Development of a laboratory installation of a digital measuring system for visualization of internal pipeline processes

A Petrov\textsuperscript{1*}, A Popov\textsuperscript{1} and A Molotok\textsuperscript{1}

\textsuperscript{1}Northern Trans-Ural State Agricultural University, 7 Respubliki St., Tyumen, Russia
E-mail: darker2012@yandex.ru, 264241@mail.ru, a.a.molotok@utmn.ru

Abstract. The article describes the tendency of the Russian thermal power complex to structure and visualize methods for calculating thermal processes inside the pipeline using digital technologies such as Big Data and Computer Vision. It is concluded that the next step in the development of pipeline measurement systems is to increase the degree of multifunctionality and versatility of measuring devices, as well as that at present principles of building and implementing AIS, are being rethought taking into account the latest achievements in IT. The article also describes planned to create a laboratory facility that will be used for the viability of the concept of an automated information system, data collection, testing of mathematical models, and creating software to improve the efficiency of functioning. The main features are the visualization of processes occurring in the pipeline systems of the oil and gas complex and housing and communal services.

1. Introduction
Nowadays the most important problem for the country’s development after the transformation of internal economic processes is increasing production capacity which is directly connected with sustainable energy-saving. Due to this fact, the importance of control, diagnostics, and accounting for raw materials and energy resources which are produced by oil-gas and energy complexes and then transported and consumed by both public utilities and other consumers is growing.

2. Materials and Methods
2.1. Automation of measurement systems in COVID-19 pandemic
The situation of the Russian Federation is quite favorable because alongside with current events (the COVID-19 pandemic) the Federal National Program on Digital Economy is being implemented. Also, it has become a power base to implement digital technologies of new generation to all spheres of industries. Since one of the most important directions of energy-saving is automation (particularly the automation of measurement systems) a new direction of improvement of technological and commercial accounting devices will soon be formed. Using Big Data and Computer Vision Technologies we can structure and visualize many computational methods of thermophysical processes to reduce their conceptualization when training specialists.

However, the educational aspect is only a degression from the general topic of the article. Certainly, the correct account of energy sources leads to their saving by both a minimal unit of this economic system (an individual consumer) and the entire fuel and energy sector.
3. Results

3.1. Advanced Dashboard Digitalization

The actual necessity of thorough digitization of the instrumentation pool sets a number of rather difficult tasks for developers of the automated information system (AIS):

1. To create measuring devices of a new generation (multifunctional and generic measuring devices). Perhaps the development of the devices will be targeted to the increase of their comprehensibility by specialists and the multiplatform character of this device[1-8].
2. To structure, analyze, and optimize data getting from existing AIS. In other words, to use the existing software adapted to take readings from the devices of later AIS versions using Big Data Technologies[9-11].
3. To reframe structure and application of the AIS considering the latest achievements in IT. In particular, to direct it to network ontologies and Semantic Web[12-16].
4. When making AIS to make a prognosis of possible events and implement current sanitary-hygienic requirements taking into account the latest changes related to the pandemic.

These tasks are solved by processing and rethinking information to improve existing domestic and foreign patterns. Also, it is necessary to find ways of using advanced researches in fluid and gas mechanics, thermophysics, considering their possibilities to be digitalized.

3.2. Process modeling in a virtual environment

Now it is necessary to state that the authors of this article understand the word “digitalization” as the ability of some process to be modeled in a virtual environment. It is logical that this implies the concept of “the degrees of digitalization” which means to model some process in a virtual environment so clearly that it could be indistinguishable by characteristics from reality. For example, a perfect digital twin has the maximum degree of digitalization because mathematical algorithms that describe its activity have been as much as possible close to the real parameters of an object. Mathematical models that have been used to make digital twins are tested for various fluctuations to model extreme situations. That is why experiments conducted in a virtual environment get exactly the same results as in a real one[17-24].

Consequently, we can formulate the practical significance of the article, which is to describe the conception of a new generation of intelligent devices that are used to measure flow and thermal characteristics of multiphase flows and their visualization.

3.3. Process visualization of piping systems

The article describes a laboratory device that will be used to study the viability of the concept of an automated information system to collect data, test mathematical models, and write software to improve productivity.

The main features of the system are to visualize processes that occur in pipeline systems of the oil and gas sector and communal services. The installation itself looks like this (Figure 1).

As you can see in picture 1, the device has a polymethylmethacrylate pipe with various additional elements that simulate different zones for passing a working body. The essence of this form of device is that when the working body runs through the pipes (2-6), most of the possible structures of the gas-liquid flow in the pipe will be created. Since the pipe material is transparent, it will be possible to fix visually a formed structure and regulate the further "life cycle" of the working body. The working body under research enters the unit in 1 and exits in 7. Rate and other parameters are formed by external devices (superchargers, aerators, etc.), which are not permanent parts of the device (they are not listed here).
Figure 1. Laboratory installation of the experimental section of the pipeline (1) Input canal, (2) Fixed angle support, (3) Chamber with an oil seal compensator, (4) U-shaped compensator, (5) Corner canal, (6) Fixed support, (7) Output canal, (8) The sensors of fluid flow and sound.

In addition, the device hosts 8 sensors that convert an analog signal to a digital one, thereby forming a database for further software training. The digital signal is stored as databases on the server. Between the working body which is being researched and the input devices of measuring systems, there are always measuring transducers that convert a physical signal into an electrical one, which can be converted to a digital one. It should be noted that the measuring converter (sensor) produces an equivalent signal, which in digital form can be described by the simplest formula:

\[ y = f(x) \]  \hspace{1cm} (1)

where

- \( y \) - is the output value of the sensor;
- \( x \) - is the input value of the sensor.

We can make a conclusion that measuring \( y \) value we can define \( x \) value. Of course, it is necessary to note that the formula itself may be changed depending on the particular experimental data obtained and the research conducted, on the correction coefficient for the whole formula. As a result, we often get some sort of calibration result, in which for a number of known values of \( x \), the corresponding values of \( y \) are measured and a calibration curve is constructed.

For the device described above it gives us a full stream of correct indicators to form databases. Consequently, researchers are able to make two measurements:

1. To remove the digital signal from the sensors when a particular working body passes through the sections (2-6).
2. To fix the image of changes in the working body (since the pipes of which the device was made are transparent).

Thus, it is possible to correlate the sensor readings with a fixed image. Even having a pair of "indication-images", it is possible to create software that allows us to output an image of the working body depending on the sensor readings.

4. Discussion
The usage of such software for the fuel and energy sector is vital since it literally allows the engineer "to look into" the pipe online and see the state of the working body.

The experimental platform will allow conducting experiments with various liquids and gas impurities, researching the effects of internal and external influences on different environments. Moreover, creating a real visual "map of the state of the liquid" depending on its structure, state, and physical measurements (taking readings from the sensors) allows having a new look at the processes occurring inside of it.
This process allows conducting various observations and experiments with some liquid and gases inside the pipe, thereby simulating the process cycle.

5. Conclusions
The usage of digital technologies for analysis, observation, and inference of patterns will allow creating more accurate mathematical models that describe the actual processes with a high degree of confidence. Also, it will help comparing how these processes occur in different environments, as well as learning more about the nature of their differences. In the future, using modelled processes, it will be possible to derive the necessary dependencies and visualize them.

References
[1] Lampropoulos G, Keramopoulos E, Diamantaras K 2020 Enhancing the functionality of augmented reality using deep learning, semantic web and knowledge graphs: A review, Visual Informatics, Vol 4, pp 32-42 https://doi.org/10.1016/j.visinf.2020.01.001
[2] Bildstein A, Feng J, Bauernhansl T 2019 Combining Channel Theory and Semantic Web Technology to build up a Production Capability Matching Framework (Procedia CIRP) Vol 81, pp 139-144 https://doi.org/10.1016/j.procir.2019.03.025
[3] Saravana Kumar C S, Santhosh R 2019 Effective information retrieval and feature minimization technique for semantic web data, Computers & Electrical Engineering, Vol 81, 106518, https://doi.org/10.1016/j.compeleceng.2019.106518
[4] Flotyński J, Walczak K, Krzyszkowski M 2020 Composing customized web 3D animations with semantic queries, Graphical Models, Vol 107, 101052, https://doi.org/10.1016/j.gmod.2019.101052
[5] Molood B, Quan B, Qing L 2019 Automated Class Correction and Enrichment in the Semantic Web, Journal of Web Semantics, Vol 59, 100533, https://doi.org/10.1016/j.jwebsem.2019.100533
[6] Fakroon M, Alshahrani M, Gebali F, Traore I 2020 Secure remote anonymous user authentication scheme for smart home environment, Internet of Things, Vol 9, 100158, https://doi.org/10.1016/j.iot.2020.100158
[7] Bicakci S, Gunes H 2020 Hybrid simulation system for testing artificial intelligence algorithms used in smart homes, Simulation Modelling Practice and Theory, Vol 102, 101993, https://doi.org/10.1016/j.simpat.2019.101993
[8] Sharif N M, Ahamad T K, Mohammed Azmi Al-Betar, Syibrah Naim, Ammar Kamal Abasi, Zaid Abdi Alkareem Alyasseri, Optimization methods for power scheduling problems in smart home: Survey, Renewable and Sustainable Energy Reviews, Vol 115, 109362, 2019, https://doi.org/10.1016/j.rser.2019.109362
[9] Mayr D, Martins L 2019 Reverse engineering database queries from examples: State-of-the-art, challenges, and research opportunities, Information Systems, Vol 83, pp 89-100, https://doi.org/10.1016/j.is.2019.03.002
[10] Baehr J, Bernardini A, Sigl G 2020 Ulf Schlichtmann, Machine learning and structural characteristics for reverse engineering, Integration, Vol 72, pp 1-12, https://doi.org/10.1016/j.vlsi.2019.10.002
[11] Raffo A, Oliver J D 2020 Barrowclough, Georg Muntingh, Reverse engineering of CAD models via clustering and approximate implicitization, Computer Aided Geometric Design, Vol 80, 101876, https://doi.org/10.1016/j.cagd.2020.101876
[12] Mendoça M, Perozo N 2020 Jose Aguilar, Ontological emergence scheme in self-organized and emerging systems, Advanced Engineering Informatics, Vol 44, 101045, https://doi.org/10.1016/j.aei.2020.101045
[13] Verdonck M, Gailly F 2020 Sergio de Cesare, Comprehending 3D and 4D ontology-driven conceptual models: An empirical study, Information Systems, Vol 93, 101568, https://doi.org/10.1016/j.is.2020.101568
[14] Linli Z, Gang H, Wei G 2020 Mapping ontology vertices to a line using hypergraph framework, International Journal of Cognitive Computing in Engineering, Vol 1, pp 1-8, https://doi.org/10.1016/j.iicce.2020.04.001

[15] Rabiser R, Schmid K, Eichelberger H, Vierhauser M, Guinea S, Grünbacher P 2019 A domain analysis of resource and requirements monitoring: Towards a comprehensive model of the software monitoring domain, Information and Software Technology, Vol 111, pp 86-109, https://doi.org/10.1016/j.infsof.2019.03.013

[16] Vialletto G, Noro M 2020 An innovative approach to design cogeneration systems based on big data analysis and use of clustering methods, Energy Conversion and Management, Vol 126, 112901, https://doi.org/10.1016/j.enconman.2020.112901

[17] Härting R C 2018 Christopher Reichstein, Matthias Schad, Potentials of Digital Business Models – Empirical investigation of data driven impacts in industry, Procedia Computer Science, Vol 126, pp 1495-1506, https://doi.org/10.1016/j.procs.2018.08.121

[18] Pascal H 2018 Learning from System Engineering to deploy Product Lifecycle Management, IFAC-PapersOnLine, Vol 51, Issue 11, pp 1592-1597, https://doi.org/10.1016/j.ifacol.2018.08.269

[19] Enríquez J G, Sánchez-Begines J M, Domínguez-Mayo F J, García-García J A, Escalona M J 2019 An approach to characterize and evaluate the quality of Product Lifecycle Management Software Systems, Computer Standards & Interfaces, Vol 61, pp 77-88, https://doi.org/10.1016/j.csi.2018.05.003

[20] Emmanouilidis C, Bertoneččí L, Bevilacqua M, Tedeschi S, Ruiz-Carcel C 2018 Internet of Things - Enabled Visual Analytics for Linked Maintenance and Product Lifecycle Management, (IFAC-PapersOnLine) Vol 51, pp 435-440, https://doi.org/10.1016/j.ifacol.2018.08.339

[21] Petrov A, Popov A 2020 Application of computer vision technology in the development of ultrasonic repeller, E3S Web of Conferences Vol 164, https://doi.org/10.1051/e3sconf/202016406013

[22] Petrov A, Popov A 2020 Overview of the application of computer vision technology in fish farming, E3S Web of Conferences, Vol 175, 0215 https://doi.org/10.1051/e3sconf/202017502015

[23] Islam Khan A, Al-Habsi S 2020 Machine Learning in Computer Vision, Procedia Computer Science, Vol 167, pp 1444-1451, https://doi.org/10.1016/j.procs.2020.03.355

[24] Feng X, Jiang Y, Yang X, Du M, Xin L 2019 Computer vision algorithms and hardware implementations: A survey, Integration, Vol 69, pp 309-320, https://doi.org/10.1016/j.vlsi.2019.07.005