An appendix to “Texture databases – A comprehensive survey”

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ABSTRACT

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Texture analysis is an area of intense research activity. Like in other fields, the availability of public data for benchmarking is vital to the development of the discipline. In “Texture databases – A comprehensive survey”, Hossain and Serikawa recently provided a precious review of a good number of texture datasets, and put an order into this scattered field. The aim of this appendix is to complement the cited work by providing reference to additional image databases of bio-medical textures, textures of materials and natural textures that have been recently employed in experiments with texture analysis. There is in fact a good number of little-known texture databases which have very interesting features, and for this reason are likely to receive increasing attention in the near future. We are convinced that this extension, along with the original article, will be useful to many researchers and practitioners working in the field of texture analysis.

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1. Introduction

Texture analysis has been an area of intense research activity for at least forty years. As a fundamental feature of images, texture plays a central role in many machine vision applications: surface sorting and grading, defect detection, content-based image retrieval, computer-assisted diagnosis, object tracking and face recognition are just some examples.

The selection of a proper set of images for experimenting with texture descriptors is a typical problem in this field. We believe it is no exaggeration to state that any researcher working on texture analysis has at least once in his career faced with the following question ‘which dataset(s) should I use in my experiments?’. For the benefit of those readers concerned with this matter, Hossain and Serikawa (2013) have recently surveyed a set of texture databases in the field of medical imaging, natural textures, textures of materials and dynamic textures. It is the aim of this paper to complement their precious work by covering an additional set of texture databases that did not find a place in the cited reference. Along with the celebrated Brodatz, CUReT, OuTex, VisTex, and so on – already reviewed by Hossain and Serikawa (2013) – there are in fact quite a few texture databases which, despite their being scarcely known, have very interesting features and are therefore likely to receive increasing attention in the near future. Our review is limited to those datasets that are open-access and free for research and non-commercial activities. Commercial databases are not considered in this study.

In the remainder the texture databases are divided into three groups: bio-medical textures (Sec. 2), natural textures (Sec. 3) and textures of materials (Sec. 4). There is no section for dy-
2. Bio-medical textures

In the bio-medical field, the amount of digital images generated for diagnostic and therapeutic purposes is increasing steadily (Oberoi et al., 2013). Unfortunately, as Kauppi et al. (2013) recently noted, most data are not public, therefore it is difficult to carry out large experimental comparisons and state-of-the-art surveys. In this section we review eight datasets from different bio-medicals areas. The specific properties of each dataset, like signal source and additional information, are summarised in Tab. 1.

### Table 1. Bio-medical textures: properties of the databases.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Signal source</th>
<th>Additional information</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT emphysema</td>
<td>X-rays</td>
<td>Thickness: 1.25 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Voltage: 125 kV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Current: 200 mAs</td>
</tr>
<tr>
<td>Epistroma</td>
<td>Light microscopy</td>
<td>Magnification: 20x</td>
</tr>
<tr>
<td>IICBU ‘Binucleate’</td>
<td>Fluoresc. microsc.</td>
<td>Magnification: 60x</td>
</tr>
<tr>
<td>IICBU ‘Lymphoma’</td>
<td>Light microsc.</td>
<td>–</td>
</tr>
<tr>
<td>IICBU ‘Liver’</td>
<td>Light microsc.</td>
<td>Magnification: 40x</td>
</tr>
<tr>
<td>Mammographic (12er)</td>
<td>X-rays</td>
<td>–</td>
</tr>
<tr>
<td>Mammographic (20er)</td>
<td>X-rays</td>
<td>–</td>
</tr>
<tr>
<td>MESSIDOR</td>
<td>Digital ophthalmosc.</td>
<td>–</td>
</tr>
</tbody>
</table>

2.1. Computed-tomography emphysema database

This database includes 115 high-resolution computed-tomography (HRCT) slices and 168 image patches manually selected and annotated from them (CT-Emphysema, 2008). Of the two groups the latter is mainly composed of stationary texture images (Fig. 1) and is therefore the most relevant to this study. Each patch is classified as either normal tissue, centrilobular emphysema or paraseptal emphysema. The patches are provided as grey-scale 16 bit tiff images with a resolution of 61 × 61 pixels. The dataset has been the basis for testing the effectiveness of some texture descriptors in this field (Gangeh et al., 2011; Sørensen et al., 2010).

![Fig. 1. The three classes of the computed-tomography emphysema database (patches): Normal tissue, centrilobular emphysema and paraseptal emphysema.](image)

2.2. Epistroma

The Epistroma database (Epistroma, 2012) is based on a set of tissue samples taken from a series of 643 patients with histologically-verified colorectal cancer at the Helsinki University Central Hospital, Helsinki, Finland, from 1989 to 1998 (Linder et al., 2012). The dataset contains 720 png 24 bit colour images of variable resolution cropped from digitized micro-array array slides of the patients’ tissue. Each image is labelled as belonging to one of the following two classes: epithelium or stroma (Fig. 2). The dataset has been recently used to prove the feasibility of texture analysis for automated identification of epithelium and stroma in tumor tissue micro-arrays (Linder et al., 2012).

![Fig. 2. The two classes of epistroma database: epithelium and stroma.](image)

2.3. IICBU Biological Image Repository

The IICBU Biological Image Repository database was proposed as a benchmark for testing and comparing the performance of image analysis algorithms for biological imaging (Shamir et al., 2008). The whole database is composed of 11 subsets representing different classification problems and image types of which the datasets ‘Binucleate’, ‘Lymphoma’, ‘Liver gender (CR)’, ‘Liver gender (AL)’ and ‘Liver aging’ are particularly rich in texture images. The first includes 16 bit grey-scale tiff images of resolution 1280 × 1024 pixels from two classes: binucleate and non-binucleate cellular phenotypes (Fig. 3).

![Fig. 3. The two classes of the IICBU ‘Binucleate’ database: Binucleate and Non-binucleate](image)

The second contains 24 bit colour tiff images of resolution 1388 × 1040 pixels from three classes representing different types of malignant lymphoma (Fig. 4): chronic lymphocytic leukaemia (CLL), follicular lymphoma (FL) and mantle cell lymphoma (MCL).

![Fig. 4. The three classes of the IICBU ‘Lymphoma’ database: chronic lymphocytic leukaemia, follicular lymphoma and mantle cell lymphoma](image)

The three ‘Liver’ subsets represent slices of liver organs extracted from sacrificed mice, stained with haematoxylin and eosin, and imaged through a bright-field microscope (Fig. 5). The resulting 48 bit colour tiff images (resolution: 1388 × 1040 pixels) are labelled across three axes of differentiation: age (1, 6, 16 and 24 months), gender (male/female) and diet (ad-libitum/caloric restriction).
Recent references where the datasets described in this section have been used to test texture descriptors are the works of Huang et al. (2013); Hervé et al. (2011); Orlov et al. (2010).

2.4. Mammographic patches

This database is the result of a project aiming at the development of a standard reference for computer-aided mammography. It is a recollection of mammographic patches from screening mammography taken from different sources (de Oliveira et al., 2008). Previously selected and annotated patches are provided as 16 bit grey-scale png with a resolution of 128 × 128 pixels. The database is organised in two sub-databases of 12 (Fig. 6) and 20 classes, respectively. In both cases the patches are pre-classified according to the BI-RADS classification system (The American cancer society, 2013), which is based on breast density (values from I to IV, where I stands for entirely fat; IV for extremely dense) and category of lesion (values from 1 to 6, where 1 stands for negative; 6 for biopsy-proven malignancy). Both datasets have been recently used for testing texture features in computer-aided diagnostics and image retrieval (de Oliveira et al., 2010; Deserno et al., 2012).

2.5. MESSIDOR

MESSIDOR (Méthodes d’Evaluation de Systèmes de Segmentation et d’Indexation Dédiées à l’Ophthalmologie Rétinienne) is a database of 1200 digital images of eye fundi (Fig. 7) acquired within the ophthalmologic departments of the following three medical institutions (MESSIDOR, 2005). The images have been acquired with a colour video 3-CCD camera and are presented as 24 bit colour tiff with variable image resolution: 1440 × 960, 2240 × 1488 or 2304 × 1536 pixels. Each image is classified according to two different attributes: retinopathy grade (four classes, from 0 to 3 in ascending order of severity – 0 = normal) and risk of macular oedema (three classes, from 0 to 2 in ascending order of severity – 0 = normal). The combination of the two attributes therefore gives 12 possible classes. Both regions of interest (Deepak et al., 2012) and full-size images (Oberoi et al., 2013) from MESSIDOR have been recently used as a basis for evaluating texture analysis algorithms.

3. Natural textures

Following the categorisation proposed by Hossain and Serikawa (2013), the three datasets included in this section are composed of heterogeneous texture classes mostly dominated by general outdoor scenes like buildings, vegetation, walls, plants, etc. A common feature of the three datasets is that the images have been acquired under uncontrolled illumination and viewing conditions.

3.1. Mayang’s texture library

Mayang’s textures\(^\text{1}\) latest version (16) is a huge project containing 4350 images from the following nine macro-classes: architectural, buildings, fabric, man-made, metal, nature, plants, stone and wood (Fig. 8). The images have been acquired with different cameras and under uncontrolled illumination and viewing conditions. The resolution is also variable, ranging from 2 to 18 MPixels.

3.2. Salzburg texture image database (STex)

The Salzburg texture image database (STex) is a project maintained by the Multimedia Signal Processing and Security Lab, at the University of Salzburg, Austria (STex, 2009). The dataset contains 476 colour texture images captured around the city of Salzburg. Each image corresponds to a different class such as bark, fabric, gravel, stone, wall, etc. (see Fig. 9). The images are provided as 24 bit colour pnm with a resolution of 1024 × 1024 pixels.

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\(^1\)The free version of the library has a download limit of 20 textures/day.
3.3. USPTex

The USPTex dataset (USPTex, 2012) includes 191 classes of general scenes like roads, vegetation, walls, clouds, gravel and the like, as well as materials such as seeds, rice, tissues, etc. – see Fig. 10. The database is maintained by the Scientific Computing Group at the Universidade de São Paulo, São Paulo, Brazil. Each class is represented by 12 samples provided as 24 bit colour png images with a resolution of 128 × 128 pixels. The dataset has been referenced in recent works on texture analysis algorithms (Backes et al., 2012; Florindo and Bruno, 2012).

4. Textures of materials

In this section we present nine databases of texture images representing real-life materials. Some datasets include one type of material only, such as wood (Secs. 4.3 and 4.7), granite (Sec. 4.6) and ceramics (Sec. 4.8); the others contains different natural, and man-made materials. In table 2 we summarise the conditions under which the images have been acquired. In the table the term ‘viewing direction’ refers to the orientation of the optical axis of the camera with respect to the normal vector of the material’s surface; ‘rotation’ indicates any rotation around such axis – also referred to as roll (Hill, 2001), and ‘scale’ any change in the object-camera distance or in the optical zoom (which provokes a change in the objects’ dimensions).

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Illum.</th>
<th>Viewing dir.</th>
<th>Rot.</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTF Bonn ‘ATRIUM’</td>
<td>V, C</td>
<td>V, C</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>BTF Bonn ‘UBO2003’</td>
<td>V, C</td>
<td>V, C</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Drexel</td>
<td>V, C</td>
<td>V, C</td>
<td>Yes, C</td>
<td>Yes, C</td>
</tr>
<tr>
<td>Forest species</td>
<td>F</td>
<td>F</td>
<td>Yes, C</td>
<td>No</td>
</tr>
<tr>
<td>Jerry Wu</td>
<td>F</td>
<td>F</td>
<td>Yes, C</td>
<td>No</td>
</tr>
<tr>
<td>Kyllberg Sintorn</td>
<td>F</td>
<td>F</td>
<td>Yes, C</td>
<td>No</td>
</tr>
<tr>
<td>MondialMarmi</td>
<td>F</td>
<td>F</td>
<td>Yes, C</td>
<td>No</td>
</tr>
<tr>
<td>Parquet</td>
<td>F</td>
<td>F</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>VsC TSG</td>
<td>F</td>
<td>F</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Note: V = variable, C = controlled, F = fixed

4.1. BTF Database Bonn

BTF Database Bonn is part of a wide research project developed and maintained by the Institute of Computer Science II at the University of Bonn, Bonn, Germany (Müller et al., 2005). It currently includes five image datasets, of which two are particularly rich in texture: ‘ATRIUM’ (Fig. 11) and ‘UBO2003’ (Fig. 12). They contain six and four classes of materials, respectively. Each material sample has been acquired under eight different viewing and lighting conditions, giving 81 × 81 = 6561 images for each class. Image resolution is 256 × 256 for dataset ‘UBO2003’ and 800 × 800 for dataset ‘ATRIUM’. The BTF database has been included in recent experimental works on texture analysis (Fernández et al., 2013; Paci et al., 2013).

4.2. Drexel texture database

The Drexel Texture Database, proposed by the Drexel Vision Group at Drexel University, Philadelphia, USA, includes 20 classes of different materials such as bark, sandpaper, sponge, etc. – see Fig. 13. Each material has been acquired under different and controlled conditions of illumination, distance, rotation and viewing direction (Oxholm et al., 2012). Textures are provided as high-dynamic-range (HDR) colour images with a resolution of 128 × 128 pixels.

4.3. Forest species database

The forest species database (Fig. 14), maintained by the Laboratory of Wood Anatomy at the Federal University of Paraná at Curitiba, Brazil, contains microscopy images of 112 different forest species (Martins et al., 2013). The database has been acquired from previously stained and dehydrated slices of wood using an Olympus CX40 microscope with 100× magnification. The resulting images are available as 24 bit colour png with a resolution of 1024 × 768 pixels. Thirty-seven of the 112 available species are softwoods and the remaining 75 are hardwoods. The two groups are further subdivided into 23 genera and eight families, and 62 genera and 22 families, respectively.

4.4. Jerry Wu photometric image database

The Jerry Wu photometric image database (Jerry Wu, 2003) is a project maintained within the TextureLab at Heriot-Watt University, Edinburgh, UK. The database is named after Dr. Jerry Wu, who developed it as a part of his Ph.D. The database
Araucaria angustifolia, Larix laricina, and with a resolution of 512 conditions. The images are provided as 8 bit grey-scale bmp-fied materials acquired under different viewing and illumination conditions. The images are provided as 8 bit grey-scale bmp-fied materials acquired under different viewing and illumination conditions (Fernández et al., 2013, 2011; Nurzyńska et al., 2013; Kononenko and Bevk, 2009).

4.5. Kyberg Sintorn Rotation Dataset

The Kyberg Sintorn Rotation Dataset (Kylberg-Sintorn, 2013) contains 39 textures of rough surfaces (Fig. 15) of unspecificied materials acquired under different viewing and illumination conditions. The images are provided as 8 bit grey-scale bmp with a resolution of 512 × 512 pixels. Various authors have employed this dataset for benchmarking texture analysis algorithms (Fernández et al., 2013, 2011; Nurzyńska et al., 2013; Kononenko and Bevk, 2009).

4.6. MondialMarmi

MondialMarmi is a database of granite images containing, in the current version (1.1), 12 classes representing commercial types of granite (Fig. 17). The project is maintained by the Department of Industrial Engineering at the Università degli Studi di Perugia, Perugia, Italy. The database contains four images for each class; each image corresponds to one granite tile. The images are 24 bit colour bmp with a resolution of 544 × 544 pixels. MondialMarmi includes both hardware- and software-rotated images at nine rotation angles: 0°, 5°, 10°, 15°, 30°, 45°, 60°, 75° and 90°. Scale, viewing direction and illumination conditions are invariable. This dataset has been used in recent works for comparing texture analysis algorithms (Paci et al., 2013; Kylberg and Sintorn, 2013; Fernández et al., 2013; Bianconi et al., 2012).

4.7. Parquet image database

The Parquet image database includes 14 classes of engineered wood (Fig. 18) representing different types of commercial parquet (Parquet, 2012). Each class includes from two to four different subclasses (tones) with minimal colour and texture difference from each other. The dataset contains a total of 295 images with a number of image samples for each tone variable from six to eight. The images are provided as 24 bit colour bmp with resolution variable from class to class. Rotation, scale, viewing direction and illumination conditions are invariable. The database has been recently employed to compare the effectiveness of machine vision algorithms for surface grading (Bianconi et al., 2013).

4.8. VxC TSG image database for surface grading

The VxC TSG database (VxC TSG, 2005) is composed of 14 different classes of commercial tiles taken from the ceramic industry (Fig. 19). The database is provided by the Grup de Visió per Computaor (Computer Vision Group) at the Universitat Politècnica de València, Valencia, Spain. Similarly to the Parquet database (Sec. 4.7) each class includes three different subclasses (grades) with minimal difference from each other (López et al., 2008). The number of samples for each class is variable, ranging from 14 to 30. The image resolution also differ considerably from class to class.
sectioning is widely acknowledged as a central issue in computer vision. Changes in scale, rotation and viewing direction. Particularly interesting, to this end, is the recently proposed Drexel texture database, which presents 20 texture classes under several different yet controlled viewing and illumination conditions. BTF Bonn ‘ATRIUM’ and ‘UBO2003’ also feature variable illumination and viewing directions, but include fewer classes. Mayang, STex and USPTex excel in terms of the number of classes, providing 4350, 476 and 191, respectively.

We agree with other authors (Kauppi et al., 2013; Hossain and Serikawa, 2013) who affirm that the situation is somewhat critical in the field of bio-medical textures: the number of publicly available datasets is indeed very limited in this area. Considering the importance of the potential applications in this field, we strongly agree with those authors calling for open repositories of standardized case data and ground truth information (Deserno et al., 2012).

A final remark is about the availability of test-suites. These are collections of classification/segmentation problems with predefined subdivisions into training and validation sets (Ojala et al., 2002). Test-suites make it possible to execute experiments in a ‘standardised’ manner, this way enabling meaningful comparisons of texture analysis algorithms. At present we are aware of no test suites associated with the texture databases presented in this appendix. It is to be hoped that this gap will be filled in future works.

6. Conclusions

The availability of suitable image databases for benchmarking is widely acknowledged as a central issue in computer vision. Hossain and Serikawa (2013) have recently put some order in this panorama by providing a survey of texture databases. In this appendix we have tried to complement their work by presenting some additional datasets that did not find a place in the cited work. We believe that this extension, along with the original article, will be useful to many researchers and practitioners working in the field of texture analysis.

7. Acknowledgements

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