A-PRIORI-INFORMATION IN DIGITAL IMAGE PROCESSING

U. Engelmann, H.P. Meinzer
German Cancer Research Center
Institute of Dokumentation, Information and Statistics
Im Neuenheimer Feld 280, D-6900 Heidelberg, F.R.G.

Abstract

While working on image analysis systems we found no global approach to the information reduction process necessary to extract the semantic description of an image. Up to now image processing uses standard methods, self developed specialized algorithms and a great deal of a-priori-information on the subject under investigation. Standard methods are described in the literature and are more or less useful for a given problem. These standard methods have to be adapted to the problem and in most cases extended by self developed, dedicated methods. The third ingredient of the solution of a given problem is the use of a-priori-information (a.p.i.). Every practical solution needs a-priori-information to simplify the segmentation process and to make the algorithms efficient. Today most image segmentation methods do not work without a-priori-information.

This paper distinguishes two classes: Static a-priori-information and structural a-priori-information. Static a.p.i. are for example fixed values like grayvalues, distances, length, etc.. Structural a.p.i. is information about the structure of an image or an object in the image, e.g., shape of objects, grayvalue distributions etc.. An algorithm which uses static a.p.i. is inflexible and restricts its own applicability. Little differences in the input data can render the method useless. Structural a.p.i. reacts flexibly to little changes in the input data because it uses information about the structure of the data and not the data itself. The quality of algorithms depends on the amount and kind of a-priori-information. Algorithms which use structural a-priori-information are more flexible and reliable in application.

1. Introduction

Digital images contain a great deal of information. By methods of digital image processing and pattern recognition an attempt is made to reduce the large amount of information to a brief and abstract description of the image contents. This process can be divided into the steps

- image preprocessing
- image segmentation
- pattern recognition.

In the first step the image will be improved, i.e. some properties will be enhanced. For example this process reduces the amount of noise to support the second step which solves the next task, the segmentation. This step recognizes meaningful contents of the image which are in fact subimages or sets of pixels with a certain semantic meaning. In a final step (pattern recognition) a further reduction of information to a formal description of the image is performed. The last two steps are often mixed up. Confronted with such a task, we first find some standard methods in the literature which look very nice at a first glance (1,2,3,4). When attempting to apply them, we soon recognize that this is not all we need to solve our problem. So we begin to modify the standard methods and if this is not enough, we develop our own dedicated methods (which can be presented at a congress).

2. Using a-priori-information

Investigating the described process in more detail, we find a third important matter that helps us to analyze an image: a-priori-information (a.p.i.). Whoever has to solve an image processing task uses a lot of information he has a priori about a distinctive class of images. When he decides which standard methods may be suitable, he uses a-priori-information the first time. When he modifies a method for his dedicated task he also uses a-priori-information. Self-developed methods contain the greatest amount of a.p.i.. When he gives an image segment a certain meaning the use of a.p.i. is obvious. Thus, we can summarize that basically three ingredients are used to build an image processing task:

- standard methods
- self-developed methods
- a-priori-information (a.p.i.).

In this paper we do not want to say anything against the use of a.p.i.. In fact, a priory information is a powerful help and indispensible in his context. The best image processing system, which works a very long time successfully in routine, is the visual system of the human being himself. It is very fast and reliable and solves problems in less then a second which a computer program cannot solve in hours. One explanation for this superiority is that man has a-priori-information about image contents. We use this information instinctively when we use our visual system and also in most cases during the development of artificial systems.

3. Distinction of a-priori-Information

The quality of an image processing system becomes obvious when the input images differ from the training images. The reaction of the system largely depends on the kind of a.p.i. it contains. A bad kind of a.p.i. are fixed values. A better kind of a.p.i. is knowledge about the structure of the image.

A small example can demonstrate the difference between these two kinds: A given problem may be to find dark objects on a light background. The objects can be segmented by a threshold operation because the grayvalue histogram is always bimodal. There are two ways to implement the segmentation:

1) A fixed gray value is the optimal threshold, e.g. 57.
2) The threshold value is the minimum between the two peaks in the smoothed grayvalue histogram.

If the input image in this example differs in the grayvalues because the illumination is not always the same or the preparation of the material is not absolutly constant, the fixed value will fail but the second method will again be successful. Thus, we distinguish

- static a.p.i.,
- structural a.p.i..

The boundary between this two kinds is vague. Structure is also static. We do not mean the structure itself but implementation or representation of a.p.i in the algorithm. The implementation expense is higher when we use structural a.p.i., and a static value can be implemented very quickly (the 'quick and dirty' principle). The runtime of an algorithm with static values will always be better than a version with structural a.p.i.. But the structural version will still be successful when the circumstances change and the fixed values fail.

4. Some Examples

A-priori-information can be used in different stages. In the first stage, we use information about the objects in the image. Here it is helpful to have a model of the object which can be determined by some parameters. The a-priori-information is the model and the parameters will be determined in the analysis process. A model is structural a-priori-information. The model does not change, only the parameters which will be determined for each object.

Objects in images can be detected by their edges. Therefore a-priori-information about the structure of edges can be very helpful. Marr and Hildreth (6) used structural a-priori-information about edges to detect the position of an edge. The idea is that extractable information is basically only found where there are changes in grayvalues. The places of maximum change can be found by peak detection of the gradient or equivalently by the zero-crossings of the Laplacian. Combining these zero-crossings of various scales gives a good representation of the image content. Another approach to detect objects in an image is to analyse the texture of the objects (7). Texture depends on structural features of the objects. It is also structural a-priori-information. The visual system of the human being also uses structural a priori information. This structural information can help us in the development of artificial visual systems (5). Ullman uses the knowledge of the rigidity of most objects to determine the three-dimensional structure from motion.

In the developmental process of an image processing system we should always be conscious of the a-priori-information we use. A good example for the consciuos use of a.p.i. is a paper of Liedtke and Kappei (8). They first collected their a.p.i. about a class of images and the segmentation algorithm is based on this information.

5. Conclusion

The decision how to implement a.p.i is a decision between implementation expence and runtime at one hand and reliability at the other hand. The quality of algorithms depends on the amount and kind of a-priori-information. Algorithms which use structural a-priori-information are more flexible and reliable in application. Therefore the system developer should always be conscious as to where he uses a-priori-information, and he should try to use structural a-priori-information.

Acknowledgement

We thank our colleagues J. Dengler, R. Streicher and K. Ullrich for their helpful comments and examples.

Literature

1) Castleman, K.R.: Digital Image Processing. Prentice Hall, Englewood Cliffs, 1979.

2) Gonzales, R.C., Wintz, P.: Digital Image Processing, Addison-Wesley, Reading, Mass., 1977.

3) Pratt, W.K.: Digital Image Processing, John Wiley, New York, 1978.

4) Rosenfeld, A., Kak, A.C.: Digital Picture Processing, Academic Press, New York: 1976.

5) Ullman, Sh.: The Interpretation of Visual Motion, MIT Press, Cambridge, 1979.

6) Marr, D., Hildreth, E.: "Theory of edge detection", Proc. R. Soc. Lond. B., 207, 1980, pp. 187 - 217.

7) Haralick, R.M.: "Statistical and structural Approaches to Texture." Proc. IEEE, 67, No. 5, 1979, 786 - 804.

8) Liedtke, C.-E., Kappei, F.: "Wissensgesteuerte Segmentierung von Urothelzellbildern.", Mustererkennung 1983, 5. DAGM Symposium. VDE-Verlag, Berlin, 1983, pp. 390 - 395.