Education in optical design by artificial intelligent system

Rong-Seng Chang, Der-Chin Chen
Institute of Optical Sciences, National Central University
Chung-Li, Taiwan 32054, R.O.C.

ABSTRACT

The education system for optical design and assembly can be done by integrating the optical design program with expert system and stock lens kit and test equipment through microcomputer and digit optical bench with Robot vision system. Student set up the lens set according to their ideal and calculation to build up the optical system in optical bench make the design more real.

The student learning optical knowledge by two ways: the learning by doing (Rote learning) and learning by being told. The level of information refers to the degree of generality.

After input the datam and question the program answers the student the conclusion about the goal the subgoal, shows how it reached the conclusion by pring out the rules. Student can keep asking explanations.

The explantation help the student to get all the full understanding of the system's reasoning process as well as to debug the error of the knowledge base.

1. INTRODUCTION

In computer aid eductional program, most of them use compnter only, here we combine the artificial intelligent with real optical bench as well as with the lens box to help student understanding optical lens system and the creating capability.

2.System set up

The system has twoparts the optical bench and the computerprogram.

Optical design program connected to the real optical system by microcomputer was discussed. 1~4 To replace the optical components or change the lens distances according to the software optimization program; the servomotors drive the lens holders to suitable positions. The new lenses datum such as lens curvaturs, index of refracti9on etc. can be input into the program simply by key in the code number of the lens from lens library subroutine. In order to get real time and real world close loop feed back into optimization program, the update optical system are tested by resolving power projector to project the test pattern through optical system to a screen which is inspected and processed by HAMAMATSU C1000-03 TV camera and HP9825 microcomputer, the value of testing feed back gives a new direction for the next turn of optimization.

Optical design can be done in real time process by IBM PC-AT microcomputer which integrated the optical design program with optical bench and lens sets together. Completely or partially using the stock lenses to simulate an optical system in optical bench during design makes the design more real. Using stock lens can reduce the price and save time for the fabrication. By moving the lens holder which connected to digit-meter gives real time datum input of the surface distances to the microcomputer optical design program. Near the bench a lens box containing conventional available lenses and lens sets from ORIEL, MELLES GRIOT, etc. and some of it from our optical shop, is ready to use. The optical datum and the code number

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of each lens are saved in the library subroutine. Real time input the lens datum such as lens power, curvature of each surface, etc. can be done simply by key in the code number. The electronic hardware consist of three parts the position control electronics, lens position sensing and the optical bench.

The purpose of the position control electronics is to move two lens holder to the computer commanded position in the bench. It can be divided into two parts: the lens position generator and the servo systems.

(1) lens position control:

The computer generates a series numbers for the servo systems. There are two separate 12 bit output from interface card of microcomputer, one for each lens holder, each output corresponds to a position of a lens holder. The lowest number (0) will cause the lens holder to move to the rear-most position in the range, highest number (4095) moves to the front most position. The length of the movement is 20 mm, the resolution of the movement is micrometer. All number in between then correspond linearly to positions along the range of travel in even intervals of one part in 4096 of the total range of the particular holder.

(2) servo systems

There are two identical servo systems. One for each lens holder. Their purpose is to accept a number corresponding to the desired lens postiion from the computer and drive them to that position by means of a D-C servo motor and lead screw. Position feedback is provided by a linear potentiometer with +5 volts applied to the end nearest the front and the rear-most end grounded. The digital to analong converter (DAC) along with the DAC buffer converts the position number from the computer to an analong voltage that goes from 0 to -5 volts as the input number goes from 0 to 4095. This voltage is summed with the wipper voltage and the difference is fed to an 80 Hz low pass filter to dampen the sudden transitions at 100 Hz from the compouter. The filtered error voltage is then amplified by a high current Op-Amp to the lens drive servomotor thus closing the loop.

The lens position sensors are two Nikon digimicro MU-50 digit meters. The pin No. 1 the meter code output are BCD code which connected to interface card plugged into microcomputer. The sensed datum are transfered to compnter program by the subroution INP which is written by machine language.

(3) Optical bench and the test chart with TV camera

There are several ways to evaluate the optical system during optical design such as interferometer, MTF measurment system etc. The most simple and convenient way is the resolving power test pattern projection. Test pattern which are projected to a screen through tested pattern to evaluate the optical system. The optical design program may aim at it directly. The projection type requires no processing of film for in-process inspection of lenses as many camera lens testing laboratory did, and provides inspectionof resolving power, its symmetry over the whole picture area, contrast, astigmatism as well as difference in focal point between the center and periphery of the screen. However the human eyes are all different, the result of inspection are all different from person to person, therefore instead of human eyes we use the TV camera to recognize the test pattern The three bar target are evaluated according to their contrast transfer function (CTF) values, which is defined as image contrast divided by object contrast, and the contrast is the ratio of the difference of brightness to average brightness which is proportional to the gray level of digitized TV camera. A/D converter give us 8 bit digital signal of all 512 or 1024 points along the vertical sampling line, and convert a full 512 by 512 points into a digital signal in two seconds. In order to make designer disigner distinguish the brightness of bars easily, M1003 intensity display circuit is used, which will display the intensity signal along a selected vertical line on the TV monitor. Selection of scanning line can be control manually for calibration then automatically scan the fram according to the computer command. HAMAMATSU C1000-03 TV camera equipped with M999-04 GPIB interface which conforms to the IEEE standard 488, it allows camera be able to couple into HP9825 microcomputer directly. Since both the image contrast and the object contrast are measured with same camera, the camera error factor are canceled. Nevertheless, the resolution of TV camera is still a linitation for isnpection. Since we are not dealing with extra high precisim optical system and the detectivity of C1000-03 TV camera is much better than human eyes the precision and the stability of TV camera which are under 0.2 percentage in the temperature range ten to forty centigrade, are high enough for the purpose of present stage.

The quantities of tilt are measured and input to microcomputer by autocollimator with TV camera which connected to the eye piece of autocollimator and the microcomputer digitizer. The new aberration generated by the tilted component are calculated. After compare to the original design and using aberration balance method to reoptimization, the suggestion of the new tilt will be displayed. According to this suggestion, manually to tilt each componenets and the tilted quantities will be checked and evaluated again. To repeat this process again and again until get satisfied result. To tilt the component back need to be manually in present stage. Sometimes the suggested quantities are too small to adjust and outside the tolerance of manually adjusting accuracy. We adjust it as much close to the aimed value as possible and let the computer pick up the tilted value whatever they are, reoptimize the optical system again for another cycle of adjustment until get satisfied result. After manually adjusting the optical system, we bond the lenses by sealant such as epoxy, glue, etc. Sometimes the bond process will generate a small amount of tilt, therefore we should check the tilt of bond component and compensat it by reoptimize the rest part of optical system before the bonding of next lens. The automatically operation the tilting and bonding can be done after more accurate piezoelectrical driver be build in the Robtic arm in near future. The experimental set up includes the autocollimator, TV camera and interface electronics, the autocollimator consists of a zoom lens capable of focussing from a few centimeters to infinity. The illuminated cross hair image can be projected over this distance by focussing knob which was connected to stepping motor being interface with the microcomputer. The auto collimator can be focussed in turn by the command of microcomputer on each surface of the optical system and reflected back through the eye piece and TV camera to the display of computer. The eye piece contains a fixed cross hair which is independent adjustable for focus to get clear image in the TV screen. Special pattern recognization program are written for recognizeing the reflected center and the orientation of the cross hair, the algorithem is as following: Scanning four sides of the picture fram clockwise, find the intersection point, we call it the edge point, of cross hair with the fram and lable the seguence of the points exclude the edge points from reference cross hair of eye piece, check the total number of edge points if it is more the four, usually 8 points, then the zoom focus is not on the surface, so ask the computer to zoom it again until we get four points. Connect each edge point with the one next to their neighborhood find the intersection point of these lines, which is the center of cross hair. Calculate the inclination of the lines, we get the orientation of the cross hair.

3. Artificial Intelligent Software

The computer softward is designed by the artificial intelligent aned expert system techniques. The rules based expert system has an already built-in knowledge of telescope, microscope, etc. However, it also provides a framework for the student to key in new rules. There are four different rules: urles with formula, production rules, the table with production rules and the action rules. Rules with formula build up the telescope model for domainspecific knowledge consisting of a set of relationships in the from of equations and empiric functions. The student could assign the values of those variables as input and lets the computer find a way to solve for the unknowns. Action rules can either print some message or execute procedures when certain goals succeed.

To select the optical components or change the lens distances according to the software optimization program. The student can drive the lens holders to suitable positions along the bench. The new lenses datum such as lens curvature, index of refraction etc. can be input to the program simply by key in the code number of the lens from lens library subroutine. The system can be tested by resolving power projector to project the test pattern through optical system and evaluated by TV camera. The quantities of tilt also can be measured by autocollimator which project a crosshair through optical system and reflected back to autocollimator eye piece then to TV camera. The image of TV camera are digitized and recognized by microcomputer. The value of test will give a new direction for the next term of optimization.

The student learning optical knowledge by two ways: the learning by doing (Rote learning) and learning by being told. The level of information refers to the degree of generality. High level information from the lens design papers or books in the theory discussion, and teacher's teaching etc. are abstract information that is relevant to a broad class of problems. Most of them are belonging to learning by being told. The low level informations such as restoring the example of student's designed optical system as well as the direct input from the lens bench of our real world optical design system. Those detailed information relevant to a single problem, are belonging to learing by doing. There is an important distinction between our rule-based systems and most conventional lens design program: there is a clear separation of general knowledge about the rules forming knowledge base from the input data and the rule interpreter. The rules could be added and modification easily by the students.

The optical system clesign model is build up from the equations of Warren's book! The equations and their variables are shown in table 1. Their relating the graph shown in Figure 1. The polygon with nodes represent each of the variable. The polygone-shaped (the polygons are shaded) subgraphs represent the rules. The numbers in the pholygons shade show the number of equation in table 1. The R-graph model could be changed or expanded according to the new rules to be added.

Then the R-graphy will be expanded to a new polygone as shown in Figure 1 as a dash line formed triangle.

The solution process goes through the R-graph and check all polyyones with only one unknown node, then contiunes until as many unknowns as possible are evaluated. The control strategy is a modified forward and backward chaining process with consecute-substitution procedure. Whenever theconsecutive-substitution fails. The equation solving procedur solves set of simultantous algebraic linear and nonlinear equations. The forward chaiining strategy also gives the best choice of the camera andlight source by searching and compairing the characteristic tables of high speed cameras and the light sources. After the equation solving and the decision making, the planniing will be pring out. Parts of the rules built up are shown in list 1. The program answers the user the conclusion about the goal and the subgoal, shows how it reached the conclusion by print out the rules. User can keep asking explanations about goals backward until the system answers "that's all the explanations". The explantation help the user to get all the full understanding of the system's reasoning process as well as to debug the error of the knowledge base.

When the user gives a goal to the system, it will either invoke rules or ask user to reach conclusions. The action rules will be triggered to execute some procedures by certain goals, i.e. When the primise is evaluated to be true and return a non-zero number. the procedures listed in action part "procedure 1, procedure 2..." will be exucted one by one.

FORMULAS	VARIABLES		
1. L = Fo + Fe	1. L	Fe	Fo
2. M = Fo / Fe	2. M	Fe	Fo
3. M = CAo / CAe	3. CAe	CAo	M
4. M = Ue / Uo	4. M	Uo	Ue
5. ED = L * Uo	5. L	Uo	ED
6. ER * (L - Fe) = Fe * L	6. L	ER	Fe

Table 1. production rules with formula of the Gaussian structure.

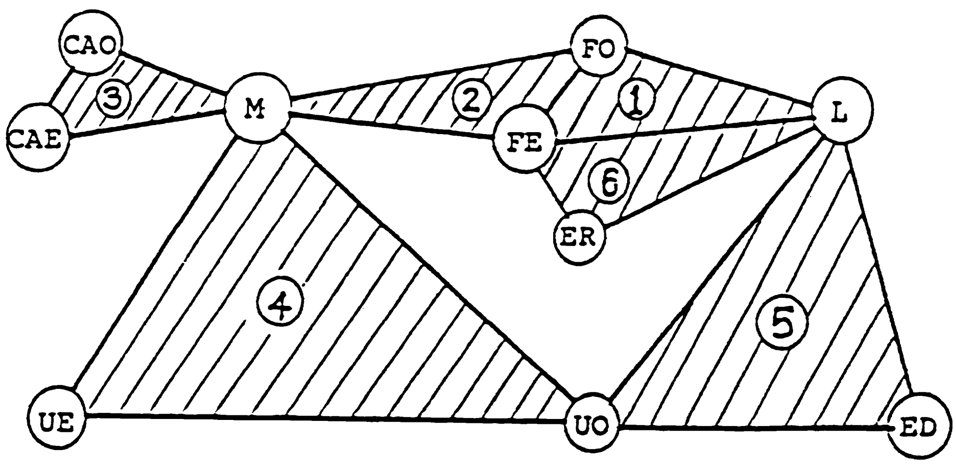

Figure 1. R-graphy of formula of the Gaussian structure in Table 1.

The input numbers is treated as characters. After the re-arrangement of characters according to the basic mathematics operations principle, we can get the result of those operations. Those result are still character representations. Using the function ASCII-TO-NUM to get the num erical results.

EXAMPLE

This example are taken from the book of "Modern Optical Engineering" by Warren J. Smiths. The problem is as follwoing:

Statement of problem:

Try to design a telescope with length 10", magnititude 4, F.O.V. is 0.1 Find focal length of objective, eyepiece, eye relief, etc.

Set L = Lenqthe of telescope tube

M = magnititude of the system

UO = F.O.V./2

FO = Focal length of objective lens

FE = Focal length of eye piece

ER = Eye relief

ED = Dia of eye lens.

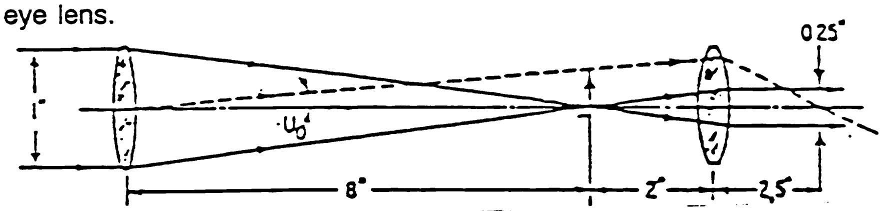

Fig.2 The inverting telescope of Example

Parts of the solution print out as following:

Do you want to know some data ? (YES or NO)
YES

Which data do you want to know ? (enter variable names) FO, FE, ED

Which data do you know ? (Enter variable names). L, M, UO

Please enter the (L).
10

Please enter the (M).
4

Please enter the (UO).
0.05

** The answer is as following:

Focal length of Object lens (FO).

*** The given values ***
L M UO

*** Use the equations ***
2 1

*** Cancel the variables ***
FE

*** The variable and its cofficience ***
FO

0 order cofficience
-1 *L*M

1 order cofficience
1 + 1*M

Solution
FO = 8

Focal length of Eyepiece (FE).

*** The given values ***
L M UO

*** Use the equations ***
2 1

*** Cancel the variables ***
FO

*** The variable and its cofficience ***
FE

0 order cofficience
1 *L

1 order cofficience
-1 *M + -1

Solution
FE = 2

Diameter of Eyepieces (ED).

*** The given values ***
L M UO

*** Use the equations ***
5

*** The variable and its coffience ***
ED

0 order cofficience
-1 *L*UO

1 order cofficience
1

* PUCH BUTTON EXPLAIN *

Do you want the explaination?
YES

Please enter the unknow variable.
FO, FE, EO

Please eneter the known variable.
L, M, UO

THE EXPLAINATION IS:
THE GIVEN VALUES L M UO
USE THE EQUATION 2 1
CANCEL THE VARIABLES FE
WE CAN FIND FO

5. Conclusion

The education system for optical design and assembly has been done by integrating the optical design program with expert system and stock lens kit and test equipment through microcomputer and digit optical bench with Robot vision system. To use this system, the student study optics not only by learning but also by doing, they get the knowledge not only by be told but also by creating.

6. REFERENCE

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