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THE FUNDAMENTAL STRUCTURES OF THE MEDIA DIGITAL IMAGING AND ITS PROFOUND DIFFERENCES TO SILVER-HALIDE BASED PHOTOGRAPHY

CH. WITTWER

Photography Department, School of Art & Design Zurich (SfGZ),
Ausstellungsstrasse 60, 8031 Zurich, Switzerland

The concept of using computers to process images is more than 30 years old. Besides secret military applications, the technology was first used publicly in the NASA unmanned planetary science program in the middle 1960's. Since then, digital image processing technology evolved rapidly into other scientific areas. Until the middle 1980's, people in the graphic arts industry were unaware of the possibilities of digital image processing, but today this technology is the hot topic. However, digital imaging is not only a technical development of conventional imagery, it is an entire new media, which will change the perception and significance of all mechanical images such as photographic-, video- or film-images in a revolutionary way.

KEY WORDS: Digital imaging, photography, media technology, silver-halide technology, digital photography

1. INTRODUCTION

The import of new technology and especially of new media can be fascinating but also irritating. When Louis J.M. Daguerre presented his first daguerreotypes to the public in August 1839 [1], people reacted very differently. Some of them, like Alexander von Humboldt, thrilled by the fine details and structures the plates could render, saw in the new media almost a magic tool that could create images detached from the "subjective human hand." Others, like the famous French painter Paul Delaroche, had less positive feelings about it. An anecdote states that when Delaroche first saw the daguerreotypes he exclaimed "La peinture est morte!" ("painting is dead!") [1]. Looking back on over 150 years of photographic history and evolution, it becomes very clear that photography did not replace painting, but liberated it from the task of recording reality in an objective and authentic way. This liberation lead the media to impressionistic and abstract style developments, opening a whole new perspective that stimulated the development of painting during the 20th century [2].

Today, the new imaging technology, which is inseparable from the development of computer technology, also produces different reactions, ranging between fear and euphoria. Some people see in digital imaging only a technical development beyond conventional silver-halide imagery, and fear that silver-halide materials and the related chemical processes could, by the end of this century, be completely replaced by digital technology. Others recognize that digital imaging encompasses more, because

we deal with an entirely new media that will change the perception and significance of all mechanical images, such as photographic-, video- or film-images, in a revolutionary way [3]. There will be a coexistence of both media, conventional silver-halide technology and digital imaging, because both media have very different characteristics, even if the final result (*e.g.* the printed image in a magazine) can look identical.

2. DIGITAL PHOTOGRAPHY VERSUS DIGITAL IMAGING

The term digital photography is appropriate when objects are recorded using a camera system in which conventional film-material is replaced by linear or area arrays of photosensitive CCD-cells. These systems can look from the outside very similar to conventional cameras, in fact they often combine existing camera bodies with the imager, which resides in a special electronic back fixed to the body (Fig. 1). Because

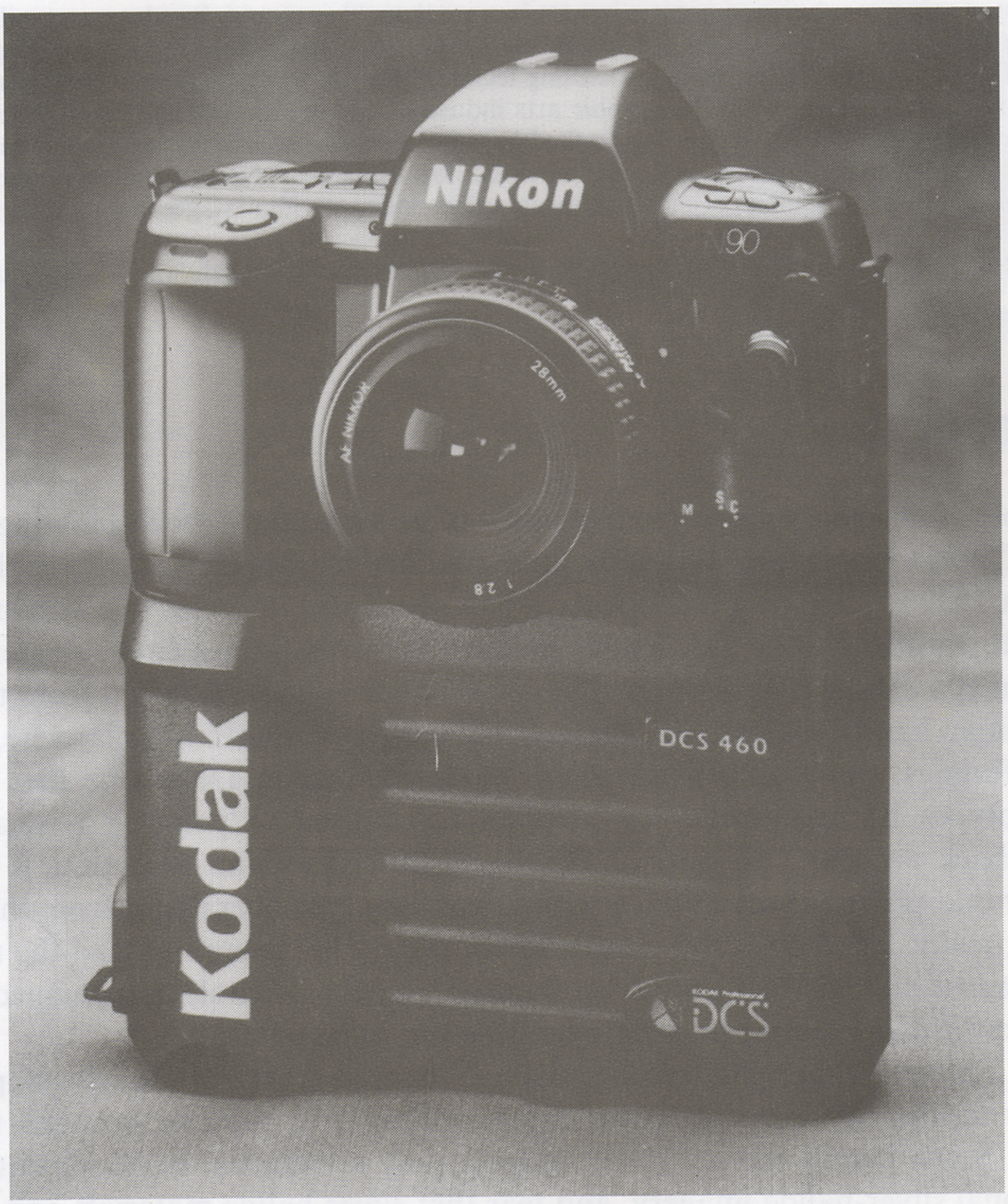

Fig. 1 Kodak's DCS 460 Digital Camera with a 3060×2036 pixel CCD imager was named the European Digital Product of the Year 1995–1996.

the final visible result of the imaging process-the print or displayed image-is again in an analog format, it seems that digital image processing is just a new technology. In fact it is a new media. To refer to it the term digital imaging is more consistent, because it excludes the term "photography", which etymologically evolved from the greek "photos" (=light) and "graphein" (=to write), describing the automatic process of information recording on light-sensitive emulsions using light as a messenger. Furthermore, digital imaging contains more, namely all manipulations and visualizations of digital data, including thermography, spacecraft imaging, image restoration, medical imaging, forensic imaging, but also non-scientific applications such as image manipulations, retouching and synthetic image modeling. Similar to photography, digital imaging as a media strongly links the sciences and art. This is why in complex multimedia and internet projects there is always a team, consisting of computer specialists and graphic designers, involved.

3. ANALOG AND DIGITAL WORLDS

An analog photograph is a human-readable information entity with an actual physical body in the form of silver clusters or color molecules embedded in gelatin. Silver-halide materials have a chemical attribute and are organic, almost "living" organisms affected by heat, moisture, light and pollution [4]. Conventional continuous-tone photography is referred to as an analog media because a black-and-white print can show infinite tonal values (graylevels) between minimum density (base plus fog) and maximum black. However, a silver gelatin print examined under a microscope shows only two different values in its microstructure: density=presence of a silver grain or a silver grain cluster and no density = absence of silver. Nevertheless this binary structure, conventional photography is not a digital media, because the two symbols are directly perceptible by the human visual system and not encoded.

A digital image, on the other hand, is an immaterial, machine-readable stream of bits in the form of a two-dimensional matrix. Since the image is represented as numbers, it can be processed using standard functions such as addition, subtraction, multiplication and averaging. The information content of the image can easily be altered and manipulated, by working not only in the spacial but also in the frequency domain [5]. Digital images are not visible, because when they are in their output form, they are again in an analog format. The immaterial numeric structure underlying the image cannot be seen. Although the pixel structure can be made visible by enlargement, we only see a materialized analog representation of the digital image and not the matrix itself. By creating a matrix of numbers, in which they not only represent the digital codevalues of the pixels but also have their own tonal values, it is possible to visualize simultaneously the (analog) image and its underlying (digital) matrix (Fig. 2).

4. INFORMATION AGE COMPATIBILITY

The most effective channel of communication is visual information. Images are everywhere and more than 100 million new images are produced every day to satisfy

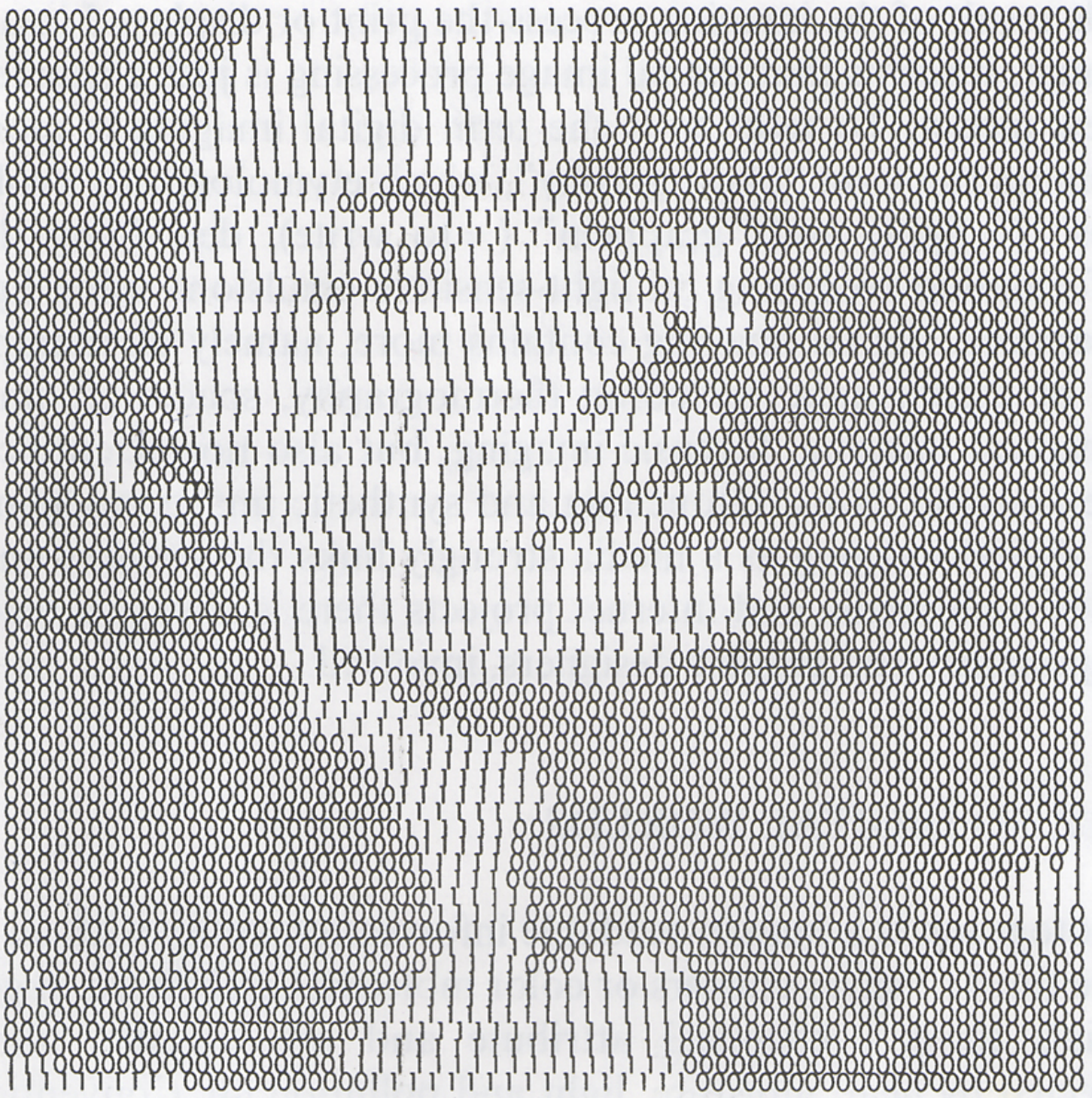

Fig. 2 Synthesis of analog representation and digital matrix.

the needs of the communication industry. Digital imaging technologies affect many different segments of the communication industry, including printing, pre-press, photography, graphic design, multimedia and art. While it is possible to describe the main characteristic of the 19th century with "industrial age", the developments in the 20th century are too complex to summarize with only one term. In 1963 Karl Pawek defined the 20th century as the optical age [6]. But technology, the most relevant factor in creating new consciousness and in stimulating social developments, changes at an ever increasing speed, thus at this time we are transforming into another age model, the information age, which can be characterized by the increasing importance of digital media, interactivity, multimedia and networkbased communication.

The digital image fits very well into this new age, because it can fullfill its very basic needs: It is cheap, fast and flexible. It is a symbol of the irrevocable and unstoppable process of replacing information fixed to atoms by information tied to Bits [7]. The significant trend in the communication industry to change from analog to digital technology has several reasons:

- The digital image as a matrix is a definite notation system and can be copied exactly with no loss or change of information. Analog information suffers from degradation (multiple-generation-loss) and is more affected by distortions during transmission. In contrary to the conventional photographic process, where there is an original (the transparency or the negative), the term original loses its relevancy for digital images, because the only difference between the "original" file and its copies is in the date of creation.

- Digital images are more flexible because they can be processed and manipulated not only in the spacial, but also in the frequency domain.
- The combination of different forms of digital information including sound, images, video and text is very easy (multimedia option).
- A digital image can present a large amount of information in a visual format, which can be easily interpreted. The same amount of information cannot be readily viewed in any other manner.
- Digital information can be compressed and error corrected, which improves speed and reliability of data transmission.
- Digital imaging systems are capable of representing images of a wider dynamic and tonal range than the human eye can resolve or that can be reproduced using conventional film-material.
- For storing purposes, silver-halide technology is a powerful tool. But there are some serious problems with the permanence of photographic records; these materials are affected by heat, moisture, light and pollution. The main problem with the storage of digital files is not the limited physical lifetime of the storage media itself, but the fact that because technology is changing very fast, the time until the media is obsolete can be shorter than its physical durability. In contrary to human-readable analog information, digital information, thus a stream of bits, can only be interpreted by appropriate software. Besides the application needed to encode a bit stream, specific hardware and system software are also required. Although the behaviour of hardware can be simulated by emulators, to do so requires detailed hardware specifications [8]. The task however to transfer digital files every few years from older to new forms of storage media and to save them with all information necessary to encode them, is very time consuming and expensive.

5. MANIPULATION AND REALITY

Photography never was and never can be objective. There are important media inherent characteristics, which place photographic realism far away from reality:

- A photograph is a two-dimensional representation of a three-dimensional space.
- A photograph is always a framed fragment of a whole.
- A photograph isolates a moment in time and therefore can not render motion.
- Conventional photography renders only visual information. However, there are special materials which can record electromagnetic energy below 400nm (ultraviolet) or above 700nm (infrared).
- All other human sensual perceptions are not reproduced by the photographic process.
- Black-and-white photography converts original color values into gray tones.
- Color photography converts original color values into process-specific color values. This conversion process does alter information, because colors used in photographic color materials have a specific and limited color gamut.
- During the photographic process (excluding photomicrography) objects are reduced in size. Average photographic lenses are maximized for a scale of reproduction between $1/\infty$ and 1/10.

Despite all these media inherent subjective, selective and abstractive factors, photography had for a long time the stamp of an objective and reliable source of information, of a source of authenticity. Several reasons contribute to this fact:

- In the early days of photography, and still today, people are impressed and fascinated about the media's ability to resolve finest details. It is well known that conventional silver-halide material (film speed 100 ISO) can resolve about 50 line pairs per mm (=1270 line pairs per inch) [9]. These 50 black-and-white line pairs correspond to a spatial resolution of 100 pixels/mm (=2540 ppi). Because the resolution is format independent, the amount of stored information increases dramatically using larger film-formats. A 4×5" film format can store up to 300 MByte of information.
- The fact that objects reproduce themselves automatically on light-sensitive material using light as a messenger gives photographic images a special quality not found in paintings. A photograph is not only an interpretation of the real; it is also a trace, something directly stencilled off the real, like a fingerprint [10]. This is one reason why, until today, photographs were used as factual evidence in police investigations and in court.
- Photography can show things beyond human perception. In 1889 Eadweard Muybridge and Etienne-Jules Marey could prove that in the motion of horses the "flying gallop position", as it is depicted in many earlier paintings, does simply not occur (Fig. 3/4). Photography became a tool to analyze motions of every kind that could not be resolved by the human eye, and the meaning of the term "truth to nature" lost its force, because "what was truth could not always be seen, and what could be seen was not always truth" [2].

Fig. 3 John F. Herring: The finish of Derby stakes (cropped), 1835.

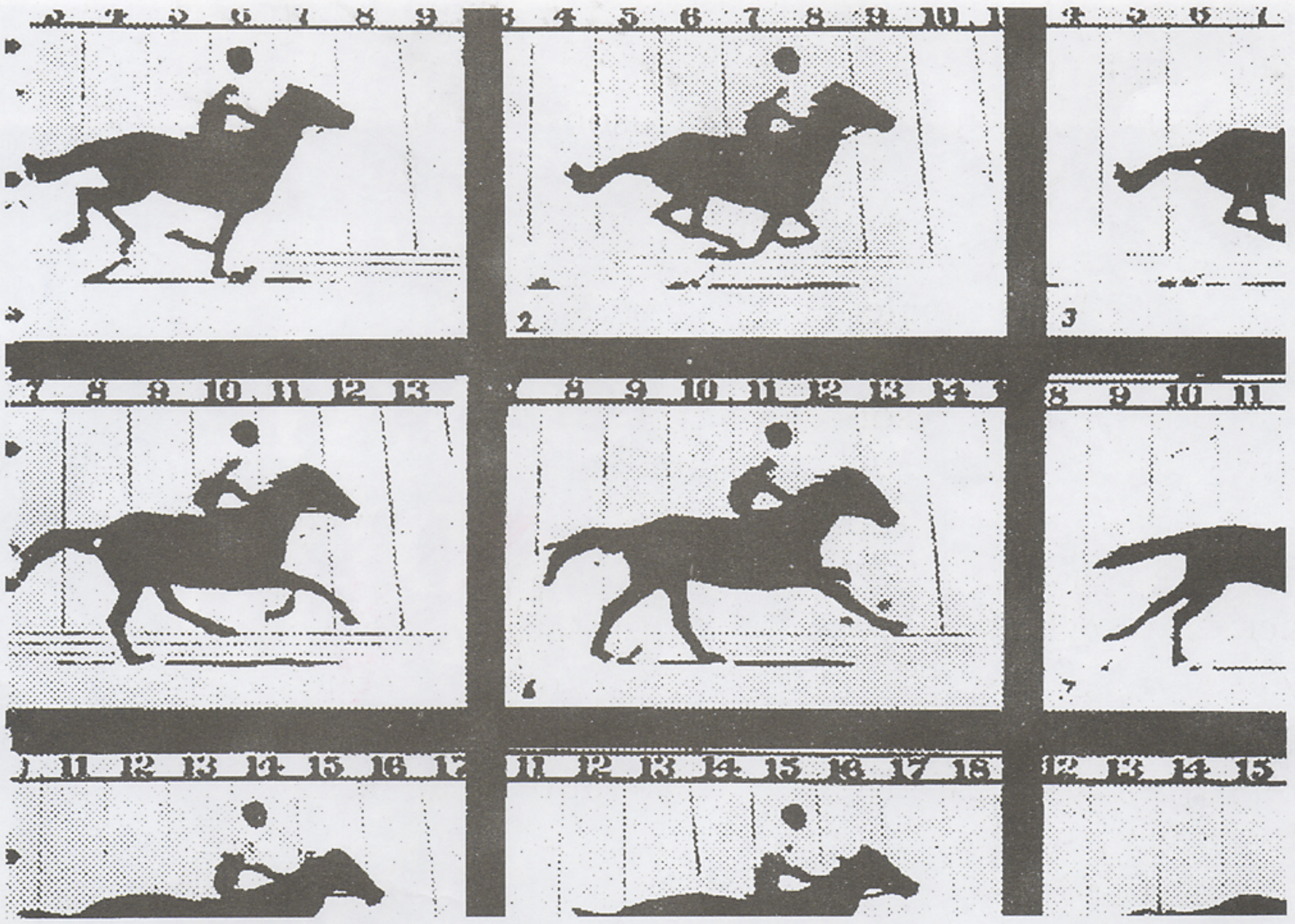

Fig. 4 Eadweard Muybridge: Horse in Motion (cropped), 1878.

Today the analysis of motion can be done with far more sophisticated tools. High-speed photography can realize shots with an exposure time of down to a few picoseconds. There are manifold applications for high-speed photography in fields including biology, aerodynamic, chemistry, aerospace research, ballistics, and sports where special photo finish cameras can determine the winner of a race down to 1/10,000 of a second. This use of photography as a scientific tool had and still has a great influence in people's belief in the truth of photographic realism.

Photomicrography and telephotography also opened up unseen worlds for the human observer. Both Daguerre and Talbot had taken photographs through solar microscopes even in the early 1840s, and recordings of the moon excited great interest. The illustrations of both the macro- and the microcosmos by photographs influenced the public's consciousness of nature and the work of prominent artists, including Klee, Le Corbusier and Moholy Nagy. The scientific applications of photography and its influence on art and the human consciousness strengthened the medium's reputation as an authentic and reliable source of information.

The powerful and easy-to-use tools of digital imaging are starting slowly but surely to destroy these subtle bonds between reality and image. Most image manipulations applied today are very obvious and therefore recognizable. Real controversy, however, is provoked by manipulations which misuse the photographs' inherent credibility. The most famous case, both because it occurred relatively early and has been talked about a great deal in photojournalistic circles, is the 1982 National Geographic cover of the pyramids of Giza (Fig. 5). In this case a horizontal photograph was made into a vertical image suitable for the cover by electronically moving one pyramid closer to the other [11].

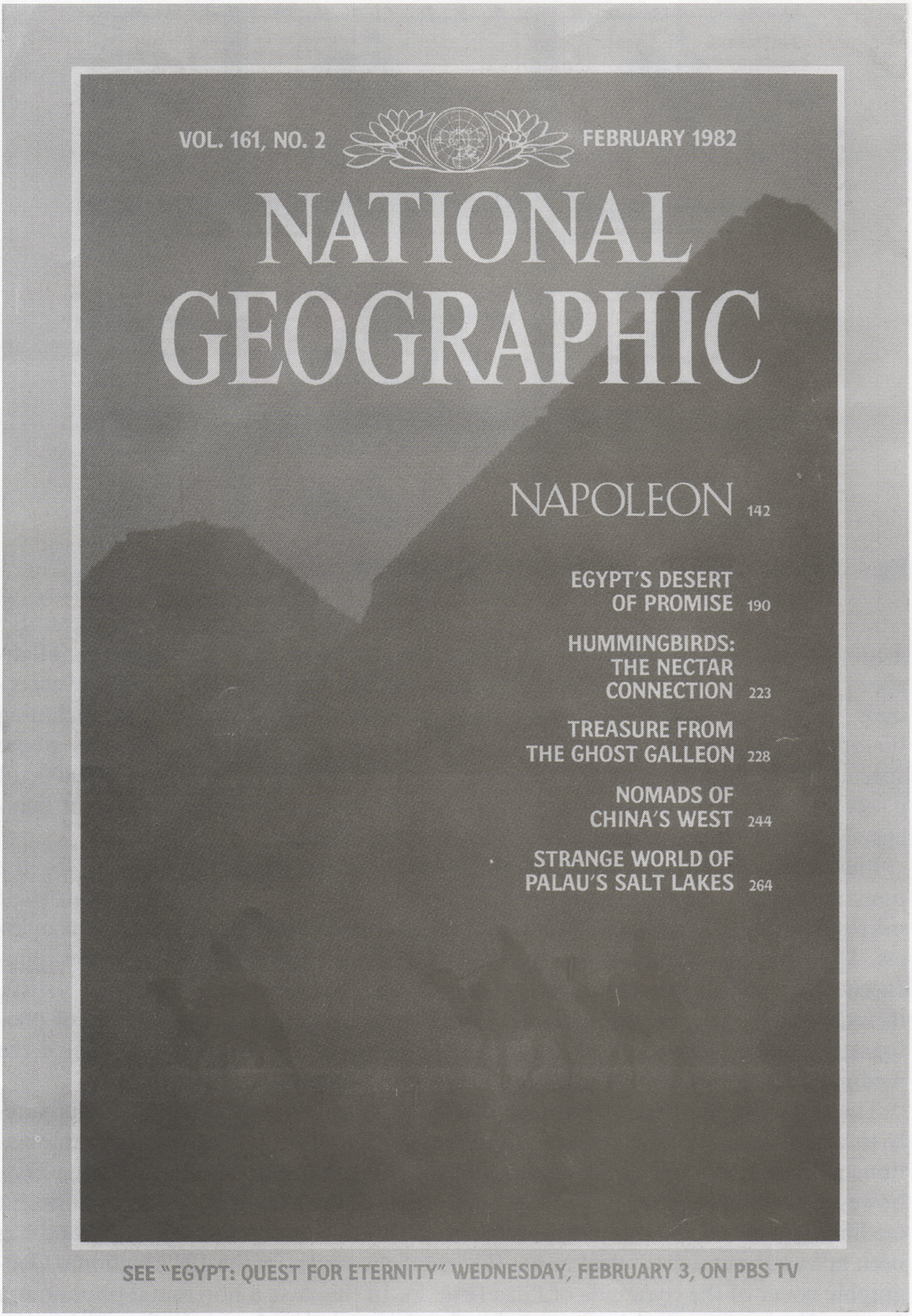

Fig. 5 National Geographic Cover, 1982. (See colour page at the end of the issue.).

In the last few years, such practice became more and more common. In fashion magazines almost hundred percent of the image material is electronically retouched or manipulated without informing the readers. Magazine covers, which are seen as an advertising platform for the magazines themselves, can contain manipulated images even if the publication is based on its photojournalistic credibility. In the case of the Time magazine cover of O.J. Simpson's altered mug shot, people had a direct comparison to the unmanipulated image presented on the cover of Newsweek. Fred Ritchin, professor of photography and telecommunications at New York University, proposed to use a so called "not a lens" icon to identify computer-altered photographs and to avoid the further erosion of photojournalist's credibility [11]. But as of today, there is no universal declaration standard to mark manipulated images used in a photojournalistic context.

6. TECHNICAL LIMITATIONS

Without denying that digital imaging technology evolved rapidly in the last few years, a closer look shows that there are still some major unsolved technical problems. Behind the futuristic look of some digital camera bodies there are technological concepts which strongly remind at techniques used in early color-photography. Especially color separation is yet not solved satisfactorily. CCD-chips, for example, which are covered by a colored pattern (*e.g.* Bayer pattern), are allowing one-shots, but they are working with interpolation and cannot take full advantage of the imagers resolution. This technological concept is strongly related to additive tricolor analysis technology used in color photography in the early 20th century (Autochrome plates) and still used today in the Polachrome color system (Polaroid). Another approach is done in the case of digital cameras, which split up the incoming light and analyze the red, green and blue information with three CCD-chips. A similar technology was used in analog photography by the "Bermpohl Kamera", a widely used system in the 1930 – 40 [12].

Cameras with linear CCD-arrays (camera scanners) or with three-shot technology are in photographic practice not very suitable, because they are strictly limited to motionless objects. In order to replace the millions of conventional cameras on the market today by digital systems, there must first be developed a more sophisticated concept of color separation using one-shot technology: In analog photography it was the Kodachrome film, introduced in 1935, which revolutionized and pushed the development of color photography by introducing new technology: a single exposure on an integral tripack of three emulsions combined with the chromogenic process [12]. In the same manner the first one-shot technology without interpolation will strongly push digital photography.

Still, there are some other technological problems which must be solved first to introduce digital cameras to a wider audience:

- Digital cameras are still too expensive, mainly because it is very difficult to produce large CCD-imagers in one piece without any not be working CCD-elements.

Recently Philips has presented the modular CCD-Chip, which could be a solution for this problem.

- Another still problematic area is color reproduction. WYSIWYG (What You See Is What You Get) is mostly a pious hope in desktop publishing, and even expensive color management software can not solve the problem of different color gamuts completely.

These different technological problems in mind it is not surprising that the public is still sceptic against the new digital imaging technology. However, for images used in newspapers and for product photography used in catalogs, digital cameras can today provide the necessary quality and efficiency. For other applications, including high-quality printing, hybrid technology will for a long time provide better results. High-resolution silver-halide material, high-end scanning technology and improved image manipulation hard- and software are in combination a powerful tool. The hybrid approach, in which analog film material is used in the first place and digitization takes place in the second step, is therefore the most popular approach at this time.

7. FUTURE DEVELOPMENTS

The trend to work with digital information affects all parts of the communication industry including the graphic arts. Digital imaging however will not replace conventional photography completely in the next ten years, but in certain specific areas including photojournalism and commercial photography, significant changes will take place. The growing importance of the Internet as a platform for data interchange will strongly push the image from its static analog structure to a flexible digital one. Other trends which will affect the daily work in the communication industry are the increasing importance of digital online image databases offered by stock agencies as well as copyright issues related to digital data files. The future information infrastructure, which will have a plentitude of online information available, will be faced with abuse that hardly can be charged, because the actual laws, made back in the "telegraph era", do not cover electronic communication. The most important problem today is not the need for more information, but the struggle to find the right information in the non-hierarchic, chaotic structures of the information highway [13].

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