Coin Data Acquisition for Image Recognition

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Abstract

A fundamental part of a numismatist's work is the classification of coins according to standard reference books. For this application, image processing techniques like Image Enhancement, Image Segmentation and Optical Character Recognition (OCR) are investigated. The recently started European project COINS combines these two research areas by developing a vision based system for automated coin recognition. Digital image acquisition of coins is the first step in the processing pipeline: when making a digital photo of a coin, the setup of the image acquisition system determines the quality of the image. If images of coins are processed by image recognition methods, the accuracy of the results is highly related to image quality. This paper is intended as a technical guide for an optimal acquisition of ancient coins. For that purpose, it provides an explanation of basic principles of digital photography and describes an adequate acquisition setup with respect to numismatists' needs.

Keywords

Image Acquisition, Coin Recognition

1. Introduction

Traditional methods to fight the illicit traffic of ancient coins comprise manual, periodical search in auction catalogues, field search by authority forces, periodical controls at specialist dealers, and a cumbersome and unrewarding internet search, followed by human investigation. However, these methods only prevent the illicit trade of ancient coins to a minor extent. To date, no automatic coin recognition system for ancient coins has been researched and applied successfully. The recently granted European COINS project (Zaharieva *et al.* 2007b) focuses on technologies aimed at permanent identification and traceability of ancient coins based on their image-based recognition.

Initial research on image-based coin recognition focused on modern coins (e.g. Nölle *et al.* 2003; Reisert *et al.* 2006; van der Maaten and Poon 2006). Tests performed on image collections both of medieval and modern coins show that algorithms performing well on modern coins do not necessarily meet the requirements for classification of medieval ones (Zaharieva *et al.* 2007a). Applied and newly developed image processing techniques for classification and recognition of ancient coins are thoroughly described in (Kampel *et al.* 2009).

A conclusion of previous research done in the COINS project is that the performance of image-based recognition is highly related to the image quality. For example, a method for the automatic classification of ancient coins has to extract details out of the image which could become lost if an inadequate illumination or a too low resolution is chosen. Acquisition of coins from a photographer's point of view is described in (Hedgecoe 1982). Adameck et al. (Adameck *et al.* 2003) describe a coin validation setup which is based on images taken from moving coins. They propose a photogrammetric setup (Hossfeld *et al.* 2006).

This paper shows a basic approach for optimal acquisition of ancient coins, written especially for people with less technical knowledge. For that purpose, we provide an explanation of basic principles of photography and describe an adequate acquisition setup.

The paper is organized as follows: Section 2 explains basic principles of digital imaging. Guidelines for the setup of the whole acquisition system are described in Section 3. Section 4 covers the actual storing of the image data along with a short introduction to image compression. A conclusion is finally given in Section 5.

2. Principles of digital imaging

Unlike traditional analog film cameras that record a light image on film, digital cameras record discrete numbers for storage on a flash memory card or optical disk. Although the assets and drawbacks of analog and digital cameras are highly debated among professional photographers, nowadays digital cameras are sophisticated enough to produce adequate images for the purpose of image-based recognition of coins.

In general, digital cameras have two major advantages over analog cameras: firstly, the acquired images can be processed directly and immediately by the computer, i.e. no photo development is needed. And secondly, the quality of acquired images can be controlled immediately by the user. Thus, only digital cameras should be used for the acquisition of ancient coins and in the following only digital cameras are discussed.

Fig. 1. An image with resolution 256 x 256.

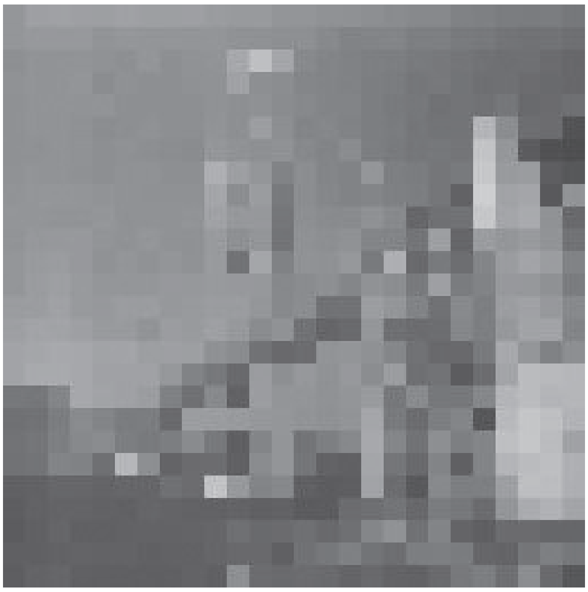

Fig. 2. The same image with resolution 26 x 26.

2.1. Resolution

Images acquired by a digital camera have to be represented using an appropriate discrete data structure. In contrast to analog photography, the image is sampled into a matrix with M rows and N columns (*sampling*) and for each sample (i.e. each pixel) an integer value is assigned (*quantization*). The finer the sampling and quantization, the closer the reconstructed image is to the ideal image.

Both M and N define the resolution of the images. For an example see *Figs 1* and *2* where an image is shown with the original resolution of 256 × 256 and the same image with a resolution of 26 x 26.

For modern digital photo cameras, the maximal possible resolution of the acquired images is specified in terms of *megapixels*. One megapixel comprises one million pixels, so for instance a camera capable of taking photos with a resolution of 4224 × 2376 comes up to 10,036,224 pixels or roughly 10 megapixels. The resolution plays a crucial role for the quality of an image. Important details can become lost with low resolution. For instance, in *Fig. 2* the bridge cannot be recognized anymore due to the low resolution.

For the selection of a sufficient resolution the *Shannon sampling theorem*, known from signal processing theory, has to be considered. The theorem has a simple physical interpretation in image analysis: the sampling interval should be chosen in such a size that it is less than half of the smallest interesting detail in the image. The practical meaning of this can be demonstrated by a simple example. Consider a circular coin with a diameter of 4cm that is photographed so that the coin just fits into the image frame (see *Fig. 3*). If we sample this coin with a way to small sampling rate of 24 (*Fig. 4*), a 24 × 24 image is created were all useful details are lost (*Fig. 5*). For instance, if we want to preserve details of 0.1mm size on this coin the sampling rate, according to the Shannon sampling theorem the sampling rate has to be $(40/0.1) \cdot 2 = 800$. In other words, a resolution of at least 800 × 800 has to be chosen. If the coin diameter makes only a third of the image dimensions, the resolution has to be 2400 × 2400.

2.2. Color imaging

For gray value images, quantized samples represent the brightness of the pixels. For color images, color is usually represented via the *RGB model* (referring

Fig. 3. A coin with a diameter of 4cm.

Fig. 4. Grid indicating a 24 x 24 sampling.

Fig. 5. Sampled image.

to red, green and blue). Thus, a particular pixel is associated with a three-dimensional vector (*r, g, b*) which provides the respective color intensities, where (0, 0, 0) is black, (*k-1,k-1,k-1*) is white, (*k*-1,0,0) is "pure" red, and so on. *k* is the quantization granularity for each primary. Usually, k is 256 which means that 256^3 = 16,777,216 different colors can be represented.

2.3. Exposure

Exposure is the total amount of light allowed falling on the image sensor during the process of taking a photograph. There are essentially three factors that go into making an exposure whether on film or on a digital sensor: the lens *aperture* (see Section 2.4), *shutter speed* (Section 2.6) and the sensor sensitivity called *ISO* (Section 2.7). Each of these parameters individually and taken together affect how much light from a scene is recorded. An appropriate exposure depends on the illumination conditions in the scene to be photographed: dark scenes need a longer exposure than bright scenes. Today, cameras usually automatically determine the correct exposure at the time of taking a photograph by using a built-in light meter.

2.4. Camera lens

A *photographic lens* (also known as *objective lens* or *photographic objective*) is an optical lens or an assembly of lenses used in conjunction with a camera body and mechanism to make images of objects. The lens is concerned with the projection of incident light irradiating from real world objects onto the camera's image plane, as illustrated in *Fig. 6*.

In general, many different types of lenses for various purposes exist. The two main optical parameters of a photographic lens are the maximum aperture and the focal length:

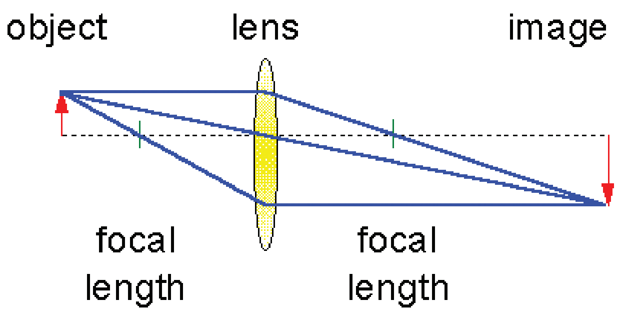

Fig. 6. The optical lens.

- **Focal length**: The focal length is defined as the distance from the optical center of the lens to the focal point.
- **Aperture**: The aperture (size) is the diameter of the opening through which light is admitted.

The focal length determines the angle of view and the size of the image relative to that of the object. An example of how lens choice affects the angle of view is shown in *Figs 7* and *8*. Here the lens with a focal length of 28mm provides a narrower angle of view compared to the lens with a focal length of 70mm. The larger the focal length the more the camera "zooms" to the object.

Fig. 7. A scene photographed with a 28mm lens.

Fig. 8. The same scene photographed with a 70mm lens.

The aperture limits the brightness of the image and the fastest shutter speed usable. The maximum usable aperture of a lens is usually specified as the *f-number*, which is equal to the focal length divided by the effective aperture diameter in the same units. The used aperture influences the depth of field (the range of distances from the camera where the image is acceptably sharp). A smaller f-number produces a longer *depth of field*, allowing objects at a wide range of distances to all be in focus at the same time.

Lenses/objectives can be classified into several types:

- Normal lens: angle of view about 50° (similar to human vision) and focal length equal to the diagonal measurement of the image plane.
- Macro lens: angle of view narrower than 25° and focal length longer than normal. These lenses are used for close-ups, e.g. for images of a larger size than the object.
- Wide-angle lens: angle of view wider than 60° and focal length shorter than normal.
- Telephoto lens: angle of view narrower and focal length longer than normal.
- Zoom lens: lenses with an adjustable focal length. Commonly, the lens may zoom from moderate wide-angle through normal to moderate telephoto.

For a detailed imaging of small objects like coins, a macro lens is the best choice. *Fig. 9* shows a Canon macro lens with a focal length of 100mm.

Fig. 9. Canon Objective EF 100mm 2.8 Macro USM.

Depending on the distance of the subject from the camera, the lens has to be at a certain distance from the image sensor to form a sharp image. The Autofocus feature of cameras allows them to obtain correct focus on a subject, instead of requiring the user to adjust focus manually.

2.6. Shutter speed

The shutter speed refers to the amount of time that the shutter of the camera is open and the film is exposed to the light. Slower shutter speeds (exposing the medium for a longer period of time) produce greater exposures. Shutter speed is measured in seconds. For example, a typical shutter speed for photographs taken in sunlight is 1/125th of a second.

In general, a slower shutter is only needed for dark scenes, but is critical for moving objects causing a motion blur on the image. For coin acquisition, a fast shutter speed (e.g. 1/125th of a second) is an appropriate choice if the coins are adequately illuminated.

2.7. ISO sensitivity

A camera's ISO function sets the light sensitivity of the image sensor. ISO settings are often rated at 100, 200, or 400 but go as high as 800, 1600, and even 3200 on some advanced models. A lower ISO setting is used when capturing overly bright scenes, since it reduces the light sensitivity of the image sensor. A higher ISO setting is often used when shooting under dimmer conditions (cloudy days, indoors, etc.), since it increases the light sensitivity of the image sensor. The disadvantage of a high ISO setting is that it also increases the noise level of the image. This is illustrated in the photographs shown in *Figs 12* and *13*. The image in *Fig. 12* was taken at ISO 100 whereas the image of *Fig. 13* was taken at ISO 3200 and shows a considerably higher amount of noise.

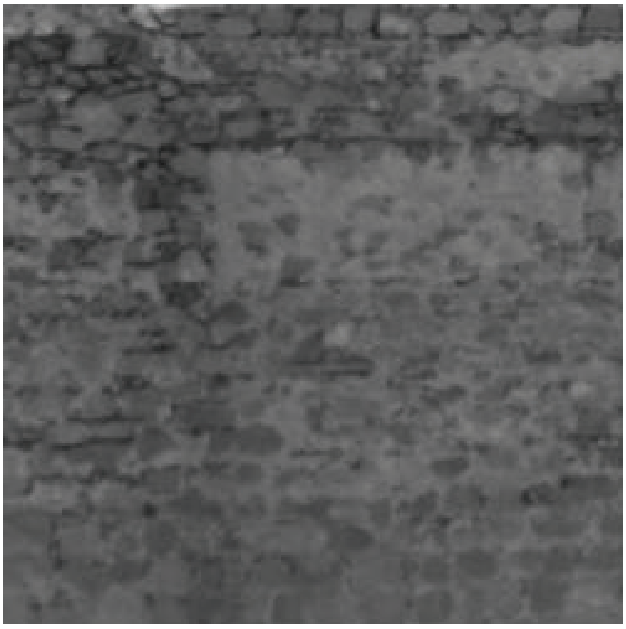

Fig. 10. Image of a wall taken at ISO 100.

For the acquisition of coins a low ISO setting should be chosen (usually ISO 100). If an adequate illumination is provided there is no need to have a higher ISO setting since in bright scenes a high ISO setting destroys the image quality.

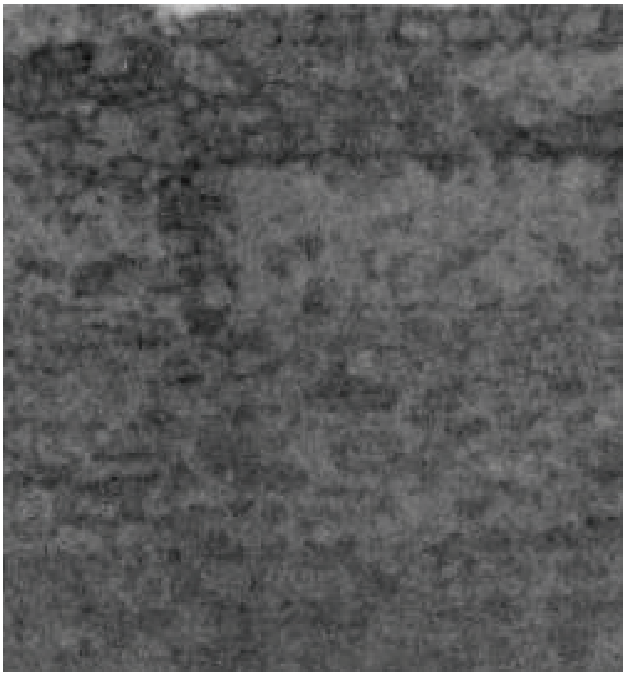

Fig. 11. Image of a wall taken at ISO 3200.

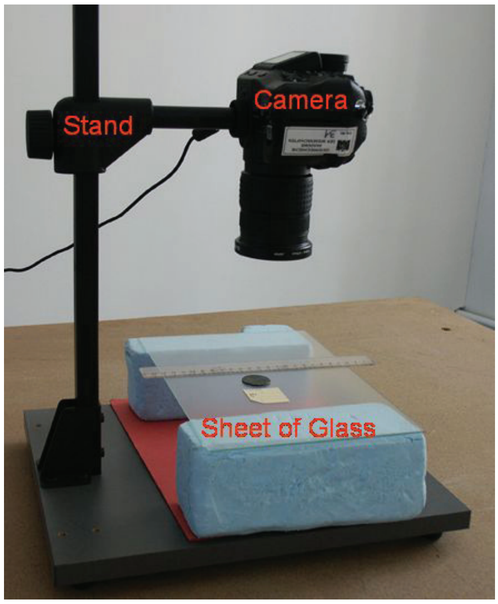

Fig. 12. Acquisition setup used at the Museum of Fine Arts, Vienna.

Fig. 13. Image of a coin directly placed on the background producing a shadow.

3. Acquisition setup

This section describes the acquisition setup for photographing ancient coins. An example for a proper acquisition setup is shown in *Fig. 14*. The digital camera is mounted on a stand and the coins are laid on a sheet of glass to avoid shadow casts at the coin border.

Fig. 14. Coin placed on a raised glass sheet producing no shadows.

3.1. Camera stand

A camera stand is a device that holds the camera in a fixed position. For coin image acquisition, it should be used for mainly two reasons: Firstly, with a stand the distance between camera and coin is kept constant during the whole acquisition process. Therefore, the camera settings (e.g. focus) have to be adjusted only once and the acquisition of a large amount of coins can be achieved more quickly. Secondly, the stand provides parallelism between the camera's image plane and the coin surface, allowing for an optimal acquisition of all coin details without noticeable distortions.

3.2. Supporting surface

For an easy localization of the coin in the image a uniform background should be used. Ideally, for the background a color atypical for ancient coins should be chosen. In the setup shown in *Fig. 12*, a sheet of red paper is used. If the size of the coin has to be determined in the final image, a ruler should be put next to the coin. Additionally, a label is needed to uniquely identify the coin later on.

A simple and easy way to avoid shadows is to lay the coin on a raised glass sheet as shown in *Fig. 12*. The effect of this approach is shown in *Figs 13* and *14*: if the coin is directly placed on the background paper a shadow is cast (*Fig. 13*), whereas by a placement on a raised glass sheet no shadows are visible in the image (*Fig. 14*).

3.3. Illumination

Appropriate illumination setups are of great relevance for the final quality of the images. Illumination should be sufficient to make all details visible on the coin and uniform on the whole coin area. Generally, two kinds of light sources exist: natural light sources and artificial light sources. Both are described in the following.

3.3.1. The light spectrum

The distribution of radiation over the range of possible wavelengths is called spectrum or spectral distribution. *Fig. 15* shows the whole spectrum of electromagnetic radiation. It can be seen that only a very narrow band of radiation between 380 and 780 nm is visible to the human eye.

From the physical point of view, a specific color can be identified by its electromagnetic spectrum (the distribution of radiation wavelengths). For

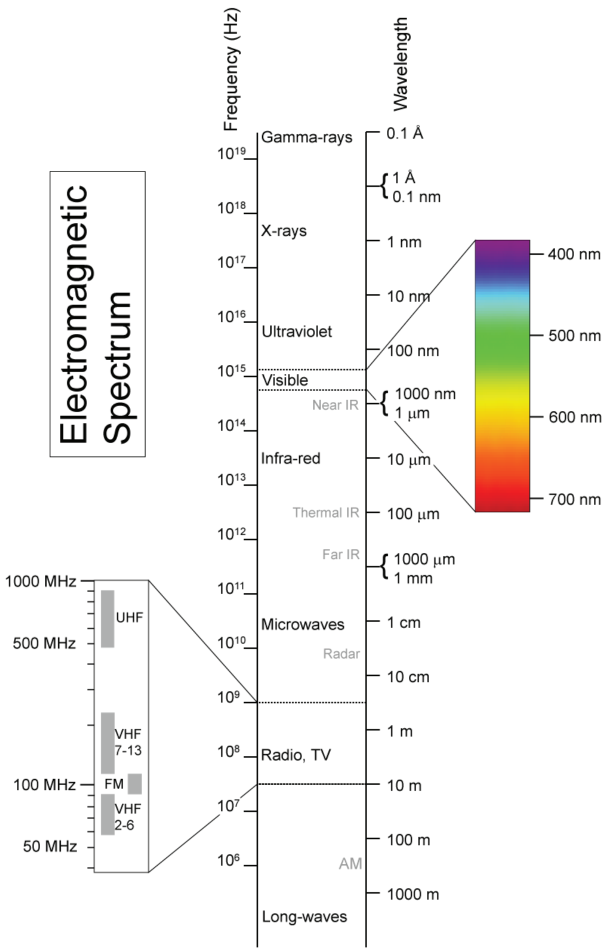

Fig. 15. The electromagnetic spectrum.

instance, monochromatic radiation consists of only one particular wavelength. However, both human visual perception and digital color models simplify color values by its amount of red, green and blue light (see Sec. 2.2).

3.3.2. Natural illumination

Natural illumination consists of solar radiation (light directly emitted from the sun) and diffuse sky radiation (scattering mechanisms due to clouds). The handicap of natural illumination is that it cannot be controlled because it depends of the weather and time of day. Especially, it cannot be kept constant for longer period. As a consequence, artificial illumination should be preferred over (single) natural illumination.

3.3.3. Artificial illumination

Commercially available illumination sources cover the entire spectral range from the ultraviolet to the mid-infrared region. They are manufactured in a variety of package sizes and geometrical arrangements, optimized for specified applications. Illumination sources can be divided into the following types:

- incandescent lamps
- (arc) discharge lamps
- fluorescent lamps
- light emitting diodes (LED)

Generally, all of these types are expected to give adequate illumination for coin acquisition. However, a detailed evaluation is a topic for future research.

4. Image file formats

Image file formats provide a standardized method for organizing and storing image data. The most common image file formats are JPEG, TIFF, PNG, GIF and BMP. Today's cameras usually support the TIFF file format and the JPEG file format. Some cameras offer a third option, that of saving the actual data generated by the sensor in a proprietary format. For instance, Canon calls their version of this "RAW", Nikon calls it "NEF".

Regardless of the image file format used, the size of the image file corresponding to the image which the camera produces depends on the pixel count. In most cameras each pixel generates 3 bytes of data, one for red, one for green and one for blue. This means that a 3 megapixel camera generates 9 million bytes of data, or 9 MB (megabytes). To decrease the size of the final file, image compression is applied which can either be lossy or lossless. Lossy compression tries to eliminate "unnecessary" information in the image which means that the retrieved image is different from the original. With lossless compression, the original image is retrieved without loss of information. Lossy compression provides much higher compression ratios (i.e. the amount of compression) but introduces compression artefacts.

Consider an image of a coin with a resolution of 600 × 602. Saved as a raw image file (without compression), it uses 1.08 MB of disk space. If the TIFF file format is used, a lossless compression is achieved and the file size is reduced to 0.95 MB (compression ratio of ~1.1:1). For a higher compression ratio the JPEG file format providing lossy compression has to be used. A compression ratio of ~8:1 comes up to a file size of 0.13 MB and for the human observer no difference to the original can be noticed. However, at higher compression rates image quality degrades significantly. With a compression ratio of ~50:1 an image file has the size of only 0.023 MB, but compression artefacts in the form of small block structures can be recognized.

It must be noticed that the JPEG format also supports lossless compression with adequate compression rates. For the storing of images that are planned to be processed by an image recognition system later on, a lossless compression should be preferred.

5. Conclusion

In this paper several aspects of digital photography relevant for numismatists acquiring ancient coins have been explained and discussed. This includes various parameters of the camera to be chosen like resolution, aperture, ISO sensitivity, shutter speed, focal length as well as pertinent principles like camera lens and autofocus. The second part of the paper was about the description of a whole acquisition system including a camera stand, supporting surface and illumination. The presented system allows for the fast acquisition of ancient coin sets and provides a constant image scale due to the camera stand and a shadow-free coin border due to the glass sheet as a supporting surface. Regarding the actual recording using digital image file formats, an introduction to image compression was given and the need for lossless compression was stressed when images are intended to be processed automatically by a computer vision system.

Acknowledgements

This work was partly supported by the European Union under grant FP6-SSP5-044450. The authors would like to thank Dr. Klaus Vondrovec (*Museum of Fine Arts, Vienna, Austria*) and Dr. Mark Blackburn (*Fitzwilliam Museum, UK*) for their help during the writing of this paper.

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