DOI: https://doi.org/10.15407/kvt210.04.080

KUTSIAK O.A., PhD (Engineering),
Senior Researcher of the Bioelectrical Control & Medical Cybernetics Department
ORCID: 0000-0003-2277-7411, e-mail: spirotech85@ukr.net

International Research and Training Center for Information Technologies
and Systems of the National Academy of Sciences of Ukraine
and the Ministry of Education and Science of Ukraine,
40, Akad. Hlushkov av., Kyiv, 03187, Ukraine

MOBILE SYSTEM FOR THE PATIENT'S MOTOR FUNCTIONS STATE DIAGNOSTICS

Introduction. *The diagnostics of motor functions state plays an important role both as a result of the central nervous system impairments (stroke etc.) and as a result of injuries, traumas etc. As mobile devices expand the possibilities of modern medicine, the actual task is the synthesis of an effective mobile system for the motor functions state diagnosing at various stages of rehabilitation.*

The purpose of the paper *is to develop a mobile system for personalized motor functions diagnostics for recovery of motor functions and speech motility, which functional capabilities contribute to the rehabilitation effectiveness increasing and usability both in clinical and home conditions, as well as in the fields conditions.*

Results. *The motor and speech functions recovery in patients both after affection of the central and peripheral nervous system, as well as after injuries and traumas, in particular not only in clinical, but also in home and field conditions, makes requirements for personalization, mobility, ease of perception and usability of information given to the user.*

According to the requirements, the interface of mobile system for the motor function diagnostics was developed: set of user tasks was defined, scenario was developed for the patient to test own motor functions within the mobile system. The relation database's infologic model has been developed for the storage and accumulation of patients' motor functions data and following analysis by a physician.

The algorithm for personalized motor functions diagnosing has been developed. It is based on expanded range of evidence criteria without taking into account by known analogues. The algorithm is implemented in the MovementTestStroke 1.2 mobile system with taking into account the interface and relation database. Such a system provides objectification of assessment, reduction of the probability of a physician's error and urgency in diagnostic and treatment decision-making, provides necessary and sufficient information to the user in a convenient digital and graphical forms, simplifies for the physician the motor functions state analyzing and the personalized treatment strategy creating.

Conclusions. *The mobile system MovementTestStroke 1.2 for motor function diagnostics can be used in clinical and home conditions to assess the motor functions state affected by central nervous system pathologies. With some system's modification based on additional research it can be used to assess the state of motor functions affected also by injuries and traumas. This creates the basis for personalized, mobile, urgent diagnostic and treatment decision-making by the physician.*

Keywords: *diagnostics, motor functions, quantitative assessment, criteria, algorithm, software system, mobile system, stroke, injuries*

INTRODUCTION

Movement activity is an extremely important factor in the creation, preservation and recovery of health. The movement activity disorders occur in people both as a result of the central and peripheral nervous system impairments (stroke, cerebral palsy, neuropathy etc.), and as a result of injuries, traumas etc. Also the speech disorders, among which motor aphasia is the most common, occupy a significant place as a result of such impairments [1–3].

Full rehabilitation of motor and speech functions is associated with the mobilization of the patient's reserves, which is adequate to the patient's state, to recover these impairment or lost functions. Therefore at all rehabilitation stages the diagnostics (quantitative assessment) of motor functions state as well as their recovery effectiveness, in particular for the creation of a personalized treatment strategy, plays the important role [4, 5]. It is emphasized that such a diagnostics is important not only for patients after a stroke or with impairments of the peripheral nervous system, as well as in the case of injuries [6] and the usage of the quantitative diagnostics methods of the motor functions state can play an important role in a physician's decision-making assisting in the monitoring for personalized recovery progress of these functions and the planning of necessary actions in its controlling [7].

The wide access to mobile devices affects on digital medicine development, so the usage of mobile systems in modern medicine is perspective. It is noted that mobile devices can expand the possibilities of making the diagnostic and treatment decisions by a physician [8, 9]. Mobility means not only the implementation on the mobile platforms basis, but also the convenience of obtaining the necessary and sufficient information for the urgent making the diagnostic and treatment decisions by a physician.

After the completion of the patient's general rehabilitation in clinical conditions, the patient's treatment in most cases continues at home under the supervision of a physician, so mobile diagnostics systems may be used by the patient.

It should be noted, that since many people are being injured in wartime, a physician need to monitor the patient's recovery process within the motor functions rehabilitation, in particular, to diagnose the motor functions state of extremities in order to adjust the rehabilitation strategy. Therefore, in these conditions mobile means of motor functions diagnostics have also a place, as they enable to a physician the urgent decisions-making.

Therefore, the synthesis of an effective mobile system for diagnosing the state of motor functions at various stages of rehabilitation is an urgent task. The solving of this actual problem requires the usage of the methods and means of digital medicine and their further development.

PROBLEM STATEMENT

In world practice, the various methods and tools are used to diagnose the patients' motor functions. The method of three-dimensional motion capture is widely used in the practice for motor functions assessment [5, 7, 10]: for this purpose the sensors-markers are placed on certain areas of the patient's extremities. Movements are captured by the camera, and after that the results are processed by appropriate algorithms. There are also complexes for motor functions assessment, where the movements fixa-

tion is used with the help of hybrid sensors that combine the functions of an electromyogram recording, an accelerometer and a gyroscope [11–14].

In these mentioned systems for the motor functions assessment the emphasis is mostly on the motor disorders assessment of the upper extremity [7, 11–13]. For the tasks of further motor functions rehabilitation it is necessary to obtain a larger number of parameters, as well as taking into account the fine motor skills of the hand, the lower extremity and the gait. It should be noted that complex mobile sensors, which are placed on the patient's extremities to record the signals, are not always available for clinics in Ukraine.

The instrumental methods are used to assess the motor functions state: dynamometry — to determine muscle strength, goniometry — to determine the movements' volume, myotonometry - to determine the muscle tone [15], as well as test methods of expert assessment. Since appropriate instrumental assessment methods are not available for every clinical institution of Ukraine, and, in particular, the dynamometry method is difficult to apply for weak muscles [15, 16], the test methods of expert assessment of motor function state by evidence criteria are used practical and affordable for the study of quantitative diagnostics of motor functions.

As a result of the analysis of methods and tools of expert assessment of motor functions, the following should be highlighted:

1. Rivermead Motor Assessment. The motor functions assessment of the upper and lower extremities, as well as the trunk on a two-point gradation as the patient performs the tests.

2. Motricity Index. The motor functions assessment of the upper and lower extremities. The scale has an uneven gradation in points [17].

3. Fugl-Meyer Stroke Scale. Contains points for evaluating motor functions: motor speed, sensitivity, balance, range of motion in the joint, pain in the joint. Each item has an uneven points' gradation.

4. Motor Activity Log. The upper extremity is assessed on a six-point scale as the patient performs the tests. The scale is aimed at assessing the patient's ability to perform the appropriate tests.

5. Wolf Motor Function Test (WMFT). The patient's attempts to perform the movements by upper extremity are assessed on a six-point scale [18].

6. The Stroke Impairment Assessment Set (SIAS) scale for assessing the motor, sensory and movement impairments using the patient's performance of appropriate tests. The scores for each item are added to the total score. In particular, this method requires certain instrumental support [19].

7. A quantitative assessment scale with a nine-point gradation based on the Medical Research Council scale and manual muscle testing are used.

8. The Berg Balance Scale and National Institutes of Health Stroke Scale are of neurological direction. They have the nature of a questionnaire, and in addition to the items responsible for the movements state, they contain items related to neurological reflexes, level of consciousness, self-care.

The complexes for motor functions assessment have been developed, in which the patient performs tests according to appropriate scales [20–22] and the assessment is carried out using statistical methods. These systems give a generalized result to the motor functions assessment.

As we can see, such test scales are used to assess the motor functions, however, either their focus is only on the upper extremity, or the uneven gradation of

the scales, or the nature of the scale does not enable the scales to be fully applied for the purposes of creating the movement rehabilitation strategy.

It should be noted that within the analysis, the presence of mobile tools for the patient's motor functions diagnosing, which are developed in global practice, was not observed.

As a result of such an analysis, in previous studies [15], the main and additional evidence criteria with the appropriate assessment scales, which have the same six-point gradation and are compared with the scale of paresis dynamics (it is convenient for creating a total quantitative assessment) are chosen for the movement disorders state assessment. On the basis on expert assessment by these criteria the technique for motor functions state quantitative assessment has been developed [15, 23]. The approbation of this technique confirmed its advantages and expediency of the usage in clinical practice [2, 15, 23]. On the basis of the technique the software system MovementTestStroke has been developed to assist a physician in motor functions state assessment and decision-making on rehabilitation [24]. It was tested in the conditions of patients after a stroke. The software expands the technique for motor functions quantitative assessment in terms of detailed assessment of fine motor skills of the hand, but does not take into account the possibility for monitoring the patient at home, as well as convenient presentation of information to the user (physician and patient), and accumulation of results for further analysis. This is especially necessary for application in the field conditions to monitor the motor functions state after injuries and traumas.

The purpose of the paper is to develop a mobile system for personalized motor functions diagnostics for recovery of motor functions and speech motility, which functional capabilities help to increase the rehabilitation effectiveness and the usability both in clinical and home conditions, as well as in the field conditions.

The object of the research is the patient's motor functions state diagnosing, and *the subject* is a mobile information user-assistance system for personalized motor functions diagnosing for recovery of motor functions and speech motility in patients with impairments of the central and peripheral nervous system, as well as after injuries and traumas.

According to the specified purpose, the research is aimed at developing and implementing the algorithm of informational assistance in motor functions diagnosing for recovery of motor functions and speech motility, in particular to enable the patient to control own motor functions at home and to accumulate the results of these functions dynamics in patients.

The motor and speech functions recovering of both patients with impairments of the central and peripheral nervous system, as well as after injuries and traumas, in particular not only in clinical, but also in home and field conditions, puts forward, in addition to the requirement for personalization, which is generally accepted in modern medicine, as well as requirements for mobility, urgency, ease of perception and usability of the information provided to a physician for making the diagnostic and treatment decisions.

Therefore, according to the requirements and the specified purpose, the task is to develop the interface of the software system for motor functions diagnosing, a relation database (DB) for storing and accumulating the results of the patients' motor functions dynamics and the urgent diagnostic and treatment decision-making by a physician, as well as an algorithm for motor functions state diagnosing with taking into account modified interface and relational database,

and to implement the algorithm in the mobile information assistance system MovementTestStroke 1.2 for motor functions diagnosing.

THE INTERFACE OF MOBILE SYSTEM FOR MOTOR FUNCTION DIAGNOSTICS

The software implementation of informational assistance in the motor functions diagnosing MovementTestStroke 1.1 [24] has the interface, which is intended for the physician's usage in clinical conditions and is inconvenient for the usage by a patient at home. To eliminate this shortcoming the interface's structure for the program of information assistance in the motor functions diagnosing has been modified. In the interface's modification a set of user (physician and patient) interaction with the MovementTestStroke 1.2 mobile system is defined. This set is presented on the UML use case diagram (Fig. 1) [25].

The physician and patient perform authorization. The physician keeps the register of patients and analyzes the patients' motor function results. And in return the patient performs motor function testing according to the instructions received from the physician, and enters them into the system. To enable the patient to control own motor functions, the scenario based on UML sequence diagram, which reflects the time-ordered objects interactions, for the patient was developed in the structure of the mobile system's interface (Fig. 2) [25].

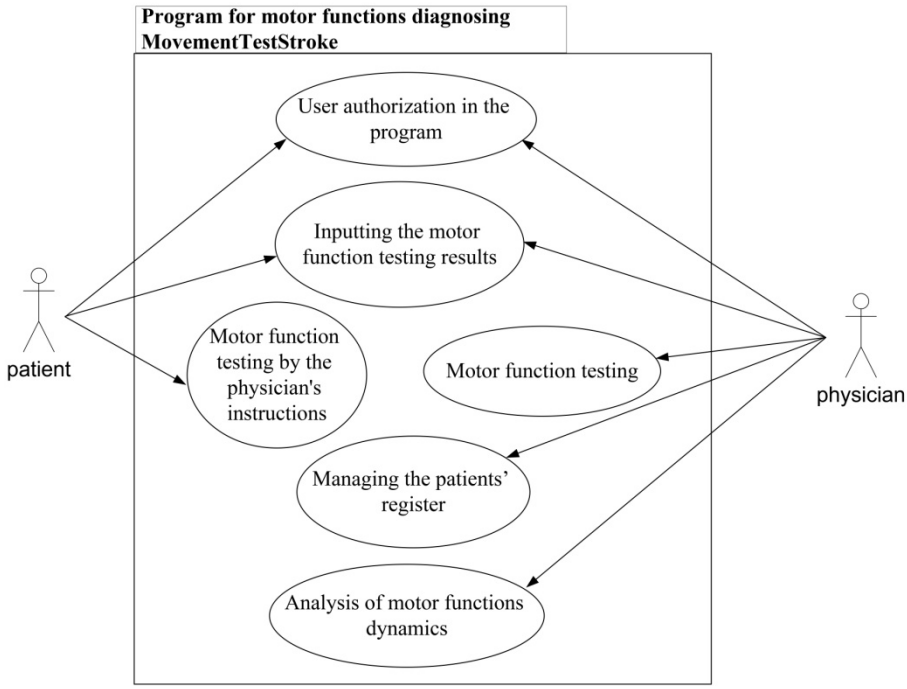

Fig. 1. UML use case diagram: set of user (physician and patient) interaction with the MovementTestStroke 1.2 mobile system for motor functions diagnosing

When the patient enters the system, he is authorized with the password provided by the physician. The password is the number of the patient's medical card. After that the window with testing sessions numbers related to the dates is activated. And from each testing session the proceeding to the motor function testing windows is activated (Fig. 2). At the moment of testing window is activated by a patient, the drop-down list with motor function testing objects (extremities, joints, hand, gait) is only activated.

Compared to the scenario for a physician in the previous software implementation MovementTestStroke 1.1 interface [24], the interface of the mobile diagnostics system for the patient is simplified. Such a simplification is aimed at the patient's consideration of only one movement testing object without distraction to all others. And it provides the usability by a specific patient at home. The drop-down list sets the evidence criteria and their number on the interface. So with the patient's selection of the testing object, the evidence criteria with control elements are activated. These criteria specify the proceeding to the fixation of information on the motor functions current state and the output of results (paresis degree) of the selected object.

With the activation of the control element of the right evidence criterion, the program proceeds to selection of right verbal characteristic to match the motor function current state. When the patient selects the characteristic, the program returns, but instead of fixation element, a numerical value in points appears.

After processing all evidence criteria of the selected test object, the paresis degree for this object is determined and is displayed on the interface. And if the selected object is assessed not for the first time, its recovery effectiveness is determined. The results within the current testing object are stored in the database.

In case of a patient's request for general results of motor functions testing, a sample by query from database is generated by the software. This sample includes information on the motor functions state level of the testing objects that were assessed. And for the dynamics the normalized results for the current test and the previous ones as a percentage in the form of a diagram are displayed. After completing all testing actions, the patient exits the program.

The developed structure of the mobile system’s interface enables to apply the motor functions diagnosing at home, and the comparison in dynamics enables to control motor functions by the patient independently or with the help of assistants. It is also perspective to simplify the motor function testing technique for usage by the patient at home.

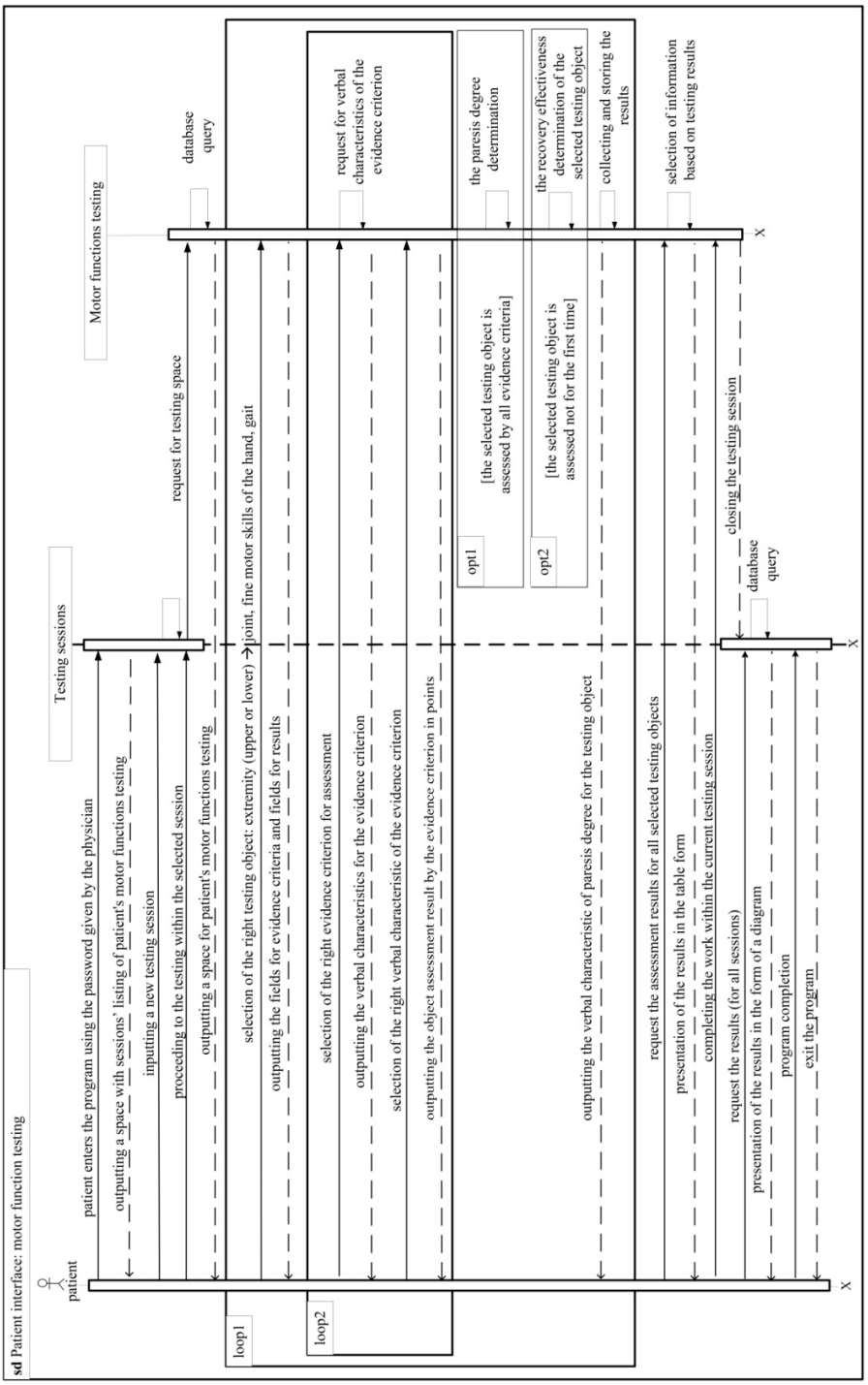

Fig. 2. UML sequence diagram: scenario for the patient in structure of interface of the mobile system for motor functions diagnosing

RELATION DATABASE MODEL FOR THE MOBILE SYSTEM FOR MOTOR FUNCTIONS DIAGNOSTICS

The usage of a file database in the software implementation MovementTest-Stroke 1.1 for the information assistance in the motor functions diagnosing [24] does not contribute to the data usability and, moreover, complicates the further analysis of research results. Therefore, the infologic model of the relational database was developed (Fig. 3) for storing and accumulating the patients' motor functions data, and its following analysis by a physician.

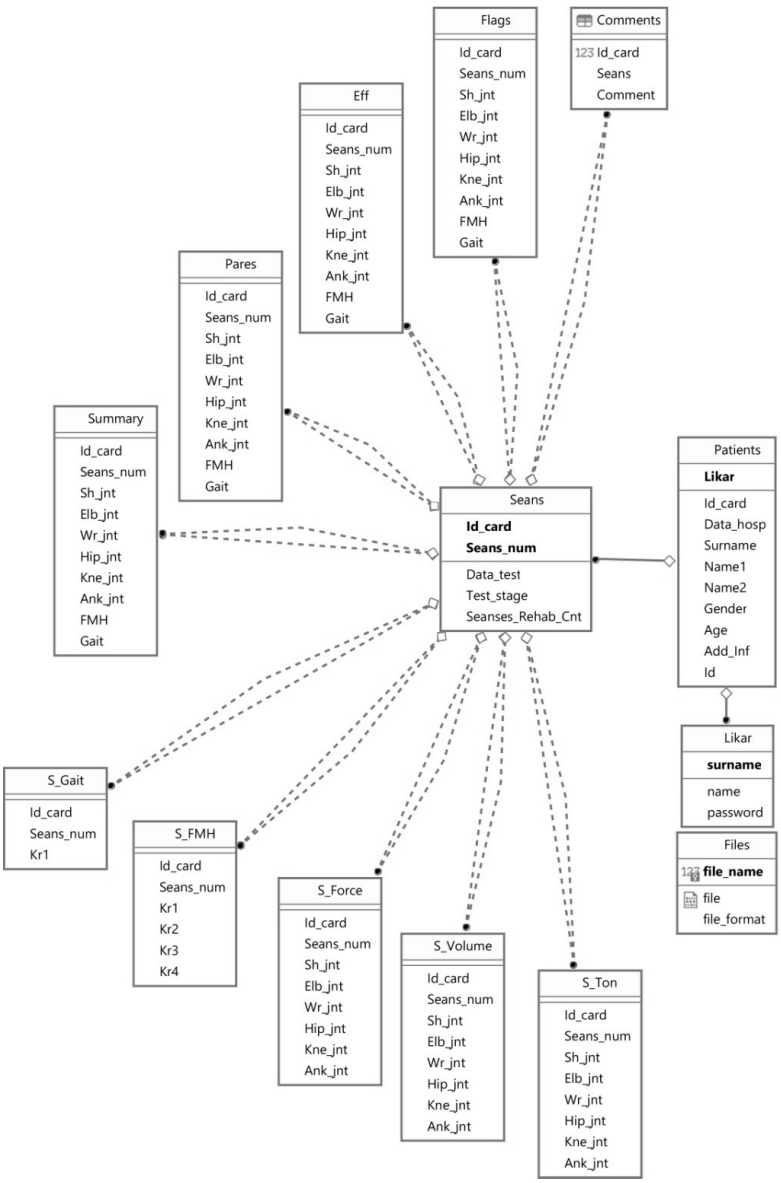

Fig. 3. Infologic model of the relational database for the mobile system for patient's motor functions diagnosing

The database model consists of such table objects.

1. The *Files* table contains the user's manual of the software information assistance system for the motor functions diagnosing.

2. The *Patients* table contains basic patients' information: medical card number, date of admission (hospitalization), surname, name, patronymic, gender, age, physician (surname and name), patient's additional information, as well as an additional field — the serial number of a patient in the table to read the information.

3. The *Likar* table stores physicians' data who manage patients, as well as the passwords by which the physician enters the software information assistance system for the motor functions diagnosing. The field related to a physician's surname has a connection with the corresponding field of the patients' table (*Patients*).

4. The *Seans* table contains the fields related to a patient's medical card number, session's number, testing date, testing stage within the rehabilitation course, and the number of performed rehabilitation sessions. This table is purposed for managing sessions of each patient and linking the obtained results to each session. The patient's medical card number field has a connection with the corresponding field of the patients' table (*Patients)*. The appropriate fields of the results tables are linked to the fields of patient's medical card number and session's number.

5. Tables of results: *S_Force, S_Volume, S_Ton, S_FMH*, *S_Gait* store information appropriately on muscle strength, movements' volume, muscle tone – for parts (joints) of the upper and lower extremities, the criteria for fine motor skills of the hand (in particular for monitoring recovery of oral speech) and gait assessment. The tables *Summary, Pares, Eff, Flags* store information appropriately on the summarized results of motor functions state, the paresis degree, and the recovery effectiveness within rehabilitation process for the selected test objects (for the parts of upper and lower extremities, fine motor skills of the hand and gait). In all these tables the fields of patient's medical card number and session's number are linked to the appropriate fields of the session table (*Seans*).

6. Table *Comments* for comments related to session stores comments that may be entered during a patient's motor function testing session. In this table the fields of patient's medical card number and session's number are linked to the appropriate fields of the session table (*Seans*).

The implementation of such relational database model in a mobile system for motor functions diagnostics will enable to store results at various stages of patients' rehabilitation, and in the following to carry out an in-depth analysis of motor functions dynamics by software tools using.

ALGORITHM FOR MOTOR FUNCTIONS DIAGNOSING

The algorithm for personalized motor functions diagnosing for the purpose of their recovery, as well as, if necessary, speech motility recovery is presented (Fig. 4).

At the first stage, the physician performs an expert assessment of the motor functions state according to evidence criteria. If the testing is carried out by the patient himself or his assistant, then the expert assessment is carried out by them according to the instructions received from the physician. The result of this stage is a set of verbal characteristics according to evidence criteria.

At the second stage, the work is carried out directly with the mobile information assistance system MovementTestStroke in the motor functions diagnosing. The authorization of a physician or patient in the program takes place.

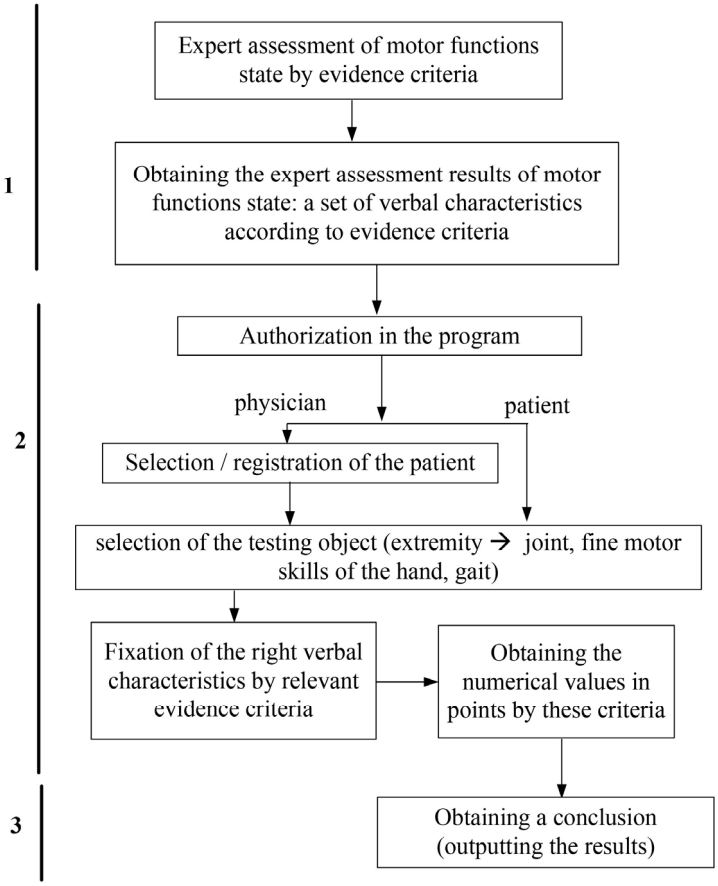

Fig. 4. Algorithm for motor functions diagnosing for their and speech motility rehabilitation

The physician or patient selects the appropriate motor functions testing objects (extremity, joint, hand, gait) on the interface. The fine motor skills of the hand is diagnosed either in general or also, if necessary, to diagnose speech motility. Next the necessary evidence criteria for motor functions assessment are selected. In particular, the diagnositics is based on the usage of an expanded range of evidence criteria for diagnosing the extremities, gait and fine motor skills of the hand (indirect speech motility diagnosing), which is not taken into account by known analogues and is not amenable to visual assessment.

With the selection of criteria, there is proceeding to the fixation of verbal characteristics for each evidence criterion — the program in the analytical unit converts them into numerical values in points and displays them on the interface. After completing the assessment for each evidence criterion for the testing object, the program determines its paresis degree according to the summarized score (in points). And if the assessment of the selected object is not for the first time, the program determines its recovery effectiveness.

At the third stage, a conclusion is formed in textual and graphic forms. The text presentation contains the data of the current motor functions assessment in points with a description of verbal characteristics for each testing object according to all evidence criteria. The graphic presentation is a table with data in points, as well as a diagram that shows in dynamics the normalized motor functions level in percentages for all testing objects are evaluated during the course of rehabilitation. The patient receives only graphic information in the form of diagrams, and the physician receives all information.

The algorithm of personalized motor functions diagnosing is implemented in the MovementTestStroke 1.2 mobile system. The system provides information for the user (physician and patient) in convenient digital and graphical forms. It simplifies the motor functions testing for the patient, and the analysis of motor functions state for the physician. Its advantage is in the personalization and objectification of assessment, reduction of the probability of a physician's error and identifying the disorders specifics.

The MovementTestStroke 1.2 program can be used not only to assess the state of motor functions affected by pathologies, in particular stroke. With some system's modification based on additional research it can be used to assess the state of motor functions affected also by injuries and traumas etc. This creates the basis for personalized planning the motor and speech rehabilitation by a physician. MovementTestStroke 1.2 was implemented in Visual Studio 2019, C# language. The relational database was designed in the SQLite database management system: SQLiteStudio and DBeaver software environments, linked to the MovementTestStroke 1.2 program using the SQLite library.

CONCLUSIONS

The algorithm for personalized motor functions diagnosing for recovery of motor functions and speech motility has been developed. It is implemented in the mobile system MovementTestStroke 1.2, which uses an expanded range of evidence criteria for motor functions diagnosing, in particular, diagnosing the state of fine motor skills of the hand to recover the speech motility. Such a system provides objectification of assessment, reduction of the probability of a physician's error and urgency in diagnostic and treatment decision-making, provides necessary and sufficient information to the user in a convenient digital and graphical forms, simplifies for the physician the motor functions state analyzing and the personalized treatment strategy creating.

The structure of interface for mobile system for information assistance in the motor functions diagnosing has been developed. It provides the application of the motor functions diagnosing both in clinical and home conditions, as well as in the field conditions.

The relation database model was developed to store and accumulate the results of the motor functions dynamics of patients for the purpose of further patient-physician consultations.

The mobile system MovementTestStroke 1.2 for motor function diagnostics can be used in clinical and home conditions to assess the motor functions state affected by central nervous system pathologies. With some system's modification based on additional research it can be used to assess the state of motor functions affected also by

injuries and traumas. This creates the basis for personalized, mobile, urgent diagnostic and treatment decision-making by the physician, especially in field conditions. On a technical point of view, the system can be used both an independent program and a component of programs for a patient's movements rehabilitation or a program unit in electronic electromyostimulation devices.

REFERENCES

1. Ginex V. Motor recovery in post-stroke patients with aphasia: the role of specific linguistic abilities. *Topics in Stroke Rehabilitation*. 2017, Vol. 24, Issue 6, pp. 428–434. URL: https://doi.org/10.1080/10749357.2017.1305654 (Last accessed: 1.06.2022).
2. Vovk M.I., Kutsiak O.A. Information technologies for muscle functions control. Retrospective analysis and development prospects. *Cybernetics and Computer Engineering*. 2022, № 1 (207), pp. 87–100. (in Ukrainian).
3. Vovk, M.I., Halian, Ye.B., Kutsiak, O.A. Computer Software & Hardware Complex for Personal Oral Speech Restoration after a Stroke. *Sci. innov.* 2020, Vol. 16, № 1(91), pp. 54–68. https://doi.org/10.15407/scine15.05.054 (Last accessed: 1.06.2022).
4. P. Maceira-Elvira. Wearable technology in stroke rehabilitation: towards improved diagnosis and treatment of upper-limb motor impairment. *Journal of NeuroEngineering and Rehabilitation.* 2019, Vol. 16. URL: https://doi.org/10.1186/s12984-019-0612 (Last accessed: 1.10.2022).
5. Adams J.L. Digital Technology in Movement Disorders: Updates, Applications, and Challenges. *Current Neurology and Neuroscience Reports*. 2021, Vol. 21. URL: https://doi.org/10.1007/s11910-021-01101-6 (Last accessed: 1.06.2022).
6. Kostiuk M. Trauma Assessment. URL: https://www.statpearls.com/articlelibrary/viewarticle/30531 (Last accessed: 1.06.2022).
7. Corona F. Quantitative assessment of upper limb motor impairments in people with neurological diseases: diss. … Doctor of Philosophy / Università degli Studi di Cagliari. URL: https://iris.unica.it/bitstream/11584/255954/2/tesi%20di%20dottorato_Federica%20Corona.pdf (Last accessed: 1.06.2022).
8. Hassen D.B. Mobile-aided diagnosis systems are the future of health care. *EMHJ.*2020, Vol. 26, No. 9, pp. 1135–1140.
9. Rahimi S.A. Are mobile health applications useful for supporting shared decision making in diagnostic and treatment decisions? *Global Health Action*. 2017, Vol. 10. URL: https://doi.org/10.1080/16549716.2017.1332259 (Last accessed: 1.06.2022).
10. Motor function diagnosis apparatus and method, and program: patent JP6433805B2. Tottori University; publ. date 05.12.2018
11. Bingyu Pan et al. Motor Function Assessment of Upper Limb in Stroke Patients. *Journal of Healthcare Engineering*. 2021, Vol. 2021. URL: https://doi.org/10.1155/2021/6621950 (Last accessed: 1.06.2022).
12. Maceira-Elvira P. Wearable technology in stroke rehabilitation: towards improved diagnosis and treatment of upper-limb motor impairment. *Journal of NeuroEngineering and Rehabilitation.* 2019, Vol. 16. URL: https://jneuroengrehab.biomedcentral.com/articles/10.1186/s12984-019-0612-y (Last accessed: 1.06.2022).
13. Jalloul N. Wearable sensors for the monitoring of movement disorders. *Biomedical journal*. 2018, Vol. 41, pp. 249–253. URL: https://doi.org/10.1016/j.bj.2018.06.003 (Last accessed: 1.06.2022).
14. Movement monitoring system and apparatus for objective assessment of movement disorders: patent US 2011/0213278 A1. Fay Horak et al. publ. date 01.09.2011.
15. Vovk M.I., Kutsiak O.A., Lauta A.D., Ovcharenko M.A. Information Assistance of Researches on the Dynamics of Movement Restoration after the Stroke. *Cybernetics and Computer Engineering*. 2017, № 3 (189), pp. 61–78. (in Ukrainian).
16. T. Paternostro-Sluga. Reliability and validity of the Medical Research Council (MRC) scale and a modified scale for testing muscle strength in patients with radial palsy. *J Rehabil Med*. Vol 40, Issue 8. URL: https://www.medicaljournals.se/jrm/content/abstract/ 10.2340/16501977-0235 (Last accessed: 1.06.2022).

17. Collin C., Wade D. Assessing motor impairment after stroke: a pilot reliability study. *J Neurol Neurosurg Psychiatry*. 1990, Vol. 53(7), pp. 576–579.
18. Schaechter J.D. Motor Recovery and Cortical Reorganization after Constraint-Induced Movement Therapy in Stroke Patients: A Preliminary Study. *Neurorehabilitation and Neural Repair*. 2002, Vol. 16(4). URL: https://doi.org/10.1177/154596830201600403 (Last accessed: 1.06.2022).
19. Chino N. Stroke Impairment Assessment Set (SIAS). *Jpn J Rehabil Med*. 1994, Vol. 31, No. 2. URL: https://doi.org/10.2490/jjrm1963.31.119 (Last accessed: 1.06.2022).
20. Jarm T., Kramar P., Županič A. Rating Stroke Patients Based on Movement Analysis. *IFMBE Proceedings 16*. 2007, pp. 266–269, URL: https://doi.org/10.1007/978-3-540-73044-6_66 (Last accessed: 1.06.2022).
21. Olesh E.V. Automated Assessment of Upper Extremity Movement Impairment due to Stroke. *Plos One*. 2014, Vol. 9, Issue 8. URL: https://doi.org/10.1371/journal.pone.0104487 (Last accessed: 1.06.2022).
22. A motor function test system: patent WO2005/039412 A1. Panella L. et al. publ. date 06.05.2005.
23. Vovk M.I., Kutsyak O.A. Software module for personal diagnostics of motor functions after stroke. *Cybernetics and Computer Engineering*. 2019, № 4 (198), pp. 62–77
24. Vovk M.I., Kutsyak O.A. AI-technology of motor functions diagnostics after a stroke. *Cybernetics and Computer Engineering.* 2021, № 2 (204), pp. 84-100.
25. Booch G., Rumbaugh J., Jacobson I. The Unified Modeling Language User Guide. Boston, 1999. 482 p.

Received 30.09.2022

ЛІТЕРАТУРА

1. V. Ginex. Motor recovery in post-stroke patients with aphasia: the role of specific linguistic abilities, *Topics in Stroke Rehabilitation*, 2017. Vol. 24. Issue 6. P. 428–434. URL: https://doi.org/10.1080/10749357.2017.1305654 (Дата звернення: 1.06.2022).
2. Вовк М.І., Куцяк О.А. Інформаційні технології керування м'язовими функціями. Ретроспективний аналіз та перспективи розвитку. *KiBT*. 2022. № 1 (207). С. 87–100.
3. Vovk, M.I., Halian, Ye.B., Kutsiak, O.A. Computer Software & Hardware Complex for Personal Oral Speech Restoration after a Stroke. *Sci. innov.* 2020. Vol. 16, № 1(91). pp. 54–68. URL: https://doi.org/10.15407/scine15.05.054 (Дата звернення: 1.06.2022).
4. P. Maceira-Elvira. Wearable technology in stroke rehabilitation: towards improved diagnosis and treatment of upper-limb motor impairment. *Journal of NeuroEngineering and Rehabilitation.* 2019. Vol. 16. URL: https://doi.org/10.1186/s12984-019-0612 (Дата звернення: 1.10.2022).
5. Adams J.L. Digital Technology in Movement Disorders: Updates, Applications, and Challenges. *Current Neurology and Neuroscience Reports*. 2021. Vol. 21. URL: https://doi.org/10.1007/s11910-021-01101-6 (Дата звернення: 1.06.2022).
6. Kostiuk M. Trauma Assessment. URL: https://www.statpearls.com/articlelibrary/viewarticle/30531 (Дата звернення: 1.06.2022).
7. Corona F. Quantitative assessment of upper limb motor impairments in people with neurological diseases: diss. … Doctor of Philosophy / Università degli Studi di Cagliari. URL: https://iris.unica.it/bitstream/11584/255954/2/tesi%20di%20dottorato_Federica%20Corona.pdf
8. Hassen D.B. Mobile-aided diagnosis systems are the future of health care. *EMHJ.* Vol. 26. No. 9. 2020. pp. 1135–1140 (Дата звернення: 1.06.2022).
9. Rahimi S.A. Are mobile health applications useful for supporting shared decision making in diagnostic and treatment decisions? *Global Health Action*. 2017. Vol. 10. URL: https://doi.org/10.1080/16549716.2017.1332259 (Дата звернення: 1.06.2022).
10. Motor function diagnosis apparatus and method, and program: patent JP6433805B2. Tottori University; publ. date 05.12.2018
11. Bingyu Pan. Motor Function Assessment of Upper Limb in Stroke Patients. *Journal of Healthcare Engineering*. 2021. Vol. 2021. URL: https://doi.org/10.1155/2021/6621950 (Дата звернення: 1.06.2022).

12. Maceira-Elvira P. Wearable technology in stroke rehabilitation: towards improved diagnosis and treatment of upper-limb motor impairment. *Journal of NeuroEngineering and Rehabilitation.* 2019. Vol. 16. URL: https://jneuroengrehab.biomedcentral.com/articles/10.1186/s12984-019-0612-y (Дата звернення: 1.06.2022).
13. Jalloul N. Wearable sensors for the monitoring of movement disorders. *Biomedical journal*. 2018. Vol. 41. pp. 249–253. URL: https://doi.org/10.1016/j.bj.2018.06.003 (Дата звернення: 1.06.2022).
14. Movement monitoring system and apparatus for objective assessment of movement disorders: patent US 2011/0213278 A1. Fay Horak et al. publ. date 01.09.2011.
15. Вовк М.І., Куцяк О.А., Лаута А.Д., Овчаренко М.А. Інформаційний супровід досліджень динаміки відновлення рухів після інсульту. *Кибернетика и вычислительная техника.* 2017. №3 (189). С. 61–78.
16. T. Paternostro-Sluga. Reliability and validity of the Medical Research Council (MRC) scale and a modified scale for testing muscle strength in patients with radial palsy. *J Rehabil Med*. Vol 40. Issue 8. URL: https://www.medicaljournals.se/jrm/content/abstract/ 10.2340/16501977-0235 (Дата звернення: 1.06.2022).
17. Collin C., Wade D. Assessing motor impairment after stroke: a pilot reliability study. *J Neurol Neurosurg Psychiatry*. 1990. Vol. 53(7). P. 576–579.
18. Schaechter J.D. Motor Recovery and Cortical Reorganization after Constraint-Induced Movement Therapy in Stroke Patients: A Preliminary Study. *Neurorehabilitation and Neural Repair*. 2002. Vol. 16(4). URL: https://doi.org/10.1177/154596830201600403 (Дата звернення: 1.06.2022).
19. Chino N. Stroke Impairment Assessment Set (SIAS). *Jpn J Rehabil Med*. 1994. Vol. 31. No. 2. URL: https://doi.org/10.2490/jjrm1963.31.119
20. Jarm T., Kramar P., Županič A. Rating Stroke Patients Based on Movement Analysis. *IFMBE Proceedings 16*. 2007. P. 266–269, URL: URL: https://doi.org/10.1007/978-3-540-73044-6_66 (Дата звернення: 1.06.2022).
21. Olesh E.V. et al. Automated Assessment of Upper Extremity Movement Impairment due to Stroke. *Plos One*. 2014. Vol. 9. Issue 8. URL: https://doi.org/10.1371/journal.pone.0104487 (Дата звернення: 1.06.2022).
22. A motor function test system: patent WO2005/039412 A1. Panella L. et al. publ. date 06.05.2005.
23. Vovk M.I., Kutsyak O.A. Software module for personal diagnostics of motor functions after stroke. *Cybernetics and Computer Engineering*. 2019. № 4 (198). P. 62–77
24. Vovk M.I., Kutsyak O.A. AI-technology of motor functions diagnostics after a stroke. *Cybernetics and Computer Engineering.* 2021. № 2 (204). P. 84–100.
25. Booch G., Rumbaugh J., Jacobson I. The Unified Modeling Language User Guide. Boston, 1999. 482 p.

Отримано 30.09.2022

Куцяк О.А., канд. техн. наук,
старш. наук. співроб., відд. біоелектричного керування та медичної кібернетики,
ORCID: 0000-0003-2277-7411, e-mail: spirotech85@ukr.net

Міжнародний науково-навчальний центр інформаційних технологій
та систем НАН України та МОН України,
пр. Акад. Глушкова, 40 м. Київ, 03187, Україна

МОБІЛЬНА СИСТЕМА ДІАГНОСТУВАННЯ
СТАНУ РУХОВИХ ФУНКЦІЙ ПАЦІЄНТА

Вступ. Діагностика стану рухових функцій відіграє важливу роль як внаслідок уражень центральної нервової системи (інсульт), так і внаслідок травм, поранень тощо. Оскільки мобільні засоби розширюють можливості сучасної медицини, актуальним

завданням є синтез ефективної мобільної системи діагностування стану рухових функцій на різних етапах реабілітації.

Мета статті — розробити мобільну систему персоналізованого діагностування рухових функцій для їхньої реабілітації та реабілітації моторики мовлення, функційні можливості якої сприяють підвищенню ефективності реабілітації та зручності використання як у клінічних і домашніх, так і у польових умовах.

Результати. Відновлення рухових та мовленнєвих функцій пацієнтів як з ураженнями центральної та периферичної нервової системи, так і після травм і поранень, зокрема не тільки у клінічних, але й у домашніх та польових умовах, висуває вимоги персоналізації, мобільності, зручності сприйняття і використання наданої користувачу інформації.

Відповідно до цього розроблено інтерфейс мобільної системи діагностування рухових функцій: визначено напрями взаємодії користувачів, набір завдань користувачів у системі, розроблено сценарій для пацієнта для тестування власних рухових функцій в межах мобільної системи. Розроблено інфологічну модель реляційної бази даних для зберігання та накопичення даних про рухові функції пацієнтів та подальшого їх аналізу лікарем.

Розроблено алгоритм персоналізованого діагностування рухових функцій, що базується на розширеній гамі доказових критеріїв, які не враховуються відомими аналогами. Алгоритм реалізовано у мобільній системі MovementTestStroke 1.2 з урахуванням інтерфейсу та реляційної бази даних. Така система забезпечує об'єктивізацію оцінювання, зменшення ймовірності помилки лікаря та оперативність у прийнятті діагностико-лікувальних рішень, надає необхідну і достатню інформацію користувачу у зручному цифровому та графічному вигляді, спрощує лікарю аналіз стану рухових функцій і формування персоналізованої стратегії лікування.

Висновки. Мобільна система діагностування рухових функцій може застосовуватися у клінічних і домашніх умовах для оцінювання стану рухових функцій, уражених внаслідок патологій центральної нервової системи. З модифікацією системи на базі додаткових дослідженнях її можна буде застосовувати для оцінювання стану рухових функцій, уражених внаслідок травм і поранень. Це створює основу персоналізованого, мобільного, оперативного прийняття лікарем діагностично-лікувальних рішень.

Ключові слова: *діагностика, рухові функції, кількісне оцінювання, критерії, алгоритм, програмна система, мобільна система, інсульт, травми.*