An Attempt to Develop Zoom Lens Design Expert System

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Abstract

We have developed zoom lens design expert system, intending to operate with little user intervention. The paper puts the emphasis on the knowledge representation, system architecture, reasoning and control strategy of the system MEX-1.

1. Introduction

Zoom lens design is a very complex task. It requires the experts with versatile domain knowledge, rich lens design experience and expertise of utilizing optical system design CAD software. Generally, the experts use CAD software interactively to design optical lens with intervening in the design process from beginning to end. The quality of designed optical lens depends on the expert's experience of selecting an appropriate start construction and using CAD software to a great extent.

In order to automate optical lens design, we employ artificial intelligence and expert system technique into optical design field. We have developed a zoom lens design expert system MEX-1. The work is done based on the Chinese Optical Lens Data Base System (COLDB), with which we can locate lenses by various input conditions, and on the experience and knowledge of our institute researchers on designing zoom lens objectives in past decades. The expert system is also combined with the optical design CAD programs CODEV (product of ORA) and CAOD (product of our institute). When users give the requirements to MEX-1, the system can design a lens automatically with little personal intervening in the design process. The basic working steps of MEX-1 are as follows:

(1) Obtaining the requirements from users.

(2) Selecting a starting point from COLDB closest to the user's requirements.
(3) Executing the optimization of the selected starting point with Optical CAD.
(4) Evaluating the image quality of the result derived from the optimization with Optical CAD.
(5) Generating a prototype by the solution of the first order optics and third order aberration equation, if the user's requirements are very special and the system can not select a startig point in step (2).

2. The Knowledge Representation of MEX-1

We divide the lens design task into four subtasks in the system.
(1) Selecting a starting point from COLDB closest to the user's requirements.
(2) Executing the optimization of the selected starting point with Optical CAD.
(3) Evaluating the image quality of the result derived from the optimization with Optical CAD.
(4) Generating a prototype by the solution of the first order optics and third-order aberration equation for the user's special requirements.

The expert knowledge of completing each subtask is represented in the multiple level expert system tool LDEX-1 appropriate to optical lens design. Each subtask is completed by an expert system respectvely. The model of expert knowledge consists of four parts.

** HYPOTHESES
** ACTS
** FINDINGS
** RULES

HYPOTHESES describe the conclusions and suggestions generated by the system. ACTS represent the actions executed by the system, the definition of which is interpreted by a subroutine. The facts on which the system reasoning relies are described in the FINDINGS, which also are divided as follows according to the characteristics of them.

* CHECKLIST
* MULTIPLE CHOICE
* NUMERICAL VALUES

RULES combine the three parts described above, representing the

expert's knowledge of optical lens design. The rules in the system have two forms according to their roles.

* F-F RULES
* F-H RULES

An example of the expert model is given as following.

////OE1. MOD For choosing starting point JAN. 23, 1991
**HYPOTHESES
CON1 User's request is self—contradictory
CON2 Starting design is chosen
CON3 Gaussian computing
⋮
**ACTS
ACT1 Searching for COLDB (YAN, FNO, ZOORATIO) (ZOORATIO<4)
ACT2 Searching for COLDB (YAN, ZOORATIO, FNO) (ZOORATIO>4)
ACT3 Automatic design
ACT4 Going to Gaussian computing module
⋮
**FINDINGS
*CHECKLIST
SP11 S11
SP22 S22
*MULTIPLE CHOICE
PH35 Photo lens 35mm
PH20 Photo lens 120mm
CN35 Cinema lens 35mm
CN16 Cinema lens 16mm
CN08 Cinema lens 8mm
TV54 TV 5/4 in
TV44 TV 4/4 in
TV23 TV 2/3 in
*/MULTIPLE CHOICE/
LLE4 Lens—LE4
LGT4 Lens—GT4
*NUMERICAL VALUES (User must answer)
ZOOR Zoom—ratio
EFLN Focal length
FNOO F/number value
⋮
**RULES
*F-F

```
F (PH35, T)
->IMAH, 21.6
F (PH20, T)
->IMAH, 38.9
⋮
F (ZOOR, A)
->LLE4, T
A = 000000.00:000004.00
F (ZOOR, A)
->LGT4, T
A = 000004.01:000150.00
*F-H
F (PH35, T) &F (LGT4, T)
->CON1, 1.0
F (PH20, T) &F (LGT4, T)
->CON1, 1.0
⋮
F (LLE4, T)
->ACT1, 0.95
F (LGT4, T)
->ACT2, 0.95
**END
```

3. The System Architecture

The architecture of the whole system is shown in Fig-1. It consists of expert system and the software of optical system design. Every part of them will be explained briefly. Now the expert system MEX-1 consists of five subsystems. Each of them is an expert system.

EX-1 Subsystem: The user can input the design requirement interactively. If the requirement have something wrong or contradictive, the system can point them out, and the user can modify them. After that, the system will search for starting point in COLDB according to the user's requirement. The searching strategy is according to the order of the field, aperture, zoom-ratio and EFL. If the user gives very special requirement that it can't find a starting point from the COLDB, the EX-4 subsystem will generate a prototype by the solution of the first order optics and the third order aberration equation.

EX-2 Subsystem: After the starting point is chosen by EX-1 subsystem,

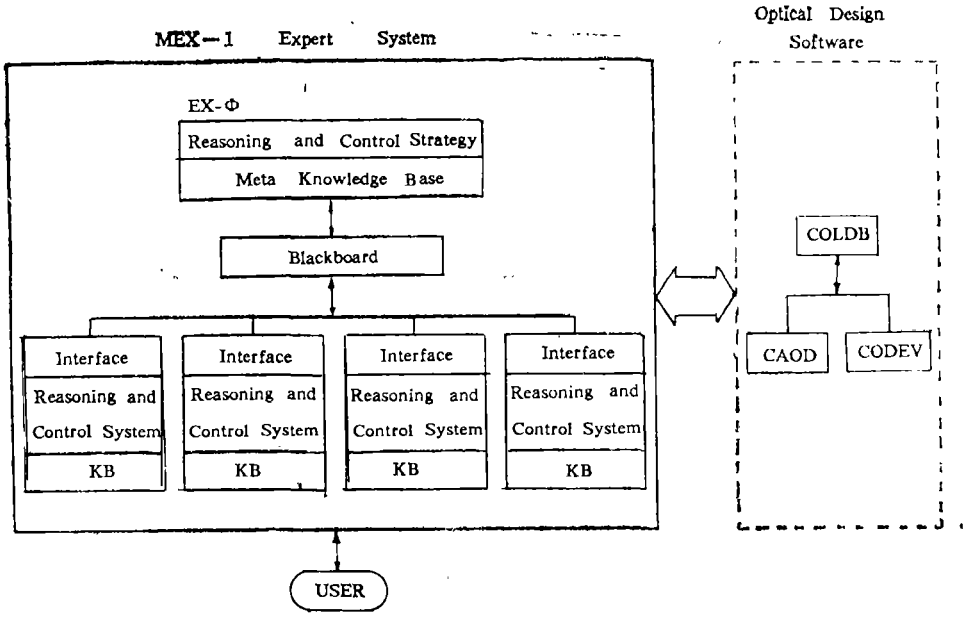


Fig.1 System architecture

EX-2 subsystem optimizes the starting point with Optical CAD. This subsystem analyses the optimizing result and decides what action the system will do:

(1) Optimizing once more.

(2) Going to EX-3 subsystem (for image evaluation).

(3) Turning back to EX-1 subsystem for choosing the starting point again.

EX-3 Subsystem: The system will use this subsystem to evaluate the image quality. If the image evaluation is successful, the system will output total report, including structure layout, structure data, abberation, MTF, and spot diagram. Otherwise, the system will return back to EX-1, EX-2 or EX-4 subsystem.

EX-4 Subsystem: This subsystem can use the solution of the first order optics and the third order aberration equation to generate a prototype for user's special requerts.

EX-0 Subsystem: It is also an expert system. It can coordinate the all subsystems in order to solve a complex design task. The knowledge base contains the expert's experience in using the four subsystems mentioned above. According to the state of process and on way result, this subsystem will decide what to do next step or when to stop the whole system job.

The optical system design software in the system.

(1) COLDB (Chinese Optical Lens Data Base): COLDB covers many

kinds of optical lens. There are over 2000 lenses, and 500 of them are zoom lenses. Also it contains about 1000 kinds of optical materials.

(2) Optical design software CODE V and CAOD: Using for high quality and special optical system design and optical engineering analysis.

(3) Special optical design module: Consisting of a prototype solving program based on first order optics and third aberration equations, a zoom ratio adjustment program, a lens scaling program, a structure analysis program and glass substitution program.

4. The Reasoning and Control Strategy of MEX-1

Since the whole design task is divided into several subtasks, and they are complete by multiple expert systems. It is necessary to control and coordinate these subsystems. The system employs model-based control strategy. This is done by EX-0, which knowledge base contains the knowledge of how the experts use different subsystem to solve a design task. It determines when and which subsystem begins to work, and receives information from the subsystems through the blackboard after work of each subsystem completed.

The blackboard is MEX-1's global working space for exchanging information between EX-0 and each subsystem or among different subsystems.

5. Conclusions

MEX-1 is a zoom lens design expert system implemented on Micro VAX-II computer system. In essence, it is a composite expert system, based on model-control of multiple expert systems coordinate work. The system can design a zoom lens that meets user's requirements, the whole process will be completed automatically. Our study is only an attempt to employ artificial intelligence and expert system technique into optical lens design field. Currently, MEX-1 is still a prototype system and the work on MEX-1 will be continued.

6. Appendix: an Example of MEX-1

(1) Dialogue

Please answer questions from the system in turn:

Checklist:

1) S11
2) S22

Choose numbers:

*E

Multiple choice:

1) Photo lens 35mm
2) Photo lens 120mm
3) Cinema lens 35mm
4) Cinema lens 16mm
5) Cinema lens 8mm
6) TV 5/4 in
7) TV 4/4 in
8) TV 2/3 in

Choose one:

*7

Numerical input:

1) Zoom-ratio
   Enter numerical value: *5.
2) Focal length
   Enter numerical value: *20.
3) F/number value
   Enter numerical value: 2.

SUMMARY OF CASE

LIST OF FINDINGS:

TV 44	TV 4/4 in		
LGT 4	Lens-GT4		0.00
ZOOR	Zoom-ratio		0.00
EFLN	Focal length		5.00
FNOO	F/number value		20.00
IMAH	Image height:	(mm)	2.00
YANH	Field angle:		8.00
ACTS:			21.80

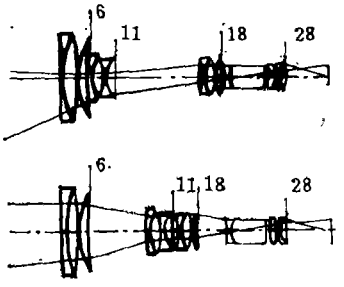
0.95 Searching for COLDB(YAN, ZOO_RATIO, FNO) (ZOO_RATIO>4)

$Would you like further information? : *n

$Would you like further information? : *n

2. Starting Point---Zoom-Ratio:6

EFL 15-90 Yan 28 F/2.2 ERF 30



214.15mm

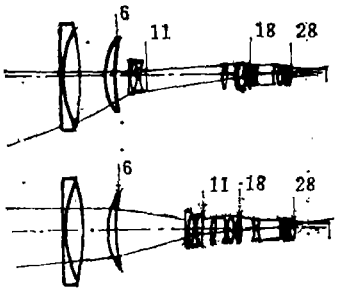
Egl SP EFL 15-90 Positions:1.3

F/2.2 Yan 28 Scale:0.1167

24-MAY-91

3. Result---Zoom-Ratio:5

EFL 20-100 Yan 22 F/2.0 ERF 15



265.87mm

Egl Result EFL 15-150 Positions:1.3

F/2.8 Yan 28 ERF 2 Scale:0.094

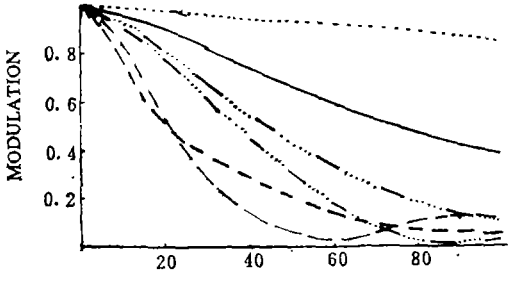
25-MAY-91

MEX-1 EG1:STARTING POINT EFL 15

DIFFRACTION MTF

POSITION 1 24—MAY—91

DEFOCUSING 0.00000



DIFFRACTION LIMIT	WAVELENGTH	WEIGHT	
AXIS	656.3nm	1	
T 0.7 FIELD(20.63°)	587.6nm	2	
S			
T 1.0 FIELD(28.04°)	486.1nm	1	
S	435.8nm	1	

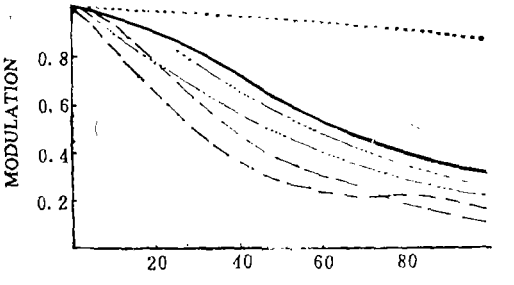
EG1 RESULT: EFL 20-100

F/2.0 ERF 15

DIFFRACTION MTF

POSITION 1 25-MAY-91

DEFOCUSING 0.00000



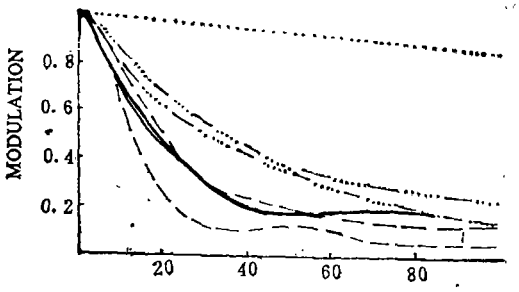
DIFFRACTION LIMIT	WAVELENGTH	WEIGHT	
AXIS	656.3nm	1	
T 0.7 FIELD(15.54°)	587.6nm	2	
S			
T 1.0 FIELD(21.60°)	486.1nm	1	
S	435.8nm	1	

MEX-1 EG1:STARTING POINT EFL15

DIFFRACTION MTF

POSITION 3 24—MAY—91

DEFOCUSING 0.00000



DIFFRACTION LIMIT	WAVELENGTH	WEIGHT	
AXIS	656.3nm	1	
T 0.7 FIELD(3.60°)	587.6nm	2	
S			
T 1.0 FIELD(5.08°)	486.8nm	1	
S	435.8nm	1	

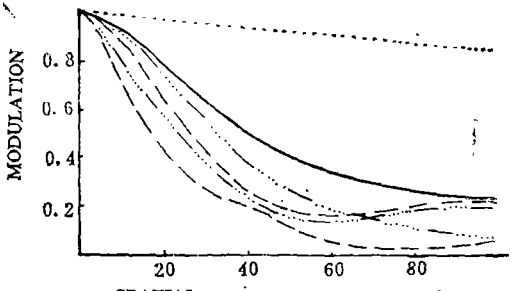
EG1 RESULT: EFL 20-100

F/2.0 ERF

DIFFRACTION MTF

POSITION 3 25-MAY-91

DEFOCUSING 0.00000



DIFFRACTION LIMIT	WAVELENGTH	WEIGHT	
AXIS	656.3nm	1	
T 0.7 FIELD(3.20°)	587.6nm	2	
S			
T 1.0 FIELD(4.57°)	486.1nm	1	
S	435.8nm	1	

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变焦距镜头设计专家系统的研究

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摘要：已研制出了一个变焦距镜头设计专家系统，几乎不通过用户干预能设计出较好的镜头。着重讨论了MEX-1系统的知识表示系统结构、推理和控制机制。