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Edited by G. Goos and J. Hartmanis

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PREFACE

Pictorial information systems promise to soon enter the mainstream of computer science and computer engineering. With the advances and new applications in picture processing, such as computed tomography, whole-body scanner, earth resources survey satellite image processing, cartographic applications, etc., the problem of efficient, economical storage and retrieval of vast amounts of pictorial information becomes more important and requires careful considerations. Present day database management systems are designed primarily for efficient storage and retrieval of alphanumeric data. Little attention has been paid to the storage and retrieval of non-alphanumeric information such as digitized images which require large amounts of storage even for pictures of average complexity. The rapid advances in computer graphics, especially raster graphics, have given additional impetus for development of sophisticated pictorial information systems capable of handling both raster-formatted and vector-formatted picture data. On the other hand, advances in database technology, knowledge-based systems, and syntactic picture processing have led to the consideration of complex data structures for pictorial information representation.

Two problems can be distinguished in designing pictorial information systems - the storage and retrieval of a large number of pictures, and the storage and retrieval of very large pictures or pictures of great complexity. Also to be considered is the intended usage of a pictorial information system -- whether it is intended mainly for retrieval of pictures, or processing and manipulation of pictures is the main purpose. These considerations can lead to the design of entirely different pictorial information systems.

In this volume, various issues in the design and implementation of pictorial information systems are presented. We first consider data structures and encoding techniques for pictures. A pixel array can be thought of as a special case of a tree structure. Structuring a digital picture by sub-areas instead of individual pixels and naming the nodes of the tree by their relative geographical locations, provide information for accessing particular regions in a picture. Such combination of hierarchical and area representations of picture data are desirable, because most picture processing algorithms operate on area, and the hierarchical representation of the picture content presents to the application programs picture information from the most general form to the most detailed form.

In Chapter One, Omolayole and Klinger describe techniques for structuring picture data in storage in a multilevel tree structure and reducing the data at each level without distoring the prominent object structures in the picture. An area partitioning algorithm is used in combination with proven image processing techniques to organize picture portions into several levels using a tree structure. The advantages are that subareas containing no useful information can be suppressed, and storage is saved. Also, the user can be guided to probe only the important subareas of a picture

Hierarchical data structures are also useful in organizing a picture database for similarity-directed retrieval. A major difference of picture database management system from ordinary database management system is the need to retrieve pictures based upon similarity measures. Therefore, pictures which are similar to each other should be stored either logically or physically close together. Moreover, by storing similar pictures together, a loose clustering of the pictures can be achieved, which may aid further detailed clustering. In Chapter Two, Chien presents a data structure, called the hierarchical projection tree, which combines hierarchical clustering algorithms with one-dimensional projections to store and retrieve pictures represented by feature vectors or multi-dimensional vectors. This data structure is especially useful for storing and accessing pictures (feature vectors) using nearest neighbor search technique. Chien then proceeds to discuss how to construct a hierarchy of pictorial data by utilizing their global characteristics, such as gray level histograms, eliminating the need to extract feature vectors. With the development of fast algorithms for optimal histogram matching [CHANG 78], histogram matching technique for similarity retrieval from such a hierarchical data structure can be a promising approach.

In similarity retrieval from a pictorial database, very often it is desired to find pictures (or feature vectors, histograms, etc.) that are most similar to a test picture (or feature vector). In Chapter Three, Yang and Chang discuss techniques to encode pictures (or feature vectors) into convex polygons or hypercubes, so that similarity retrieval and updating of encoded pictures can be facilitated. Such encoding techniques can be used, for example, in the hierarchical projection tree proposed by Chien. A review and evaluation of the state of art of similarity retrieval techniques is presented in Chapter Six, where Lee describes various types of similarity measures for extracting picture primitives. Using similarity measures, one can not only store similar pictures logically or physically close to each other to improve retrieval efficiency, one can also use such similarity measures to answer fuzzy queries involving nonexact retrieval conditions.

In addition to the need to perform similarity retrieval of pictures, a pictorial information system often must also support structural retrieval of pictures. Storage, retrieval, editing, and segmentation of pictures all require the definition of data structures, which can be expressed in terms of abstract graphs. Graphs offer a very general structure for the encoding of picture data and the underlying relationships among parts of a picture. For example, the hierarchical data structure discussed in Chapter One is a "picture tree", a special type of directed graph. Some of the most common occurrences of graphs are in the context of picture segmentation, scene analysis and global shape analysis. In Chapter Four, Pavlidis discusses graph grammars and their expressive power. It is shown that first order context-free graph grammar produces essentially only trees, and second order graph grammar produces essentially only series-parallel graphs, in addition to trees. Higher-order graph grammars, or non-context-free graph grammars, can be used to generate arbitrary graphs.

Multilevel hierarchical or pyramid structures are useful in describing a picture in terms of its parts. The multilevel tree representation of a picture can also be used to model texture patterns. To describe relationships among the parts, a hierarchical or non-hierarchical relational graph can be used. The underlying structure rules for the tree or graph are called the syntax of the picture, which are discussed by Fu in Chapter Five. A set of such syntax rules, or a grammar, can be used to generate a set of trees or graphs representing pictures. Attributes associated with node and/or branch labels in the tree or graph can be regarded as semantic information in picture representation. Many picture data operations can be performed on such a syntactic-semantic representation at different levels, rather than directly on the picture itself. Tree matching or graph matching according to a similarity criterion can be carried out using a tree distance or graph distance, which can be defined in terms of minimum-distance error transformations between two trees or two graphs. The definition of similarity measures for picture primitives is then discussed by Lee in Chapter Six.

As mentioned above, the design of pictorial information systems depends very much on the application areas, functions provided, intended usage of the system, and size as well as complexity of the database. In Chapter Seven, Zobrist and Bryant describe IBIS, the Image-Based Information System developed at JPL for managing spatially-referenced data and performing spatially-oriented processing. This system emphasizes the flexible conversion among three picture data types: tabular, graphical (vector-formatted) and image (raster-formatted) data. In the IBIS system, raster-formatted LANDSAT images and vector-formatted census data are stored in two separate databases. Examples are given showing that information retrieval, information analysis, and report generation for IBIS usually involve processing and transformation among these three types of picture data.

Tamura, in Chapter Eight, describes the EIDES image database and its management software system developed at the Electrotechnical Laboratory in Japan. The EIDES image database adopts a standard format for image files, so that various types of images can be accommodated, to support experimental studies of pattern recognition and image processing. Moreover, image file management tasks are separated from image processing tasks, so that the user can retrieve and edit stored images using system-supported softwares on the one hand, and design his own image processing programs on the other hand.

In Chapter Nine, picture paging techniques are described by Reuss et. al., as a technique for minimizing storage and transmission costs in the handling of large-scale image data that can not entirely fit into the main memory of a computer. Algorithms for page set selection are then described.

The next two chapters are concerned with the use of relational database in pictorial information systems. Relational database can be used in two ways: (a) management of picture files: The most common arrangement for managing picture files is the use of a relational database (or a collection of normalized tables), either to store the names of the pictures and/or subpictures (the "nominal system"), or to store the geographical locations of pictures and/or subpictures (the "ordinal system"). For a discussion of the nominal system and ordinal system for picture referencing, the reader is referred to Chapter Seven. (b) Picture structure representation: Hierarchical picture structures can be represented by a relational database, each level being represented by different subsets of relational tables. The design of such a relational pictorial database system is described in Chapter Ten by Chang et. al., in which generalized zooming techniques for pictorial information retrieval are also described. On the other hand, a relational graph can be transformed into a set of relational tables so that existing techniques in relational database management can be easily applied. In Chapter Eleven, Chang and Fu describe a relational database system which is interfaced with an image understanding system, and the design of a flexible query language for pictorial information retrieval based upon Zloof's query-by-example (QBE) approach [ZLOOF 75]. Another recent example of a general purpose graphic system using the relational database approach can be found in[UNO 79].

In Chapters Twelve, Thirteen, and Fourteen, applications of pictorial information systems in the area of cartography, computerized tomography, and X-ray pictures, are described by Kobayashi, Huang, and Kunt, respectively, which again illustrates the diversity in application areas as well as design approaches. An excellent survey of cartographic and geographic information systems can be found in [NAGY 79]. For cartographic applications, the commonly used data structures are either the cellular organization, or a linked organization consisting of line segments, chains, or polygons. A recent survey of picture data structures can be found in [SHAPIRO 79].

The final two chapters discuss the design of image query languages and intelligent query systems. In Chapter Fifteen, Lien and Harris present an image database management system IMDB and its query language IQ. The system maintains five types of files: image, window, transform, color, and zoom. The user can retrieve images from the image database; load it into the working directory; define windows, pixel transforms, false color functions, and zoom scales; perform successive operations on images to transform images to new images; and save new images in the database.

In Chapter Sixteen, Bhargava discusses the design of intelligent query systems for large databases. In pictorial information systems, a large quantity of data is gathered to cover all possible inferences that can be drawn in the future. A user is usually interested in retrieving or updating a very small subset of data, but the probing of the database is usually expensive. The user is also unaware of potential information available in the database, and presents his intent in a set of unstructured queries. It is undoubtedly true that an intelligent query system will be very useful, if the system can utilize semantic information in helping the user to locate the information he needs. The following four categories of semantic information has been identified by Bhargava: (a) database semantics including data description semantics and data value semantics, (b) user's knowledge and usage semantics, (c) real-world semantics, and (d) database organization semantics. For pictorial information retrieval, we may also add picture semantics, which is either embedded in the picture data structure, or a separate picture grammar. How to combine the above listed semantic information, and design a knowledge-based pictorial information system which can support user's retrieval needs, remains to be a challenging research problem.

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TABLE OF CONTENTS

A HIERARCHICAL DATA STRUCTURE SCHEME FOR STORING PICTURES

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I. INTRODUCTION

With the falling cost of data storage, it is imperative that large data must be organized in storage so as to maximize the flexibility of usage. A picture in computer storage is often represented by large sequential files generated from raster-scanning devices. Analysis programs operating on raster-scan data organization encounter prohibitive I/O cost [12]. From the works of Yarbus [26] and Mackwork et. al., ([18],[19]) it is evidenced that a large percentage of the data collected from a picture is redundant in the analysis of the picture. This chapter concerns techniques for structuring picture data in storage in a multilevel fashion and reducing the data at each level without distorting the prominent object structures in the picture. An area partitioning scheme is used in combination with proven image processing techniques to organize picture portions into several levels using a tree structure.

In keeping with the theories [29] on data base design the picture data structure approach here pays attention to:

1. accessibility of picture data in storage,
2. flexibility of picture data usage essential to most pattern recognition applications,
3. picture data independence,
4. multi-level data storage for structured sets of operation,
5. redundancy reduction in the multi-level structured data, and
6. analysis of small portions of a picture at one time.

The work reported in this chapter is an extension of [13],[14],[15],[16], and [20]. The theoretical background of the techniques are presented in the next three sections with illustrations from three real life pictures (see Figures 1.1, 1.2

and 1.3 respectively, and Figures 1.4, 1.5 and 1.6 show their raster images. The picture data structure scheme and a summary of the data structure are discussed in the last two sections.

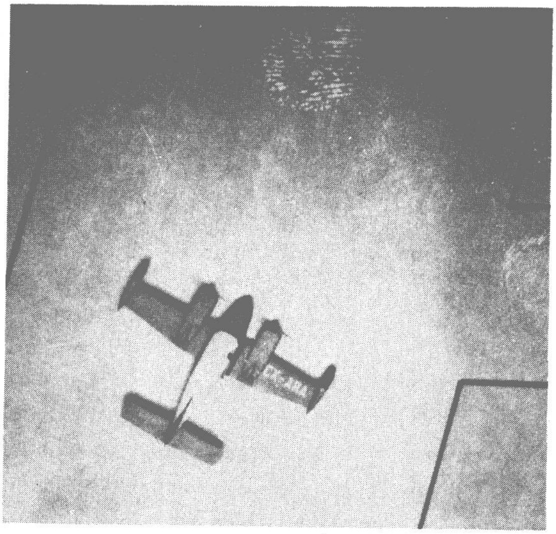

Figure 1.1
A plane on the runway

Figure 1.2
Face of a young Afro-girl

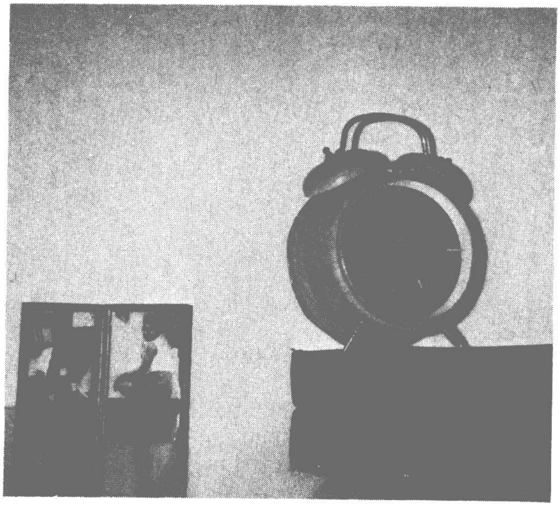

Figure 1.3
Clock Scene

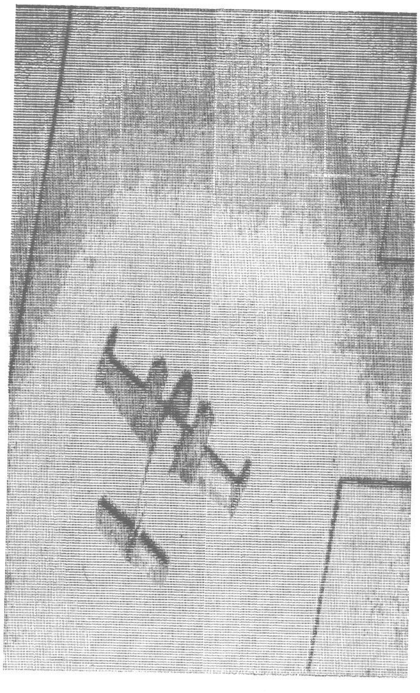

Figure 1.4
The digital image of Figure 1.1

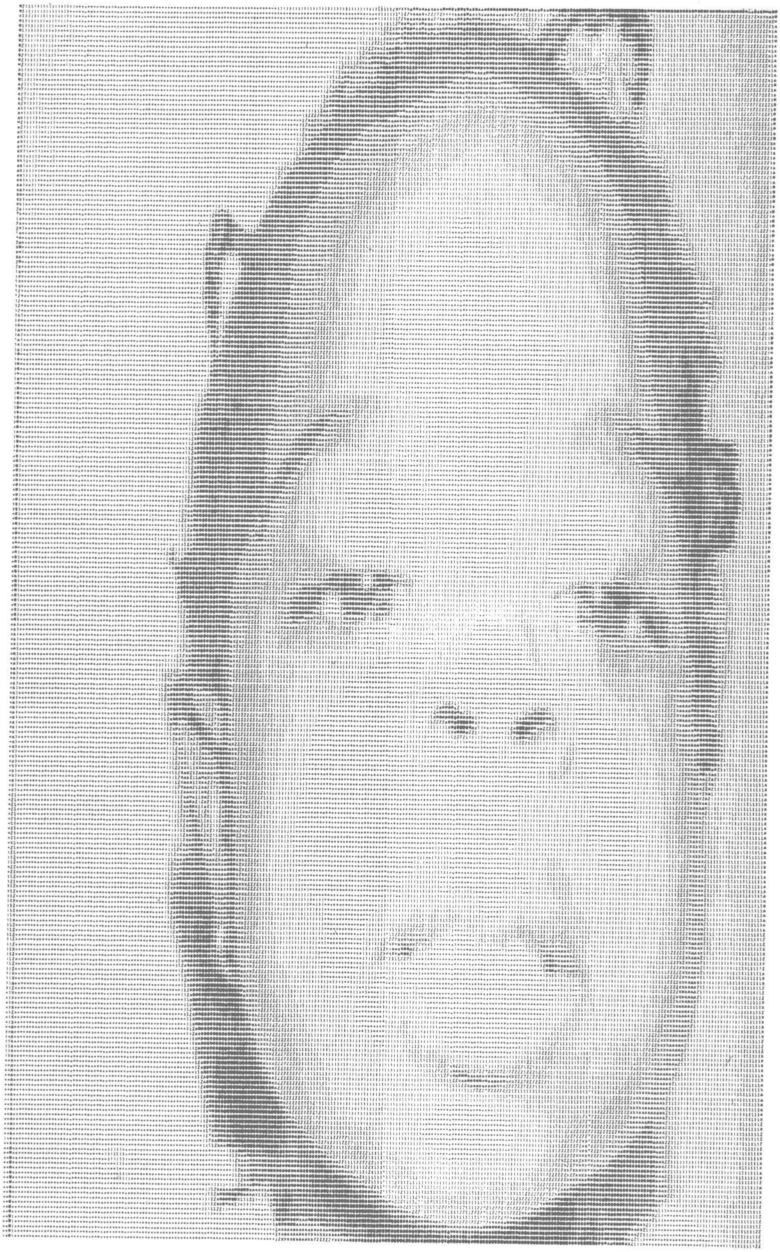

Figure 1.5

The digital image of Figure 1.2

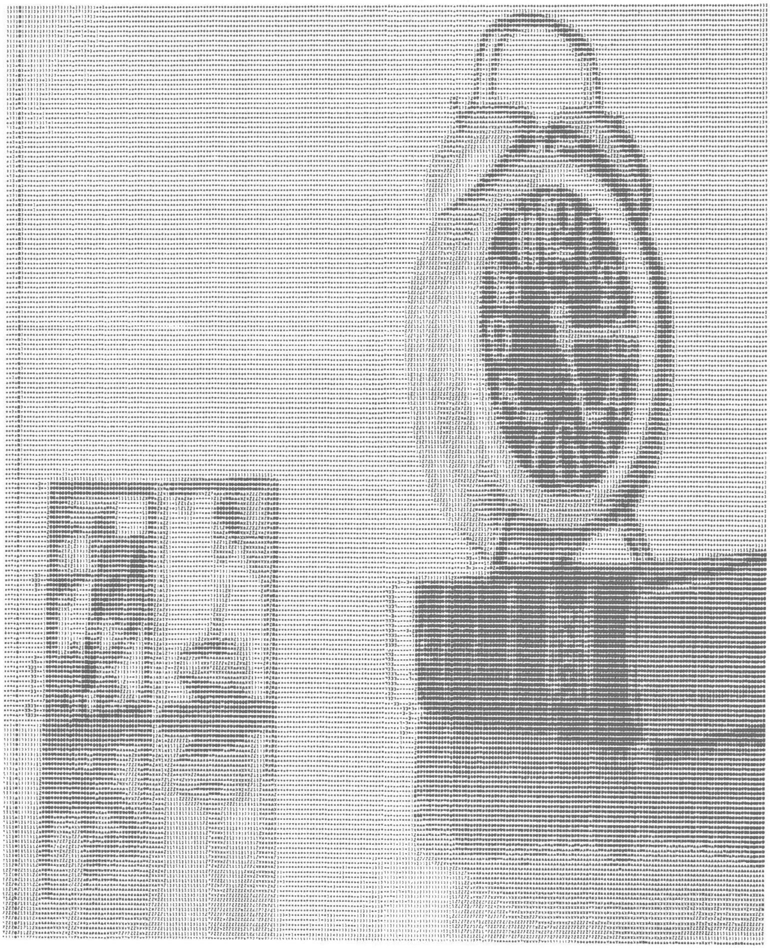

Figure 1.6
The digital image of Figure 1.3

II. ONE-PIXEL-WIDE EDGE-LINE DETECTION

The essential part of the information conveyed by a picture is concentrated in the boundary lines between adjacent regions of objects in the picture. The boundary lines are extracted as edge-lines ([3], [4], [7], [8], [10], [21]). One-pixel-wide edge-lines are specifically sought in order to avoid representing "blobs" in the picture data structure as edge-line information. In view of the above the edge-line detection techniques used here have been carefully selected only for the purpose of designing the picture data structure. The techniques used are summarized in Figure 2.1.

The Kirsch edge operator [11] is applied to the digital images of Figures 1.4, 1.5 and 1.6 in order to bring out prominent edge-lines. This operator is used because