

REVIEW

of the official reviewer on the dissertation work by 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
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	1.1 Compliance with priority areas of science development or government programs: 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) 2) The thesis was completed within the framework of another state program (indicate the name of the program) 3) <u>The dissertation 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)</u>	The dissertation corresponds to the priority direction of science development for 2021-2023 “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; project AP09058069 "Very weak solutions of evolutionary equations"(2021-2023)
2.	Importance for science	The work <u>makes</u> /does not make a significant contribution to science, and its importance is <u>well disclosed</u> / not disclosed.	The developed parallel algorithms for the numerical solution of hyperbolic equations with singular coefficients are used to model a tsunami in the Caspian Sea. The developed software can be used to study waves in inhomogeneous media in various fields of science.
3.	The principle of independence	The level of independence: 1) <u>High</u> ; 2) Average; 3) Low; 4) There is no independence.	The high level of independence in research and in writing the dissertation is reflected in the review and analysis of the scientific literature, the development and testing of parallel algorithms, software development, various simulations and summing up the results of the work.
4.	The principle of inner unity	4.1 Justification of the relevance of the thesis: 1) <u>justified</u> ; 2) partially justified; 3) not justified.	The relevance of the dissertation is justified by analyzing the literature and giving specific examples. In particular, by the famous Schwartz impossibility result, if the singular coefficients are delta-like functions, then there is no classical

			<p>solution. To deal with such problems, the concept of very weak solutions is used.</p>
		<p>4.2 The content of the thesis reflects the topic of the thesis: 1) reflects; 2) partially reflects; 3) does not reflect.</p>	<p>The content fully reflects the topic of the dissertation. Chapter 1 provides the theoretical basis; Chapter 2 is devoted to the development of parallel algorithms for the numerical solution of the given equations; in Chapter 3, a software developed for studying wave equations with singular coefficients is described.</p>
		<p>4.3 The purpose and objectives correspond to the topic of the thesis: 1) correspond; 2) partially correspond; 3) do not correspond.</p>	<p>The purpose and objectives of the dissertation are clearly stated in Introduction and correspond to the topic of the dissertation.</p>
		<p>4.4 All sections and provisions of the thesis are logically interconnected: 1) completely interconnected; 2) partially interconnected; 3) there is no relationship.</p>	<p>The introduction, three main chapters and the conclusion of the dissertation are logically connected. The introduction presents the relevance of the topic, the purpose, objectives and novelty of the dissertation. The three interrelated chapters provide theoretical proofs, practical calculations, and the development of algorithms.</p>
		<p>4.5 The new solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with the known solutions: 1) there is a critical analysis 2) partial analysis; 3) the analysis is not the author's own opinion, but quotes from other authors.</p>	<p>The analysis is partially carried out; there are few comparisons of the developed parallel algorithms with other algorithms that solve the same equations.</p>
5.	The principle of scientific novelty	<p>5.1 Are the scientific results and provisions new? 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new).</p>	<p>The scientific results and provisions are completely new since this is the first study of the development of parallel algorithms for the numerical solution of hyperbolic equations with a singular coefficient and the proof of the existence of a very weak solution to the tsunami equation with a singular coefficient.</p>
		<p>5.2 Are the conclusions of the dissertation new? 1) completely new;</p>	<p>The results of the dissertation are completely new; in particular, the theoretical proof of the existence of a very</p>

		<p>2) partially new (25-75% are new); 3) not new (less than 25% are new).</p>	<p>weak solution of the tsunami equation with a singular coefficient; the hybrid parallel algorithm and the software simulating a wave equation with 4 different singular coefficients. The results obtained are confirmed by published scientific articles.</p>
		<p>5.3 Technical, technological, economic or management decisions are new and justified: 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new).</p>	<p>The technical solutions obtained in the work are completely new; they include the hybrid parallel algorithm and an open-source cross-platform software that is based on an absolutely stable fully implicit finite difference scheme.</p>
6.	The validity of the main findings	<p>All the main conclusions are based/ not based on scientifically significant evidence or well-grounded (for qualitative research and areas of training in the arts and humanities)</p>	<p>The main findings of the dissertation are well-grounded and proven.</p>
7.	The main provisions for the defense	<p>It is necessary to answer the following questions for each provision separately: 7.1 Is the provision proven? 1) proven; 2) rather proven; 3) rather not proven. 7.2 Is it trivial? 1) yes; 2) no. 7.3 Is it new? 1) yes; 2) no. 7.4 Applicability area: 1) narrow; 2) average; 3) wide. 7.5 Is it proven in the article? 1) yes; 2) no.</p>	<p>7.1 The main provisions are proven. First, it is theoretically proven that there is a very weak solution to the tsunami equation; secondly, they are proven by practically developed parallel algorithms and software. 7.2 The provisions are not trivial. The obtained scientific results are relevant and novel. 7.3 The provisions are new, they include: the existence of a very weak solution of the tsunami equation with a singular coefficient, the theoretical proof of its uniqueness and consistency; justification by numerical solution, and the 3 different parallel algorithms developed. 7.4 The level of application is wide. The 3 parallel algorithms presented in the dissertation can be used for numerical solutions and parallelization of other problems of mathematical physics. 7.5 The main provisions are proven by publishing the main results in the following peer-reviewed scientific journals indexed in Scopus and WoS: Altybay A., Ruzhansky M., Tokmagambetov N. Wave equation with distributional propagation speed and mass term:</p>

			numerical simulations. // Applied Mathematics E-Notes. - 2019. - Vol. 19. - P. 552-562. (Scopus, Q3) Altybay A., Ruzhansky M., Tokmagambetov N. A parallel hybrid implementation of the 2D acoustic wave equation International Journal of Nonlinear Sciences and Numerical Simulation (Scopus, Q2, Percentile 61); as well as in four journals included in the list recommended by the Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan.
8.	The principle of reliability. Reliability of sources and information provided	8.1 The choice of methodology is justified or the methodology is described in sufficient detail. 1) <u>yes</u> ; 2) no.	The methodology used in the development of parallel algorithms for the numerical solution of hyperbolic equations with singular coefficients is described in detail.
		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: 1) <u>yes</u> ; 2) no.	The results of practical calculations of the dissertation were tested on supercomputers and high-performance graphics processors.
		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): 1) <u>yes</u> ; 2) no.	Theoretical conclusions, models, and algorithms have been proven and confirmed by experimental research.
		8.4 Important statements are <u>confirmed</u> / partially confirmed/ not confirmed by references to relevant and reliable scientific literature	All the important statements in all sections of the thesis are confirmed by references to relevant and reliable scientific literature.
		8.5 The literature sources used are <u>sufficient</u> / not sufficient for a literature review	The list of references contains 89 sources, which is sufficient for a literary review.
9	The principle of practical value	9.1 The thesis has theoretical significance: 1) <u>yes</u> ;	The theoretical value of this work is confirmed by the proof of the existence, uniqueness and consistency of very weak

		2) no.	solutions to the tsunami equation and is justified by numerical simulations.
		9.2 The thesis is of practical importance and there is a high probability of applying the results obtained in practice: 1) yes ; 2) no.	The results obtained are of practical importance; the developed parallel algorithms can be used to solve other mathematical physics problems, and the software is a good help for researchers of hyperbolic equations with singular coefficients.
		9.3 Are the practice suggestions new? 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new).	The practice suggestions in the dissertation are partially new; parallel computing technologies are already available in the hybrid computational models and work well. The thesis suggests the effective use of these technologies in one calculation the computational algorithm in the software that is based on an implicit finite difference scheme.
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. There a number of typos and grammatical errors. However, these remarks do not detract from the value of the scientific results obtained.

The dissertation work by Altybay Arshyn makes an original and significant contribution to the field of research. The methodology applied in his research is effective and appropriate for the thesis topic.

The dissertation work meets all the requirements for PhD dissertations, and the author, Altybay Arshyn, deserves to be awarded the degree of Doctor of Philosophy (PhD) in the specialty: 6D075100 - Computer Science, Computer Engineering and Management

Official Reviewer:

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(signature)

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