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Review Article

Recent Solutions in the Field of Automated Monitoring and Quality Control of Telemedical Services

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Abstract *- Currently, telemedical services are becoming increasingly widespread. Therefore, for automated and anticipatory control of diseases, pathologies, and medical errors, it is advisable to develop complexes for automated monitoring and control of telemedical services. This study aims to determine the current development level of software packages for computer-aided monitoring and control of telemedical services and to predict future development trends. This study considers Russian and foreign organizations engaged in creating automated distributed monitoring and online quality control systems for telemedical services. A systematic literature review was conducted to identify market leaders and characteristics of existing and emerging systems. This analysis helped determine: the current technical level of the complexes mentioned above, the main technical solutions used and the technical requirements for advanced complexes, and the trends of further industry development. It was found that in the Russian market, no systems allow full control of the quality of informational telemedical services, making such complexes promising for development and commercialization. Proposals for the architecture and functional capabilities of the software complex for automated monitoring and control of telemedical services were formulated.*

Keywords *- Automated monitoring, Image artifact, Neural network, Quality control, Telemedical service, Telemedicine, Video stream control.*

1. Introduction

As modern information technology has entered everyday life, medical organizations worldwide are trying to organize and improve telemedical processes [1, 2]. However, medicine is a very conservative industry that is wary of innovations, so attempts to connect doctors and patients beyond face-to-face appointments have been slow to adopt [3, 4]. As a result, telemedical services became a common part of international medical practice only during the COVID-19 pandemic [5–7].

Many approaches exist to interpret the term "telemedicine" [8]. The most noteworthy is the one proposed by the World Health Organization. In 1997, they provided an almost universal definition. Thus, according to experts, telemedicine should be considered a format for providing healthcare services, given that distance is a critical factor [9]. However, there is a caveat: there must be at least two subjects: an employee of a medical organization and a consumer of a consulting service. The tasks of telemedicine come down to informing people and informing them about diagnosis, therapy, and prevention of diseases and injuries [10, 11]. Additionally, telemedicine can be used as a research and evaluation tool [12]. Currently, telemedicine is being considered, among other things, as a tool for educating healthcare workers to improve the health of the population and the development of local communities [13–15].

Since telemedical services are now becoming more widespread [16], it is advisable to develop and use special computer programs - complexes of automated monitoring and control of telemedicine services for automated and proactive control of various situations, including critical ones (diseases, pathologies, medical errors) [17, 18]. Such software complexes for automated monitoring and control of telemedicine services (hereinafter the complex) are mainly designed to perform the following functions:

- Ensuring continuous monitoring of telemedical service parameters;
- Visual monitoring of the quality of telemedical services;
- Detection of video artifacts in broadcasts from subscriber equipment and telemedicine systems (an artifact is understood hereinafter as any specific element present in the image frame; an artifact may be a characteristic natural feature of the image, or it may be a manifestation of some critical situation and

pathology or a result of a failure in the operation of software and hardware components);
- Analyzing the results of measurements and identifying the fact inconsistency of broadcast telemedicine signals with the established values of quantitative metrics;
- Recording the content of the telemedical signals;
- Informing the monitoring service on duty about alarm events via e-mail and at the system's interface;
- Full quality control cycle of the telemedical services provided;
- Generation of alarm messages according to the set thresholds for triggering alarms;
- Analytics in terms of graphing and reporting;
- Multiscreen viewing of live and recorded broadcasts;
- Report generation.

Additionally, this type of software complex must ensure the detection of cases of possible video signal degradation, which may lead to unexpected situations in the process of providing telemedical services [47]. Consequently, to implement such software, it is advisable to use artificial neural networks, the most effective modern tools for "intelligent" image analysis [20–23]. However, the use of heterogeneous self-trained neural networks is not advisable since it increases the cost of their development and implementation; moreover, it may lead to medical and diagnostic errors, as well as differences in the formulation of medical and diagnostic decisions by different neural networks concerning the same patient [24–26]. Simultaneously, the software and hardware solutions used are constantly being updated, and their technical requirements are increasing.

For effective use of telemedical services, the following tasks have priority:

- Obtaining an integral assessment of the quality of information services implemented over distributed networks;
- Performed a preliminary analysis of the service status based on the statuses of the monitoring objects included in the distribution chain;
- Optimization of resources aimed at ensuring quality monitoring of services;
- Automated control of the presence of video artifacts in the signal without involving human resources and minimizing the subjective component.

2. Literature Review and Analysis

Quite often, the scale of events in terms of the volume of data recorded by special equipment and programs during a day is enormous [27–29]. Their number, in some situations, exceeds several million. In practice, approaches to analyzing large volumes of events without tools and means of automation are unrealizable [30]. This is partly an incomplete statement, but manual processing of the relevant data may lead to errors, distortions, and inaccuracies and is very time-consuming [48]. Hence, a comprehensive monitoring system capable of analyzing data, establishing correlating relationships, and so on is promising [32, 33]. This is the optimal method to eliminate potential errors.

Companies are now beginning to use machine vision and natural language processing (N.L.P.) [34] to facilitate the structuring of unstructured data, such as images and video sequences [35–37]. This groundwork should be used for a multi-format information system for automated distributed monitoring and online quality control of information services using artificial intelligence technologies.

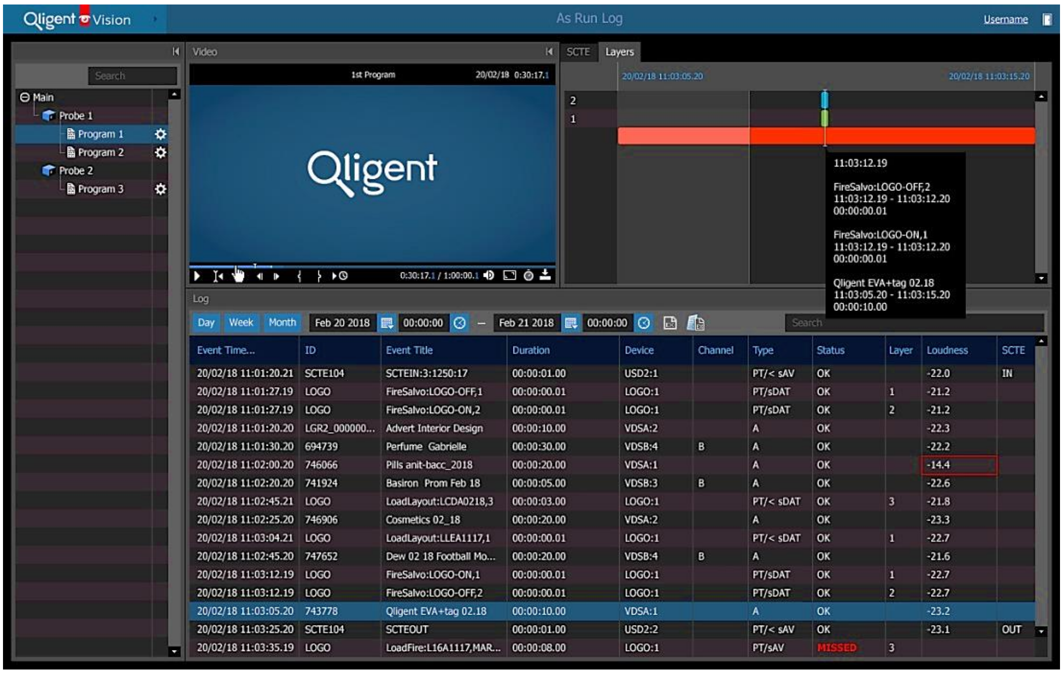

Fig. 1 Interface of the *Qligent Vision* multifunctional platform working environment

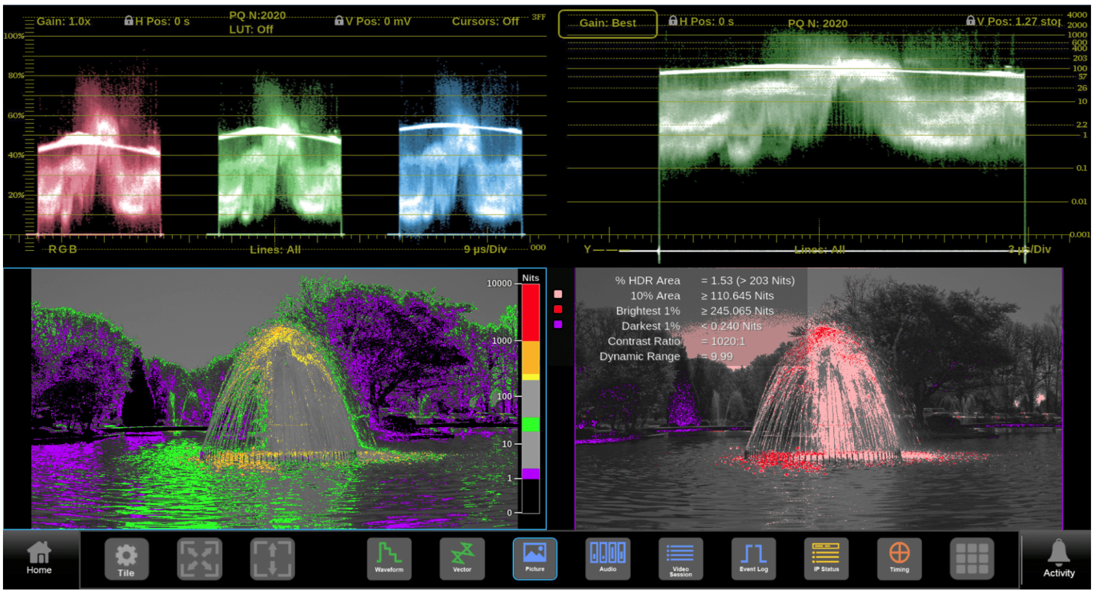

Fig. 2 Telestream IQ PRISM waveform monitor software module interface

To date, work on creating a system for automated distributed monitoring and online quality control of information and telemedical services has been carried out in several Russian and foreign organizations. For example, in Russia, there is a widely known system, "Qligent Vision," designed for twenty-four-hour monitoring of the quality of streaming video broadcasting on the Internet around the world [38]. The system offers to aggregate the received data in the central server, calculate S.L.A. (Service Level Agreement) and display statistics. The interface of the Qligent Vision multifunctional platform working environment is shown in Fig. 1.

The Telestream Company (U.S.A.) [39] is well known abroad; it specializes in developing products that allow working with video data regardless of how it was created, distributed, or viewed. One of the company's developments is the "Telestream I.Q." system, which monitors video services in distributed networks. This system can be developed in the field of machine learning. Note that the system can merge data in a one-to-many scheme [39]. Telestream IQ PRISM Waveform Monitor Software Module Interface is shown in Fig. 2.

Additionally, there are other manufacturers of similar systems and software products. For example, leading international manufacturers include:

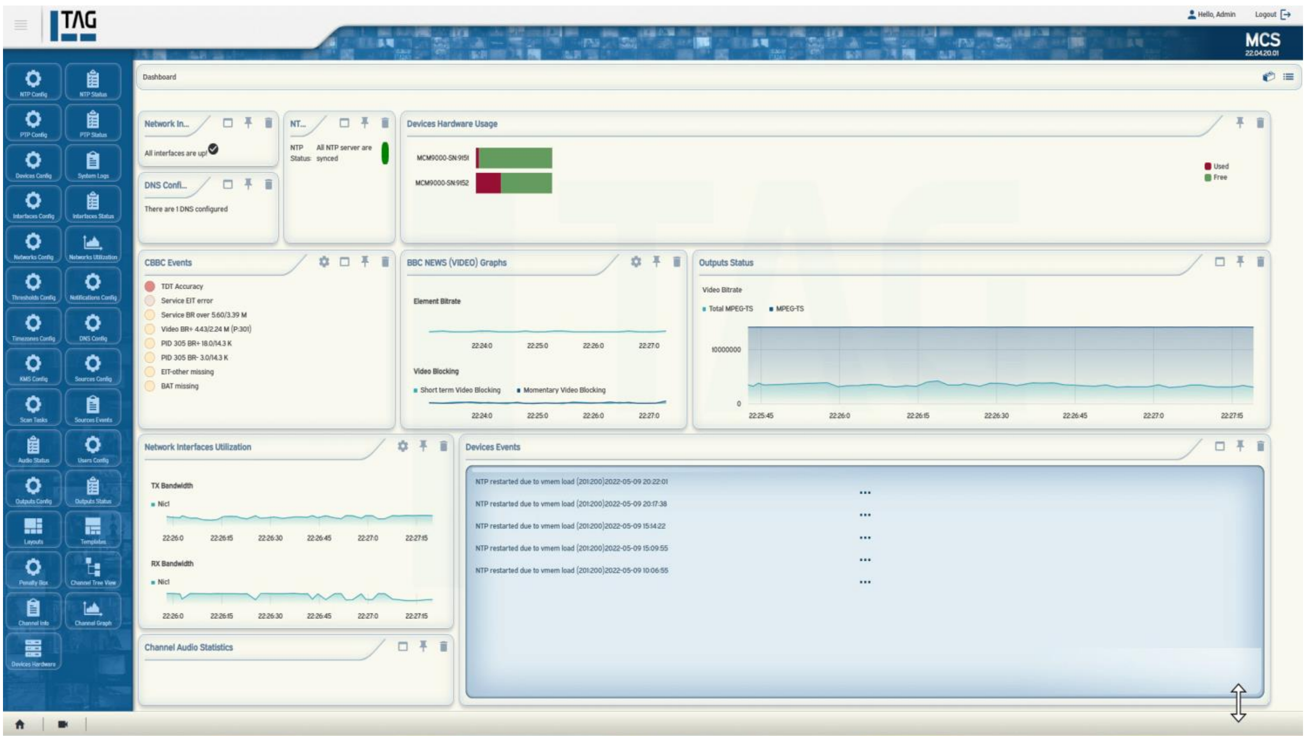

Fig. 3 Interface of the working environment of the multifunctional platform from *T.A.G. Video Systems*

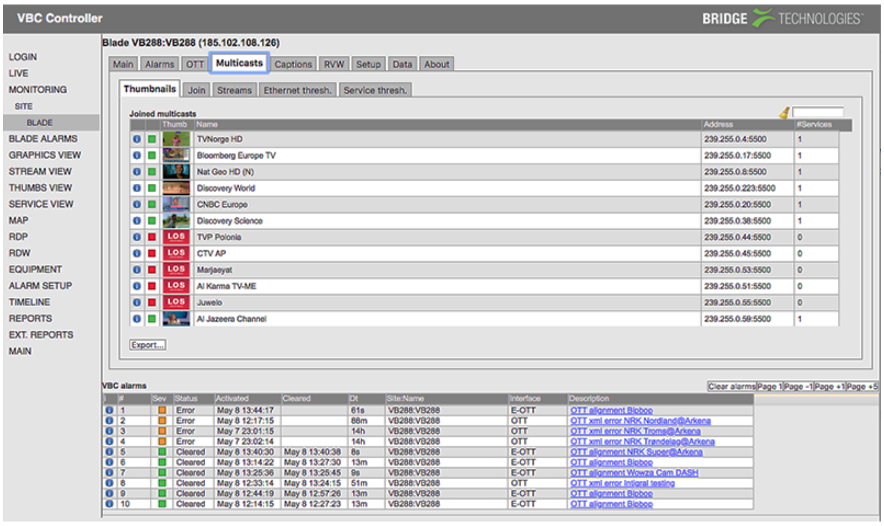

Fig. 4 The interface of the *V.B.C. Controller-working* environment at Bridge Technologies Co. AS

1. T.A.G. Video Systems (France) [40], which produces monitoring systems for the largest T.V. channels and content producers, such as "HBO," "FOX," "B.B.C.," "N.B.C.", and others. The working environment interface of the multifunctional platform from T.A.G. Video Systems is shown in Fig. 3.

2. Bridge Technologies Co. AS (Norway) [41] is a well-known developer of software and hardware solutions for monitoring and analysis of I.P., O.T.T. and R.F. signals. The interface of the "V.B.C. Controller" program workspace from Bridge Technologies Co., AS is shown in Fig. 4.

Russian manufacturers are described below.

1. Limited Liability Company "QLIGENT.RU" [38] is an innovative company operating in the field of information technologies that develops and supplies advanced solutions for media service quality assessment and control to consumers. The company's head office is located in Nizhny Novgorod. "QLIGENT.RU" maintains representative offices in different countries (United States, India, Great Britain and others). The key objective of their work is to promote products offered by society under the brand Qligent. Among its clients are major television and telecommunication companies. These are the open joint-stock company First Channel, R.T. on Russian, Rostelecom, and not only. The scheme of interaction between the main elements of video broadcasting and analysis using Qligent products is shown in Fig. 5.

2. *Elecard* [42] is a company that was founded in the late 1980s. Since the mid-1990s, it has developed products for encoding, processing, and transmitting information in different formats. The solution line includes modern software, a special SDK package, and tools for multidimensional analysis and digital content monitoring. Elecard is also engaged in solution development for IPTV, T.V. broadcasting and other spheres. Elecard offers multifunctional products that provide fast and high-quality digital data processing. An element of the work environment interface of Elecard's multifunctional platform is shown in Fig. 6.

3. Telenor L.L.C. develops technologies in the field of digital video broadcasting. The company implements complex hardware and software complexes and has experience in long-term operator activities. This company specializes in the development of software and hardware monitoring systems. Additionally, it produces products for television broadcasting and interactive services. These are TeleSCREEN and TeleTAG, respectively. Another noteworthy company offering is a system for monitoring the operation of television hardware and technical facilities called TeleMONITOR.

4. In this systematic review paper, the data obtained from more than 40 articles on the topic were analyzed. The articles were collected from Web of Science and Science Direct databases. A search was conducted using the following keywords: telemedicine services, telemedicine systems, and computer-aided monitoring and control software packages. The timeframe for the publications was from 2012 until 2022. More than 17 000 articles were found (Fig. 7).

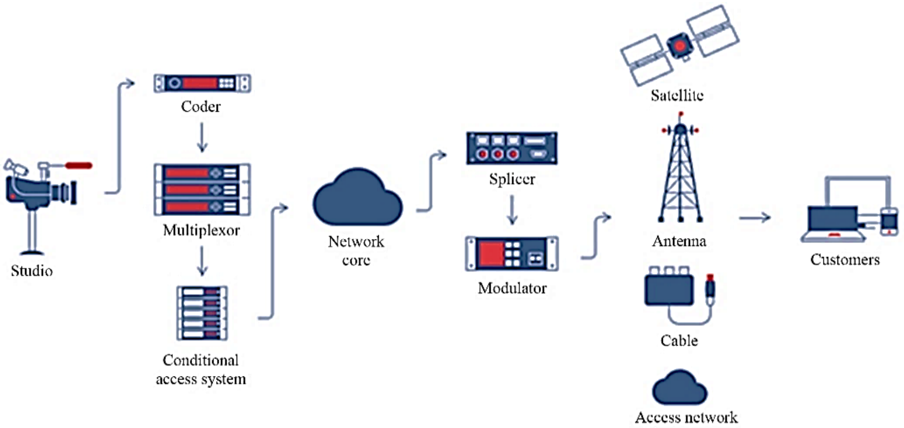

Fig. 5 Diagram of the interaction of the elements of broadcasting and video analysis using Qligent products

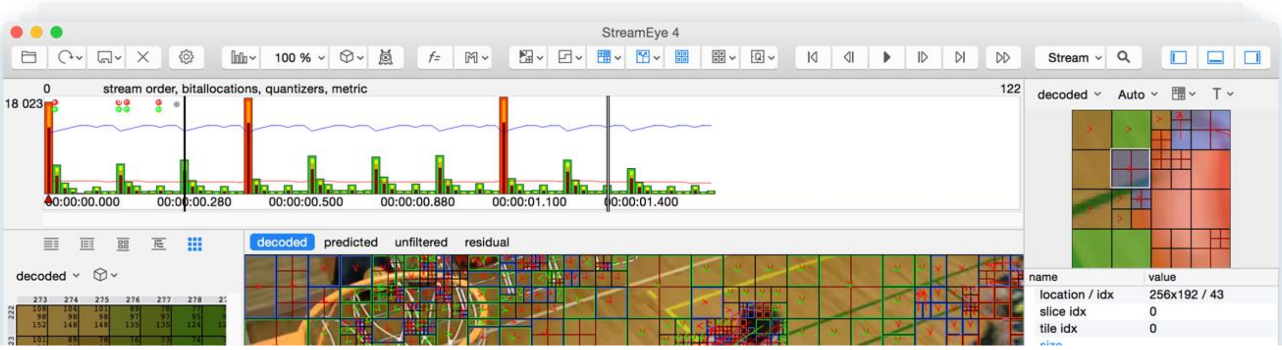

Fig. 6 Interface element of "StreamEye" software from *Elecard*

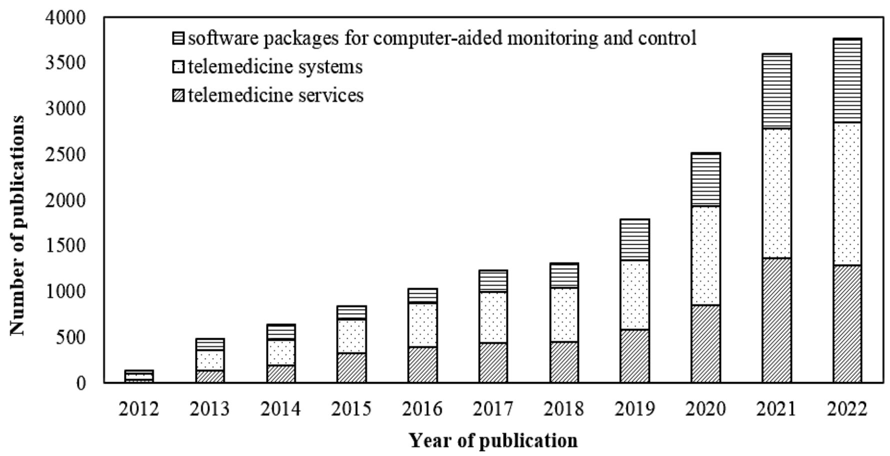

Fig. 7 The dynamic of scientific publications on telemedicine (2012–2022)

The review methodology reported in this article is presented in Fig. 8. It includes identifying scientific articles published on the interested topic, records screening, eligibility evaluation and analysis of the final articles left. The screening stage began with the removal of duplicates. The records, which were left after duplicate removal, were then screened for relevant content. The scientific publications without access to the full texts were removed at this point. Then, the final search was conducted to select the most relevant articles for assessment. Clear contributions, reliable data and research were the basis for choosing articles upon which the review was built.

3. Functional Capabilities of Modern Software Complexes for Automated Monitoring and Control of Telemedical Services

Telestream iQ, one of the market leaders in video quality monitoring, was chosen as the basis for the following comparative analysis of the systems mentioned earlier of automated distributed monitoring and operational quality control of information services. Telestream iQ helps operators navigate the complexity of the transition from S.D.I. to I.P., the transition from traditional linear T.V. to streaming O.T.T. distribution, and the transition to cloud technology for all types of video delivery services

[43]. Telestream iQ provides improved visibility, diagnostic and troubleshooting tools, and S.L.A. compliance, which ultimately reduces operations costs and increases video services' efficiency.

What makes the system special is its flexibility in terms of customization and scalability. It provides control of signal metrics, as well as quality monitoring of services provided to stakeholders. This system includes the so-called probes and the central core. The essence of the latter comes down to making decisions regarding the status of signal delivery according to predetermined rules of logic.

Telestream I.Q. system has a wide functionality that covers all the needs for real time monitoring of the services provided, visual and instrumental control of the parameters of any objects in the media production chain, comprehensive infrastructure monitoring and analytics and report generation (Fig. 9).

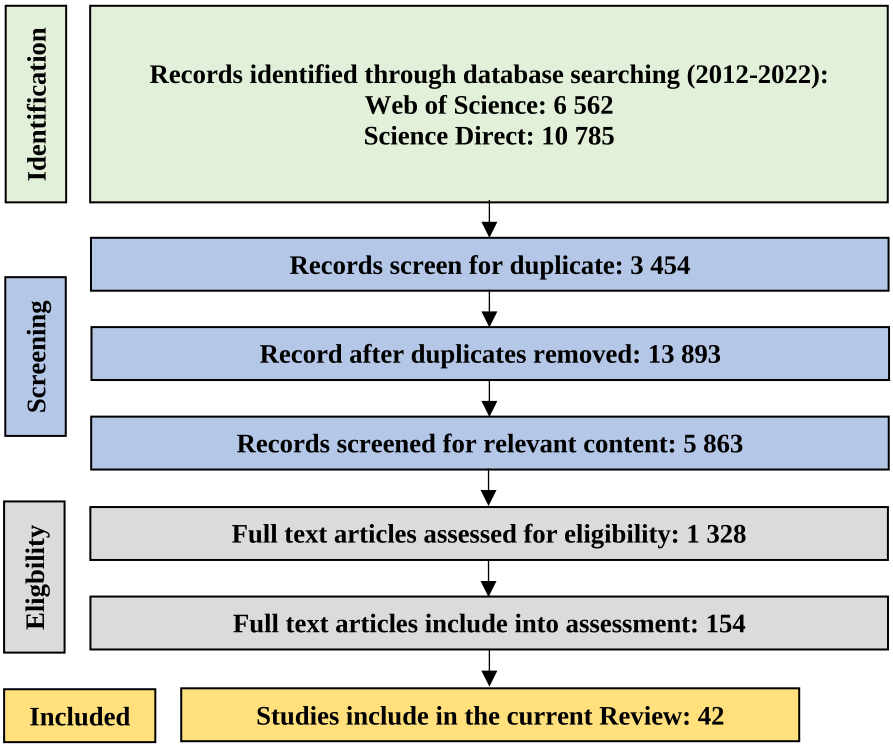

Fig. 8 Flowchart for the review process

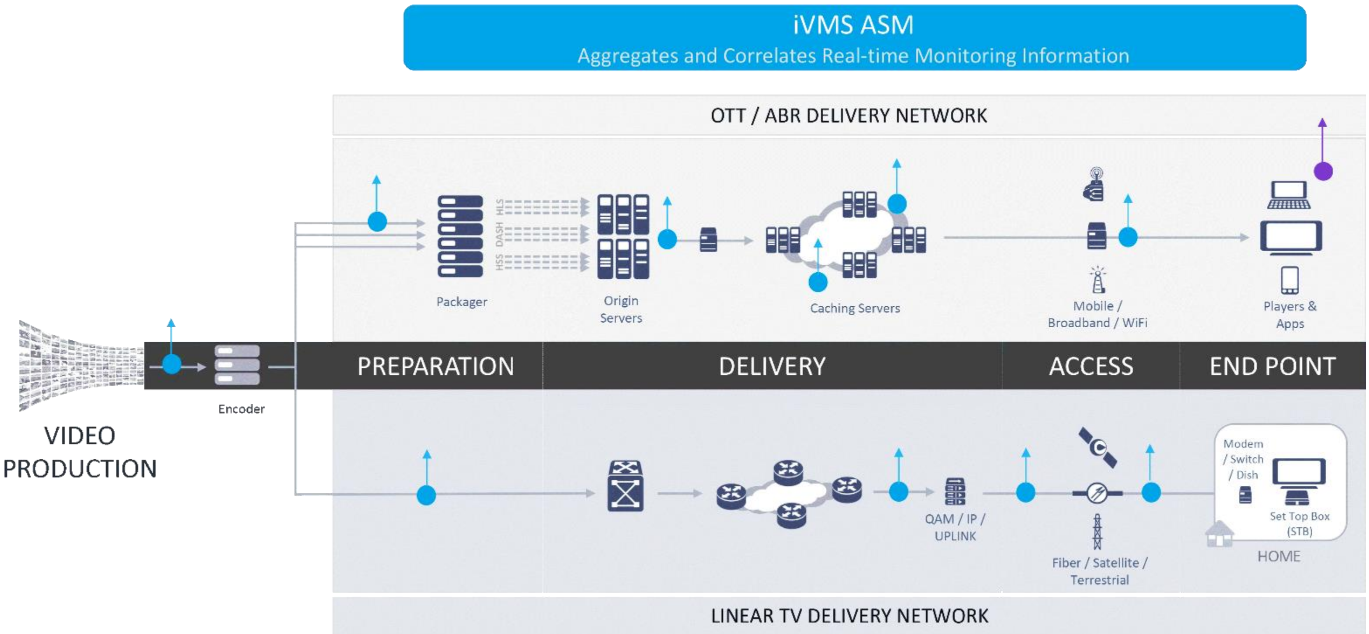

Fig. 9 Principles of operation of the "Telestream I.Q." system

The software solution is a distributed system consisting of sample analyzers and a single data collection center that consolidates and output information to the user in a prepared view on a personalized interface. The system contains three types of input and output components: data reception (data entry), aggregation (storage and analytics), and visualization/recording (data output). In addition to the system's services, hardware analyzers may be used as data sources. The key functionality of the system is:

- Control of service delivery in general
- Visualization of the service delivery path;
- The possibility of economic but effective monitoring (round-robin);
- Group addition and configuration of monitoring objects;
- Individual user views;
- Fully customizable interface templates;
- Ability to view signals from any point in real time;
- Support for receiving and sending data from external systems via open protocols;
- Monitoring of subscriber equipment;
- Ability to use hardware capacities for stream encoding and decoding.

The main features of the product are:
- Virtual correlation services, as the systems can work with top-level monitoring objects, which are virtual services "services" whose status is calculated by building a correlation of monitoring objects whose state is under observation;
- User workspaces, or user-oriented, which enable complete customization of the system "for yourself" for ease and comfort when working with any product component;
- Customizable object view, i.e., if necessary, any object presentation page in the system may have a different view; through the use of the view editor, the administrator of the complex may set up a more convenient view for the other users, using all the available graphic components in the system;
- Group operations that, when used, eliminate the difficulty of configuring many objects in the system;
- Centralized control, which allows monitoring all the servers in the network, creating layouts for the multiscreen processor, downloading events from the database for previewing, viewing channel status, outputting problem channels to the server, exporting video with errors from the storage, providing the operator with sound and visual notifications of problems, sending reports by e-mail, etc.

Main advantages of Telestream iQ:
- Automated monitoring of every transition in the video delivery chain with a generalized end-to-end view;
- Deep dive analytics to identify video quality issues and their root causes;
- The largest and most comprehensive range of video analysis sensors covers SMPTE 2110, linear T.V. (T.S.) and A.B.R. distribution.

The interface to one of the Telestream I.Q. modules is shown in Fig. 10.

Fig. 10 Interface of one of the "Telestream I.Q." system modules

For further review and analysis of current solutions in the field of monitoring and quality control of telemedicine services, the following manufacturers were considered:

- Those using telemedicine systems to provide services to the public;
- Developing software products for telemedicine systems;
- Those developing software products for telemedicine systems for the provision of services to the public;
- Developing software products for telemedical service quality control systems.

Potential competitors have been identified as systems such as

Qligent Vision is a software-based, distributed, flexibly scalable solution for comprehensive broadcast monitoring. This solution is designed for in-depth analysis of all aspects of broadcast quality at all points and troubleshooting technical failures in all areas of content delivery.

Key features:
- Minimization of losses from incorrect tapping;
- Reducing personnel costs: full automation of monitoring, control and reporting procedures;
- Improving the quality of media services - reducing the number of broadcast failures, increasing the speed of response to failures and their elimination.

Key features
- Twenty-four-hour automated quality control of video streams;
- Twenty-four-hour automated control of content block output;
- Controlled recording of broadcasts, viewing "broadcasts" and records via the Internet.

Teletor L.L.C. TeleSCREEN is a system intended to improve the quality of T.V. and video services by using automatic quality monitoring at all stages of signal delivery. Due to its functionality, the system can be applied in telemedicine. Functional capabilities of the system:

- Scalability. The system capacity can be scaled up as needed. Various versions of the system are available, which allow for providing comprehensive quality control and expanding the number of control points as the network grows;
- Support for various input interfaces. The system can perform a simultaneous professional analysis of various video and audio signals;
- Intelligent data analysis. The system analyzes signals, which allows for identifying alarm situations and alerting personnel about them. It also analyzes the causes of alarms for further troubleshooting;
- Alarm notification and logging of emergencies. The system signals the occurrence of malfunctions through audio or video alerts;
- Visualization and video logging of alarms. The system can automatically record monitored signals, allowing the situation to be recorded and a complete analysis to follow;
- Integral sound-level analysis. The system analyzes and displays the integral-volume level of all audio tracks, calculates corrections and automatically controls the volume correction devices, allowing a higher quality of service.

Particularly noteworthy is the unified T.V. and radio broadcasting control system of FGUP - RTRS. The key tasks that can be solved through its application are as follows:

- Control of equipment functions in the "here and now" mode. The system evaluates operating parameters, compares them to the preset values, and registers changes;
- Quality control of signals with subsequent transfer of recorded data to the control points;
- Creation of program image archives;
- Display of the recorded information in the form of parameters, numbers, and histograms in the "here and now" mode;
- Verification of readings broadcast by the transmitters;
- On-air monitoring. It is about evaluating the propagation of different signals, identifying interference parameters through data analysis, and accounting for critical parameters at receiving points through R.M.S.

The system has a database in which the results of the control of technical facilities are stored. The information goes to the monitoring service, where it is checked, analyzed and archived. Reports on the control results (summaries) are sent to the list of interested parties. Such a system can also be used in telemedicine.

The Elecard Multistream Player is a broadcast monitoring system that provides uninterrupted visual and instrumental signal quality control with a multi-window output. The Elecard Multistream Player software implementation and user-friendly interface provide the advantages of easy configuration and fast integration into existing digital video broadcasting network infrastructure. The system's functionality makes it suitable for telemedicine applications.

Elecard MultiStream Player supports various DVB tuners and signal-capturing devices, which makes it possible to tailor the program to an individual customer's needs.

System Features
- Visual monitoring of video signal quality, audio signal levels, and bitrate of the incoming stream;
- Ability to monitor in multi-window mode on several monitors;
- Viewing the selected channel in full-screen mode;
- UHD (4K) support;
- HEVC support;
- Informing the user about the triggered error (event) via SMS, specified e-mail, etc.

Elecard Boro is a feature-rich solution providing quality control of HTTP, DASH, U.D.P. and other protocols. The tool also facilitates QoS parameter monitoring in distributed networks with centralized access to statistical data.

This software product includes a so-called probe and a special server. Thanks to it are possible to quickly organize and implement monitoring activities to assess the delivery of content to consumers. The solution provides localization of many common and frequently occurring problems.

The above-mentioned probe can be placed at any point in a particular network. The optimal variant is several modules at once, as an example of placement: the head station, the network endpoint, and distribution nodes.

The probe is launched at the selected monitoring point. It searches for errors and transmits the recorded data to the server. The latter processes them, and reports are generated in a digestible form. Alerts are sent to the users via e-mail. Thanks to its functionality, the system can be applied in telemedicine.

Bridge Technologies V.B.C. offers centralized management and status display of all monitored services and provides an unprecedented view of network health and the flow of all types of media streams across the entire network. Key elements of V.B.C. include configuration management, multi-point flow performance comparison, worst case identification, detailed analysis, flow and service status monitoring, graphical display of historical alarm data using Microtimeline technology, Visio map import with active alarm indications, trending graphs for up to two years, SNMP (Simple Network Management Protocol) trap forwarding with multiple destinations, alarm logging and S.L.A. (Service Level Agreement) report generation. Bridge Technologies V.B.C. has a built-in map view that allows geotagging probe locations and displaying alarms as a map.

T.A.G. Video Systems A MULTIVIEWER is a tool for multiple application views combined with probing and monitoring. The tool is fully integrated with sensing and monitoring capabilities. It can receive, monitor and visualize all broadcast media formats, such as uncompressed 2110/2022-6, compressed MPEG-TS and O.T.T. streams, down to encoded video content and quality. This solution provides the operator with a simple and reliable tool for error detection, alerts and multiple views. The generated output mosaic is an H.D. or UHD video stream encoded and transmitted as 2110–21 and standard H.264/H.265 SPTS, also in the Zixi protocol, along with H.L.S. parallel output providing remote control, mobile device access and flexible installation topology [44].

Telestream Wirecast Studio is a cross-platform software for live video capture and playback. This software allows live streaming on multiple platforms simultaneously, using various video sources. Telestream Wirecast Studio allows mixing video and audio, adding titles, captions, headlines, and backgrounds. A simple and affordable broadcasting solution makes live broadcasting accessible to a wide audience. The main features of the program are:

- Possibility to use an unlimited number of video cameras;
- Layering of background sounds;
- Adding graphic elements;
- Collection of ready-made titles and transitions;
- Ability to use any input source;
- Output format selection;
- Support for streaming protocols, MMS, RTSP, RTMP;
- Fast switching between video streams.

The software allows directly changing the background during the broadcast. The composition can include up to 35 layers, allowing adding all the necessary inscriptions and graphic elements. This system can be used in telemedicine to provide online services [45, 46]. It is not necessary to be proficient in video technology to create an online broadcast with this software. The program is designed for various patient users and features an intuitive interface. All one must do is connect to video sources, and they can start broadcasting. The program includes many video transitions, including 3D, i.e., the virtual studio can be used. A video stream can be simultaneously output to several devices, and one can choose different video broadcasting speeds.

4. Comparison of Different Software Complexes for Automated Monitoring and Control of Telemedicine Services

The review revealed that there are currently no officially declared complexes of automated distributed monitoring and operational video quality control in the Russian market of telemedicine services. In this connection, these Russian systems, which are possible prototypes and analogs on the Russian market, were analyzed to determine the current technical level and determine the requirements for such a Complex, which is promising for development:

- Unified T.V. and radio broadcasting control system of the Federal State Unitary Enterprise Russian Television and Radio Broadcasting Network (FGUP RTRS);
- The system of visual and instrumental monitoring of digital television and radio channels TeleSCREEN 4.0 (Teletor L.L.C.). A general description of these systems is given above. All the main indicators concerning the interface, analysis, monitoring, sound-level analysis, and video recording were considered for this comparison of software complexes. A comparison of technical characteristics and determination of the current technical level is shown in Table 1.

Table 1. Comparison of the technical characteristics of different Russian complexes

<table>
<tr><th rowspan="3">Indicator name</th><th colspan="4">Indicator value</th></tr>
<tr><th rowspan="2">Advanced complex for developing automated monitoring and control of telemedicine services</th><th colspan="3">The Russian and foreign facilities of similar purpose</th></tr>
<tr><th>Unified television and radio broadcasting control system of RTRS FSUE (FGUP RTRS, Russian Federation)</th><th colspan="2">TeleSCREEN 4.0 (Teletor L.L.C., Russian Federation)</th></tr>
<tr><td colspan="5">Number of simultaneously displayed channels</td></tr>
<tr><td>- S.D.</td><td>At least 80</td><td rowspan="3">16</td><td colspan="2">Up to 80 channels SD (MPEG-2, TS)</td></tr>
<tr><td>- H.D.</td><td>At least 16</td><td colspan="2">Up to 15 channels HD (MPEG-4.10, TS)</td></tr>
<tr><td>- Radio channels</td><td>At least 256</td><td colspan="2">Up to 256 radio channels</td></tr>
<tr><td>Operation mode</td><td>24/7</td><td>24/7</td><td colspan="2">Static (fixed configuration) Scanning mode (dynamic cyclic configuration change)</td></tr>
<tr><td>Video Formats</td><td>Signals received via hardware network cards or video capture cards of the following standards and interfaces: MPEG-TS, ST 2022–6, ST 2110, SRT, NDI, HLS, RTMP, UHD Quad-link 3G-SDI, 12G UHD-SDI, SD-SDI, HD-SDI, HDMI.</td><td>Analog (SECAM, PAL, NTSC) and digital (DVB-T, DVB-T2, DVB-C)</td><td colspan="2">MPEG-1, MPEG-2, MPEG-4.2, MPEG-4.10</td></tr>
<tr><td>Audio Formats</td><td>Broadcast signal</td><td>Analog F.B. RB</td><td colspan="2">MPEG-1 Layer II, Dolby Digital, A.A.C., A.M.R.</td></tr>
<tr><td rowspan="2">Data stream (container)</td><td rowspan="2">No worse than MPEG-2 TS, MPTS or SPTS T2-MI, RTP/RTSP</td><td rowspan="2">16 S.D. channels, 4 Mbps streaming</td><td colspan="2">MPEG-2 TS, MPTS or SPTS</td></tr>
<tr><td colspan="2">T2-MI, RTP/RTSP</td></tr>
<tr><td>Input interface</td><td>Signals received via hardware network cards or video capture cards of the following standards and interfaces: MPEG-TS, ST 2022–6, ST 2110, SRT, NDI, HLS, RTMP, UHD Quad-link 3G-SDI, 12G UHD-SDI, SD-SDI, HD-SDI, HDMI.</td><td>Receiving DVB-T/T2/C digital signals, demodulation and technical analysis of DVB-T/T2 digital signals (Signal Level, SNR, M.E.R., S.F.N. Drift, Channel Impulse Response, Error rates), analysis of DVB-T/T2 streams, analysis of MPEG2-TS content (table parsing, ETR 290 pr.1,2&3 Bitrate, QoS SAE/DSE).</td><td colspan="2">Up to 8 1000Base-TX
Up to 40 DVB-ASI
Up to 40 SD-SDI
Up to 24 HD-SDI
Up to 12 Dual Link HD/Up to 8 3G-SDI
Up to 5 DVB-T/T2
Up to 5 DVB-S/S2
Up to 7 Analog RF (PAL, SECAM, NTSC, FM/AM)</td></tr>
<tr><td>Output video interface</td><td>Web-interface</td><td>No data available</td><td colspan="2">DVI-D; HDMI v1.3, v1.4; DisplayPort</td></tr>
<tr><td>Output audio interface</td><td>Web-interface</td><td>No data available</td><td colspan="2">3.5" mini jack, stereo, unbalanced S/PDIF, DVI-D, HDMI, DisplayPort</td></tr>
<tr><td rowspan="2">Control of external equipment</td><td rowspan="2">Preferable</td><td rowspan="2">According to SNMP</td><td colspan="2">Signal-switching matrix control</td></tr>
<tr><td colspan="2">Dexcrambler control</td></tr>
<tr><td colspan="5">Analysis and monitoring</td></tr>
<tr><td>I.P. network</td><td>Available</td><td>Channel broadcasting in the I.P. streams</td><td colspan="2">MDI: D.F., MDI: M.L.R., MLT15/24, M.L.S., Multicast Rate, Multicast Join Logging, Multicast Join Time
lost packets chart</td></tr>
<tr><td>DVB network</td><td>Available</td><td>DVB-T, DVB-T2, DVB-C</td><td colspan="2">Reception status, R.F. level, M.E.R., PER, BER, Demodulation status, modulation type, F.E.C. Code</td></tr>
</table>

			rate, SNR, Error counts graphical representation of the constellation
Data stream (container)	Available	Of synchronization signals in the digital transport stream the long absence of the transport stream	No input data flow structure error
Video image	Detecting artifacts in the video	No audio/video signal on the input No image (black frame) Image "freezing" (still image)	Image freeze, black frame (adjustable thresholds), block frame structure (adjustable thresholds), video data decoding errors
Audio	Available	Audio level (no sound) The audio signal did not match the set level	Low sound level (adjustable thresholds), audio data decoding error clipping
Meta-data	Available	Input signal level speed of digital stream and each service separately the error-free bitrate of the data stream received signal-to-noise ratio SNR transport stream parameters, QoS estimation Central carrier deviation control, S.F.N. drift measurement (DVB-T2) teletext/hidden subtitles with visual control of selected pages	SCTE 104 analysis SCTE analysis 35 Teletext, subtitle control
Control protocols	Yes	BER error rate M.E.R. measurement	Protocol error, no input Data, data flow errors, timing errors
Signaling to external monitoring systems	Available	Source placement type: external used network protocol: NTP hour layer: from Stratum1 to Stratum3	SNMP Get SNMP Trap, Syslog
Receiving and displaying alarms from external devices	Available	Available	SNMP Trap
Remote visual monitoring	By using artificial intelligence	Available	line-adapted technology (HTTP, slideshow) Video broadcasting (HTTP)
Recording a fragment of a transport stream	Available	Available	Manual mode Automatic mode (recording when a failure is detected)
Sound level analysis			
Integral value of the audio track volume	Preferable	No data available	For each track
Volume correction calculation	Preferable	No data available	For each track
Controlling the audio-volume correction equipment	Preferable	No data available	AppearTV Audio Leveling
Video Recording			
Recording	Available	16 S.D. channels, 4 Mbps stream, 24 T.B., 30-day storage time	SPTS/MPTS (no change), SD/HD-SDI (with encoding), AES/EBU (without encoding), Analog (with encoding)

			Cyclic automatic (configurable parameters), manual.
Protection against unauthorized access	Available	Available	Available
Statistic processing, report generation	Available	Available	Available

5. Summary of the Review and Trends in Further Development

After analyzing the collected information, the following conclusions can be made:

- There are currently no systems on the Russian market that can fully control the quality of telemedicine information services;
- Currently, there are no systems on the market that explicitly use artificial intelligence to analyze video content and identify artifacts;
- Companies that claim to be developers of similar or similar purpose systems do not specialize in creating neural networks and work with artificial intelligence.

From the above conclusions, it follows that the complex proposed for development can become competitive due to its technical characteristics, which should be on par with international systems analogues. The analysis of the competitive advantages of the complex offered for development compared with the possible known domestic and foreign analogs is presented in Table 2.

Table 2. Analysis of promises for the implementation of the competitive advantages of the proposed development of the complex compared with known equivalents

Main characteristics of the created products/technology	Foreign technologies			Russian technologies		
	TAG VS	BridgeTech VBC	Telestream IQ	ТелеTOP TeleScreen	Elecard Boro	Qligent Vision
Keeping statistics on the service availability	No	Yes, artificially, identically named objects can form into service.	Yes	No	No	Yes, one can specify the monitoring points on the map
Creating virtual services based on logical graphs from monitoring objects	No	No	No	No	No	No
Receiving any data from third-party systems using scripts	No	No	No	No	No	No
Support for all Russian standards and types of signals	No T2, SDI	No S.D.I.	No T2	No ST2022–6 and ST2110	No S.D.I.,	No ST2022–6 and ST2110
Support for the built-in perception quality monitoring system on the subscriber's home devices	No	No	No	No	No	No

Comparison of the software complex proposed for development with the leading developments of various vendors (U.S.A., China, E.U., etc.) allows us to conclude that the proposed complex can become a worthy competitor to Western analogs. This comparison and conclusions are made in terms of comparing both hardware and software solutions. It is also expedient to consider the inclusion of the task on the analysis of audio-volume level and video image analysis (for example, "freezing" of the image and video data decoding errors) for a greater advantage in use.

Based on the results of the review, the main trends in the industry can be identified, which include:

(a) The trend of applying technical solutions leads to the following results:

- Reduction of internal controlled parameters at a given level of reliability in determining the technical condition of multifunctional technical means;
- Increase the efficiency and reliability of monitoring objects;
- Increase the reliability and stability of communication

channels, reducing the time of information transfer;
- Increased efficiency of data collection, processing and conversion processes;

Expansion of the functional capabilities of monitoring tools and systems;
- Reduction of localized artifacts in the visualization data;
- Automatic learning on the available video data;

b) Application of principles leads to the following results:
- Increase the overall performance of the software and hardware complex;
- Protection of computer systems from unauthorized activity;

c) Application of technical solutions leads to the following results:
- Increase in the speed of decision-making;
- Increase the accuracy of object identification;
- Support of several video codecs, e.g. H.264, VP8, HEVC, MPEG4;
- Improved the accuracy of anomaly detection and image quality diagnostics.

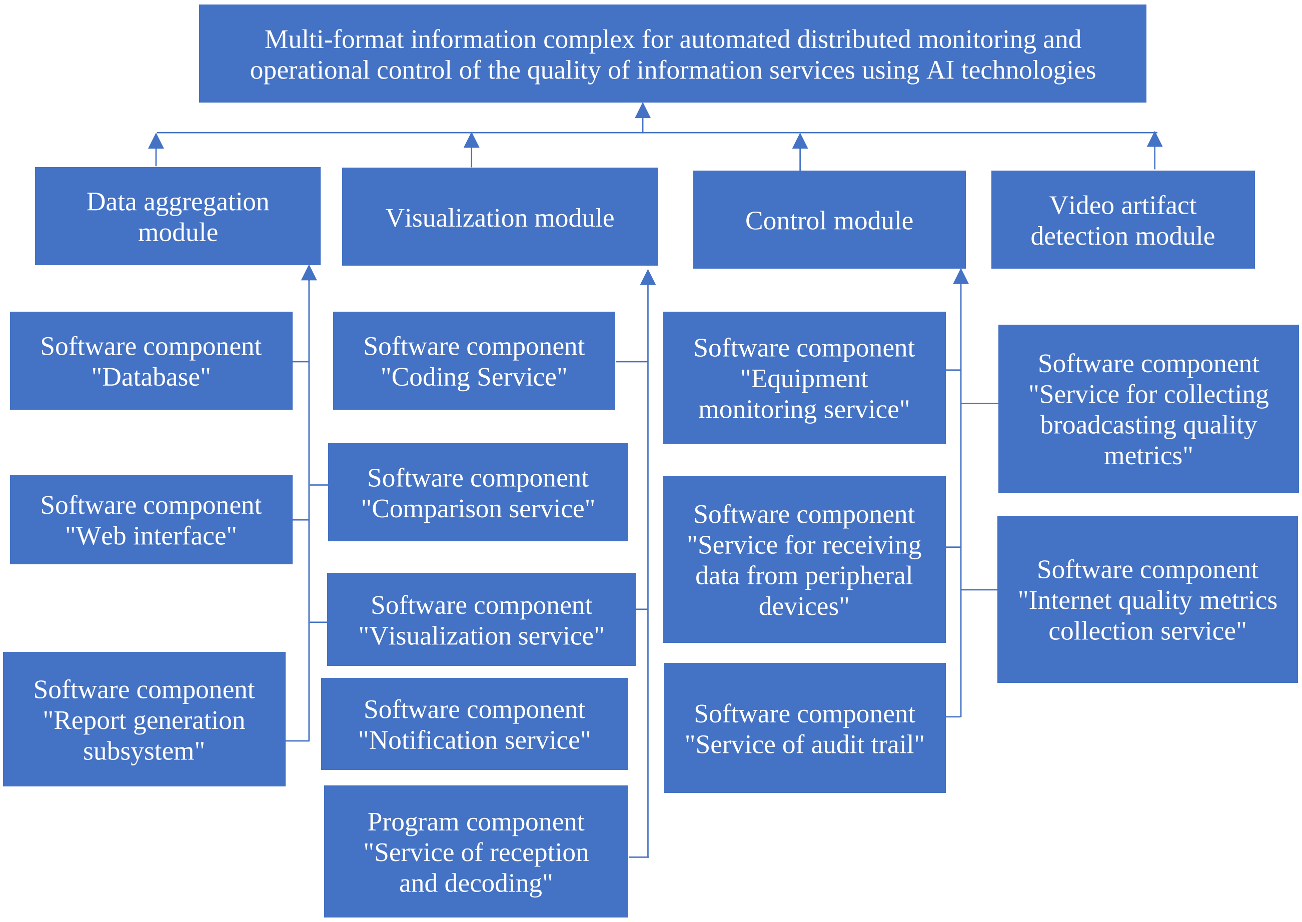

Fig. 11 An outline of the generalized architecture of promising for development and commercialization in the Russian market multi-format information system for automated distributed monitoring and operational quality control of information services using artificial intelligence technology

All this allowed us to form the following proposals on the architecture and functional capabilities of the software complex for automated monitoring and control of telemedicine services proposed for development and commercialization in the Russian market. The proposed scheme of the generalized architecture of the multi-format information complex for the development and commercialization in the Russian market of the automated distributed monitoring and operational quality control of information services with the use of artificial intelligence technologies is shown in Fig. 11.

The architecture of such a complex should include the following:

(a) A data aggregation module, designed to configure the complex, forms an interface and collects and centralizes data coming from metrics collection devices as part of the following:
- "Database" software component, which is an organized structure designed to store, modify and process interrelated information, mostly of large volumes;

- "Data Presentation Service" program component, which is a set of program packages and commands enabling interaction between the database and the user interface
- "Notification service" program component informing the user via e-mail about the triggering of this or that trigger when the metrics threshold values are exceeded;
- "Comparison service" program component was designed to compare the obtained values of signal quality metrics with the template ones;
- "Report generation subsystem" program component, which generates a summary of information from the database in a specified format for a specified period;
- "Web-interface" program component, which is a set of tools with which the user interacts with the complex via a web browser;

b) Control module, designed to collect data from monitored devices and transmit it to the data aggregation module, which consists of the following

- "Subscriber equipment monitoring service" software component that performs alternate channel switching and perception quality monitoring;
- "Video broadcast quality metrics collection service" software component, decoding video signals and extracting service quality metric values required for further analysis
- "Service for receiving data from third-party devices" program component, which polls third-party devices for receiving data according to generated user scripts;
- "Service for collecting Internet broadcasting quality metrics," responsible for analyzing Internet broadcasting (O.T.T.) streams and allocating service quality metrics.
- "Control record service" software component designed for automatic logging of video and audio information for a period set by the user for further submission to regulatory authorities or for parsing errors in the video stream;

c) Module of detecting artifacts in the video stream, using neural network models, designed to monitor video signals for image degradation caused by the appearance of foreign block structures due to interference or incorrect-coding settings;

d) A visualization module designed to visually display incoming signals, stream metadata, or additional useful information received from the control module or data aggregation module, consisting of

- "Receiving and Decoding Service" software component, responsible for receiving and generating the presentation of useful data;
- "Visualization service" software component, responsible for the direct display of the information generated in the video wall via the server hardware features;
- "Encoding service" software component allows encoding the formed representation and broadcasting it into the network for reception on the remote clients or data aggregation module.

The functional characteristics of promising multi-format information complex of automated distributed monitoring and operational quality control of information services using artificial intelligence technologies should provide:

- Automatic quality control of the services provided based on the data coming from the monitoring objects;
- Formation of alarm messages according to the set thresholds for triggering
- Control record;
- Analytics in terms of building graphs and reports;
- Multiscreen viewing of live and recorded broadcasts;

Video - quality degradation detection.

Below are listed the requirements for the main technical characteristics. Input data of the complex shall be signals received through hardware network cards or video capture cards of the following standards and interfaces: MPEG-TS, S.T. 2022–6, ST 2110, S.R.T., N.D.I., H.L.S., RTMP, UHD Quad-link 3G-SDI (SMPTE ST-425, 4 x 3 Gbps), 12G UHD-SDI (SMPTE ST-2082, 12 Gbps); SD-SDI (SMPTE-259M, 10 bit, 270 Mbps), HD-SDI (SMPTE-292M, 10 bit, 1.5 Gbps), HDMI.

The complex output data shall be:

(a) Continuous system analysis results:

- Displays the state of monitoring objects in the web interface;
- Visual display on image output devices of input signals received via hardware network cards or video capture cards;
- Notification via e-mail, at the interface, in the instant messaging network;

b) Reports on object status statistics:

- Summary report generated manually (by request) or automatically (by schedule) transmitted via SMTP (e-mail);
- Summary report by request or schedule in *.XLS, *.XML, *.CSV, *.PDF formats.

Complex-working mode - 7 days a week, 24 h a day. For the functioning of the complex, it is necessary to have one of the web browsers: Firefox (version no lower than 73), Chrome (version no lower than 81), or Microsoft Edge (version no lower than 89).

6. Conclusion

This study developed software complexes' technical level and development trends for automated monitoring and control of telemedicine services. This paper considers Russian and foreign companies involved in creating automated distributed monitoring systems and online quality control of information and telemedicine services. Market leaders were identified, and existing and emerging systems' technical and functional characteristics were analyzed. Software packages were compared. The main technical solutions used and determined the technical requirements for the complexes were identified. No systems that can fully control the quality of information telemedicine services were found in the Russian market. It makes them promising for development and commercialization. Proposals for the architecture and functional capabilities of the promising software complex have been formulated.

The architecture of the perspective Complex should include the following blocks:

- Web interface (data aggregation module);
- Visualization service (visualization module);
- T.V. broadcasting quality metrics collection service (control module);
- Data reception service from third-party devices (control module);
- Service for the collection of Internet broadcasting quality metrics (control module);
- Video artifact detection module;
- Receiving and decoding service (visualization module);
- Encoding service (visualization module).

Additionally, the following functions can be considered for inclusion into the Set functionality:

- Audio volume-level analysis;
- Video image analysis in terms of the following: the absence of audio/video signal at the input; the absence of image (black frame); freezing of the image (freeze frame); errors in video data decoding.

It should also be noted that since there is no separate state, national, or international standard that contains unambiguously defined requirements for the object of development, the following standards should be considered during further development of the Complex: GOST 34244–2017, GOST R 57377–2016/ISO/TR 16056-2:2004, GOST 25202–82, GOST IEC 62368-1-2014, GOST R 55036–2012 ISO/TS 25237:2008, GOST 34. 321–96, GOST R 55542–2013, GOST R ISO/TO 16056-1-2009, GOST R 58020–2017, GOST R 53534–2009.

Author Contributions

A.A.T. is responsible for conceptualizing, reviewing and editing the manuscript draft and supervising and administering the project. G.S.L. conducted a formal analysis and investigation and prepared the manuscript draft. E.Yu.L. is in charge of the methodology and software. A.K.L. carried out the validation, data curation, and visualization. All authors read and approved the manuscript.

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