A Rule-Based Expert System Utilizing Edge Enhancement and the Thresholding Method

What is an Expert System?

Feigenbaum, a pioneer in expert systems (1982, p. 1), states: An 'expert system' is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. The knowledge necessary to perform at such a level, plus the inference procedures used, can be considered a model of the expertise of the best practitioners in the field.

The knowledge of an expert system consists of facts and heuristics. The facts constitute a body of information that is widely shared, publicly available, and generally agreed upon by experts in a field. The heuristics are primarily private, little-discussed rules of good judgment that characterize expert-level decision-making. The performance level of an expert system is mainly a function of the size and quality of its knowledge base.

The basic structure of an Expert System

An expert system consists of:

- A knowledge base of domain facts and heuristics associated with the problem,
- An inference procedure (or control structure) for utilizing the knowledge base in the solution of the problem,
- A working memory- "global database"- for keeping track of the problem status, the input data for the particular problem, and the relevant history of what has thus far been done.

An expert system serves as a systematic repository of knowledge accumulated by many specialists with diverse experiences. Therefore, it

can and does ultimately achieve a level of consulting expertise that surpasses its "tutors."

Some Background Knowledge about Edge Detection

Edges are fundamental features of an image that are extensively used in image classification and analysis systems to delineate the boundaries of an object.

Edge Detection Methods

An image edge is a local change or discontinuity in image luminance. There are two basic approaches to image edge detection: enhancement/thresholding and edge fitting methods. In the former, discontinuities in an image attribute are enhanced or accentuated by a spatial operator. An edge is deemed present if the enhanced discontinuity exceeds a threshold level. The edge fitting approach involves fitting an ideal edge replica, a two-dimensional ramp or step function, to the image over a region. If the fit is close, an edge is judged to be present.

An edge enhancement/thresholding edge detection system consists of multiple spatial operators, a point operator, and a threshold decision. However, it is also possible for only one spatial operator to exist in this system. In this method, the discrete image array is spatially processed by a set of N linear operators or masks to produce a set of gradient functions. Next, at each pixel, the gradient functions are combined using a linear or nonlinear point operator to create an edge-enhanced array. Typical forms of the point operator include the root mean square (RMS), magnitude (mag), and maximum (max). The enhanced array A(j,k) measures the edge discontinuity at the center of the mask. An edge decision is formed based on the amplitude of A(j,k) in relation to a threshold (t). If $A(j,k) \geq t$, an edge is assumed to be present; if $A(j,k) < t$, no edge is indicated. The edge decision is typically recorded as a binary edge map E(j,k), where a one indicates an edge and a zero indicates no edge.

There are two types of spatial edge enhancement operators: the differential and the template matching operators.

Differential And Template Matching Operators

The differential operators perform discrete differentiation on an image array to generate a gradient field. This group includes the Roberts, Prewitt, and Sobel operators. These operators typically use an RMS point nonlinearity to produce an edge-enhanced array. A magnitude point nonlinearity is often employed for computational simplicity.

The template matching operators are a set of masks representing discrete approximations to ideal edges of various orientations. These operators include the compass gradient, the Kirsch, and the 3- and 5-level template masks. With these operators, the enhancement is formed as the maximum of the gradient arrays.

Program Description

The knowledge base of imgexp may be divided into three groups as follows:

- The knowledge about the tools and operators
- The sequence of a tool and an operator that yields an inefficient result
- The rules that are used when the **`imgexp`** questions the user to consult him

`imgexp` is based on an edge enhancement and thresholding edge detection system. The knowledge representation utilized consists of logically grouped facts. Each operator corresponds to a group, and each operator is described with four facts: opname, tool, input, output, and nondecomp.

From the facts in the knowledge base, it should be noted that there are tool facts. These facts represent the reality that an operator, for example, Sobel, is not furthermore decomposable to its components, if any, as the ***`maindecomp`*** fact.

The ***`bad sequence`*** facts try to express that if the user wants to select such an ordering of tools and operators, he will not be satisfied with the result of his choice to detect edges.

The ***`rule`*** facts ask the user questions to determine what the user wants to do.

The **`imgexp`** expert system program is mainly an advising system. It also explains the results the user gets from his choices; **`imgexp`** expects data from the user to give advice. Therefore, it utilizes the forward chaining control structure. It fires rules whose head matches the data the user has entered. Thus, the proper rules can be triggered.

Evaluation

The program's most significant limitation is its inability to process authentic images in order to determine what may have gone wrong. Consequently, in this instance, the expert system is assumed to be processing images and providing some advice or explanation to the user.

Another limitation could be that an alternative scheme representing the knowledge might be utilized. The representation of knowledge in the knowledge base resembles frame-like structures, although no concepts of frames were applied in this program.

Summary

In this paper, I describe an Expert System that advises on edge detection algorithms. This Expert System interacts with the user to obtain necessary inputs and then acts on them.

References

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