ADVANCES IN COMPUTER VISION AND IMAGE PROCESSING

Editor: THOMAS S. HUANG

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IMAGE ENHANCEMENT AND RESTORATION

ADVANCES IN COMPUTER VISION AND IMAGE PROCESSING

A Research Annual

IMAGE ENHANCEMENT AND RESTORATION

Editor: THOMAS S. HUANG
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PREFACE

The goal of this series is to present in-depth treatment of topics of current interest in computer vision and image processing. The terms computer vision and image processing are used in their broad sense to include image coding, enhancement, restoration, and understanding, as well as the analysis of three-dimensional time-varying scenes. Computer vision and image processing have important applications in diverse areas, such as robotics, industrial automation, medical diagnosis, and defense-related problems. These applications draw concepts and techniques from many different disciplines including multidimensional signal processing, pattern recognition, and artificial intelligence. We aim to have each volume of this series concentrate on a special topic or several closely related topics.

Although in this series we publish mainly invited papers, suitable unsolicited contributions may also be published after careful reviewing. Potential contributors are advised to contact the Editor before submitting their manuscripts.

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Chapter 1

ENHANCEMENT OF NEWS PHOTOS

Donald E. Troxel

OUTLINE

Advances in Computer Vision and Image Processing, vol. 2, pages 1–29

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ABSTRACT

A multiuser multiprocessing image-processing system for the enhancement and manipulation of news photographs has been developed. This interactive picture manipulation and enhancement facility is capable of executing a variety of image-processing operations while simultaneously controlling real-time input and output of facsimile pictures. The facility was designed to provide a reliable news photo-processing system that would be cost effective in the commercial production environment.

Additional goals met by the system include flexibility and ease of operation by photo editors. This system has been in continual operation since its first installation in March of 1978. Virtually all The Associated Press news photos originating outside the United States have been processed by this system before retransmission to domestic newspapers.

1. INTRODUCTION

1.1 Statement of the Problem

The overall problem faced by a news photo distribution service is to make timely delivery of the highest possible quality news photos to newspapers, magazines, and television stations. Although a variety of methods are used for delivery, such as couriers and mail, the principal means for delivery to newspapers is by facsimile machine.

Facsimile transmissions within the United States and Canada are normally over leased voice-grade telephone lines. Transmissions to and from overseas points use cable, radio, and satellite links. The Wirephoto[1] networks operated by The Associated Press use different standards for domestic and overseas transmissions. The facsimile transmissions from London to New York must be received on one standard and retransmitted on the other.

It is difficult to overemphasize the importance of timely transmission. At virtually any instant, there is a newspaper deadline approaching at some location in the United States. A news photo will not be printed in that edition if it arrives after the deadline. News photos considered for

distribution by The Associated Press come from every conceivable source, including commercial and government press releases, The Associated Press news photographers, The Associated Press archives, freelance photographers, submissions by member newspapers, and even photos of television news reports. When news events can be predicted or are of sufficiently long duration, a portable darkroom is often set up so that film can be developed and pictures can be transmitted directly from the site of the news event.

Picture quality is also very important. The newspaper photo editor will choose the picture that he thinks will be the most appealing to his readers. Many factors influence this choice. The picture must be newsworthy and have suitable contrast, sharpness, and composition. Many news photos are taken under somewhat difficult conditions. When one considers that the news photographer must snap his photo while reaching above a crowd, in poor light, at a moving scene, it is not surprising that the subject of interest may not be centered or in good focus or that the exposure was not optimum. The subject of interest may occupy only a small fraction of the negative. In these circumstances, it is simply not feasible for the photographer to go back and take another picture.

Instead, it may be necessary to process the available picture by cropping the area of interest and enlarging it to a suitable size for transmission. It is also desirable to adjust the tone scale in order to enhance the contrast in the area of interest and to sharpen an otherwise fuzzy picture. Skilled darkroom personnel can accomplish all of these functions, but substantial time and repeated tries are required to produce the best results. In practice, the best pictures from the photographers' negatives are normally not achieved because there is not sufficient time for these repeated wet darkroom operations.

1.2 History

The first news service picture radioed from London to New York was published on page 1 of *The New York Times* on May 1, 1926. The transmission time was 1 hour and 45 minutes. Since that first transmission, there has been a succession of improvements in the distribution of news photos that has reduced the transmission time, increased the quality of the resulting pictures, and reduced both the cost and preparation time required for transmission. In the 1930s, The Associated Press distributed news photos throughout the United States via telephone lines, using drum-type facsimile transmitters and receivers.

In August 1970, The Associated Press began funding a research program at Massachusetts Institute of Technology (MIT) with the broad charter of developing improvements for the distribution of news photos.

During the first phase of this project, a new type of facsimile machine to replace the obsolescent mechanical devices then being used was developed by Schreiber [18]. A prototype flat-bed laser scanner was constructed in which almost nothing moved but the paper. Recording is on 3M dry silver paper, with the exposed image developed by heat. Initial manufacture of facsimile machines called Laserphoto[2] was by Harris, and The Associated Press began installing this equipment in 1973. The Associated Press is now manufacturing Laserphoto machines for use in the United States and overseas. After The Associated Press replaced all of the facsimile equipment with approximately 800 receiving stations and 600 transmitters, there was an "overnight" switch in transmission standards that doubled the resolution and increased the perceived signal-to-noise ratio.

The next phase of the project at MIT was to develop a computer-based system for the storage, enhancement, and later retransmission of news photos. The first transmission from that computer system, installed in The Associated Press headquarters in New York City, was on March 14, 1978. Because this system allows the photo editors to perform many operations, such as cropping, enlargement, reduction, brightening, darkening, and the addition of captions, thus obviating the need for virtually all darkroom processing, The Associated Press has named the system the Electronic Darkroom. The original computer installation is still in continual operation. Essentially all news photos originating outside the United States are processed with this equipment prior to distribution to The Associated Press's United States subscribers. For the past several years, The Associated Press has been developing new versions of the Electronic Darkroom and first exhibited a miniature version at the American Newspaper Publishers Association meeting in Dallas in June 1982.

2. DESIGN GOALS

The primary goal was to provide a reliable picture-processing system that would be cost effective in the commercial production environment of The Associated Press. More specific design goals included real-time response for multiple input and output facsimile channels; ease of conversion between domestic and international facsimile standards; use of an optimal lightness scale; storage and retrieval of at least 100 pictures, which is the approximate news photo traffic in one day; and a multiprocessing environment that provides for a variety of image-processing operations, such as cropping, enlargement, contrast enhancement, shar-

pening, standards conversion, composition of multiple images, and caption generation. Other major considerations were to provide for easy and flexible operation by photo editors, to facilitate the incorporation of new peripherals and image-processing operations, and to provide for ease of replication, maintenance, modification, and extension.

Cost-effectiveness was achieved by using mass-produced commercially available subsystems wherever possible and by not overspecifying the computational power required to manipulate pictures. A PDP-11/40 (later than the PDP-11/34) has proved sufficiently powerful to perform the bookkeeping operations and relatively massive data manipulations inherent in the processing of high-quality pictures.

Initially, the only pictures of interest were those resulting from the then current domestic facsimile standards. However, we anticipated conversion to increased resolution standards after the replacement of the existing facsimile equipment with Laserphoto transmitters and receivers. We also anticipated that other input signals might be used in the future. In order to accommodate these various standards, we provided that the standard picture format be a rectangular grid with 16,384 (2^{14}) or fewer samples per dimension and up to 32 bits per picture element (pel or pixel). A typical picture produced by the original domestic standards consists of 1200 samples per line, 800 lines, and 8 bits of intensity information per pel. Phase Two standards consist of 1792 samples per line, by approximately 1280 lines. The Associated Press has since developed a new facsimile interface that produces 2067 samples for each of the 1280 lines.

The earlier Laserphoto interfaces converted each luminance sample to 8 bits. Although this was generally satisfactory, it is clear [10, 12] that it is preferable to transform image samples into the lightness domain before quantizing to 8 bits. The Laserphoto equipment was converted to the square-root domain in late 1978. The square-root domain is very similar to the lightness domain in that the shadows are expanded, so that noise introduced by quantization and subsequent processing is nearly equally visible throughout the whole signal range instead of first appearing in the shadows.

The real-time operating constraints arise from the free-running nature of the picture scanners and recorders and the desire to provide operators with quick response to parameters and commands communicated by console, light pen, tablet, or position of various knobs and switches.

Multiprocessing is essential since many operations must be performed in parallel. Manipulation of transmission and reception queues, viewing of intermediate or final results, cropping, enlarging, and filtering are a few examples of more frequent operations. Multiprocessing is also ad-

vantageous in the research and development environment, since several experiments may be conducted in parallel.

Ease of use is desirable in any system. This is particularly true when the operators are photo editors, communications technicians, or researchers with little or no computer experience. Inevitably, a rich variety of commands becomes available in a complex system. Frequently used commands and their required arguments will be easily remembered, whereas little-used commands commonly send operators scurrying to a reference manual. Several mechanisms are provided to minimize the number of instances requiring an operator to search for the reference manual. A list of available commands is quickly displayed in response to the typing of "HELP." An extract of the appropriate portion of the manual is displayed by typing "HELP (command name)." If an operator is somewhat familiar with the use of a command, he can type "? (command name)" to force explanatory prompts for all arguments. Not all arguments must be entered, since most have default values that will be used unless otherwise specified. For this frequently occurring case, the operator can simply type the command name with no arguments. The system will then issue explanatory prompts for all parameters that must be specified.

In order to minimize the number of commands, they are usually written in a generalized manner to accommodate as many situations as possible. Consequently, commands sometimes have a large number of arguments. Generous use of default parameters makes otherwise cumbersome commands easy to use. Frequently, however, an operator will desire a different set of default conditions. This is accommodated by providing the operator with the ability to use his own symbol table, which he can interactively modify. He can then restructure the command language, using meaningful (to him) abbreviations and his own set of default parameters. Further, he can set up routes to initiate a sequence of processes in which later operations operate on the data resulting from earlier operations. Finally, he can create command files that can be executed by the DEMO process, so named because of the need to automate the frequent demonstrations to visitors. Of course, an operator can readily change that name through the use of a symbol if it is not to his liking.

It is desirable for new processing algorithms to be incorporated into the system for evaluation. This should be possible for persons who have limited programming experience. The system should take care of most of the overhead, such as acquiring and saving image data. A modular, well-documented system facilitates maintenance and expansion. When a conflict arises between modularity and efficiency, modularity should be given highest priority, except in the most critical places.

3. HARDWARE DESCRIPTION

The major hardware components of the Electronic Darkroom are shown in Figure 1. The original implementation used a PDP-11/40, and no modifications were necessary to operate with a PDP-11/34.

The television picture display is required so that the correctness of image input and processing operations can be verified before substantial time is spent on further processing or facsimile transmission. When we started our development, economic pressures precluded the purchase of then available television displays. We therefore developed a display that has been previously reported [22]. A second model has been developed by Goldwasser [5]. Key features of this display are the availability of multiple video formats without sacrifice of memory capacity, the use of pseudorandom noise to eliminate contouring [17], and convenient CPU access to image data, namely, as ordinary main memory.

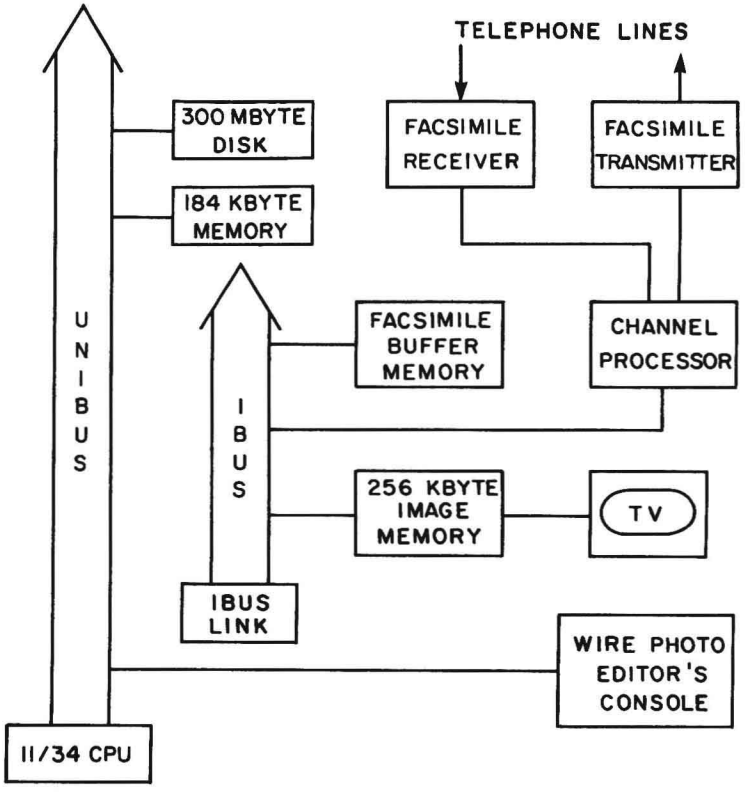

Figure 1. Major hardware components.