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Image Processing Algorithms Based on Pyramidal Structure

THESIS
for a master's degree

on the specialty 1-45 81 01 «Telecommunication systems and computer networks»

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INTRODUCTION

Digital image processing is being used in many domains today. In image enhancement, for example, a variety of methods now exist for removing image degradations and emphasizing important image information, and in computer graphics, digital images can be generated, modified, and combined for a wide variety of visual effects. In data compression, images may be efficiently stored and transmitted if translated into a compact digital code. In machine vision, automatic inspection systems and robots can make simple decisions based on the digitized input from a television camera. But digital image processing is still in a developing state. In all of the areas just mentioned, many important problems remain to be solved. Perhaps this is most obvious in the case of machine vision: we still do not know how to build machines that can perform most of the routine visual tasks that humans do effortlessly. It is becoming increasingly clear that the format used to represent image data can be as critical in image processing as the algorithms applied to the data.

A digital image is initially encoded as an array of pixel intensities, but this raw format is not suited to most tasks. Alternatively, an image may be represented by its Fourier transform, with operations applied to the transform coefficients rather than to the original pixel values. This is appropriate for some data compression and image enhancement tasks, but inappropriate for others. The transform representation is particularly unsuited for machine vision and computer graphics, where the spatial location of pattem elements is critical. Recently there has been a great deal of interest in representations that retain spatial localization as well as localization in the spatial—frequency domain. This is achieved by decomposing the image into a set of spatial frequency bandpass component images. Individual samples of a component image represent image pattern information that is appropriately localized, while the bandpassed image as a whole represents information about a particular fineness of detail or scale. There is evidence that the human visual system uses such a representation,1 and multiresolution schemes are becoming increasingly popular in machine vision and in image processing in general. The importance of analyzing images at many scales arises from the nature of images themselves. Scenes in the world contain objects of many sizes, and these objects contain features of many sizes. Moreover, objects can be at various distances from the viewer. As a result, any analysis procedure that is applied only at a single scale may miss information at other scales. The solution is to carry out analyses at all scales simultaneously. Convolution is the basic operation of most image analysis systems, and convolution with large weighting functions is a notoriously expensive computation. In a multiresolution system one wishes to perform convolutions with kernels of many sizes, ranging from very small to very large. and the computational problems appear forbidding. Therefore, one of the main problems in working with multiresolution representations is to develop fast and efficient techniques.

Most of the work revolves around a representation known as a "pyramid", which is versatile, convenient, and efficient to use. Pyramid-based methods have been applied to some fundamental problems in image analysis, data compression, and image manipulation.

GENERAL DESCRIPTION OF THE WORK

The work is devoted to theoretical and practical study of the image processing algorithms based on pyramidal structure, the development of algorithms for enhancement of their contrast as well as software implementation of the developed algorithms. Low-contrast images processing is applied in various areas of telecommunications, enhancement the clarity of images in electron microscopy, correction of the quality of aerospace images, as well as formation and quality enhancement of biological and medical images, including radiographs, thermo grams and radioisotope diagnostics. Software implementation of the developed algorithms makes it possible to achieve portability and high performance in relation to application tasks.

The work corresponds to paragraph 5 "Computer science and space research" of the State Program of innovative development of the Republic of Belarus for 2016–2020. Enhancement the quality of images is of great economic importance, since it reduces the cost of performing work by reducing the scale of the survey.

Relevance of the subject

Digital image processing is being used in many domains today. In image enhancement, for example, a variety of methods now exist for removing image degradations and emphasizing important image information, and in computer graphics, digital images can be generated, modified, and combined for a wide variety of visual effects. In data compression, images may be efficiently stored and transmitted if translated into a compact digital code. In machine vision, automatic inspection systems and robots can make simple decisions based on the digitized input from a television camera. But digital image processing is still in a developing state. In all of the areas just mentioned, many important problems remain to be solved. Perhaps this is most obvious in the case of machine vision: we still do not know how to build machines that can perform most of the routine visual tasks that humans do effortlessly.

Aim of the work

The aim of the work is to develop efficient algorithms for image processing based on pyramidal structure.

Tasks of the work

To achieve the aim, the following tasks were solved: image analysis based on Laplace and gaussian methods, development of an algorithm for image processing based on pyramidal structure.

Object of the research

The object of the research are images.

Subject of the research

The subject of the research are algorithms for image processing based on pyramidal structure.

Area of the research

The content of the master's work corresponds to the educational standard of higher education of the second stage (magistracy) of the specialty 1-45 81 01 “Telecommunication systems and computer networks”.

Information base

The information base for analysis is based on data obtained from databases that are freely available on the Internet.

Scientific novelty

Three algorithms for processing the images in the spatial domain were introduced and implemented. The algorithm for images based on pyramidal structure. Algorithm for enhancement of low-contrast images based on selecting the histogram of the output image, calculating the cumulative of the output image, calculating the normalized and cumulative of the input image and comparing the values of the cumulative of the input and output images, forming the output image with the specified histogram. An iterative contrast optimization algorithm based on the procedure of grouping low-contrast image histogram components into a specific number of bins according to a selected criterion, redistributing these bins evenly according to the gradation and the ungrouping procedure of previously grouped levels.

Theoretical and practical significance of the work

The theoretical and practical significance of the work lies in the fact that it describes the image processing by means of their spatial processing in real time, based on pyramidal structure, as well as in the reasonable efficiency and possible universal applicability of the developed algorithm.

Personal contribution of the author

The personal contribution of the author is that the main results on pyramidal structure algorithms of image processing, their software implementation and analysis were obtained personally by the author. Task setting and discussion of the results were carried out together with the supervisor.

Reliability of results

The reliability of the results is confirmed by the correspondence of programming simulation results with the theoretical assumptions as well as correspondence with the theoretical conclusions obtained by other authors in similar works.

Testing and implementation of results

The results of the master's thesis can be used for training purposes, as well as a component of the image processing systems

Publications

The main results of the work are presented in the report to the 56th scientific conference of graduate students, undergraduates and students of the BSUIR in 2020.

Algorithms of image processing based on Gaussian and Laplacian pyramids / I. Baryskievic, M. Hussein // Технические средства защиты информации : тезисы докладов XVII Белорусско-российской научно – технической конференции, Минск, 11 июня 2020 г. – Минск: БГУИР, 2020. – (В печати)

Structure and size of the work

The structure of the master's work is determined by the purpose, objectives and logic of the research. The work consists of introduction, three chapters, conclusion and bibliography. The total amount of master's work – 70 pages. The work contains 48 figures. The bibliographic list includes 22 titles.

SUMMARY OF THE WORK

Pyramid, or pyramidal representation, is a type of multi-scale signal representation developed by the computer vision, image processing and signal processing communities, in which a signal or an image is subject to repeated smoothing and subsampling. Pyramid representation is a predecessor to scale-space representation and multiresolution analysis.

Pyramid generation kernels

A variety of different smoothing kernels have been proposed for generating pyramids Among the suggestions that have been given, the binomial kernels arising from the binomial coefficients stand out as a particularly useful and theoretically well-founded class. Thus, given a two-dimensional image, we may apply the (normalized) binomial filter (1/4, 1/2, 1/4) typically twice or more along each spatial dimension and then subsample the image by a factor of two. This operation may then proceed as many times as desired, leading to a compact and efficient multi-scale representation. If motivated by specific requirements, intermediate scale levels may also be generated where the subsampling stage is sometimes left out, leading to an oversampled or hybrid pyramid. With the increasing computational efficiency of CPUs available today, it is in some situations also feasible to use wider support Gaussian filters as smoothing kernels in the pyramid generation steps.

Gaussian pyramid

In a Gaussian pyramid, subsequent images are weighted down using a Gaussian average (Gaussian blur) and scaled down. Each pixel containing a local average corresponds to a neighborhood pixel on a lower level of the pyramid. This technique is used especially in texture synthesis. Pyramid.

Laplacian pyramid

A Laplacian pyramid is very similar to a Gaussian pyramid but saves the difference image of the blurred versions between each level. Only the smallest level is not a difference image to enable reconstruction of the high-resolution image using the difference images on higher levels. This technique can be used in image compression.

Applications of the pyramids

In the early days of computer vision, pyramids were used as the main type of multi-scale representation for computing multi-scale image features from real-world image data. More recent techniques include scale-space representation, which has been popular among some researchers due to its theoretical foundation, the ability to decouple the subsampling stage from the multi-scale representation, the more powerful tools for theoretical analysis as well as the ability to compute a representation at any desired scale, thus avoiding the algorithmic problems of relating image representations at different resolution. Nevertheless, pyramids are still frequently used for expressing computationally efficient approximations to scale-space representation.

Detail manipulation

Laplacian image pyramids based on the bilateral filter provide a good framework for image detail enhancement and manipulation. The difference images between each layer are modified to exaggerate or reduce details at different scales in an image.

Some image compression file formats use the Adam7 algorithm or some other interlacing technique. These can be seen as a kind of image pyramid. Because those file format store the "large-scale" features first, and fine-grain details later in the file, a particular viewer displaying a small "thumbnail" or on a small screen can quickly download just enough of the image to display it in the available pixels so one file can support many viewer resolutions, rather than having to store or generate a different file for each resolution.

CONCLUSION

The analysis and property evaluation of Gaussian, Laplacian, and controlled image pyramid structures are performed.

Algorithms for synthesis of Gaussian and Laplacian pyramids in the spatial domain and a controlled image pyramid in the wavelet domain are developed.

An algorithm for synthesizing the significance map based on the analysis of low-level image properties (intensity, color, orientation), the formation of a Gaussian pyramid structure, the calculation of characteristic maps and visibility maps by intensity, color and orientation, and the calculation of the resulting significance map of the original image. It is shown that the significance map synthesis algorithm is effective for detecting low-contrast objects in the image.

An algorithm for improving image quality based on combining the source images using the Laplacian pyramid is proposed. The developed algorithm is effective for use in both single-sensor and multi-sensor systems. It is shown that the lowest value of the standard error is provided when using a three-level pyramid structure.

Software implementation of image processing algorithms based on pyramid structures in the MATLAB programming environment is carried out. The developed user interface allows to select input parameters for evaluating the efficiency of the developed algorithms.