CAM-2019

Computer Assisted Mathematics Conference

Electrotechnical University "LETI"
Saint-Petersburg, Russia
July 22-24, 2019

PROGRAM CAM-2019

July 22

10.00 -10.30	**Conference opening**	
	Plenary session	
10.30-11.30	The Digital Gap Between School and Life. How Can We Reduce it in Math?	*Alexei Semenov*
11.30-12.30	Teaching Mathematics Today: How And What	*Vladimir Khalin Nikolai Vavilov Alexander Yurkov*
12.30-13.30	Game Theory and Social Networks	*Vladimir Mazalov*
13.30-14.30	**Lunch**	
14.30-16.30	**Round table** Discussion is dedicated to but not limited to the following issues: *What do we mean by algorithmic mathematics? by discrete mathematics?* *How should math program change? school program? University program?* *How should methodology of teaching math change in school and university under the influence of computer science? under the influence of new intelligent technologies? under the influence of new directions in mathematics?* *What parts of math curricula should disappear in school, in university?* *What are the risks of changing teaching methods?* *What should be the relation between group and individual teaching? between full-time and distance learning?*	
16.30-17.00	**Coffee break**	
19.00- 23.00	St.Petersburg walking tour	
23.00-02.00	Drawbridges night: night walk along the Neva with catering	

July 23

Morning session		
11.00-11.30	Fractals in the Classroom with Mathematica and KeTCindy	*Tatiana Mylläri Setsuo Takato Satoshi Yamashita Takeo Noda Aleksandr Mylläri*
11.30-12.00	On the Experience of Using the Wolfram Mathematica Environment in the Course of Discrete Mathematics	*Oleg Ivanov and Grigory Friedman*
12.00-12.30	DSL with Automatic Differentiation for Dynamical Systems Parameters Determination	*Ivan Dolgakov and Dmitry Pavlov*
12.30-13.00	Mathematical Modeling and Programming in Science Education	*Michael Weigend*
13.00-13.30	Protein Clustering and Gene Loss Prediction	*Alexandr Seliverstov Oleg Zverkov Lev Rubanov Vassily Lyubetsky*
13.30-14.30	**Lunch**	
Afternoon session		
14.30-15.00	Teaching Students to Use the Gauss Method for Matrices with Integer Coefficients when Implemented on a Computer	*Tatiana Kosovskaya*
15.00-15.30	Elliptic Integrals, Functions, Curves and Polynomials	*Semjon Adlaj*
15.30-16.00	Flexible Discrete Math Offline Test Generator	*Sergei Kurdubov Varvara Kurdubova*
16.00-16.30	**Coffee break**	
16.30-17.00	Multi-Dimensional Continued Fractions and Computer-Assisted Search for Analogs of the Golden Ratio	*Andrei Lodkin*
17.00-17.30	Automated Support for Students to Extract Knowledge from Thematic Resources in the OntoMASTER Integrated Environment	*Ivan Pisarev Elena Kotova Andrey Pisarev*
17.30-18.00	Discrete and Continuous Models of Real Systems. Fractals and Probability Densities in Nonlinear Dynamics Problems	*Alexander Liaptsev*

July 24

Morning session		
10.00-10.30	Approximation of Automata With Respect to the Predicate of the Annihilation	*Elena Tolkacheva Igor Kostyrev*
10.30-11.00	Computer Laboratory and Aesthetic Geometry in the Physical-Technical High School	*Revolt Pimenov*
11.00-11.30	Computations with Young Diagrams and Young Tableaux in Representation Theory and Asymptotic Combinatorics	*Vasilii Duzhin*
11.30-12.00	**Coffee break**	
12.00-12.30	Constructive Tasks as a Tool of Invasive and Non-invasive Assessment of Knowledge	*Anton Chukhnov*
12.30-13.00	Algorithm for Optimizing the Search for Minimal Additive Chains	*Andrey Suchkov*
13.00-13.30	The Relationship of Goal-Setting in the Teaching of Mathematics with its Technological Support	*Sergei Pozdniakov*
13.30-14.30	**Lunch**	
Afternoon session		
14.30-15.00	Educational Tasks as Stand-Aalone Objects	*Ilya Posov*
15.00-15.30	Gamification of Maths: from Involvement to the Study	*Mikhail Koroteev*
15.30-16.00	Using Online Analytics Tools to Predict the Cognitive Potential of Students in an Integrated Learning Environment	*Elena Kotova*
16.00-16.30	Possible Improvements of Modern Dynamic Geometry Software	*Davorka Radaković Djordje Herceg Mirjana Ivanović and Dejana Herceg*
16.30-17.00	Concept of Isomorphism Graph in Distance Competition: Comparative Analysis the Results of Russia and Thailand	*Athit Maytarattanakhon*
17.00-17.30	**Conference closure**	
17.30 -19.00	**Buffet table**	

The Digital Gap Between School and Life.
How Can We Reduce it in Math?

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Teaching Mathematics Today: How And What

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Game Theory and Social Networks

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Abstract. Social networks represent a new phenomenon of our life. The growing popularity of social networks in the Web dates back to 1995 when American portal Classmates.com was launched. This project facilitated the soon appearance of online social networks (SixDegrees, LiveJournal, LinkedIn, MySpace, Facebook, Twitter, YouTube, and others) in the early 2000s. In Russia, the most popular networks are VKontakte and Odnoklassniki.

Social networks are visualized using social graphs. Graph theory provides main analysis tools for social networks. In particular, by calculating centrality measures for nodes and edges one may detect active participants (members) of a social network. We use for the analysis of social networks game-theoretic approach. We propose a new concept of the betweenness centrality for weighted graphs using the methods of cooperative game theory. The characteristic function is determined by special way for different coalitions (subsets of the graph). The betweenness centrality is determined as the Myerson value. The results of computer simulations for some examples of networks, in particular, for the popular social network "VKontakte", as well as the comparing with the PageRank method are presented. Then we apply game-theoretic methods for community detection in networks. Finally, for approaches based on potential games we suggest a very efficient computational scheme using Gibbs sampling.

Fractals in the Classroom with Mathematica and KeTCindy

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Abstract. We present our project of using Computer Algebra Systems (CAS) and Dynamic Geometry Systems (DGS) in teaching introductory course on Fractals. In our examples we use Wolfram Mathematica and KeTCindy.

Mathematica is very powerful CAS, it is easy to use, program codes are clear and compact, it has good graphic capabilities. KeTCindy is a plug-in to DGS Cinderella that generates high-quality TeX graphics. Moreover, KeTCindy makes it possible to import the data calculated or simulated by using other systems (like Maxima, Scilab, and R) and combine them with the graphical data, so that extremely wide range of mathematical objects can be presented.

Classic fractals (Sierpinski gasket, Sierpinski carpet, Mandelbrot set, and others) are used for examples and demonstrations. Different approaches and paradigms are used to construct fractal sets: Game of chaos, Multiple Reduction Copy Machines, and others.

Depending on the situation and final goal, both Mathematica and KeTCindy can be used in the classroom, or preference could be given to one of the systems. As was mentioned earlier, Mathematica is easy to use, but it is expensive and, in a way, it is too easy to use, it doesn't expand horizon for the students. From the other side, KeTCindy is not as easy to start using, but it is free and encourages students (and faculty) to study/use R, Maxima, etc. In addition, some dynamical visualizations seem easier to do with KeTCindy than in Mathematica.

On the Experience of Using the Wolfram Mathematica Environment in the Course of Discrete Mathematics

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Abstract. A necessity is advocated in the paper of computer-aided lectures and seminars on Discrete Mathematics with use of Wolfram Mathematica. A variety of examples is discussed of the exercises being given to students in the framework of the teaching course.

DSL with Automatic Differentiation
for Dynamical Systems Parameters Determination

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Abstract. Determination of dynamical system parameters is tightly bounded with efficient and accurate derivatives calculation. The most promising results can be achieved with automatic differentiation (AD) technique.

Most known AD tools operate on the Turing complete languages and have runtime overhead due to the restricted source code analysis. The current paper is announcing the Turing incomplete statically typed domain-specific language aimed to fill this gap. The Turing incompleteness provides an ability of sophisticated source analysis and as a result a highly optimized compiled code. Among other things the language syntax supports functions, compile-time ranged for loops, if/else branching constructions, real variables, arrays, and an ability to manually discard calculation where the automatic derivatives values are expected to be negligibly small. DSL is implemented in Racket and can be compiled to Racket or ANSI C.

Mathematical Modeling and Programming in Science Education

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Abstract. Using mathematical models to represent aspects of physical reality is an essential activity in science and science education. This contribution discusses four approaches of using computer programming and mathematical models in classroom activities:

1) Mathematical models, found in the textbook, can be the basis for computer programs. Students, when creating useful interactive python programs calculating concentrations or pH-values, experience similar intellectual challenges as in solving traditional text book problems.

2) Scratch-animations simulating physical or chemical systems simulation can be specifically designed to check the validity of given mathematical models.

3) A computer-related challenge is to design a simulation (like gas diffusion in a closed system with two phases) that might be a basis for discovering a mathematical model (like Henry's law) or just an element of a mathematical model.

4) Using sensor technology and a Raspberry Pi, students create a computer program that automatically visualizes the observed system behaviour (like changes in gas concentrations) in order to find a mathematical model.

Protein Clustering and Gene Loss Prediction

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Abstract. Effective methods for inferring two relations of genes, orthology and paralogy, are considered. A new approach to the problem is discussed, which takes into account the mutual arrangement of genes on a chromosome. We have developed an efficient algorithm implemented in a program for a multiprocessor computing device, which makes it possible to refine gene orthology and discover genes lost or acquired during the evolution of most species from a given set. In particular, this method has predicted a gene such that the loss of the gene during the evolution led to a decrease in regenerative capacity and simultaneously to an increase in the size of the forebrain in birds and mammals. We have also predicted genes, the loss of which is accompanied by an increase in life expectancy in rodents and primates.

Teaching Students to Use the Gauss Method for Matrices with Integer Coefficients when Implemented on a Computer

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Abstract. The paper is written on the base of a part of course "Analysis of algorithms" for students of the Computer science department of the faculty of mathematics and mechanics of Sankt-Petersburg State University. By the example of computer implementation of Gauss method it is illustrated the difference between algebraic complexity (the number of arithmetic operations) of integer numbers processing and computational complexity which depends on the length of the input data notation.

The formula setting the increasing the length of matrix coefficients while Gauss method implementation is proved.

The problems appeared while processing large integers, connected with the "cutting" of digits, are shown.

To overcome the pointed out problems, the possibility of multi-digit integers use is offered. It is shown that the upper bounds of number of steps while processing multi-digit integers coincides with such bounds for multy-tape Turing machine.

Elliptic Integrals, Functions, Curves and Polynomials

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Abstract. The extensive subject of elliptic integrals, functions and curve, being at the junction of analysis, algebra and geometry, has numerous applications in mechanics and physics. Two approaches to the study of elliptic functions have become classical, namely that of Jacobi and that of Weierstrass. Two separate chapters were devoted to these two approaches in the (well-known) course of modern analysis by Whittaker and Watson, without attempting to unite them. Also, two separate chapters are devoted to these two approaches in the latest version (1.0.22 on March 15, 2019) of the NIST Digital Library of Mathematical Functions.

An wide-spread inculcation "explained" that the Weierstrass approach is more suitable for theoretical research, whereas the Jacobi elliptic functions are more common in applications. But, in fact, this dichotomy is artificial, and learning functions and elliptic curves may be combined in an algebraic approach, establishing a canonical "essential" elliptic function which linear fractional "symmetry" transformations acquire the simplest forms. Although such a natural and fundamental object to be (rightly) called the Galois essential elliptic function, was introduced only recently (already in our millennium), its use has quickly become fruitful, not only and not so much for the effective recovery of known results but also for achieving new calculations that once seemed too cumbersome to pursue.

The methodological significance of this natural algebraic approach, which undoubtedly transcends back to the (revolutionary) contribution of Galois, is clearly manifested by its application to several fundamental problems of classical mechanics with the achievement of non-standard, capacious and highly efficient solutions.

Flexible discrete math offline test generator

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Abstract. This article describes the software package representing new math tests generator.

The main features of our software are in the focus on creating a high-quality printed product and large variability of the generated tasks. That were achieved by using the LaTeX text processor and power of the Python language. Logically it consists of the control shell, the task parser, subject logic, formatting system and task database. The logic implements the set of abstractions that can be used in tasks (for example graphs,

boolean functions, etc.). The task database exists in the form of JSON files with the specially created task formation language.

Currently, the most developed branch in task database is the discrete mathematics problems and abstractions. More than fifty types of tasks were implemented: operations on sets, representation of sets by Euler-Venn diagrams, algebra of sets, various ways of representing graphs, operations on graphs, some problems on graphs, representing Boolean functions in various ways, finding perfect forms, constructing and minimization using Karnaugh maps, Venn diagrams and hypercubes, analysis and synthesis of logic circuits.

The task generator can be used by a teacher when conducting practical and control classes, creating individual materials for the students. Tasks can be differentiated by the level of complexity when changing control parameters.

The generated tasks were used in education process for more than 1000 students of Military Academy of the Signal Corps and the improvement of mastering of discrete math was shown.

Multi-Dimensional Continued Fractions and Computer-Assisted Search for Analogs of the Golden Ratio

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Abstract. Classical continued fractions provide a well-known tool to approximate real numbers by rationals. In the problem of the approximation of real vectors by rational ones, there exist many algorithms generalizing the continued fractions techniques. On the other hand, there exists a geometric object, the Klein polyhedron, used for different but related purposes. We introduce a modification of the Klein polyhedron that provides an approximation of a vector.

It is known that the golden ratio has an extremal property: it is the worst approximable among the reals. We give an equivalent geometric characteristic in terms of the Klein polyhedra and propose to use it in search for an extremely poorly approximated vector.

Also, we propose to look for this vector (that is a stable fixed point for a certain finite-dimensional operator) by an iterative process.

Automated Support for Students to Extract Knowledge from Thematic Resources in the OntoMASTER Integrated Environment

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Abstract. The growth of information volumes necessitates the development of automated systems to support students' learning activities in the area of research at all

stages, including processing, modeling, analysis of experimental data, and scientific publications in various fields of research.

An interdisciplinary approach to research, dynamic changes in terminology in subject areas, and an exponential increase in the number of scientific publications in Russian and English, bring into focus the issues of automated creation of linguistic support for open automated research systems.

Due to the fact that currently there is no comprehensive solution to the above problems, the development of methods and algorithms for the automated provision of research management systems is relevant and requires solving a number of tasks. These include: the development of terminological dictionaries and thematic ontologies of knowledge areas; development of algorithms for automated search and replenishment of thematic corpuses of texts on research topics; development of an algorithm for extracting specialized terms from information resources; development of a method and algorithms for organizing a hybrid database and knowledge base (metadata) of multi-level data classification; development of a method for graphical editing of linguistic software and building scenarios for automated research.

Methods and tools available for online analysis of information resources are becoming increasingly popular in the educational environment. Scientific literature is replete with articles, reviews, which makes it difficult for students to find relevant information, often in the area of "linguistic uncertainty" in constructing the conceptual conceptual structure of areas of knowledge. The vagueness of the definitions of the basic concepts of the studied areas of knowledge leads to their incorrect interpretation.

The purpose of the development of the network software OntoMASTER is to assist students in mastering the basic concepts of areas of knowledge with the methodological support of the educational process.

Discrete and Continuous Models of Real Systems.
Fractals and Probability Densities in Nonlinear Dynamics Problems

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Abstract. The relationship between discrete and continuous models in the description of real systems is sufficiently well studied in the description of objects of the microcosm and formulated as the principle of complementarity of quantum mechanics. However, the probabilistic character is also inherent in macroscopic systems described by nonlinear equations of dynamics.

For example, the Poincare cross section in the phase space of the Lorentz system in the case of a strange (chaotic) attractor is a fractal with fractional dimension, in which the points filling the fractal randomly form a structure with a certain regularity. This paper shows how to calculate the probability density distribution in such a fractal. Numerical calculations of the fractal for the rotator system in the external harmonic field show a good qualitative correspondence of the Poincare cross section pattern as a result

of solving the system of differential equations and as a result of calculating the probability density distribution of the points of such section.

Approximation of Automata With Respect to the Predicate of the Annihilation

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Abstract. The considered questions of approximability with respect to various predicates are particularly relevant in automata theory, given the connection between approximability and the fundamental algorithmic decidability of the predicate problem. Automata are the most natural mathematical model for systems that may be in different states. They not only change under the influence of certain external conditions, but also affect the external environment themselves. With the rapid development of Computer Science, not only theoretical constructions in the field of informatics itself were received, but also the transfer of constructions from abstract mathematical structures to the basic models of theoretical informatics. The transfer of questions of approximability with respect to the predicate of the annihilation of the first kind from varieties of semigroups and polybasic structures to automata is connected with the fundamental property of the automaton — its recognizability.

Considering a tribasic semigroup distributive algebra as a model of a semigroup automaton, it was shown that when passing to polybasic structures, the uniformity of the predicate of equality and the predicate of the annihilation of the first kind disappears. Consequently, the criteria for decidability of the problem of equality and annihilation predicates will be different. Taking into account the results described in the article and the fact that, in the general case, the answer to the question of algorithmic decidability of the word equality problem is negative, there posed the question of preserving the uniformity of the predicates of equality and annihilation of the first kind for complex and polybasic semigroup algebraic structures. The approximability of automata by tribasic semigroup distributive algebras is associated with the algorithmic decidability of the corresponding problems. The special interest is in the question of the algorithmic decidability of the cancellation problem, i.e., if there exists an algorithm that determines whether one word is zero for the other for any two words.

Computer laboratory and Aesthetic Geometry in the Physical-Technical High School

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Abstract. The article is about school's course on geometry of transformations and solution of non-standard tasks in the computing class. Here are some methodological

observations about using computers at school's geometry and about using symmetries and inversion. Article includes description of several lessons and illustrations of aesthetic geometry.

Computations with Young Diagrams and Young Tableaux in Representation Theory and Asymptotic Combinatorics

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Abstract. Young diagrams and Young tableaux are very popular combinatorial symbolic objects which, particularly, have applications in asymptotic representation theory, Grobner bases theory, construction of exact solutions for integrable Hamiltonian systems and others.

There are many unproven conjectures about Young diagrams and tableaux which require confirmations using massive computations.

For some problems of asymptotic combinatorics and asymptotic representation theory, a software package was developed and numerous computer experiments were carried out.

In the frame of this work, we have developed a software package in C++ which includes many functions for dealing with two- and three-dimensional Young diagrams and tableaux. This package is oriented on using Young diagrams and tableaux for solving algebraic and combinatorial problems. It includes the following functions: calculation of the transition and co-transition probabilities of specific Markov processes on 2D and 3D Young graphs, calculation of the ratios of dimensions of Young diagrams, RSK correspondence, visualization tools for 2D and 3D Young diagrams for studying their limit shapes, implementation of the random uniformly distributed generator of Young tableaux of a given shape using a special modification of the Schutzenberger's jeu de taquin and many others.

This package allows to perform various calculations with 2D and 3D Young diagrams and the final version could be shared with other specialists in this field.

Constructive Tasks as a Tool of Invasive and Non-invasive Assessment of Knowledge

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Abstract. Constructive tasks are very impotant and appear in every branch of mathematics. This work is devoted to some experiments with constructive tasks held within the education and assessment process.

First some constructive tasks in distance form were given to the students within the course of Mathematical Logics and Theory of Algorithms. The tasks served only as a support tool and students were not obliged to solve them. Second, the tasks of the same types were given to the elder students which had already passed the course with additional request to log their intellectual activity while solving the tasks.

The third experiment was held during the written exam. Constructive tasks which were given to the students appeared to be reverse ones to the tasks they had solved during the semester.

Algorithm for Optimizing the Search for Minimal Additive Chains

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Abstract. The representation of a number as an addition chain is important for solving problems of information storage and processing. So far, there are no known efficient algorithms for constructing minimal addition chains for a given number. The report provides an overview of state-of-the-art in this area and applications of addition and other chains in other tasks.

The Relationship of Goal-Setting in the Teaching of Mathematics with its Technological Support

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Abstract. Technological support of teaching mathematics depends on what methodological and pedagogical goals are put for education. Achieving or failing to achieve these goals is provided by type of feedback or other words through assessment of students' learning activities. In this work, two types of assessment are contrasted: a test form of knowledge testing (implemented by a system of intermediate control and final exams) and a formative assessment (determined by the teacher's informal reaction to the student's productive activities and the way these activities are organized).

It is shown that the first type of assessment corresponds to the consideration of the training program as a learning goal, the second — as a means of learning. In the first case, the purpose of training is the acquisition of specific knowledge and skills, in the second — mastering the general mechanisms of learning activities characteristic for particular subject area (in this article, for mathematics). For the first goal, it is effective

to use template tasks (generated exercises) and simulators, for the second — to use various tools that support constructive and research activities.

Educational Tasks as Stand-Alone Objects

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Abstract. Solving tasks is a very common e-learning activity, and students usually have it in any kind of on-line courses. Tasks in different courses vary a lot in the way they interact with students, for example, they have different user interfaces with different input controls, sometimes they provide hints and instant feedback, sometimes tasks are not more than just pieces of text with pictures or formulas. Tasks usually need a lot of time to prepare, but it almost always impossible to extract a task from a e-learning system (LMS, for example) that contains it, and transfer to another e-learning system. So, if a teacher uses different types of tasks supported by different e-learning system, s/he has to use all of them simultaneously.

There are a number of approaches to deal with this issue, for example, standards IMS QTI, LTI, Scorm deal with packaging of tasks or other learning objects in portable and interoperable way.

The report discusses very different types of tasks from different courses and competitions, interoperability use cases, discusses shortcomings of existing standards based on these use cases and proposes another way to store educational tasks as stand-alone files that may solve arising issues.

Gamification of Maths: from Involvement to the Study

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Abstract. Euclidea and Pythagorea are geometric construction puzzles. They have millions of users and tens of thousands of fans all over the world. The creators of the games share their experience and try to answer why the games became popular and how they help to involve people in maths.

Using Online Analytics Tools to Predict the Cognitive Potential of Students in an Integrated Learning Environment

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Abstract. The need to form students qualifications for a digital future changes teaching strategies and approaches to university education in the direction of digital design of the learning process. The expandable space of available data allows the use of new educational data mining (EDM) methods to explore unique data types, understand student activity, predict academic results, improve process performance, make management decisions and adapt the learning environment.

The objective of this study is to create a personalized educational environment for individual accompaniment of students on the basis of a cognitive potential model. The task of supporting the learning process is to obtain information on the dynamics of cognitive growth ("growth" of the knowledge level) of each student based on the data obtained during the learning process. The task of differentiating students, predicting the success of training to improve the adaptation and customization of the learning process is considered.

An approach to predicting the success of learning based on a cognitive model is important for understanding the productivity of learning materials by students in an information-rich environment.

Organizing feedback in the structure of the learning process based on student differentiation allows you to manage and customize learning scenarios to improve the adaptation of the individual process. An integrated web environment combines traditional learning tools with innovative digital online tools.

Possible Improvements of Modern Dynamic Geometry Software

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Abstract. Contemporary education is starting to supersede the traditional one (teacher-to-student lessons) with technology-rich learning using various educational tools and a selection of materials that are effective, efficient and appealing to students. Dynamic Geometry Software (DGS) today is widely used in teaching and learning mathematical topics. Such kind of educational software can evolve in several ways, by either adding new features on the surface or by evolving the evaluation engine at its core. The implementation of a DGS needs to be straightforward and modular.

To achieve the evolution of a DGS core we have developed a programming framework for the Dynamic Geometry Software, XXXXX, with a genericized functional language and the corresponding expression evaluation engine. Engine acts as a framework into which specific semantics is embedded in the form of code, annotated with metadata. An ordinary expression tree evaluator is transformed into an object-oriented one by this framework. Whilst other DGS are based on purely functional expression evaluators, our solution has the advantages of being more general, maintainable, understandable, easy to implement, and providing a natural way of specifying object properties in the user interface, minimizing typing and syntax errors. The modular approach enables independent development of subject-specific components, which are easily added to the evaluation engine in the form of plug-ins. The object-oriented nature of the framework enables development of self-contained units, such as objects and visual elements which encapsulate domain-specific semantic and present it to the user as virtual placeholders for real-life objects and notions.

In this paper we present several possible improvements of Dynamic Geometry Software, particularly having in mind the platform that we have implemented. Additionally we discuss benefits of these features and their influence on the users/students. The approach is tested on XXXXX — our DGS platform, developed in C# on the .NET Framework.

Concept of Isomorphism Graph in Distance cCompetition: Comparative Analysis the Results of Russia and Thailand

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Abstract. Distance competition is one of the tools that can reach students in a comprehensive way and the price is cheap. The problem of distance competition is that the number of computers or notebooks may not be enough. The education system in Thailand and Russia is quite different. In particular, the management of mathematics courses in the whole country is different in terms of content management at each level. However, both Russia and Thailand have not included the content of the graph to the secondary level.

Therefore, it is easy to be able to measure students' understanding and new concept about Isomorphism graph for both countries.