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Original Contribution

STAGES IN THE DEVELOPMENT OF DIGITAL IMAGES

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ABSTRACT: *Digital imaging is a key part of modern technology, finding application in almost every sphere of human activity – from medicine and science to the arts and communications. This technological process is part of the broader evolution of digitalization, which is going through significant stages of development based on innovations in computing technologies and optoelectronic systems.*

KEY WORDS: *Digital images, Photogrammetry.*

1. Introduction

The development of digital imaging involves several key stages, starting with analogue photography and reaching advanced techniques such as artificial intelligence and virtual reality. This article aims to summarize the main points in the development of digital images, based on both historical facts and modern research, while at the same time presenting the main directions for their processing [1,2,3,4,5,6,7].

2. Milestones in the development of digital images

Digital imaging forms the basis for a significant number of technological and scientific applications, ranging from medical diagnostics to artificial intelligence. Their development goes through several main stages, characterized by innovative technologies and methodologies that cover the period from the 19th century to the present day.

The first stage in the development of digital imaging was the stage of early innovation, which included telephotography and analog techniques and covered the period from 1860 to 1950. Although digital technology did not initially exist, early experiments with electrical transmission and image processing laid the

foundations for modern digital technologies. During this period, there were significant advances in the field of photography, with experiments with electronic technologies made during this period having a fundamental role in the creation of digital images [1,2,3,4,5,6,7].

Shelford Bidwell was one of the pioneers in early experiments with electrical image transmission. In the 60s of the 19th century, he developed a technology that he called "telephotography". Using an electrical system with selenium cells, Bidwell was able to convert light signals from an image into electrical impulses. These pulses are transmitted over telegraph lines and then used to restore the image to the receiving country. The process is complex, but it demonstrates the idea of digitally converting images and transmitting them into electronic form. Bidwell's telephotography was not a practical application of the wide transmission of images, but its significance was enormous—it provided a theoretical basis for the later development of digital image processing and the transmission of visual data via telegraphs and later in the Internet age [1,2,3,4,5,6,7].

In the same period (from 1860 to 1950), photography still relied on chemical processes, the most significant invention in this era being the daguerreotype, which consisted of the use of a silver plate coated with chemicals, on which a lighting process was carried out to create an image. Although these techniques cannot be considered digital, they lay the foundations for the processes by which images are created, processed and reproduced. Over time, new methods emerged, such as the photochemical processes of fixators and the use of X-rays to create images, which predate modern computer processing technologies. These early technologies, although not involving digital processing, represent major steps towards the technologies that underpin digital imaging [1,2,3,4,5,6,7].

In the 1920s, experiments with electronic imaging began, which involved the use of vacuum tubes to electronically transmit visual information. One of these early experiments is known as electronic television, which uses cathode rays to scan images and transmit them over television lines. The mechanisms of these early television technologies, although not digital, were nevertheless based on the use of electrical signals for image processing. During these years, the first attempts were made to electronically generate images in scientific research, which would later be used in digital imaging and photography. However, these early technologies were not developed enough to replace traditional photography and establish themselves as the main methods of image creation [1,2,3,4,5,6,7].

In the 30s of the 20th century, another important technology began to develop, which would later be used for digital image creation: photomechanical printing methods and the creation of visual images. The ability to digitally store and transmit images is starting to emerge as an opportunity within these

technologies. For example, the use of metal sensors that can capture and process light signals heralds the development of photosensors and CCD (Charge-Coupled Device) sensors that will be used in the coming decades. Many of these early technological experiments revealed the foundations of digital imaging, which would later lead to the creation of a full-fledged digital image based on the computer processing of visual information [1,2,3,4,5,6,7].

The second stage in the development of digital images is the era of electronic sensors, which covers the period from 1960 to 1970, which was critical for the development of digital images. That's when the key event that will be the foundation for the future of digital photography takes place: the invention of electronic sensors. This is a stage that marks the beginning of the transition from analogue to digital technologies, in which electronic devices begin to replace traditional mechanical and chemical methods of creating and processing images [1,2,3,4,5,6,7].

In the 1960s, initial efforts began to create electronic sensors that could capture light signals and convert them into digital data. In 1969, American physicists Willard Boyle and George Smith of Bell Labs developed the Charge-Coupled Device (CCD), which would become the basis of future digital image sensors. CCD sensors work on the principle of electric charging, using light-sensitive elements (pixels) that convert light into electrical charges. These charges are stored and transported sequentially, allowing for the creation of a digital image. CCD sensors offer very high sensitivity to light and can be used to create images in a variety of fields, from television cameras to astronomical observations. In the 1970s, image sensors became more accessible for a variety of scientific and commercial applications. However, this is only the beginning of a long process of innovation that led to the mass production of digital cameras in the following decades [1,2,3,4,5,6,7,8].

The invention of the CCD sensor is a radical step forward in digital imaging technology. Although in the early years these sensors were mainly used in scientific research and professional applications, such as telescopes and television cameras, they laid the foundations for the future development of digital cameras and digital image capture devices. One of the first scientific applications of CCDs was their use in astronomy to observe celestial objects. Sensors are beginning to replace photographic plates in astronomical telescopes, offering significantly greater sensitivity and resolution. In 1965, the first image of Mars captured by the Mariner 4 probe was created using a CCD sensor, marking an important moment in the history of astronomical research. CCD sensors are beginning to find application in the television industry as well. Originally used in high-resolution television cameras, they are beginning to become the standard in the industry, allowing the transmission of high-quality television images and video recordings, which is an important advance for the digitization of visual technologies [1,2,3,4,5,6,7,8].

With the development of CCD sensors, the initial attempts to create digital cameras began to appear. Initially, these devices were huge and voluminous, mainly used for military, scientific and professional needs. For example, in 1975, Kodak engineer Stephen Sasson created the first digital camera using such a sensor. The camera is significantly heavier and larger compared to today's devices, but it demonstrates the basic idea of digital image capture. Sasson's camera was originally an experimental prototype that recorded black and white images on a cassette. Although it was not intended for mass production, its creation was significant because it marked the beginning of the future development of compact and affordable digital cameras. With the development of new technologies, these sensors are also beginning to be used to create images in medical diagnostics. For example, the use of digital X-ray machines is beginning to be seen as a method to improve the quality and accuracy of medical images [1,2,3,4,5,6,7].

The third stage in the development of digital images is the stage of standardization and popularization, which began in the 1990s. This period was key to the development of digital imaging, with a real revolution in the standardization and mass popularization of digital technologies. This stage witnessed the emergence of digital photography based on electronic sensors, which gradually replaced analogue methods of capturing and storing images. Also, during this period, major industry standards were established and markets were rapidly expanding, leading to a global shift in the way people create, share, and use images.

After 1990, key digital image standards emerged and became established, having a huge impact on industries that use visual information. One of the most important was JPEG (Joint Photographic Experts Group), which became the main format for image compression. The JPEG standard, which was introduced in 1992, allowed for a significant reduction in image size without significant loss of quality. This made digital images easier to store, transfer, and share, while still providing high resolution and clarity. JPEG and other formats such as GIF (Graphics Interchange Format) and TIFF (Tagged Image File Format) became industry standard, allowing for standardized storage and transmission of images. JPEG, in particular, established itself as the most popular format for storing photos on the Internet and is the basis for numerous online platforms and applications [1,2,3,4,5,6,7].

There was a significant increase in the mass production and sale of digital cameras. Major manufacturers such as Canon, Nikon, and Sony began producing cameras that offered features that rivaled those of traditional film cameras, but with digital technology, built-in image processing chips, and the ability to store images directly on digital media. In 1995, Canon launched the EOS series of models that incorporated digital sensors, and Sony released its first digital camera, the DSC-F1. These high-resolution cameras began to

replace traditional film cameras, giving users the convenience of storing images on memory cards and easily transferring them to computers. During this period, the prices of digital cameras decreased, and storage technologies such as flash cards and CD-ROMs became increasingly affordable. This led to a rapidly growing popularity of digital photography among the general public [1,2,3,4,5,6,7].

During the same period, the rapid development of digital image processing software began. Adobe Photoshop, first released in 1988, underwent significant improvements in the 1990s, establishing itself as an industry standard in graphic design, photography, and advertising. Photoshop offers powerful tools for editing, manipulating, and retouching images, which are used by both professionals and amateur photographers. Image processing programs allow users to adjust brightness, contrast, and saturation, remove blemishes, and add various visual effects. Photoshop and other editing software products, such as Corel PaintShop Pro and GIMP (GNU Image Manipulation Program), have become essential tools for digital artists, photographers, and designers, accelerating the professionalization of digital art [1,2,3,4,5,6,7].

During this period, the Internet revolutionized the way people shared and stored images. In 1991, the first World Wide Web was created, and just a few years later, image-sharing platforms such as Flickr and Photobucket appeared. In 1994, Yahoo! was founded, which also began offering image hosting services. During the same decade, Internet forums and news sites began to use images uploaded and shared by users. In 1995, AltaVista and Yahoo! began providing image search engines, helping users find and share images on the Internet. Online platforms such as eBay began to include product images, contributing to the growing importance of digital images in e-commerce. Also, JPEG and GIF formatting became the standard for images on websites, due to their small file sizes and their ability to maintain quality under compression. These technologies created the foundation for visual content on the Internet and laid the foundation for the emergence of social networks in the following decade [1,2,3,4,5,6,7].

In the late 1990s, mobile phones began to integrate with cameras, leading to one of the biggest transformations in the way people created and shared images. Although initially low-resolution and limited in functionality, these cameras marked the beginning of the future evolution of mobile photography. In 1997, the Japanese company Sharp released the first mobile phone with a built-in camera, the J-SH04. The camera had a resolution of 0.11 megapixels, which was sufficient for low-resolution photos. However, mobile phone cameras began to find widespread use in Japan and later throughout the world, initially their main function being to allow for personal photography and easy sharing. With the growing popularity of mobile phones and the increasing quality of their cameras, digital photography moved into the hands of every user [1,2,3,4,5,6,7].

The latest stage in the development of digital imaging is the stage of artificial intelligence, which marks the future of digital imaging. Artificial intelligence (AI) plays an increasingly important role in digital imaging, changing the ways in which visual data is created, processed and analyzed. From more sophisticated methods for correcting photos to creating artificial images, AI is becoming not only a tool but also an engine of innovation in this field. The future of digital imaging is inextricably linked to the development of AI technologies, which promise to change not only the visual industry, but also the entire way we understand and interact with images. With advances in AI, image processing is reaching new heights. Machine learning algorithms enable face recognition, scene segmentation and the creation of synthetic images that find applications in medicine, the automotive industry and entertainment [1,2,3,4,5,6,7].

3. Conclusion

The development of digital imaging has come a long way from its beginnings in the 19th and 20th centuries to the modern technologies that form the basis of modern applications in various fields - from medicine and science to arts and entertainment. The main stages in the development of digital imaging include early experiments with photography and electronic systems for transmitting visual information, followed by significant innovations in the 1960s and 1970s with the invention of the first electronic sensors and CCD technologies. The transition to digital photography and the Internet revolution in the 1990s contributed to the mass adoption and popularization of digital imaging, and with the advancement of artificial intelligence and machine learning algorithms, they reached new heights in image processing and recognition in various industrial and scientific applications [1,2,3,4,5,6,7].

The future of digital imaging is not only tied to the development of new technologies such as hyperspectral sensors and quantum computing, but also to their increasingly widespread application in everyday life. The integration of AI into image processing will enable more sophisticated and accurate analyses. Image processing technologies will continue to transform the way we create, share and interpret visual data, while improving the efficiency, accuracy and accessibility of visual information [1,2,3,4,5,6,7].

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