Quantum information technology on the Edge

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Abstract

This is an introductory text to a collection of selected papers from the Joint Workshop on the Quantum Information Technologies and Edge Computing (QuaInT & doors 2021) which were held in Zhytomyr, Ukraine, on the April 11, 2021. It consists of short summaries of selected papers and some observations about the events.

Keywords

Quantum Information Technologies, Edge Computing

1. Introduction

1.1. QuaInT 2021: At a glance

Quantum **In**formation **T**echnologies (*QuaInT*) is a peer-reviewed international workshop interdisciplinary between Computer Science, Physics and Mathematics, focusing on research advances and applications of quantum information science and technology.

QuaInT topics of interest (inspired by [1, 2, 3, 4, 5, 6]):

- Annealing-based computing
- Cloud-based quantum computing
- Quantum information science education

QuaInT 2021: Workshop on the Quantum Information Technologies, April 11, 2021, Zhytomyr, Ukraine
doors 2021: Edge Computing Workshop, April 11, 2021, Zhytomyr, Ukraine
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- Quantum machine learning
- Quantum algorithms
- Quantum coding theory
- Quantum communication
- Quantum complexity theory
- Quantum computing models
- Quantum cryptography
- Quantum finance
- Quantum image processing
- Quantum information processing
- Quantum intelligent systems
- Quantum optimization
- Quantum programming
- Quantum software engineering
- Quantum simulation
- Quantum and probability logic

The first part of this volume represents the proceedings of the Workshop on the Quantum Information Technologies (QuaInT 2021), held in Zhytomyr, Ukraine, on April 11, 2021 (figure 2). It comprises 1 contributed paper ([7]) that was carefully peer-reviewed and selected from 4 submissions (https://notso.easyscience.education/quaint/2021/). Each submission was reviewed by at least 3, and on the average 3.25, program committee members. The accepted paper present the state-of-the-art overview of successful cases and provides guidelines for future research.

Figure 1: QuaInT 2021 logo

1.2. QuaInT 2021 Program Committee

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- *Wei Chen*, University of Science and Technology of China, China
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Figure 2: Joint workshop opening

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Additional reviewers:

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- *Oleg Pursky*, Kyiv National University of Trade and Economics, Ukraine
- *Andrii Striuk*, Kryvyi Rih National University, Ukraine

1.3. doors 2021: At a glance

> Peter the Great hacked through a window to Europe. We use doors.

E**d**ge C**o**mputing W**or**k**s**hop (*doors*) is a peer-reviewed international Computer Science workshop focusing on research advances and applications of edge computing, a process of building a distributed system in which some applications, as well as computation and storage services, are provided and managed by

> (i) central clouds and smart devices, the edge of networks in small proximity to mobile devices, sensors and end users, and
>
> (ii) others are provided and managed by the center cloud and a set of small in-between local clouds supporting IoT at the edge.

The goal of *doors* is to bring together researchers and practitioners from academia and industry working on edge computing to share their ideas, discuss research/work in progress, and identify new/emerging trends in this important emerging area. The emergence of the Internet of Things (IoT) and the demand for responsiveness, privacy, and situation-awareness are pushing computing to the edge of the Internet. There are many challenges in the design, implementation, and deployment of different aspects of edge computing: infrastructure, systems, networking, algorithms, applications, etc. doors would like to open discussions in these areas.

doors topics of interest are opened to:

- algorithms and techniques for machine learning and AI at the edge
- cellular infrastructure for edge computing
- distributed ledger technology and blockchain at the edge
- edge computing infrastructure and edge-enabled applications
- edge-based data storage and databases
- edge-optimized heterogeneous architectures
- fault-tolerance in edge computing
- fog computing models and applications
- geo-distributed analytics and indexing on edge nodes
- hardware architectures for edge computing and devices
- innovative applications at the edge
- interoperability and collaboration between edge and cloud computing

Figure 4: Pandemic times in Zhytomyr Polytechnic State University

- monitoring, management, and diagnosis in edge computing
- processing of IoT data at network edges
- programming models and toolkits for edge computing
- resource management and Quality of Service for edge computing
- security and privacy in edge computing

The second part of this volume represents the proceedings of the Edge Computing Workshop (doors 2021), held in Zhytomyr, Ukraine, on April 11, 2021 (figure 4). It comprises 7 contributed papers ([8, 9, 10, 11, 12, 13, 14]) that were carefully peer-reviewed and selected from 14 submissions (https://notso.easyscience.education/doors/2021/). Each submission was reviewed by at least 3, and on the average 3.2, program committee members. The accepted papers present the state-of-the-art overview of successful cases and provides guidelines for future research.

doors 2021

Figure 3: doors 2021 logo

1.4. doors 2021 Program Committees

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- *Andrii Striuk*, Kryvyi Rih National University, Ukraine
- *Tetiana Vakaliuk*, Zhytomyr Polytechnic State University, Ukraine

2. Articles overview

3. QuaInT 2021 Article overview

Kamil Khadiev (figure 5) in the article [7] consider online algorithms as a request-answer game. An adversary that generates input requests, and an online algorithm answers. Author consider a generalized version of the game that has a buffer of limited size. The adversary loads data to the buffer, and the algorithm has random access to elements of the buffer. Author consider quantum and classical (deterministic or randomized) algorithms for the model. Kamil Khadiev provide a specific problem (The Most Frequent Keyword Problem) and a quantum algorithm that works better than any classical (deterministic or randomized) algorithm in terms of competitive ratio. At the same time, for the problem, classical online algorithms in the standard model are equivalent to the classical algorithms in the request-answer game with buffer model.

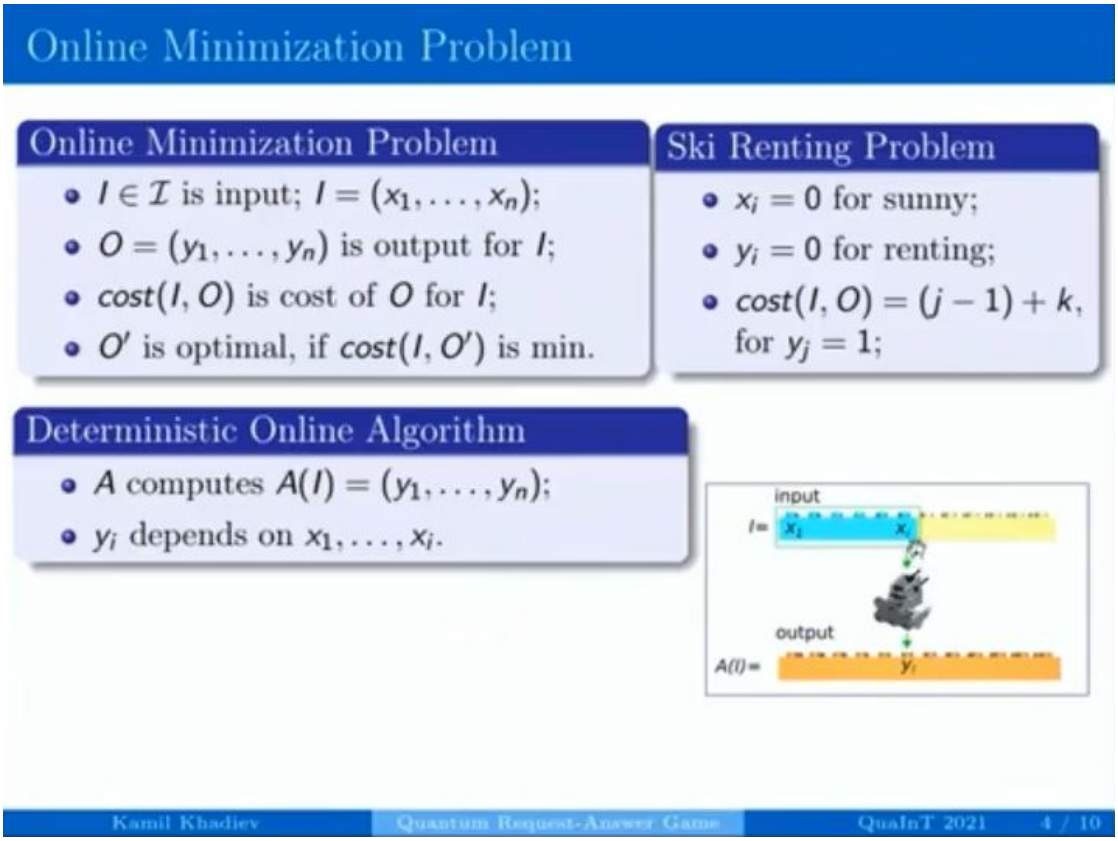

Figure 5: Presentation of paper [7]

4. doors 2021 Articles overview

The development and effective application of Fog Computing technologies require the most complex tasks related to the management and processing of huge data sets, including the tasks of rational construction of low-level networks that ensure the functioning of end devices within the IoT concept. The article "Graph model of Fog Computing system" [8] authored by Andriy V. Ryabko, Oksana V. Zaika, Roman P. Kukharchuk and Tetiana A. Vakaliuk (figure 6) describes the use of graph theory methods to solve such problems. The proposed graph model can provide the ability to determine the basic properties of systems, networks, and network devices within the concept of Fog Computing, the optimal characteristics, and ways to maintain them in working condition. This paper shows how to plot graphs, and then customize the display to add labels or highlighting to the graph nodes and edges of pseudo-random task graphs which can be used for evaluating Mobile Cloud, Fog and Edge computing systems. The graphs are described and visualized in Matlab code. Each task has an amount of computational work to perform, expressed in Megacycles per second. Each edge has an amount of data to transfer between tasks, expressed in kilobits or kilobytes of data. The set can be used by researchers to evaluate cloud/fog/edge computing systems and computational offloading algorithms. The

Figure 6: Presentation of paper [8]

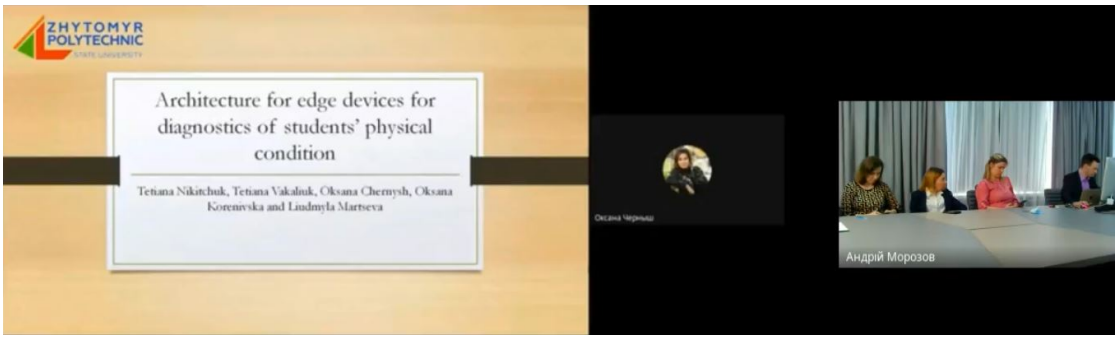

Figure 7: Presentation of paper [9]

task graphs can be used in single-user systems, where one mobile device accesses a remote server, or in multi user systems, where many users access a remote server through a wireless channel.

Tetiana M. Nikitchuk, Tetiana A. Vakaliuk, Oksana A. Chernysh (figure 7), Oksana L. Korenivska, Liudmyla A. Martseva and Viacheslav V. Osadchyi in the article "Architecture for edge devices for diagnostics of students' physical condition" [9] investigates the possibility of technical realization of hardware complex. It presupposes the use of sensors of registration of a photoplethysmographic curve, which describes a pulse wave and defines the parameters of students' cardiovascular system functional state. The method of photoplethysmography allows the use of non-contact sensors. Therefore, there is no artery compression, which eliminates circulatory disorders and allows the use of calculations to determine the saturation of oxygen by the pulse wave. It is recommended to use several optocouplers connected in series, parallel or parallel-series in a chain, with control of their mode of operation from the intensity of the received pulse wave signal depending on human body constitution. The edge device hardware is a part of the IoT system, which also includes another edge device, which instantly transmits data to the database on the edge server for the data further processing and storage.

The concept of the Internet of Things is increasingly defining the development of communication networks both now and in the future. The largest application of the IoT concept is

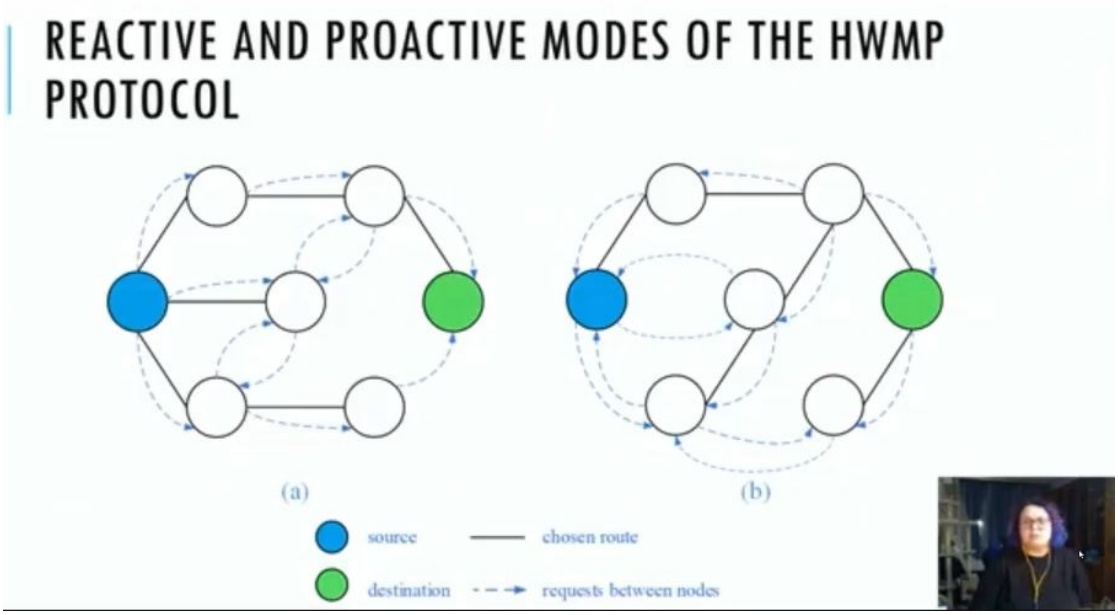

Figure 8: Presentation of paper [10]

wireless touch networks (WTN). Due to the potentially widespread use of WTN in all areas of human life, they are also called pervasive sensory networks. WTN belongs to the class of self-organizing networks, for which the construction principles, routing protocols, quality of service parameters, traffic models, and characteristics are significantly modified compared to traditional infrastructure networks, etc. The features of the application of dynamic routing protocols for the construction of a self-organizing network of autonomous IoT systems are considered. Anastasia D. Sverdlova (figure 8), Artur O. Zaporozhets, Ihor V. Bohachev, Oleksandr O. Popov, Anna V. Iatsyshyn, Andrii V. Iatsyshyn, Valeriia O. Kovach, Volodymyr O. Artemchuk and Nataliia M. Hrushchynska in the article "Self-organizing network topology for autonomous IoT systems" [10] provides an overview of the main methods for calculating the topology of self-organizing networks. A review of known dynamic routing protocols for mobile radio networks is given, the advantages and disadvantages of proactive and reactive approaches are shown.

Edge computing is an extension of cloud computing where physical servers are deployed closer to the users in order to reduce latency. Edge data centers face the challenge of serving a continuously increasing number of applications with a reduced capacity compared to traditional data center. Tania Lorido-Botran (figure 9) and Muhammad Khurram Bhatti in the article "*ImpalaE*: Towards an optimal policy for efficient resource management at the edge" [11] introduces *ImpalaE*, an agent based on Deep Reinforcement Learning that aims at optimizing the resource usage in edge data centers. First, it proposes modeling the problem as a Markov Decision Process, with two optimization objectives: reducing the number of physical servers used and maximize number of applications placed in the data center. Second, it introduces an agent based on Proximal Policy Optimization, for finding the optimal consolidation policy,

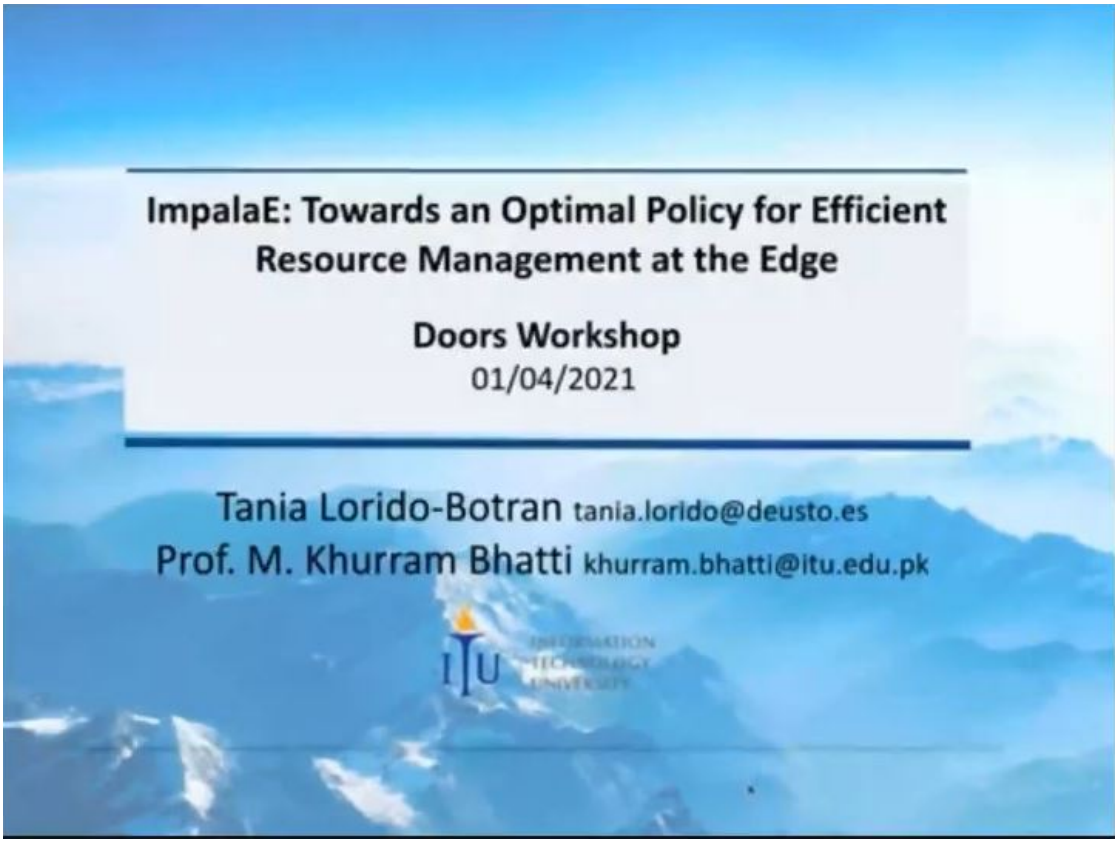

Figure 9: Presentation of paper [11]

and an asynchronous architecture with multiple workers-shared learner that enables for faster convergence, even with reduced amount of data. We show the potential in a simulated edge data center scenario with different VM sizes based on Microsoft Azure real traces, considering CPU, memory, disk and network requirements. Experiments show that *ImpalaE* effectively increases the number of VMs that can be placed per episode and that it quickly converges to an optimal policy.

Nadiia M. Lobanchykova (figure 10), Ihor A. Pilkevych and Oleksandr Korchenko in the article "Analysis of attacks on components of IoT systems and cybersecurity technologies" [12] presents the results of IoT analysis, methods and ways of their protection, prospects of using edge computing to minimize traffic transmission, decentralization of decision-making systems, and information protection. A detailed analysis of attacks on IoT system components was carried out and protection recommendations were developed.

Taras A. Uzdenov (figure 11) in the article "Task scheduling in Desktop GRID by FSA method: a practical example" [13] considers a new approach to solving the problem of dispatching task flows, the complexity of which is known, for GRID-systems with inalienable resources, the performance of which can be determined. A method based on this approach has been developed. The efficiency of the proposed method is compared with the well-known and widely used in

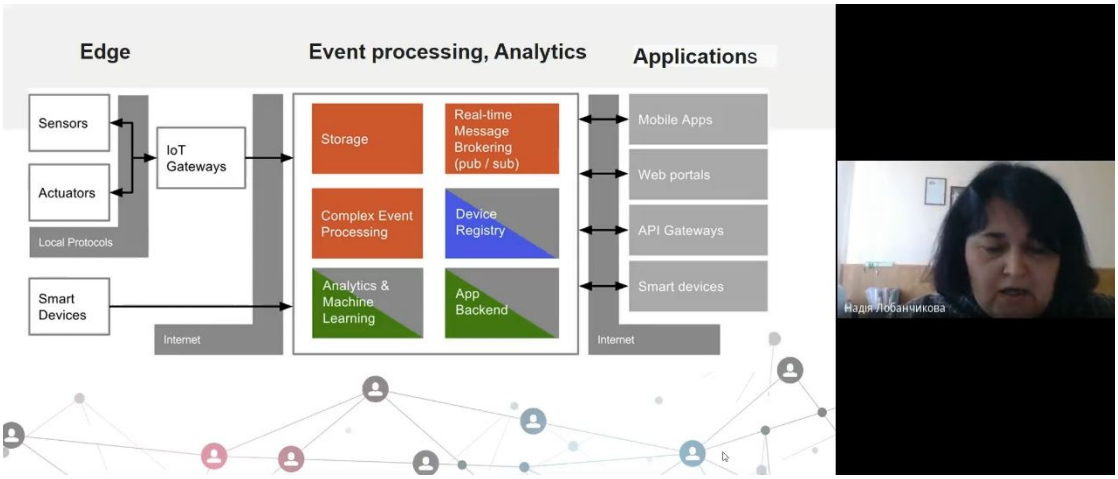

Figure 10: Presentation of paper [12]

Figure 11: Presentation of paper [13]

various projects method FCFS. A feature of this method is the simplicity of implementation. An example of a simple practical problem that can be solved using the proposed method is described in this paper.

Volodymyr Kvasnikov (figure 12), Mariia Kataieva and Victor Kobylyansky in the article "Analysis of metrological support of nano-measurements" [14] analyzes the existing methods and means of measuring objects in the nanometer range and develops their classification based on the main principles of use. The main parameters on which each described method is based are considered and the conditions for their most effective application are determined. It is proved that the chemical and electrical sets of properties of the nanomaterial can change when the particle size decreases to the nanometer size, which requires the inclusion of additional chemical and electrical tests in existing methods. Based on the analysis, it was determined that

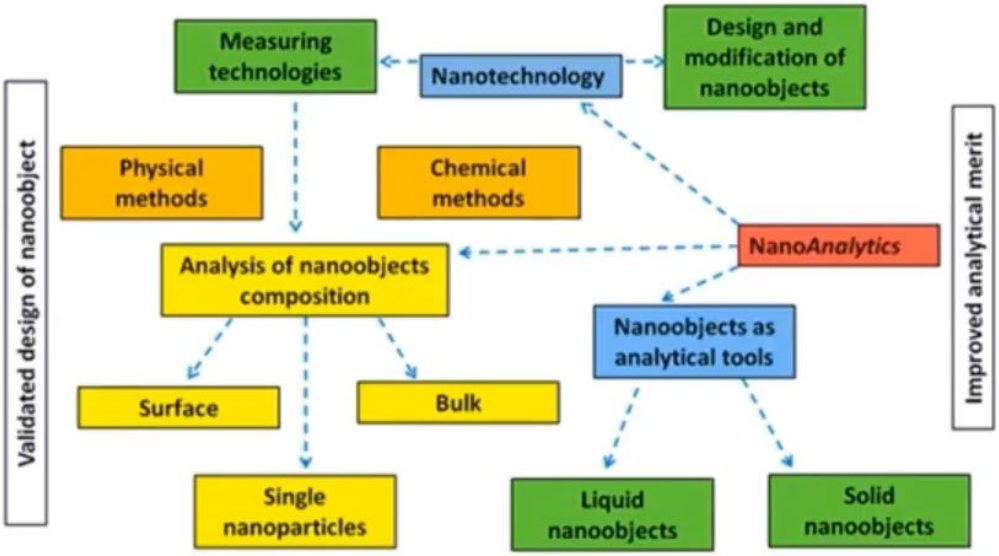

Figure 12: Presentation of paper [14]

the most functional and universal in solving a wide range of problems is the method of scanning probe microscopy. The classification of existing methods of scanning probe microscopy based on the nature of their applications is developed. The main information parameters on which each described method is based are considered, and the conditions of their most effective application are determined. To increase the accuracy of nanomeasurements, a methodology based on the principle of integration of information provided by different methods has been developed. The use of the differential-digital method is proposed, which includes the use of an additional information parameter in the mathematical model. An algorithm for including additional (a priory) information in the conditions for measuring the nanostructures has been developed, which leads the problem to the correct one according to the method of the control link, which characterizes the deviation of the parameters of measuring nanoobjects from their nominal values. It is proved that increasing the number of measurement methods used in the metrological analysis of nanoobjects will increase the reliability and accuracy of measurement results, and each method will provide additional information parameters to create a computerized method of calculating the control link. The main condition for correct comparison of the result is knowledge of the specific parameters on which each method is based.

5. Conclusion

The Joint Workshop on the Quantum Information Technologies and Edge Computing (QuaInT & doors 2021) was organized by Kryvyi Rih National University (with support of the rector Mykola I. Stupnik) and Zhytomyr Polytechnic State University (with support of the rector Viktor V. Ievdokymov) in collaboration with Kryvyi Rih State Pedagogical University (with support of the rector Yaroslav V. Shramko), Institute of Information Technologies and Learning

Tools of the NAES of Ukraine (with support of the director Valeriy Yu. Bykov) and University of Educational Management (with support of the vice-rector for research and digitalization Oleg M. Spirin).

We are thankful to all the authors who submitted papers and the delegates for their participation and their interest in QuaInT & doors as a platform to share their ideas and innovation. Also, we are also thankful to all the program committee members for providing continuous guidance and efforts taken by peer reviewers contributed to improve the quality of papers provided constructive critical comments, improvements and corrections to the authors are gratefully appreciated for their contribution to the success of the workshop.

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