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Igor Vujović

Multiresolution Approach to Processing Images for Different Applications

Interaction of Lower Processing with Higher Vision

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Preface

When I was invited to deliver a speech on the presented topic at the 8th International Conference on Advanced Computational Engineering and Experiment (ACE-X 2015) in Paris, I had my doubts as to whether and how I could make this topic interesting to the entire audience, rather than only to a couple of scientists. In the times of budget cuts and reduced investment in science (in Croatia at least), what could I offer that would be interesting to all listeners? The presentation should be interesting, informative, and understandable to the audience consisting of specialists from a variety of technical research fields. That excludes mathematical considerations, equations, theorems, and the like. My benchmark was a comment of my coworker who said that I do not need to present and compare state-of-the-art narrow topics, but offer a broader perspective on our research. The audience would like to hear what we are doing, what we have done, and what the options for further research are. The conclusion was that an overview of the current and previous research of our team could give a wider, interesting perspective to the entire audience.

The book covers several research fields studied by me and my coworkers from the Faculty of Maritime Studies, University of Split. We are making headway in all these areas and expect to get some new results soon. Some results presented here are preliminaries and need to be confirmed in the future. Research fields include:

1. video surveillance,
2. biomedical applications,
3. improved communications through teleoperation, telemedicine, animation, augmented/virtual reality, and robot vision,
4. monitoring of the condition of a ship's systems and image quality control.

The field of video surveillance includes the impact of weather conditions on the system's performance, security and safety applications, traffic monitoring and control, outdoor, indoor, and similar applications. Since image processing is of key importance here, this research filed deals not only with all other aspects of low-level image processing, but high-level vision applications as well. This research field is not surprising since I am a maritime faculty employee and we, among other things, also study maritime transportation.

The research field of biomedical applications was mostly based on image processing until 2014. It included the diagnosis of occupational asbestosis by X-ray images and visualization of anomalies in medical images. This part of research was conducted in cooperation with my colleges from the Faculty of Electrical Engineering and Computing and School of Medicine at our University. We started to analyze electromyographic (EMG) signals in 2014, which are not images, but recordings of the brain's electrical signals. This research field is of interest to maritime experts because EMG can help determine the influence of long contracts on the mental health of seafarers.

The most interesting research field is improved communications due to the strong phrases used, but it is harder for experimentation due to funding difficulties. In this research, we collaborated with faculties of electrical engineering and computing.

Although there is no obvious connection between the research fields of condition monitoring and image quality control, we found it in materials as parts of maintenance, degradation research, and aging studies. We are monitoring ship vibrations to determine their possible impact on various ship systems like steering systems. Vibrations can result in false readings and could have considerable impact on the durability of different elements of ship systems.

Integral transforms in signal processing are the background to all applications. I intentionally started with research fields, because signal processing is not interesting to the wider audience. The actual task my team is working on is signal processing. The character of the signals—depends on the application.

In this book, I will try to present some aspects of each research field.

I would like to thank prof. Fabiana Rodrigues Leta for inviting me on such a wonderful voyage of exploration of the interesting and new world of science. It is evident from this book that many applications are interconnected through similar or even same algorithms, models, background, math, or even line of thinking.

I would like to thank prof. Andreas Oechsner for his assistance with Springer.

I would also like to thank my colleague prof. Ivica Kuzmanić, who recommended me to prof. Leta, and Joško Šoda (senior lecturer and research associate) whose constructive comments and advice about the speech and the presentation were most helpful.

Acknowledgments

I would like to thank prof. Fabiana Rodrigues Leta for inviting me to deliver a speech on this subject. Without it, this book would never happen.

I would like to thank prof. Andreas Oechsner for assistance with Springer. He is the main organizer of the conference series—International Conference on Advanced Computational Engineering and Experiment (ACE-X).

I would also like to thank my colleague prof. Ivica Kuzmanić, who recommended me to prof. Leta and Joško Šoda (senior lecturer and research associate) whose constructive comments and advice on the speech and the presentation were most helpful.

I would also like to thank the reviewers who have shown understanding while assessing this work.

The equipment used in this research was partly obtained by different projects at the University of Split, Faculty of Maritime Studies, and particularly by the scientific research project no. 250-2502209-2364 and the international research project "The possibilities of reducing pollutant emissions from ships in the Montenegrin and Croatian Adriatic implementing Annex VI of MARPOL Convention" supported by the Ministry of Science, Education and Sport of the Republic of Croatia.

Contents

Abbreviations

2D-DWT	Two-dimensional Discrete Wavelet Transform
ANN	Artificial Neural Network
CAD	Computer-aided Diagnostics
CCD	Charge Coupled Device
CR	Compression Ratio
DOF	Degree of Freedom
DWT	Discrete Wavelet Transform
EDF	European Data Format
EM	Energy Measure
EMD	Empirical Mode Decomposition
EMG	Electromyographic
FT	Fourier Transform
HF	High Frequency
IWT	Inverse Wavelet Transform
LF	Low Frequency
LWT	Lifting Wavelet Transform
NNC	Neural Network Classifier
PCC	Percentage of Correct Classifications
ROI	Region of Interest
SAR	Synthetic Aperture Radar
SGW	Second Generation Wavelets
SHM	Structural Health Monitoring
STFT	Short-term Fourier transform
USCGC	United States Coast Guard Cutter
WE	Wavelet Energy
WT	Wavelet Transform

Abstract

Nowadays, computers are expected to perform complex tasks involving the processing of huge amounts of data. People are often unaware that such intensive operations are required in computer vision tasks. Different phenomena related to pixel/voxel or global size can cause failure of higher vision applications. Such phenomena include illumination variations, noise, camera jitter, shadows, visibility, weather conditions, etc. This paper analyzes the influence of lower vision tasks (e.g., denoising or thresholding) on higher vision tasks (e.g., motion segmentation or product quality). The interaction between lower and higher vision is illustrated with examples of visual quality control and advanced visualization in marine communications used to decrease the stress felt by seafarers due to their separation from their families.

Chapter 1
Introduction

Abstract Application of the image processing is popular due to the fact that cameras are widely used sensors in automated systems nowadays. Motivation for the book is found in the research examples and explained in the introduction. This chapter presents an introduction to the book contents. Organization of the book is presented.

Keywords Image processing applications · Data visualization · Wavelets · Multiresolution approach

Due to rapid technological development, and especially the development of sensor technology and computational power, a huge number of automated systems is being developed and installed. Their purpose is to make our everyday lives easier. Cameras are some of the most widely used sensors in automated systems. Fields like medicine and engineering are almost unimaginable without cameras. For example, nowadays, surgeries are performed using cameras, allowing the surgeon either to see what he is doing, or to transmit information over the Internet, or as a diagnostic tooldiagnostic tool. Surveillance applications are also very important and widely used, for example in traffic surveillance or to secure an area or a building, as well as in computer vision applications in the automated production industry and quality control systems. Since cameras obviously necessitate the processing of huge amounts of information, image processing is a rapidly growing field. The main purpose of image processing is to reliably collect and send information, e.g. by video stream or images, from source to destination. Above all, there is a need to transmit information in real time. Many different techniques and methods plagued by problems are used to process image information. One of the problems that have to be resolved is the problem of illumination variations. If this issue is not resolved, many serious problems pertaining to the reliability of the built systems, which could lead into potentially hazardous situations, could arise. For example, one can make an incorrect medical diagnosis due to the bad performance of lower vision algorithms. In order to resolve this problem, some transformation has to be used.

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This book presents an overview of wavelet approach to various problems in image processing and data visualization. A modern approach to solving the problem of illumination variations by using the time-frequency analysis method known as wavelet transform (WT) is presented. It is discussed how lower vision processing influences higher vision applications.

This book is organized as follows:

Chapter 2 deals with the concept of interaction between the efficiency of lower vision and the results at the higher level of visual applications.

Different approaches to WT realization (as an example of integral transforms) are explained in the Chap. 3. This chapter includes basic concepts and an explanation of the multiresolution idea.

The first research field presented is visual quality control. Literature overview is presented in the first section of the Chap. 4. The second part gives an experimental example of the multiresolution approach to visual quality control. Finally, the visualization of material properties is mentioned in the third section of the Chap. 4. Particularly, it states our current research topic and future development. To be more concrete, we deal with properties of the relative dielectric constant, which is important in many areas of electrical engineering, from selection of materials to communications.

Augmented and virtual realities, as parts of another research field studied by our research group are explained and some preliminaries presented in the Chap. 5. In the first section, an example of animated world is presented for security and terrorist attack detection purposes. The second section covers the issue of the health of mariners and how it could be improved by advanced communication technologies. It is difficult to predict how mariners will communicate in the future and the impact of such future communication on their mental health. There is no doubt that bleeding-edge communication technologies will have major influence on their way of life.

The most comprehensive part of our research are biomedical applications. It includes computer aided diagnostics and the role of multiresolution analysis in medical signal processing. It covers some aspects of medical imaging and EMG research. I hope I cut the presentation of this topic to reasonable measure. A multiresolution approach to EMG analysis is presented in the first section of Chap. 6. The second section deals with computer-aided diagnostics explained on an example of occupational asbestosis. The first subsection covers pulmonary X-ray compression and the influence of compression on the reliability of medical diagnostics. The second subsection deals with the visualization of asbestos infected areas intended to help medical doctors and radiologists to observe suspicious areas and determine correct diagnosis.

Multiresolution approach to different video surveillance applications is presented in Chap. 7. The first section presents experimental examples in indoor cases, and the second section in outdoor cases. The indoor examples covered in the section are robot vision and human motion detection.

Finally, the last chapter presents the conclusions.

Chapter 2
Interaction of Lower and Higher Vision Applications

Abstract In this chapter, an interaction between the lower vision application performance and the higher vision application performance is explained.

Keywords Low level vision operations · High level vision operations · Interaction · Positive feedback · Negative feedback

Figure 2.1 illustrates the interaction between lower and higher vision applications at the symbolic level. Although lower vision operations do not change the spatial size of data, they can change the color map or switch color image to gray image, which should downsize the total quantity of data.

After image acquisition, the data is entered into the image matrix. After the performance of any image processing operation (low-vision application), data remains organized in the matrix form. After lower processing, the image matrix is subjected to image analysis (high-vision application). A high-vision application yields information, which could take the form of complex data, structured data, char data or some other complex data.

There is interaction between lower and higher vision applications. Information obtained by higher vision applications can be used to narrow the area of search in the case of tracking operations. This is an example of positive feedback.

However, if a lower vision application operates badly, due to e.g. illumination variations, and produces e.g. bad segmentation, the tracker will perform worse than if segmentation was properly made. This may result in the detection of greater or smaller number of targets that there are in reality, or lead to wrong identification of targets and confusion of noise with targets.

This concept can be reduced to 1D case, for example, if electrical voltage over time is analyzed or if vibration signal of turning machine [53] is used as a diagnostic tool. In such a case, data processing results can impact reliability of the data analysis, which is higher level. In the data analysis, someone reaches the conclusions about the input data set. This conclusion can be a state, a word, a number, or anything else with smaller amount of data than the input data set. For example, we can reach the conclusions about monotonity of the function by examining time change of the function.

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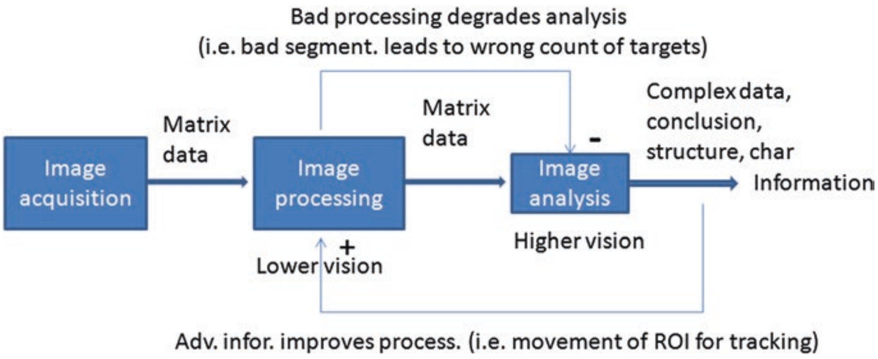

Fig. 2.1 Negative and positive influence to lower and higher vision

Generally speaking, there are a negative and a positive influence of the lower data (image) processing to the performance of the higher level applications. If the low level application (algorithm or function) operates within desired parameters, than such low level application will influence the performance of the higher level application in positive manner.

It has to be noted that higher level application can send a feedback to lower level application. The higher vision application can influence the performance of the lower level application by a positive or a negative feedback. If the higher level application operates outside desired parameters, than the negative feedback can "disorient" the lower level application. However, if the higher level application operates within the desired parameters, than the information from the higher level can improve the performance of the low level application, for example, by reducing the data set that should be taken into account by the lower level application, and, hence, increase the execution speed. This is of vital importance in online applications.

Such interaction between lower and higher level applications is important in any application, including applications based on the multiresolution approach.

Chapter 3
Multiresolution Approaches in Image Processing

Abstract This chapter explains a multiresolution approach to the image processing. Several transforms are mentioned, which can be used in the multiresolution approach. Wavelets are compared with Fourier transform, and short-term Fourier transform. Wavelet implementation issues are presented. Wavelet analysis is illustrated by an experimental example.

Keywords Wavelet · Multiresolution approach · Pyramidal implementation · Lifting implementation · Subband coding

The multiresolution approach does not only involve the repeated use of the same transform, but also the change of resolution with acceptable data loss. The multiresolution approach is usually considered to be a WT. Indeed, no one uses FT for the multiresolution approach due to the loss of the time and frequency data. However, short-term Fourier transform (STFT) can be used in the multiresolution approach to analyze non-stationary signals, such as vibration signals. In recent years, many new transformations have been proposed, e.g.:

- bandelets [54],
- complex WT [57],
- contourlets [14–17],
- curvelets [7–13],
- edgelets [1–3],
- ridgelets [55].
- shapelets [4–6],
- wedgelets [56], etc.

They are all inspired by the WT and modified to fit specific problems. All of them are intended to be used in the multiresolution approach. The common differences between wavelets and new transforms are the angle of details or filter definitions. Basically, by considering WT, we can cover all of them since some transforms are better suited for specific problems.

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There are three approaches to wavelet implementation [18–23]:

- pyramidal,
- subband coding, and
- lifting.

In the pyramidal approach, data is averaged with the neighboring data by the weighting function. The correlation of the signal with the weighting function reduces the resolution of the signal.

The point of subband coding is the division of the signal spectrum into independent subbands. Signals in subbands are treated individually for different purposes. Two-band filter bank is used for LF and HF band.

In lifting, the original signal is split in odd and even samples. The lifting scheme consists of repeated steps:

- split,
- predict, and
- update.

E.g. if Haar wavelet is implemented by lifting, the average of even and odd data has the role of approximation in subband coding. The difference of even and odd data has the role of details in subband coding.

Figure 3.1 illustrates the abovementioned concepts. Figure 3.1a illustrates the concept of the pyramidal scheme. It should be noted that downsampling process reduces the descriptive data by factor 2 in most cases. Figure 3.1b shows the concept of the subband coding. Figure 3.1c presents the lifting concept.

WT is a time-frequency technique for signal analysis. The "multiresolution" technique performs better than FT analysis for non-stationary signals, because both time and frequency information are preserved. In a way, WT is an optimized sampling. STFT oversamples the object of interest based on the Nyquist sampling theorem.

WT alters the window to overcome resolution problems. In doing so, a good temporal resolution and bad frequency resolution are obtained at HF. Good frequency

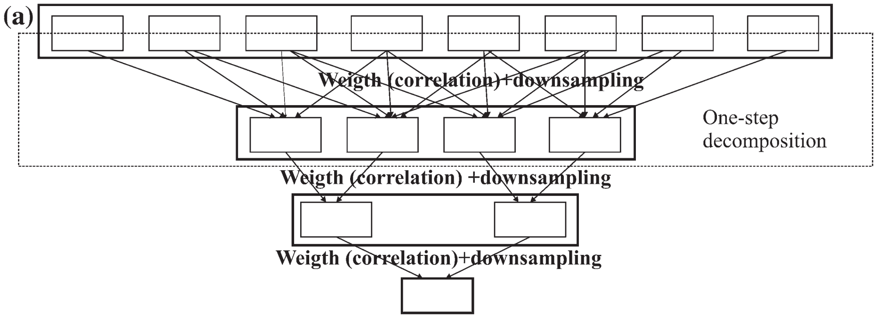

Fig. 3.1 Wavelet implementation: **a** pyramidal scheme, **b** subband coding scheme, **c** lifting scheme

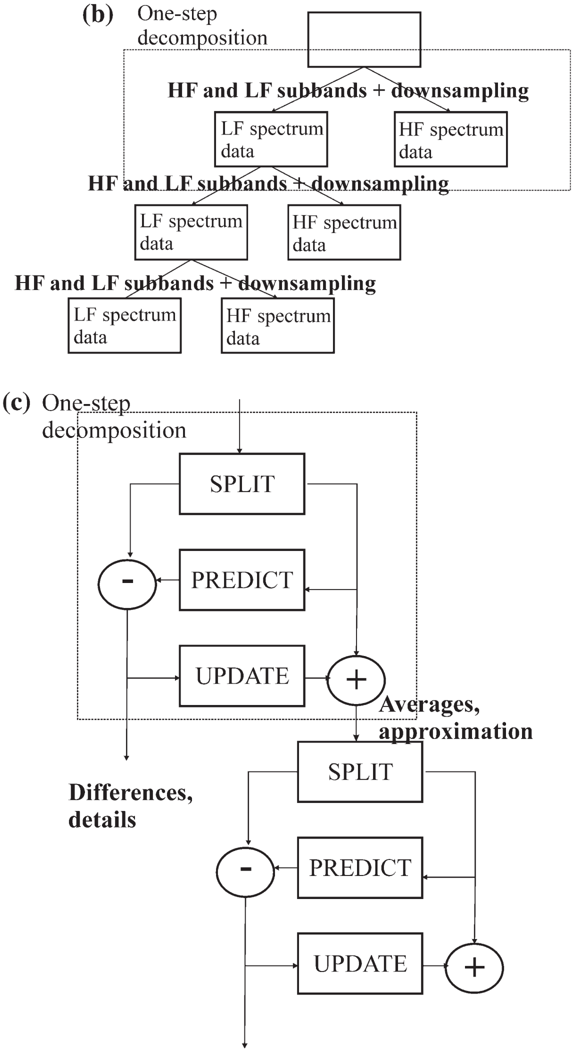

Fig. 3.1 (continued)

and bad temporal resolution are obtained at LF. However, the Heisenberg principle remains intact.

The multiresolution approach is covered in many references, including everything from mathematical approaches to different applications [24–27].

Figure 3.2 shows an example of wavelet decomposition by WT. In the first stage, the image is decomposed into:

- approximation (LL1), and
- details in horizontal (LH1) direction,

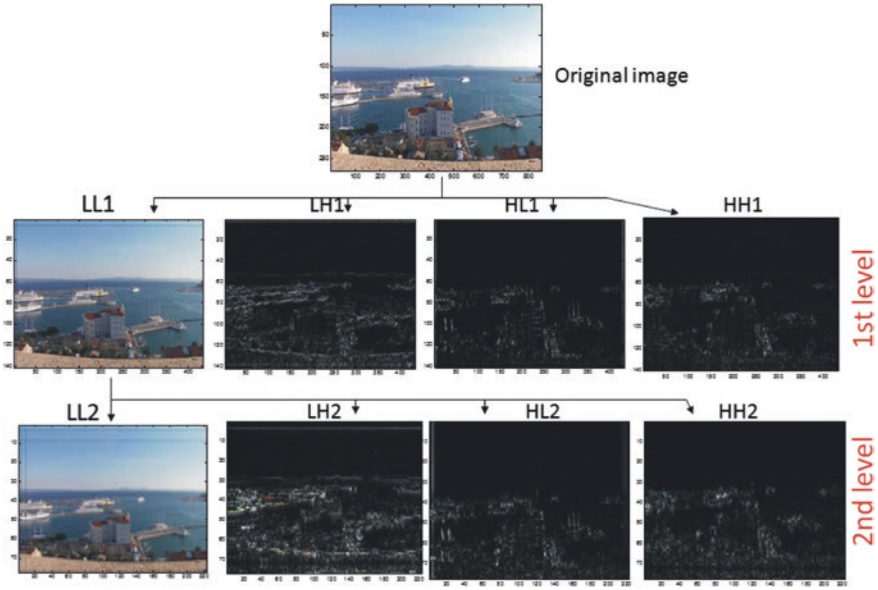

Fig. 3.2 An example of multiresolution approach—decomposition at two levels

- details in vertical (HL1) direction, and
- details in diagonal (HH1) direction.

Then, the approximation is decomposed further to obtain approximation and details at the second level of decomposition. Further decomposing of the approximation coefficients (LL1) produce split of the lower half band into four ranges that are:

- approximation of the approximation (LL1) from the first level (LL2),
- details in horizontal (LH2) direction from the fist level approximation (LL1),
- details in vertical (HL1) direction obtained by the decomposition of the approximation at the fist level (LL1), and
- details in diagonal (HH1) direction obtained by the decomposition of the approximation at the fist level (LL1).

At every level, the amount of data to be analyzed is reduced. It can be seen that human eyes, at first sight, cannot determine the difference between the original image, LL1 (which has a half of the rows and half of the columns of the original image) and LL2 (which has a half of the rows and half of the columns of the approximation image, LL1). See Fig. 3.2 once again.

Figure 3.3 shows how even the superresolution problem can be seen as an inverse transform problem, for example inverse WT (IWT). In this case, details (details coefficient matrix, to be exact) are obtained by a noise model and the simplest way is to set details to zero, which means that the assumption is that there is no noise. Hence, the "superresolved" image appears darker. This is not a real superresolution, but it can be called a quasi-superresolution, hence there are no

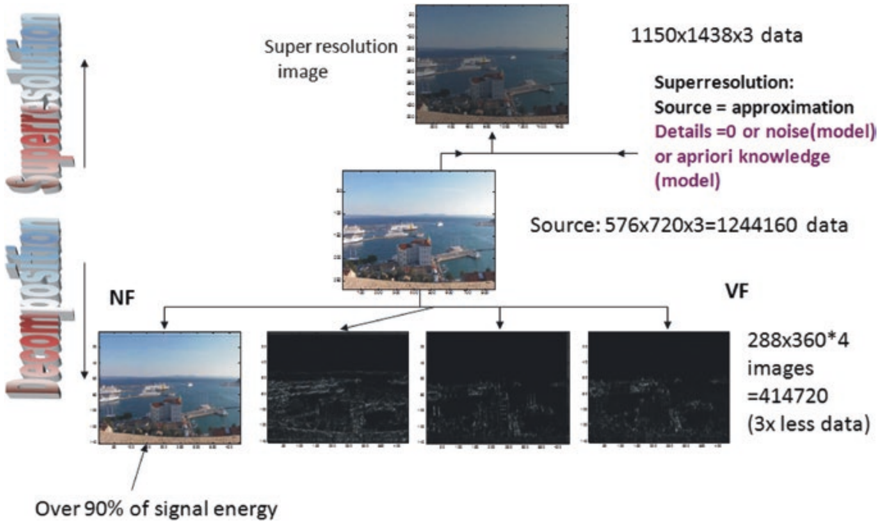

Fig. 3.3 Similarity of problem of superresolution by WT and IDWT

two or more low-resolution images which could be used as source for the high resolution image. Quasi superresolution is defined in several research papers of our team [69, 70].

Additionally, the source image is used as the approximation (approximation coefficients matrix, to be exact). Brightness and sharpness of the superresolved image depend on noise/details model/prediction.

Problem of decomposition by an integral transformation or a problem of a synthesis is in the multiresolution approach the same, just moving in opposite direction.

Multiresolution approach owns its popularity to such flexibility. Additional point in the flexibility is a fact that over 90 % of all signal’s energy is contained in the approximation coefficients. Hence, in many applications is possible to reduce amount of data, not just by downsampling, but also by even totally neglecting the details coefficients (details are usually noise, although, in some cases, can contain a useful information).

The multiresolution approach can be used in 1D signals. At the low resolution, the entire signal is examined. At the high resolution, the chosen parts of interest are examined in details. For example, one can detect small surges, which should be analyzed and increase the resolution in small time intervals when the surges occur.

This book mostly deals with the multiresolution approach in case of images. This approach will be presented at the examples from researches of our team in following chapters.

Chapter 4
Visual Quality Control

Abstract Quality control is an interesting topic in signal processing. This chapter deals with quality control with a camera input to the algorithm. A literature overview is given. It is presented how the multiresolution can be used in this application. The last section explains how to use visualization techniques in dielectric material's properties analysis.

Keywords Energy measure · Normalized wavelet approximations · Noise · Material's properties visualization · Relative dielectric constant

In this chapter, I will present a literature overview of the visual quality control systems, with the accent to the multiresolution approach. It is presented that there are not a lot of researches with the particular application of the multiresolution approach or, specifically, wavelet applications.

The second section presents the research of my research team in this field. Finally, some directions for further research are presented in the last section.

The constant of this chapter is in the research of material's influence to the final results. The final results are obtained by the multiresolution approach. Wavelets were used in the presented cases.

4.1 Literature Overview

An interesting application of computer vision is the development of automated visual control quality systems. There are references about this topic. For example, visual inspection of wire bonding is described in [28]. The authors wanted to improve computer vision technique to be at least as good as human perception. Visual inspection of metal parts was reported in [29]. This system recognized several possible defects through an image analysis algorithm. A vision system for plank tracing in sawmills is presented in [30]. The system uses cross-correlation in phase in the FT domain. Matlab was the test software. Visual quality inspection

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in cast iron production is elaborated in [31]. Machine learning methods were implemented and compared. An intelligent vision system for ceramic tile industry was proposed in [32]. The intelligent part of the system is included by neural network classifier (NNC). The surrogate feature vector is introduced in [33], in which wavelet multiresolution properties were successfully combined with discriminative properties of Zernike moments. However, this approach also uses NNC. It was reported that 192 instead of 256 moments were sufficient and more efficient for different robot vision and visual quality control applications. However, only the Haar wavelet was used. Structural damage health monitoring performed by image processing is presented in [34]. Displacement of control points was estimated by the optical flow method. Another civil engineering problem solved by image processing is facilitation with the estimation of damage caused by natural disasters [35]. It was performed by detecting changes on satellite images.

The Empirical Mode Decomposition (EMD)-based Wavelet damage detection method was developed for damage detection (both time and location of damage) [36]. In the same dissertation, the wavelet-energy (WE) based system identification method was developed. WE is used to identify physical parameters of the structure. Surface failures on ceramic tiles were investigated in [37].

DWT was used in preprocessing and ANN for the detection of surface defects. A defect detection computer vision system is presented in [38]. It quantifies different types of ceramic tile defects. It was tested in industry. An integrated quality control industrial system is presented in [39].

3D was obtained by monochrome single camera and 6 DOF robot mounted laser scanner probe device. The approach is not, however, mulitresolutional. Surface roughness metrology is presented in [40]. It is based on high quality images and complex wavelets used for machine components, improving corrosion resistance, creep life, fatigue strength and other factors.

Structural health monitoring (SHM) in civil engineering can be performed by a visual system, as in [41]. Displacement fields were calculated by the so called image correlation coefficient.

This literature overview shows the diversity of applications of computer vision-based quality control systems. The next section shows an example of the multiresolution approach to a visual quality control. This example is based on the wavelet multiresolution approach.

4.2 Example of Multiresolution Approach to Visual Quality Control

There are several points at which the multiresolution approach can be introduced into visual quality control.

The first is the use of the transformed domain to reduce the amount of data to be analyzed by other means.

The second frequent use of the visual quality algorithm is in data (images) preprocessing, e.g. denoising (prefiltering).

The third is the use of the transformed domain for feature extraction, leading to image analysis (higher vision application).

The natural extension is the combination of a low-vision application (filtering) with a high vision application (feature extraction which leads to the final conclusion). Although the use of the transformed domain is mystified to an extent, it is basically performed to facilitate the task.

Figure 4.1 illustrates the influence of external conditions on image quality. Figure 4.1a shows the image of a product. Figure 4.1b shows the same product under non-uniform illumination variations. Figure 4.1c is an attempt to visualize only illuminations, which can be considered as a type of noise. The results of visual quality control can be assumed to vary depending on the level of the illumination variations.

Wavelets were observed to increase the tolerance of visual quality control systems to error. As experimentally verified in [42], in the original image, tolerance to error is only 1 %. As shown, the used wavelets are best suited for speckle noise.

The results [42] mean that the image of a product can be changed by as many as 25 % (in case of speckle noise) without influencing the correctness of product classification (for possible removal).

In order to evaluate and obtain the above mentioned results, energy measure (*EM*) is introduced in [43]:

$$EM = \frac{1}{N}\sum_{i}\sum_{j}\sum_{k} a(i,j,k)^2 \tag{4.1}$$

where:

- *EM* designates the energy measure,
- *N* the number of pixels in the ROI for the considered level of decomposition,
- *i* and *j* spatial coordinates of the pixel for which *a* is energy, and
- k the color designation (red 1, green 2, and blue 3).

Therefore, *a*(*i, j, k*) is the energy of the pixel contained in the *k*th color calculated in Hilbert space (wavelet domain). Energy measure is used as a number for comparison of energies of damaged and undamaged ROIs. EM is calculated in Hilbert space using Parseval relation [43]. The calculated energy is divided by the number of coefficients in the ROI.

Possible computer vision algorithm problems are: edge detection, color conversation for edge detection purposes, ROI shape modeling, ROI recognition, ROI analysis with conclusions about quality, image measurements, etc. Since, this is not a self-learning method, it greatly depends on the reference model. If there is a new product, an anomaly cannot be detected if the desired image is not already in the memory.

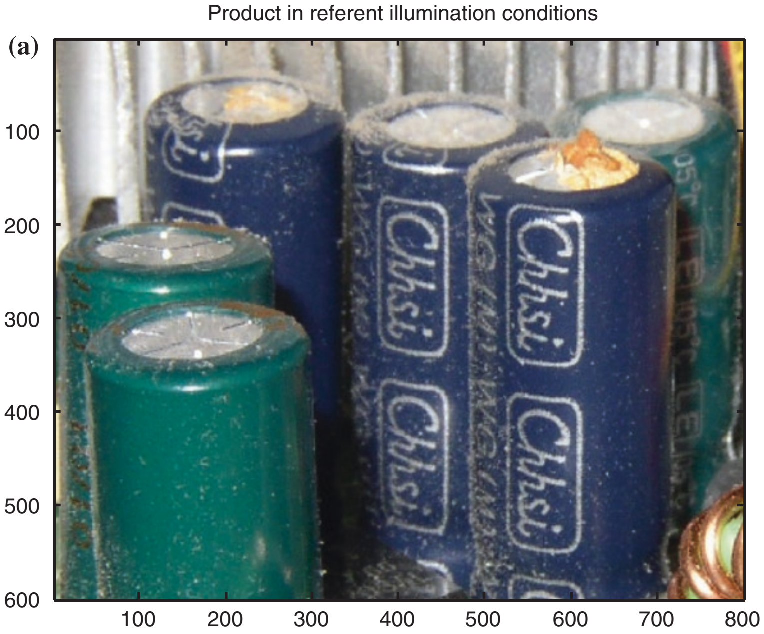


Fig. 4.1 Example of electronic circuit: **a** clear image, **b** image under non-uniform illumination variations, **c** visualized variations

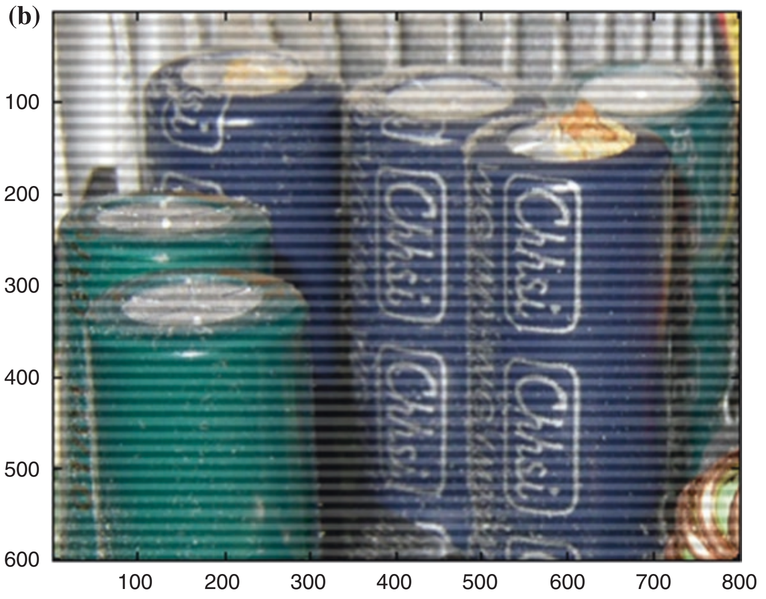
It can be shown that illumination variations are a zero-sum game if a sufficient number of frames are used in the analysis. The idea is to use several frames and suppress the influence of illumination variations.

In order to experimentally illustrate expectations, the following experiment was executed. The original image (Fig. 4.2a) is artificially changed. Global illumination variation is simulated by adding a constant brightness of 40, -100, and 60 to the original image. Intuitively, the sum of changes is zero. However, the problem is that the product must not be moved through the scene prior to the evaluation completion. But since an automated system only requires a few frames, a small portion of a second, this should not be a serious problem.

Figure 4.2b shows the average of variation-poisoned images. There are some differences from the original. Figure 4.2c shows the absolute difference of Fig. 4.2a, b. Figure 4.2d is a histogram of image differences (Fig. 4.2c).

The difference can be seen to be in the lower part of the spectrum. Therefore, the LF filter can logically be expected to suppress the differences, which should virtually be set to zero. The problem with such intuitive evaluation is in the fact that images have limited possible pixel values. The values should therefore be normalized and the loss effect should be included in the calculations.

Figure 4.3 is an example of what happens when an image is subject to illumination variations. Figure 4.3b shows wavelet approximation coefficients of the image under illumination variations. Figure 4.3c shows the difference between


Product image under illumination variations

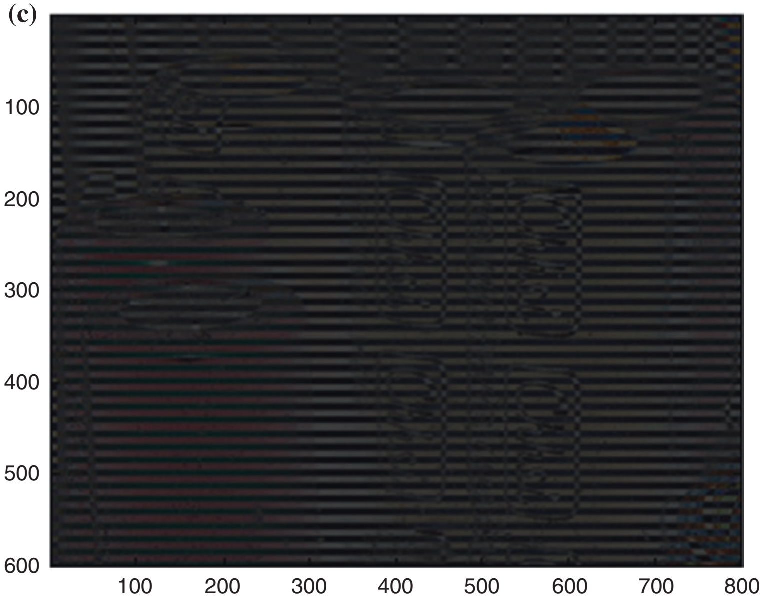

Difference between referent and image under illumination variations

Fig. 4.1 (continued)

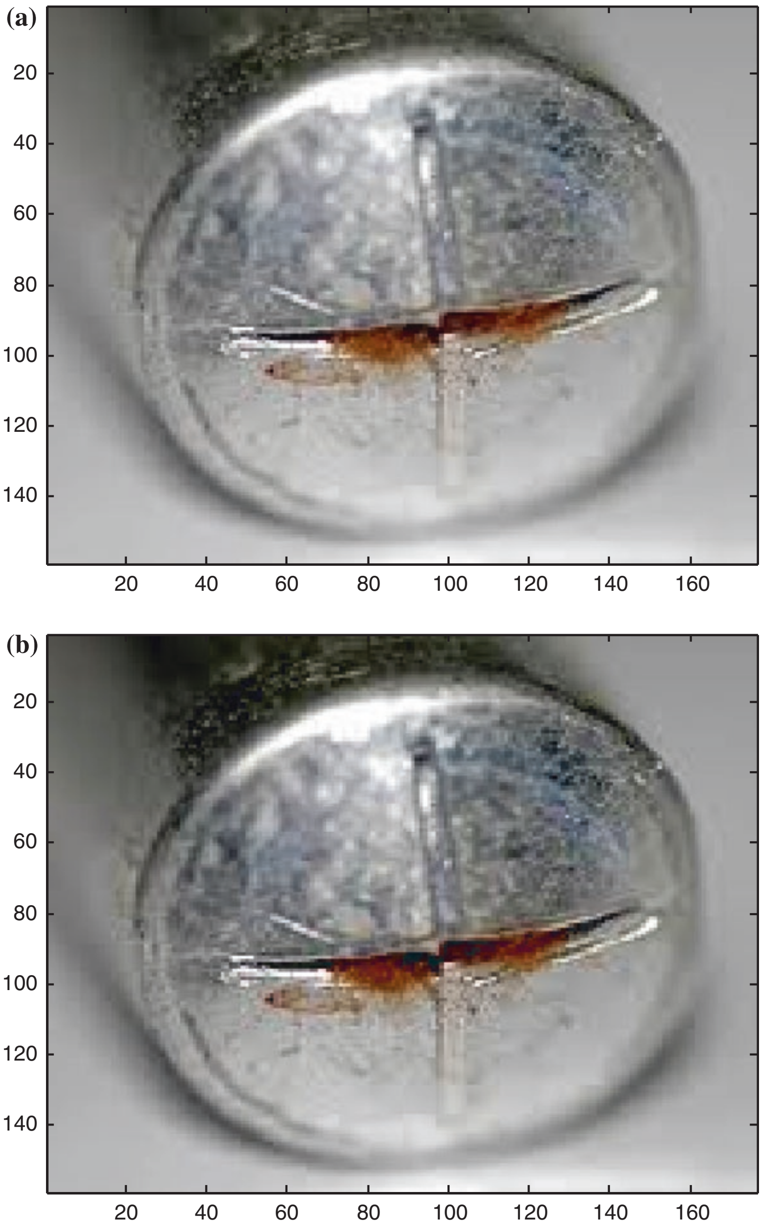


Fig. 4.2 **a** Original image, **b** average of images with three added variations, **c** difference between the original and the average of images with three added variations, **d** histogram of differences

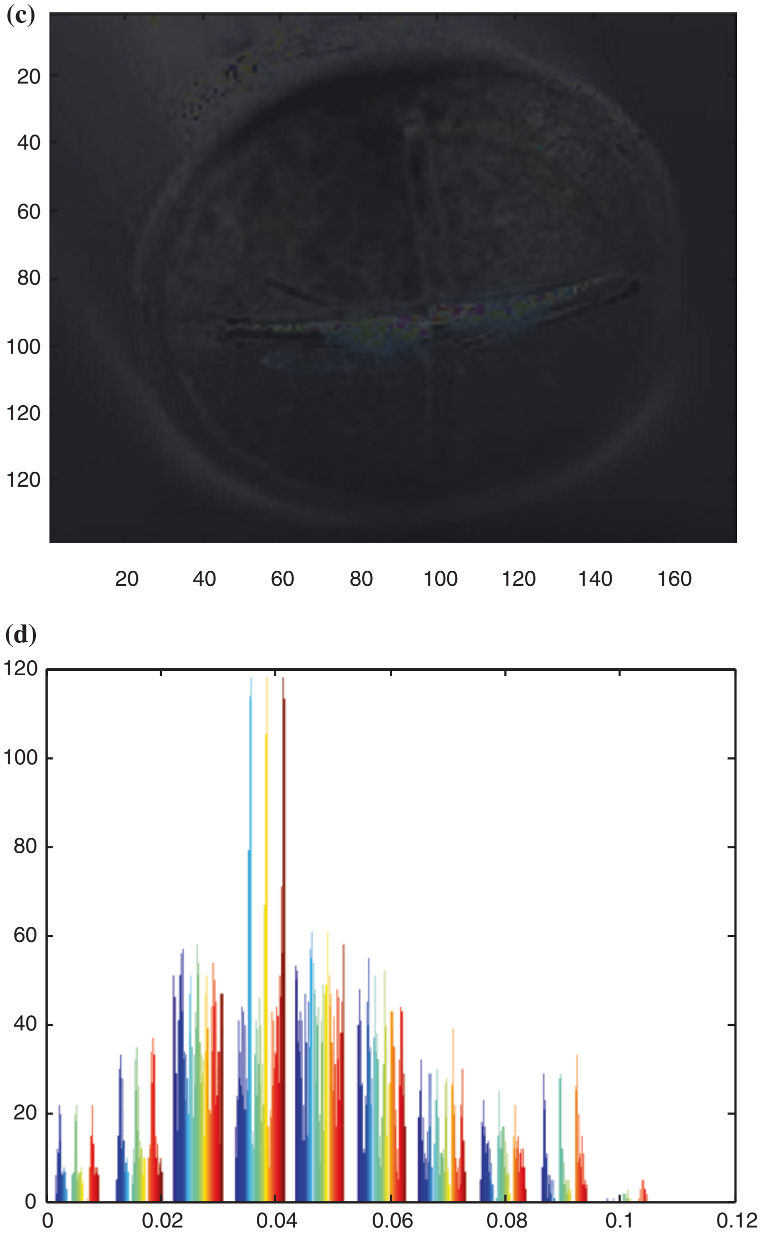


Fig. 4.2 (continued)

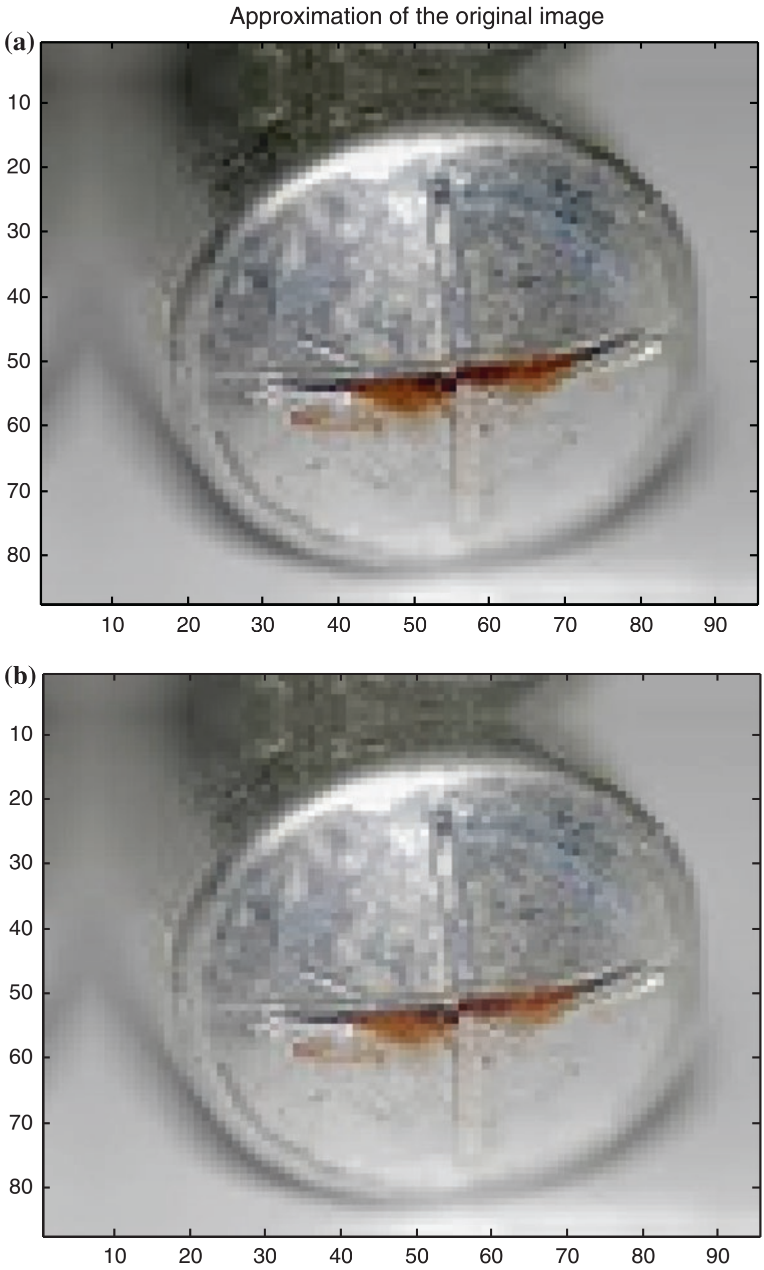
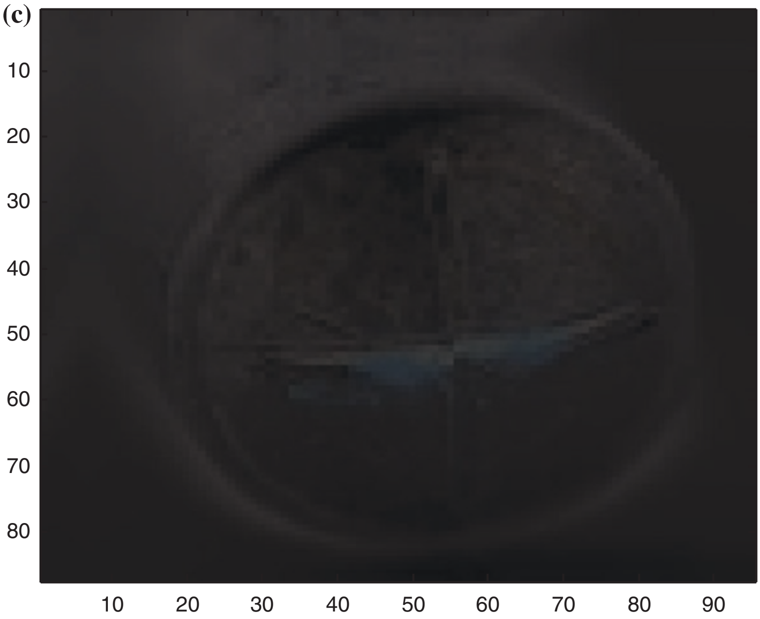


Fig. 4.3 **a** Wavelet approximation of the original image, **b** approximation of the illumination-added image, **c** difference between (**a**) and (**b**), **d** histogram of (**c**)



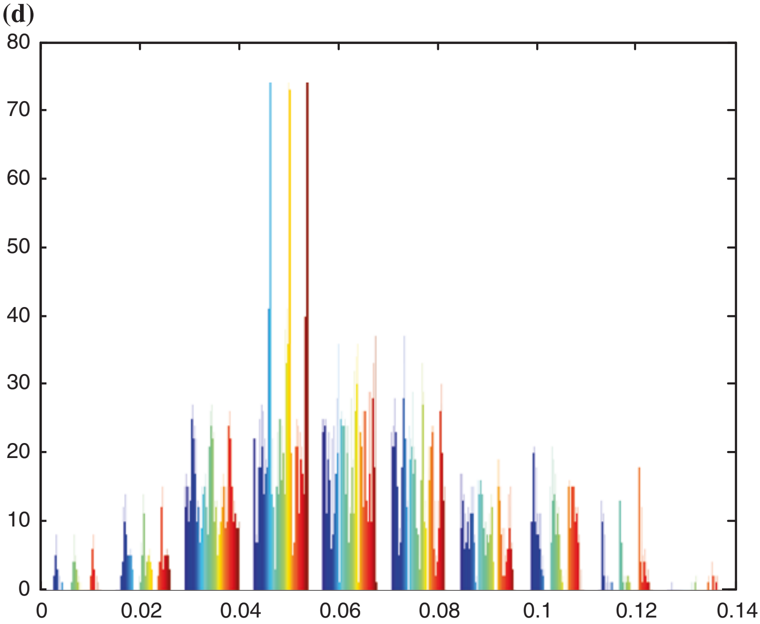


Fig. 4.3 (continued)

the approximation of the original and illumination-added image coefficients. Figure 4.3d shows the histogram of differences.

The wavelet filter (in this case dB8) can be seen to produce wider spectra (bandwidth) of differences and lower amplitude. Of course, this is an image with only one added variation.

The next stage in our experiment was to include all images with three added variations into the simulation. In order to obtain an average, we should perform the following operation:

$$r_1 = \frac{|a_n + b_n + c_n|}{\max(|a_n + b_n + c_n|)} \tag{4.2}$$

where a_n, b_n, and c_n are normalized wavelet approximations of illumination-added images.

Figure 4.4c shows that the result of the described procedure reduces amplitude and bandwidth by examining the histogram of the normalized sum. Figure 4.4a, b shows addition of illumination variations and the image difference.

Table 4.1 shows results obtained by our previous researches in this field. It is tested how the performance of the visual quality control system is influenced by three typical types of noise. Algorithm is based on the multiresolution algorithm developed in [58]. It is, essentially, an energy-based wavelet algorithm.

Normalized average region of interest (ROI) energy is calculated for a satisfactory product (made within fabrication tolerance) and for an unsatisfactory product. The calculated energies are presented in the Table 4.1. It can be seen that the highest tolerance to a noise is to, so called, the speckle noise. This was unexpected conclusion at the time of the research. It can be noticed that tolerances to the Gaussian and to the Salt and Pepper noise are relatively small. This could indicate that wavelet energy algorithm is not satisfactory for every types of noise. So, the algorithm parameters should be changed, such as different thresholds, levels of decomposition, wavelet family or number of moments.

The presented method has disadvantages at this stage of development. Firstly, numbers for normalized ROI energy vary from case to case. It is possible to conclude what is a good product and what not, but not based on uniform measure, which should be deduced. This is a problem, because there is no referent range of numbers for comparison. Hence tolerance to noise is low, it will be hard to realistically determine range of energies which are for good and for bad products. So, it is imperative to generate a reliable energy measure for this application.

The second problem is in investigation of different operating conditions. It is not possible to expect the same condition all the time. Stochastic disturbances can make an algorithm to fail. These disturbances should be minimized to increase the reliability.

Low-level processing must be implemented to reduce the influence of illumination variations (which are, in fact, one type of the stochastic disturbances) on the performance of visual quality control systems. A similar conclusion can be reached in the case of the influence of different types of noise or any other low level phenomenon. Consequently, bad low-level processing performance can only

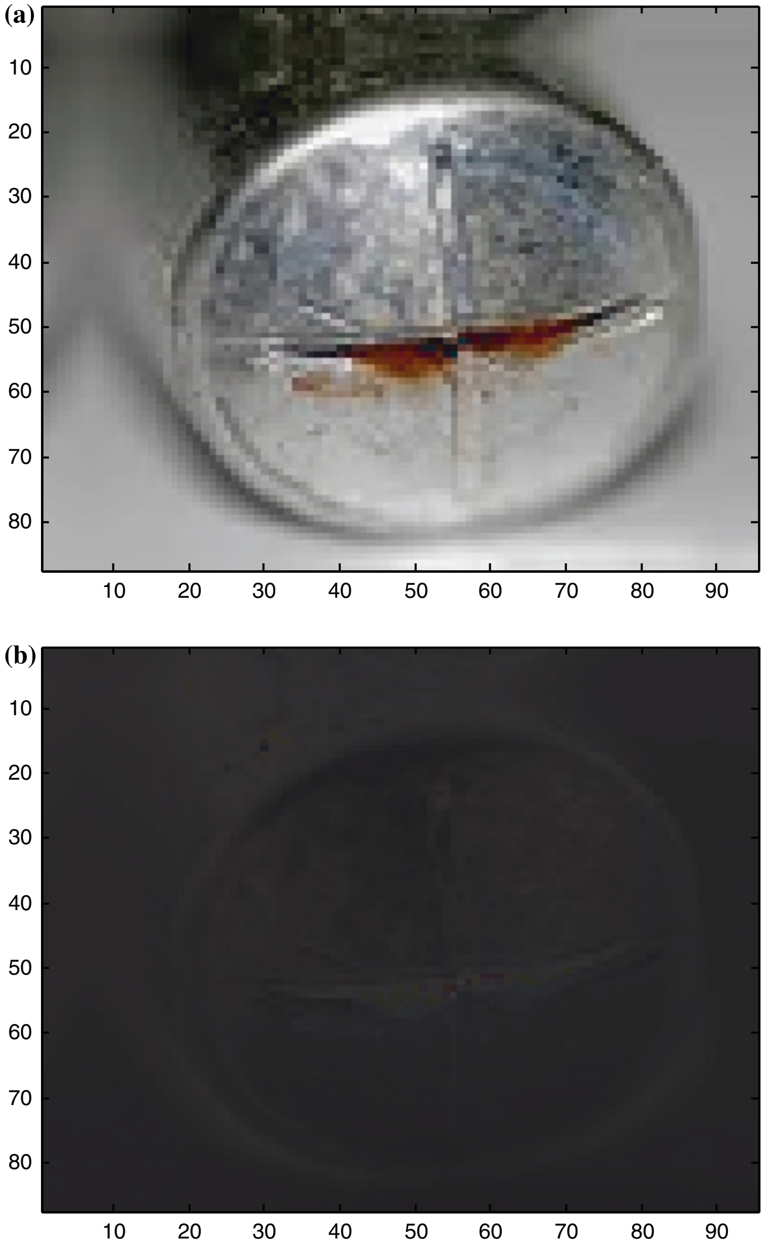


Fig. 4.4 **a** Normalized sum of variation-added approximations, **b** the difference between the normalized sum and approximation of the original image, **c** histogram of the normalized sum

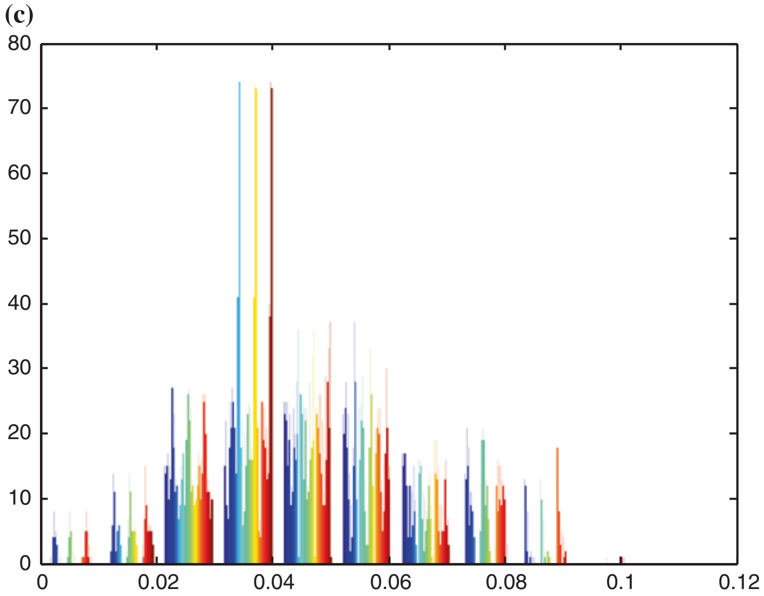


Fig. 4.4 (continued)

Table 4.1 Numerical experiment results for robustness of the visual quality control system to noise

Noise type	Speckle noise	Gaussian noise	Salt and Pepper noise
Normalized average ROI energy for satisfactory product	0.6743	0.6115	0.5517
Normalized average ROI energy for unsatisfactory product	0.5046	0.5780	0.5374
Tolerance to noise (%)	25.167	5.478	2.592

lead to poorer high-level vision application performance. In this case, illumination variations can be concluded to influence product quality evaluation.

The further research should be in investigation of possibility to find a reliable energy measure and to implement the finalized algorithm in industry.

4.3 Visualization of Dielectric Constant Dependences

Data processing can be used to visualize material's properties. The result can be in making conclusions easy to comprehend. So, the low level processing of data can result in high level conclusion about material's properties. Examples are given in [60, 61]. Material's properties are important in the quality control, because it can be possible to predict the product's quality from the material's properties.

For example, some technological procedures can change material's properties and lead to defects. If these defects are not taken into account, then the product can fail to perform due to the changed dielectric constant or the dielectric breakdown.

Typical influential parameter is the moisture. The relative dielectric constant is dependent of the moisture. The moisture can be found in the soils, the solid materials, gas dielectrics, etc. Absorbed moisture during production can make fatal defects in materials crystalline structure. Such defects usually increase chances for the dielectric breakdown. If it is possible to detect such fatal defects in the process of the quality control, it would make products that come out of factory more reliable.

Changes in the value of the complex relative dielectric constant are not solved in general by theory. It depends on materials type. There are studies that provided the results for different types of i.e. soils.

According to [62], the real part of the dielectric constant increases exponentially with moisture percentage. Tangent of dielectric loss or imaginary part of dielectric constant increases linearly with volumetric moisture content.

Another interesting research [63] shows that electromagnetic transparency increases by drying the material and that transmitted power decreases if moisture increases, which is linked to the dielectric constant. It was concluded that in X-band (a high frequency band used in satellite communication) exists direct relation between moisture and dielectric constant, expressed with [63]:

$$\mathrm{Real}(\varepsilon_r) = 3.95\exp(2.79Mc) - 2.25 \tag{4.3}$$

$$\mathrm{Imag}(\varepsilon_r) = 2.69\exp(2.15Mc) - 2.68 \tag{4.4}$$

where numbers depends on material and these numbers were obtained for the researched material [63] by experiments. Mc is the moisture content.

According to [64], porous low-value dielectric constant materials absorb more moisture. The chemically absorbed moisture degrades electrical and reliability performance of the dielectrics with low value of the dielectric constant.

A model of volumetric moisture content influence to the dielectric constant is evaluated and confirmed in [65]. It is polynomial dependence of the first or the third order, expressed with:

$$\theta = a \pm b \cdot \varepsilon_r \tag{4.5}$$

$$\theta = a - b \cdot \varepsilon_r + c \cdot \varepsilon_r^2 - d \cdot \varepsilon_r^3 \tag{4.6}$$

where a, b, c and d are dependent on the material's type. These empirical equations were confirmed in some types of soils, but not in electrical products with great influence of the relative dielectric constant.

Since, my team is stationed at the Maritime Faculty, we are especially interested in the influence of the abovementioned to the marine applications. It cannot be emphasized enough how important such research are in maritime affairs. Ships and offshore facilities are under a high impact of the moisture due to high humidity in and around sea water.

One of electrical engineering fields is a field of satellite communications and Internet, radar satellites, GPS, etc. This field is increasingly interesting in marine applications due to more advanced application, which are wider every day. In [66], an influence of moisture content to the ionosphere disturbances is considered for the X-band. It was concluded that such an influence can be expressed with:

$$\varepsilon_r = \left(a \cdot e^{b \cdot Mc} - c\right) + j\left(d \cdot e^{e \cdot Mc} - f\right) \tag{4.7}$$

where a, b, c, d, e, and f depend on the material of the communication part considered, and Mc is the moisture content.

For example, if some communication equipment is made from wood (depending on wood's type), these constants can be, for example:

- $a = 3.95$,
- $b = 2.79$,
- $c = 2.25$,
- $d = 2.69$,
- $e = 2.15$, and
- $f = 2.68$.

Multiresolution can be used in:

- curve/surface fitting of different dependencies,
- visualization of a part of the range, which is of interest in specific application (the whole experimental data can be in shown in one resolution, and the specific range of data in the different resolution),
- estimation of different parameters,
- solving the equations of dependencies, etc.

This is the research started in the last year (2013). There is no way of telling would it be successful. However, this chapter let us aware of materials' influence to the final properties of products and to the quality of the manufacturing processes.

Chapter 5
Possibilities for the Improvement of Human Work Conditions by Virtual/Augmented Reality

Abstract This chapter deals with possibilities for the improvement of human work conditions and with the relaxation at remote and isolated work places (oil rigs, ships, spacecrafts, etc.). It is shown how cutting-edge visualization and communication techniques can improve safety and security. Furthermore, a multiresolution role is explained.

Keywords Virtual reality · Animated world · Mariners' health · Communication systems · Security

Another example of our research is advanced visual techniques. There are references about the use of augmented/virtual reality in medicine, telesurgery, or robot control [44–47]. These applications are well-understood. They are mostly based on satisfactory communication systems. If communication fails, the application fails. Since in some applications, such as treatment of stroke patients, the application can be performed in situ, communication between different parts of the world plays no vital role.

Possible applications of virtual reality range from serious applications to entertainment industry. Examples of serious applications are:

- search and rescue,
- distant robot control, or
- flight simulators, and so on.

Medical applications are telesurgery or rehabilitation. In the entertainment industry, applications are in:

- games,
- holonovels,
- interactive novels, and
- future movies.

The development of such systems is sponsored by the largest industries, such as military, biomedical and entertainment.

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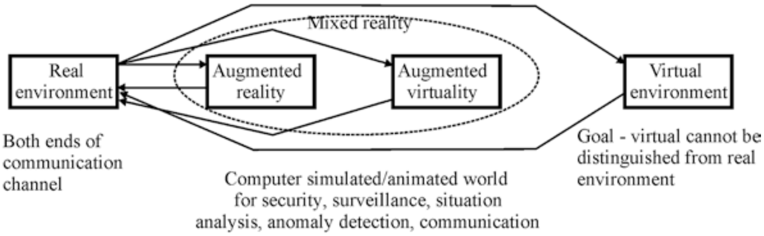

Fig. 5.1 From computer animated world towards virtual reality

Basically, advanced visualization techniques are categorized as augmented reality, augmented virtuality or virtual environment [46]. Figure 5.1 shows the interaction of real and advanced visualized worlds. It should be noted that due to the advancement of other sensors, such environments cannot rightfully simply be called visualized worlds. It is interesting to point out the advancement in tactile sensors. Other integrated sensors are audio and recently, smell. Some researches about flavor have also been made in the food industry. The integration of all sensors will make virtual reality possible which could be considered a substitution for the real senses and the real world. Furthermore, it would allow the uploading of a person's mind into a virtual reality computer system and make possible immortality sort of possible, which could be e.g. therapeutic in case of terminal illnesses.

Any form of advanced visualized world is based on communication. Both ends of the communication channel end in the real world. In the beginning, there is an actual stimulus in the real world. At the end, an actual reaction is produced that affects the real world. In order to visualize the situation, a human operator is under visual (and other senses in the future) stimulation, which is augmented to another space to facilitate the task/decision. There are two steps of augmentation:

- augmented reality, and
- augmented virtuality.

They are both called mixed reality. In mixed reality, the operator is aware of both the real and the augmented world, but gets the results by concentrating. In virtual reality, it should be impossible to distinguish the real world from the virtual world, because all senses are involved in the virtual environment and the operator's real world location is isolated from real-world stimuli. However, this high level of virtuality is not necessary to perform the desired tasks.

A possible application of virtual/augmented reality is to make glasses with small cameras, which would create the illusion of 3D space. A small processor can take care of edge detection and recoloring of full planes. This output should be connected to the nerves of people suffering from visual disabilities to make their lives easier. That is an example of biomedical application. In this case lower vision (edge detection, plain close, recoloring) should be used to enable the human brain to interpret them at higher vision, e.g. to avoid obstacles or find a way home.

Once again, it should be aware of the interaction between lower data processing and higher level applications. In this case, sensors are usually visual in nature, such as a CCD. Low level image processing is performed between visual sensors and an input to the higher vision application, such as a computer code for animation. If a lower vision performed its task unsatisfactory, the result will be confusion for a user of such an animated/augmented world. For example, colors can be changed rapidly. This will make harder to an operator to focus to the essence of the application. As a feedback, a command sent back to a virtual/augmented/animated world control application could be seen as unsatisfactory reaction.

Multiresolution is included through the data processing part between the sensors and the control application. In another part of the system, multiresolution application can be in making higher resolution in focused part of the virtual/augmented/animated world and lower resolution to a part of the world marked as unimportant background. It should be noticed, that the background could be classified as the important and as the unimportant. The important background could interact with objects in focus. It is, essentially, a way human brain operates: we do not notice usual, irrelevant details. However, major thing are noticed in the best possible resolution.

Two examples are presented in this chapter:

- example of animated world in security application, and
- analysis of the influence of the improved communications to mariner's health.

5.1 Animated World Example

Primitive virtual/augmented world is the animated world. Functions of virtual, augmented and animated world could be the same. However, operator can get into the spirit in the virtual world easily and in the animated hardly, because animation is considered as unnatural.

The following example is a case of the application in port's security. Animated world discards everything irrelevant letting the operator to focus on the real treat.

Figure 5.2 illustrates anomaly detection for security applications in the animated world, which is a low-level augmented reality [48]. Potential terrorist is detected by differencing the referent model and the visualization of the real scene currently obtained by sensors.

Unimportant (irrelevant) parts of the background are:

- most of the sea surface, and
- most of the dock surface.

Parts of the background that should be in focus are:

- dock's part close to the ship and ship's trajectory,
- proximity of the ship and the tug boat (to avoid collision), and
- possible anomaly (or anomalies) in case of Fig. 5.2b.

Operator's role is to distinguish between treat and non-dangerous anomaly, such as tourists, fish boats, boats in stress, or else.

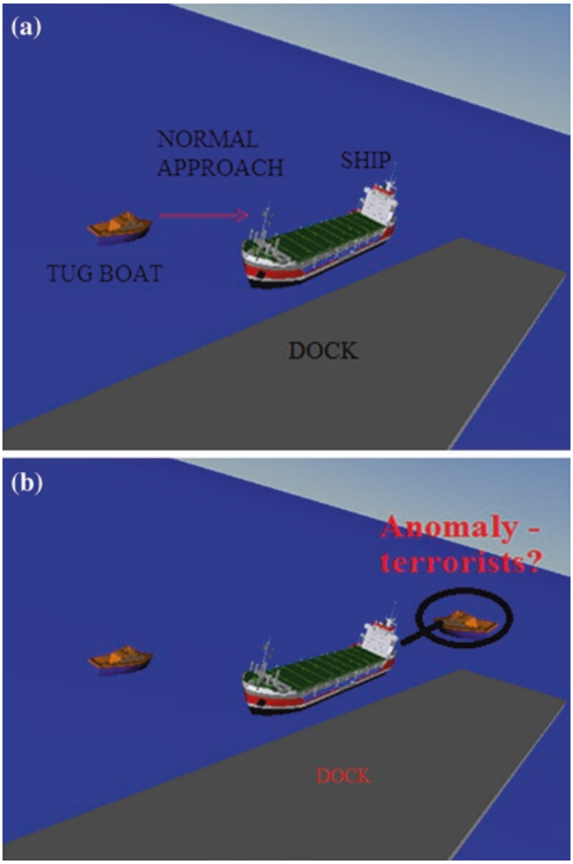

Fig. 5.2 Potential terrorist attack detected in animated world: **a** a normal approach to the arriving ship, **b** unusual situation—anomaly, which could be terrorist attack

Interaction between lower and higher vision application is obvious. In order to operate faster, it is necessary to reduce data to be processed. It is performed by extending the area of the lower resolution (irrelevant parts of the background). However, reduced resolution can cause inability to detect small changes (i.e. a small boat), which could be potential treats. Further research of our team in this research field is to add a learning quality to vision algorithms, which will incorporate an optimal approach between the lower resolution parts and the anomaly detection.

5.2 Improved Communications in Maritime Affairs

In this section, an example of advanced visual communication is considered. We will discuss how such techniques can be used to help seafarers suffering from the psychological trauma of separation from home [49].

The example of human error [49], which may be caused by fatigue and excessive workload and lead to captain's perceptual error, is collision of the M/V Santa Cruz II and the USCGC Cuyahoga on a clear, calm night on the Chesapeake Bay. The most fatal result was lost of lives of 11 Coast Guardsmen. It is difficult to take account all the effects which could influence seamen psychology. One typical influence is the noise.

The noise is caused by different sources, such as ship's engines, generators, air-conditioning, etc. It can cause problems even if cannot be heard, i.e. in [49]:

- thorax (3–7 Hz),
- heart (4–8 Hz),
- abdominal and thoracic organs (4–9 Hz),
- spine (2–6 Hz), and/or
- pelvis (4–9 Hz).

Head problems are caused by frequencies between 20 and 30 Hz.

Due to the advancement of modern communication systems, seafarers are no longer under so much pressure, because of, for example, telemedical care, including consultations, counseling or telesurgery, and improved physical trauma treatment aboard ships.

Psychological traumas have also been observed [50, 51]. The anticipated benefit of improved communications is the easement of psychological problems caused by separation. The extent to which modern communication improved the life of seafarers over the last century cannot be stressed enough. Even in the twentieth century (except in the last decades), personal communications were limited and a cause of stress to seafarers. Nowadays, seafarers have cell phones at their disposal with satellite links, which enable communication at almost any time. Furthermore, modern ships also have available Internet. It is not only possible to use e-mail communication, but also to see each other through applications such as Skype.

Future trends in communication technology include [49]:

- 3D video conferencing as an improvement of the present day videoconferencing,
- 3D video phone,
- virtual reality with haptic interface,
- holographic visualization in 3D space, etc.

New technologies should be approached with caution. A Samsung report [52] states that possible symptoms of watching 3D pictures include:

- altered vision,
- lightheadedness,
- dizziness,
- involuntary movements such as eye or muscle twitching,
- confusion,
- nausea,
- loss of awareness,
- convulsions,
- cramps and/or
- disorientation.

Seafarers are not a risk group, rather the problem lies at the other end of the communication channel. The identified risk groups are [49, 52]:

- pregnant women,
- young children,
- teenagers,
- the elderly,
- people prone to seizures or stroke,
- people prone to dizziness or motion sickness,
- people with eye problems,
- people who are out of shape, and
- people who have been drinking.

This opens the question of whether new technologies are safe for communication between a pregnant wife and husband on an off-shore job.

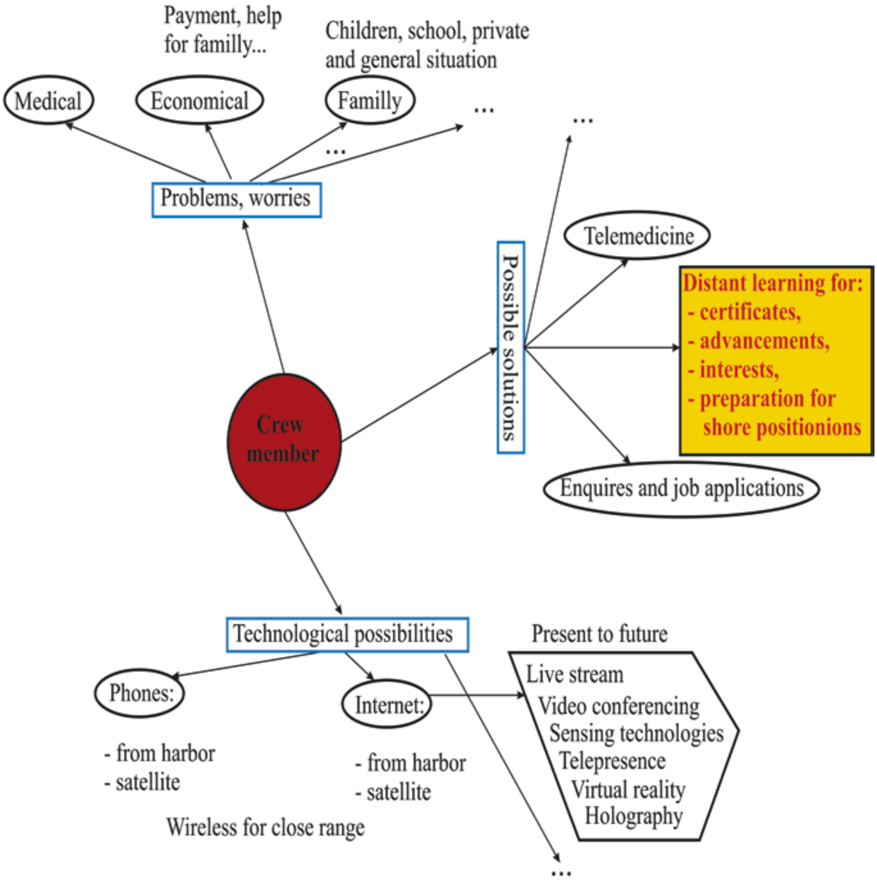

Fig. 5.3 Possibilities of new visualization technologies for seafarers

Figure 5.3 shows the possibilities of new visualization technologies in the improvement of seafarers' lives (see [49]). The currently available technological possibilities are phones and the Internet. Phones and the Internet can be used from the harbor or by satellite. Future technologies are:

- live stream over satellite from any part of the Earth,
- video conferencing (3D),
- sensing,
- telepresence,
- virtual/augmented reality, and
- holography.

Possible applications are in medicine, economy and family lives. Modern technologies will enable distant learning. This can be useful for seafarers, as it would allow them to obtain certificates and prepare for shore jobs. Seafarers could make inquires and submit job applications when not on duty. Figure 5.3 illustrates just how much can be achieved with advances in this field, which could reduce and virtually close the gap between off-shore and on the shore jobs.

The multiresolution approach can be used in several ways:

- coding of data to preserve confidentiality and privacy of communication and/or transmitted data (wavelet coding),
- compression of data to increase transmission speed (it is especially important in high resolution visual data, which are large pockets of data and in a teleoperation applications),
- filling of missing data pockets,
- prefiltering,
- postfiltering, etc.

The interaction between lower and higher vision is obvious in case of data compression for transmission from land to ship and vice versa. It should take greater role in future communications. Such an interaction can also increase efficiency of the algorithm for filling of missing data. It is a way for further researches in this research field of our team.

Chapter 6
Computer-Aided Diagnostics and Multiresolution Analysis Role in Medical Signal Processing

Abstract Multiresolution role is considered for the application in computer-aided diagnostics. Two examples are shown, which are in the scope of our research group. The first example presents preliminary results in EMG analysis of brain signals obtained by experimenting with stutterers. The second example shows research results in diagnostics of occupational asbestosis. It was found how much levels of wavelet decomposition can be used without damage to the medical information in pulmonary X-ray images of the asbestos infected patients.

Keywords Computer-aided diagnostics · EMG · X-ray images · Image compression · Stutterer · Asbestos

An interesting research field deals with biomedical applications. Biomedical applications could be:

- analysis of medical images,
- help in diagnostics by emphasizing certain data or by suggesting possible actions or diagnosis,
- archiving biomedical data in compressed digital form, etc.

In this chapter, we will discuss two examples:

- preliminaries in electromyographic (EMG) of stutterer's brains, and
- an older research in diagnostics of occupational asbestosis with newer visualization technique.

The first topic presents a new field of research for our team. Some preliminary results are presented as an example of the multiresolution approach.

The second topic is an example how visualization technique can help in diagnosing a disease. It points to the areas with suspicious shadows, which makes a medical doctor to examine these areas.

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6.1 Multiresolution Approach to EMG Analysis

This research is performed with the collaboration of School of Medicine in Split. Stutterers (experimental subjects with problem of stutter) have a speech dysfunction. Our goal is to analyze signals obtained by electrodes attached to a head surface at laryngeal part of human brains. Several signals are recorded during experiments and stored in the edf format.

The source format includes:

- EMG activity of laryngeal sector of brains,
- microphone signal,
- screen sensor, and
- electrical impulse stimuli of brains.

Multiresolution approach is used to correlate laryngeal timings with electrical stimulielectrical stimuli. As an example, two level wavelet decomposition of one measurement is shown in Fig. 6.1. The upper graph shows time sequence of the recorded laryngeal signal. It is analyzed by Daubechies wavelet of 8th order. Since it is not necessary to obtain on-line, high speed, of execution, it is chosen to use higher orders of wavelets. The second reason for using higher orders of wavelets is in the shape of the source signal and the dynamics of the sourced signal. At the first level of the decomposition, the source signal is split into low and high frequency bands. We expect that important phenomena occur in the high frequency band (red ellipsoid and arrow in the middle row of the image).

The third row of the Fig. 6.1 shows the second level of the decomposition. Both the lower and the higher frequency bands are again split into low and high subbands. The decomposition can go further. Intuitive analysis leads to even 32 levels of the decomposition with wavelet orders of even far as 44 to obtain satisfactory and reliable results.

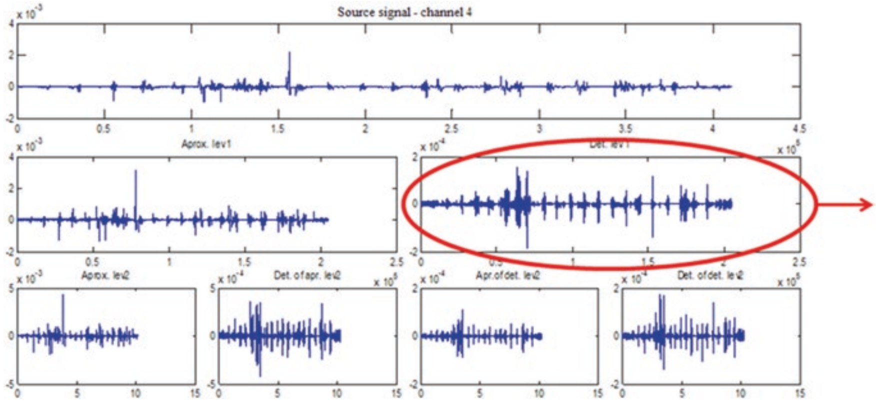

Fig. 6.1 Multiresolution analysis of the EMG signal of the test subject 2

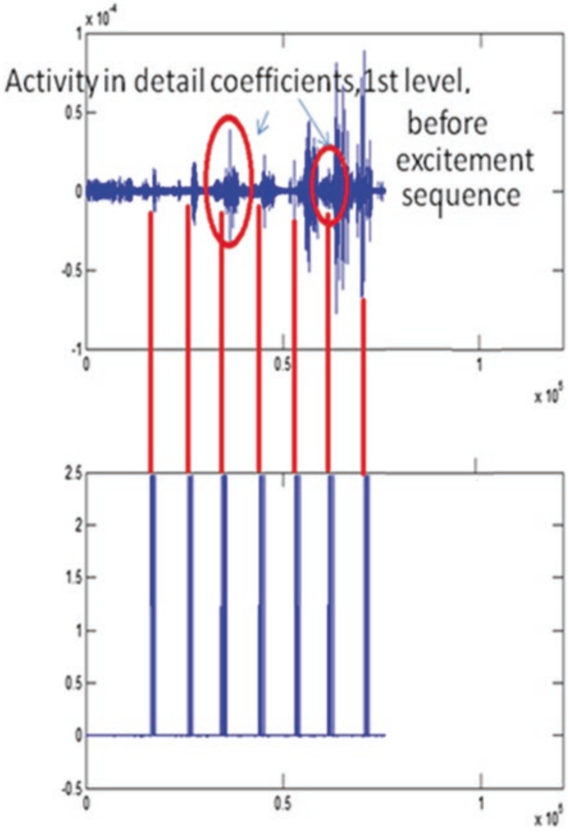

Fig. 6.2 Time synchronization between extinction and the "impulse" response

Figure 6.2 shows time synchronization between the impulse (stimulus) and the respond of the brains. The details coefficients were analyzed. The brains' respond is timed after the electrical stimuli, which is expected, at first. Test subject are expected to talk (to name the image shown to them) after the stimuli. It can be seen that the brains' activity increases after a few stimuli phases, which could be related to the subject's preparations to talk.

It can be seen that WT shows activity in brain before people actually talk. It is our hope that the stutter could be predicted and, perhaps, one day, filtered or reduce by some sort of bleeding-edge electronic devices.

It should be outlined that this is only a preliminary research and that there is no guarantee what will happen with the research in future.

Figure 6.3 shows the spectrograms of the lower and the higher frequency bands. The y-axis represents time and the x-axis the normalized frequency. It can be seen from Fig. 6.3b that the most frequent details coefficients are in the mean of time range, where a half of the frequency range is used. The approximation coefficients (see Fig. 6.3a) do not produce so clearly readable spectrogram. This is

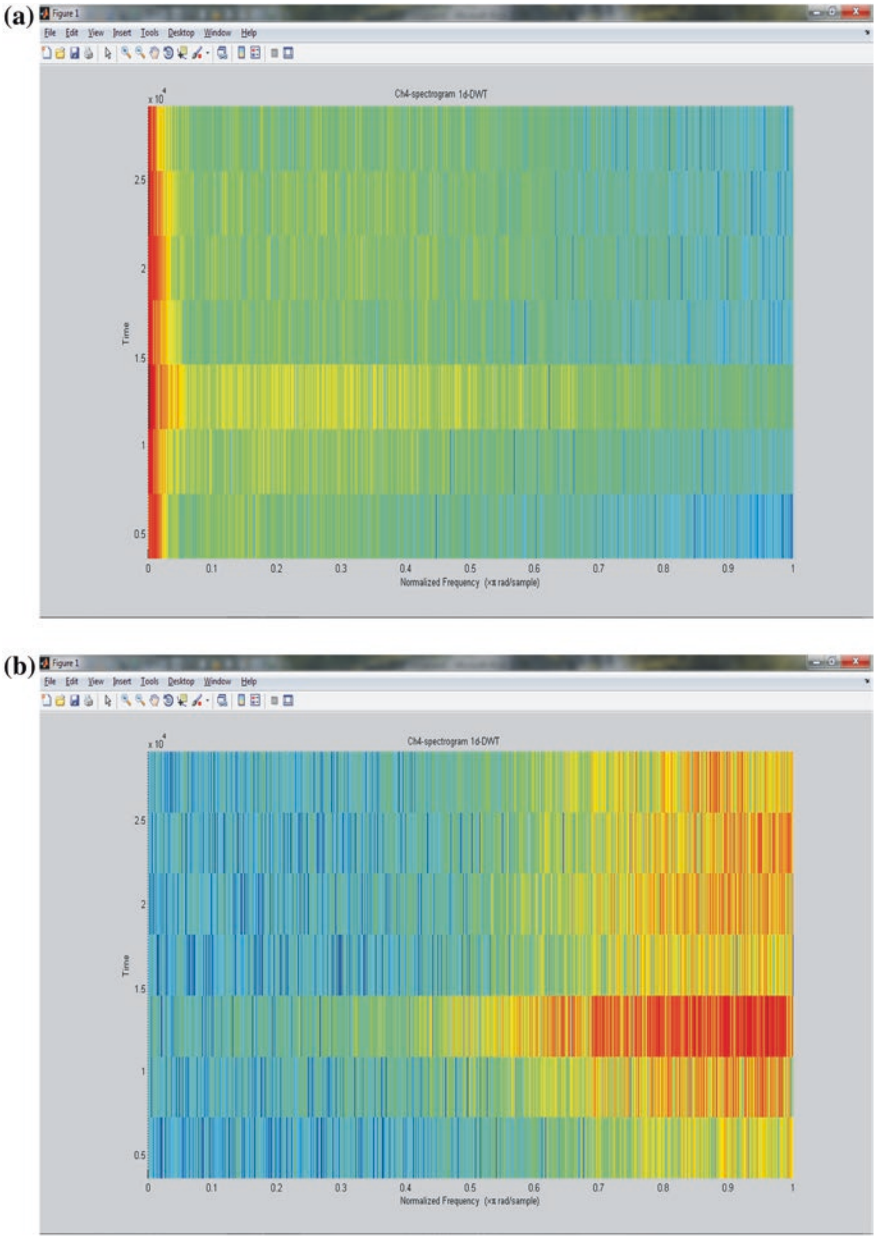

Fig. 6.3 Spectrogram of the analyzed signal: **a** lower frequency band (wavelet approximation coefficients), **b** higher frequency band (wavelet details coefficients)

one of reasons for the higher bands usage—to make conclusions easier. It should be noted the choice of the bands is not general and depend on the application and specifics of the analyzed signals.

The multiresolution approach is used in this preliminary research. It means that a path to the results is chosen from level to level. For example, it is possible to choose HF band at the first level of the decomposition, the LF band at the second, or any other combination. This leads to future tree analysis for the optimal and the reliably results.

In this research, we examine a lot of data (low level processing) to obtain the conclusions (high level information).

6.2 Computer-Aided Diagnostic of Occupational Asbestosis

In this section, a multiresolution approach is presented in cases of image compression and visualization.

Image compression is performed in order to store X-ray images for future use. It was imperative that the medical information is preserved.

Visualization is performed to help medical doctors in a diagnostic procedure. In this case, to point out to the ROIs.

6.2.1 Pulmonary X-Ray Compression

Test subject were asbestos infected patients. Particularly, pulmonary X-ray images were digitalized and input into computer. A multiresolution algorithm was developed for image compression purposes. A goal was to determine maximum compression ratio for reliable medical diagnosis. Two parameters were taken into account: wavelet type and levels of decomposition. Decomposed image coefficients were recorded. The reconstruction had to be performed to obtain the original image size necessary for diagnostics. However, it is possible to observe that an image can be a little fuzzier in some cases after reconstruction. For example, Haar wavelet at 14th level of decomposition is reconstructed to the original size with observable defects, but details (which are shadows in the infected tissue) are so observable that medical diagnosis remains the same as from the original image.

Conclusions of this research were [59]:

- symlets can be used for up to do 14th level of decomposition and obtained $CR = 1316$,
- biorthogonal wavelets cannot be used always. Their reliability is till 10th level of decomposition and $CR = 131.65$,
- reverse biorthogonal wavelets can be used till 14th level of decomposition, because there are of medical value when asbestosis is considered,
- algorithm produce 100 % correct restored images (in sense of medical diagnosis) if mentioned wavelets are used for determined levels of decomposition, and
- memory space can be reduced from 4.5 MB to 3.5 kB under abovementioned conditions (wavelet family and level).

Hence, it is possible to conclude that low level processing (image compression operations) can influence medical diagnostics (high level operation). This is a fine example of clear influence. If a low level algorithm does not perform within desired parameters, than the medical diagnosis would be wrong. If the algorithm operates satisfactory, than the medical conclusion would be correct. It can be concluded that it is possible to obtain high CR with preservation of the medical information.

These conclusions were obtained by help of medical doctors and radiologists [59]. In cases where there was no consensus between experts, this level of decomposition was discarded, because it is unreliable. In this application, there is no space for errors, because storing of the wrong medical information would be disastrous.

6.2.2 Visualization of Infected Areas

The second example is in help to medical doctors. The visualization multiresolution algorithm was developed, which emphasizes the areas of asbestos deposits (actually, changed pulmonary tissue). This algorithm must detect suspicious areas (which could be asbestos), and perform a visualization algorithm to point out these areas and make it visible.

Our research showed that only some tones of gray could be asbestos-infected areas. So, it is necessary to emphasized desired tones with different color, which could be more visible to human eyes.

Figure 6.4 shows an example of the operation of the developed algorithm. Text box at the right side of the figure are added for this book and serves as explanation of the algorithm operation. The same is valid for all lines toward the mentioned text box.

Further development should be at the application level, i.e. change of background color, change of the ROI color, etc.

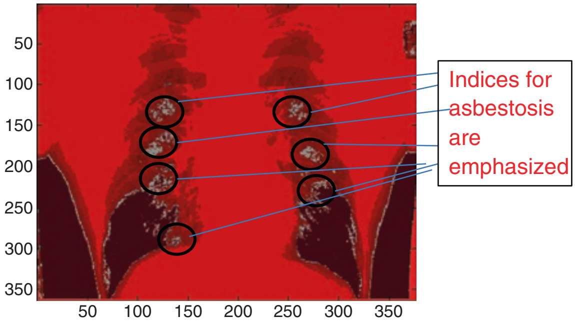

Fig. 6.4 Computer-aided diagnostics: easier detection of shadows, which are indications of asbestosis

Chapter 7
Multiresolution Applications in Video Surveillance

Abstract In this chapter, a multiresolution approach is solving several video surveillance issues is explained. Firstly, edge detection in robot vision is considered. Then, illumination variations problem is addressed with example in people motion detection. Camera jitter problem is addressed in the outdoor example. Removal of weather conditions is considered. Finally, an algorithm for data fusion is presented, which uses wavelet multiresolution approach in oil spill detection from the SAR images.

Keywords Indoor · Outdoor · Robot vision · Edge detection · Camera jitter · SAR images

Surveillance applications can be divided by a space it is covered. If the space is limited, inside buildings, than it is indoor applications. Otherwise, it is outdoor application. This chapter will present out researches from both cases. In this chapter, research in several topics will be presented:

- indoor robot vision,
- indoor motion detection,
- outdoor camera jitter problem,
- influence of weather condition to the problem of traffic surveillance, and
- oil spills detection at open sea.

7.1 Examples of Indoor Applications

The first topic is the robot vision application.

A robot is used indoor, to move between rooms through the corridor. Actual algorithm for motion control is not the scope of our research, but the input to the motion control algorithm. The robot was relatively old and it worked with edge detection to identify its position in the memorized map. Our research was an investigation of different edge detectors performance.

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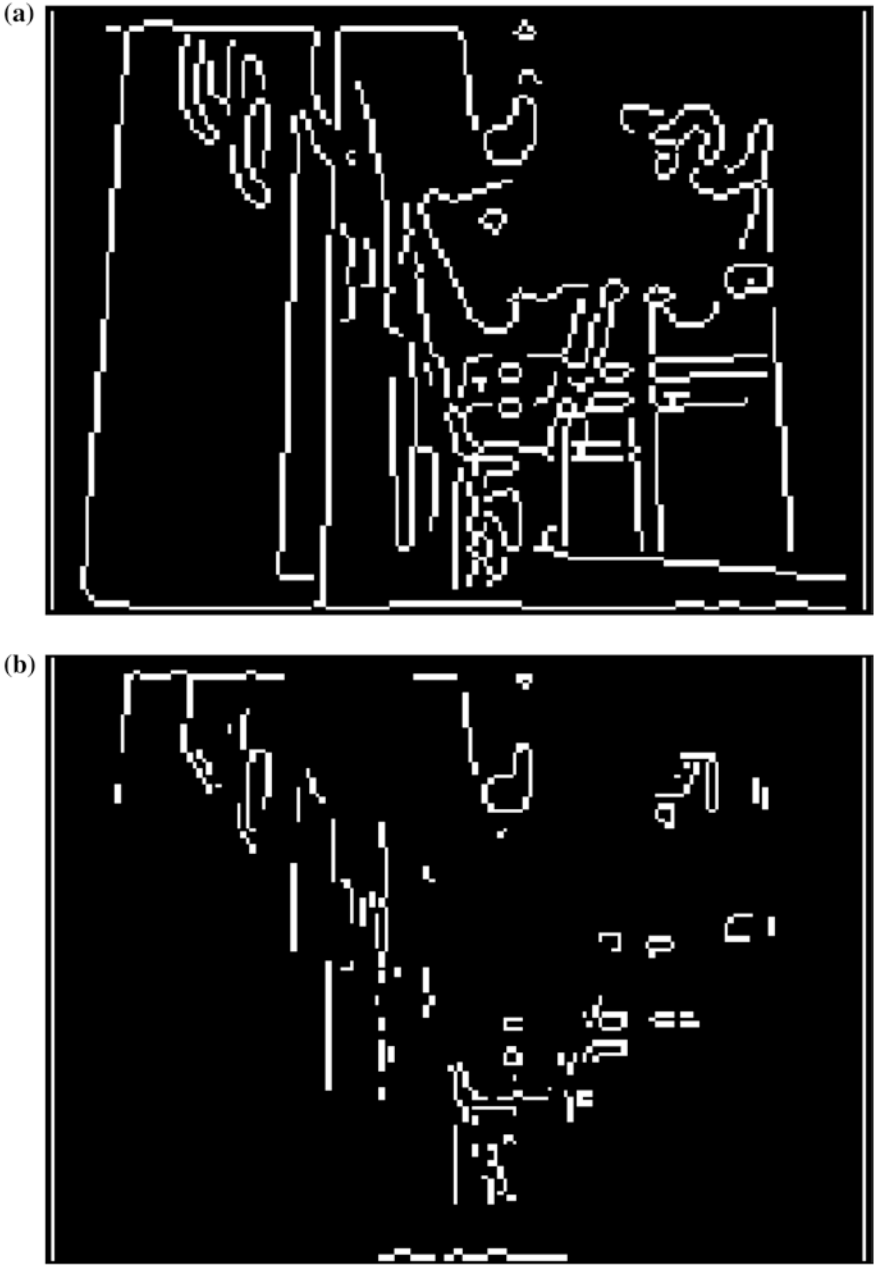


Fig. 7.1 Application of different edge detectors to the same scene: **a** Canny, **b** Perwit, **c** wavelet algorithm

Fig. 7.1 (continued)

Figure 7.1 illustrates a difference between input to the motion control (higher level operation) produced by different edge detectors (low level/vision operation).

It is obvious that different edge detectors (low vision) will influence the data input to the higher vision applications (such as orientation and navigation).

Figure 7.1a shows the result of one of the most popular edge detectors—Canny. Figure 7.1b shows the result for the same frame of the Perwit edge detector. Results of the gradient method applied to the wavelet approximation (1st level of the decomposition) is given (for the same frame) in Fig. 7.1c. The output is not denoised. This is a space for improvement at the low-level stage (in the field of low level image processing). It is not necessary to point out the advantage of better detector to the higher vision applications.

Figure 7.2 shows an example of indoor motion detection in laboratory conditions.

The simple background subtraction algorithm produces an image in Fig. 7.2b. It can be seen that the output image contains a lot of static scene parts, which should be eliminated in the motion mask. Figure 7.2c shows an example of such elimination by the WT.

From Fig. 7.2d it is possible to compare how much of illumination variations were eliminated by the multiresolution approach by the WT.

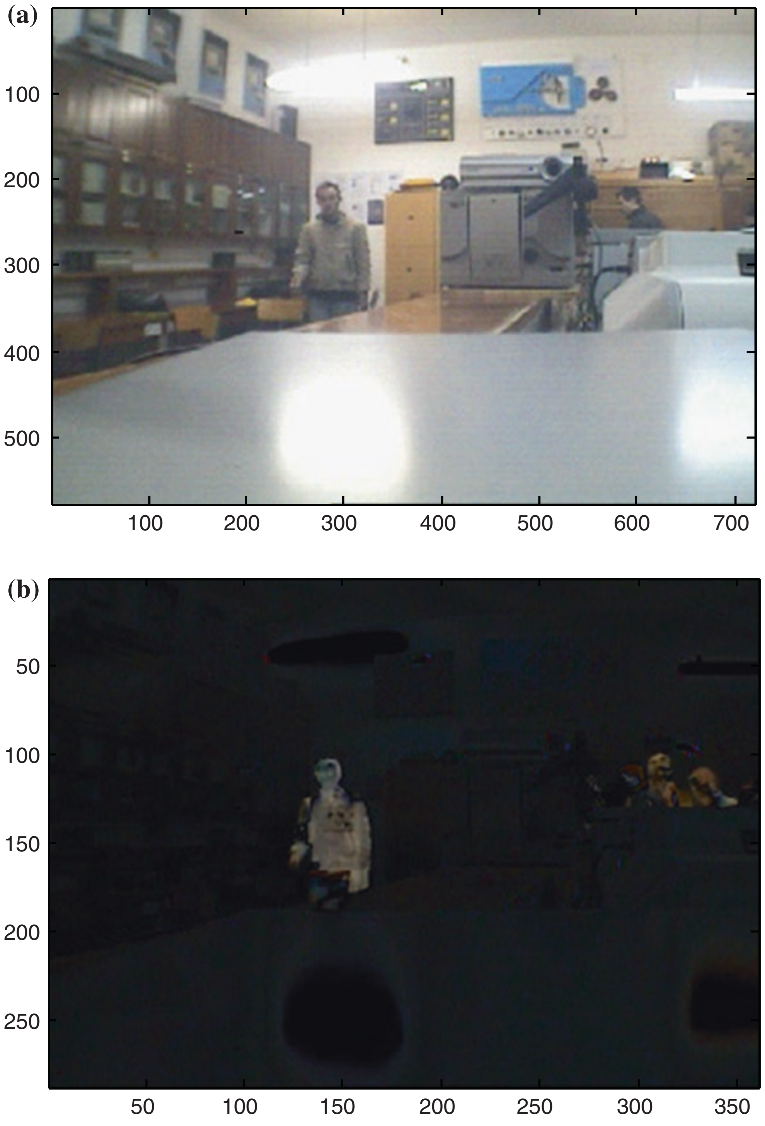


Fig. 7.2 An example of motion detection and related problems in indoor applications: **a** frame 183 in the video sequence, **b** difference in wavelet approximations of the start frame and frame 183, **c** segmented motion, **d** difference of (**c**) and (**b**) for extraction of variations

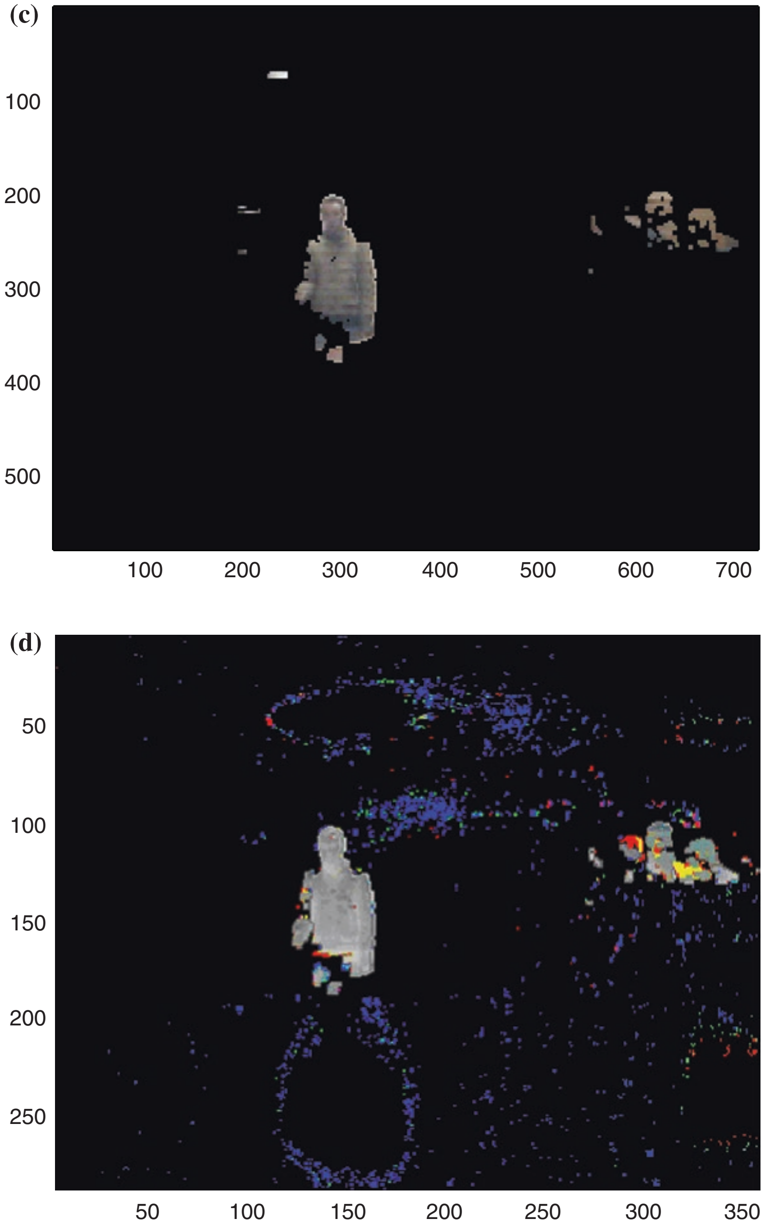


Fig. 7.2 (continued)

7.2 Examples from the Outdoor Applications

One of great problems is the problem of the illumination variations, as illustrated in Fig. 7.3. This problem is present in both the indoor and the outdoor applications of the video surveillance systems. If the considered scene is not in the control environment, there are more problems, such as:

- camera jitter,
- influence of the weather conditions,
- moving shadows,
- part of day (change in Sun's position during daytime),
- waving tree effect, etc.

Figure 7.3 shows advantages of the multiresolution algorithm developed in our research. The developed algorithm is based on [67]. It is improved. The original algorithm [67] is framed as competitive algorithm in Fig. 7.3. The developed algorithm is framed as proposed algorithm in Fig. 7.3. The competitive algorithm is the multiresolution algorithm from the category of memory-based motion detection algorithms. It is based on the energy contained in the coefficients of the lifting wavelet transform (LWT) and the accumulation of it in the buffer.

To make optimization between different algorithm objectives, two wavelets were used. The competitive algorithm uses the 2nd level of decomposition. By implementation of several small changes, the developed algorithm improved robustness to the camera jitter effect. The improvement is confirmed by statistical evaluation using statistical image quality measures—percentage of the correct classifications (PCC) and the precision.

These measures of the image quality are defined with equations:

$$PCC = \frac{TP + TN}{TP + TN + FP + FN} \tag{7.1}$$

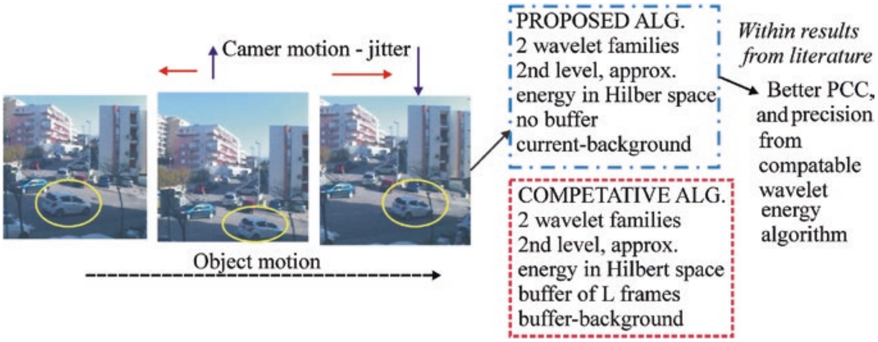


Fig. 7.3 Camera jitter effect reduction by the multiresolution approach

where:

- *TP* is the number of true positive classifications,
- *TN* is the number of true negatives classifications,
- *FP* is the number of false positives classifications, and
- *FN* is the number of false negatives classifications.

It can be said that the PCC measures the absolute "correctness" of the algorithm. PCC defined in (7.1) does not tell everything, because it can be high and that the perceptually the result is not so well. So, the control parameter is introduced. It is *precision*, defined by:

$$precision = \frac{TP}{TP + FP} \tag{7.2}$$

Precision measure is introduced because *FP* is generated by the camera jitter and needs to be minimized to reduce the camera jitter effect.

Another example of problems in the outdoor applications is the weather conditions influence.

An interesting example of the multiresolution approach in solving such a problem was introduced in [68]. Researchers used the method of wavelet multi-level decomposition and wavelet fusion to:

- determine the number of layers of rain and/or snow noise,
- formulate a fusion rule based on rain (snow) noise pollution, and
- make wavelet fusion on specific layer of multiple continuous degraded images.

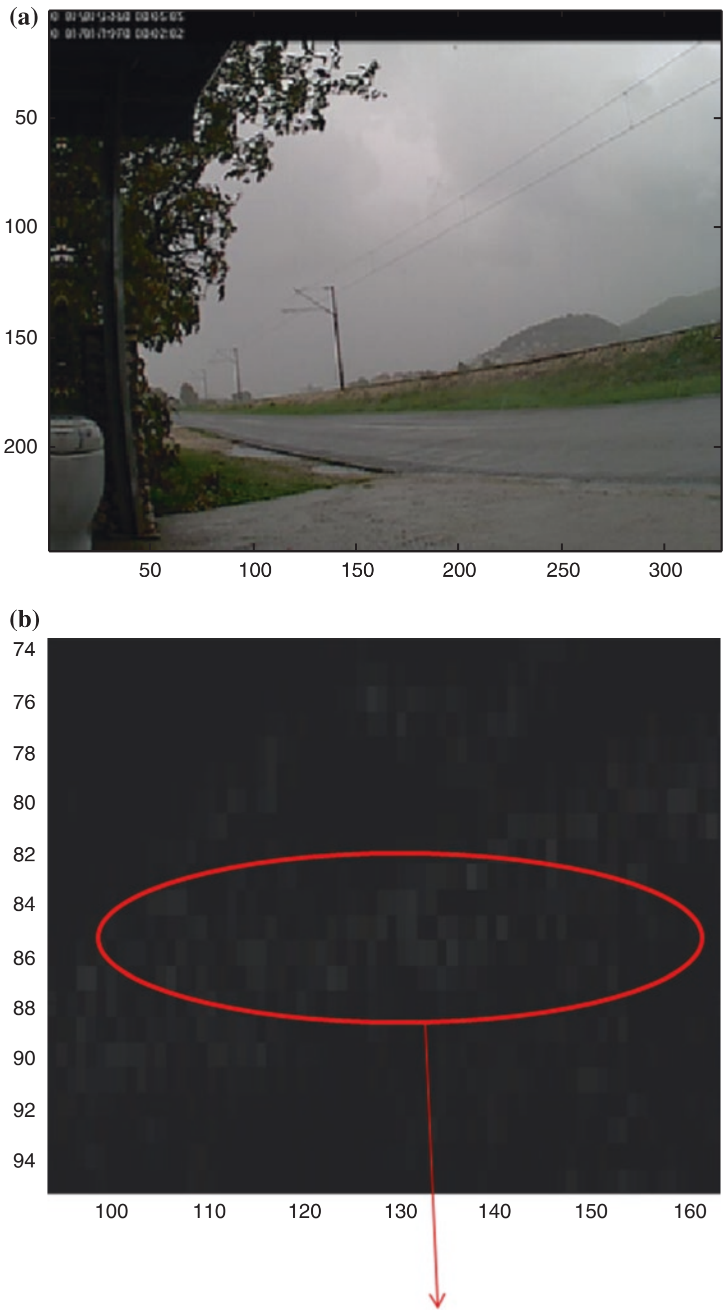
The first phase of the algorithm is the wavelet decomposition. The images are decomposed for ten layers. This was used to identify the high-frequency coefficients from the 4th layer to the 2nd layer as interested in the detection of rain or snow noise.

The second phase was on the high-frequency coefficients, which were isolated as the rain or snow noise. The coefficient matrix corresponding to each direction of the 4th layer and the 2nd layer is figured out, and the pollution degree *S* matrix corresponding to these coefficients matrix is solved. *S* matrix is made for a unitization processing, which can get the new *S* matrix. The greater the value corresponding to the *S* matrix in the same position is, the more serious the position is polluted by rain or snow noise. This algorithm already uses the local energy. The difference in local energies is expressed with:

$$G = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} \sqrt{\Delta x f(i,j)^2 - \Delta y f(i,j)^2} \tag{7.3}$$

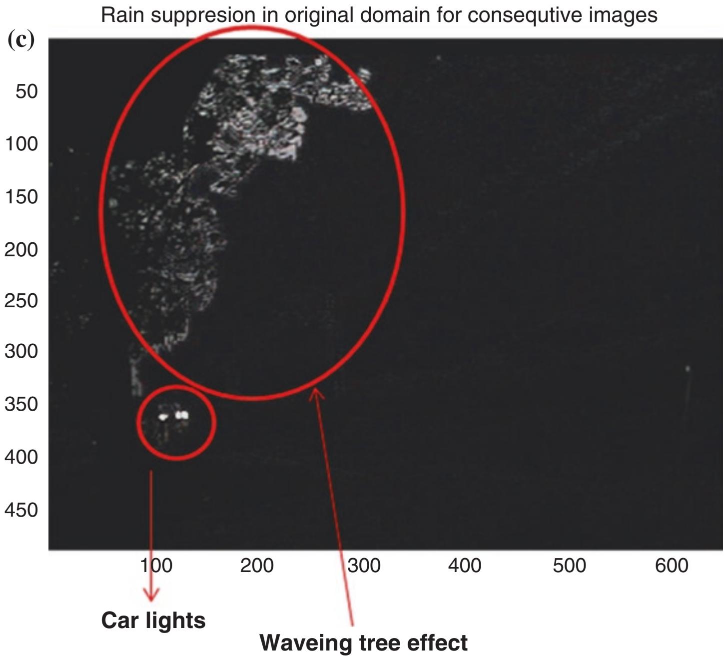
while the energy of the pixel at the position *i* and *j* is expressed with:

$$E = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} f(i,j)^2 \tag{7.4}$$



Rain in contrast to green graise

Fig. 7.4 An example of weather conditions and weaving tree effect to the motion detection in the outdoor applications: **a** the original frame, **b** rain as false motion, **c** waving tree effect, **d** rain suppression by the multiresolution approach


Rain suppresion in original domain for consequtive images

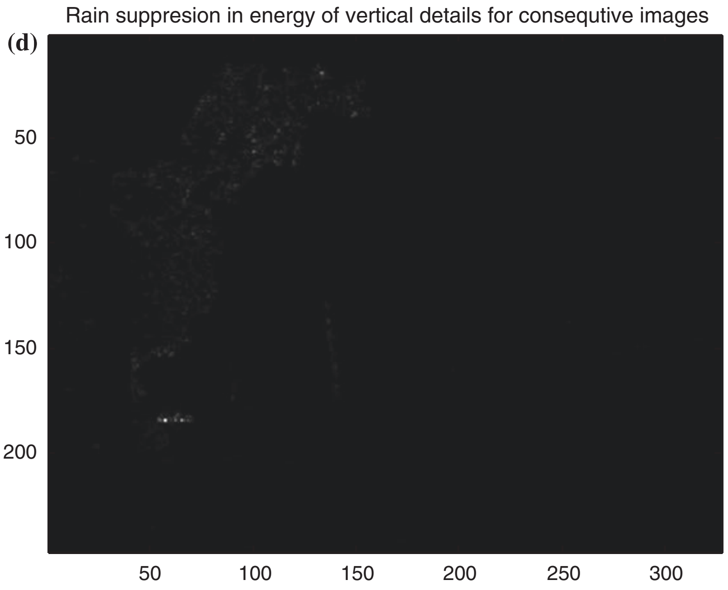

Rain suppresion in energy of vertical details for consequtive images

Fig. 7.4 (continued)

Multiplying G and E, we obtain the snow or the rain pollution of the current frame from the video sequence acquired by the video surveillance system:

$$S = G \cdot E \tag{7.5}$$

Figure 7.4 illustrates the abovementioned problems in our research of the road traffic surveillance.

Figure 7.4a shows an example of the current frame's approximation coefficients obtained by the surveillance camera located at the intersection of the state road.

After the first phase of the decomposition, the matrix for the analysis has a half of the elements of the original frame. This matrix of detailed coefficients is visualized in Fig. 7.4b. It can be noticed that the rain drops are detected as the motion, which is not desirable. This effect should be reduced as much as possible. The rain is confused to a motion, because of the contrast between the rain drops and the graise.

Figure 7.4c shows the motion detection result based on the background subtraction without any suppression algorithm. It can be seen that the effect of the waving tree makes almost impossible to distinguish a real motion (a moving car) from the false motion (moving tree due to wind). It happens because the tree branches have a real motion, although it is disturbance from the point of view of our application.

Figure 7.4d shows the results of the rain suppression algorithm to the motion detection. It can be seen that the waving tree effect is also suppressed.

These results are preliminary and there is no guarantee that the conclusion made today will be valid in future.

7.3 SAR Images Analysis for Control of Ecological Incidents

Another research field is the SAR satellite images, which are hard to process without problems at low level processing, such as:

- jitter,
- scatter,
- illumination,
- weather or other problems.

It is easily to find influences of bad threshold determination, for example, to oil spills detection.

General advantages of the multiresolution approach are:

- better filter coefficients,
- faster implementation by SGW,
- filter coefficients obtained by the WT produces better results by the PCC criterion than other techniques, i.e. Chebyshev, Butterworth and ecliptic,
- WT converge faster toward solution thanks to the second generation wavelets.

The algorithm for oil spills detection (Fig. 7.5) developed in our researches is a typical example of the interaction of the low and the high level data. In this case a low level processing is performed at the image processing level with the multiresolution wavelet approach. The data fusion is performed by using higher level information—presence of the ship in the searched area.

The algorithm from Fig. 7.5 generates the alarm based on two types of data. The results are also preliminary and there is no guarantee that the conclusions made up to date will hold in future.

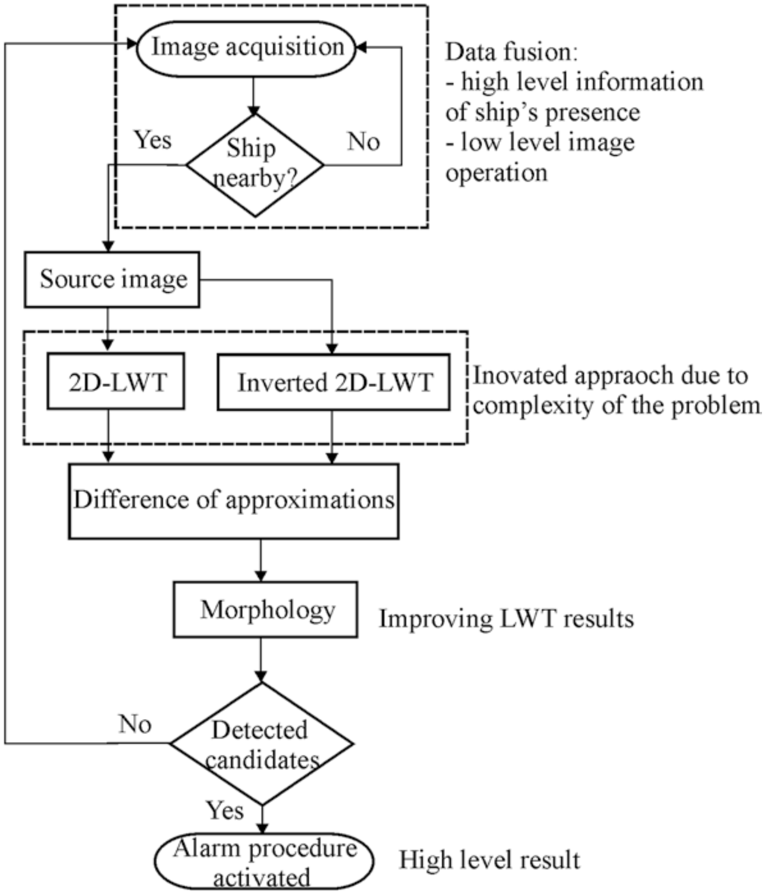


Fig. 7.5 An algorithm for the oil spills detection by data fusion and the multiresolution approach from the satellite SAR images

Chapter 8
Conclusions

Abstract Area covered with this book includes several well-funded industries: the industry of medical electronics, the military industry and the entertainment industry. This chapter summarizes the conclusions from all chapters. General conclusion is the interaction between low-level vision applications and high-level vision applications, which are responsible for the final result of the system.

Keywords Medical electronic industry · Military industry · Entertainment industry · Visual system performance

The area of image processing and analysis, scientific visualization and augmented/virtual reality is of interest to the richest industries in the world, e.g. biomedical or military/security industries. Advances in the field of augmented/virtual reality also include a well-funded industry—entertainment. Industry managers are only interested in final results, and are often not even aware of the existence of problems—lower image processing tasks which greatly influence the performance of higher vision applications.

The influence of lower vision applications on the performance of higher vision applications is illustrated by examples. It is an intuitively interesting topic. The right question should be how to suppress all the possible influences and simultaneously maintain quality and speed of execution of higher vision applications. If we want, for example, to implement an advanced virtual reality based communication system to enable seafarers to communicate with their families, we need to pack and transfer data to maintain resolution and transfer speed. Such applications have to ensure the unpacking of a small number of data through a satellite-band communication channel into a great number of detailed high resolution data. One of the possible solutions is to use the multiresolution approach for data compression. Nowadays, WT is a standard multiresolution tool. One of the ways to improve such applications is to study WT improvements and eventually, find new transformations best suited for the task.

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The possibilities of development for this field of research are tremendous. We can hope that the newly developed techniques won't be misused.

As stated in the Introduction, research fields presented in this book are:

1. video surveillance,
2. biomedical applications,
3. improved communications through teleoperation, telemedicine, animation, augmented/virtual reality, and robot vision,
4. monitoring of the condition of ship systems and image quality control.

Chapter 4 presented previous research in visual quality control and preliminary results of study of properties of dielectric materials. We arrived at the conclusion that the multiresolution approach is quite promising in these applications.

Although Chap. 5 presented preliminary research results from another field, it also involved the application of the multiresolution approach. It investigated the issue of application of virtual reality in security and contra-terrorist surveillance. The future communication trends and possibilities of the multiresolution approach were presented. Via the data processing part, multiresolution is included between the sensors and the control application, and in obtaining higher resolution in the focused part of the virtual/augmented/animated world and lower resolution in the part of the world marked as unimportant background. The presentation of advantages of such systems in the normal working days of seafarers was of special interest.

Chapter 6 presented preliminary research in EMG signal analysis. Multiresolution approach in CAD was presented in separate sections. CAD was covered by two applications: image compression with the reliable preservation of medical information, and assistance with the diagnostics procedure. The level of image compression without damage to useful (medical) information and the manner of use of different wavelets were established. Furthermore, it was shown that WT exhibits activity in the brain before people actually talk.

Chapter 7 presented the multiresolution approach in video surveillance. Examples of indoor and outdoor applications were presented. It was concluded that the multiresolution approach has some advantages in these applications. The developed algorithm was compared with the competitive algorithm of the same class for the camera jitter problem. The conclusion was that the proposed algorithm had some advantages judging by statistical image quality measurements. Applications covered in this chapter were: the influence of edge detectors on robot vision application in indoor environment, variation illuminations in motion detection for indoor applications, outdoor solution for the camera jitter problem, outdoor rain removal in traffic surveillance, and oil spills detection at open sea by SAR images. The advantages of the multiresolution approach were illustrated by case studies.

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