Real Time Image Processing: Summary about Analog and Digital Camera

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I. Analog camera

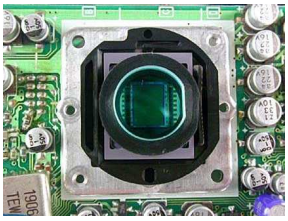
A. Introduction - Traditionnal Analog Camera

1) Basics: An analog signal is any continuous signal for which the time varying feature of the signal is a representation of some other time varying quantity. Analog refers to the way the camera records the video, as well as the resolution of that video. A typical analog video device contains two basic parts: **camera section**, that receives visual information and interprets it as an electronic video signal - consists of CCD device (Figure reffig:subfig1), lens and motors to handle the zoom focus and aperture, **VCR section** (for camcorders), that receives an electronic video signal and records it on a video tape as magnetic patterns.

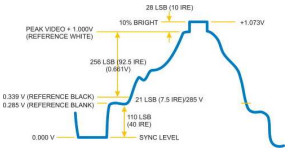
2) "Analogy" with digital cameras: Digital cameras have all these same elements, but have an added component that takes the analog information and translates it to bytes of data. It records the picture and sound as 1s and 0s. Copying 1s and 0s is done easily without losing any of the information you recorded. Analog information, on the other hand, "fades" with each copy. Moreover, video information in digital form can be loaded onto computers, where you can manipulate with it easily.

B. Heart of the Analog Camera

Essential component of an analog camera is the semiconductor device that converts visual information into an electronic signal - CCD device (Figure reffig:subfig1). A camera "sees" the world through lenses which serve to focus the light from a scene onto a small semiconductor image sensor. This sensor, a Charge-Coupled Device, measures light with a half-inch panel of 300,000 to 500,000 tiny light-sensitive diodes called photosites. This way, camera records the scene in front of it: *It picks up greater amounts of light from brighter parts of the scene, and lower amounts of light from darker parts of the scene*. Each photosite measures the amount of light



(a) CCD sensor



(b) Composite video analogue signal

(photons) that hits a particular point, and translates this information into electrons (electrical charges): A brighter image is represented by a higher electrical charge, and a darker image is represented by a lower electrical charge. Just as an artist sketches a scene by contrasting dark areas with light areas, a CCD creates a video picture by recording light intensity.

C. Colour generation

To create a color image, a camera has to detect not only the total light levels, but also the levels of each color of light. Since the full spectrum of colours can be obtained by combining the three colours: red, green and blue, a camera actually only needs to measure the levels of these three colours to be able to reproduce a full-color picture.

D. Analog video signals

Contain the luminance and chrominance of the image, which may be carried in separate channels, as in **component video** and **S-Video**, or combined in one channel, as in **composite video** (Figure 1(b)). Composite video exists in standard formats that differ in frame rate, scanning speed, vertical line resolution and line rate. Composite video standards are: NTSC, PAL, and SECAM. It is a composite of three source signals called Y (brightness), U (hue) and V (saturation)

Table I
ANALOGUE VIDEO FORMATS

Format	Video tape	Resolution
Standard VHS	regular VCR tapes	230 to 250 horizontal lines
VHS-C	reduced tape size	same as Standard VHS
Super VHS	same tape size as VHS	380 to 400 horizontal lines
Super VHS-C	reduced tape size compared to Super VHS	same as Super VHS
8mm	small 8mm tapes	same as Standard VHS
Hi-8	special Hi-8 tapes in 30, 60 and 120 minutes length	higher resolution than 8mm camera - 400 lines

with sync pulses. Mixing of the various signals into the original composite signal causes a ”dot crawl” visual effect. Composite video is particularly prone to errors in reproducing exact colours due to the overlap of the color and luminance signals. Video professionals jokingly refer to NTSC as Never The Same Color. This has led to a proliferation of systems such as **S-Video** and **component video** to maintain the signals separately. S-Video is generally superior to composite video in reproducing colours correctly. Component video is used in professional video production and provides the best quality and the most accurate reproduction of colours. Analogue formats used for storing video signals are presented in Table I

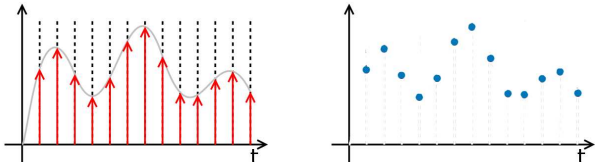
E. Trivia

The first camcorder patent was issued to the prolific American inventor Jerome Lemelson in 1980. Lemelson had tried to patent the idea for a camcorder in 1977, but the U.S. Patent Office rejected him, claiming the idea was too far-fetched and that no company could ever be able to manufacture and sell the device. Among other things, Lemelson also invented crucial components for the VCR, Walkman, ATM and bar-code scanner.

II. DIGITAL CAMERA

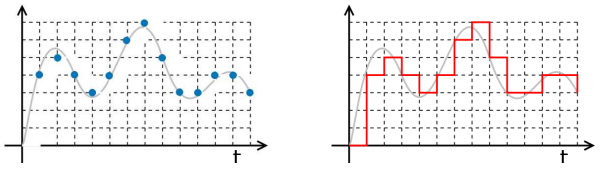
A. Definition of digital camera

In order to process data with computers, these data need to be digital values. Hence, digital camera allows to create digital data which can be treat. To obtain a digital signal with an analog signal, two operations can



(c) Discretisation of analog signal (d) Discrete signal

Figure 1. Creation of discrete time signal



(a) Quantization of analog signal (b) Digital signal

Figure 2. Creation of digital signal

be apply: sampling and quantization. Sampling allows to obtain a discrete time signal whereas quantization permit to approximate precise values within a fixed number of digits. Figure 1 presents how to create a discrete time signal from analog signal by sampling, whereas figure 2 presents how to create a digital signal after to do a quantization and samping.

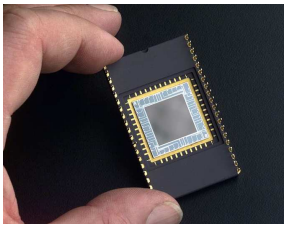
The main principle of digital camera is to create a signal like represented in figure 2(b) to represent data of an image.

B. Creation of digital signal

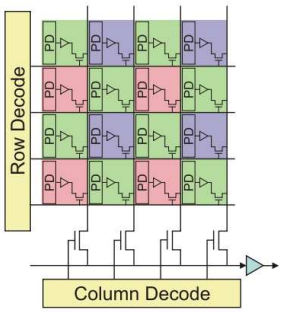
In this section, we will present how digital signal is created with digital camera. We will present two types of sensor which are used to create digital signal: CCD and CMOS.

1) CCD: CCD sensors allow to create analog signal. Historically, it was the first technology of sensor. CCD sensors are used to create analog signal. Creation and specificities of analog signal are explained in section I-B. Then, converter Analog to Digital (CAD) is used to convert an analog signal to digital. Generally, CAD converts a tension (analog signal) to bits (digital signal).

2) CMOS: CMOS sensors allow to create either analog signal or digital signal directly. Figure 3(a) represents a CMOS sensor. No converters are used to have digital signal. In the case of digital camera, CMOS sensors are used to obtain directly digital signal without using



(a) CMOS sensor



(b) Structure of CMOS sensor

Figure 3. CMOS sensor

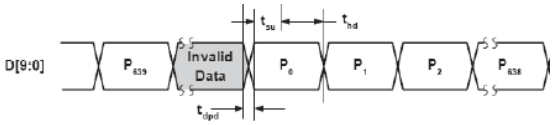


Figure 4. Representation of data signal

any converter. Figure 3(b) represents electronic structure of a CMOS filter. Two composants are used in CMOS sensors: photodiodes and transistors. If light intensity is suffisant, photodiodes supply a courant enough important to allow transistors to deliver a logic value 1. If not, the logic value 0 is producted

C. Specificities of digital signal

In this section, we will present an example of digital signal from a camera. Signal from digital camera can be decomposed in different signals: data signal and synchronisation signal:

1) data signal: This signal contains value of each pixel in bits. The figure 4 presents the organisation of data from digital camera:

2) synchronisation signal: The other type of signals provide by signal camera are mainly synchronisation signals. Three signals are usually used from digital camera: vertical synchronisation to know actual line position, horizontal synchronisation to know actual row position and clock pixel to know actual pixel position.

III. COMPARISON

A comparison should permit to know what kind of different type is the best. However, in the case of digital or analog camera, utilization of one or other type depends of the technology wanted. We will present cases when we have to use analog and digital camera.

A. Analog camera

Analog camera is used to perform with analog electronic and analog system. The advantage of these systems is that it is generally very fast. The output of these cameras is generally composite video.

B. Digital camera

In the last years, computers could be used to allow image processing. However, computers required to have discrete values to apply mathematical transformations. Digital cameras were invented to apply theory of digital signal processing using computers or digital system like FPGA. The output of these cameras are genrally USB, 1394 or RJ-45.