

REVIEW

of the official reviewer for the dissertation work

of Altybay Arshyn on the theme «Development of high-performance parallel algorithms and software complex for modeling hyperbolic type equations with singular coefficients: tsunami and acoustic wave propagation» presented for the degree of Doctor of Philosophy (PhD) in the specialty «6D075100 - Computer Science, Computer Engineering and Management».

| № | Criteria | Eligibility (one of the options must be checked) | Justification of the position of the official reviewer |
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| 1. | The topic of the thesis (as of the date of its approval) corresponds to the directions of development of science and/or state programs | <p>1.1 Compliance with priority areas of science development or government programs:</p> <p>1) The thesis was completed within the framework of a project or target program financed from the state budget (indicate the name and number of the project or program)</p> <p>2) The thesis was completed within the framework of another state program (indicate the name of the program)</p> <p>3) The thesis corresponds to the priority direction of the development of science, approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan (indicate the direction)</p> | <p>The thesis corresponds to the priority direction of science development: "Information, telecommunication and space technologies, scientific research in the field of natural sciences" and was carried out within the framework of the state grant financing for the following project: AP09058069 "Very weak solutions of evolutionary equations"(2021-2023).</p> |
| 2. | Importance for science | The work makes a significant contribution to science, and its importance is well disclosed | In this work, the existence, uniqueness and consistency of very weak solutions of the hyperbolic tsunami equation with a singular coefficient is proved and substantiated by its numerical simulation. The developed parallel algorithms make a significant contribution to applied science and are of great importance. |
| 3. | The principle of | Self-reliance level: | The level of independence of the |

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| | independence | <u>1) High;</u> 2) Medium; 3) Low; 4) No independence | author of the thesis consists in analyzing literature data, performing theoretical part of the work, in the development of parallel algorithms, generalization and interpretation of the obtained results and conclusions. |
| 4. | The principle of inner unity | 4.1 Justification of the relevance of the thesis: <u>1) Justified;</u> | The relevance of the topic of the thesis is justified in the introduction section by giving specific examples and analyzing the literature. |
| | | 4.2 The content of the thesis reflects the topic of the thesis: <u>1) Reflects;</u> | The thesis is devoted to the development of high-performance parallel algorithms and software for modeling hyperbolic equations with singular coefficients: the propagation of tsunamis and acoustic waves, which fully reflects the topic of the thesis. |
| | | 4.3. The purpose and objectives correspond to the topic of the thesis: <u>1) correspond;</u> | The purpose and objectives of the thesis are divided into four points and each point clearly states what to do and corresponds to the topic of the thesis. |
| | | 4.4 All sections and provisions of the thesis are logically interconnected: <u>1) completely interconnected;</u> 2) the interconnection is partial; 3) there is no interconnection | The introduction, three main chapters and the conclusion of the thesis are logically completely interconnected. |
| | | 4.5 The new solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with the known solutions: <u>1) there is a critical analysis;</u> <u>2) partial analysis;</u> 3) the analysis does not represent one's own opinions, but quotes from other authors | The new solutions proposed by the author are partially analyzed in comparison with existing solutions, the algorithms proposed by other authors are analyzed when developing parallel algorithms, and |

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| | | | in the third section, the software for modeling processes describing by equations of mathematical physics is also partially analyzed. |
| 5. | Scientific novelty principle | 5.1 Are the scientific results and provisions new? 1) <u>completely new</u> ; 2) partially new (25-75% are new); 3) not new (less than 25% are new) | The scientific results and provisions are completely new since this is the first study of a very weak solution of the tsunami equation with a singular coefficient and the first study in the development of parallel algorithms for the numerical solution of hyperbolic equations with a singular coefficient. |
| | | 5.2 Are the dissertation findings new? 1) <u>completely new</u> ; 2) partially new (25-75% are new); 3) not new (less than 25% are new) | The results of the thesis are completely new and confirmed by published scientific papers, in particular, the paper “A parallel hybrid implementation of the 2D acoustic wave equation”, published in the International Journal of Nonlinear Sciences and Numerical Simulation (Scopus, Q2, Percentile 61) |
| | | 5.3 Technical, technological, economic or management decisions are new and reasonable: 1) <u>completely new</u> ; 2) <u>partially new (25-75% are new)</u> ; 3) not new (less than 25% are new) | The technical solutions obtained in the work are partially new. The third section of the thesis on software related to technical management, in my opinion, is partially new. |
| 6. | The validity of the main findings | All main conclusions <u>are</u> /are not based on scientifically significant evidence or well-grounded (for qualitative research and areas of training in the arts and humanities) | The thesis is consists of 3 sections and a general conclusion, each section has a brief conclusion. The conclusions are based on extensive scientific evidence. In particular, the |

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| | | | <p>first chapter describes a very weak solution, the study of stability of finite difference schemes for equations, the application of the tsunami model to study the Caspian tsunami. The second chapter describes the algorithms, their testing, and the analysis of the obtained results. The third chapter describes an application of the developed software.</p> |
| 7. | <p>The main provisions for the defense</p> | <p>It is necessary to answer the following questions for each provision separately:</p> <p>7.1 Is the provision proven? 1) <u>proven</u>; 2) rather proven; 3) rather not proven; 4) not proven</p> <p>7.2 Is it trivial? 1) <u>yes</u>; 2) <u>no</u></p> <p>7.3 Is it new? 1) <u>yes</u>; 2) no</p> <p>7.4 Application level: 1) narrow; 2) <u>medium</u>; 3) wide</p> <p>7.5 Is it proven in the article? 1) <u>yes</u>; 2) no</p> | <p>7.1 The provision is proven. In the thesis, the provision presented in 5 points can be summarized in two points: the first point is the theoretical proof of the existence of a very weak solution to the tsunami equation, and this point was given in Chapter 1, Section 1.3. The second point is the practical development of parallel numerical algorithms, this point is given in the second chapter where 3 parallel algorithms and calculation results are described.</p> <p>7.2 The provision is not trivial. The obtained scientific results are relevant and have a scientific novelty.</p> <p>7.3 The provision is new. The theoretical proof of existence, uniqueness, the consistency of a very weak solution to the tsunami equation with a singular coefficient,</p> |

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| | | | <p>and justification by a numerical solution is a new provision. The developed parallel algorithms and applications are also new in the field of usage.</p> <p>7.4 The level of application is medium. Parallel algorithms for numerical solution of hyperbolic equations with singular coefficients presented in the thesis can be applied to numerical solution of other equations of mathematical physics. Here my remarks are that the developed parallel algorithms are less studied from the point of view of algorithmic research, and little comparative analysis of the algorithms is given. It would be useful if there was a comparative analysis with other algorithms.</p> <p>7.5 Proven in the paper. The results were published in the following scientific journals included in the Scopus database: Altybay A., Ruzhansky M., Tokmagambetov N. Wave equation with distributional propagation speed and mass term: numerical simulations. // Applied Mathematics E-Notes. - 2019. - Vol. 19. - P. 552-562. (Scopus, Q3) Altybay A., Ruzhansky M., Tokmagambetov N. A parallel hybrid</p> |
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| | | | <p>implementation of the 2D acoustic wave equation</p> <p>International Journal of Nonlinear Sciences and Numerical Simulation (Scopus, Q2, Percentile 61) and 4 articles were published in the journals included in the list of the Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan.</p> |
| 8. | <p>The principle of reliability</p> <p>Reliability of sources and information provided</p> | <p>8.1 Choice of methodology - is justified or the methodology is described in sufficient detail</p> <p><u>1) yes;</u></p> <p>2) no</p> | <p>The research methodology used in the work is described in the second part of the thesis. The methods used in the development of the algorithm for paralleling the two-dimensional wave equation with a time-dependent singular coefficient and the parallelization of the tsunami equation in a graphics processor are described in detail.</p> |
| | | <p>8.2 The results of the thesis were obtained using modern methods of scientific research and methods of processing and interpreting data using computer technologies:</p> <p><u>1) yes;</u></p> <p>2) no</p> | <p>The results obtained in the thesis were tested on supercomputer clusters and high-performance graphics processors.</p> |
| | | <p>8.3 Theoretical conclusions, models, identified relationships and patterns have been proven and confirmed by experimental research (for areas of training in pedagogical sciences, the results have been proven on the basis of a pedagogical experiment):</p> <p><u>1) yes;</u></p> <p>2) no</p> | <p>Theoretical conclusions, models, algorithms in the thesis are confirmed by experimental research.</p> |

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| | | 8.4 Important statements are <u>confirmed</u> / partially confirmed / not confirmed by references to current and reliable scientific literature | Important information in the work is confirmed by references to accurate and reliable scientific literature. |
| | | 8.5 Used literature sources are <u>sufficient</u> /not sufficient for a literature review | The thesis uses 89 pieces of literature, the list of used literature is sufficient for the literary review. |
| 9 | Practical value principle | 9.1 The thesis has theoretical value: 1) <u>yes</u> ; 2) no | The theoretical significance of the work was clearly demonstrated by the theoretical proof of the existence, uniqueness, and consistency of very weak solution of the tsunami equation with a singular coefficient. |
| | | 9.2 The thesis is of practical importance and there is a high probability of applying the results obtained in practice: 1) <u>yes</u> ; 2) no | Modeling of rapidly changing physical phenomena over time is often carried out using the equations of mathematical physics with a singular coefficient. The thesis is designed to numerically solve and parallelize the hyperbolic equations with a singular coefficient, so the results can be used in practice. |
| | | 9.3 Are the practice suggestions new? 1) <u>completely new</u> ; 2) partially new (25-75% are new); 3) not new (less than 25% are new) | Practical suggestions are new, there are two new proposals. The first proposal is the application of developed parallel algorithms to other equations of mathematical physics, which is presented in the second chapter of the thesis. The second proposal is to present the developed software as a simulation tool for researchers of wave equations with singular coefficients, which is presented in the third |

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| | | | chapter of the thesis. |
| 10. | The quality of writing and design | Academic writing quality: 1) high; 2) average; 3) below average; 4) low. | The quality of academic writing is average, the thesis contains some grammatical errors, incomplete sentences, but this does not affect the overall quality of the thesis and the obtained scientific results. |

The solution:

to award the degree of Doctor of Philosophy (PhD) in the specialty: 6D075100 - Computer Science, Computer Engineering and Management

Official Reviewer:

Baigereyev Dossan, PhD,
Associate Professor of the Department of Mathematics,
Sarsen Amanzholov East Kazakhstan University



(signature)

Baigereyev D.
(FULL NAME)

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