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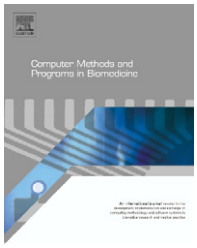

# MaZda—A software package for image texture analysis

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ABSTRACT

MaZda, a software package for 2D and 3D image texture analysis is presented. It provides a complete path for quantitative analysis of image textures, including computation of texture features, procedures for feature selection and extraction, algorithms for data classification, various data visualization and image segmentation tools. Initially, MaZda was aimed at analysis of magnetic resonance image textures. However, it revealed its effectiveness in analysis of other types of textured images, including X-ray and camera images. The software was utilized by numerous researchers in diverse applications. It was proven to be an efficient and reliable tool for quantitative image analysis, even in more accurate and objective medical diagnosis. MaZda was also successfully used in food industry to assess food product quality. MaZda can be downloaded for public use from the Institute of Electronics, Technical University of Lodz webpage.



## 1. Introduction

A texture perceived by humans is a visualization of complex patterns composed of spatially organized, repeated subpatterns, which have a characteristic, somewhat uniform appearance [1]. The local subpatterns within an image are perceived to demonstrate specific brightness, color size, roughness, directivity, randomness, smoothness, granulation, etc. A texture may carry substantial information about the structure of physical objects. In medical images it describes internal structure of human tissues or organs. Consequently, textural image analysis is an important issue in image processing and understanding.

Although textures are easily perceived by humans, there is no strict definition what constitutes a texture in image processing terms. Humans usually assess texture only qualitatively, while often quantitative texture analysis is required, e.g. in systems for medical diagnosis. To perform such quantification, mathematically defined texture properties have to be generated by means of texture analysis computer programs. These programs are usually based on general purpose software like Matlab [2]. They are capable of solving particular problems for particular categories of images with specifically chosen textural properties. If the problem or image category differs, such software tools become insufficient. Therefore, a choice of other texture descriptors or image analysis methods is necessary, which is a non-trivial problem. Mazda offers a new approach and seems to be a more appropriate tool to perform the task. The software was already utilized in many areas including MRI measurement protocol optimization [3], various medical studies [4–16], food quality studies [3,17–19], etc.

In 1998, the European COST B11 (1998–2002) project was started and one of the objectives was the development of methods for quantitative textural analysis of magnetic resonance images. At that time there was no commercially available software capable to conduct a quantitative analysis of texture within freely selected regions of interest (ROI) and to provide an interpretation of computed results. MaZda was the first program created to satisfy these objectives. In fact, its development started 2 years earlier in 1996. It was a program for texture analysis in mammogram images [20]. The first

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version of MaZda computed textural features derived from a co-occurrence matrix, which in Polish is named Macierz Zdarzeń. The name of the software is an abbreviation of this term. In 1998, several procedures developed and implemented in NMRWin [21] program at the German Cancer Research Center were adapted and implemented in MaZda. Later, in 1999, procedures for statistical and discriminative analysis of feature vectors were developed. For the last 10 years MaZda has been continuously improved. Within framework of COST B21 project (2003–2007), MaZda was extended by adding color and 3D image analysis, 2D and 3D image segmentation, data classification, analysis automation and other functions.

The program code has been written in C++ and Delphi™ with the use of OpenGL libraries. It has been compiled for computers that use Microsoft Windows® 9x/NT/2000/XP operating systems. The package includes two executable files named MaZda (image processing and computation of textural features) and b11 (for data visualization, classification and segmentation). It has been widely used by participants of COST B11 and B21 projects, followed by other collaborating scientists and students in numerous research areas.

MaZda is accompanied by an open source C++ library (MaZda SDK). It includes classes for accessing and storage of images, regions of interest and report files. Thus, by means of the available library, MaZda users are able to create their own image analysis modules. MaZda can execute such modules and can exchange data with them. Moreover, it has a built-in script interpreter engine. As a result, users can define sequences of computations to be executed on collections of images.

There are only few other examples of image texture analysis software available. The other non-commercial packages like KeyRes [22] and LS2W [23] provide only a limited number of Mazda functionalities.

KeyRes Co-Occurrence Features is a software which allows estimation of co-occurrence-based texture features for monochrome and color images (after converting into gray-scale). It supports several basic image formats like TIFF, GIF, JPEG and BMP. Texture features are estimated in windows with variable size, for different inter-pixel distances for evaluation of CO matrix. 3D image visualization, correlation map between estimated features and plot, and the features histogram are also available. KeyRes was written using C/C++ language and may be run under Matlab environment.

The LS2W software is a part of WaveThresh3 package for performing statistics based on wavelet techniques. The package is an add-on to the popular statistical S-Plus software (Insightful Corporation). It includes both various wavelet transforms and a number of statistical techniques (also based on wavelet transform). Its applications involve image analysis. The LS2W applies the Non-Decimated Wavelet Transform [24]. This transform is suitable for a model of locally stationary wavelet processes. In contrast to the traditional, frequency-based Cramér representation, this model permits a location-scale decomposition of the covariance structure of time series which appear to be stationary within localized regions, though their form may evolve from one region to another. Transform coefficients estimated by this software are useful for characterization of textures which possesses locally stationary, multiscale structure.

## 2. Image analysis pathways in MaZda

There are several pathways of image analysis that are handled by MaZda package (Fig. 1). Starting with the input data, there is a choice between the analysis of 2D gray-scale, 2D color or 3D gray-scale images. MaZda implements procedures for loading of most popular standards in MRI. Also it loads Windows Bitmaps, selected Dicom formats or unformatted gray-scale image files with pixels intensity encoded with 8 or 16 bits. A user is given a choice between analyzing the image as a whole or analyzing freely defined regions of interest. (The region has to be shaped by means of MaZda's 2D or 3D region editors.) Depending on the choice made, the results of the image texture analysis are feature distributions within the image (feature maps), or text lists of features computed within regions of interest (feature vectors). Feature maps may be useful for image segmentation, while the feature vectors for classification of image content.

Feature vectors computed by MaZda include up to several-hundred elements per individual region of interest. Such a large number of features, creating several-hundred-dimensional spaces, are not easy to handle by statistical analysis or by classifiers. Thus, MaZda employs techniques for reduction of feature vector dimensionality by selecting the most discriminative features (MDF) for further analysis. There are several methods for feature selection, using various selection criteria, which can be chosen by the user.

There are three main pathways of analysis offered by the b11 module. The data (feature vectors) can be statistically analyzed and visualized to compute and display relations between features and classes of textures. In addition, there are methods implemented for supervised and unsupervised classification. The b11 may be used for formulating rules for texture classification or designing an artificial neural network (ANN) classifier. Finally, feature maps can be employed for image segmentation.

## 3. Regions of interest

Regions of interest are sets of pixels in 2D images or voxels in 3D images selected to be analyzed. Defining a specific region of interest (ROI) concentrates the computation effort on an image fragment that is relevant to the goal of analysis and thus helps to avoid unnecessary processing. ROIs are of great interest in biomedical image processing applications. For example, tomography images of the human body contain various kinds of organs or tissues. To analyze image properties in a selected organ and not in the surrounding tissue, the image fragment corresponding to the organ must be defined, as the ROI for the analysis.

The ROIs in MaZda can be of arbitrary shape. The software allows definition of up to 16 ROIs within a single image. These regions can overlap if required. If there are more then 16 regions required for the analysis, they have to be analyzed successively, up to 16 at a time.

ROIs can be loaded from a file or defined with MaZda ROI editors. To edit 2D ROIs (Fig. 2a), drawing tools for lines (with various line thickness), squares, rectangles, circles, ellipses