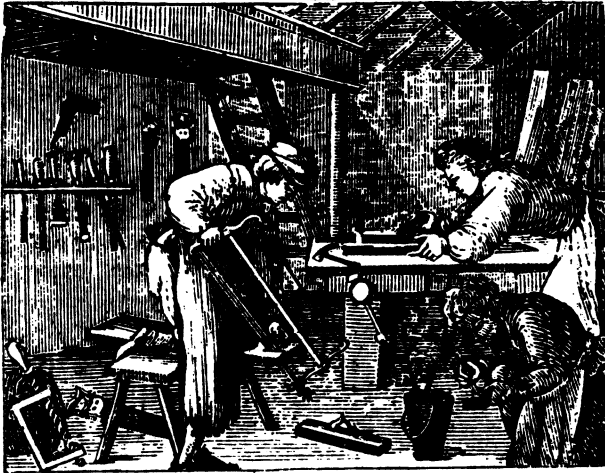# Workshop Report

NEW DIRECTIONS IN MACHINE-PATTERN ANALYSIS

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Introduction

The Fourth Machine Pattern Analysis Workshop, sponsored by the Machine Pattern Analysis Technical Committee of the IEEE Computer Society (formerly the Pattern Recognition Committee) and supported by the United States Postal Service, took place on March 3-5, 1975, with relatively little fanfare but a good deal of enthusiasm at the Asilomar Conference Grounds in Pacific Grove, California. Many of the participants were relics of the earlier meetings, but there were also a number of new faces.

The themes agreed on by the workshop committee were (1) Hardware Developments, (2) Transportable Software, and (3) Industrial and Office Automation. The format of the workshop consisted of thematic presentations interspersed with critical evaluations of each area. There were also some round-table discussions and informal fireside evening sessions.

By and large, the discussions were much more applications oriented than in the three previous workshops in this series (1966 in San Juan, 1968 in Delft, and 1972 in Hot Springs), and theoretical presentations dealing with advanced statistical classification concepts were conspicuously lacking. The forty-five participants were again almost evenly divided between industry, government and nonprofit research organizations, and universities. The leisurely and informal nature of the sessions fostered a number of lively exchanges of views, and the friendly atmosphere of the Asilomar conference facilities, its relative isolation, and the communal meals provided additional opportunities for the technical interchange of information between individual participants.

Subsequent publication of some of the material presented at the workshop in IEEE publications is likely. A summary of the presentations in each of the three principal topic areas is given below.

Theme I—Hardware Development

The first major theme of the workshop elicited a comprehensive review of input and output devices for both the pattern recognition and the image processing aspects of machine pattern analysis. These two areas were, incidentally, differentiated by one participant according to the criterion that the former involves the *classification* of patterns while the latter consists of the *transformation* of one form of an image into another.

A large variety of commercial devices are available for machine pattern analysis. All too frequently a major part of the problem is the noise and distortion introduced either in converting the patterns into computer readable form or during the inverse process. Thus, success in experimentation requires thorough familiarization with the properties and characteristics of the various devices and with the fundamental limitations imposed by the underlying physical principles.

The families of devices considered during the two sessions comprising this part of the program included flat-bed and rotating-drum scanners, vidicon and image-dissector cameras, mechanical and cathode ray tube flying-spot scanners, and linear solid-state arrays of both the photodiode and the charge-coupled device (CDC) type. The properties of different light sources and light detectors, including tungsten lamps, arc lights, lasers, photodiodes, and photomultiplier tubes were also described and compared.

The relatively slow flat-bed scanners and drum scanners were recommended for high-precision work involving mensuration of either pattern geometry or gray-scale. Vidicons and image dissectors were preferred for medical image processing, with the choice between them based on speed requirements, illumination, photometric fidelity, and cost. It appeared to be the consensus that solid-state arrays were making rapid progress in

achieving workable levels of uniformity and sensitivity and that within a few years they may constitute the preferred mode of input for many image processing applications.

There was considerable emphasis on the characterization and specification of transducers in terms of resolution, geometric distortion, modulation transfer function, shading, dynamic range, speed, and spectral characteristics. Techniques of measurement and calibration were reviewed, and methods for compensating for the imperfect operational characteristics of the devices were described.

The special difficulties involved in working with color images were selected for attention by one participant. The "dimensions" of color (brightness, saturation, and hue) were discussed in terms of their significance in producing adequate reproductions. The special compensation required for film sensitivity and for producing color images by means of a subtractive mixture was explained and demonstrated, and the problems introduced by the perceptual aspects of color were mentioned. The high degree of correlation in the reflectance characteristics in the three primary bands was illustrated by means of histograms obtained from several standard images.

The particular scanning applications demonstrated in some detail included radiographic images, planetary scenes, the digitization of strip charts, and the Universal Product Code (UPC) system for automating the recording of grocery products at supermarket checkout counters. This last application differs from most machine pattern analysis in the amount of control available on the target pattern. Much of the discussion of this application was in fact taken up in the considerations involved in developing the relatively complicated bar-chart patterns forming the UPC.

The session closed with a cogent presentation of the desirability of developing one or more national scanning facilities for biomedical applications. Justification for such development includes the high cost and rapid obsolescence of scanning and display equipment, and the necessity for timely, uniform, and accurate conversion of biomedical material including photographic transparencies, tissue specimens, and live patients. Organizational and functional guidelines were provided for the postulated scanning

center and its staff, with some of the requirements based on the hard lessons learned from the shortcomings of past research projects in this area. Slides from a number of current research projects were shown during this presentation.

Theme II—Software Development

There were two sessions devoted to this theme. One session dealt with software transportability—the problem of making techniques and algorithms usable by the general pattern recognition community. The other session concentrated on the need to develop standardized data bases for the evaluation and comparison of techniques and algorithms. A total of ten speakers took part in the formal presentations at these two sessions.

In the session on software transportability, there were four presentations aimed at making software technology more widely usable. The first presentation considered the difficulties in transporting software from the standpoint of both the creator and the user. These difficulties stemmed from the fact that computer systems and computer languages, upon which computer software was built, were in most cases not transferable. Except for the simplest of computer programs, any attempt to transport a computer program from the originator to the recipient requires a tremendous amount of pre-planning and organization by both parties. A description of the VICAR software system at JPL's image processing laboratory was offered to illustrate this viewpoint. There followed a discussion of the current experiences of JPL in distributing software to other organizations. Based on these experiences, a new software system that conceivably could overcome many of the current difficulties was proposed.

A second viewpoint considered transfer of software as one of three keys to the availability of pattern recognition technology: hardware, software, and training or understanding in its use. Software transferability was deemed the most complex. The presentation also summarized the efforts that have been undertaken at LARS to increase the transferability of software technology. These included: (1) a completely documented software system (LARSYS), (2) a remote

terminal system making the software available to the user community, and (3) an extensive user training program designed exclusively for the potential recipients of the pattern recognition technology.

Transferable software systems for pattern recognition research in a network environment were also discussed. It was pointed out that a major concern in this context was the need to establish protocols (conventions). This should include system-oriented as well as function-oriented protocols. As an example, the goals and the protocols of the ARPANET were described. There followed a description of the interactive speech processing system developed at the SCRL, and some of its features designed to improve software transferability were outlined.

The fourth presentation was devoted to the design of transferable computer programs for the analysis of characteristic features. It was suggested that many of the statistical program packages, such as SSP, BMD, and SSPS, were not directed towards pattern recognition problems. As a consequence, they do not include many of the known powerful techniques. The conclusion was that any transportable software package should include a feature analysis program implementing one or more of the following methods: (1) rotational transforms, (2) general linear transforms, (3) nonlinear transforms, and (4) search procedures.

There were also four presentations in the session on data bases and standards. Two of the presentations addressed the problem of creating artificial data bases by means of which techniques and algorithms could be evaluated. The rationale for such data bases was considered, and the need to make a distinction between an artificial data base and a complex set of multidimensional pseudorandom variates was stressed. The latter approach was considered particularly suitable for building up more knowledge about the algorithms and theories, while the former would be useful in the test and evaluation of practical devices. Several computer techniques for implementing this approach were presented.

In addition to the above presentation in which ideas and concepts were emphasized, methods were also discussed for implementation of the ANSI (American National Standards Insti-

tute) handprint character specifications. To create a set of characters simulating the variations that exist in a real environment, the stroke centerline of a standard ANSI character was represented by a series of linear approximations. Transformations were then applied to the standard characters resulting in characters of carefully controlled variation and distortion. While not eliminating the eventual need for actual data during final testing of recognition devices, it was suggested that this technique should provide a versatile artificial data base for algorithm design and evaluation. This presentation drew a lively resonse from the participants, with the majority strongly opposing the generation of large artificial data bases with a built-in noise component. It was agreed, however, that such simplified models of real world disturbances could have some pedagogical value.

The two other presentations in the session were concerned with the development of real data bases. Focusing on problem-oriented OCR bases, four categories of functional characteristics of the OCR problems in postal reading machines were identified—formatting, framing, recognition, and directory. Ideally, the performance of each function should be examined with a computer compatible data set which has been derived from mailpieces to serve as an input to that function. Consequently, the USPS has under development several new data bases to be submitted to the IEEE Computer Society Repository. One such data base was described in detail. It consisted of about 32,000 alphanumeric characters at 24 X 24 resolution on magnetic tapes. Signal amplitudes were digitized at 16 levels.

Related to the general question of controlled input for character recognition was a late-night impromptu presentation on a special set of constraints for handprinting. This approach, consisting of box and line combinations, had several purported advantages over earlier constraints such as the two-dot, four-dot, and Union Jack designs. The method has been subjected to limited tests.

The final talk in the session was devoted to a discussion of the need for a *minimum* data base for image processing research. It was pointed out that, for economic reasons as well as a desire to standardize, researchers in image analysis relied on very small

data sets to develop and test their algorithms. This clearly raised the question of statistical confidence, robustness of algorithms, and other problems that cannot be resolved without a large data base. An analysis of the factors influencing these conflicting requisites placed upon the size of pictorial data bases then followed.

Theme III—Industrial and Office Automation

Two sessions were devoted to this theme, one accentuating design principles and the other applications. Topics considered included robots, identification of machine parts for automatic assembly, a postal application of OCR, and a clinical prototype of a human chromosome classifier.

There were three presentations concerned with robots for different applications, yet possessing similar design problems insofar as cognition is concerned. Using the Mars Rover as a vehicle for discussion, a design scheme for a virtual robot was presented in which human support is provided whenever needed (e.g., cognition functions) until such time as the state-of-the-art in artificial intelligence allows the machine to take over the responsibility. In this way the virtual robot structure remains invariant and isolated from changes in subsystems and functions, thus providing an effective test system throughout the design period.

The second presentation was concerned with the visual sensory system for the Rover. Particular attention was addressed to means for allowing such robot systems to keep track of objects while in motion. In addition to the necessity for calibration of the sensory system, the problem of object tracking was broken down into four areas of consideration: (1) object detection, (2) object location, (3) computation of the parameters of object motion, and (4) special modifications to locate specific features of the object.

The third presentation provided a description of a programmable, computer-controlled system of manipulators (industrial arms), end effectors, and visual and force sensors. The system can be trained to perform a variety of tasks, including inspection, assembly, and material handling. Training aids take the form of voice control, joysticks, etc.

Two speakers addressed the problem of how such systems can recognize

machine parts. The first described a syntactic approach to the analysis of machine parts. A binary image of the part is transformed into a one-dimensional curve representing the medial axis. This curve is then segmented and a sequence of symbols is produced. A finite state machine (eighty states) is then used to determine grammatical correctness and to locate important areas on the part. This method was recommended as leading to a high speed, low cost inspection system.

The second presentation advocated a heuristic procedure for recognizing parts using decision trees. The system in which the procedure is used is the programmable, computer controlled manipulator described earlier. Some fifty features were defined for the parts of interest, but rather than measuring all fifty for each part, a sequential method was used. The procedure for determining which features to measure first involves isolating each feature and investigating the gap between the marginal probability distribution corresponding to each of the classes of interest. Whenever the gap is "large enough," that feature is deemed adequate for separating the adjacent classes concerned. By following this procedure to its logical conclusion, a decision tree is obtained which allows successful discrimination of machine parts with relatively few measurements.

One speaker described a new system, OCR II, for reading machine printed addresses on mail to allow automatic sorting. The address is scanned through a rectangular window, proceeding bottom-to-top so that the zip code and/or state is located first in the address. The format of the address directory and its application for identifying destinations were explained.

The only biomedical presentation in these sessions described a special purpose, stand alone clinical prototype for automated chromosome analysis. The system consists of an automated microscope with television scanning and digitization under minicomputer control, and special video processing hardware for automatic focusing and slide positioning. An interactive gray level display allows human interaction with the system. Hardcopy output of processed images in conventional clinical format is provided. ■