In Memory of Vladimir Gerdt

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This article is a memorial, it is dedicated to the memory of the head of the Scientific Center for Computational Methods in Applied Mathematics of RUDN, Professor V. P. Gerdt, whose passing was a great loss to the scientific center and the computer algebra community. The article provides biographical information about V. P. Gerdt, talks about his contribution to the development of computer algebra in Russia and the world. At the end there are the author’s personal memories of V. P. Gerdt.

Key words and phrases: computer algebra, quantum computing, mimetic methods, polynomial computer algebra methods

1. Introduction

The name of Vladimir Gerdt is widely known among computer algebra community. Many years he was a professor at the Joint Institute for Nuclear Research (JINR), where he was the head of the Group of Algebraic and Quantum Computations (http://compalg.jinr.ru/CAGroup), and an organizer of many mathematical conferences. A few years ago, he was invited to head the Scientific Center for Computational Methods in Applied Mathematics founded in RUDN university. His passing was a great loss to the entire community.

2. Biography

Vladimir Gerdt was born in Engels near Saratov. He earned his M.Sc. in Theoretical Physics from Saratov State University in 1971, his Ph.D. in Theoretical and Mathematical Physics from JINR in 1976, and his D.Sc. in Mathematics and Computer Science from JINR in 1992. In 1997 he got the scientific title Professor in Mathematics and Computer Science by
specialty “Application of Computer Techniques, Mathematical Modelling and Mathematical Methods to Scientific Research”.

After his M. Sc. Vladimir Gerdt worked in JINR until his death in January 5, 2021. He began as an engineer-programmer (1971–1975), then he worked as a junior researcher (1975–1977) at the JINR Department of Radiation Safety where a software for neutron spectroscopy was developed. In 1977 he moved to the JINR Laboratory of Computing Techniques and Automation renamed in 2000 as Laboratory of Information Technologies, where he worked as a researcher (1977–1980) and as a senior researcher (1980–1983), and since 1983 as the head of the research group on computer algebra. Vladimir Gerdt worked abroad for several years, in Lille and Aachen, using Russian, English, German and French in his work.

![Image](image.png)

**Figure 1. Vladimir Gerdt in his office. Dubna, 1998**

### 3. Professional activities

V. Gerdt prepared 243 scientific articles, he edited 10 books. His latest researches are devoted to the construction of involutive monomial bases and to the discretizations of incompressible Navier–Stokes equations. His last huge article was published in ArXiv in September 2020.

Vladimir was the referee at journals and organizations:

— Journal of Symbolic Computation;
— Programming and Computer Software;
— Physics of Particles and Nuclei Letters;
— Russian Foundation for Basic Research;
— Russian Science Foundation.

Vladimir was a member of:

— Association for Computing Machinery (ACM);
— ACM Special Interest Group on Symbolic and Algebraic Manipulation (SIGSAM);
— Editorial Board of Journal of Symbolic Computation (Academic Press);
— Advisory Board of Computer Science Journal of Moldova;
— Special Computer Algebra Group of German Societies on Computer Science.

Vladimir took part in the coordination of the international research projects:

— he was adjoint coordinator of the INTAS-93-0030 project “Computer Algebra, Symbolic and Combinatorial Tools in Differential Algebra and Differential Equations, with impact in Fundamental Physics and Control Theory” with 10 research teams from EC countries and 7 research teams from NIS countries;
— scientific coordinator of cluster A: Computer Assisted Mathematics of the INTAS-93-0893 project “ERSIM-FSU Cooperative Network in Informatics and Applied Mathematics” with 10 research teams in EC countries and 10 research teams from NIS countries.

Vladimir Gerdt paid great attention to teaching. He gave 24 lecture courses for students and young scientists. Under his supervision 10 master theses were prepared, 9 Ph. D. theses were defended. He was the scientific consultant of Yuri Blinkov’s thesis for Doctorship of Sciences.

4. Vladimir Gerdt and computer algebra

4.1. At the beginning of computer algebra

Vladimir was one of the first who started computer algebra usage in the USSR in the 70th. This activity was supported by Academic Dmitry Shirkov and Professor Nikolay Govorun.

In the early 80th the Joined Institute for Nuclear Research (JINR, Dubna) bought the computer CDC-6500. It was powerful enough for the implementation of the universal computer algebra systems. Professor Tony Hearn kindly
passed the REDUCE system to the JINR during his visit to Dubna. Professor Gerdt with colleagues took a large part in its implementation in the institute and assisted in spreading the REDUCE in the scientific centers of the USSR. Vladimir got the “First JINR Prize (1986) for the Research on Installation, Development and Application of Program Systems for Symbolic Computation on Mainframe Computers”.

Vladimir was on Committees of many conferences. The main of them are:
— International Symposium on Symbolic and Algebraic Computation (ISSAC);
— Conference on Applications of Computer Algebra (ACA);
— Polynomial Computer Algebra (PCA);
— Computer Algebra in Scientific Computing (CASC), Vladimir was one of its founders. Now CASC-2021 is the 23rd conference in this series. It takes place in Sochi (Russia).

4.2. Partial differential equations

A large cycle of works by Vladimir Gerdt was devoted to the study of the compatibility of systems of partial differential equations (PDEs) by means of computer algebra. The key to solving the problem was the Cauchy-Kovalevskaya theorem, which reduces the study of the solvability of some classes of systems of partial differential equations to the study of the compatibility of a system of algebraic equations for the coefficients of the corresponding power series.

Theoretical research on the compatibility of systems of nonlinear differential equations in general form was started at the beginning of the 20th century by Riquier [1], Janet [2], and Thomas [3]. V. P. Gerdt told us about the long months he spent in the 1980s searching and studying these far from well-known works written in various European languages.
Riquier proposed a complete ordering for partial derivatives, using which he distinguished some of the derivatives, called principal ones, with respect to which the system of PDEs can be resolved. The remaining derivatives, called parametric, leave arbitrariness in the solution and affect the setting of the initial conditions. As a result, a theory was constructed containing the Cauchy–Kovalevskaya theorem as a special case. Along the way of algorithmization of these results, Janet introduced the partition of independent variables into multiplicative and non-multiplicative for the principal derivatives. Thomas generalized the Riquier–Janet approach over the case of nonlinear algebraic equations with respect to the principal derivative. He showed how to check the consistency of a system or to split it into subsystems in a finite number of steps (Thomas decomposition).

These works, at first, gave rise to a modern theory, which makes it possible to investigate the compatibility of systems of partial differential equations and carry out their decomposition into subsystems (Thomas decomposition), created by V. P. Gerdt together with D. Roberts and very elegantly inscribed in the theory of differential rings. Later, the theory was used to create the DifferentialThomas package, recently implemented in Maple (https://www.maplesoft.com). A monograph by D. Roberts is devoted to this issue [4].

4.3. Polynomial computer algebra

One of the most important achievements of algebra in the XX century was the creation of the theory of Gröbner bases, which made it possible to study problems from the theory of polynomial rings and algebraic geometry using a computer [5]. The main obstacle to the application of this technique is the cost of calculating these bases according to the Buchberger algorithm, therefore, the development of more efficient methods for finding Gröbner bases has been and remains an urgent problem of computer algebra. The key idea of the theory of Gröbner bases is the division of a polynomial into polynomials generating a certain ideal \( J \). In the case of the ring \( \mathbb{Q}[x] \) every ideal is principal and any polynomial \( g \) can be uniquely divided by the polynomial \( f \) generating the ideal \( (f) \). In the case of the ring \( \mathbb{Q}[x_1, \ldots, x_n] \) one can also talk about dividing the polynomial into polynomials \( f_1, \ldots, f_r \) generating the ideal \( J \), but this was realized only in the middle of the XXth century. One of the very first steps in introducing the operation of division of polynomials was to define the admissible McCauley ordering [6]. In the process of such division, expressions of the form \( hf_i \) are successively subtracted from \( g \), where \( h \in \mathbb{Q}[x_1, \ldots, x_n] \), so that the leading coefficients in \( g \) are canceled. As a result, instead of \( g \), a new polynomial \( g' \) is obtained, the degree of which is less than the degree of \( g \) and \( g - g' \in J \). Unfortunately, in the case of many variables, \( g' \) is uniquely determined in this way only when a special basis is chosen, the Gröbner basis, and only in this special basis it follows from \( g \in J \) that \( g' = 0 \).

A wonderful idea proposed by V. P. Gerdt is that the division of a polynomial into polynomials generating the ideal \( J \) can be made unambiguous if we preserve an additional structure on the set of monomials \( M \), which he called involutive division. The concept of involutive division is closely related to the partitioning of independent variables introduced by Janet (see above) in the study of the compatibility of systems of partial differential equations.
V. P. Gerdt brought ideas that arose in the theory of PDEs to polynomial algebra, which made it possible to look at old problems in a completely new light.

Involutive division allows for any monomial $m$ choosing one of the monomials of a given finite set $U$ and thus uniquely determine the choice of $hf_i$ when dividing $g$ by $(f_1, \ldots, f_r)$. The remainder of the division can now be called the normal form of the polynomial $g$ with respect to the polynomials $f_1, \ldots, f_n$. However, checking $g \in (f_1, \ldots, f_r)$ is reduced to checking $g' = 0$ not for every basis $f_1, \ldots, f_r$, but only for an involutive basis whose principal monomials satisfy certain properties, found and described by V. P. Gerdt and his disciple Yu. A. Blinkov. The first concrete example of involutive division was described by A. Yu. Zharkov, another disciple of V. P. Gerdt [7]–[10]. Soon V. P. Gerdt and Yu. A. Blinkov constructed many other involutive divisions. This made it possible to formulate a fundamentally new algorithm for constructing Gröbner bases [11]–[19].

Under the leadership of V. P. Gerdt, his disciples Yu. A. Blinkov and D. A. Yanovich created a number of algorithms and programs for calculating involutive bases of ideals of polynomial rings, including the open-source software package GINV (http://invo.jinr.ru). Their algorithms for calculating involutive bases appeared to be faster than Buchberger’s algorithm and able to compete with the algorithms optimized by Fougeres and his disciples. The theory of involutive bases itself has become an important branch of computer algebra, to which the participants of international conferences on computer algebra regularly devote their articles and reports.

### 4.4. Mimetic methods for solving partial differential equations

Power series expansions are a very poor method for finding solutions to compatible systems of differential equations, except in the rare case when the solution is interesting in a small neighborhood of a given point. The main and, by and large, the only method for solving such systems is the finite difference method, according to which the system of differential equations in $\mathbb{R}^n$ is reduced to an infinite system of algebraic equations for the values of the sought functions at the grid nodes. Research in the field of finite-difference approximations of differential equations inheriting their basic properties has more than 60 years of history. Discretizations inheriting certain properties of continuous (differential) equations are called mimetic or compatible [20]–[25]. Discussing reports at conferences, we often heard from V. P. Gerdt about the importance of this concept for the development of numerical methods of mathematical modeling, as well as about the flexibility of the concept of inheritance, allowing for different interpretations.

In the last century, the transition from differential equations to algebraic ones was done by hand. V. P. Gerdt and Yu. A. Blinkov proposed a new approach in which this transformation was performed in computer algebra systems. The studies mentioned above have stimulated interest to the question of what happens to the differential consequences of discretization. V. P. Gerdt singled out a class of strongly consistent difference schemes. The property of strong consistency means not only the approximation of the original differential equations by the finite-difference scheme, but also the approximation of any algebraic consequence of these equations by the algebraic consequence of the
difference equations that make up the scheme. These consequences include, in particular, local conservation laws.

V. P. Gerdt in his recent studies, carried out together with Yu. A. Blinkov and D. Roberts, strove to show the advantages of S-compatible schemes over others. For the demonstration, they have chosen one the system of Navier–Stokes equations, one of the most complex systems of great importance for applications. For this system, an S-compatible difference scheme was constructed and numerous computer experiments were carried out. A multipage report on this work by V. P. Gerdt was published in ArXiv [26] shortly before his death. One can only regret that the size of this study will not allow it to be published entirely as a full journal article.

4.5. Applications of polynomial computer algebra methods in generalized Hamiltonian dynamics

The use of involutive methods in applied, engineering and physical problems described by systems of underdetermined and overdetermined differential equations has become an area of special interest for V. P. Gerdt in the early 1990s. In mechanical systems, the configuration and phase spaces of which are subject to constraints and restrictions, evolution problems inevitably require involutive analysis. This is especially true for physical systems which possess a degenerate Lagrange function and are described in the framework of the generalized Dirac Hamiltonian dynamics. In a large cycle of works carried out by V. P. Gerdt together with colleagues from Bulgaria (D. Mladenov), Georgia (S. Gogilidze, A. Khvedelidze) and Moldova (Yu. Paliy), an algorithm was developed and applied for finding a complete set of constraints (of the first and second kind) for polynomial mechanical systems with a degenerate Lagrange function and are described in the framework of the generalized Dirac Hamiltonian dynamics. In a large cycle of works carried out by V. P. Gerdt together with colleagues from Bulgaria (D. Mladenov), Georgia (S. Gogilidze, A. Khvedelidze) and Moldova (Yu. Paliy), an algorithm was developed and applied for finding a complete set of constraints (of the first and second kind) for polynomial mechanical systems with a degenerate Lagrange function, which is based on the ideas of the theory of Gröbner bases and involutive division of polynomials. The efficiency of the proposed algorithm was demonstrated, in particular, when calculating the constraints in the so-called mechanical $SU(3)$ Yang–Mills model on a light cone, where, thanks to the use of computer calculations, for the first time it was possible to determine and classify the complete set of constraints inherent in the model.

4.6. Applications of polynomial computer algebra methods in quantum theory

Computational problems related to the description of quantum systems became another area of application of Gröbner bases in the studies of V. P. Gerdt. In the 21st century, quantum theory has ceased to be just a purely fundamental physical theory. It has acquired the status of the basic element of a new quantum technological design. These changes gave rise to new computationally intensive tasks. One of these problems is the problem of classifying quantum systems in terms of their quantum resource, in particular, depending on the complete set of characteristics responsible for the phenomenon of entanglement of quantum states. The joint research performed in Dubna in the period from 2006 to 2016 by V. P. Gerdt, Y. Paliya and A. Khvedelidze focused on this class of problems.

In these works, the algebraic structure of the ring of polynomial invariants of basic composite binary quantum systems, such as qubit-qubit and qubit-qutrite pairs, was studied. As these studies have shown, computer algebra
methods allow performing labor-intensive computational calculations and, thereby, determine the quantum resource of low-dimensional quantum systems, which is interesting from the point of view of various applications, including the theory of quantum information.

5. Personal memories

![Figure 4. Vladimir Gerdt and Victor Edneral at Schliemann’s excavations. Peloponnese, 1995](image)

We met Vladimir Gerdt at the 3rd international conference on computer algebra and its applications in theoretical physics, which took place in September 1985 in Dubna. Later, we met at a couple of dozen conferences, at seminars, at defenses. I soon noticed that he took great care of those who were with him. Vladimir never spoke badly about anyone. He criticized, of course, but only in specific cases. A distinctive feature of Vladimir was great respect for people, for each person. And people felt it. It should be added, that Vladimir was a believer and observed orthodox church fasts and rituals. Without advertising it in any way.
Vladimir had wide erudition and organized very interesting excursions for conference participants in amazing places. We were with him in Peloponnese, in Germany, in France, in Japan, in Spain, in Israel, in China e.t.c.

I do not remember who said “Where the captain is, there is the captain’s bridge”. This is about Vladimir. He was quickly becoming the soul of any company, he saw any task in every detail and imagined the roles of everybody.

A clear mind allowed him to ask wonderful questions during conference reports. Always to the point. Without any self-promotion. He was very humble.

![Figure 5. Alexandr Myllari and Vladimir Gerdt. Jordan river. 2017](image)

### 6. Dedication

Professor Gerdt made numerous contributions to the fields of symbolic computation, differential algebra, and applications in physics. He was an excellent scientist and a kind-hearted and considerate man. Thank you very much, Vladimir!

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8. Additional materials

8.1. Last video of Vladimir Gerdt

1. Compact involutive monomial bases. Joint scientific seminar of the Institute of Applied Mathematics & Communications Technology, 18 Nov. 2020. URL: https://events.rudn.ru/event/102.
2. Computer algebra based discretizations of incompressible Navier–Stokes equations. Joint scientific seminar of the Institute of Applied Mathematics & Communications Technology, 25 Nov. 2020. URL: https://events.rudn.ru/event/103.

8.2. Memorial photo galleries of Vladimir Gerdt

1. Collection of Yu. A. Blinkov.
   URL: https://disk.yandex.ru/d/dTxdWYb2_TBAYg
2. Collection of V. F. Edneral.
   URL: https://yadi.sk/d/tdFNE877AzQAcw

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Памяти Владимира Гердта

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Настоящая статья — мемориальная, она посвящена памяти руководителя научного центра вычислительных методов в прикладной математике РУДН, профессора В. П. Гердта, чей уход стал невосполнимой потерей для научного центра и всего сообщества компьютерной алгебры. В статье приведены биографические сведения о В. П. Гердте, рассказано о его вкладе в развитие компьютерной алгебры в России и мире. В конце приведены личные воспоминания автора о В. П. Гердте.

Ключевые слова: компьютерная алгебра, квантовые вычисления, миметические методы, методы полиномиальной компьютерной алгебры