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QUALITY ASSURANCE AND RELIABILITY ANALYSIS OF INFORMATION MEASURING SYSTEMS EXEPLIFIED BY THE SYSTEM ATLANT

The paper presents description of the developed measures for improving the quality of the system Atlant and reliability of its operation.

Keywords: *reliability, failure rate, decision support, quality of cancer diagnosis.*

Telemedicine network "Rosatom-FMBA-MIFI" with the control center at the department of Computer Medical Systems of the National Research Nuclear University at Moscow Engineering and Physical Institute (NRNU MIFI) has been created to solve the problems of improving the quality of cancer diagnostics. The telemedicine network is based on high-technology systems of the cancer diagnostics Atlant, and it integrates multiple consumers in Russia, such as medical care units (MCU), academic centers and clinical hospitals [1]. The diagnostic network includes: NRNU MIFI, Blokhin Cancer Research Center of RAMN, CMSU # 141 (Udomlya, Kalinin NPP), MCU # 135 (Desnogorsk, Smolensk NPP), MCU # 125 (Kurchatov, Kursk NPP), MCU # 118 (Poliarny zory, Kolskaya NPP), MCU # 33 (Novovoronezh, Novovoronezh NPP) CMSU # 38 (Sosnovy Bor, Leningrad NPP), Saratov Medical Center FMBA (Balakovo, Balakovo NPP). Further expansion of the telemedicine network throughout Russia by introduction of new server capacities and porting additional users to the network is scheduled.

The system Atlant is an important tool for the implementation of technology to support medical decision-making based on expert systems and remote consulting, as well as on timely and operational support of medical staff by necessary data, which may be requested, for example, during surgical operation. Unique reference knowledge base containing color images of tumor samples in various organs and the corresponding standardized descriptions has been formed within the system frame with the participation of specialists of Blokhin Russian Cancer Center of RAMN, Clinical Hospitals # 83 and # 85, and others.

Expert systems are based on a database, which is stored on servers in the control center of telemedicine network. In addition, each medical institution has its own copy of the database. This is because a direct access to the base greatly increases the load on the network and, therefore, reduces data communication equipment speed. Addressing of customers to consultation archive should be carried out with minimum time and minimal load on the network. Therefore, the format of digitized images (number of digits, resolution, compression, etc.) is defined by a required picture quality, sufficient for reliable diagnostics. Redundancy of transmitted data affects the transmission rate and the time spent on consultation. Particularly acute this problem is in rapid diagnostics during operations when the surgeon is waiting for a medical diagnostician answer to determine the volume and approach of surgical intervention.

The initial source for building the knowledge base was the numerous clinical cases described in detail by highly qualified doctors (experts), and that allows ordinary doctors working with the system Atlant to rely on the country's leading experts in making important diagnostic decisions.

The system includes support for making medical decisions during histological diagnostics, built on the basis of automated image processing systems, which provides invaluable help in the diagnosis formulation. The diagnostic system Atlant, which implemented a computer model of the macro and microanalysis, the technology of rapid transmission of requested data and remote consulting, has been successfully used for more than 10 years in clinical practice.

The strict requirements of quality and reliability are made for vital systems, where the system Atlant belongs to. Implementation of these requirements is insured by selection of suitable hardware-software tools and system architecture, applied communication protocols. Among hazardous factors unfavorably affecting the efficiency of the system are notably the threats associated with the loss or corruption of transmitted data, which requires a number of additional measures to improve data reliability.

The World Wide Web is used as the data transmission medium in the system Atlant. The medium has a number of drawbacks, such as dependence on the provider, a possible decrease in the rate of data transmission during network congestion, illegal access, etc. The latter issue is extremely relevant now. The problem of reliability of received information arises in case of fully open data exchange. Online medical information must be protected. For this reason, it became necessary to use special methods for the protection of medical data. The developed software product allows solving the following tasks:

- verification and authentication of the source of messages;
- confidentiality and integrity of data (i.e. assurance against unauthorized change of information);
- authentication (notarization of the parties).

The system Atlant provides online remote medical consultations in real time and with proper quality of communication; therefore, it must have a high level of fault tolerance and the ability to quickly recover after failures. We shall consider any events leading to the impossibility of image transmission, and partial or total loss of communication as a system failure. It can be failures of hardware that ensures the registration of optical images, generation of digital data and its processing, failures in data transmission channels, etc. These failures in medical operational practices are unacceptable.

Therefore, to improve the reliability, the developers of the system under consideration have used special software for monitoring the network, which affords an opportunity of remote analysis of faults and rapid response. The practice of telemedicine network operation "Rosatom-FMBA-MIFI" has shown that the network nodes that are remote from the control centre often have limited capacity of Internet-channels. In some cases, the transmission rate of channels does not exceed 256 Kb/s and can drop even lower. The objective of software for monitoring is the online tracing of the network state and fault detection (for example, problems caused by overloaded and/or failed servers, other devices or network connections, occasional connection loss, reduced network performance, long boot of servers, etc.). The monitoring software is an effective tool for managing a computer network, and it performs a number of important functions, including:

- control and monitoring of network resources;
- allocation of memory required to execute computing tasks;
- network configuration management;
- fault diagnostics.

The introduction of the computer system for decision support in the analysis and formulation diagnosis inevitably raises the accuracy issue of decisions recommended by automated diagnostic systems. Since the correct description of a microscopic sample largely depends on the quality of a digital image, special attention has been paid to the development of color calibration in the system to minimize errors in the automated issuance of expert information. For this purpose, medical staff together with technicians have selected special equipment, which includes microscopes, microscope control units, cameras, capture cards, video cards, interface devices. Software libraries for image analysis and special programs have been developed to control cameras and control units of microscopes. Algorithms of decision-making for automated diagnostics have been developed and special software created to provide images in the correct format and quality. Experts in practice as well as analytically [2] have confirmed the adequacy of the automated diagnostics system. They experiment carried out to assess errors in diagnostics using the system Atlant showed that by applying the system young doctors erred in only 5% of difficult diagnostic cases, while in self-reliant diagnostics (without using the system) errors in complex cases made up 25 %.

The analysis of long-term operation of telemedicine network "Rosatom-FMBA-MIFI", which is based on Atlant systems and has been functioning since 2000, has allowed to reveal the shortcomings of the system and to take action to prevent failures in the future, which have occurred during the system operation.

An important feature of the system is the probability of failure during specific user session. To estimate this probability, we will use the widely applied exponential law of distribution of uptime. Therefore, first, we shall estimate the failure rate of the system Atlant.

We shall take the following as initial data for the calculations: 2760 communication sessions with users were conducted for the whole period of the system operation, with three sessions not held for the following reasons:

- one of the nodes of the network suffered from a virus attack (at present the appropriate securities have been installed and there is no of such failures);
- another failure was caused by mechanical damage of the cable connector due to the careless handling of equipment (user fault);
- the third failure occurred due to poor connection at the system controlling card.

Since, as a result of conducted improvements in the network, the cause of the first mode failure has been eliminated, we shall believe that in the network corresponding to the up-to-date state, there were two actually significant failures during the operation time. In view of operability independence of individual nodes in the network, the failure rate of the system Atlant for a single user can be estimated from the available data (results of operation):

- N = 2760 tests of communication sessions were conducted (one test time T = 1 hour);
- two sessions (n = 2) turned out to be failure.

Under conditions of an exponential law of distribution of failure time, the estimate $\hat{\lambda}$ of the parameter λ is obtained by the method of maximum likelihood [3]:

$$\hat{\lambda} = \frac{n}{\sum_{i=1}^{n} t_i + (N-n)T},$$

where t_i is failure times observed in the experiment, N is the sample size, T is the duration of tests.

In our case, the numerical value of failure rate λ_0 obtained from the experimental data is equal to $\lambda_0 = 0{,}0007$ (1/hr).

The probability of failure *P* of the system for a given value λ per one hour will be:

$$P_T = 1 - \exp[-\lambda T] < 1 - \exp[-0{,}7 * 10^{-3}] \approx 0{,}0007.$$

For the construction of the upper confidence limit on the parameter λ, we shall take into account that the number of failures *n* occurring in the system is distributed according to the binomial law, which is well approximated by the Poisson distribution with parameter μ = NP. Te upper confidence limit for the value μ is determined from the equation given in [4]:

$$\sum_{k=1}^{n} \frac{\mu_B^k}{k!} \exp\{-\mu_B\} = \alpha,$$

where α is the level of significance.

This limit has been calculated and it is equal μ_B =5.3 with the level of significance α = 0.1 and the number of failures *n* = 2. This value μ_B corresponds to a random event, which consists in the fact that this event occurs during a large number of tests *N*=2760, and it can be considered as the sum of independent low-probability events, the distribution law of each event quantity occurrence is also a Poisson distribution with parameter $\mu_1 = \lambda T$. Poisson law is a reproducing law [5] by the parameter μ, therefore $\mu = N\mu_1$. As between the quantities μ_1 and μ there is unambiguous correspondence, the upper confidence limit μ_{1B} for the parameter μ_1 is the following

$$\mu_{1B} = f(\mu_B) = \frac{\mu_B}{N} \approx 2 * 10^{-3} \text{ and } \lambda_{1B} = 2 * 10^{-3} \text{ (1/h)}.$$

It should be noted that failures of the telemedicine network control center "Rosatom-FMBA-MIFI" located at the Department of Computer Medical Systems NRNU MIFI were observed over the entire ten-year period of the system operation. Therefore, the reliability improvement of the system Atlant is possible through preventing failures of user equipment.

References

1. **Nikitayev V.G., Pronichev A.N., Berdnikovich E.U., Chistov K.S.** Strategy of constructing high-tech systems for computer microscopy: experience of development and implementation of such systems in the nuclear industry and medicine. Devices and systems. Management, monitoring and diagnostics. # 10, 2011, p. 1-4.

2. **Vlasov V.A., Nikitayev V.G., Pronichev A.N., Chistov K.S.** Statistical trials construction for testing automated medical systems of microscopic images analysis. Devices and systems of control, monitoring and diagnostics, # 4, 2008.

3. **Gnedenko B.V., Belyaev U.K., Solovyev A.D.** Mathematical methods and theory of reliability. Moscow: Nauka, 1964.

4. **Vlasov V.A.** Estimates and confidence intervals. Moscow Engineering and Physical Institute, 2006.

5. **Rao S.** Linear statistical methods and their application. "Science." Chief editorial board of physical and mathematical literature. Moscow, 1968.