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AN EXPERT SYSTEM FOR SELECTION OF LOWER EXTREMITY (THIGH) PROSTHESIS AND EVALUATION OF PROSTHETIC QUALITY (PART II)

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1. INTRODUCTION

Part I* of this article was devoted to discussion of the general structure of an expert system (ES) for selection of lower limb prostheses and of its subsystems (ES for selection of prosthetics on the basis of absolute and relative contraindications, ES for selection of units and corresponding codes, and ES for determination of parameters for fitting of prostheses). Examples of the functioning of the separate subsystems with patients were given.

Part II of the article is devoted to discussion of the problems of diagnostics and evaluation of the prosthetic quality as a subsystem, and of software and hardware for the operation of the general ES.

2. EXPERT SYSTEM FOR DIAGNOSTICS OF PROSTHETIC QUALITY

Using automated logical output which relies on a knowledge base (KB) of experts, observations of the physician, complaints of the patient, and bench testing, the ES for the evaluation of prosthetic quality (ES EPQ) was developed to reveal defects of prosthetics, in particular for invalids with unilateral amputation of the thigh. This ES allows the determination of the presence and extent of expression (on a scale of 0-10) of about 100 defects of prosthetics while using approximately the same number of fuzzy† signs.

The main KB of the ES EPQ is the KB of the physician-prosthetist, where defects of prosthetics (contraindications for prosthetics, errors in the choice of the units of the prosthesis, and errors in the development of the scheme for fitting) are linked by fuzzy relations with symptoms of the defects (complaints of the patient and visual observations of the prosthetist). A fragment of the knowledge base is presented in Table 1.

The local system ES EPQ is based on the FOKUS system [10] and provides logical, goal, and graphic support.

Logical Support. The most probable defect and (or) group of defects are determined from the entered symptoms. The logical output is based on fuzzy logic and allows the use of a broad range of variability of symptoms. The logical output attempts to explain each specific symptom and has high sensitivity to the extent of its expression.

The diagnosis is expressed in percent (0-100) and shows how precisely the entered set of symptoms characterizes the set of decisions obtained. The procedure of the logical output allows diagnostics under conditions of uncertainty when a number of symptoms are not determined. When a symptom is completely uncertain the user sets its value as the interval (0-10), thus excluding it from consideration.

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*É. K. Amirnova, V. A. Efimov, A. P. Kuzhekin et al., Med. Tekh., No. 3, 26-31 (1991).

†For basic definitions of fuzzy set theory and fuzzy logic see [6].

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TABLE 1. Fragment of the KB for Making Decisions on the Basis of Observation of the Prosthetist

Section 1

N	Defects
1	Tight reception sheath
2	Excessive horizontal divergence of "knee-crus" unit
3	Insufficient angle "X" (varus prosthesis construction)
4	Tight knee unit
5	Rigid back buffer
* 6	Excessive equinus of foot (foot bending)
7	Excessive forward motion of foot

Section 2

N	Symptoms
1	Complaint of painful stump with prosthesis
* 2	Pain in groin caused by front edge of reception sheath
3	Pain in perineum
4	Increase in step width
5	Decrease in step width
* 6	Accent on the healthy leg when walking
7	Bending of body over the prosthesis when walking
8	Leaning toward the side with prosthesis
* 9	Leaning of the patient backwards
10	Cyanosis and edema of the distal segment of the stump
11	Hyperemia (rubor) of skin in areas of load
12	Loose-fitting reception sheath ("outer pocket")
* 13	Hampered transference of the prosthesis (toe catching)
* 14	Hampered transference of body from prosthesis
15	SP: sharp forward motion of prosthesis crus
16	Distance between medial line and knee hinge increased
17	Insufficient bending of prosthesis at knee hinge
18	SP: decreased amplitude of motion at knee hinge
19	Hesitation on heel
20	Rotation of the heel
21	Load on the outer edge of foot
22	Load on the inner edge of foot

Section 3

an/Pr	1	2	3	4	5	6	7	8
1	7-10					5-10		
2				7-10		3- 7	7-10	
3			5-10		5-10	3-10		5-10
4								
5								
6		5-10				0- 5		
7		3- 7						

an/Pr	9	10	11	12	13	14	15	16
1		5-10	7-10		2-10			
2					2- 5			5- 7
3			3-10	5-10				7-10
4					5-10		7-10	
5						5- 7		
6	5- 7				5- 7	7-10		
7	2- 5				3- 7	5-10		

an/Pr	17	18	19	20	21	22
1						
2						2- 5
3					7-10	
4	5-10	5-10				
5			7-10	5-10		
6						
7			4- 7			

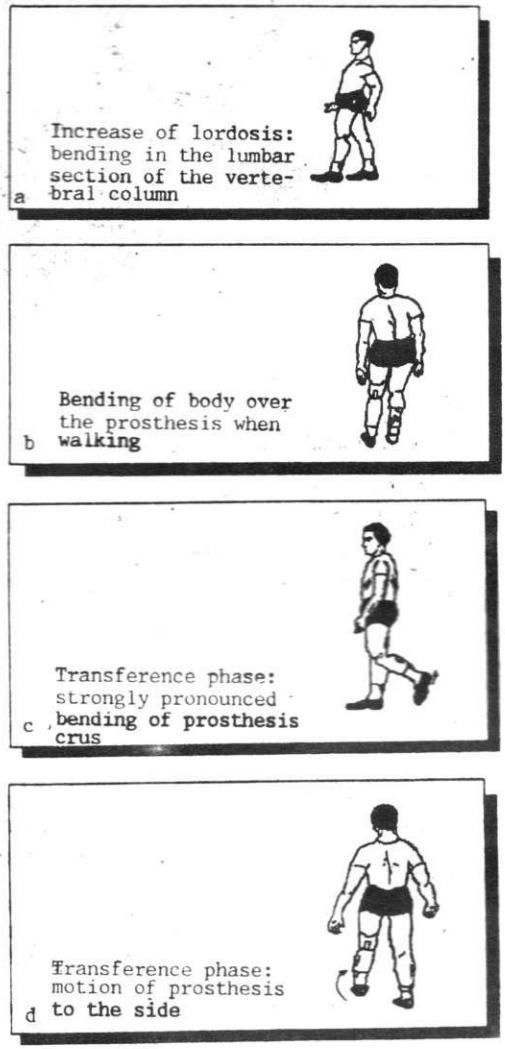

Fig. 1. Examples of graphic support in ES EPQ: a) observed symptom "increase of lordosis: bending in the lumbar section of the vertebral column;" b) observed symptom "bending of body over the prosthesis when walking;" c) observed symptom "transference phase: strongly pronounced bending of prosthesis crus;" d) observed symptom "transference phase: motion of prosthesis to the side."

As was already noted [2], the system can function in both forward and backward logical modes. When using backward logical mode the user can check his hypothesis concerning the presence of a specific defect (or group of defects) of prosthetics from the initial set of symptoms. The system can either prove the suggested hypothesis or reject it.

Goal Support. A list of recommendations for achieving the goal of eliminating each defect is provided.

Graphic Support. To assist the physician and to support his visual observations a number of symptoms are represented in graphic form (Fig. 1). More than 20 characteristic graphic images of defects with their linguistic descriptions are provided by the system.

The second KB in the ES EPQ is the KB of the physician-prosthetist and engineer-prosthetist which relies on the fuzzy links between defects of prosthetics and their symptoms obtained during bench testing. It should be noted that this KB has objective character only concerning the results of testing (curves, signals from light diode, etc.) but as in the case of the previous KB has subjective character concerning interpretation of the results of testing (link between observed symptoms and defects).

TABLE 2. Content of Bench Testing KB

N	Anomalies
1	Loose reception sheath
2	Insufficient rigidity of anterior foot segment
3	Insufficiently effective prosthesis binding
4	Prosthesis too long

N	Symptoms
1	SP on the healthy extremity: additional (specific) extrema in the region of the main minimum
2	Main minimum is displaced with respect to the mean
3	SP on the healthy extremity: additional extremum after passing the main functional minimum
4	SP on prosthesis: lack of maximum at push-off
5	TP: HJ amplitude is extremely enlarged
6	Steepness of AJ graph is extremely large at transference from plantar to dorsal maximum compared to the same fragment for healthy extremity
7	Healthy extremity AJ shape changes from step to step
8	SP on healthy extremity: AJ shape has additional dorsal bending ("jumping" effect)
9	Variability of SP is more than 40-50 msec
10	Bipedal support interval enlarged, prosthesis back

	1	2	3	4	5	6	7	8	9	10
1	5-10				5-10					5-10
2				5-10		5-10				5-10
3	5-10	5-10			5-10		5-10		5-10	
4			5-10					5-10		

Notes. AJ) Ankle joint; SP) support phase; TP) transference phase; HJ) hip joint.

The results of bench testing should be coordinated with the main KB (KB of the physician-prosthetist). Fragments of the KB of interpretation of the bench testing [9] and the corresponding fuzzy links are presented in Table 2. Coordination of two knowledge bases during the diagnostic process allows separation of the objective and subjective symptoms and increases the confidence level of the evaluation of the prosthetic quality, and also fulfills the requirements of an ES of the second generation having depth of presentation of knowledge.

All of the prosthetic defects may be provisionally divided into three main groups: defects caused by ignoring contraindications to prosthetics; defects caused by improper choice of units and their adjustment and use; defects caused by errors in the scheme of fitting of the prosthesis.

Diagnostics of prosthetic quality from the mentioned groups of defects is complicated because of the fact that various prosthetic defects are expressed by a rather limited set of symptoms. There are a number of symptoms which are characteristic of a large group of defects; the superposition of symptoms deteriorates the real diagnostic picture; change of the walking pattern depends strongly on the individual characteristics of the patient (type of gait, nature of the injury, age, physique, etc). As a result the manifestation of the same prosthetic defect may be significantly different in different patients. Thus, when preparing the KB it is necessary to enter a significant supplement of symptoms to provide for stability of the logical output of the system.

For convenience in the use of the system all symptoms are divided into nine main groups: sensations of pain, changes in the patient's body, changes in step, figure of walking, prosthesis transference, foot, knee hinge, reception sheath, and additional symptoms. All symptoms are informative in the sense that any obviously observed symptom is always determined by the existence of some defect.

TABLE 3. Defect Diagnostics

Forward logical mode M Diagnosis = 90

N	Observed symptoms	Values	
1	Increase in step width	10	10
2	Accent on the healthy leg when walking	2	5
3	Bending of body over the prosthesis when walking	5	7
4	Hampered transference of the prosthesis (toe catching)	3	7
5	Distance between medial line and knee hinge increased	5	5
6	Load on the inner edge of foot	2	4

Forward logical mode M Diagnosis = 90

N	Expected defects	MIN	MAX
1	Excessive horizontal divergence of "knee-crus" unit	10	10

TABLE 4. Defect Diagnostics in the Absence of Several Symptoms

Forward logical mode M Diagnosis = 80

N	Observed symptoms	Values	
1	Increase in step width	10	10
2	Accent on the healthy leg when walking	2	5
3	Bending of body over the prosthesis when walking	5	7
4	Distance between medial line and knee hinge increased	5	5

Forward logical mode M Diagnosis = 80

N	Expected defects	MIN	MAX
1	Excessive horizontal divergence of "knee-crus" unit	9	10

TABLE 5. Diagnostics of Defect by Forward Logical Mode and Analysis of Specific Defect by Backward Mode

Forward logical mode M Diagnosis = 80

N	Observed symptoms	Values	
1	Pain in groin caused by front edge of reception sheath	3	7
2	Hampered transference of the prosthesis (toe catching)	2	5
3	Hampered transference of body from prosthesis	7	10
4	Hesitation on heel	7	10
5	Rotation of the heel	7	10

Forward logical mode M Diagnosis = 80

N	Expected defects	MIN	MAX
1	Rigid back buffer	6	10
2	Excessive forward motion of foot	0	10

Backward logical mode M Diagnosis = 60

N	Expected defects	MIN	MAX
1	Rigid back buffer	6	10

Backward logical mode M Diagnosis = 20

N	Expected defects	MIN	MAX
1	Excessive forward motion of foot	0	10

TABLE 6. Diagnostics of Defects and Evaluation of the Change in Reliability in the Absence of Several Symptoms by the Forward Logical Mode and Analysis of Specific Defect by Backward Logical Mode

Forward logical mode M Diagnosis = 70

N	Observed symptoms	Values	
1	Complaint of painful stump with prosthesis	5	5
2	Accent on the healthy leg when walking	3	7
3	Cyanosis and edema of the distal segment of the stump	5	5
4	Hyperemia (rubor) of skin in areas of load	5	7
5	Hampered transference of the prosthesis (toe catching)	3	7
6	Hampered transference of body from prosthesis	5	10
7	Hesitation on heel	3	5

Forward logical mode M Diagnosis = 70

N	Expected defects	MIN	MAX
1	Tight reception sheath	3	10
2	Excessive forward motion of foot	0	10

Backward logical mode M Diagnosis = 40

N	Expected defects	MIN	MAX
1	Tight reception sheath	0	10

Backward logical mode M Diagnosis = 40

N	Expected defects	MIN	MAX
1	Excessive forward motion of foot	0	10

TABLE 7. Defect Diagnostics in the Absence of a Symptom

Forward logical mode M Diagnosis = 70

N	Observed symptoms	Values	
1	Pain in perineum	7	10
2	Decrease in step width	3	6
3	Leaning toward the side with prosthesis	3	7
4	Hyperemia (rubor) of skin in areas of load	5	7
5	Loose-fitting reception sheath ("outer pocket")	7	10
6	Distance between medial line and knee hinge increased	5	7
7	Load on the outer edge of foot	3	6

Forward logical mode M Diagnosis = 70

N	Expected defects	MIN	MAX
1	Insufficient angle "X" (varus prosthesis construction)	5	10

TABLE 8. The Influence of Insufficient Expression of Observed Symptoms on Defect Diagnostics

Forward logical mode M Diagnosis = 90

N	Observed symptoms	Values	
1	Hampered transference of the prosthesis (toe catching)	2	4
2	SP: sharp forward motion of prosthesis crus	5	5
3	Insufficient bending of prosthesis at knee hinge	3	7
4	SP: decreased amplitude of motion at knee hinge	2	4

Forward logical mode M Diagnosis = 90

N	Expected defects	MIN	MAX
1	Tight knee unit	5	6

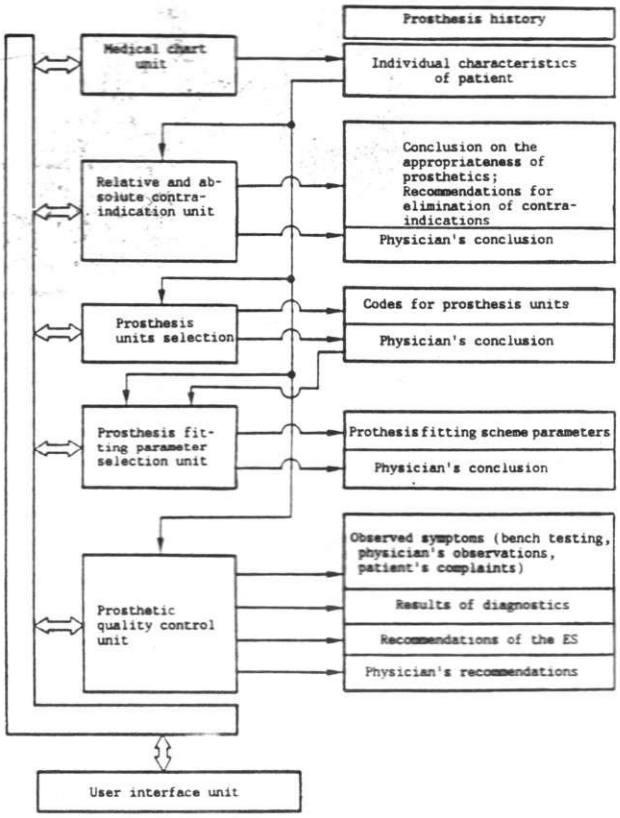

Fig. 2. Structure of the module "prosthesis history."

We will consider a number of examples to demonstrate the functioning of the ES EPQ subsystem.

A fragment the KB of the physician-prosthetist with corresponding fuzzy links is presented in Table 1. Section 1 of this table presents a list of possible prosthetic defects, Section 2 describes a list of symptoms which could be observed by a physician as a result of the defects mentioned in Section 1, and Section 3 presents the logical relations establishing correspondence between the considered prosthetic defects and their visual expression. Each symptom is described by a lower and upper limit.

The formation of a KB for the ES EPQ can be demonstrated with the following examples.

Example 1. Prosthetic defect number 6 in Section 1 of Table 1 (marked with an asterisk), "excessive equinus of foot (foot bending)," has the following symptoms:

– "pain in groin caused by front edge of reception sheath" (number 2, Section 2). This symptom is always present for this defect and usually markedly expressed [interval evacuation of (5-10)];

– "accent on the healthy leg when walking" (number 6, Section 2). For this defect the considered symptom may be moderately expressed or not expressed at all [interval evaluation of (0-5)];

– "leaning of the patient backwards" (number 9, Section 2). This symptom is present and moderately expressed [interval evaluation of (5-7)];

– "hampered transference of the prosthesis (toe catching)" (number 13, Section 2). This symptom is present and moderately expressed [interval evaluation of (5-7)];

– "hampered transference of body from prosthesis" (number 14, Section 2). This symptom is always present for this defect and markedly expressed [interval evaluation of (7-10)].

We will consider the functioning of the ES EPQ with the following complementary examples.

Example 2. The given set of symptoms can be fully explained by the presence of one defect (Table 3).

Example 3. If symptoms 4 and 6 in Example 2 are not observed the reliability of the diagnosis of the corresponding anomaly (defect) decreases from 90 down to 80% (Table 4).

Example 4. The given set of symptoms can be explained by the presence of the first defect (Table 5) (evaluation of [6-10]); a second defect may be present [evaluation of (0-10)]. Analysis of this kind of result may be performed in more detail by the backward logical mode (see Example 8 below).

TABLE 9. Results of Diagnostics of Defects Taking into Account the Biomechanical Characteristics of Patient's Gait

Forward logical mode • Biomex Diagnosis • 100

Observed symptoms	Values
SP on the healthy extremity: additional (specific) extrema in the region of the main minimum	
TP: HJ amplitude is extremely enlarged	
Variability of SP is more than 40-50 msec	

Expected anomalies	Min	Max
Loose reception sheath	5	10

Forward logical mode Biomex Diagnosis • 100

Observed symptoms	Values
SP on prosthesis: lack of maximum at push-off	
Steepness of AJ graph is extremely large at transference from plantar to dorsal maximum compared to the same fragment for healthy extremity	
Bipedal support interval enlarged, prosthesis back	

Expected anomalies	Min	Max
Insufficient rigidity of anterior foot segment	5	10

Forward logical mode Biomex Diagnosis • 100

Observed symptoms	Values
SP on the healthy extremity: additional (specific) extrema in the region of the main minimum	
Main minimum is displaced with respect to the mean	
SP on the healthy extremity: additional extremum after passing the main functional minimum	
TP: HJ amplitude is extremely enlarged	
Healtny extremity AJ shape changes from step to step	
SP on healthy extremity: AJ shape has additional dorsal bending ("jumping" effect)	
Variability of SP is more than 40-50 msec	

Expected anomalies	Min	Max
Loose reception sheath	0	10
Insufficiently effective prosthesis binding	5	10
Prosthesis too long	5	10

Example 5. The given set of symptoms can be explained by the presence of two defects simultaneously (Table 6). The absence of symptoms 2 and 9 from Section 2 of Table 1 results in a decrease in the reliability of the diagnosis and also the probability of the second defect (for more detailed analysis of this example by the backward logical mode see Example 9 below).

Example 6. In this case (Table 7) the reliability of the diagnosis decreases because of the absence of symptom 6 from Section 2 of Table 1.

Example 7. Decrease in reliability of the diagnosis and of upper limit of probability of the defect are explained (Table 8) by the insufficiently pronounced expression of the observed symptoms compared with that of Section 3 of Table 1.

We now consider the above examples using the backward logical mode of the logical support block. The forward mode procedure assumes initially that all possible defects (Section 1, Table 1) may be present, and those which best characterize the given list of symptoms are chosen. The backward logical mode allows the analysis of the presence of a specific defect (or group of defects) using a given list of symptoms. The combination of these two procedures (forward and backward modes) allows more detailed analysis of the uncertainty present in the considered situation.

Example 8. As was shown in Example 4, the two most probable (forward mode) defects were "rigid back buffer" and "excessive forward motion of foot." The question remained whether both these defects were present or only one or the other of them. The backward logical mode provided the answer to this question (Table 5). For this purpose each defect is supposed to exist alone:

TABLE 10. Results of Diagnostics of Defects of Patient A. and Recommendations for Elimination of Defects

Forward logical mode MED1 Diagnosis = 70

N	Observed symptoms	Values	
1	Increase in step width	7	10
2	Bending of knee joint of healthy leg	7	10
3	Bending of body over the prosthesis when walking	3	7
4	Distortion of pelvis to the stump side	7	10
5	SP: sharp forward motion of prosthesis crus	5	7
6	Distance between medial line and knee hinge increased	5	7
7	SP: rotation of the heel	3	7
8	TP: crus swings to inside	2	4

Forward logical mode MED1 Diagnosis = 70

N	Expected defects	MIN	MAX
1	Abduction contracture is unbalanced	0	10
2	Insufficient prosthesis length	5	10
3	Excessive horizontal divergence of "knee-crus" unit	0	10
4	Tight knee unit	0	10
5	Hard heel and sole of shoe	0	10

Back ward logical mode MED1 Diagnosis = 60

N	Expected defects	MIN	MAX
1	Abduction contracture is unbalanced	4	10
2	Insufficient prosthesis length	4	10
3	Tight knee unit	2	10

Abducent contracture is unbalanced

Recommendations:

– when designing prosthesis specify tolerance for abduction contracture. Simultaneously conservative treatment and training of contracture should be prescribed;
– when abduction contracture is strongly expressed and fulfillment of previous recommendation is impossible, surgery (correcting subtrochanteric osteotomy) should be prescribed.

Insufficient prosthesis length

Recommendations: check stump–prosthesis fit. If fit is normal, determine which segment is shortened. Lengthen prothesis crus and/or thigh.

Tight knee unit

Recommendations: loosen knee unit and adjust to function optimum

Excessive horizontal divergence of "knee-crus" unit

Recommendations: shift reception sheath in horizontal plane to the outside (increase X2 value). Parameter "angle X" may be enlarged.

– defect "rigid back buffer" is present and varies in the interval of (6-10), all the other defects (including "excessive forward motion of foot") are absent, i.e., their probabilities is (0-0);

– defect "excessive forward motion of foot" is present and varies in the interval of (0-10), all other defects are absent (0-0).

Backward mode predicts the presence of the defect "rigid back buffer" with a reliability of diagnosis of 60%. The decrease in reliability when compared with the forward logical mode is explained by the fact that in forward mode symptoms 1 and 2 could be explained by the second defect "excessive forward motion of foot." If the second defect is excluded these

symptoms remain unexplained, which results in a decrease in the reliability of the diagnosis. A similar procedure with respect to the second defect "excessive forward motion of foot" results in a decrease in the reliability of the diagnosis to 20% because the strongly expressed symptoms 4 and 5 cannot be explained by the presence of this defect.

The analysis performed showed that either both considered defects or only the defect "rigid back buffer" are present in the system.

Example 9. Analysis of results of Example 5 shows (see Table 6) that the most probable situation is the simultaneous presence of two defects, "tight reception sheath" and "excessive forward motion of foot."

Experience in the application of the ES shows that it is reasonable to use both forward and backward logical modes in diagnostics. Their combination provides more detailed analysis in cases where the presence of the defects is uncertain. If errors were made in the development of the scheme of fitting of the prosthesis (the recommended dimensions were not followed at stage 3) or materials other than those recommended were used at stage 4, then the physician can diagnose these errors using the backward logical mode for the observed set of symptoms.

3. SOFTWARE AND HARDWARE FOR THE ES

The ES is an integrated application program package which can be divided into three macro blocks: modified ESPLAN [1] and FOKUS [10] shell programs and an integrated environment providing a number of service functions [2, 3].

The use of modular programming techniques provides for high flexibility of the program package. The package reflects the general functional structure of the system and the scheme of information flow (Fig. 2). Each layer is implemented as a module, the "prosthesis history" (a term used in prosthetics) module being the connecting link.

The formation of the connecting module for each patient begins with filling in of the "medical chart" unit and continues along the stages of the process of prosthetics. The "prosthesis history" module contains a bus for bidirectional transfer of information between each of its units and between units and operator, thus providing for the input and transfer of information.

It should be noted that the stage of prosthetic quality control is performed much later than other stages; the "prosthesis history" module archives the necessary information.

The system is based on the menu principle. The user is presented with a menu bar with options "medical chart," "achieving," "contraindications," "prosthesis unit selection," "fitting," "quality control," "help," "prosthesis history," and "exit."

The system is available in two variants, for routine use and for training. The latter has a larger help library to assist trainees in operation of the system and in orientation in the field of prosthetics. For example, the training version includes a help line for each command of the main menu.

The system also includes a number of service utilities for creation and editing of a KB, for data output to a printer, and a multi-window interface. The system utilizes the algorithmic languages PROLOG, PASCAL, and C, which are typical of expert systems of second generation [11].

The system requires an IBM PC XT/AT (or compatible) with a minimum of 640 kbyte RAM, a graphic adapter (CGA, EGA, or VGA), interface for "Epson FX-800" (or FX-1000) printer, and a color monitor. The ES functions with the MS DOS operating system (version 3.3).

4. RESULTS OF PRACTICAL APPLICATION OF THE ES

The system was tested in practice in the clinic of the TsNII of Prosthetics of the Russian Ministry of Social Security and in the polyclinic of the Moscow Orthopedic Workshop.

For this purpose a group of patients with different ages, levels of amputation, conditions of the stump, accompanying diseases, and prosthetics history (primary and secondary) was selected.

The methodology of the studies consisted of the following stages:

– registration of the case history including reason and time of amputation, prosthesis design (for patients with secondary prosthetics), occupation of the patient, activity, character of social and environmental conditions, and other data about the patient which could significantly influence the making of a decision;

– clinical examination of the condition of the locomotor system of the patient, which was performed in three stages: examination of the condition of the stump, support phase of the prosthesis, and transference phase of the prosthesis.

The examination of the condition of the stump was carried out to reveal pathologies which would prevent the prosthetic process.

In the support phase the following parameters were evaluated: correspondence of the length of the prosthesis to the length of the healthy extremity, quality of the stump–reception sheath fit, ratio of segments of the extremity, quality of adjustment of binding, etc.

In the transference phase the patient was asked to walk on an even surface at various walking rates, and characteristics of gait connected with defects of prosthetics were registered. On the basis of bench testing, methods described in [4, 5, 7-9], and the KB from Table 2, prosthetic defects were determined and specified with corresponding interpretation (see examples from Table 9).

We will consider an example of application of the ES according to the procedure described.

Example. Patient A., 27 years old, underwent right thigh amputation in 1986 due to an injury sustained in an industrial accident, uses a prosthesis actively.

Results of examination: right thigh stump is two-thirds in length, of muscular type, painless, and of conical shape. Moderate atrophy of tissues of stump, post surgical cicatrix is mobile, painless, and not joined with the underlying tissues. Motion in right hip joint is not restricted, small abduction contracture is observed. Skin hyperpigmentation at sites of adductor muscle attachment is observed.

The thigh prosthesis used by the patient is uniaxial, lockless, with polyamide-gauze reception sheath reinforced along anterior and posterior parts.

The results of diagnostics of prosthetic quality and recommendations for the elimination of defects revealed by the ES EPQ are presented in Table 10.

Recommendations of the system for selection of units of the prosthesis and parameters of the scheme of fitting are presented Part I of this paper.

Analysis of the results of diagnostics shows that the set of symptoms (see Table 10) may be explained by five defects. It was necessary to elucidate whether the observed symptoms could be explained by a single defect or only by a combination of two or more defects. The backward logical mode helps to elucidate this question.

The first hypothesis was not confirmed (sharp decrease in the reliability of the diagnosis); the coexistence of defects 1, 2, and 4 (Table 10) best fits the observed symptoms. In spite of some decrease in the reliability of the diagnosis, the precision of prediction of defects increased. Other combinations of the defects were not confirmed (low reliability of the diagnosis).

After following the recommendations (Table 10) of the system obtained with use of the goal support block of the ES EPQ the walking pattern of the patient improved, walking with the prosthesis became more comfortable, and no further complaint was received from the patient.

5. CONCLUSIONS

The developed and tested ES for selection of prostheses of the lower extremities and diagnostics of the prosthetics quality has the following characteristics.

1. It takes into account the fact that decision making is influenced by many factors and criteria.
2. It possesses a flexible decision making system (it selects a few alternative decisions and evaluates the reliability of each).
3. It provides the functions of a training system with depth of presentation of knowledge.
4. It reduces the number of iterations of working procedures during selection and adjustment of a prosthesis.
5. It provides a positive psychological influence on the patient, therefore decreasing the number of conflicts between patient and physician.
6. It provides a prognosis of needs for various prosthesis units on the basis of statistical data about patients.
7. It increases the diagnostic reliability in the evaluation of quality of prosthetics (when using the ES it was found that even an expert prosthetist sometimes fails to consider all possible combinations in the system of relations symptom–defect).

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