Chapter VI
Perceptual Data Hiding in Still Images

Mauro Barni
University of Siena, Italy

Franco Bartolini
University of Florence, Italy

Alessia De Rosa
University of Florence, Italy

ABSTRACT

The idea of embedding some information within a digital media, in such a way that the inserted data are intrinsically part of the media itself, has aroused a considerable interest in different fields. One of the more examined issues is the possibility of hiding the highest possible amount of information without affecting the visual quality of the host data. For such a purpose, the understanding of the mechanisms underlying human vision is a mandatory requirement. Hence, the main phenomena regulating the human Vvisual system will be firstly discussed and their exploitation in a data hiding system will be then considered.

INTRODUCTION

In the last 10 years, digital watermarking has received increasing attention, since it is seen as an effective tool for copyright protection of digital data (Petitcolas, Anderson, & Kuhn, 1999), one of the most crucial problems slowing down the diffusion of new multimedia services such as electronic commerce, open access to digital archives, distribution of documents in digital format and so on. According to the watermarking paradigm, the protection of copyrighted data is accomplished by injecting into the data an invisible signal, that is, the watermark, conveying informa-

tion about data ownership, its provenance or any other information that can be useful to enforce copyright laws.

Recently, the idea of embedding some information within a digital document in such a way that the inserted data are intrinsically part of the document itself has been progressively applied to other purposes as well, including broadcast monitoring, data authentication, data indexing, content labelling, hidden annotation, and so on.

Regardless of the specific purpose, it is general agreed that one of the main requirements a data hiding scheme must satisfy regards invisibility; that is, the digital code must be embedded in an imperceptible way so that its presence does not affect the quality of the to-be-protected data.

As far as the embedding of a hidden signal within a host image is concerned, it is evident that the understanding of the mechanisms underlying human vision is a mandatory requirement (Cox & Miller, 1997; Tewfik & Swanson, 1997; Wolfgang, Podilchuk, & Delp, 1999). All the more that, in addition to the invisibility constraint, many applications require that the embedded information be resistant against the most common image manipulations. This, in turn, calls for the necessity of embedding a watermark whose strength is as high as possible, a task which clearly can take great advantage from the availability of an accurate model to describe the human visual system (HVS) behaviour. In other words, we can say that the goal of perceptual data hiding is twofold: to better hide the watermark, thus making it less perceivable to the eye, and to allow to the use of the highest possible watermark strength, thus influencing positively the performance of the data recovery step.

Many approaches have been proposed so far to model the characteristics of the HVS and to exploit such models to improve the effectiveness of existing watermarking systems (Podilchuk & Zeng, 1998; Wolfgang et al., 1999). Though all the proposed methods rely on some general knowledge about the most important features of HVS, we can divide the approaches proposed so far into theoretical (Kundur & Hatzinakos, 1997; Podilchuk & Zeng, 1998; Swanson, Zhu, & Tewfik, 1998; Wolfgang et al., 1999) and heuristic (Bartolini, Barni, Cappellini & Piva, 1998; Delaigle, Vleeschouwer, & Macq, 1998; Van Schyndel, Tirkel, & Osborne, 1994) ones. Even if a theoretically grounded approach to the problem would be clearly preferable, heuristic algorithms sometimes provide better results due to some problems with HVS models currently in use (Bartolini, 1998; Delaigle, 1998).

In this chapter, we will first give a detailed description of the main phenomena regulating the HVS, and we will consider the exploitation of these concepts in a data hiding system. Then, some limits of classical HVS models will be highlighted and some possible solutions to get around these problems pointed out. Finally, we will describe a complete mask building procedure, as a possible exploitation of HVS characteristics for perceptual data hiding in still images.

BASICS OF HUMAN VISUAL SYSTEM MODELLING

Even if the human visual system is certainly one of the most complex biological devices far from being exactly described, each person has daily experience of the main phenomena that influence the ability of the HVS to perceive (or not to perceive) certain stimuli. In order to exemplify such phenomena, it may very instructive to consider two copies of the same image, one being a disturbed version of the other. For instance, we can consider the two images depicted in Figure 1, showing, on the left, a noiseless version of the *house* image, and, on the right, a noisy version of the same image. It is readily seen that: (1) noise is not visible in high activity regions, for example, on foliage; (2) noise is very visible in uniform