moving objects. The 3D wavelet transform gives the advantage of considering the relevant spatial as well as temporal information of the movement.

1 INTRODUCTION

Since the appearance of the wavelet transform before two decades it has been used in many applications in signal processing. An early use of the wavelet was in image compression [2], feature extraction for the purpose of image indexing [7], and for medical image segmentation [5]. The use in video processing was in video coding and compression as well as in video transition [4]. However, its use for segmentation of frames in a video is scarce.

Image segmentation in traffic monitoring systems is the detection and isolation of the moving objects that take part in the current traffic situation. A reliable and efficient segmentation is needed to meet the requirements of the subsequent tracking and interpretation tasks. Because it has to work on a great volume of data, the guarantee of a high-speed response is a must for real time applications. In the case of traffic monitoring image segmentation is applied to a sequence of images that encode the traffic parameters and temporal information during a definite time period. The robust segmentation algorithm must utilize such information.

Toreyin *et al.* [8] proposed to use the 2D wavelet analysis to extract the region of interest (ROI). The work is based on a background subtraction, where generally a mask is created from the difference between the current traffic scene image and the estimated background image. The background is estimated based on the wavelet transform coefficients at the 3rd level. This work was chosen as a reference to compare our results with.

2 3D WAVELET-BASED SEGMENTATION

2.1 3D Wavelet Transform

The fast wavelet transform as introduced by Mallat [3] uses separable orthogonal basis functions, and therefore the multidimensional transform can be decomposed into a tensor product of orthogonal sub-spaces. The 3D scaling function and the 3D wavelet functions can be each expressed as a product of three one-dimensional functions. The smallest input to the 3D wavelet analysis is an octal data element which may has a cubic shape. Eight coefficients are the result. One coefficient contains the approximation a of the data in the input cube and other 7 detail coefficients $d^i, i = 1..7$. For the extraction of the ROI two detail coefficients are relevant, namely d^4 and d^7. The sub-band d^7 is computed by applying the wavelet function ψ on all the three axes x, y and z-axis. So it contains information about the possible changes along all the axes. The other sub-band d^4 is computed by applying the scaling function ϕ on the x and y axes and the wavelet ψ to the z-axis. It represents the change in time between the approximated spatial domains. In [6] we have proposed a 3D wavelet-based algorithm for the detection of moving objects in a traffic surveillance video. Moving object detection is based on extracting a mask for a group of frames. This mask represents the ROI in this group. The number of frames in a group depends on the level of the wavelet analysis. Previously we have used only the Haar wavelet. In this work we study the use of other Daubechies mother wavelets and we introduce an enhancement on the proposed algorithm in order to adapt the generated masks to the scene and the aimed application.

2.2 The Proposed Algorithm

The proposed algorithm consists of three parts. The first and main part is the analysis of the input image sequence by the 3D wavelet transform. As explained before, d^7 contains a great part of the motion information. But the extracted regions show only the borders of the motion. On the other hand d^4 shows the area where the movement occurred clearly but noisy. The combination of both sub-bands gave the best results for this purpose. The output of this step is a primary segmentation. The aim of the second part of the algorithm is to create a binary mask. This is done by thresholding the output of the wavelet analysis followed by a smoothing step using the median filter. For the following region growing step a morphological dilation is used. This part of the algorithm can be considered as a segmentation improving step. The masks are then used to extract the area of the active traffic for each frame of the sequence.

2.3 Testing Different Mother Wavelets

In this section we introduce the use of different mother wavelets among the family of Daubechies Wavelets. Daubechies discovered the first wavelet family of scale functions that are orthogonal and have compact support [1].

Haar wavelet ψ_{haar}, also known as the 1st Daubechies wavelet, is the basis of the simplest wavelet transforms. The associated filter is of length two. This means that the resulting approximation and details are all eighth the number of columns, rows and slices. For higher order Daubechies wavelets ψ_{dbN} the N denotes the order of the wavelet. The support length of ψ_{dbN} and ϕ_{dbN} is $2N-1$ and the length of the associated filter is double as the number of the vanishing moments, *i.e.* $2N$. If $n = length(s)$ where s is the given signal, then the approximation and detail coefficients are of length $floor(\frac{n-1}{2}) + N$. Because of the length of the filters the analysis is done overlapping with a stepwise shift. The detection of an event by higher order wavelets takes longer than that by lower order. Due to the overlapping the sharp edges are detected as wide events. This affects the segmentation negative by producing enlarged moving area. Results of ψ_{haar}, ψ_{db4} and ψ_{db8} are presented here.

2.4 Masks From Different Resolutions

To improve the results of the proposed algorithm, the generated masks from the 3 different levels are combined together. Five different combination strings are tested. The 1st combination string assigns a pixel to a ROI if the corresponding pixel in the 1st level's mask belongs to the ROI and if any of the corresponding pixels in the 2nd or 3rd levels' masks belongs to the ROI too. This string gives the results of the 1st level of the analysis a dominant rule in the combination with the other levels. The 2nd and 3rd combination strings give the results of the 2nd and 3rd levels the dominant rules, respectively. The 4th combination string combines simply all the masks by an or-operator. The 5th combination string uses the and-operator for all masks.

3 EXPERMINTAL RESULTS

Many data sets were captured using a stationary video camera. The data sets can be categorized into three groups: 1) a front view with small camera observation angle to a street, 2) varying lighting conditions 3) wide view of a crossing, with many types of traffic. The results have a lower resolution than the original images, depending on the algorithm and the tested data set. In all cases a projection of the segmented images to a higher resolution image is done after the running of the algorithms. So, the extracted ROI is shown in the original resolution of the input image.

For statistics and a better visualization the results are given in form of bounding boxes. The error can be measured as 1) ratio of the boxes that contain no objects related to the total number of extracted boxes (false alarm). 2) number of objects that are not contained in any box (missed objects) and 3) number of objects that are delayed to be detected related to the total number of objects in the sequence.

Table 1 shows the results at each level for the 3D wavelet-based algorithms in terms of extracted boxes against the results of the 2D wavelet-based segmentation proposed by [8]. The main features of the results of [8]: The algorithm is sensitive to changing in light conditions, was not able to detect a new object as soon as it appears, it needs much time for a stable estimation of the background, and tends to miss more objects for a scene with slow motion. Figure 1(a) shows a sample of the results.

For some data set the results of the 3D wavelet-based algorithm show perfect detection of the objects from the first appearance. Generally, the extracted ROI is larger than the object if the level of the analysis increases. Therefore, the error measures decrease as the level of the analysis increases. However, the results are much better than those obtained by the 2D wavelet-based algorithm specially for the problem of the movement of the trees in the background as shown in Figure 1(b).

Two data sets were used to test the performance of the different mother wavelets. This is done because of the stable lighting conditions, the homogeneity of the background, and the simplicity of the scenes in this category. As displayed in Table 2 the

Table 1: Results of all methods

Method	**F**alse alarms		**B**ounding boxes	**M**issed objects	**D**elay detections
2D Seg	521	43,5%	1198	23,5%	7,9%
3D Seg Msk1	27	3,8%	711	10,3%	5,9%
3D Seg Msk2	153	17,2%	890	3,0%	0,3%
3D Seg Msk3	185	24,3%	762	2,8%	1,4%
CombMsks 1	49	7,1%	690	10,7%	7,2%
CombMsks 2	112	16,5%	679	5,9%	3,5%
CombMsks 3	112	18,0%	622	9,5%	6,2%
CombMsks (OR)	242	34,7%	697	0,6%	0,4%
CombMsks (AND)	40	6,5%	614	17,0%	13,3%

(a) (b) (c) (d)

Figure 1: Results of the 2D, 3D wavelet-based algorithm and the proposed enhancements

number of the extracted bounding boxes as well as the number of false alarms are increased dramatically. We refer that to the increase of the length of the filters and the overlapped analysis. Moreover, there were delayed detected objects by the results of DB4 3rd level for both test sets. Computationally, as the length of the filters increases, the complexity of the analysis also increases.

The highest rate of false alarms of 35% is found to be generated by the results of the 4th combination string. However, it gives the best results in terms of missed objects and delayed detection. The main problem with this combination scheme is that the extracted ROI is too big considering the moving objects themselves as shown in Figure 1(c). In contrast are the results of the 5th combination string. The false alarm rate is very low but the missed objects and delayed detections score very high.

The results of the other combination strings are found to enhance the results obtained by single level analysis. They are all better in terms of false alarms compared to the results of the 2nd and 3rd levels of the 3D wavelet-based algorithm. Figure 1(d) shows the same frame as in Figure 1(b), one false alarm was removed.

Table 2: Results of DB1, DB4 and DB8 for the first and second data sets in terms of extracted boxes

No.	**M**ethod	**B**ounding boxes	**F**alse alarms		**M**issed objects		**D**elay detections	
1	DB1-Lvl1	14	2	14,3%	0	0,0%	0	0,0%
	DB1-Lvl2	20	5	25,0%	0	0,0%	0	0,0%
	DB4-Lvl1	24	11	45,8%	0	0,0%	0	0,0%
	DB4-Lvl2	36	25	69,4%	2	15,4%	2	15,4%
	DB8-Lvl1	22	9	40,9%	0	0,0%	0	0,0%
	DB8-Lvl2	24	11	45,8%	0	0,0%	0	0,0%
2	DB1-Lvl1	12	1	8,3%	0	0,0%	0	0,0%
	DB1-Lvl2	16	5	31,3%	0	0,0%	0	0,0%
	DB1-Lvl3	16	5	31,3%	0	0,0%	0	0,0%
	DB4-Lvl1	22	10	45,5%	0	0,0%	0	0,0%
	DB4-Lvl2	36	24	66,7%	0	0,0%	0	0,0%
	DB4-Lvl3	32	24	75,0%	3	27,3%	3	27,3%
	DB8-Lvl1	22	11	50,0%	0	0,0%	0	0,0%
	DB8-Lvl2	28	19	67,9%	0	0,0%	0	0,0%
	DB8-Lvl3	32	21	65,6%	0	0,0%	0	0,0%

4 DISCUSSIONS AND CONCLUSION

The 3D wavelet-based algorithm is more reliable to detect objects entering the scene than the 2D wavelet-based algorithm. The detection of the moving objects takes place from the 1st group of frames. In contrast to the conventional background update algorithms, the proposed algorithm needs no time to adapt itself to the image sequence. Because of the longer observation interval it can be supposed that the use of lower resolution levels helps in the detection of objects that stop for a short time and then move again.

The use of Haar wavelet gave better results than those of DB4 and DB8. It is computationally very simple and can be implemented efficiently on hardware.

Generally the results obtained from the 2nd combination string gave the best compromise considering all error measures.

A main advantage of the multiresolution algorithms is that the processing is done in a lower spatial resolution than that of the input images. The size of the low resolution images is much smaller and the computational complexity is reduced. With a simple projection or mapping step the results return to the resolution of the input images.

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