Bridging Printed Media and the Internet via Digimarc's Watermarking Technology

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ABSTRACT

This paper introduces *Digimarc MediaBridge*, explains the basics of its digital watermarking technology and shows how it seamlessly transports readers from a paper page to a Web page. Since much of our information still comes from printed media, whether in the form of newspapers, magazines, or packaging, *Digimarc MediaBridge* marries the best attributes of print with the visual impact and content expansiveness of the Internet. *Digimarc MediaBridge* works by using the science of steganography to communicate in ways that hide a message within the pixel patterns of an image. It allows a Web camera or scanner to translate the *Digimarc MediaBridge* image into an instruction to launch an Internet browser and to display the Web site of the author's choice.

KEYWORDS

Digital watermark, Digimarc, *Digimarc MediaBridge*, steganography, watermark.

1. INTRODUCTION

Throughout history, images have been used to communicate information in many forms and for many purposes. In recent times, capturing, storing, editing, retouching, printing, copying, and transmitting high quality colored images have become a multi-billion dollar industry, as well as a primary focus of national and international research institutions and organizations.

This tremendous growth has resulted in many advances benefiting the imaging field and its applications. For example, affordable high-resolution scanners and digital CMOS cameras (cameras on chips) are widely used. Color printers and color laser copiers have become easily affordable. Professional image editing and manipulation software packages have been developed for the PC and Mac platforms that are more powerful and easier to use. The speed and the storage capacity of hard disks, CD-ROM, DVD, and optical storage devices have increased tremendously to allow for the display and storage of a very large number of high-resolution images and video sequences. Affordable, ultra-fast computing platforms have become available for office and home use. The high-speed Internet backbone has become ubiquitous, and high-speed modems have become the standard entry-level Internet connection. Powerful image compression algorithms such as JPEG, and Internet browsers that are able to upload, download, and view high-resolution images are currently in general use on the Internet. So enabled, more and more images appear in the physical and digital world around us.

With all this new and powerful imaging technology, unauthorized copies of digital images are very easy to make and store. Hence, early research efforts in digital watermarking technology focused on watermarking as a technique to communicate and enforce copyrights, detect counterfeit copies, and deter improper use of digital media, in general, and digital images, in particular [1]-[7].

To create digital watermarks, early research focused on manipulating the pixels of an image in various ways. For instance, in one early watermarking technique, ones and zeros in a watermark payload are encoded by increasing or decreasing the pixel values around selected "signature" points. This technique is detailed in a patent filed by Corbis and now owned by Digimarc Corporation [1]. In another technique, the ones and zeros are encoded by summing or subtracting an ensemble of uncorrelated noise frames from an image [2]. Again, this technique is detailed in a patent owned by Digimarc. Both techniques are sensitive to visibility concerns and tailor the encoding to exploit data hiding features of the underlying content.

Another major use of digital watermarking technology is the ability to embed more "active" information within media content. By active, we mean a signal that causes some action to occur. For instance, with *Digimarc MediaBridge*, a visually inconspicuous watermark, or signal, is embedded in a digital image. This signal can be detected and read with a PC camera and the *Digimarc MediaBridge reader (*which can be downloaded at www.digimarc.com). Hence, the watermark links the reader to a chosen site on the Web.

Thus, digital watermarking technology can be used to facilitate both traditional and electronic commerce. In both types of commerce, images are extensively used, but their full potential is not currently exploited. Images processed by these applications are used for advertising and promoting products in magazines, newspapers, and in the greatest show on earth: the Internet. The adage "a picture is worth a thousand words" is the basic driving force behind this use. As we know, a picture inherently conveys much more information to the consumer than text or audio alone. And with the advent of such active digital watermarking, yet

another level of information can be invisibly added to an image. This additional information remains dormant until the reader software detects it. This dormant information can then be displayed, used to control the software or hardware that is processing the image, and used to obtain more information from the Internet. This dormant information gives the image intelligence; hence we have coined the term "smart image" [8].

Section (2) of this paper further explains the concept of smart images, such as a *Digimarc MediaBridge* image. Section (3) presents a brief overview of *Digimarc Corporation's* digital watermarking technology. Section (4) demonstrates how *Digimarc MediaBridge* creates a bridge between traditional and electronic commerce. The final section presents some conclusions.

2. DIGIMARC MEDIABRIDGE IMAGES

We define a Digimarc MediaBridge image as a physical still image that contains visually imperceptible data that remains dormant until it is detected and retrieved by reader software. This data includes pointers to a complete knowledge structure on a local database or on the Internet. This knowledge structure may include information about ownership rights, image creation, image content, and instructions for the software and hardware that process the image. The dormant data is interwoven with the media content and cannot be easily removed from the image without degrading the image quality. This data travels with the image and survives image processing and manipulation operations, such as scaling, rotation, cropping, filtering, compression, and digital-to-analog (e.g. printing) and analog-to-digital (e.g. scanning) conversion. Sections (3) and (4) explain how this data can be added to the image.

2.1 HOW DIGIMARC MEDIABRIDGE IMAGES ARE DIFFERENT

Adding imperceptible dormant information to an image facilitates image interpretation. In general, image interpretation requires the use of intelligent pattern-recognition algorithms that are extremely hard to design. These algorithms exploit the image data itself and do not require additional information. Although this field is very attractive, it has had limited success in some industrial applications and its general use is still a challenging research area. However, by adding dormant information to the image, the image becomes smarter, and the image interpretation problem is reduced to detecting and reading the embedded information using sophisticated signal processing algorithms.

The dormant data in a *Digimarc MediaBridge* image is different from the header, encapsulated information, or metadata (additional information about the data) often added to a digital image file to facilitate file manipulation and display. Metadata structures are used to provide unique identifying information about digital images. These data structures contain text data and are appended to the image files rather than embedded within the image itself [9]. Therefore, once the digital image is printed on paper, all the metadata structures are left behind. Moreover, metadata has the disadvantage of increasing the size of the image file and generally may not survive a change in the image format (e.g., from TIFF to JPEG or vice versa). On the contrary, the data in a *Digimarc MediaBridge* image is interwoven with the image and survives printing and image reformatting. This data can be retrieved and decodeded to provide unique identification information about the image, and used instead of metadata to facilitate the archiving, indexing, cataloging, previewing, and retrieving of digital images.

Digimarc MediaBridge images are different from bar coding, which is intrusive to an image's aesthetics and, otherwise, visually distracting. And *Digimarc MediaBridge* does not require any special, single-function equipment, like a bar code reader. Instead, it uses a digital camera or scanner, both of which have become fairly common. In fact, they are bundled with many of today's multi-media PC systems.

Digimarc MediaBridge images are also different from "DataGlyphs," which was recently introduced by Xerox Corporation. "DataGlyphs" encodes machine-readable data onto paper documents to facilitate document processing [10]. The idea is similar to the ubiquitous and visible bar codes on consumer products. Instead of vertical line segments of differing widths, the data is encoded as small 45-degree diagonal lines called glyphs. Each of these lines represents a single binary 0 or 1, depending on whether it slopes to the left or right. Sequences of these glyphs can be used to encode numeric, textual, or other information. These glyphs are then printed on the document as visible gray patterns, which can appear as backgrounds, shading patterns or conventional graphic design elements. Although the presence of these patterns may go unnoticed in text documents, it introduces a major degradation in quality when added to a natural picture.

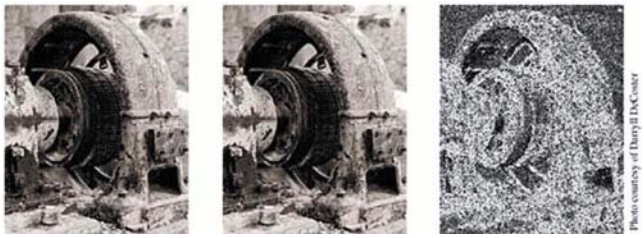
Digimarc MediaBridge images are different from images with hot spots, usually encountered in interactive multimedia applications or Internet browsing. Images with hot spots are usually dummy bitmaps that are used as a graphical interface to guide the user to select the proper choice during an interactive session. They contain no additional information beyond the face value of the image; hence they contain no intelligence. All apparent intelligence is due to the associated multimedia program. Replacing an image of this kind with another image of the same size would have no impact on the program as long as the user remembers where on the image to click in order to activate a desired choice. Similarly, copying the image to another application and clicking on any of its hot spots would not cause anything to happen. On the other hand, *Digimarc MediaBridge* images are independent of the software or hardware that may process them. The information they contain is what gives the software or hardware the desired intelligence. Replacing a *Digimarc MediaBridge* image with an ordinary image will deprive the software or hardware of its apparent intelligence.

3. DIGIMARC'S WATERMARKING TECHNOLOGY

Digital watermarking technology can be used for embedding dormant information into *Digimarc MediaBridge* images. For this purpose, a useful and effective watermarking technology must provide a method to embed data imperceptibly, promote a high information rate or capacity, allow the embedded data to be readily extracted by hardware or software, require minimum processing time, and incorporate a fair amount of robustness against standard image manipulation operations and basic attacks.

To help illustrate what a digital watermark is (see Figure (1)), we have included a comparison of an original image (1a), a watermarked image (1b), and the result of an image calculation

done through an image-editing tool (1c). By subtracting the original image from the watermarked image and exaggerating the result, the image calculation allows you to see the imperceptible changes to the image caused by embedding the watermark.



(a) Original **(b) Invisibly watermarked** **(c) Exaggerated**

Figure 1. The effects of watermarking

Digimarc's digital watermarking technology can be classified as a mixed domain technique, since it embeds signals in the frequency as well as in the spatial domain representation of the image. The frequency domain signal is used for synchronization purposes, while the spatial domain signal contains the payload.

3.1 THE EMBEDDER

The process of embedding a digital watermark into an image using *Digimarc's* watermarking technology can be summarized as follows. First, the image is divided into blocks of pixels. Then the watermark is independently embedded in each of these blocks. This allows the watermark to be detected from an image region as small as one block. Spread spectrum techniques are used to make the signal imperceptible and to combat the effect of image manipulation and filtering [10].

3.2 THE READER

The reader reverses the operation of the embedder. It starts by extracting the synchronization signal from the frequency domain of the image. It then uses this signal to resolve the scale, orientation, and origin of the watermark signal. Finally, it reads and decodes the watermark signal. Since the reader does not use the original image, the read process starts by estimating the watermark signal. In this case, the original image is considered to be noise, or a noisy two-dimensional channel. Since the pixels of the original image are assumed to be highly correlated locally, the digital value of the spread watermark signal can be estimated by first predicting the original pixel value using the local properties of the image, then subtracting it from the current pixel values. This produces an image representing the scattered watermark.

4. DIGIMARC MEDIABRIDGE

In this section, we describe *Digimarc MediaBridge*, which creates a bridge between traditional commerce and electronic commerce (see Figure (2), below).

In this application, *Digimarc's* watermarking technology is used to embed digital watermarks in printed images such as magazine advertisements, event tickets, CD covers, book covers, direct mailers, debit and credit cards, greeting cards, coupons, catalogs, business cards, and goods packaging.

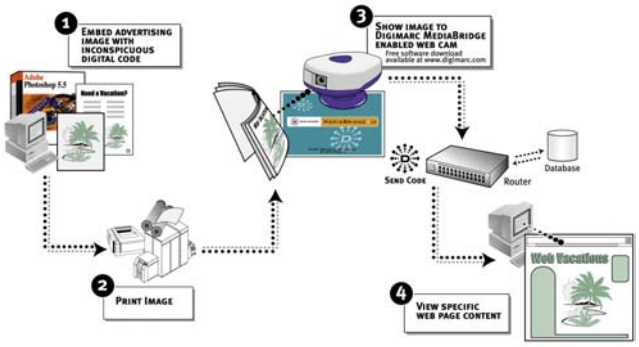
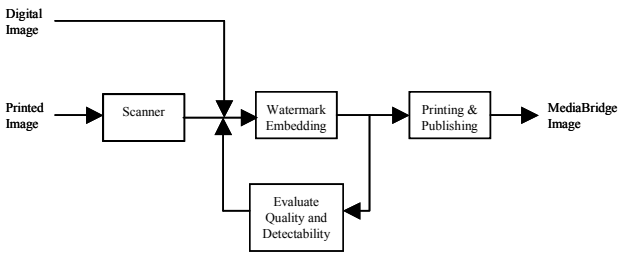


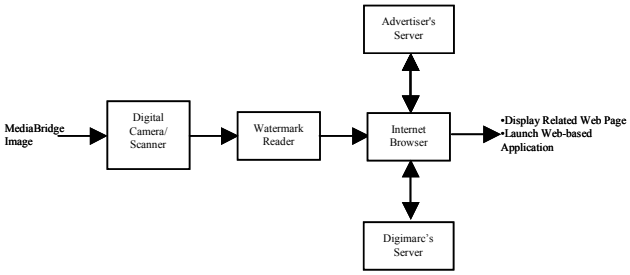
Figure 2. Digimarc MediaBridge process

As shown in Figure (3a), creating a *Digimarc MediaBridge image* is very simple. The process starts with a digital image, on which the watermark is embedded, as described in Section (3). This produces a *Digimarc MediaBridge* image in digital form. Finally, the digital *Digimarc MediaBridge* image is printed and published using a normal screen-printing process.

When a person uses a digital camera or flatbed scanner to produce a digital image version of a printed *Digimarc MediaBridge* image, the *Digimarc MediaBridge reader* application detects and reads the embedded watermark (Figure (3b)). The embedded watermark represents an *n*-bit index to a database of URLs stored on a known location on the Internet, e.g., the Digimarc server. This index is used to fetch a corresponding URL from the database. Then the URL is used by the Internet browser to display the related Web page or start a Web-based application specified by the creator of the image. Hence, *Digimarc MediaBridge* creates a bridge between the printed material and the Internet, permitting users to link directly to relevant Web destinations without any typing, mouse clicks, or time-consuming searching. This provides physical media with digital capabilities, allowing new forms of interaction with the digital world, thereby enhancing publishing, advertising, and electronic commerce.



(a)



(b)

Figure 3. Digimarc MediaBridge; (a) embedding information (b) decoding information

4.1 ADVANTAGES OF THE DIGIMARC MEDIABRIDGE SYSTEM

One of the biggest advantages of *Digimarc MediaBridge* is that it allows the reader access to much more data than is contained in the printed image, alone. This added data can take many forms, such as video and audio; thus enriching the reader's experience and adding a great deal of value to the author's message, as well.

In addition, embedding imperceptible digital watermarks offers several advantages over printing the URL on an advertisement, or, even, over using some type of bar coding. First, using digital watermarks does not require any real estate of the image and thus preserves the image quality. Presenting the URL or bar coding on an image consumes some of the image's valuable real estate and degrades its image quality (maintaining aesthetics is critical to most publications). Second, *Digimarc MediaBridge* does not require the user to type the URL in order to access the Internet. Typing URLs, especially long ones, can be confusing and error prone, and may hinder some users from accessing the Internet. For example, the reader can be directed to a specific Web page within even a very large site, like IBM's million or so pages, or Microsoft's site. Third, the imperceptible watermarks can be language-dependent and allow better tracking of advertisements. Depending on the language of the advertisement, a corresponding code can be embedded to allow the user to go directly to a Web page with the same language as that of the advertisement. Similarly, different watermarks can be used for different publications to allow advertisers to track their advertisements and optimize their advertising campaign. With printed URLs, this can be achieved only by using very long URLs, which is clearly undesirable.

Digimarc MediaBridge offers great flexibility to advertisers. Once an image is embedded with the desired digital watermark, the knowledge structure at the advertiser's server can be relocated or updated as desired without re-embedding, re-printing and re-publishing the advertisement. If the knowledge structure has been relocated, the advertisers need only update the related URL at *Digimarc's* server, so that the new Web page will be displayed to the user once the input device detects one of their advertisements.

Digimarc MediaBridge also has several advantages over traditional Internet search engines. When using an Internet search engine to retrieve desired information from the Internet, the user is confronted with multiple Web sites and information overload. Most of these Web sites are very confusing, deep, and often loaded with graphics, images, or animation. Searching these Web sites to retrieve the desired information over a slow Internet link can be time consuming and frustrating, especially to Internet novices. *Digimarc MediaBridge*, on the other hand, retrieves the desired information directly and quickly by showing a *Digimarc MediaBridge* image to the PC camera or scanning it with a scanner. No browsing of several Web pages is necessary.

4.2 SYSTEM REQUIREMENTS

A minimum PC configuration for use with *Digimarc MediaBridge* is a 233 MHz Pentium CPU, 32 Mbytes of DRAM, a 1G byte hard disk, and attached PC video camera or scanner. A better PC configuration would enhance the performance of the application. The PC must also run the *Digimarc MediaBridge* software. The PC may be connected to the Internet through a dial up modem, ISDN, DSL, or a direct LAN connection. The digital camera may be either a still or a video camera. A good quality CCD (Charge Coupled Device) or CMOS (Complementary Metal Oxide Semiconductor) digital camera provides the best *Digimarc MediaBridge* performance. Also, an analog camera connected to a classic video capture board could be used instead of the digital camera.

A digital camera or scanner is needed only when dealing with *Digimarc MediaBridge* image*s* in printed form. They are not needed if the image is already in digital form, as is the case when the image is posted on the Internet. In this case, Internet browsers such as Netscape Navigator and Microsoft Internet Explorer could be enhanced to include the watermark reader. Also, Internet browser capabilities can be enhanced further to display an icon on a corner of the image to indicate a hotspot when a *Digimarc MediaBridge* image is encountered. When the user clicks on this hotspot, the browser displays a special menu that is unique to that image, guiding the user and suggesting further action. The user may then select any of the displayed menu items to retrieve more information from the Internet and maximize his information gain. The content of the menu and its associated pointers is retrieved from a central server such as *Digimarc's* server.

4.3 USAGE EXAMPLES

Digimarc MediaBridge image*s* can be used in a variety of ways to facilitate commerce. For example, if a reader wants to get more information about an advertised product in a magazine, he simply shows the ad to the camera and goes directly to a precise location on the advertiser's Web site. He can get all the product details and specifications, locate a local dealer, or order online. If the reader wants to get more information on the subject of one of the articles in a magazine, he can hold the article up to the camera, and start reading. This allows him to go directly to other Web sites, where he can find and even order online related books, articles, etc. If the reader wants to subscribe to a magazine, he simply shows the front cover or the subscription card of the magazine to the camera. Subscription information appears and he subscribes on line. Similarly, if the reader wants to take advantage of an appealing offer found in a magazine, instead of calling an 800 number, he can go an easier route and apply online, immediately receiving all the associated promotions.

Digimarc MediaBridge image*s* can also be used to promote the sale of audio CDs, DVD movies, and books. For example, assume a consumer has just bought a CD of his favorite artist and is interested in other music by the same artist. Simply showing the back cover of the CD to the camera takes him to a Web site to purchase other CDs from the artist's collection. Or, if he is interested in the artist's latest song, he just holds the front of the CD in front of the camera and listens. In this case, the Internet browser first launches an MP3 audio player. Then it starts playing from the appropriate Web site a WAV file representing the latest song. The same idea can be used with DVD movies. If the consumer holds the DVD movie cover in front of the camera, the Internet browser first launches MediaPlayer. Then it starts playing a trailer of the main star's latest movie from the appropriate Web site. Similarly, showing the cover of a book to the camera takes the consumer to a site where he can order the book or see a list of books about the same subject or a list of books by the same author. Moreover, showing the book cover to the camera may play a trailer of a movie about the book, if there is one. It also allows the consumer to buy the movie online.

Digimarc MediaBridge image*s* have interesting uses with tickets for sporting events and concerts. For example, before a game a sports fan holds the front of an admittance ticket up to a PC camera. A Web page is displayed that shows the location of his stadium seat, a map of how to find the seat, and a view of the field from that seat. By showing the back of the ticket, the sports fan might see promotional material and merchandise for the event. After the event has taken place, showing the same ticket to the PC camera might take the sport fan to a Web page with detailed scoring information, game highlights, related links and merchandise specially discounted for ticket holders. Other types of events could have their own special information. For example, after a concert, a special offer on a music CD might be available only to ticket holders. For an airline ticket, the current state of the travelers frequent flyer account could be displayed. In addition, watermarking technology could be used to detect counterfeit tickets, which are becoming a large problem today.

Digimarc MediaBridge image*s* can also be used in Edutainment. It can whisk a child into the exciting world of children books. Simply insert the CD, which comes packaged with a "Smart Book," let the child show any page of the book to the digital camera, and page-by-page, the story unfolds. A pre-reader can hear a story read out loud. An older reader can follow along at his own level, or listen to a story that is too advanced to read alone. As the story unfolds, animation, songs, and exciting graphics carry the child along on a reading adventure. For activity books, the computer can also give verbal directions when the child shows a page to the camera.

The list of possible applications of *Digimarc MediaBridge* image*s* is growing every day and is limited only by the imagination.

5. CONCLUSIONS

In this paper, we introduced *Digimarc MediaBridge* and explained the use of Digimarc Corporation's digital watermarking technology in its implementation. *Digimarc MediaBridge* creates a *Digimarc MediaBridge* image, which is a physical image embedded with a specialized digital watermark. *Digimarc MediaBridge* acts as an active agent or catalyst that empowers the image with efficient access to further, specific information about the image content. This may be information located on local databases or on specific Web pages on the Internet, information that facilitates e-commerce, or information that instructs and controls further computer software or hardware actions.

So, *Digimarc MediaBridge* can make any printed image on your desk, coffee table, or kitchen counter a direct portal to the Internet …any time you want it. And *Digimarc MediaBridge* is available now…its acceptance by the publishing and advertising industries is growing rapidly (in fact, by over 160 magazines, alone). You can find *Digimarc MediaBridge*-enabled editorials and ads in such publications as *Good Housekeeping*, *Popular Mechanics*, *Wired*, and *Smart Money*. A number of camera vendors are including *Digimarc MediaBridge* as part of their bundled software. With the number of cameras and scanners in homes and in offices increasing, exponentially, the computer industry is embracing Digimarc's technology.

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