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Ontology Approach in Lens Design

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1. Introduction

Contemporary lens-CAD systems are powerful instruments for optical design ("CODE V", "OSLO", "SYNOPSYS",…). Some of them provide user with suggestions considering suitable starting point using a database of stock lenses from various vendors, what limits them to the number of existing solutions. Proposed algorithm synthesizes lens schemes for any combination of technical requirements starting from only one basic element.

To explain why this idea came to us, we have to remind that we are from the university, and teaching students stimulates to explain how to design OS (not a very big difference to whom: computer or student). Our university has started optical design practice since 1930th, so, we had accumulated big experience in optical system design. Unique combination of Information technologies and Optics in ITMO and active team which consists of both experienced and young generations of specialists.

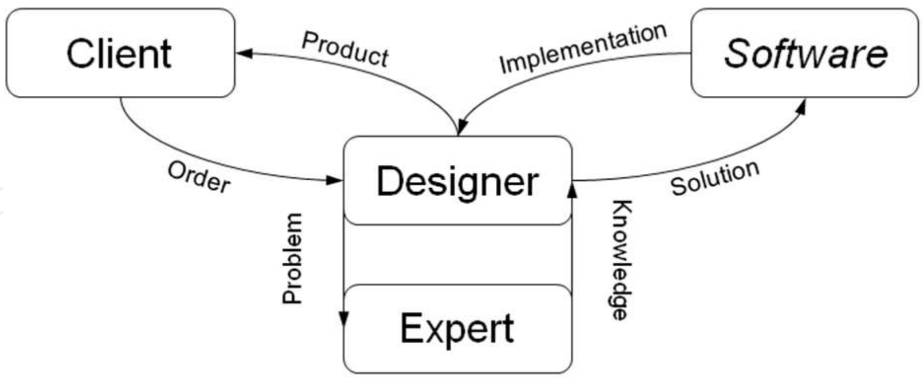
2. Optical design and ontology

What is an Ontology? Short answer: An ontology is a specification of a conceptualization. This definition is given in the article (Gruber, 1993).

What is lens design? Short answer: Optical lens design refers to the calculation of lens construction parameters (variables) that will meet a set of performance requirements and constraints, including cost and schedule limitation (Wikipedia).

For us the application of ontology to lens design gave a new inspiration to the process of starting point selection of optical system (OS). Close cooperation between optical engineers and specialists of information technologies made it possible to apply artificial intelligence to optical design and create a software for "composing" optical schemes.

It is well known that there are a lot of different kinds of optical design software for analysis and optimization, but the selection of starting point (or so called structural scheme of optical system) still remains mostly the function of human optical designer. This procedure is one of the most important steps in the optical design and it in more than 80% determines the success of the whole project. This is the most creative step of design process, which was called by Professor Russinov as "optical systems composing" similarly to composing music, where instead of sounds, optical designer uses the optical elements. We present lens classification and its link with the process of optical design composing. In Figure 1 we present our explanation on important design steps.



Order	– *general technical requirements*
Problem	– *functional requirements*
Knowledge	– *starting point*
Solution	– *structural scheme, parametrical requirements*
Implementation	– *parametrical synthesis, image quality optimization*
Product	– *technical documentation (or manufactured OS)*

Fig. 1. Design steps

In figure 2 it is shown the proposed approach taking into consideration the relations between designer and expert, and in figure 3 - stages of the optical design procedure.

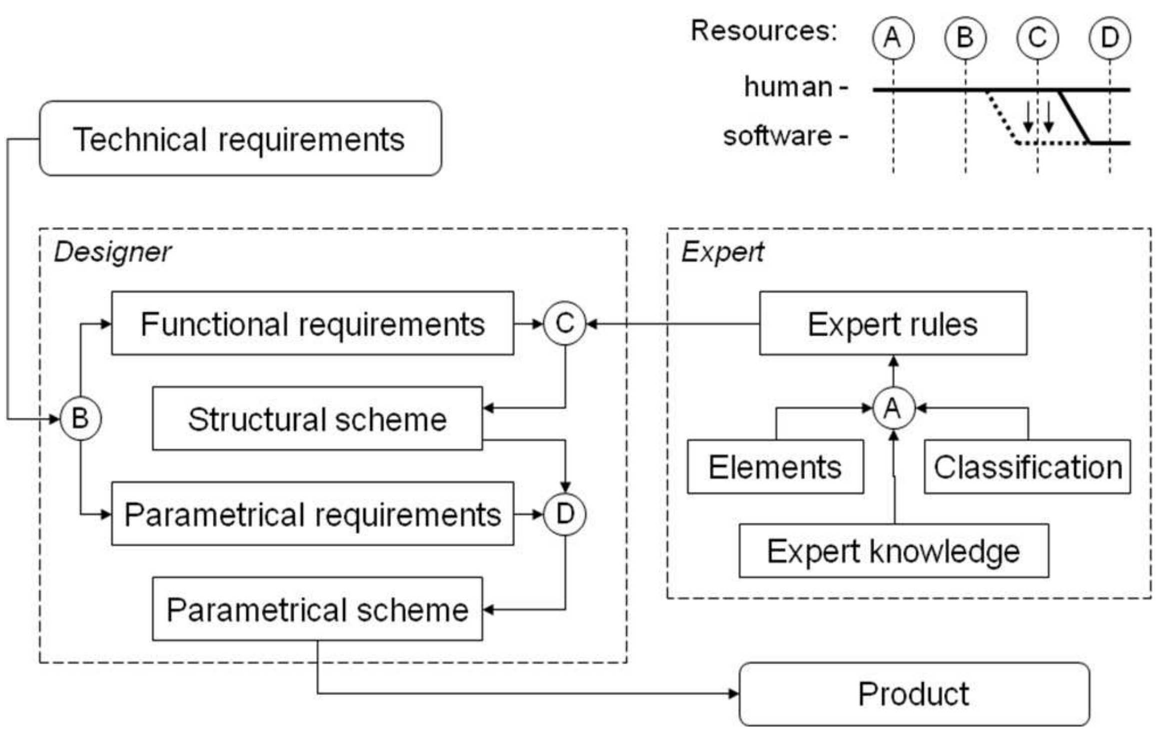


Fig. 2. The proposed approach in terms of relations between human and software resources as well as designer and expert

Looking at Fig.3, it seems obvious that if starting point is good, all the rest stages will be implemented very fast. But in case starting point has not enough parameters, we have to repeat the step of starting point selection (changing the starting point) until it satisfies the customer requirements.

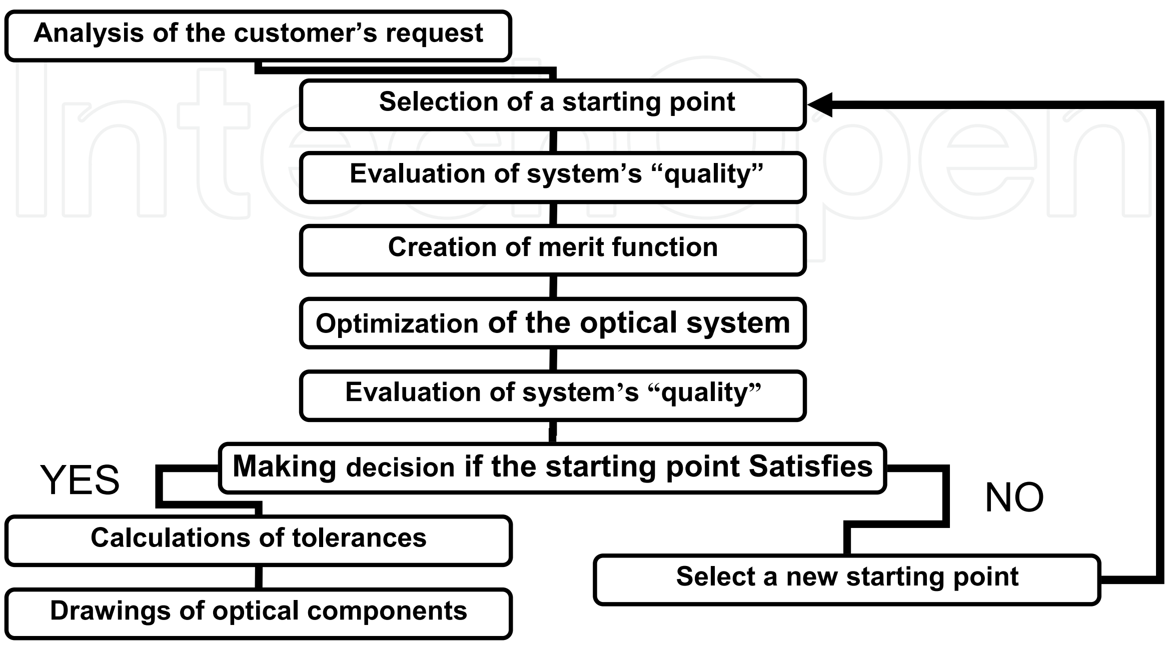


Fig. 3. Stages of the optical design procedure

3. Optical classifications and starting points

We give below some basic determinations of frequently used definitions useful for better understanding:

- Optical element (OE) is understood here as one reflective or combination of two refractive surfaces. Examples of OE are a mirror or a single lens.
- Optical module (OM) is a combination of several optical elements. Examples of OM are doublets, eyepieces, objectives – as parts of microscope optical system.
- Optical system (OS) is a combination of several optical modules. Examples of OS are telescope (includes several OM: objective lens, relay lens, eyepiece), microscope, etc.

Due to their functions in optical systems all optical elements are classified into four big groups:

- Basic Elements - are used to form the optical power in an OS, they are always positive.
- Correction Elements - are used to correct residual aberrations of basic elements. Correction elements can be both positive and negative and also afocal, which will depend on the aberration type.
- "Fast" Elements - are used for developing the aperture of an optical system, they have only positive optical power, but in distinction to basic elements, they work only from the finite distance.
- "Wide-angular" Elements - are used for developing the field angle in an OS, they are negative or afocal.

There are two basic types of data used to describe optical systems. The first are the general data that are used to describe the system as a whole, and the other is the surface data that describes the individual surfaces and their locations. Usually, an optical system is described as an ordered set of surfaces, beginning with an object surface and ending with an image surface (where there may or may not be an actual image). It is assumed that the designer knows the order in which rays strike the various surfaces. Systems for which this is not the case are said to contain non-sequential surfaces.

Entire lens space is subdivided into 3 zones: (1st zone is in front of the aperture stop, 2nd zone is inside the aperture stop region, 3d zone is behind the aperture stop) (see Fig. 4).

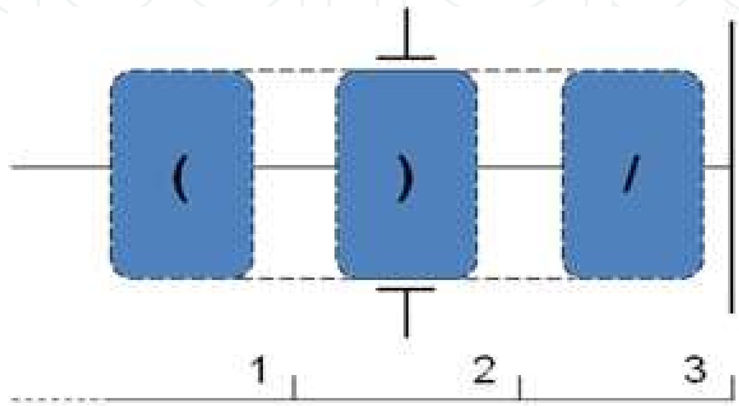


Fig. 4. Surface Location

The general data used to describe a system includes the aperture and field of view, the wavelengths at which the system is to be evaluated, and perhaps other data that specify evaluation modes, vignetting conditions, etc. If we describe these data in symbolical values we've got general classifications, see bellow.

Before one starts the optical design, it is very important to classify optical system using different classifications depending on the customer's request. Different types of characteristics are used for optical systems' classifications and there exist big amount of the classifications. There are many different approaches how to design a lens.

General classifications describe optical systems properties in conventional values. For example, if we designate the object (image) infinite position as "0" and finite position as "1", we would have the most general classification which divides all optical systems into four big classes due to object-image position, Table 1:

Conventional notation of Systems' class	Name of the systems' class
"00"	binocular type
"01"	photographic lens type
"10"	microscope objective type
"11"	relay lens type

Table 1. General classification depending on object-image position

Technical classification operates with physical values. If we input physical values Real physical values for seven optical characteristics (J, W, F, L, Q, S, D), then we get the technical classification, which is of the most influence to the starting point selection for the objectives ("01" type). Technical classification is presented in Table 2, and the link between general and technical classifications is shown in Table 3.

Notation	Name	Units
J	Aperture speed	nondimentional
W	Angular field	Angular units
F	Focal length	mm
L	Spectral range	Nm
Q	Image quality	Wave units
S	Back focal distance	mm
D	Entrance pupil position	mm from the first surface

Table 2. Technical characteristics for photographic objective

Notation for characteristic	Conventional notation depending on technical data
J	"0"; OS is not fast; D/F'<1:2.8
	"1"; OS is fast; 1:2.8<D/F'<1:1.5
	"2"; OS is super fast; 1:1.5<D/F'
W	"0"; OS with small angular field;
	"1"; OS with average angular field;
	"2"; wide angular OS;
F	"0"; short focal length OS; F'<50 mm
	"1"; average focal length OS; 50mm<F'<100 mm
	"2"; long focal length OS; F'>100 mm
L	"0"; monochromatic OS;
	"1"; ordinary polychromatic; 10nm<
	"2"; super polychromatic correction;
Q	"0"; "geometrical " image quality;
	"1"; "intermediate" image quality;
	"2"; "diffraction" image quality;
S	"0"; OS with short back focal length; S'<F';
	"1"; OS with average back focal length; 0.5F'<S'<F';
	"2"; OS with long back focal length; S'>F';
D	"0"; with entrance pupil located inside OS
	"1"; with entrance pupil located behind OS; (removed back entrance pupil);
	"2"; with entrance pupil in front of OS (removed forward entrance pupil).

Table 3. Links between general and technical classifications

Example of estimation of system's class in terms of general classification is given for a Cook triplet with following value of characteristics:

OS in not fast, so J=0,
OS with average angular field, so W=1,
OS with short focal length F=0,
ordinary polychromatic OS, so L=1,
OS with "geometrical " image quality, so Q=0,
OS with back focal length S'=43 mm, so S=2,
Entrance pupil is inside the OS, so D=0.

The sum of all seven general characteristics is called index of complexity (IC) of the objective, for our triplet it is equal:

IC=0+1+0+1+0+2+0=4;
Index of complexity (IC) varies from 0 to 14.

Selection of starting point for optical systems depends very much on the systems' complexity. From experience we can say that system with IC>7 is a complex system and, as a rule, to design such a lens, it is necessary to invent (optical scheme will have "know-how" solution). Please, notice: in spite of that characteristic "D" (aperture stop position) cannot be called "technical or, even, general characteristic", it belongs to scheme construction, we included this symbol into our classification, because it gives significant input into the starting point selection.

Numbers "0,1,2" are symbols, which belong to general classification and indirectly connected with the selection of starting point for OS.

"0" is symbol for the technical characteristic of OS, which can be realized in the easiestOS.
"1" is symbol for technical characteristic which would indefinitely require more elements to build OS than in case "0", and
"2" is for advanced technical characteristic which would require the most complex OS for achievement the required data.

Using the classification described above we can describe 3^7 = 2187 classes of OS, which are located between class "0000000" and "2222222", for example, "2222222" describes fast wide angle long FOCL OS, polychromatic with expanded spectral range, diffraction limited, with increased BFL, and APS coincident with exit pupil. It is very hard to design OS, which belongs to this class.

A complete list of optical systems for today's applications would require hundreds of entries, but a few of the design tasks that have been handled by traditional optical design software are listed in the following table. Design tasks classification is presented in Table 4.

Imaging Systems	Non-imaging systems	Laser systems	Visual systems (working with human eye)
System Layout	Illumination Systems	Fiber couplers	Microscopes
Lens Design	Solar Collectors	Laser focusing	Telescopes
Laboratory Instruments	Faceted reflectors	Scanners	Low vision aids
Optical Testing	Condensers	Cavity design	Virtual reality
Astronomical Telescopes	Light Concentrators	Beam delivery	Night vision

Table 4. Design tasks classification

So, as the result of the analysis of the customer's request we must have clear understanding what kind of optical system we are going to design, its general and technical characteristics, and its possible construction. Evaluation of the system's complexity is also important to know before selecting starting point.

4. The problem of a starting point selection

Many programs approach the starting point by supplying a number of standard or sample designs that users can apply as starting points (relying on the user's knowledge to select or generate a suitable starting design form). Smarter approaches are being explored, including expert systems (Donald Dilworth's ILDC paper, "Expert Systems in Lens Design"), and the intriguing possibility of training neural network to recognize a good starting point (research presented by Scott W.Weller, "Design Selection Using Neural Networks"). Some designers use database programs (for example, LensView,…) which recently appeared in the market. Creation of starting point is the main stage of the whole design process. If starting point was successfully matched we can get the result very fast. Bad starting point leads to failure of the design process after loosing some time for understanding the wrong choice. Besides matching the starting point the merit function has to be created.

The procedures of selecting the surfaces' types for the optical elements (OE) construction and the selecting the OE themselves for structural schemes construction are done using the finite set of selection rules and is called structural synthesis of optical scheme. Formula for structural synthesis scheme contains the type, the quantity and the arrangement of the OE.

The procedure of determining optical elements parameters in the selected optical scheme is called parametrical synthesis.

Our approach leads to receiving the optimal number of the elements in optical systems and puts all of them in certain strict sequence, which makes them more efficient both from technical and economical point of view. Anyway, this part of the general approach to optical design process, as well as other parts is programmed as "open access (entry)'', and, moreover, it offers additional opportunities to its development and correction.

Structural syntesis is based on using for lens design the surfaces with well-known properties only, such as working at its aplanatic conjugates, concentric about the aperture or the chief ray, flat or near image surfaces. In Russia this approach was developed by Mickael Russinov (Russinov,1979) and his successors (Livshts at al, 2009), (Livshits&Vasiliev, 2010) and in the USA by Robert Shannon (Shannon, 1997). The main feature of this method is the complete understanding of the functional purpose of each optical surface.

Due to the predicting properties of this approach it is possible to formalize the process of structural scheme synthesis, what allowed, in its turn to create the simple algorithm and elaborate the synthesis program.

The main concept of the method is:

- Every optical system (OS) consists of the finite set of optical modules (OM);
- Each OM has its own function in the OS and consists of a finite set of optical elements (OE);
- Each OE can be formed using only the finite set of optical surfaces' types.

The procedures of selecting the surfaces' types for the OE construction and the selecting the OE themselves for structural schemes construction are done using the finite set of selection rules and is called structural synthesis of optical scheme.

The structural scheme construction based on the two levels hierarchy of the components is presented. The objects of the lower level are optical surfaces and the objects for the upper level are optical elements. This approach made it possible to resolve the components of any structural scheme according to the hierarchy levels.

Rule examples:

- If only air spaces differ among the several configurations, the problem becomes that of the zoom lens (true zoom lens – special case of multi--configuration OS).
- If any other parameters of the lens are to zoom, such as wavelengths or element definitions (for inserting and removing sections of the lens), the true multi-configuration form of zoom must be used.

5. Selection rules for objects, optical surfaces and elements for structural scheme synthesis, attributes and ties

Optics - expert determines the applicability of each OE, used in the structural scheme. He fixes the applicability index value for every OE.

Multiplicativity (maximum quantity of the same type optical elements in the certain position of structural scheme) is also determined by optic-expert in conformity with the heuristic rules. As it was shown in (Livshts at al, 2009), optical system can include only one basic element and the quantity for each of wide-angular, correction and light powerful elements can vary from 0 to 3, moreover, it is possible to have from 0 to 3 correction elements on each of three positions allowed for these elements. In conformity with the heuristic rules the following optical elements' sequence is accepted (the structure of optical scheme is presented in Figure 5).

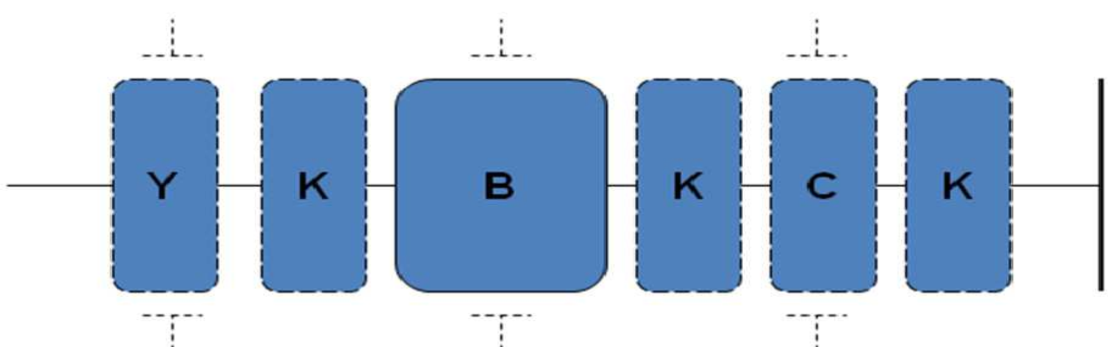


Fig. 5. Composition of Elements

So, in the high-performance optical system we have wide-angular, basic and fast elements. It is possible to put correction elements between them and after the light powerful element. This structure will be more simple if it is not necessary to have high aperture speed or wide field angle, then the corresponding optical elements (light powerful or wide-angular) are absent, but basic and correction OE are always present.

The permissibility of the optical elements neighbouring is analyzed. It is determined by the position of OE in the scheme and its thickness, for example, OE with "III" thickness cannot stand together with another thick element in one optical scheme, but OE with thickness "II0" and "00I" are fine to be neighbours.

Formal rules of cementing optical elements were elaborated. It is possible to cement two neighbouring OE if their surfaces which have to be cemented are of the same type.

The selection of the objects for putting them into the upper level is done on the basis of the set of the heuristic rules. The structural schemes' variants are formed using these rules. The best variant becomes the first in the structural schemes' list. The other variants are disposed in certain order in accordance to the diminishing of the total index of applicability for all OE of the structural scheme.

The input data for the selection rules are seven optical characteristics, which are given in the technical specification (J, W, F, L, Q, S, D) (Livshts at al, 2006) and the optical features of surfaces and elements.

The overall conventional scheme for starting optical design is present in figure 6.

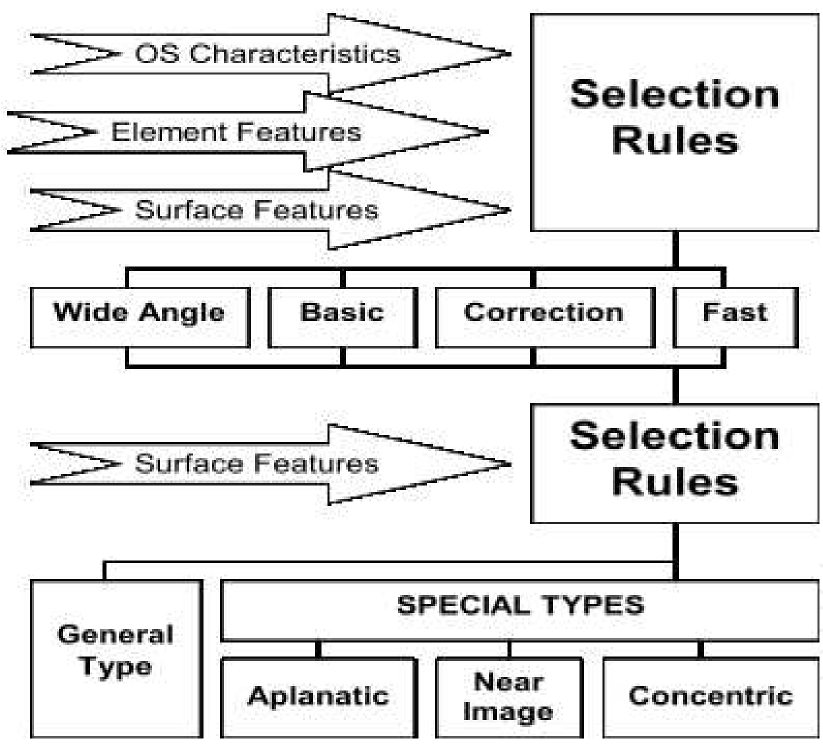


Fig. 6. Conventional scheme for starting optical design

6. Knowledge based methods

There is already a long story of using expert systems to solve different design problems. Expert Systems (ES) - are the most widely used class of AI applications, focused on disseminating the experience of highly qualified specialists in the areas where the quality of decision-making has traditionally depended on the level of expertise, for example, CAD, medicine, law, geology, economics, etc.

ES are effective only in specific "expert" areas, where an empirical experience is important. R1 system was one of the first successful attempts to use expert systems in the industry in the early 1980s (McDermott, 1980). This system is designed to assist developers in determining the configuration of a computer system constructed from different units of the family VAX.

All ES have similar architecture. The basis of this architecture is the separation of knowledge embedded in the system, and algorithms for their processing. For example, the program solves the quadratic equation, and, uses the knowledge of how to solve this kind of equations. But this knowledge is "hardcoded" in the text of the program and it cannot been either read or changed by user, if the original source code is not available. If the user wants to solve a different type of equation he/she should ask a programmer to create a new program.

Now, suppose the task is set slightly differently: the program being run must read the type of the equation and the method of its solution from a text file and the user is allowed to enter new ways of solving equations, for example, to compare their efficiency, accuracy, etc. The format of this file should be "friendly" both to a computer and a user. This way of organising the program will allow to modify its functionality without the help of a programmer. Even if the user chooses only one type of equations, the new approach is preferable to the former , because to understand the principle of solving equations, it is only necessary to examine the input text file. This example, despite its simplicity and non-typical domain of ES applications (for solving mathematical equations specialised software packages are used, rather than expert systems), illustrates the architecture of ES - the presence in its structure the knowledge base, available for the user's view directly or by means of a special editor. Knowledge base is editable that allows someone to change the behaviour of ES without reprogramming it.

Real ES may have a complex, branched structure of modules, but any ES always have the following main blocks (Figure D1. Structure of the ES):

- **Knowledge Base** (KB) is the most valuable component of an ES core. It is a set of domain knowledge and methods of problem solving, written in a readable form to non-programmers: expert, user, etc. Typically, knowledge of KB written in a form close to natural language. The written form of knowledge is called a knowledge representation language. Different systems may use different languages. In parallel to this "human" representation, KB can be saved in an internal "computer" representation. Conversion between different forms of representation should be done automatically since editing of KB does not suppose the work of the programmer-developer.
- **Reasoner** or Inference engine (R) is module simulating the reasoning on the basis of expert knowledge stored in the knowledge base. The reasoner is a constant part of any ES. However, most real-ES have built-in functionality to control of inference using the so-called "meta-rules" also saved in KB. An examples of meta-rules is given below:
  IF aperture is high (J=2);
  THEN check the elements with high index of appcicability first.
  This rule allows to adjust the reasoning process taking into consideration expert's knowledge (heuristics in optical design)
- **Editor** of the knowledge base (E) is intended for developers of ES. This editor is used for adding new rules to knowledge base or edit existing ones.

- **User Interface** (UI) is a module designed to interface with the user, allowing the system requests necessary data for its operation, and outputs the result. The system mat has fixed interface that focuses on a certain mode of input and output, or may include a **tool of designing custom interfaces** for better user interaction.

The authors have included a new module to ES architecture - Ont - the ontology of optical elements.into this work It allows ones to use a generic and extensible domain vocabulary of the rules for the KB. Ontology will be discussed below in detail.

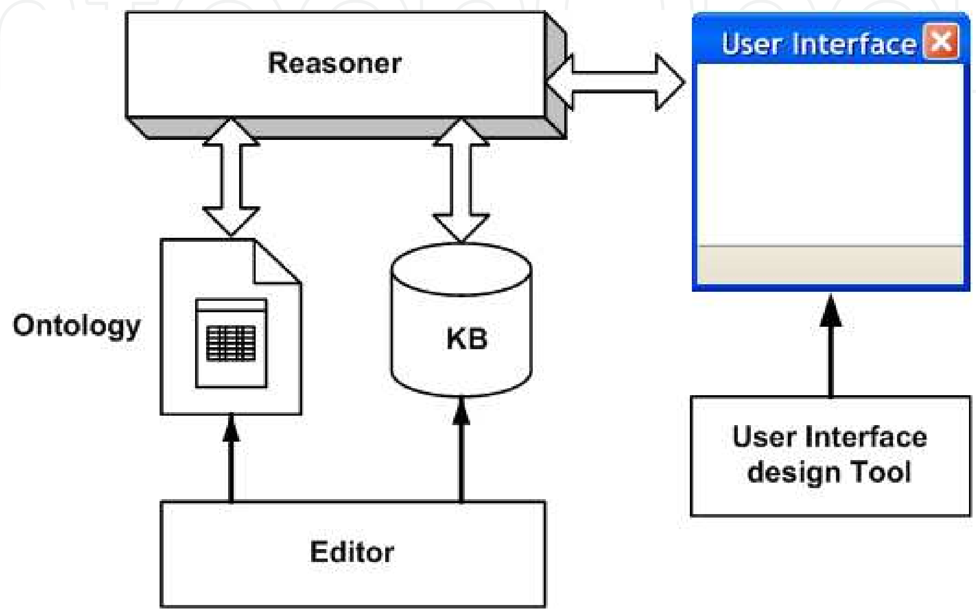


Fig. 7. Structure of the ES

Knowledge representation in the form of production rules is most common in expert systems, because the records of KB are actually knowledge written on a subset of natural language. The consequence is that the rules are easy to read, they are simple for understanding and modification, the experts have no problem to formulate a new rule, or to point out the fallacy of an existing one.

Production systems are a model based on production rules, allowing to describe knowledge about solving problems in the form of rules of "IF condition, THEN action».

The concept of "production systems" is a special case of knowledge based systems. The idea of representing knowledge in the form of products appeared in the work of Emil Leon Post (Post, 1943).

The main components of a production system architecture are (Figure 8.):

- KB production rules;
- Working memory;
- Controlling recognition-action cycle.

Reasoning modelling is based on the process of pattern matching, in which the current state of the solutions are compared with existing rules to determine further action.

The knowledge base contains a set of production rules or simply productions, which are condition-action pairs that define the basic steps of problem solving. The condition part (IF-part) rule is a pattern, where we can determine at what point you want to use (activate) the rule for the next stage of solving the problem. Part of the action (THEN-part) describes the corresponding step of solutions. The conditional part of the rule is also called the antecedent, and part of the action - consequent.

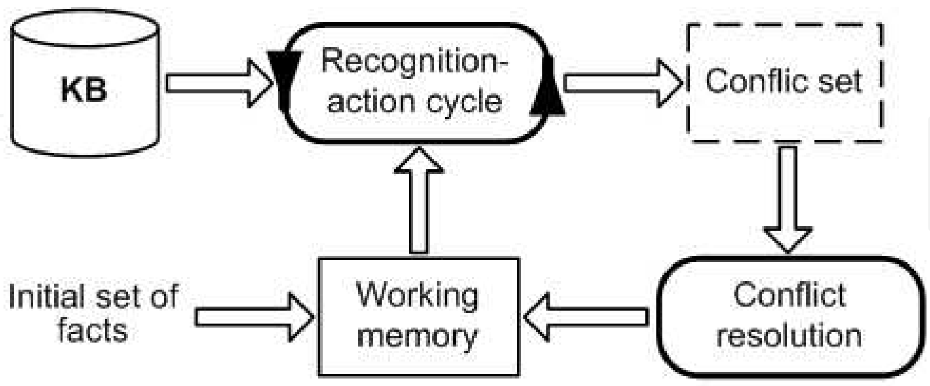


Fig. 8. Production system architecture

Working memory contains the current set of facts constituting a world model in the process of reasoning. Initially this model contains a set of samples, representing the starting description of the problem.

During the recognise - act cycle facts from the working memory are matched with the conditional parts of rules in the knowledge base. If the condition of a rule matches a pattern, it is usually placed in a conflicting set. Products contained in the conflict set are called admissible, since they are consistent with the current state of working memory. When the cycle-detection operation is finished, the process of conflict resolution, in which one of the acceptable products is selected and activated takes place. Finally, the working memory is modified in accordance with THEN-part of the activated rules. This whole process is repeated until the samples in the working memory will not fit any of the rules of KB.

Conflict resolution strategies differ in different implementations productional models and can be relatively simple. For example, select the first of admissible rules. However, many systems allow the use of sophisticated heuristics for choosing rules from a set of conflict. For example, the system OPS5 supports the following conflict resolution strategies (Brownston at al, 1985):

- Refraction is to prevent infinite loops: after activation of a rule it can not be used again until they change the contents of working memory.
- Recency is to focus the search on the same line of reasoning: preference rules are that there are facts that have been added in the working memory of the latter.
- Specificity prefers a more specific rules before more general, one rule is more specific than another if it contains more facts in the conditional part.

As the conditions and actions in the rules may be, for example, the assumption of the presence of some property that evaluates as true or false. The term action should be interpreted broadly: it may be a directive to carry out any operation, recommendation, or modification of the knowledge base - the assumption that there is any derivative properties. An example of a production is the following expression:

IF Aperture speed is low,
THEN base element with "III" thickness.

Both IF and THEN parts of a rule allow the multiple expressions, combined by logical connectives AND, OR, NOT:

IF Entrance pupil position located inside
AND NOT Angular field is small,
THEN correction element with "II0" thickness.

In addition to production rules knowledge base should include the simple facts which are coming in through the user interface or inferred during reasoning process. The facts are simple statements such as "Aperture speed is low." The facts, as true assertions are copied into the working memory for use in a recognise - act cycle.

Sequential activation of the rules creates a chain of inference (reasoning). In the present work we use the data-driven search, in which the process of solving the problem starts with the initial facts. Then, applying the admissible rules, there is a transition to the new facts. And it goes on until the goal is reached. This process is also called “forward chaining”.

Forward chaining of reasoning applies to problems where on the basis of available facts it is necessary to determine the type (class) of an object or phenomenon, to give advice, to diagnose, etc. These tasks include, for example, design, data interpretation, planning, classification, etc. The conclusion, based on data applied to problems in the following cases is that:

- All or most of the data set in the space of the problem, for example, the task of interpretation is to select the data and presenting them for use in the interpretation of a higher level.
- There is a number of potential goals, but only a few ways to use initial facts.
- It is very difficult to formulate a goal or hypothesis because of redundancy or the source data of a large number of competing hypotheses.

Thus, a search, based on the initial facts in the problem, is used to generate the possible ways of solving it. Forward chaining algorithm is usually based on the search strategy the initial facts are added to the working memory and then its content is compared sequentially with the antecedent of each rule in BR. If the contents of working memory leads to the activation of a rule, after modifying the working memory the next rule is analysed. When the first pass over KB is completed, the process repeats, beginning with the first rule.

Separation of the knowledge base and inference machine is an advantage of expert systems. During the inference process all the rules of the system are equal and self-sufficient, that is all that is necessary for activation of the rules contained in its IF-part, and some regulations may not directly cause the other. The reasoner work is independent of the domain, which makes it universal. But sometimes, to get the solutions, some intervention to standard output process is required. For this purpose, some production systems allow one to enter specific rules into the knowledge base to manage the process of withdrawal - metarules. Metarules are not involved directly into the process of reasoning, but determine the priority of execution the regular rules. Thus, some structuring and ordering of rules is introduced in the knowledge base.

In this work the knowledge base of the general optical system consists of two modules:

- The rules for structural synthesis of optical systems.
- The ontology of optical elements.

The first important part of the knowledge base contains the optical systems structural synthesis rules. This approach based on the rules has proved its effectiveness for solving optical design problems during many years of expert system development and using. Rules based systems provide a formal way of representation of recommendations, guidance and strategies. They fit ideally in the situations when knowledge of field of application appears from the empirical associations, accumulated during the years of solving problems in the domain. Rules based presentations of knowledge are clearly understandable and easy readable. It is possible to modify the rules or add new one, or find a mistake in the existing rules.

So, as a result of CAD process of structural synthesis of optical system due to the technical specifications it is possible to get several technical solutions (scheme variants). Because of that, the ranking technology has to be used, so, the less profitable solutions will be excluded and will not appear in the final list of optical elements.

The formal presentation of the selection rules of optical system structure (as a starting point) is based on logic expressions using boolean operation conjunction (logical AND) and implication (logical consequence). This is the most convenient type of formalisation, as such equations could be easily interpreted into understandable rules "IF – THEN", which significantly simplifies the work of the expert. Besides, using formal mathematical approach, logical equations could be transferred to a more compact equivalent minimal notation, then the knowledgebase becomes "lighter". Every logic equation determines a condition of the application of the certain optical element in the designed optical system.

There is an analysis of the existing optical constructions created by generations of Russian optical designers in accordance with the theory of the synthesis and optical systems composing created by Professor Russinov. This theory together with its further development gave an opportunity to extract and generalize database consisting of more than 400 rules.

7. Ontology approach

The leading paradigm of structuring the information or content is an ontology or hierarchy of conceptual frameworks (Guarino, 1998). From the methodological point of view - this is one of the most "systematic" and intuitive ways.

By definition of Tom Gruber (Gruber, 1993), who was the first to use this concept in the field of information technology: an ontology is specification of a conceptualization – it is not only a philosophical term for the doctrine of being. This term has shifted to the sciences, where nonformalized conceptual models are always accompanied by a strong mathematical definitions. In accordance of the definition of an ontology, many conceptual structures: a hierarchy of classes in object-oriented programming, conceptual maps, semantic networks, etc. could be easily determined.

Ontology is an exact specification of a domain, or a formal and declarative representation including the vocabulary (or names) of pointers to the domain terms and logical expressions, describing what these terms mean, as they relate to each other, and how they can or may not be related to each other. Thus, ontologies provide a vocabulary for representing and sharing knowledge about a certain subject area and a lot of relations established between terms in the dictionary.

In the publication (Gavrilova, 2005) there proposed the following classification of modern ideas and research works in the field of ontology. The proposed systematisation of ontology illustrates the views of several research groups.

Ontology or a conceptual domain model consists of a hierarchy of domain concepts, relationships between them and the logical axioms that operate within the framework of this model we describe:

- by the type of relationship:
    - taxonomy - the leading relationship is «kind-of» («is-a»);
    - partonomy - the leading relationship is "is part" ("is», «has part»);
    - genealogy - the leading relationship if "father-son" ("a descendant of the predecessor");
    - attribute structure;
    - cause and effect - the leading relationship if «if-then»;
    - mixed ontology - the ontology with other types of relationships.
- by owner or user:
    - individual (personal);
    - shared (group):
        - belong to the country,
        - belong to the community (eg scientific)
        - owned company or enterprise;
    - common (opened).
- by language:
    - informal;
    - formalized;
    - formal - in languages RDFS, OWL, DAML + OIL, etc.
- by domain:
    - science;
    - industry;
    - education, etc.
- by the design goals:
    1. for design;
    2. for learning;
    3. for research;
    4. for management;
    5. for knowledge sharing;
    6. e-business.

The ontology is necessary tool for optical systems structural analysis. The purpose of this analysis is to determine the function of the every element of optical system with the consequent formalising of the design procedures. The ontology makes it possible to formalise most of the steps of optical design process and determine the cutoff values for indices of applicability of the certain elements in certain optical schemes.

This approach has a set of essential advantages because it allows to combine the creation of structured dictionary of notions in the optical domain with the technical classification used in lens design. As a result, the combination of just two procedures makes it possible to use existing optical design experience for design of new optical systems.

The ontology development is based on knowledge engineering, where the main problem is the correct search of objects (individuals), classes (sets of concepts) and the relationships between these structures.

Algorithm used for ontology engineering was as same as proposed (Gavrilova, 2003):

1. Forming glossary of a problem area, i.e. acquisition and extracting of concepts – the basic glossary in the subject field.
2. Extracting of notions (bottom to top). For example, we can start from forming the class of general concepts "a lens" and "an optical system" Then we can specify the general class "a lens" by extracting sub-classes "positive" and "negative". Further from the class of "positive lens" we can inherit, for example, such elements as "basic" and "fast".
3. Abstracting concepts (bottom-up). For example, first define the classes for the elements of "correction lens for "coma" and "corrective" lens for "astigmatism". Then it creates a common superclass for these two classes - "corrective lens", which in turn is a subclass of the most abstract concept of "lenses".
4. Distribution of the concepts on the levels of abstraction. Cyclic execution of steps 2 and 3.
5. Setting of some other relationships between concepts (properties, parts, etc.), a glossary, and their combination.
6. Refactoring of the ontology (specification, the resolution of contradictions, synonymy, redundancy, inaccuracy, restructuring and addition).

Ontology to be created belongs to the taxonomy scheme, i.e. hierarchal structure of goals and results from easy to complex organised by generalisation-specialisation relationships, or less formally, parent-child relationships. Mathematical taxonomy is a tree of classification of certain number of the objects. In the top of this structure is uniting uniform classification, or the root taxon, which belongs to all of the objects of this taxonomy. Taxons located below the root taxon are more specific elements of the classification. "Optical system", "lens", "surface", "material" were chosen as the upper level concepts. After that the taxonomy was structured in correspondence with the purpose, main characteristics and specific construction of optical system. It is of great importance that the proposed ontology allows to classify and create the semantic search of solution in the database of the optical patents.

For the formal description of the ontology the Web Ontology Language (OWL) is used. OWL is one of the family of knowledge representation languages for authoring ontologies. The languages are characterised by formal semantics and RDF/XML-based serializations for the Semantic Web. OWL is endorsed by the World Wide Web Consortium (W3C) and has attracted academic, medical and commercial interest.

OWL is designed primarily for identifying and representing of Web ontologies, which may include descriptions of classes, instances of classes and properties. Description logics being the underlying formal semantics of OWL, allows to obtain the facts which are not represented in the Web Ontology explicitly, but is followed (inferred) from its definition. Moreover, these effects may be based on a single document or multiple distributed documents that are combined with the use of special algorithms.

The main differences between OWL-XML and XML Schema are as follows:

- Ontology, in contrast to XML Schema, allows to represent knowledge, and not the data format. Most XML-based specifications consist of a combination of data formats and protocol specifications, which are attributed to a specific semantics.
- One more advantage of OWL ontologies is the possibility of performing reasoning (inference of knowledge). Moreover, these systems can be largely universal, ie do not depend on a specific subject area.

OWL exists in three dialects: OWL Lite, OWL DL and OWL Full. Each of these dialects is an extension of a simpler predecessor, both in the expressive possibilities of information and that is connected with the inference of knowledge.

The main concepts of OWL are class and individual, or instance. The differences between them require some clarification. Class - it's just a name and a set of properties that describe a set of individuals. Individual is a member of this set. Thus, the classes must correspond to a set of concepts in some domain, and individuals should correspond to real objects, which can be grouped into these classes.

When creating ontologies the distinction is often blurred in two ways:

- Levels of representation. In certain contexts, something that clearly is a class that can independently be an instance of something else.
- Subclass or instance. It is very easy to confuse the relationship type instance of the class with the class-subclass.

An example of the ontology for optical design is present on Fig. 9.

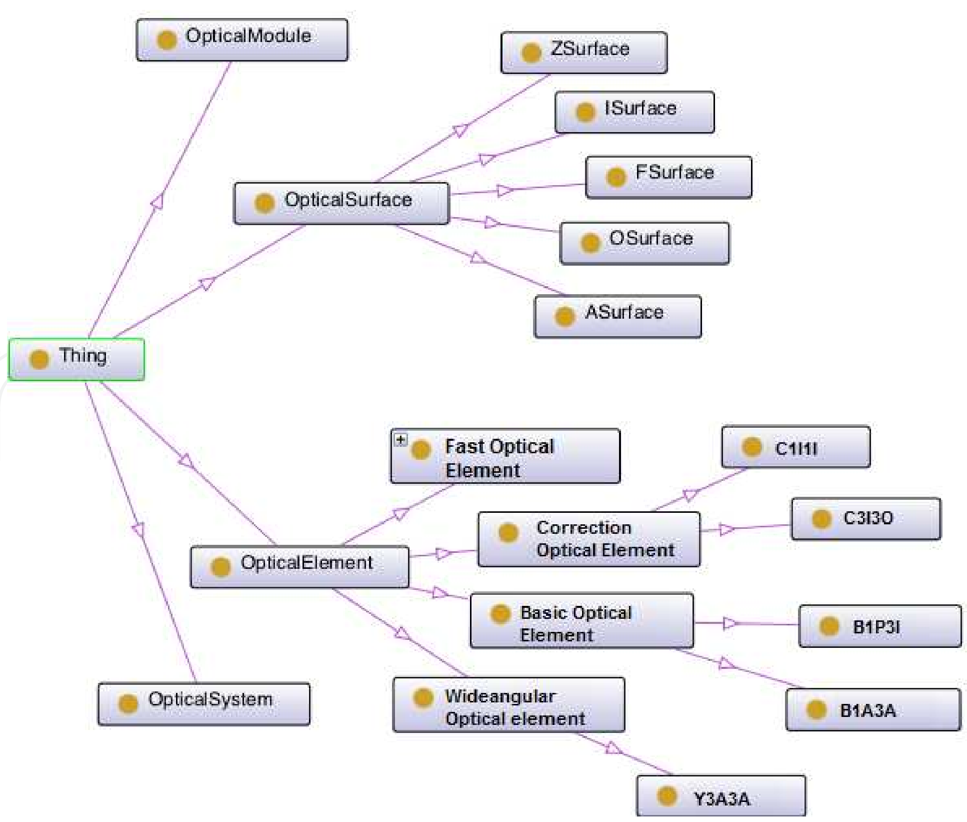


Fig. 9. A part of Optics design ontology

8. Conclusion

Presented research confirms the statement that application of information technologies to optical design brings new quality even to very traditional area of physics. Artificial intelligence, in particular experts systems, not only opened new horizons for optical designers, but attracted young researchers and software engineers, who are very important for saving and development of optical knowledge inheritance.

9. References

Brownston L., Farrel R., Kant E., Martin N. 1985 *Programming Expert Systems in OPS5. An Introduction to Rule-Based Programming*. Reading, Addison-Wesley: MA.

Gavrilova T., Laird D. 2005. *Practical Design Of Business Enterprise Ontologies In Industrial Applications of Semantic Web* (Eds. Bramer M. and Terzyan V) Springer. 61–81.

Gavrilova T.A. 2003. Ontological approach to knowledge management in the development of corporate information systems. *News of Artificial Intelligence* (2): 24-30. (in russian)

Gruber T. R. 1993. A Translation Approach To Portable Ontologies. *Knowledge Acquisition* 5 (2): 199–220.

http://wikipedia, the free encyclopedia. Wikipedia.org

Irina Anitropova, Simple method for computer-aided lens design with the elements of artificial intelligence, Proc. SPIE 1780, 1992.

Irina L. Livshits, Vladimir N. Vasiliev, Optical systems classification as an instrument for getting knowledge from optical expert, 7th Int'l Conf. on Optics-Photonics Design & Fabrication, pp. 13-14, 2010.

Irina Livshits, State-of-the-art in Russian and Former Soviet Union optical design, 2nd Int'l Conf. on Optics-Photonics Design & Fabrication, pp. 285-287, 2000.

L. Livshits, I. G. Bronchtein, V. N. Vasiliev, Information technologies in CAD system for lens design, Proc. SPIE 7506, 2009. doi:10.1117/12.837544

Livshits, A. Salnikov, I. Bronchtein, U. Cho, Database of optical elements for lens CAD, 5th Int'l Conf. on Optics-Photonics Design & Fabrication, pp. 31-32, 2006.

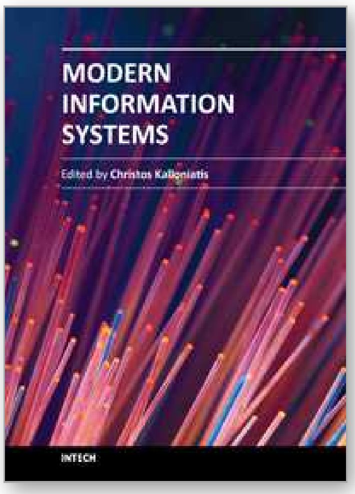
McDermot D., Doyle J. 1980. Non-monotonic logic I. Artificial Intelligence 13: 14–72.

N. Guarino (ed.), *Formal Ontology in Information Systems. Proceedings of FOIS'98, Trento, Italy, 6-8 June 1998.* Amsterdam, IOS Press, pp. 3-15.

Post E. 1943. Formal reduction of the general combination problem. *American journal of Mathematics* 65: 197–268.

Robert R. Shannon, "The Art and Science of Optical Design", Cambridge University Press 1997, ISBN 0-521-58868-5

Russinov M. Technical Optics. Mashinostroenie. Leningrad, 1979, 488 p. (in russian)



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The development of modern information systems is a demanding task. New technologies and tools are designed, implemented and presented in the market on a daily bases. User needs change dramatically fast and the IT industry copes to reach the level of efficiency and adaptability for its systems in order to be competitive and up-to-date. Thus, the realization of modern information systems with great characteristics and functionalities implemented for specific areas of interest is a fact of our modern and demanding digital society and this is the main scope of this book. Therefore, this book aims to present a number of innovative and recently developed information systems. It is titled "Modern Information Systems" and includes 8 chapters. This book may assist researchers on studying the innovative functions of modern systems in various areas like health, telematics, knowledge management, etc. It can also assist young students in capturing the new research tendencies of the information systems' development.

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