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DAMAGES OF DIGITIZED HISTORICAL IMAGES AS OBJECTS FOR CONTENT BASED APPLICATIONS

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ABSTRACT

This work presents the preliminary results achieved within a FIRB project aimed to develop innovative support tools for automatic or semi-automatic restoration of damaged digital images concerning archaeological and monumental inheritance of Mediterranean coast. In particular, this paper is focused on a methodology for describing image degradation and its meta-representation for content based storing and retrieval.

Our innovative idea is to decompose and store in a conventional RDBMS the images content, considering the damages as objects of the images. Moreover, a set of descriptors(a subset of MPEG7 descriptors) is used for the damage meta representation aimed to content based application. Finally we developed a user-friendly database management tool for manipulating the contents of the database

1. INTRODUCTION

The aim of the FIRB project, approved in 2005, is the development of novel methodologies for the description and restoration of degradation typologies occurring in digitalized copies of old photos concerning archaelogical sites of the Mediterranean coast. The adopted approach consists of defining a knowledge-based model for image restoration exploiting metarepresentations of image contents, including degradation typologies The contents of degraded images will be stored on conventional relational DBMS, rather than on a home made system[6], in order to make it fast and effective for the users to find the information they needed.

More precisely, our proposal aims:

- to develop methodologies and algorithms which are able to completely recover the original image attenuating aging effects caused by a bad preservation, or abrasions of the film material. In particular a limited class of defects is analysed: scratches, small missing data regions, blotches, noise and colour rendering distortion. The choice of a limited class of degradations is supported by the attempt of tackling some unsolved theoretical problems;
- to find a defect representation along with its interaction with scene components using an object oriented description. It implies that a set of descriptors has to be singled out. These latter are mathematical objects which are able to represent different level semantic features, considered as representative for the image, such as colour, texture, scene components, degradation, blotches dimension, scratch appearance, etc. In other words, descriptors represent an alphabet for image description. Descriptors connections, like "taking part of" or "lying on", constitute the description grammar;
- to detect a framework for formalizing and collecting information concerning the meta-representation of the defect, the restoration technique and the achieved result. This way, the right restoration process could be automatically applied if an effective meta-representation of degradation is defined.

2. CLASSIFICATION OF DEFECTS

Old images may present a huge variety of damages due to a series of different factors. Some defects may lead to a complete loss of information, while other deteriorate the overall appearance of images. Mostly, the damages are originated by inappropriate environmental conditions (temperature, humidity, lighting), inaccurate handling (dirt, image protection, cracks) human intervention (stamps, writings, restorations) and chemical factors (reactions with microorganisms). Usually, the same image may contain several distinct defects.

While the origin of image defects on the physical support (whether positive or negative) is an important issue for a manual restoration activity, several defects appear similar once images are digitally scanned and should be described and removed by similar underlying processes. The defects of old photographic prints can be divided [3] in different sets according to their appearance in the image, as outlined in following subsections.

1.a spots

1.b foxing

1.c crack

Figure 1 – Some example of defects in old photos (courtesy of Alinari Archives, Florence, Italy)

2.1 Mechanical (physical) damages

Originated usually by an inaccurate handling and/or store of the original image; may be further divided into:

- ***Deposited matter:*** different materials adhere to the surface creating small spots that cover the original image; may be seen as the presence of localized high-frequency noise; Some examples are:
  - *Dirt*;
  - *Dust*;
  - *Digital prints*;
- ***Physical alteration of images:*** usually originated by an inaccurate handling; often lead to a complete loss of information and should be removed by specialized techniques. Typical examples are:
  - *Cracks*: deteriorate the aspect of the image and may be very large; do not exhibit a dominant orientation; however, each crack has its own direction; may also appear because of folded or torn scanned images;
  - *Scratches*: thin straight lines without a preferential direction;
  - *Craquelures*;
  - *Abrasions*;
- ***Deformations:*** originated by an inappropriate conservation of original images; often caused by excessive humidity and/or temperature and corrupt the way the gelatin is fixed to the support; usually hard to detect and remove in digitalized images;
  - *Lifting*;
  - *Bending*;
- ***Human retouches:*** deliberate human retouches that usually irremediably alter the image; some examples are:
  - *Gaps*;
  - *Stamps*;
  - *Writings*;
  - *Presence of adhesive*;
  - *An impropriate restoration*.

2.2 Chemical damages

Defects originated chemically, may be further divided into:

1.d water blotches

- ***Spots:***
  - *Blotches*: originated by water or humidity; each pixel preserves the information about the real data and noise;
  - *Foxing*: originates as the result of chemical reactions between the print and some microorganisms; appears as reddish-brown spots;
  - *Other*: other types of spots in the image;
- ***Tonal and color balance defects:*** originated by an excessive exposure of original photos to light; some examples are:
  - *Bleaching* (Fading);
  - *Yellowing*;
  - *Uniform/Irregular color cast*: occurs in images where color balance has been destroyed.

Figure 1 shows some of the most common defects in the Alinari archive.

3. IMAGE DESCRIPTORS

Image features such texture, color, motion, object shape have been investigated during the past decade as possible descriptors of the image content.

Each one of them may be related to the whole image(global features) or to one or more image parts(local features). Local features are specially important if related to meaningful image parts, i.e. regions normally corresponding to objects present in the scene.

The aim of a feature extraction algorithm is to provide the value of one or more feature descriptors. For example, an object's shape may be described in terms of its boundary but also in terms of geometric properties like area, perimeter, aspect ratio, etc.

The choice of the more appropriate descriptor is strongly depending on the application.

A subset of the MPEG-7 visual descriptors can be selected from the proposed standard descriptors set for our purpose, i.e. an effective meta-representation of damages as objects in the image. The MPEG-7 visual descriptors[4][5] can be classified into general visual descriptors and domain specific descriptors. The first ones describe the low-level visual features such as color, texture, shape, motion, and so forth; the second ones are application dependent and include identification of human faces and face recognition. Three kinds of low-level visual descriptor, will be briefly discussed in this section: Color Descriptors, Texture Descriptors and Shape Descriptors.

3.1 Color Descriptors

There are seven Color Descriptors: Color space, Color Quantization, Dominant Colors, Scalable Color, Color Layout, Color-Structure, and GoF/GoP Color.

- ***Color space:*** The feature is the color space that is to be used in other color based descriptions. The following color spaces are supported: R,G,B ; Y,Cr,Cb ; H,S,V; HMMD; Linear transformation matrix with reference to R,G,B; Monochrome.
- ***Color Quantization:*** This descriptor defines a uniform quantization of a color space. The number of bins which the quantizer produces is configurable, such that great flexibility is provided for a wide range of applications.
- ***Dominant Color(s):*** Color quantization is used to extract a small number of representing colors in each region/image. The descriptor consists of the representative colors, their percentages in a region, spatial coherency of the color, and color variance.
- ***Scalable Color:*** The Scalable Color Descriptor is a Color Histogram in HSV Color Space, which is encoded by a Haar transform. Its binary representation is scalable in terms of bin numbers and bit representation accuracy over a broad range of data rates.
- ***Color Layout:*** This descriptor effectively represents the spatial distribution of color of visual signals in in an arbitrarily-shaped region, in a very compact form. Its compactness allows visual signal matching functionality with high retrieval efficiency at very small computational cost.
- ***Color-Structure Descriptor:*** The Color structure descriptor is a color feature descriptor that captures both color content (similar to a color histogram) and information about the structure of this content. To this aim, a 8x8 pixels window slides over the image. With each shift of the structuring element, the number of times a particular color is contained in the structure element is counted, and a color histogram is constructed. Values are represented in the HMMD color space, which is non-uniformly quantized.
- ***Group-of-Frames/Group-of-Pictures (GoF/GoP) Color Descriptor:*** The GoF/GoP color descriptor defines a structure required for representing color features of a collection of similar frames or video frames by means of the SCD. It is useful for retrieval in image and video databases, video shot rouping,image-to-segment matching, and similar applications. It consists of average, median, and intersection histograms of groups of frames calculated on the individual frame histograms.

3.2 Texture Descriptors

There are three texture Descriptors: Homogeneous Texture, Edge Histogram, and Texture Browsing.

- ***Homogenous Texture Descriptors :*** The Homogenous Texture Descriptor describes directionality, coarseness, and regularity of patterns in images. It is useful for image-to-image matching for texture image database retrieval. This descriptor is extracted filtering the image with a bank of orientation and scale tuned filters (modeled using Gabor functions) using Gabor filters. The computation of this descriptor is based on filtering using scale and orientation selective kernels.
- ***Texture Browsing:*** The computation of this descriptor proceeds similarly as the Homogeneous Texture Descriptor. First, the image is filtered with a bank of orientation and scale tuned filters (modeled using Gabor functions); from the filtered outputs, two dominant texture orientations are identified. This is followed by analyzing the filtered image projections along the dominant orientations to determine the regularity and coarseness. The second dominant orientation and second scale feature are optional. This descriptor, combined with the Homogeneous Texture Descriptor, provide a scalable solution to representing homogeneous texture regions in images.
- ***Edge Histogram:*** The edge histogram descriptor represents the spatial distribution of five types of edges: vertical, horizontal, 45 , 135 , and non-directional edge. Since edges play an important role for image perception, it can retrieve images with similar semantic meaning. Thus, it primarily targets image-to-image matching (by example or by sketch), especially for natural images with non-uniform edge distribution. In this context, the image retrieval performance can be significantly improved if the edge histogram descriptor is combined with other descriptors such as the color histogram descriptor.

3.4 Shape Descriptors

There are three shape Descriptors: Contour-Based Shape, Region-Based Shape and Shape 3D.

- ***Contour-Based Shape:*** The Contour Shape descriptor captures characteristic shape features of an object or region based on its contour. This descriptor is based on curvature scale-space (CCS) representations of contours and also includes of eccentricity and circularity values of the original and filtered contours. A CCS index is used for matching and indicates the heights of the most prominent peak, and the horizontal and vertical positions on the remaining peaks in the so-called CSS image.
- ***Region-Based Shape—Art:*** The MPEG-7 Region-Based Descriptor ART (Angular Radial Transformation) is suitable for shapes that can be best described by shape regions rather than contours.
  The main idea behind moment invariants is to use region-based moments which are invariant to transformations, as the shape feature. The MPEG-7 ART descriptor employs a complex Angular Radial Transformation defined on a unit disk in polar coordinates to achieve this goal. Coefficients of ART basis functions are quantized and used for matching.
- ***shape 3d***: not useful for our goal

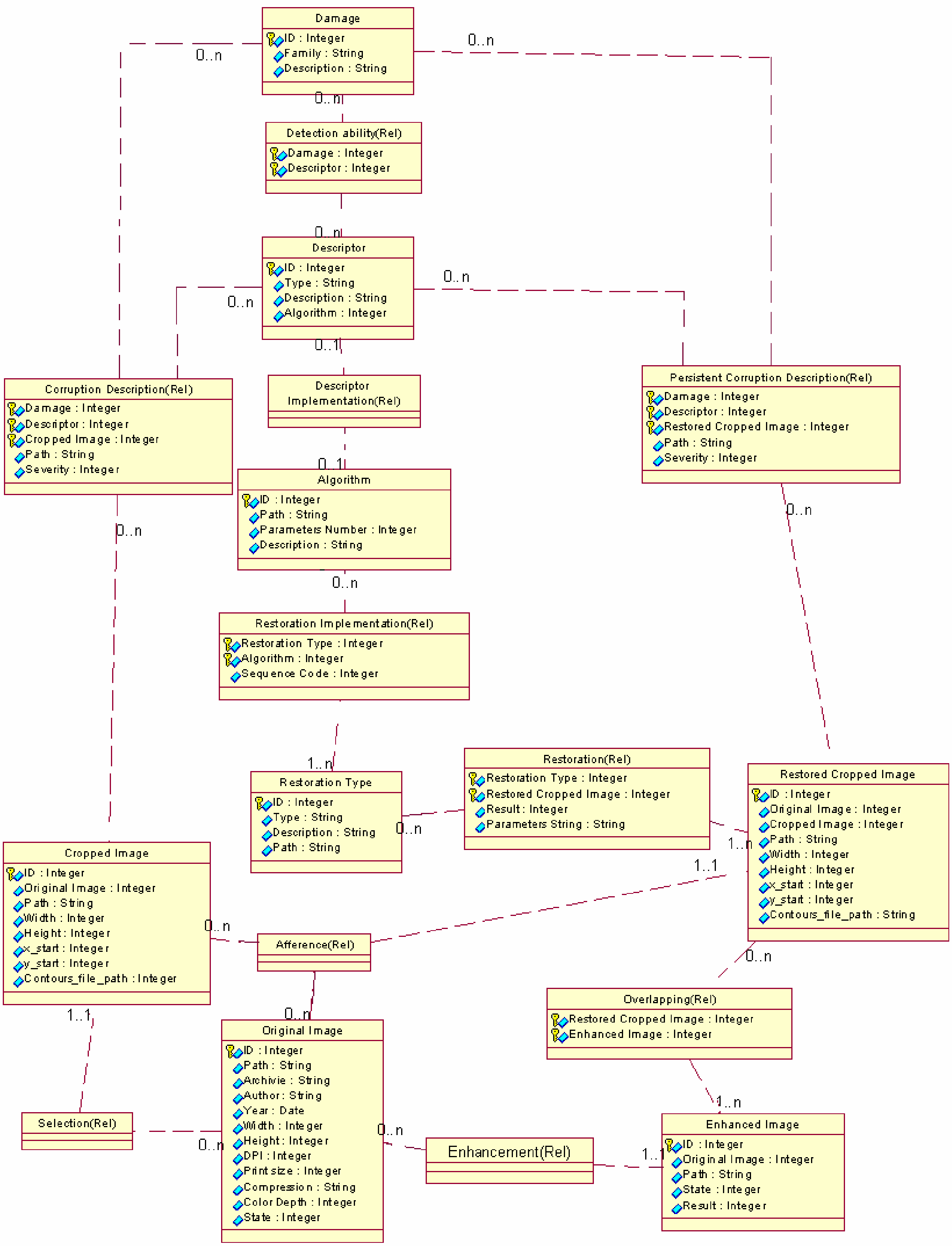

Figure 2: Entity-relationship diagram of the proposed photographic archive

4. PHOTOGRAPHIC ARCHIVE STRUCTURE

The definition of a conceptual model for characterizing degradation objects in images is a preliminary step for the implementation of the knowledge-base for the automatical selection of restoration methods of novel images. Suitable low-level descriptors (such as shape, color, texture), as well as medium/high-level descriptors (such as names, types), will be selected and implemented. Moreover, the contents of degraded images will be stored on conventional relational DBMS, forming a photographic archive [1]. This choice makes it fast and effective for users to find the information they need. The work will yield the implementation of prototypal software for processing degraded images, starting from the low-level features extraction to the high-level mapping onto the knowledge-base.

Our current activities are oriented towards developing a tool for querying the photographic archive with reference to both content and degradation features. After the initial analysis of requirements phase, we have accurately designed a relational database suitable for our needs. The database supports the user in several activities concerning the process of image cataloging and restoration. Fig.2 shows the Entity-Relation diagram of our DB. The DB permits to store all the information of the restoration process, from the original images to their enhanced versions.Principal entities involved in DB are: *original image* (the image to be processed), *cropped image* (a part of the original image with one or more defects to be removed), *damage* (degradation typologies: scratches, spots, etc.), *descriptor* (concerning image contents), *restored cropped image* (a part of the original image which has undergone one or more restoration phases), *restoration type* (the class of the restoration process applied to the image), *algorithm* (the physical implementation of the processes of restoration or descriptor extraction), *enhanced image* (output image obtained overlapping the original image and its restored parts).We have also developed a user-friendly database management tool for manipulating the contents of the database. This tool, developed in the Matlab programming language, assists the user in several phases of the restoration process. It permits to describe degradation typologies of an image, to apply several existing algorithms or to add user-defined algorithms for the restoration, and to manipulate the database contents in an efficient way. Several useful queries are implemented and their output can be saved in a custom XML format, or seen as an HTML page.

5. CONCLUDING REMARKS

In this paper the first preliminary results of our activity for FIRB project, entitled "A Knowledge based model for digital restoration and enhancement of images concerning archaeological and monumental heritage of the Mediterranean coast", has been presented. Preliminary experimental results involve images from the Alinari Archive. The research units operating in the FIRB project are working on material (about 100 images since 1840) coming from the Alinari Archives in Florence, composed of high resolution, color, b/w digital images, concerning the Mediterranean coast, digitalized from original pictures, negatives, diapositives and slides. Picture restoration experts operating in Alinari can also represent first users of the developed methodologies. Moreover, they are involved in the experiments for guiding the description of the degradation features and evaluating the final results of the restoration.

Our scheme constitutes an ontology in which at the best satisfying the need of restoration, expressed by the image meta-representation, by means of experience coming from knowledge. Finally the proposed model aims to free users, interested in digital restoration, from the annoying task of image analysis, defects detection, choice of the best restoration algorithms along with the selection of their optimal parameters. The proposed research presents some completely novel tools for digital image restoration: the restoration process is based on knowledge and then it is able to receive experience about new kinds of defects along with more recent and effective algorithms for restoration: the model constantly grows while it is used; with regard to the classes of defects related to the project: scratches, blotches, colour distortions and noise, the algorithms for their restoration account for both their physical-chemical causes and their human eye perception; image meta-representation and degradation can be also used in finer applications as content retrieval and the automatic definition of pictures degradation typologies.

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