# AN ARCHITECTURE OF THE TOOLKIT FOR DEVELOPMENT OF HYBRID EXPERT SYSTEMS

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**ABSTRACT**
Architecture of the toolkit ESWin and hybrid expert systems, supported by one, are described in this report. The knowledge representation by rules, frames and linguistic variables is used in this architecture. The possibility of keeping and extraction of data from external databases, execute of external programs are provided. This architecture supports of forward and backward fuzzy inference, reasoning with past and future events and allows to connect inference engine to neural networks and development of hybrid distributed systems.

**KEY WORDS**
Knowledge systems development tools, expert system, hybrid intelligent systems, knowledge representation, knowledge processing.

## 1.Introduction

The artificial intelligence systems can be creating with the using of classic logical or neurocybernetic methods. Each of these methods possesses of the set of dignities and deficiencies.
The main deficiencies of logical approach are:
– the sufficiently difficulty of implementation of the artificial intelligence system (the expert system) self-training or self-organization in the process of finding of the problem decision;
– the orientation to consequent data processing required for deciding;
– the problems connected with the implementation of the real-time system (data reception from the large number of the sensors or availability of the several executive mechanisms for instance).
The neurocybernetic approach possesses certain defects also:
– the complicated realization of the logical data processing;
– the complicated realization of the dialog with users;
– the complicated realization of getting of unambiguous decision in accordance with the set of rules.

The combination of these methods allows compensating deficiencies of one of the methods by advantages of other. So at present actual problem in the field of artificial intelligence is development of architecture of hybrid expert systems [1], [2], [3], [4], [5], [6], [7], [8], [9], [10].
Using the different methods of presentation and processing the knowledge (up to combinations of knowledge engineering traditional methods with neural network technologies) inheres in base of hybrid expert system architecture. Thereby organized expert system architecture allows including computing and modeling possibility as well as get data and knowledge from different sources. In the traditional expert system the knowledge engineer concerned of the knowledge extraction by dialogue with expert and place of extracting knowledge in knowledge base. In the hybrid expert system the dialogue with the expert ceases a traditional source of data and knowledge. In the hybrid expert system knowledge can be received by assistance of neural network and placed in the knowledge base without assistance of the knowledge engineer.
Architecture of the toolkit ESWin and hybrid expert systems, supported by one, described in this report.

## 2.Knowledge representation and reference

Knowledge representation by rules and frames and backward inference method on set of frames inheres in base of architecture. Forward inference can be used as additional facility of a knowledge base interpreting.

Moreover in frame structure linguistic variable are used and frame can be connected with subset of rules and procedures. Rules can cause external programs, in which can be executed computing and modeling possibility, data reduction, relationship with external equipment etc.
Frames allow to describe application domain in hierarchies of classes and owners.

All knowledge base frames possible to divide into three types: frames-classes, frames-examples and frames-patterns. The frames-classes forms the basis of knowledge base as far as slots of frames-classes are described objects

of application domain and dialogue elements and their possible values, assigned user questions and commentaries. Slots can be symbol, numerical, linguistic variable or date or time. Frames can be joined to rules and procedures, processing determined events, connected with frames.

During interpreting process of the knowledge base frames-classes can generate frames-examples, intended for the fact description. Frames-patterns present certain variety of frames-classes, where in the slots and slots values are described the concrete situations (events, examples etc).

Knowledge base constant part consists of frames-classes and frames-patterns. In the knowledge base variable part (database) frames-examples can be kept only. Possible also frames- examples place in knowledge base constant part, in such case these frames- examples stay to be unchangeable in the inference process. In general the frame looks as follows:

FRAME (‹frame type›) = ‹frame name›
PARENT: ‹parent frame name›
OWNER: ‹owner frame name›
‹slot name 1› {‹comment›} (‹slot type›) [‹slot question›?]: (‹value 1›; ‹value 2›; …; ‹value k›)
…
‹slot name n› {‹comment›} (‹slot type›) [‹slot question›?]: (‹value 1›; ‹value 2›; …; ‹value m›)
ENDF

The each slot in frames-examples and frames-patterns has single value only. A number of slot values is not limited in frames-classes. Slots can be symbol, numerical, linguistic variable.

Linguistic variable [11] intend for using the fuzzy notions in the inference. Linguistic variable is described in the set of the symbol values and membership functions of the each value. Membership function is defined on the metric scale. In rules it possible to work with linguistic variable as both numerical and symbol slots. Herewith user can input both numerical value and symbol (fuzzy) value on the request for the linguistic variable value. In case of entering numerical value ESWin shell values validity of this value using linguistic variable description (if the rules interpreting uses symbol value of the linguistic variable further).

In the knowledge base rules are used for the description of relations between objects, events, situations of subject domain. Inference is run on the base relations assigned in rules. It present references to frames and frame slots in rules conditions and conclusions. The rules presentation format looks as follows:

RULE ‹rule number›
‹condition 1›
…
‹condition m›
DO
‹conclusion 1›
…
‹conclusion n›
ENDR

Format of conditions and conclusions of rules is unified. Both condition and conclusions contain the name of slot, value of slot and their relations. Name of the slot can be complemented by the name of frame. In case frame is not indicated obviously, it is used frame-context by default. Also in conditions and conclusions can be present a certain factor, running values from 0 to 100 (at percents).
The conditions may be including facts from database. These facts are received from database by SQL-query, which automatically formed. To form SQL-query structure SOURCE is used in which the description of mapping of slots of any frame on fields of tables of database and some features of construction of SQL-query are contained.

In the rules conditions can be used relations “=” (eq), “<>”(ne), “<” (lt), “>” (gt), “in”. If the condition uses symbol value of slot, then relation “=” it may be used only. For all other values it is possible to use all fore arithmetic relations. From enumerated relations above in the rules conclusions it is possible to use relation “=” only. Besides that it is possible use some special relations. These relations are underactions executing when the rules are fired:
– execute external program;
– output of the message;
– output of the frame-example contents;
– removing a specified slot (fact);
– execute a specified rule;
– execute a procedure.

In the inference process the database is renewed by new facts in case proving of conclusions with use the relations “=” only.
Calculation of the certain factor value executes as follows: the conditions set certain factor are calculated as conjunction of the rule conditions certain factor (minimums value from values of conditions certain factors). The slot certain factor of frame-example formed on the base of conclusion is calculated as a product of conditions set certain factor and a conclusion certain factor. If already such slot were in frame-example, its certain factor is changed on new value calculated on formula as follow:

$$CF_{resulting}=CF_{source\ slot}+CF_{new}*(1-CF_{source\ slot})$$

## 3.Interaction between Expert System and Neural Networks

Mechanism of interaction neural networks with the expert system stays actual problem in designing the hybrid expert systems. On this time general approach does not exist to deciding a given problem, and hybrid system structure is designing depending on appointments of systems.

One of the important problems is connected with the different presentation and processing knowledge. Expert system's knowledge are kept in the knowledge base in the manner of frames and product rules. Searching of deciding is realized on interpreting the rules. Knowledge in ES have a formalized type unlike NN, which handle with non-formalized knowledge, presented in the manner of neurons and join between them.

Module ensuring interaction with the neural network through sockets, with using language of sectoring the documents XML *(Extensible Markup Language)* for organization communications designed on the base expert shell EsWin for the permit problems, described above this.

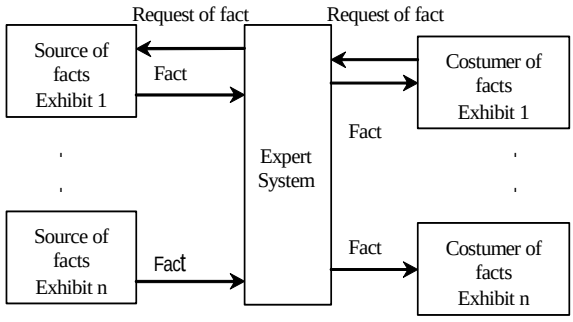


Figure 1. Interaction Expert System with external sources and consumers of facts

User, database, but in the same way and expert system itself can emerge as a source and consumer of facts. Facts enter in the expert system's facts base from the user through the dialogue in which process user gets a row of directing questions and variants of answers or user forms an answer itself. When condition rules are executes, facts are setting in the process of inference in the same way.

Expert system can get facts from the database through single-purpose structures, in which database and structure of special frame are described. SQL request is created on the base of frame slots play a role of database rows. Such approach allows to get facts from the database right in the process of inference.

Other expert system or other copy of same expert system can emerge as an external source and consumer of facts in the same way. Systems changes by facts through the general facts base in this instance. Textual or binary file, so and database can emerge as general facts base. Such method of exchange by facts superimposes certain restrictions, connected with a time of determinations of facts and organization of simultaneous access to the facts base.

The most interest as an external source and consumer of facts presents other program, with which exchange by facts occurs both on one computer, and remotely through local or global network. Neural network can emerge as programs. But a certain problem appears, which essence is concluded in the different presentation of knowledge.

For the realization of interaction rule-oriented-frame-based expert system with free sources and consumers of facts mechanism was designed. In these base there are methods of interaction between programs and using the single-purpose dictionaries.
Base of mechanism is concluded in possibility of issue or getting a fact from the external source or consumer during

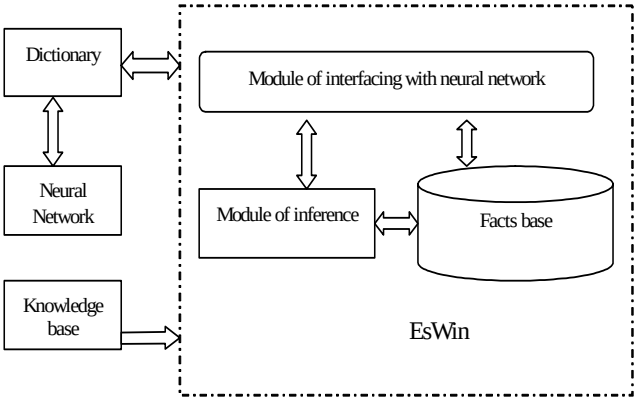


Figure 2. Interaction expert shell with neural network

the inference. For this special frame is used in the knowledge base. Special frame describes necessary parameters for the determination of interaction of expert shell with other program. If knowledge base interpreter will find a special frame in the condition of rule in the process of inference, it realizes a stopping of process of conclusion and sends an inquiry for the reception of fact from other program. After getting a fact a process of inference continues. If inquired fact does not enter from the external source in specifying gap of time, the fact is taken as empty and inference continues. But if special frame is meeting in conclusion rules, the expert system sends a fact to other program.

Working with socket connections, EsWin can be based in two modes. The first is a mode of client. EsWin can require a value of fact beside connection and get its in

this mode. At the request of fact a process of conclusion stops until a value of fact from connection enters or waiting time will not be finished. The waiting time is defined by the slot TimeOut. If for this time a value of fact does not enter, empty fact is written in the knowledgebase. So frame and slot are created, but value of slot is absent. The second mode is a mode of server. For activation a second mode we need to define a socket port and fix ESWin server.

Designed a principle of exchange by facts allows to design ES with more complex structures of interaction between ES and other programs, as on network so and on one workstation. Under such approach ES, designed on the base EsWin, is changed by data with other programs, not take into consideration that this for program.

## 4. Conclusion

In this paper the architecture of toolkit for development of Hybrid Expert Systems is described. This architecture allows unify of advantage of logical representation and processing of knowledge and associative processing by neural networks.

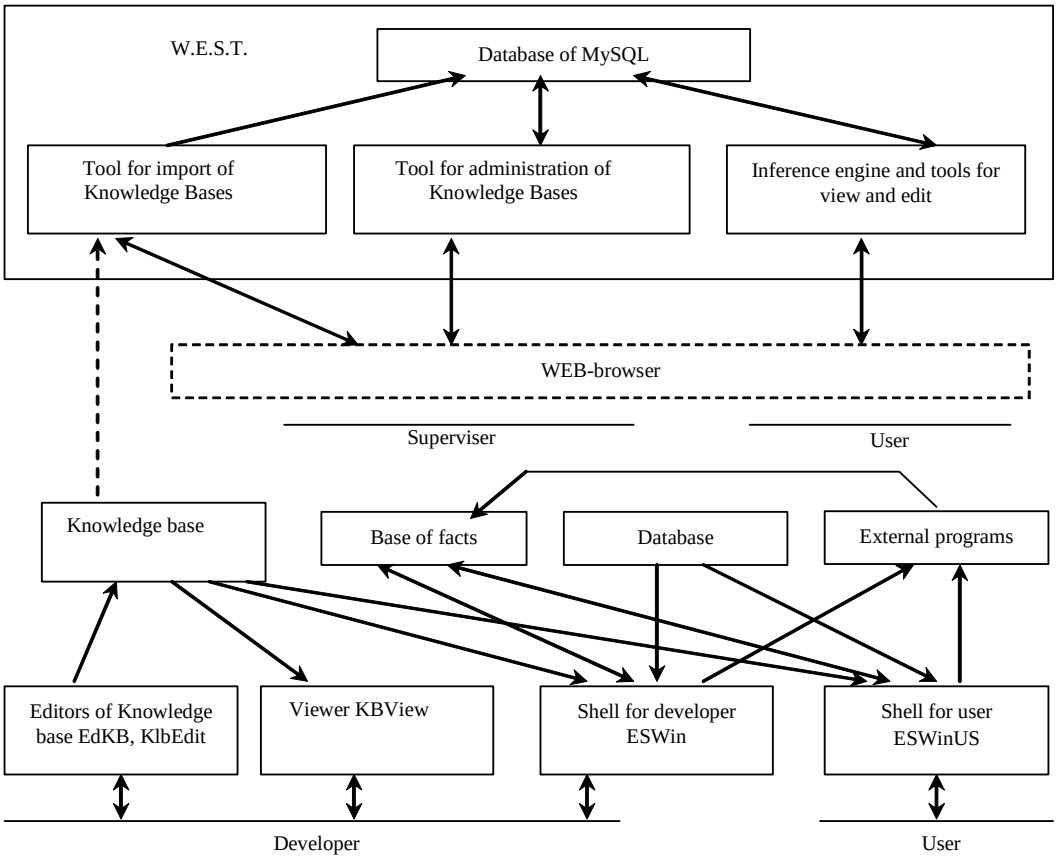


Figure 3. Structure of toolkit ESWin 2.1 + W.E.S.T.

The implementation of part of this architecture as toolkit ESWin 2.1 [12] and shell W.E.S.T. for publishing of Expert System in Internet (figure 3) are available from http://www.insycom.ru.

Toolkit ESWin software is realized in Delphi. One consist of some programs modules, main of them are:

1) program shell ESWin intended for interpreting the knowledge bases directly,

2) knowledge base editors-constructors EdKB and KlbEdit allowing in suitable form design, examine and edit knowledge bases,

3) program of viewing and diagnostics of knowledge bases wholeness KBView.

This Expert Shell is used for education in many Universities of Russia. Now new version with more full features of proposed architecture is preparing.

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