New Trends in Digital Scanning Processes

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Abstract

Handwritten document analysis and recognition deals with several different application fields. In document processing, one of the first problems that must be solved is data acquisition. The selection of the appropriate acquisition device plays a fundamental role; it depends on the different types of source documents and on the different application domains. Digital scanners allow both massive document acquisition and conversion of paper based documents into electronic documents. Depending on the environment requirements, the original quality of the analog signal must be appropriately captured and preserved in the digital conversion and the right scanner need to be selected. This paper presents an overview of the main characteristics of the scanners today available on the market and highlights their main properties. By considering the operation difficulties of actual scanners and the properties of the new plastic materials, this paper presents some ideas for future possible developments in digital scanning.

1. Introduction

Long ago it was claimed that computing technologies would create a paperless office, a claim that is not yet in sight. Many people print things rather than reading them on screen. They like to hold paper in their hands and to mark things up.

Paper results particularly versatile as a medium of information. According to Sellen and Harper [20], users still prefer paper because it makes navigation and use more flexible. Paper input is direct, two-handed, and provides a rich synergetic set of tactile and visual cues. Paper sheets support easier transitions between activities by allowing users to pick up and organize multiple documents. Paper is also extremely malleable: it can be also folded or bent. Paper can be randomly arranged and can even be used with different forms.

With the development of flexible devices we can imagine that some day computers and acquisition devices will have the same properties of paper sheets. Organic User Interface technologies, such as digital paper or flexible displays and e-ink technologies have promising potentials for the development of a paperless environment.

This notwithstanding, currently, digital documents and image processing techniques are having a wide spreading [25]. At present, scanners represent one of the most widely adopted desktop add-ons [23, 24]. In the last years, the scanner scattering has also been fostered by the expansion of the digital photography and desktop web publishing.

At its basic level, a scanner is just an input device, very similar to a keyboard or a mouse, except that it takes its input in graphical form. Scanned images can be photos needing retouch and correction or documents to be used in Desk-Top Publishing (DTP). Images can also be hand-drawn sketches, or text pages [13, 14, 15], to be further processed and recognized. The ancient manuscripts have also been investigated on the base of conventional documents in order to restore or recover their content.

Documents need to be firstly converted into a digital format so that they can successively be used in electronic document workflow [12]. This is a critical step, which can depend strongly on the application environment. The initial document quality must be suitably preserved and the appropriate scanner needs to be selected [1].

This paper presents an overview on the main scanners currently available on the market and highlights their properties, characteristics and limits. By considering the peculiarities of the plastic materials, it emphasizes some new technological solutions that can lead to interesting future developments in the field of data acquisition devices and drive to new scanners, with simple-to-use interfaces and full-service control. The paper concludes by touching new trends in digital scanning techniques to support innovative scanning processes and document analysis and recognition.

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2. Current Digital Scanners

At present several different types of scanners are available [6, 21]. They can be classified according to architecture and operating qualities. Essentially it is possible to distinguish the following scanners:

- Flatbed scanners. Also called desktop scanners, they are the most versatile and commonly adopted acquisition devices;
- Compact document scanners. They are designed nearly exclusively for OCR and document management;
- Dedicated photo scanners. They work by moving a photo over a stationary light source;
- Slide/Transparency scanners. They work by letting the light passing through a transparent image rather than reflecting it on the paper;
- Sheet-fed scanners. They are similar to flatbed scanners, except that the document is moved while the scanning head is motionless;
- Handheld scanners. They use the same basic technology of flatbed and sheet-fed scanners, relying on the user to move them;
- Pen scanners. They are specialized hand-held scanners that are used both to process type-written documents and to perform automatic word translation;
- Drum scanners. They are used by the publishing industry to obtain accurate and detailed high resolution images.
- 3D scanners. They allow analyzing real-world objects to collect data on their shape and appearance. In the last years they are being also used to produce digital representation of Ancient Cuneiform Tablets [10].

3. Basic scanning principles

The basic function of scanners is to analyze an image and to process it [19, 26]. The scanning process allows saving information into a file so that it can be later processed and, eventually, recognized in shape, structure and content.

Scanners appearance and acquisition principles have little changed over the years, but acquisition devices have become much more refined and capable of detailed and precise reproductions [9]. All scanners work on the same principle of either reflectance or transmission. The Analogue-to-Digital Converter (ADC) allows conversion of the analog signal into the digital signal so that in can be later processed by PCs.

Some scanners use a three pass scanning method, but most scanners today use single pass methods. There are essentially two ways to process colors in single pass scanners. The first method consists in scanning the whole document once with a white light and a color-sensitive acquisition device. The second method is a variant on the three-pass method: at each step, the scanner turns on the red, green, and blue lamps in sequence and records the results from each, creating a composite image.

4. Principal scanner factors

Scanner performance depends on many factors, and on the interaction among the different interfering factors. The key determinant factor in the scanner performance is the designer ability to balance these many factors to obtain the best performance at lowest cost. Each of the following factors is critical [2]:

- Light source. Without a bright and consistent light source, a scanner cannot deliver good results. While good enough for many purposes, fluorescent bulbs rarely emit consistent white light for long time and, while they are on, they emit heat which may influence the other optical components. For these reasons, most manufacturers passed to cold-cathode bulbs. By the late 1990s, xenon bulbs emerged as an alternative light source; some recent scanners also adopt LEDs.

- Optics. The document image generally reaches the acquisition device through a series of mirrors, filters and lenses. The exact configuration of these components depends on the model of the scanner, but the basic principles are practically the same. High-quality scanner use high-quality color-corrected and coated glass optics for minimum diffusion. Lower-end models typically use cheaper components to reduce costs. The focal properties of lenses may also change. Cheaper scanners use fixed-focus lenses. The more expensive and advanced scanners have focus control.

- Image sensor. It can be implemented by using different technologies:
    - PMT (photomultiplier tube), a technology widely adopted in drum scanners;
    - CCD (charge-coupled device), the type of sensor generally used in desktop scanners;
    - CIS (contact image sensor), a newer technology which integrates scanning functions into fewer components, allowing scanners to be more compact in size.

- Resolution and Interpolation. Resolution relates to the fineness of detail that a scanner can achieve. The power of a scanner is in its optical resolution. It specifies the number of dots, or pixels, the scanner sensor can really distinguish.

Most scanners can also interpolate the pixel values between the actual sensors elements to provide a higher apparent resolution. Hardware interpolation is performed directly by the scanner circuitry. Software interpolation can even more increase the image resolution [4].

- Down sampling technique. There are two basic methods to scan an image at a resolution lower than the hardware resolution. The first method simply involves taking the output from certain pixels in the CCD. The other method requires scanning at the full resolution of the CCD and then down-sampling the results in the scanner own memory. Better scanners adopt this last technique since it yields better results.

- Bit depth. Bit depth, also called color depth, refers to the number of colors that the scanner is capable of reproducing. The simplest scanner can only record black and white (1-bit scanner). In order to see the different tones in between black and white, a scanner needs at least 4 bits or 8 bits. Most modern color scanners use 24 bits. Unfortunately, during acquisition, a few of the least significant bits are lost in noise [7], and any post-scanning tonal correction reduces the range still further. Scanners with 30- or 36-bit depths have much wider range to start with.

- Automatic Dirt and Scratch removal. Software still fails in dirt and scratch removal because it cannot differentiate between dirt and a real image element. An attempt to solve this problem considers the use of a fourth infrared (IR) scanning channel, in addition to the usual three channels. Color transparency films are transparent to IR, while dirt and scratches are not. Once that detection is completed, it is possible to patch the known bad areas.

- Moiré removal. Most scanners also offer a moiré removal or "de-screening" function. Moiré patterns are the shimmering dot patterns seen when a photo-offset image is scanned; this is an optical illusion due to an interference pattern. Moiré reduction is usually achieved by scanning the image at more than the requested resolution, and down-sampling the results.

- Scanner interfaces. There are many interfaces:
    - Parallel. Connecting through the parallel port is the slowest transfer method available;
    - Small Computer System Interface (SCSI). Most SCSI scanners include a dedicated SCSI card for connecting the scanner to;
    - Universal Serial Bus (USB). USB scanners combine good speed, ease of use and affordability in a single package;
    - FireWire. Usually found on higher-end scanners, FireWire connection is faster than USB and SCSI.

- Scanner drivers. Most scanners use the TWAIN driver. Its standard programming interface came out of a consortium of scanner and software manufacturers. Over 175 different companies collaborated and provided input into the TWAIN specification. Another standard, ISIS (i.e. Image and Scanner Interface Specification), is primarily used by more high-end scanners such as film, archival, document and drum scanners. It is technically more robust than TWAIN, but not used as widely.

5. Accuracy of Scanned Images

In office automation scanned images are becoming the primary source of input. The limitations of scanners in respect to the detail accuracy need to be opportunely considered. The accuracy of the input data has to be quantified before users adopt a scanner [8, 27]. A scanner cannot produce more positional accuracy-error than the maximum error allowed in the application. Standard accuracy issues such as media stability, source availability, and differences in data collection procedures need to be quantified.

By considering color representations, one of the following scanning techniques need to be selected according the specific application environment.

- Black and White Scanning. Black and white scanning is the appropriate solution for archiving and storing projects. It is also an ideal solution in planned document conversion project. Common application fields are: archival drawing libraries, electronic document distribution, vectorization.

- Grey Scale and Color Scanning. Gray scale and color images can be quite large. The system must be capable of handling files whose size can reach tens of megabytes. Grey scale and color scanning is most commonly used for: loading background images into high-end drawing or mapping software, capturing images for use in desktop publishing, frequency analyses of the color ranges, aerial photography, topographic-sheets, navigation charts, full color maps, brochures and artwork, cartographic DBs [5].

- Separated Color Scanning. Sometimes only selected information needs to be collected from source documents. Rather than using black and white scanning, separate images of features distinguished by color can be created. This process is much faster and thus more cost effective than attempting to capture data directly from the color image. The main application fields of are: contour maps, road maps, hydrological maps, environmental maps, oil and gas mapping.

6. The new materials

The first property that appears missing in contemporary electronic acquisition devices is the ability to easily manage different 3D shapes. Another missing property is deformability. The chief reason for the limitations of today’s devices appearance is the rigid planar structure of their components. The requirement to fit and protect the electronic devices causes the peripherals to be rigid too. This planar rigidity in interface design generally limits the usability of input/output devices and their possible affordances [11]. New materials, such as Organic Light Emitting Diode (OLED) and E-Ink can allow reproducing the deformability of things. Indeed, emerging technologies are paying growing emphasis on flexible and deformable devices that can potentially take any shape or form. The field of flexible devices is as much a matter of process innovation and materials research as it is a question of electrical or computer engineering.

The most adopted technologies are:

- Organic light-emitting diodes. Organic light-emitting diodes (OLED) are based on organic polymer molecules that compose emissive and conductive layers. They are assembled together using a form of printing: the layers are deposited in rows and columns resulting in a matrix of pixels that emit light. Red, green and blue layers can be stacked such that a full-color (RGB) pixel is formed by a fully color-mixed single pixel with depth, rather than a closely-spaced planar cluster of pixels.

- Electro-phoretic devices (EPD). The EPDs, often associated with the brand name E-Ink, are specifically marketed as alternatives to traditional flexible paper. The "electronic ink" consists of thousands of microcapsules deposited onto a substrate. Each microcapsule contains positively charged white particles and negatively charged black particles suspended in a clear fluid. When a negative electric field is applied, the white particles move to the top of the microcapsule, causing that "pixel" to appear white, and vice versa. The microcapsules are bi-stable, meaning that once configured black or white, no further energy is required to hold their state. As with OLED, flexibility is achieved through the use of flexible substrates (plastic) and conductors (metal foil or printed conductive traces). E-Ink generally supports monochrome paper-based documents; grey scale images can also be displayed. Some recent prototypes make available multicolor EPDs by using color filters [17].

7. The properties of plastic materials

The new materials let us imagine devices that: curve to fit space or form; flex to accommodate shape; deform in response to physical interaction. Smaller and flexible actuators realization means also developing devices that can be built to adjust their shape according to some necessity, or depending on interactions.

The recent emergence of new "smart" materials, tiny motors, nano-manipulators, organic actuators and fast networked embedded microprocessors has created new and exciting opportunities [18].

New flexible devices need to properly support at least the following four interactivity issues [3]:

- Resolution: the quality of the text will need to be as good as, or better than, actual devices;
- Control: the use of new devices will be as easy and straightforward in use as ordinary ones;
- Portability: new devices will be as portable, or more portable, than ordinary ones;
- Authenticity: the experience of using these new devices will need to be as aesthetically authentic and tangible as holding a physical piece of actual devices.

The new materials can effectively provide a possible solution to an important device design challenge: to create interfaces that result simple to use and yet offer sufficient functionalities to control complex problems.

8. Possible Future Digital Scanners

Recent advancements in hardware technology and software solutions can lead to new generations of scanners. Electro-phoretic devices and Organic LEDs are overlaying current displays, allowing the development of high quality, ultra flat, flexible and ultra wide screens. The Electro-Magnetic Resonance inking technology is enabling new inking techniques.

In the scanners field, much of the work being done with EPDs, OLEDs and super-flat components can lead at new possible solutions. Flexible acquisition devices, not much thicker than a sheet of paper, which could be placed between the pages of a book, are already available as prototypes [22]. They could be used to digitalize delicate or bound originals. These scanners may enable scanning without having to disassemble sheets or force objects on a flat scanner bed. Such scanners, realized by spreading and integrating on a plane surface organic field-effect transistors and organic photodiodes, may also be rolled up in a document tube and taken anywhere.

Available organic photo-detectors distinguish between black and white parts on papers based on the difference in the reflectivity when exposed to ambient light. These area-type image-capturing devices do not require any optics or mechanical devices. The integration of flexible lights sources in digital scanner can lead to a new generation of self-lit plastic scanners.

Efforts are also being made in software production to recover image distortion in case of not plane, not perfectly fitting and not well oriented originals.

Geometric rectification techniques allow recovering the distortion caused by non planar document shapes and changing perspective planes. The proposed solution enables restoring the correct frontal flat view of a document representing it as a developable surface [16].

Probably such advanced technology will not be available in the immediate future to all people, but the trends for more portable, efficient, and effective scanners will encourage further research.

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