# Software Development to Assess the Dynamics of Stented Heart Vessel Rest enosis for ARM-Cardiologist

*Stanislav I. Sivakov, Department of Informatics and Computational Technology, Belgorod State University, Belgorod, Russian.*

*Valeriy M. Nikitin, Department of Informatics and Computational Technology, Belgorod State University, Belgorod, Russian.*

*Yuriy I. Afanasiev, Department of Informatics and Computational Technology, Belgorod State University, Belgorod, Russian.*

*Alexander V. Mamatov, Department of Informatics and Computational Technology, Belgorod State University, Belgorod, Russian.*

*Alexander N. Nemcev, Department of Informatics and Computational Technology, Belgorod State University, Belgorod, Russian.*

*Vadim V. Mishunin, Department of Informatics and Computational Technology, Belgorod State University, Belgorod, Russian.*

**Abstract---** The article considered the database and the software developed on the basis of the authors' team previous studies devoted to the evaluation of restenosis dynamics of the stented heart vessels. This software is the part of ARM-Cardiologist. The database was developed using MySQL database and phpMyAdmin web application. The Flask micro framework was chosen as the means of a web service development in Python. The article also presents the results of the authors' team research via the examples of specific implementation.

## I. Introduction

In the framework of the author's team previous research of the National Research University of BelSU, the structural and the functional scheme of the heart electronic model was developed and justified, which allows to describe various aspects of the cardiovascular system (CVS) operation.

The central place in this model is occupied by an automated workplace of a cardiologist (ARM-Cardiologist), whose main purpose is the generation of an electronic diagnosis, as a medical management decision project [1-2]. At the moment, the ARM-Cardiologist consists of four systems, represented on Figure 1:

"ECG computer analysis system" - the ECG computer system with the advanced functions for automatic search and the identification of the areas with diagnostically significant changes, can be classified as a tool to improve the quality and efficiency of human-computer interaction during a disease diagnosis [3];

"Expert automated system for heart rate variability analysis" is an automated diagnostic expert system for the quantitative assessment of coronary heart disease risk in the early stages based on the analysis of heart rate variability results [4-5];

"Automated system for multidimensional image recognition of the cardiovascular system state" - the system based on the algorithm of a multivariate virtual image development of a patient's cardiovascular system (CVS) used to solve the problem of pathology recognition based on the study of mutual arrangement topology and the collisions of two-dimensional image intersection of CVS state [6-7];

"The software for dynamics assessment of in-stent restenosis of heart vessels" - the program assesses the dynamics of restenosis for the stented heart vessels, which is based on the method developed by the author team to predict the risk of restenosis [8- 9].

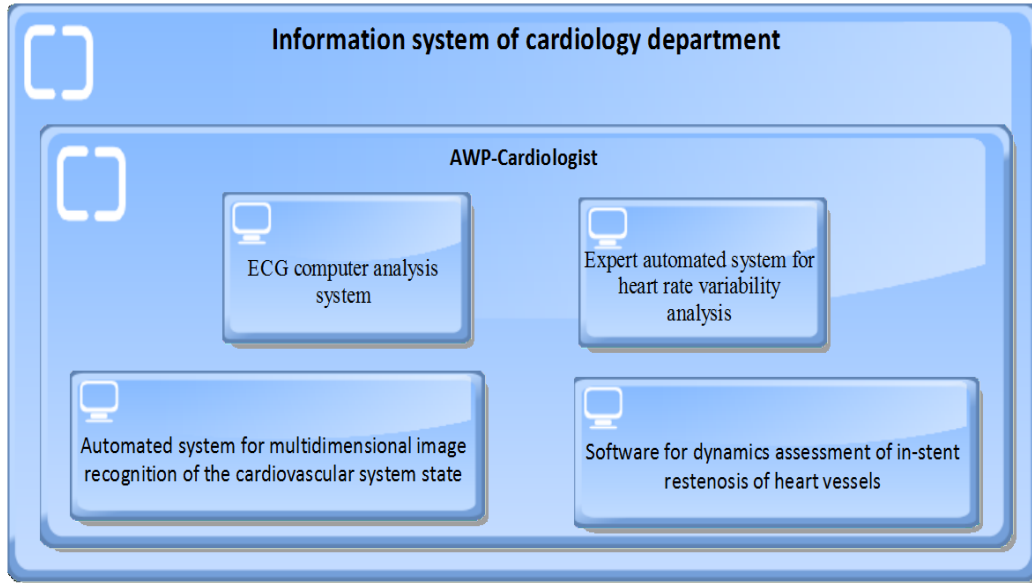This article is devoted to the description of the developed program and the research results.

Figure 1: Schematic Representation Of information System Interrelationships from the Cardiology Department (System Landscape)

### Study Methods and Developments

At the initial stage, they determined the requirements for software development tools:

1. The software must be cross-platform, so that the operability does not depend on the available hardware and software.
2. The system organization must be client-server one. This will allow you to collect information from different workstations.
3. The interface of information transfer between a client and a server must be carried out via the Internet. This will allow you not to become attached to one workplace and reinstall client applications during PC replacement, and also to combine the work of several medical institutions.
4. A selected tool should provide an opportunity to connect the most modern libraries and modules that allow to use modern mathematical methods.

The most common languages that meet these requirements are PHP, JavaScript and Python languages.

When you choose a programming language, the Stack Share online community data was used (see Table 1) [10].

Table 1: Statistical Information on the Programming Languages JavaScript, PHP and Python

| № | Indicator | JavaScript | PHP | Python |
|---|-----------|-----------|-----|--------|
| 1. | Number of votes, thousands | 6.98 | 4.94 | 5.34 |
| 2. | Number of work performed, thousands | 8.78 | 3.7 | 9.53 |
| 3. | Average popularity during the last year | 51 | 65 | 83 |
| 4. | Three most popular advantages | - can be used on the client and server interface;<br>- used everywhere;<br>- a lot of "frameworks". | - A large community of PHP programmers;<br>- open source code;<br>- A simple deployment. | - A wide variety of libraries;<br>- Easily read code;<br>-Actively developing. |

Thus, it can be concluded that Python is the most suitable programming language for the requirements. It is the most popular, actively developing language with a lot of diverse and stable libraries, and also allows you to integrate interactivity into the code using JavaScript. Flask micro framework was chosen as the means of a web service development in Python.

Database is an important component of any information system. MySQL DBMS and phpMyAdmin web application were selected as database development tools.

*Main Part*

The following database entities were identified as the result of previous research analysis by the author team [8-9]:

1. Patient (dannye pats) - this entity contains the information about patients at the cardiology department. This entity can be used for the communication with other databases both of the department and of the polyclinic in general.
2. Analyzes (analiz pats) - this entity contains the information about the analyzes passed by patients. The data will be used to compile a forecast, and also help to refine existing ones and create new forecast models during information increase.
3. Users (users) are the cardiologists who are the system users.
4. Stenosis localization (vid_lokal) - the localization of revealed patient stenosis.

The ER-model of the projected database is presented on Figure 2.
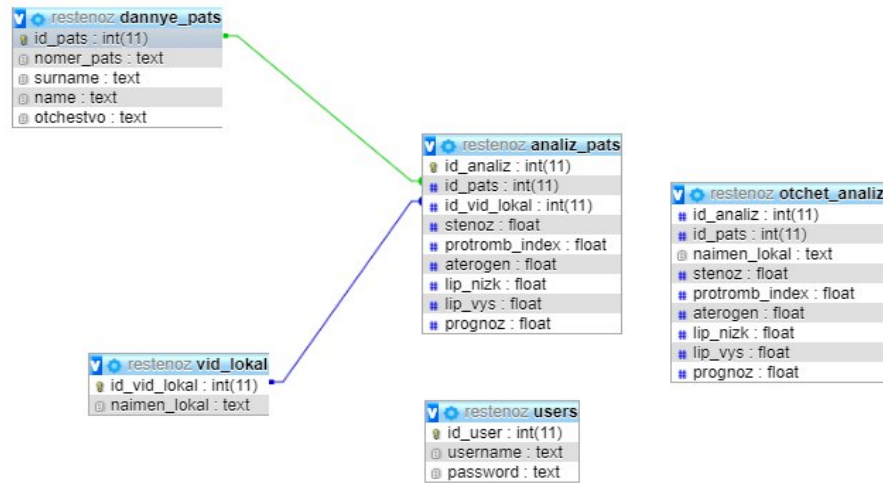


Figure 2: ER-Model Database of the Program Predicting the Risk of Cardiac Restenosis in the ARM-Cardiologist

The entities have the following attributes:

1. dannye pats:
    1.1. id_pats: int(11) – the unique identifier of the entity specimen.
    1.2. Nomer_pats: text – an attribute-foreign key, intended for communication with other databases.
    1.3. Surname: text – a patient's surname.
    1.4. Name: text – a patient's surname.
    1.5. Otchestvo: text – a patient's patronymic.
2. Analiz_pats:
    2.1. Id_analiz: int (11) – a unique identifier of an entity specimen.
    2.2. Id_pats: int (11) – a foreign key attribute intended for communication with the "dannye pats" entity.
    2.3. Id_vid_lokal: int (11) – an attribute-foreign key, intended for communication with the entity «vid_lokal».
    2.4. Stenoz: float – stenosis value.
    2.5. Protromb_index: float – prothrombin index.
    2.6. Aterogen: float – the coefficient of atherogenicity.
    2.7. Lip_nizk: float – the lipoproteins with a very low density.
    2.8. Lip_vys: float – the lipoproteins with a high density.
    2.9. Prognoz: float – the predicted value of restenosis.
3. Users:
    3.1. Id_user: int (11) – a unique identifier of an entity specimen.
    3.2. Username: text – system user login.
    3.3. Password: text – system user password.

4.  Vid_lokal:
    4.1. Id_vid_lokal: int (11) – a unique identifier of an entity specimen.
    4.2. Naimen_lokal: text – location name in which the stenosis is located.

There are two roles among the system users: a user (a cardiologist) and an administrator (a programmer-developer). The user interface is presented in the form of the diagram on Figure 3.
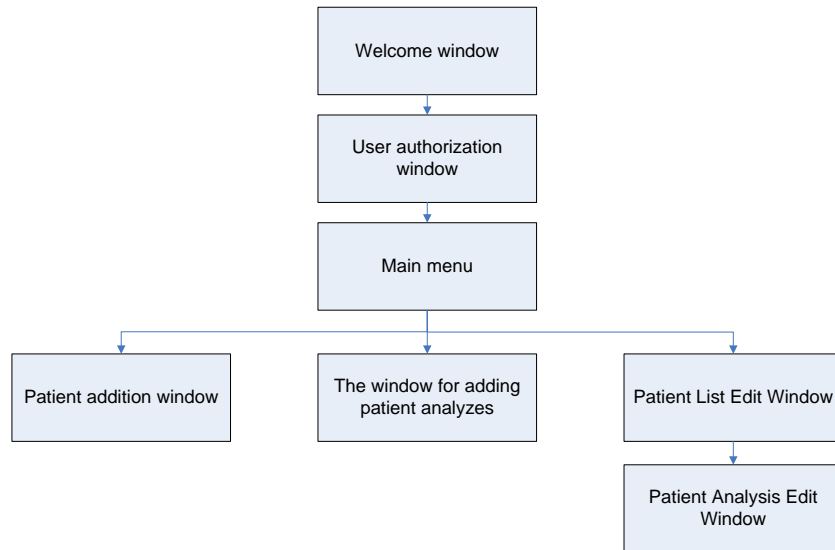


Figure 3: Interface Organization Scheme

The first window is welcome one. Figure 4 shows the view of this window when there is a connection to a server and the system is ready to work.
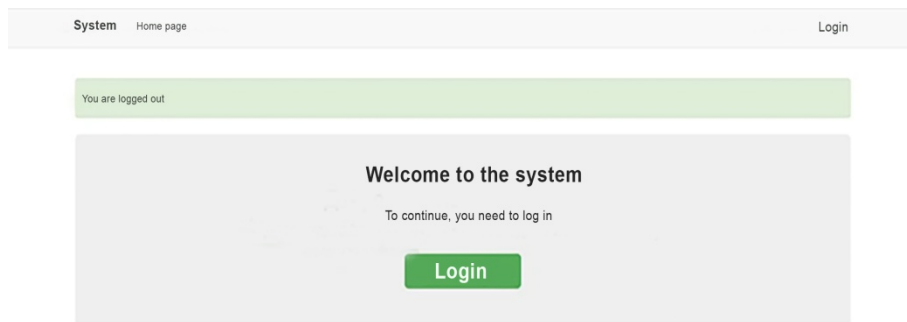


Figure 4: Welcome Window

After the clicking of "Login" button the user authorization window opens (see Figure 5). The system is private and no unauthorized users are allowed. Only administrators can add users.
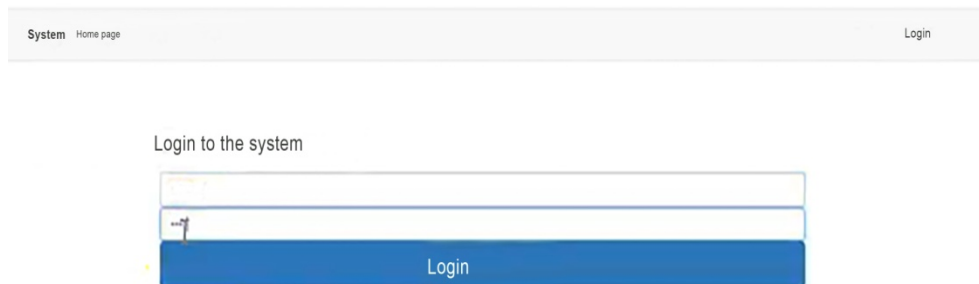


Figure 5: User Authorization Window

After authorization, the user enters the main menu - the window allows you to select the necessary actions to enter information into a database (see Figure 6).



Figure 6: Main Menu

In order to add new patients to the database, you must select the item "Add patient data" in the main menu. The window opens, and you enter the information about a patient: a patient's number, his last name, first name and patronymic (see Figure 7). To save the information to the database, click "Save" button.



Figure 7: Patient Addition Window

Having returned to the main menu, you can add the information about the patient's analyzes by selecting the item "Add patient analysis". Using the first drop-down list, you can select a patient who needs to add information about the analyzes (see Figure 8).

Further information is entered on stenosis localization, prothrombin index, atherogenicity coefficient, very low density lipoproteins and high density lipoproteins. To save the information to the database, click "Save" button.

Figure 8: Patient Analysis Record Window

In order to view the list of patients, select an appropriate item in the main menu. The list of patients is displayed on a page-by-page basis. In this window, you can add, edit or delete patient information, and the search line is also available (see Figure 9). It is possible to upload the information in pdf or xls format for further processing.



Figure 9: Patient List Output Window

To see the list of tests passed by the patient, you must click the "Analyzes" button in the corresponding patient line. In this window, you can delete old tests or add new ones for a patient (see Figure 10). Also, the window displays the predicted value of restenosis.

Figure 10: Output Window of Patient Test List

## II.    Summary

The method of risk prediction for cardiac restenosis development and the software that implements it have been tested using the examples of a specific implementation:

1.   Patient No. 9: at the time of stenting he had the following indicators: localization of stenosis - located in the vessel of the obtuse margin branches, the stenosis value S = 70%; the physical quantities of biochemical analyzes- $BC_1 = 80$ (PTI), $BC_2 = 5.1$ (atherogenicity coefficient), $BC_3 = 1.7$ (LPONP), $BC_4 = 0.9$ (LPVP).

$R = -1007.3013 + 7.8604*70 - 1.4578*80 + 18.4524*5.1 + 491.274*0.9 - 6.5503*70*0.9 = 40.3592$

Thus, at the time of stenting, the predicted value of restenosis after 6 months was 40.3592%.

Six months after the stenting operation, the examination of the patient revealed restenosis in the stent of the obtuse margin branch with 40% overlapping of the vessel lumen.

2.   Patient No. 38: at the time of stenting he had the following indicators: the localization of stenosis - located in the enveloping artery, the magnitude of stenosis S = 80%; the physical quantities of biochemical analyzes - $BC_1 = 94$ (PTI), $BC_2 = 5.3$ (atherogenicity coefficient), $BC_3 = 0.7$ (LPONP), $BC_4 = 1.10$ (LPVP).

$R = -3670.068 - 168.876*80 + 177.2463*94 + 944.4897*5.3 - 40.4895*0.7 + 1.1258*80^2 - 0.7408*94^2 - 10.0989*94*5.3 = 96.9732$

Thus, during stenting, the predicted value of restenosis after 6 months was 96.9731%.

Six months after the stenting operation, the examination of the patient revealed the restenosis in the stent of the enveloping artery with the vessel lumen overlapping by 100%.

3.   Patient No. 5: at the time of stenting, the following indicators were present: stenosis localization - located in the right coronary artery, the stenosis value S = 80%; the physical quantities of biochemical analyzes $BC_1 = 52$ (PTI), $BC_2 = 4.3$ (atherogenicity coefficient), $BC_3 = 0.7$ (LPONP), $BC_4 = 0.9$ (LPVP).

$R = -129.2103 + 2.1992*80 - 4.1480*52 + 303.8618*40.3 - 522.1097*0.7 - 619.0743*0.9 + 0.0269*52^2 - 10.6126*4.3^2 + 19.3059*0.9^2 - 2.7230*4.3*80 + 6.3003*0.7*80 + 42.9024*0.7*0.9 = 31.6268$

Thus, at the time of stenting, the predicted value of restenosis after 6 months was 31.6268%.

Six months after stenting, the patient's examination revealed restenosis in the stent of the right coronary artery with a 40% overlap in the vessel lumen.

4. Patient No. 20: during stenting, the following indicators were present: stenosis localization - located in anterior inter ventricular artery, stenosis value S = 70%, the physical values of biochemical analyzes $BC_1 = 100$ (PTI), $BC_2 = 4.3$ (atherogenicity coefficient), $BC_3 = 1.6$ (LPONP), $BC_4 = 1.6$ (LPVP).

$R = 6434.5551 – 170.2915*70 + 2.6731*100 – 466.8056*4.3 + 1484.8251*1.6 + 1.0768*70^2 + 6.2234*4.3*70 – 14.9416*1.6*70 – 3.8507*100*1.6 = 62.8218$

Thus, at the time of stenting, the predicted value of restenosis after 6 months was 62.8218%.

Six months after the stenting operation, the examination of the patient revealed restenosis in the stent of the anterior interventricular artery with the vessel lumen overlapping by 60%.

## III.  Conclusions

The conducted studies showed the possibility of biochemical blood test result use to predict the risk of the heart vessel restenosis 6 months after stenting. The developed method and the software that implements it will allow to conduct clinical trials at cardiological departments, as well as to obtain the additional data to expand the range of localizations and refine the models.

## References

[1]     Efremova, O.A., Nikitin, V.M., Churnosov, M.I., Kamyshnikova, L.A.,  Lipunova, E.A., Muromtsev, V.V. Risk virtual method assessment of coronary heart disease in carriers of polymorphic cardiogenic. *Belgorod State University Scientific Bulletin. Series: Medicine. Pharmacy* **26** (247) (2016) 64-69.

[2]     Efremova, O.A., Nikitin, V.M., Lipunova, E.A., Anohin, D.A. and Kamyshnikova, L.A. Estimate or the effectiveness of intelligent information system of early diagnosis and prognosis of cardiovascular disease. *Journal of World Applied Sciences* **26** (9) (2013) 1204-1208.

[3]     Efremova, O.A., Nikitin, V.M., Muromtsev, V.V., Lipunova, E.A. and Kamyshnikova, L.A. ECG computer analysis system with the advanced features of automated search and identification of its diagnostically significant changes. *International Journal of Pharmacy and Technology* **8** (2) (2016) 14174-14181.

[4]     Efremova, O.A., Nikitin, V.M., Mitin, M.S., Lipunova, E.A. and Kamyshnikova, L.A. Early diagnosis of coronary heart disease risk by the expert automated system based on the results of heart rate variability analysis. *Research Journal of Medical Sciences* **9** (4) (2015) 240-244.

[5]     Efremova, O.A., Nikitin, V.M., Mitin, M.S., Lipunova, E.A. and Kamyshnikova, L.A. Diagnosis of asthenic vegetative syndrome in patients with chronic viral hepatitis based on correlation analysis of heart rate variability. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **6** (4) (2015) 161-166.

[6]     Kochetkova, I.A., Dovgal V.M., Nikitin, V.M. and Lipunova, E.A. Method of visualization and recognition of the cardiovascular system state by its multidimensional image. *Belgorod State University Scientific Bulletin. Series: History. Political science. Economics. Information technologies* **20** (114) (2011) 181-185.

[7]     Efremova, O.A., Nikitin, V.M., Lipunova, E.A., Kochetkova, I.A. and Kamyshnikova, L.A. Visualization and virtual diagnosis of the cardiovascular system current state by the results of its non-invasive monitoring. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **5** (6) (2014) 1512-1518.

[8]      Sivakov, S.I., Nikitin, V.M. and Afanasiev, Y.I. Method of predicting the probability of restenosis after coronary artery stenting. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **5** (5) (2014) 1069-1073.

[9]     Sivakov, S.I., Nikitin, V.M., Afanasiev, Y.I. and Grigorova, S.Y. Analysis of efficiency of mathematical model of prognosticating the emergence of heart vehicle restenosis risk in cardiological practice. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **6** (4) (2015) 32-35.

[10]    JavaScript vs. PHP vs. Python. [Last accessed on 2018 Apr 04]. URL: https: //stackshare. Io /stackups /javascript-vs-php-vs-python