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

1. READ.MD file content

This rule-based expert system is written in Arity/Prolog32 interpreter. Some preparations must be made before running this program on a Windows box. The following steps may be followed to set up the environment and run the expert system.

1. Download and install the Arity/Prolog32 zipped file.

2. Run the expert system application inside the Prolog interpreter.

1.1 Download and install the Arity/Prolog32 zipped distribution file

To download and install the Arity/Prolog32 interpreter, please visit Peter L. Gabel's website at http://petergabel.info/ArityProlog32/InstallingArityProlog32/. After downloading, set the following system environment variables.

- C:\ArityProlog32\BIN to your PATH variable
- C:\ArityProlog32\LIB to your LIB variable
- C:\ArityProlog32\INCLUDE to your INCLUDE variable

After installing the software, you can run the Arity/Prolog32 interpreter by typing the following command in the command prompt:

```
C:\api32
```

1.2 Run the expert system application inside the Prolog interpreter

To run the expert system application, `imgexp.ari` Prolog file, download it from the <Code> section on GitHub. Go to the directory where you put the `imgexp.ari` file after downloading and run the `api32.exe` interpreter, see **Figure 1**.

In the interpreter, type in `Alt-F` and select `File > Consult File …` In the dialog box that pops up, type in the filename `imgexp.ari`, see **Figure 2**.

Now, you can interact with the expert system, trying out various tool combinations using the thresholding method for edge enhancement, see **Figure 3**.

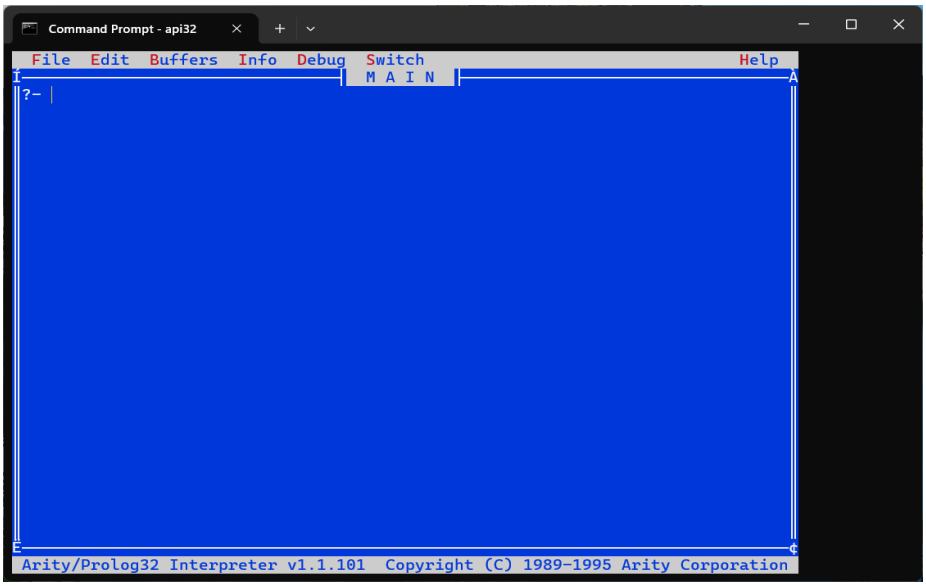

Figure 1 The Arity/Prolog32 Interpreter

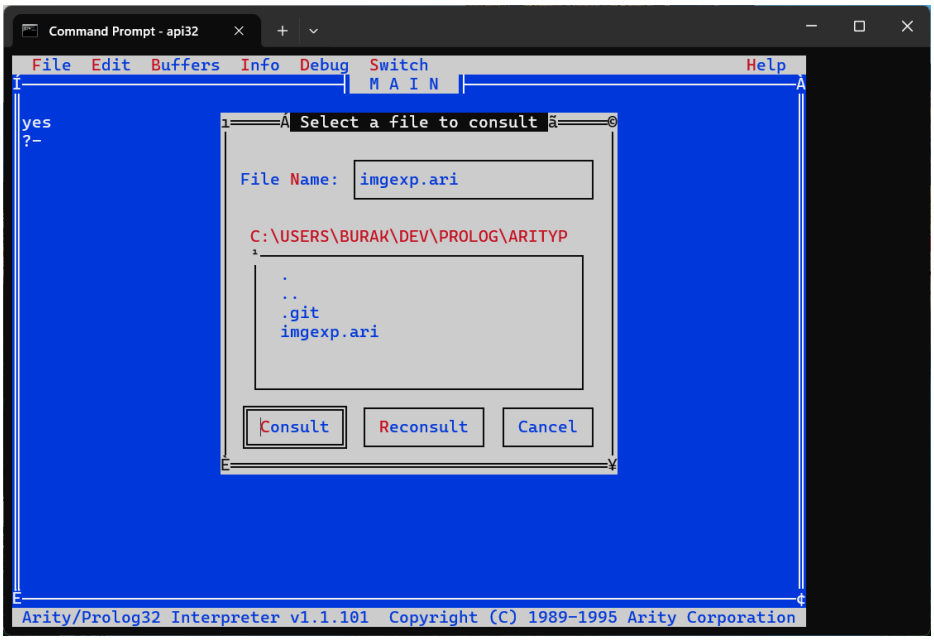

Figure 2 Consulting a Prolog file to run

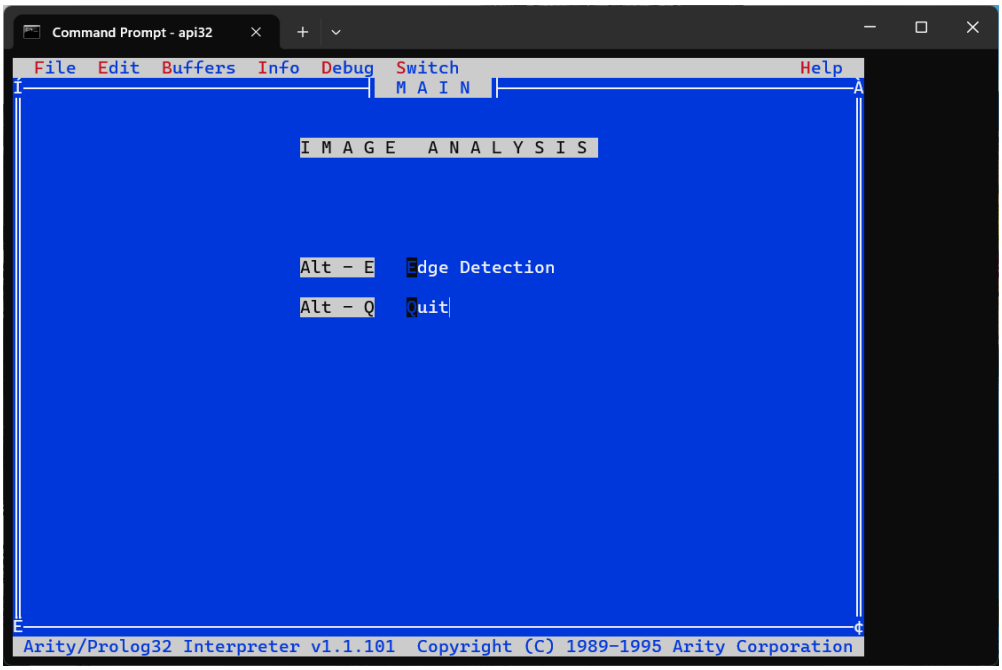

Figure 3 The Expert System for Edge Detection

2. 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.

2.1 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 acts as a systematized repository of the knowledge accumulated by many specialists of diverse experience. Hence, it can and does ultimately attain a level of consultant expertise exceeding its "tutors."

3. Some Background Knowledge about Edge Detection

Edges are primitive features of an image that are widely used in image classification and analysis systems to outline the boundaries of an object.

3.1 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 some spatial operator. An edge is deemed present if the enhanced discontinuity exceeds some threshold level. The edge fitting approach involves fitting an ideal edge replica, a two-dimensional ramp or step function, to the image over some region. If the fit is close, an edge is judged present.

An Edge enhancement/ thresholding edge detection system consists of more than one spatial operator, a point operator, and a threshold decision. However, it is also possible that only one spatial operator may 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 by 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) concerning a threshold (t). If A(j,k) >= t, an edge is assumed present, and if A(j,k) < t, no edge is indicated. The edge decision is usually recorded as a binary edge map E(j,k) where a one indicates an edge and a zero value indicates no edge.

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

3.2 Differential And Template Matching Operators

The differential operators perform discrete differentiation of an image array to produce a gradient field. This group includes the Roberts, Prewitt, and Sobel operators. These operators usually utilize an RMS point nonlinearity to produce an edge-enhanced array. A magnitude point nonlinearity is often used 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.

4. 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/thresholding edge detection system. The knowledge representation utilized consists of facts that are grouped logically. Each operator corresponds to a group. Each operator, in turn, 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.

5. Evaluation

The program's most important limitation is that it cannot process authentic images to determine what may have gone wrong. Hence, in this case, the expert system is assumed to be processing images and then giving some advice or explanation to the user. Another limitation might be that another scheme representing the knowledge could be used. The representation of the knowledge in the knowledge base resembles frame-like structures, but no concepts of frames were used in this program.

6. Summary

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

7. References

[1] *Quantitative Design and Evaluation of Enhancement / Thresholding Edge Detectors*, Ikram E. Abdou, William K. Pratt,
Digital Image Processing and Analysis, IEEE Computer Society.

[2] *Expert Systems For Experts*, Kamran Parsaye, Mark Chignell,
John Wiley & Sons, Inc

[3] *The Basic Principles of Expert Systems*, William B. Gevarter
National Bureau of Standards Report # NBSIR 82-2505
National Technical Information Center Document # PB83-2175662