AN EXPERT'S KNOWLEDGE FOR TECHNICAL DIAGNOSTIC

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INTRODUCTION

In every advisory system one of the main elements which determine its quality is the academic background. Very often, a present state of science does not allow to work out a reliable theory to describe a tested occurrence. That's why, when advisory system is made, one of the most important sources of knowledge is expert's knowledge, because they can judge the correctness of conclusions made by this advisory system. Results of these conclusions are very often contradictory to other experts' conclusions and in some cases, compromise of common decision becomes impossible. For that reason we should examine expert team in relation to their competence and compatibility of conclusions.

PRELIMINARY SELECTION AND APPRECIATION OF EXPERTS

Preliminary number of experts is stated using the following algorithm (Fig. 1):

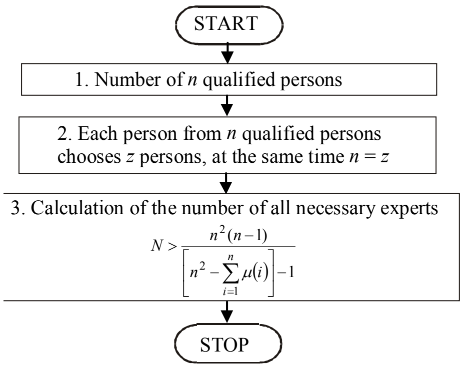

Fig. 1. Calculations algorithms of necessary experts number

Minimum – number of experts when we assume that every one of n experts choose the same number $z = n$ experts in their own group, is calculated from the formula:

$$N > \frac{nz(n-1)}{\left(nz - \sum_{i=1}^{n} \mu(i)\right) + 1} \tag{1}$$

where:

N – necessary number of experts,
z – qualified experts chosen by select experts,
$\mu(i)$ – number of not repeatable experts chosen by i-th expert from n-group.

When we assume that n experts choose the same number of experts i.e. $z=n$ than our formula reduces and we will have:

$$N > \frac{n^2(n-1)}{\left(n^2 - \sum_{i=1}^{n} \mu(i)\right) + 1} \tag{2}$$

To calculate necessary, preliminary number of experts, A, B, C, D, E, F, G, H experts from a certain institution were asked to choose eight experts from a narrow field of knowledge whom they personally know (results are shown in Table 1).Number of not repeatable experts (column 4) is stated with reference to the first group (column 2).

Table 1. Choosing wide group of experts

On.	Chosen experts n	Chosen $z=n$ experts by n experts	Number $\mu(i)$ not repeatable experts
	A	B;K;L;M;N;R;W	7
	B	A;C;J;L;M;P;X;Y	6
	C	A;D;G;K;L;N;P;R	5
	D	A;E;M;N;P;R;S;X	6
	E	B; K;M;N;P;S;T;U	7
	F	A;C;E;I;K;N;R;Z	5
	G	D;F;I;L;M;N;P;S	6
	H	C;D;F;G;R;S;T;U;	4
Altogether			46

When we replace formula number 2 with data from table number 1, we will get the necessary number of experts.

$$N > \frac{8^2(8-1)}{\left(8^2 - 46\right) + 1} = \frac{64 \times 7}{(64 - 46) + 1} = \frac{448}{19} = 23{,}578 \tag{3}$$

In this instance, a minimum group should consist of 24 experts. Since the number of all the experts presented by $n = 8$ chosen experts is 24, we may accept this number for further considerations as an elementary group of experts.

For the factual selection of each expert, objective indicators may be helpful such as: number of years' work or number of publications. Practice shows that expert's self criticism showing his comparative competence in different fields of knowledge may be relatively well correlated with his factual knowledge in this field, and so may be used in choosing experts from a group of specialists.

To estimate the degree of an expert's competence, the coefficient K_k was formed, of expert's competence expressed by formula number (4):

$$K_k = \frac{k_z + k_a}{2} \tag{4}$$

where:

K_k – coefficient of expert's competence,
k_z – coefficient of the degree of expert's knowledge of the issue,
k_a – coefficient of argumentation.

Coefficients k_z i k_a were based on self criticism of chosen experts. Each of these coefficients gets value from interval <0;1>, so coefficient K_k also gets value from interval <0;1>.

Each of the specialists competing to group of experts, defined his knowledge in issue by giving right quality of points from eleven point scale. Value of points to self criticism is shown in Table 2.

Table 2. Value of points to expert (specialist) self criticism

Value of points	Scale description
0	Expert doesn't know the issue.
1,2,3	Expert knows the issue poorly, but it is within the sphere of his interests
4,5,6	Expert knows the issue satisfactorily but he does not take part in its practical solution.
7,8,9	Expert knows the issue well and takes part in its practical solution
10	Expert knows the issue perfectly and it belongs to his narrow specialization.

Points chosen by expert are multiplied by 0,1 and the result is accepted as a coefficient of degree of knowing the issue by expert $k_{z.}$

Coefficient of argumentation k_a includes the structure of arguments, being the basis in the qualification opinion made by each expert for individual objects. The value of this coefficient may be calculated when we add up the values chosen by the expert in Table 3.

Table 3. Coefficient of argumentation k_a

Source of argumentation	Argumentation		
	high	middle	low
Theoretical analysis made by the expert	0,20	0,15	0,10
Practical experiment made by the expert	0,50	0,35	0,20
Knowledge of native authors' publications	0,05	0,04	0,03
Knowledge of foreign authors' publications	0,05	0,04	0,03
Expert intuition	0,20	0,17	0,14

Coefficient of argumentation should not be higher than 1, and its values k_a =1, k_a = 0.75, k_a = 0.5, are responsible for high, middle and low degree of influence of all sources of argumentation on the expert's opinion. The value of coefficient of argumentation k_a is going down while passing from practical experiment to theoretical analysis.

An analysis of the results received by each expert is shown in Table 4.

Table 4. The value of coefficient of expert's competence

Expert	A	B	C	D	E	F	G	H	**I**	J	**K**	L
k_a	0.97	0.93	0.77	0.80	0.82	0.79	0.71	0.83	0.57	0.59	0.53	0.77
k_z	0.9	0.9	0.7	0.8	0.8	0.8	0.7	0.8	0.6	0.7	0.5	0.7
$K_k = \frac{k_a + k_z}{2}$	0.935	0.915	0.735	0.80	0.81	0.795	0.705	0.815	**0.585**	0.645	**0.515**	0.735
Expert	**M**	N	O	P	R	S	**T**	U	W	X	Y	Z
k_a	0.56	0.83	0.76	0.79	0.82	0.71	0.53	0.76	0.56	0.83	0.59	0.77
k_z	0.6	0.9	0.8	0.8	0.9	0.8	0.6	0.7	0.7	0.9	0.7	0.7
$K_k = \frac{k_a + k_z}{2}$	**0.580**	0.865	0.780	0.795	0.86	0.755	**0.565**	0.73	0.63	0.865	0.645	0.735

When we state the threshold value of coefficient $K_k = \varepsilon$ (in consideration of the preliminary selected group ε = 0,6), on the basis of the calculated values, experts with K_k value lower than ε (K_k < 0,6) were removed. When we assume this, experts I, K, M, T will be removed. Table 4 shows in large type the experts who didn't satisfy the condition – coefficient K_k > 0,6. For further consideration the group of 20 experts was left.

DETERMINATION OF THE IMPORTANCE OF OBJECTS ON THE BASIS OF AN EXPERT'S OPINION

Multifunctional instruments (testers) carry out the measurement in case that we have doubts about because of different information levels provided by diagnostic signals. We can state that some information pieces are more and others are less essential to an operator of such an instrument. Stating each tester's functions as an object (to one function we can attribute several objects) we want to know which of them have the maximum information about the diagnosed object. Very often this statement is made by experts and this method is named: determination of the importance of objects on the basis of an expert's opinion.

In order to use this method, values of parameters measured by TESTER are shown as objects. Object diagram for measurements made by TESTER is shown in Fig. 2.

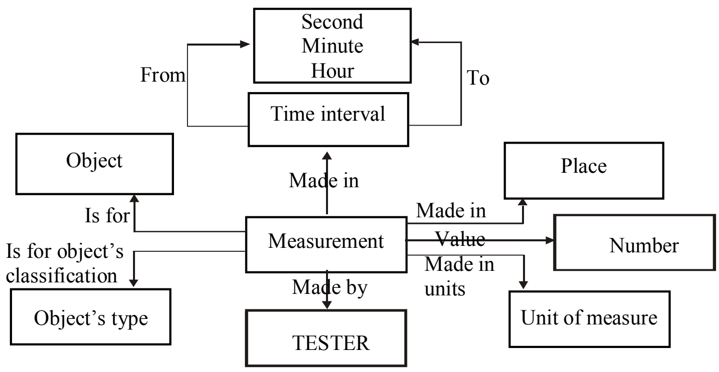

Fig. 2. Object diagram for measurements made by TESTER

From instrument’s function, the following elements were chosen and attributed to objects – symbols were given for simplification data during calculations (Table 5).

Table 5. State parameters measured by TESTER in object formulation

Unit of measure	Unit of measure	Object	Place measure	Symbol
Accumulator’s off-load voltage	[V]	Accumulator	Accumulator’s clamps	A1
Accumulator’s voltage during starting	[V]	Accumulator, starting resistance	Accumulator’s clamps	A2
Starting current intensity	[A]	Accumulator, starting resistance	Current conduit	A3
Accumulator voltage during engine’s work	[V]	Generator voltage control- ler, generator	Accumulator’s clamps	A4
Injection pressure level	[%]	Injection apparatus	Injection conduit with injector	A5
Liquid temperature	[^{o}C]	Cooling system, injection apparatus	Place where cool- ing liquid is out flowing from head	A6
Crankshaft’s revolutions on idle run	[rev/mi]	Injection apparatus	Injection conduit with injector	A7
Irregularity of crankshaft’s revolutions	[%]	Injection apparatus	Injection conduit with injector	A8
Dynamic angle of pumping start	[^{o}OWK]	Injection apparatus	Flywheel	A9
Pressure course in injection conduits	Course	Injection apparatus	Injection conduit with injector	A10
Relative fuel dose	[%]	Injection apparatus	Injection conduit with injector	A11
Effective power	[%]	Injection apparatus, combustion process	Injection conduit with injector	A12
Effective turning moment	[%]	Injection apparatus, combustion process	Injection conduit with injector	A13
Function COMPRESSION of cylinder’s tightness	[%]	Working area current conduit	Current conduit	A14

Group of 20 experts (A, B, C, D, E, F, G, H, J, L, N, O, P, R, S, U, W, X, Y, Z) made evaluation of 14 objects (marks). For better clarity of the considered problem the following assumptions were made:

m – number of experts taking part in the evaluation,

n – number of evaluated objects,

m_j – number of experts who are judging object A_j $j = 1,...k$,

m^1 – number of experts who are judging even one object (this method provides example when some experts didn't evaluate some objects because they are insufficiently competent),

$m_{\max j}$ – number of experts who gave maximum points in the evaluation of j-th object

c_{ij} – evaluation in points of relative importance of j-th object made by i-th expert.

An expert can give from 0 to K points, when he is not competent enough he gives "-". The top limit of K scale is bigger or equal to the repeated multiplication of objects, to make a possibility of giving different objects different evaluations.

n^1 – number of objects evaluated at least by one expert.

There is an assumption that each object is evaluated at least by one expert, and each expert evaluates at least one object.

An elementary indicator of a generalized expert's opinion may be, stated for every j-th object ($j = 1, 2, ...n^1$), an average value of his evaluation M_j (in points) expressed by the formula:

$$M_j = \frac{\sum_{i=1}^{m_j} c_{ji}}{m_j} \tag{5}$$

Value M_j is equal to the bottom limit of point scale and shows an example, when all the experts assessing the j-th object give the smallest possible evaluation of importance. Value M_j equal to the top level of the point scale means that all experts give the biggest possible evaluation. The biggest value M_j is, the more important is the object.

A complementary value which characterizes a generalized opinion of a group of experts about the relative importance of objects is the frequency of the biggest possible evaluation for j-th object $K_{\max j}$ expressed by the formula number 6.

$$K_{\max j} = \frac{m_{\max j}}{m_j} \tag{6}$$

where:

$j = 1,..., n^1$

Value $K_{\max j}$ gets values from interval <0;1>. It characterizes the meaning of object from the point of view of giving first places. Results of expert's evaluation are shown in Table 6. Value $K_{\max j}$ is written as a simple fraction for exposing a number of first places. Some of experts did not make evaluation of some objects, for these objects points were calculated from the average of other objects (these examples in Table 6 are grey).

Table 6. Results of expert's evaluation

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	**L**	**N**	**O**
A1	20	20	10	20	30	40	30	20	10	20	20	20
A2	50	70	90	90	90	90	80	40	70	80	80	80
A3	50	30	70	90	90	80	60	100	80	70	60	70
A4	50	75	60	80	90	70	80	100	90	60	80	80
A5	100	100	89	90	89	89	89	50	80	90	100	80
A6	80	100	79	80	70	80	70	80	90	80	80	80
A7	50	60	64	30	50	60	70	100	50	70	70	70
A8	20	80	63	20	60	60	70	70	70	70	70	70
A9	20	60	57	80	50	80	70	60	70	50	50	60
A10	20	40	64	60	80	80	70	50	70	70	70	60
A11	50	50	53	30	50	70	60	40	60	60	60	40
A12	70	100	82	90	90	70	80	80	90	70	80	80
A13	80	100	79	90	90	80	70	80	80	70	70	80
A14	100	80	93	100	90	80	80	90	100	90	90	100

	P	**R**	**S**	**U**	**W**	**X**	**Y**	**Z**	**Total**	**M_j**	**K_{maxj}**
A1	30	10	20	20	10	20	20	20	410	20,5	0/20
A2	70	60	80	80	80	70	80	80	1510	75,5	0/20
A3	80	70	50	70	80	80	60	70	1410	70,5	1/20
A4	70	80	80	60	70	80	80	80	1515	75,75	1/20
A5	90	100	90	80	90	90	90	100	1776	88,8	5/20
A6	80	70	80	70	80	80	80	80	1589	79,45	1/20
A7	50	70	70	70	70	60	70	70	1274	63,7	1/20
A8	70	60	70	60	70	70	70	70	1263	63,15	0/20
A9	50	50	60	50	50	60	50	60	1137	56,85	0/20
A10	70	70	70	70	50	70	70	70	1274	63,7	0/20
A11	60	60	60	60	60	40	60	40	1063	53,15	0/20
A12	80	90	80	90	70	80	70	90	1632	81,6	1/20
A13	70	80	80	80	70	80	70	80	1579	78,95	1/20
A14	90	100	100	90	100	100	90	100	1863	93,15	9/20

CONCLUSIONS

Methods of collective evaluation of experts should be used everywhere where we don't have data from observation or we don't have coherent, well-founded and objectively checked theory which states correlation, casual nexus between observed occurrences.

Using the object model in evaluation of measurement functions in diagnostic instruments allows us to order the diagnostic parameters realized during a diagnostic analysis according to an expert's knowledge and intuition.

Methodology of choosing experts from a group of specialists and collective evaluation of objects may be used wherever an evaluation of these objects in consideration of some distinguished quality is required.

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SUMMARY

The paper presents rules of assessment by a minimum number of experts, introduced to be of help in a diagnostic decision. It can solve the most important problem in many diagnostic procedures, mainly, frequent cases of little credibility of results of investigations. It is also a most important question in the theory of complete expert knowledge for building advisory systems.