THE LIGHTING AND OPTICS EXPERT SYSTEM FOR MACHINE VISION

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ABSTRACT:

Machine Vision and the field of Artificial Intelligence are both new technologies which have evolved mainly within the past decade with the growth of computers and microchips. And, although research continues, both have emerged from the experimental state to industrial reality. Today's machine vision systems are solving thousands of manufacturing problems in various industries, and the impact of Artificial Intelligence, and more specifically, the use of "Expert Systems" in industry is also being realized. This paper will examine how the two technologies can cross paths, and how an Expert System can become an important part of an overall machine vision solution.

An actual example of a development of an Expert System that helps solve machine vision lighting and optics problems will be discussed. The lighting and optics Expert System was developed to assist the end user to configure the "Front End" of a vision system to help solve the overall machine vision problem more effectively, since lack of attention to lighting and optics has caused many failures of this technology.

Other areas of machine vision technology where Expert Systems could apply will also be discussed.

KEY WORDS: Artificial Intelligence, Expert System, Machine Vision, System Design

INTRODUCTION

The field of artificial intelligence (AI) has been around for over two decades. However, most of that time it has been at research level at various universities and research institutes. The application of AI and its widespread acceptance has been slow coming but has picked up pace recently due to advances in AI technology and its main tool, the computer.

This paper will examine one area in the field of artificial intelligence, the Expert System, and how it can be used as a powerful tool in another area of technology, the applications of Machine Vision.

WHAT IS ARTIFICIAL INTELLIGENCE?

Artificial Intelligence is a science that enables computers to perform tasks with human-like intelligence. AI encompasses a broad field of technology that includes, but is not limited to, expert systems, computer vision, speech recognition, natural language, and machine learning.

WHAT IS AN EXPERT SYSTEM?

An expert system is a combination of a sophisticated computer program and a knowledge base to duplicate the actions of a human expert in an existing human art. The major difference between an expert system computer program and a traditional computer program is the ability of an expert system program to operate with incomplete input information (fuzzy data) and to internally generate new information from old information.

Expert systems offer a wide variety of benefits. Some of the benefits are the preservation of expertise, the distribution of scarce expertise, and combination of expertise. Expert systems are used in manufacturing, medicine, finance, and management information systems, to name a few.

HOW AN EXPERT SYSTEM WORKS

An expert system is created by transporting as much of a human expert's knowledge in a given art as possible and appropriate to a computer data base, so it can be accessed by the expert system. The gathering of the information is typically done by a knowledge engineer. It is his job to collect the information from the human expert through a series of interviews. These heuristics (rules of thumb) are translated into "if then" statements (knowledge representations). The rules are used by the expert system's inference engine. The inference engine consists of algorithms (solution methods) that correlate rules and facts and return information to the user. Figure 1 shows a block diagram of an expert system.

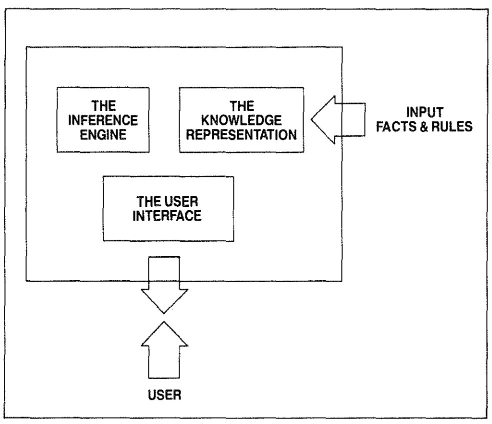

Figure 1
An Expert System

The user interface is typically through a computer terminal (CRT and keyboard/mouse combination). It is designed to be easy to interpret by non-expert users. One way this can be achieved is with the use of menus. Menus present the user with questions and multiple choice answers. The user then selects one or more (where allowed) of the given choices. Numerical value data can be entered directly on the computer keyboard.

Depending on the nature of the expert system, the output can be in the form of conclusions or directions to solve a given problem. The output can be in a form of easy to understand instructions with further explanations and illustrations through computer graphics. Expert systems are typically applied to solve complex problems through non-expert users. This tends to put a heavy burden on the expert system user interface. This is true both in the way the questions are presented to the user for proper interpretation and response, and later to enable the user to understand the system's final conclusion or instructions.

THE TOOLS FOR EXPERT SYSTEMS

SOFTWARE TOOLS: There are at least two ways one could set out to create an expert system program. One way is to utilize one of the AI computer languages such as LISP, PROLOG, or even C (a non-AI language). He would write from scratch the knowledge representation, inference algorithms, and user interface portions of the program. This method would provide flexibility but could become expensive due to the cost of engineering development.

The second method is to start with a "shell." A shell is an existing computer program with the building blocks of an expert system, the knowledge representation tools, the inference engine, and tools for user interface, built in. But, it lacks the knowledge. The knowledge is then programmed in by the knowledge engineer. The use of existing shells can prove more cost effective in the long term since the development cost of the shell is spread over many users of that shell.

HARDWARE TOOLS: One reason for slow widespread acceptance of artificial intelligence has been the cost of software and hardware tools. Until recently, most AI packages required powerful main frame computers to operate. In the past five years, more software tools, such as expert system shells that can run on personal computer work stations, are becoming available. This will make the expert system a much more viable entity as an industrial tool since the cost will be far less prohibitive.

EXPERT SYSTEMS AND MACHINE VISION

The field of machine vision also falls under the topic of artificial intelligence. Most vision systems, however, utilize conventional computer programs. Therefore, whether they can be categorized under AI is questionable. AI or not, applying machine vision can produce some great challenges in applications engineering.

One area of machine vision applications where there are often engineering difficulties is in the front end, that is, the lighting, optics, and sensor selection. Many good applications have failed due to improper front end design. Therefore, machine vision lighting and optics was selected as the topic of an expert system development. The following pages describe the creation of an expert system and how it is used to solve lighting and optics problems for machine vision applications.

THE LIGHTING AND OPTICS ADVISOR

THE OBJECTIVE: The Lighting Advisor expert system was created to help solve lighting and optics problems for a specific group of machine vision applications, namely, small parts assembly verification. The field of machine vision encompasses a large area of possible applications, such as, assembly verification, electronics, packaging, non-contact gauging, etc. It was decided that, at least initially, the Lighting Advisor should be limited to one group of applications. This expert system has been designed so that end users with little or no lighting and optics background can use it.

HOW IT WORKS: Transferring human knowledge into a form acceptable by the expert system shell proved challenging. The process became easier as the human expert could see how his knowledge was being transformed into facts and rules of logic for machine use. There are over three hundred rules in the Lighting Advisor expert system data base at the time this paper is being written.

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What is the purpose of this consultation?
Yes:
- LIGHTING
- LENS CALCULATION
- COLOR ANALYZING

1. Use arrow keys or first letter of item to position cursor.
2. Select all applicable responses.
3. After making selections, press RETURN/ENTER to continue.

PENN VIDEO LIGHTING ADVISOR

What is the feature of interest?
HOLE OR CAVITY
RAISED SURFACE (SUCH AS A BRACKET)
FEATURE SILHOUETTE
FEATURE PRESENCE OR ABSENCE
SURFACE FLAWS (CRACKS OR CAVITIES)
FEATURE OR SURROUNDING AREA FLUORESCES UNDER ULTRAVIOLET LIGHT

1. Use the arrow keys or first letter of item to position the cursor.
2. Press RETURN/ENTER to continue.

Figure 2
Two examples of questions asked in Lighting Advisor

The Lighting Advisor uses a personal computer as its work station. The software is menu driven with help available at all times. The user tells Lighting Advisor about his/her application by answering a series of questions and making choices from the menus. See figure 2. The questions pertain to the nature of the application, the feature and background surface qualities, whether the object is moving or stationary during the inspection, etc.

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How close can you put the light source to the feature of interest? (in inches)

Help:
One of the factors in suggesting appropriate lighting is the minimum distance that a light source can be placed to the feature. Consider any physical restrictions in the process or environment. If you are not sure of the physical limitations, rerun the Expert System choosing a different light distance each time.
**End - RETURN/ENTER to continue

1. Enter a positive number.
2. Press RETURN/ENTER to continue.

Figure 3
Help in understanding questions about an application

On-line help is available for each question at any menu level. One of the help screens is shown in figure 3.

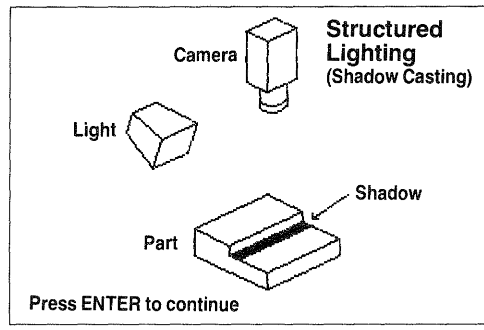

Figure 4
A graphic representation of a suggested lighting technique

The expert system reviews the answers given and returns a set of conclusions that include:

1. The lighting technique. For example: Front-light field.
2. The light source. For example: Quartz halogen lamp with reflector.
3. The camera lens. For example: The calculated focal length is 89.6. Use a 75 mm fixed focal length lens. Use a zoom lens with a focal length of 89.6 included as its usable range.
4. Possible color or polarized filtration or special optics requirements. For example: Use a beam splitter.

To help explain the Lighting Advisor conclusions, the system shows several color illustrations using the PC's graphics capabilities. Figure 4 shows the camera and light position when structured lighting is used to cast shadows.

A Case Study

This application was done two years prior to the development of the Lighting Advisor expert system. It was among many of the applications used to help prove and debug the expert system. The application requires a machine vision inspection of a critical dimension on an aluminum transmission case. The measurement needed is between an area on the side of the case and a mounting hole perpendicular to that plane. The arrows in figure 5 show the two points that the measurement is between. The accuracy of this distance insures that there is adequate clearance for the starter assembly to be attached.

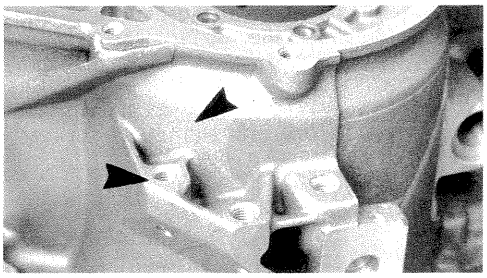

Figure 5
Points that must be measured between on the transmission case

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Conclusions:

The list of suggested solutions is as follows:

Possible lighting technique: STRUCTURED FRONT LIGHT - LIGHT FIELD AND TRIANGULATION. USE SHADOW CASTING IF POSSIBLE.

Possible light source: FIBER OPTIC BUNDLE WITH APERTURE AND LENS, QUARTZ HALOGEN LIGHT SOURCE.

Possible lens choices: THE CALCULATED FOCAL LENGTH IS 113.4. USE A 75mm FIXED FOCAL LENGTH LENS. USE A ZOOM LENS WITH A FOCAL LENGTH OF 113.4mm IN ITS USABLE RANGE.

**End - RETURN/ENTER to continue

Figure 6
Lighting Advisor's suggested solutions to the application

The lighting technique used at the time of the application consists of a structured light source to detect the raised surface position with respect to the backlit hole. An unstructured light source could not reveal depth information to the two dimensional camera. The same application was described to the Lighting Advisor expert system. The results from Lighting Advisor are shown in figure 6.

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STRUCTURED LIGHTING (Raised Surface)
Structured lighting provides a means of lighting only a portion of a part or scene. It is achieved by shaping a beam of a light with apertures and lenses, or by using lasers. Below are two ways structured lighting is used.

1. To reduce the complexity of a scene by only projecting light on the features of interest.
2. To light a three-dimensional form in a way that extracts two-dimensional information. For example, a slit can be projected at an angle to a part to determine the presence of a raised surface.

**End - RETURN/ENTER to continue

Figure 7
An explanation of structured lighting

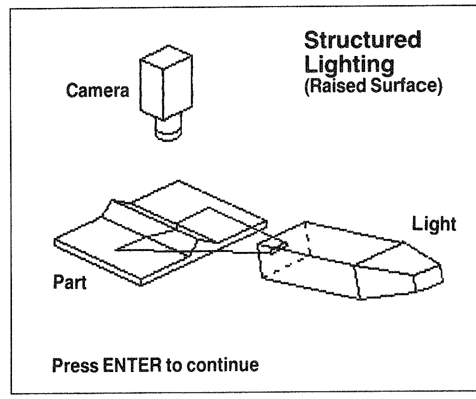

Figure 8
A graphic representation of structured lighting

This conclusion offers structured light as the major lighting technique. Figures 7 and 8 show a full explanation and graphic representation of structured lighting. The results also suggest triangulation (figures 9 and 10) and shadow casting as alternate techniques. These secondary techniques are suggested because the information input to the system matches rules that lead to this set of conclusions.

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TRIANGULATION:
Triangulation is used to determine the height of a surface. A spot of light is projected on the surface at a low angle. If the surface height changes, the spot moves relative to the camera.

**End - RETURN/ENTER to continue

Figure 9
An explanation of triangulation

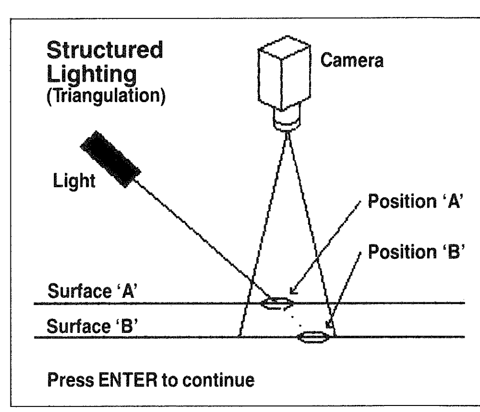

Figure 10
A graphic representation of triangulation

The technique used for the application was very similar to the triangulation technique suggested by Lighting Advisor. Figure 11 shows the two slits of light projected on the case. The light sources were fiber optic bundles with shaped apertures and lenses. One light produces the triangulation effect for the position of the raised surface. The second light backlit the hole (not a suggestion of the expert system). Figure 12 shows the monitor image from a camera looking down on the transmission case. From this image, the light spots were easily measured between with conventional analysis techniques.

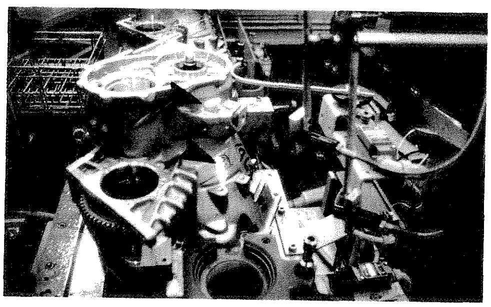

Figure 11
Projected slits of light

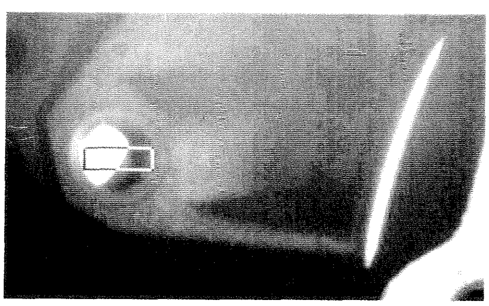

Figure 12
Monitor image of slits

CONCLUSION

The field testing of the Lighting Advisor expert system has just begun. No conclusions have been reached with respect to its usefulness. However, the preliminary results are encouraging. The development of an expert system is never really complete since human knowledge and expertise are always expanding. With respect to Lighting Advisor, there will be continuing additions and refinements.

Applying machine vision still requires a fair amount of highly specialized engineering expertise in several disciplines. Expert systems can help bridge the knowledge gap in many areas of expertise, enabling further expansion of the machine vision technology base and support. Other areas in machine vision where the expert system could play a role are system troubleshooting, selecting and optimizing inspection parameters, and controls and machine interface design. The future looks promising.

References and Acknowledgements

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