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Advancing Scientific Rigor: Towards a Universal Informational Criterion for Assessing Model-Phenomenon Mismatch

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Abstract

The escalating costs of research and development, coupled with the influx of researchers, have led to a surge in published articles across scientific disciplines. However, concerns have arisen regarding the accuracy, validity, and reproducibility of reported findings. Issues such as replication problems, fraudulent practices, and a lack of expertise in measurement theory and uncertainty analysis have raised doubts about the reliability and credibility of scientific research. Rigorous assessment practices in certain fields highlight the importance of identifying potential errors and understanding the relationship between technical parameters and research outcomes. To address these concerns, a universally applicable criterion called comparative certainty is urgently needed. This criterion, grounded in an analysis of the modeling process and information transmission, accumulation, and transformation in both theoretical and applied research, aims to evaluate the acceptable deviation between a model and the observed phenomenon. It provides a theoretically grounded framework applicable to all scientific disciplines adhering to the International System of Units (SI). Objective evaluations based on this criterion can enhance the reproducibility and reliability of scientific investigations, instilling greater confidence in published findings. Establishing this criterion would be a significant stride towards ensuring the robustness and credibility of scientific research across disciplines.

Keywords

Amount of Information, Information Channel, Measurement, Model, System of Units, Uncertainty, Underwater Electrical Discharge

1. Introduction

The dawn of modern science can be traced back four centuries, when Galileo conducted groundbreaking experiments that would shape the trajectory of physics. These experiments served as the bedrock for the contemporary understanding of the field. Among the natural sciences, physics, including its application in engineering, distinguishes itself as a remarkably rigorous discipline. It relies on the powerful tools of mathematics and measurement theory to formulate all-encompassing physical theories and technological processes that align seamlessly with experimental observations. This unique approach ensures the utmost precision and accuracy in the study and application of physical phenomena.

At the same time, the scientific community faces a pressing issue—the escalating costs of research and development, leading to a surge in the number of researchers. As of 2018, the global count of researchers ranged between 7 and 8 million [1]. This influx of researchers has placed pressure on individuals to substantiate their scientific significance and validate their positions through the publication of a requisite number of articles. Consequently, some scientists publish an excess of 70 papers per year, and publication output has grown approximately 4% annually over the past decade. From 2008 to 2018, output grew from 1.8 million to 2.6 million articles [2].

This trend has raised concerns regarding the accuracy, validity, and reproducibility of reported results [3]-[8]. The issue extends across disciplinary boundaries, impacting various scientific fields. For instance, research has uncovered the alarming fact that at least 50% of life science studies cannot be replicated [9]. Similarly, 51% of economics papers suffer from replication issues [10]. Shockingly, approximately one-third of studies published in neuroscience journals and around 24% in medical journals have been exposed as fraudulent or plagiarized [11].

Regrettably, the prevailing situation indicates a worrisome scenario where authors' citation indices soar while the practical value of their research remains dubious. This concern extends not only to disciplines like psychological science, far removed from fields like metallography [12], life science, economics, and refrigeration. In [13], an attempt was made to assess reproducibility in psychological science. The authors employed five indicators to evaluate the reproducibility of 100 published works from prestigious journals. The findings were unequivocal: replication attempts yielded weaker results, with only 36% of repetitions achieving the same outcomes, and the observed effects were half the magnitude of the estimates obtained in the original studies.

In the realm of refrigeration, an alarming study revealed that only 20% of authors deemed it necessary to compare experimental uncertainty (EU) with the disparity between theoretical data (TD) and experimental data (ED) [14]. The absence of such comparisons raises concerns about the significance and reliability of proposed models. While claims of marginal absolute percentage differences between experiment and simulation may be made, they do not guarantee satisfactory agreement between theory and experiment. Comprehensive model selection requires a minimal calculated general uncertainty of the objective function in comparison to the disparity between theory and experiment. Unfortunately, this fundamental truth has not received due prominence in engineering and physical literature.

The disheartening reality emerges that many researchers lack sufficient knowledge in the application of measurement theory and overlook the criticality of validation and verification methods [15] and uncertainty analysis [16]. These methods are essential in establishing the intricate relationship between considered technical parameters and the target research function. In contrast, research teams diligently analyze potential sources of error and calculate disparities between theoretical and experimental results in other fields, such as heat prediction during spacecraft entry into the Martian atmosphere [17]. Such rigorous practices ensure a robust and comprehensive assessment of findings, fostering greater confidence in reliability and accuracy.

To address these concerns, there is an urgent need to present the scientific community with a universally applicable, theoretically grounded criterion for assessing the permissible deviation threshold between a model and the observed phenomenon [18]. Such a criterion (comparative certainty [19]) would be applicable across all scientific and technical disciplines that adhere to the International System of Units (SI). By establishing this criterion, the reproducibility of published research results can be approached objectively, detached from the subjective opinions of experts. This would bring about a significant advancement in ensuring the robustness and reliability of scientific investigations.

2. Quantifying Model Uncertainty in Physical Phenomena: The Information Measure Approach

In the field of scientific research and modeling, an accurate assessment of the uncertainty associated with theoretical models is of paramount importance. The ability to quantify model uncertainty through comparative uncertainty not only improves our understanding of physical phenomena, but also allows us to make informed decisions based on robust and reliable predictions. In this chapter, we will delve into the background, physics, and benefits of an innovative approach known as the informational approach to model uncertainty calculation.

Traditionally, uncertainty analysis has been approached using statistical methods, which are often based on assumptions and simplifications that may not reflect the true complexity of the underlying system and focus on the analysis of uncertainties in computer calculations and experimental results. However, these certainly necessary procedures are carried out after the stage of formulating the model. Based on the analysis of the processes of storage, transmission, processing, and use of information in the formulation of the model, the presented approach offers a new perspective, using the concept of comparative uncertainty [19] to assess and quantify the uncertainty of the model in a more comprehensive and reliable way.

The essence of the informational approach lies in its ability to capture the inherent smallest uncertainty associated with the qualitative and quantitative set of variables in the model. Using this uncertainty, we can obtain a holistic measure of the overall uncertainty of the model.

The foundation of modern science relies on a fundamental agreement that the laws governing micro- and macro-physics can be described using well-defined dimensional variables or dimensionless criteria. These variables are carefully selected within a standardized system of units, such as the SI (International System of Units) or CGS (Centimeter-Gram-Second system). These systems of units encompass a set of base quantities that serve as primary descriptors, capable of generating derived variables that effectively capture the qualitative and quantitative essence of the known laws of nature [20].

This implies that all scientific knowledge and formulated physical laws, without exception, are derived from the information contained within these systems of units. Models (unique channels) formulated by thinkers extract from them and act the transmission of information to the observer. The system of units comprises a finite number of physical dimensional variables that hold the potential to characterize the physical properties of our world. Therefore, the formulation of a model of a material object is dictated by the selection of these variables. We can only model what we can imagine or observe, and the choice of a specific system of units, like a lens, establishes a particular limit on our ability to measure the observed object.

Furthermore, the system of units includes base quantities and derived variables tailored for describing different groups of phenomena (GoP). In other words, the choice of the system of units and the selection of relevant GoP impose additional constraints on the description of the studied material object, considering the number of secondary parameters incorporated in the mathematical model [20]. For instance, in electrical engineering, the SI system employs the base quantities of length (L), mass (M), time (T), electric current (I), and thermodynamic temperature (Θ). In this context, the GoP can be represented as $\mathrm{GoP_{SI}} \equiv \mathrm{LMTI}\Theta$, where the inclusion of electric current (I) is essential for analyzing the behavior of circuits, and thermodynamic temperature (Θ) is relevant for understanding the thermal effects and properties of electrical components. In photometry, the force of light (J) is added, and the final base variable in the SI system is the quantity of substance (F).

It is important to note that without a defined system of units and chosen GoP, the notion of “information about the researched object” loses its significance. The modeling of phenomena becomes impossible without these foundational elements. Just as we cannot create something out of nothing, we cannot extract meaningful insights or knowledge without a structured framework [19]. The system of units can be interpreted as the basis for all the accessible knowledge that humans currently possess about their environment. Establishing a specific system of units, such as the SI units, signifies an attempt to narrow down the set of possible variables by utilizing a reduced number of base quantities, derived variables, and dimensionless criteria.

By utilizing the π-theorem [21] and recognizing that the SI structure can be viewed as a subgroup of the infinite Abelian group [22], it was demonstrated and proved [23] [24] [25] [26] that the following results can be extended to various systems of units. These systems may include different base quantities and different numbers of derived variables and criteria. Furthermore, these results have broad applicability to different models encompassing both dimensional and non-dimensional variables and criteria.

In the below text, the exclusive use of the International System of Units (SI) is envisioned since it is widely employed in the outcomes of scientific and engineering research. Considering the seven base quantities of SI, it is noteworthy that SI encompasses a significant number of dimensionless criteria ($\mu_{SI} = 38{,}265$) [18].

The process of formulating a model, which precedes any computational or experimental endeavors, is based on certain fundamental but often overlooked steps. These steps can be outlined as follows:

The thinker (T) selects a specific model with a defined GoP and several variables. These variables can include scalar parameters such as time, universal constants, one-dimensional components of position or momentum, as well as dimensionless numbers (referred to as the infinite information quantity—FIQ [27]).

Each variable is chosen by a conscious observer on an equiprobable basis. If a system of units is selected, the probability of including a variable in the model is estimated, assuming no prior information about the phenomenon under investigation. Therefore, each variable in the model can be considered to have an equal likelihood of being included. It is important to note that this statement may appear controversial. However, it is reminiscent of the electron's dual nature as both a particle and a wave. Researchers, drawing upon their intuition, knowledge, and experience, have proposed entirely different models based on these distinct perspectives. Both approaches are valid and have been confirmed through experimental observations.

The model can be conceptualized as an information channel connecting the phenomenon under study (P) with T [28]. In this context, the uniqueness of this situation arises from the discrete set of equiprobable random variables, $X \in \{x_1, \ldots, x_j\}(P)$, which are selected by the conscious choice of T. Here, X represents any system of units such as the SI [29], which, in turn, is developed by the collective intellect of scientists.

It is intuitively appealing to assume that the number of elements in X (criteria, variables) should encompass all conceivable connections that exist in the universe. However, the possibility of discovering new base quantities in the future remains uncertain. If this line of reasoning holds true, it implies that *the initial description of P is not infinitely precise but rather influenced by human consciousness*.

By considering the model as a communication channel [28], we gain a unique opportunity to employ the concepts and mathematical tools of information theory. This allows us to assess the model's accuracy and determine its threshold discrepancy [30], even in the presence of "noises" such as the philosophical views of the T and the finite amount of information in both the SI system and the model. This perspective enables us to quantitatively analyze and account for various sources of uncertainty and potential limitations, ultimately enhancing our understanding of the modeling process and its outcomes.

Based on the principles of information theory, we can explore the conditions that allow for source compression P (X or μ_{SI}) and the limits that can be achieved through compression, particularly in the context of modeling a physical phenomenon. These conditions are closely associated with a fundamental problem: determining the minimum distortion that can be attained when reproducing the source X, given a specific representation parameter $W(\text{GoP}_{SI})$.

To address this problem, we employ the function $W(D)$ which is the source distortion parameter, D is the optimal distortion when transforming the source X into a model during simulation. For a discrete source X, *this function is determined based on the a priori total amount of information obtained during the formulation of a model for the physical phenomenon*. We can express this relationship mathematically as:

$$W(D) = \max_{\gamma_{\text{GoP}} \in Z_D} \Delta A(\mu_{\text{SI}}; \gamma_{\text{GoP}}) \tag{1}$$

Here, Z_D represents the set of all possible optimal numbers of FIQs included in a model and corresponding to the specific GoPs, resulting in a distortion equal to the optimal distortion D when transforming the source X into a model during simulation. ΔA represents the inherent quantity of information, measured in terms of entropy, that is acquired during the development of a model to describe a given physical phenomenon. γ_{GoP} is several FIQs inherent in a specific GoP_{SI}, $\gamma_{\text{GoP}} = z' - \beta'$, z' is the number of FIQs in the selected GoP, β' is the number of base quantities in the selected GoP.

Through an analysis of the communication channel's bandwidth, as discussed in [31], and the introduction of the function $W(D)$ by Equation (1), it has been discovered [28] that there exists a fundamental limitation on the accuracy of measurements even prior to any computer calculations or experimental implementation. This limitation can be represented by an ultimate comparative uncertainty denoted as ε, which can be expressed using the following equation:

$$\varepsilon = \Delta_{\Sigma}/S = (z' - \beta')/\mu_{\text{SI}} + (z'' - \beta'')/(z' - \beta') \tag{2}$$

where Δ_{Σ} represents the a priori absolute uncertainty of the model, which arises from the choice of the GoP and the number of recorded FIQs, S denotes the observation interval for the primary researched FIQ, as determined by the T (thinker), z'' signifies the number of FIQs recorded in a model, and β'' indicates the number of base quantities recorded in a model.

ε serves as a universal metric for quantitatively assessing the model's proximity to the object of study. It cannot be verified through statistical methods such as consistency, asymptotic normality, weighted estimates, or coefficients. Surprisingly, the value of ε has not received significant attention from researchers, despite its critical role in information theory [19]. Considering the ε-Equation (2), we can postulate that even the most accurate scientific theories, such as relativity theory and quantum mechanics, may be founded on subjective factors, reflecting the philosophical standpoint of the investigator at the most fundamental level. This realization raises profound epistemological questions concerning the inherent nature of reality. Consequently, the analysis of the following examples aims to detect subtle deviations from widely accepted principles in modeling physical phenomena, which could potentially provide initial indications of new physics.

3. Challenges and Considerations in Applying Comparative Uncertainty Analysis to Diverse Experimental Data

3.1. Conditions and Requirements of Applying the Informational Approach

Using relative uncertainty to analyze experimental data across different scientific groups has several disadvantages:

1) Lack of Standardization: Varied methodologies, equipment, and procedures employed by different groups lead to variations in estimating and calculating relative uncertainties. This lack of standardization hampers accurate data comparison and integration.

2) Variation in Experimental Conditions: Factors like temperature, pressure, and humidity significantly affect experimental results. Differences in control over these conditions among scientific groups introduce variations in measured values and associated uncertainties. Neglecting these variations compromises the accuracy of the analysis.

3) Systematic Errors and Biases: Relative uncertainty analysis assumes random and unbiased uncertainties. However, systematic errors and biases can exist in experimental setups, measurement techniques, or data processing methods used by different groups. Ignoring these errors distorts the analysis and yields incorrect conclusions.

4) Variation in Experimental Techniques: Different groups may employ diverse experimental techniques to measure the same physical quantity. These variations introduce inherent differences in measurement uncertainties. Without accounting for these variations, interpreting relative uncertainties can lead to erroneous conclusions.

5) Limited Information Exchange: Inadequate access to experimental protocols, raw data, and calibration standards used by other groups hinders accurate estimation of relative uncertainties across datasets. Insufficient information about experimental procedures compromises the evaluation of data quality and reliability, impacting the validity of the analysis.

To address these shortcomings, it is essential to establish rigorous standards, promote data sharing and transparency, and conduct thorough inter-laboratory comparisons. Standardizing experimental protocols, implementing quality control measures, and fostering open collaboration among scientific groups can mitigate the disadvantages associated with using relative uncertainty in the analysis of experimental data across different groups. That is why, this article suggests using comparative uncertainty as a criterion for selecting the most accurate model to describe a physical phenomenon. Comparative uncertainty provides an objective and quantitative measure to evaluate models, promoting unbiased assessments and robust comparisons. It helps researchers assess model performance, address assumptions and limitations, and enhance scientific understanding.

A comparative uncertainty analysis was performed on scientific and technical works, comparing the obtained comparative uncertainty of the model ($\varepsilon_{\mathrm{mod}}$) with the theoretically justified uncertainty ($\varepsilon_{\mathrm{opt}}$), as presented in **Table 1** [32]. When the uncertainties exhibit close values ($\varepsilon_{\mathrm{mod}}/\varepsilon_{\mathrm{opt}} \to 1$), it confirms the reliability and utility of utilizing either model to describe the studied process. Conversely, a substantial disparity between these uncertainties ($\varepsilon_{\mathrm{mod}}/\varepsilon_{\mathrm{opt}} << 1$) signifies a significant risk associated with the application of a specific model. This approach facilitates the incorporation of concepts pertaining to the transmission, accumulation, and transformation of information in both theoretical research and practical problem-solving.

The informational approach has been extensively utilized to assess measurement accuracy and determine the most suitable models for different areas of scientific activities. Examples include the Boltzmann constant [25] [33], Planck's constant [34], Hubble's constant [15], gravitational constant [16], identifying possible signals of extra-terrestrial civilizations [35], preferred models for cold storage systems [14] [36] [37], cosmology problems [38] [39], efficiency of ice makers [37], and measurements of sound speed [40].

This article focuses on analyzing studies related to the investigation of "underwater electric discharge." The author's keen interest in this subject is motivated by the following reasons. Firstly, collaboration with L. A. Yutkin, the first inventor of the "electro-hydraulic effect" [41], during research on the impact of this method on the quality of centrate (pigs' urine). Secondly, participation in a classified project involving the development and implementation of the light-hydraulic effect for wastewater disinfection, resulting in a USSR author's certificate [42] that was restricted from publication for 30 years. Consequently, the author possesses specific knowledge relevant to the subject matter, enabling definitive conclusions to be drawn regarding the value of proposed models for the study of electric discharge in liquids.

Table 1. Comparative uncertainties and optimal number of dimensionless criteria.

$\mathrm{GoP}_{\mathrm{SI}}$	LMT	LMTI	LMTΘ	LMTθI
Comparative uncertainty, $\varepsilon_{\mathrm{opt}}$	0.0048	0.0245	0.0442	0.2220
Number of FIQs inherent in $\mathrm{GoP}_{\mathrm{SI}}$, $\gamma_{\mathrm{CoP}} = z' - \beta'$	91	468	846	4247
Optimal number of FIQs inherent in a model, $\gamma_{\mathrm{mod}} = z'' - \beta''$	≈0.2 < 1	≈6	≈19	≈471

A comprehensive search for articles related to the topic "underwater electrical discharge" was conducted within the time frame of 2011-2021 using SCI-HUB to provide free entry PDF files. To ensure a thorough analysis, the search utilized various academic databases such as IEEE Xplore, ScienceDirect, Google Scholar, WorldWideScience.org, and the International Nuclear Information System. The selection process involved four specific criteria that needed to be fulfilled simultaneously:

1) The presence of a mathematical model with the presentation of theoretical calculations: Articles were evaluated based on their inclusion of a well-defined mathematical model that provided theoretical calculations related to underwater electrical discharge. This criterion ensured that the selected articles offered a solid theoretical foundation for the analysis.

2) Conducting experiments and presenting their results: The inclusion of articles that described and conducted experiments pertaining to underwater electrical discharge was essential. These articles provided valuable empirical data and insights into the phenomenon, enhancing the depth and reliability of the analysis.

3) Comparison of theoretical calculations with the obtained experimental results: A crucial aspect of the selection process involved identifying articles that explicitly compared the theoretical calculations with the corresponding experimental results. This criterion allowed for the evaluation of the alignment or disparities between theory and practice, providing a comprehensive understanding of the accuracy and applicability of the models.

4) The presence of a calculation of the total absolute or relative uncertainty achieved in the experiment: This requirement was a crucial criterion in the selection of articles. By prioritizing studies that presented such calculations, it ensured a thorough evaluation of the reliability and accuracy of the experimental data. Furthermore, it is highly recommended that the analyzed research articles include a comparison between the experimental uncertainty of the parameter under study (EU) and the discrepancy between theoretical (TD) and experimental data (ED). If the value of EU exceeds the absolute difference between TD and ED ($|TD - ED|$), it raises doubts about the validity of the proposed model and suggests potential risks associated with its practical implementation.

By employing these four selection criteria, the analysis aimed to gather articles that met rigorous standards, encompassing theoretical models, experimental data, comparison between theory and experiment, and the consideration of uncertainties. This comprehensive approach allowed for a thorough examination of the research on underwater electrical discharge, ensuring the inclusion of high-quality and relevant articles in the analysis.

A total of 800 articles were reviewed in this analysis, selected based on four simultaneous criteria to ensure a comprehensive evaluation. These criteria were applied to assess the legitimacy and practical feasibility of the presented ideas related to "underwater electrical discharge" and to facilitate comparisons with other models to identify the most suitable model for describing the process.

The authors in these publications present unique experimental setups and equipment, emphasizing the scientific significance of their findings. While many authors recognize the importance of comparing their results with data from other studies, some works lack theoretical data for comparison with experimental outcomes, despite formulating a potential model of the studied process. In their articles, authors often mention the relevance of their results for optimizing design and identifying efficient operating regimes and highlight good agreement between experimental and theoretical or numerical results. However, except for the study conducted by W. Yao *et al.* in 2019 [43], none of the other examined studies thoroughly explain the calculation of relative uncertainty in their experiments. In this article, although the authors provide information on the magnitude of relative uncertainty and the calculation method, they do not specify the individual contributions of uncertainty sources.

This lack of comprehensive fulfillment of criteria highlights a concerning state of research in the investigation of "underwater electrical discharges." Many scientists appear engrossed in physical principles, mathematical formulas, computer algorithms, and extensive experimental data, often accepting their assumptions as a reality, without recognizing the need for rigorous testing by comparing theoretical predictions with experimental outcomes. Although minor discrepancies are occasionally acknowledged, the importance of such comparisons is often overlooked by researchers.

This situation raises concerns about the accuracy and reliability of the conclusions presented. It is crucial for researchers to recognize the significance of verifying their models through the comparison of theoretical predictions with experimental results. By doing so, they can ensure the validity of their findings and gain a more comprehensive understanding of the studied phenomenon. The absence of thorough comparisons and the disregard for reporting experimental uncertainties demonstrate the pressing need for more meticulous and rigorous research practices in the field of "underwater electrical discharges."

3.2. Analysis of Results of Applying the Informational Approach

Considering the abundance of publications focused on this topic, and considering the situation, a diligent selection process was undertaken. Drawing inspiration from the wisdom encapsulated in the English proverb "Make do with what you have," a meticulous choice of six articles was made [43]-[48].

The article [43] describes an empirical approach to estimate the pressure and energy of shock waves in underwater electrical wire explosions (UEWE). The approach involves dividing the discharge process into phases, calculating energy and power values, measuring shock wave peak pressure, and using a multiparameter fitting method to derive empirical formulas for pressure and energy estimation. The formulas are validated using experimental data, showing average relative errors and standard deviations for peak pressure and shock wave energy. The text also mentions additional experiments with different discharge parameters and discusses the sources of errors in the measurement and calculation process. Shortcomings in the presentation of the material include the lack of clarity in explaining the specific methods used for measuring shock wave parameters and the empirical formulas. The text could benefit from providing more details on the measurement techniques and the specific calculations involved. Additionally, the discussion of errors and limitations could be more comprehensive, addressing potential sources of uncertainty beyond the mentioned factors.

The authors of [44] focus on the determination of circuit parameters in underwater spark discharges. It presents various methods for estimating these parameters, which are crucial for understanding and analyzing the behavior of underwater electrical discharges. Work has several shortcomings. Firstly, the absence of an RLC (resistance-inductance-capacity) meter prevents direct measurement of the actual circuit capacitance, leading to reliance on calculated values from NLS-TV (nonlinear least squares with three variables method), introducing potential inaccuracies. Secondly, NLS-SV (nonlinear least squares with a single variable method) and WCM (waveform calculation method) require knowledge of the total circuit capacitance, which is not measured directly. Validation is done using the capacitance calculated by NLS-TV, but relying solely on energy storage capacitor capacitance yields frustrating results, emphasizing the need to consider other components. Independent use of NLS-SV or WCM requires precise capacitance measurement. NLS-SV shows good convergence and accuracy with PSO (particle swarm optimization algorithm) or Levenberg-Marquardt algorithms but relies on obtaining angular frequency from the current waveform, unlike NLS-TV. WCM relies entirely on the measured current waveform, determining resistance and inductance through simple equations. However, manual information extraction from the current waveform introduces reading errors and lower accuracy compared to NLS-TV. Overall, the work highlights limitations such as reliance on calculated capacitance and the need for precise measurements of circuit components.

The article [45] explores the generation of ultra-fast cumulative water jets through underwater electrical explosions of conical wire arrays. It investigates the physics of the process and presents experimental results. However, the article lacks concrete evidence to validate the assumptions made regarding the test bench and model formulation. The absence of data on absolute or relative uncertainty calculations further weakens the findings. The authors' claim of good agreement between experimental results and the model lacks supporting graphs or calculations. Additionally, the lack of a quantitative analysis and direct comparison between the presented models and experimental results hinders effective evaluation.

The numerical simulation of electrical discharge characteristics resulting from underwater wire explosions are analyzed in [46]. The authors utilize numerical methods to model the phenomenon and provide insights into the behavior of underwater electrical discharges. The study lacks calculations for determining the relative uncertainty of the experiments, a common practice in validated studies. The authors rely solely on graphs to demonstrate the "confirmation" of their model's validity using experimental and theoretical data. However, the introduction of simplifications to improve agreement between experimental results and model calculations raises the need for a more in-depth physical discussion to justify these simplifications.

The article [47] compares underwater spark simulations using elliptical and cylindrical models. It investigates the influence of the model shape on the simulation results and presents a comparative analysis. It becomes advantageous as it allows for a quantitative assessment of the differences between the models and helps identify the most plausible and reliable model for representing underwater electrical discharges. However, the paper employs simplified assumptions and a limited complexity representation. The validation against experimental data is limited to a comparison without specific calculation of achieved uncertainties. Additionally, there is a lack of comprehensive analysis of electro- and hydrodynamic processes. The study overall has limitations in its assumptions, analysis, testing, and discussion of limitations, emphasizing the necessity for further research.

The paper [48] focuses on simulating electrohydrodynamic phenomena using computational intelligence methods, particularly for underwater electrical discharges. One notable strength of this work is its utilization of neural network modeling, which plays a crucial role in predicting the pressure values of the resulting seismic wave. However, it's important to acknowledge that neural networks have inherent limitations and uncertainties in their training and generalization capabilities. A drawback of the study is the lack of comprehensive validation against experimental data, which undermines the confidence in the accuracy and reliability of the simulation results. Additionally, the study relies on simplified assumptions and a representation of limited complexity, potentially leading to unrealistic and less precise predictions. The dataset used is restricted to current intensity and pressure data from field experiments and solutions of differential equations, limiting the range of experimental data and parameters considered. As a result, the applicability and scope of the simulation model are constrained. In conclusion, these limitations in assumptions, analysis, testing, and discussion emphasize the need for further research to enhance the accuracy and reliability of the simulation results.

Comparing the presented models and experimental results in these articles is challenging due to various factors such as the lack of direct quantitative analysis, insufficient details for comparison, different research materials and liquids, specific construction of test benches, or absence of comprehensive experimental validation.

The studies reviewed did not include a comparison of the achieved relative uncertainty of the experiment with the disparity between the theoretical predictions and experimental data. This omission raises concerns about the reliability and validity of the formulated models used in describing underwater electrical discharges. Applying these models without proper evaluation poses a significant risk. Additionally, the question of which model to prefer remains unanswered when considering relative uncertainty. To address this issue, we utilized an informational method to determine the preference for the physical interpretations of the compared models (**Table 2**).

Upon analyzing the data in **Table 2**, several trends become apparent. Researchers studying underwater electrical discharges may have personal biases that influence their selection of variables in the modeling process. However, it is important to acknowledge that limiting the number of variables can result in the exclusion of crucial connections. To achieve a more precise representation of underwater electrical discharges in various environments, it is imperative to consider a wider range of variables and their potential interactions.

The ratios of $\varepsilon_i/\varepsilon_{\mathrm{opt}i}$ exhibit a significant increase when using the GoP with a small number of base quantities and a low $\gamma_{\mathrm{mod}i}$ (LMT, LMTI): $\varepsilon_1/\varepsilon_{\mathrm{opt}1} = 9.67$ [45], $\varepsilon_2/\varepsilon_{\mathrm{opt}2} = 1.37$ [46], and $\varepsilon_3/\varepsilon_{\mathrm{opt}3} = 1.2$ [47], all exceeding 1. This contradicts the fundamental thesis of the informational method [26], which states that the accuracy limit of any model ε_i must always be less than $\varepsilon_{\mathrm{opt}i}$. Therefore, the suggested models [45] [46] [47] [48] are unpromising and require reformulation. Conversely, the experimental ratios $\varepsilon_5/\varepsilon_{\mathrm{opt}5}$ and $\varepsilon_6/\varepsilon_{\mathrm{opt}6}$ support the preferred models proposed in [43] [44].

The findings presented in [44] demonstrate a remarkable achievement comparable to the groundbreaking work of NASA engineers [49]. The research was conducted within the framework of $\mathrm{GoP}_{\mathrm{SI}} \equiv \mathrm{LMT}\theta\mathrm{F}$, where the variables' dimensions were expressed as combinations of the dimensions of five base quantities: L, M, T, θ, and F, at various degrees [20]. A total of 130 (z'') variables were employed in calculating P. In the case of selecting five independent variables ($\beta'' = 5$) according to the π-theorem [50], the number of dimensionless criteria in

Table 2. Comparison of research results.

Variable/Reference	Chosen $\mathrm{GoP}_{\mathrm{SI}}$ of the model	Number of FIQs inherent in $\mathrm{GoP}_{\mathrm{SI}}$, $\gamma_{\mathrm{GoP}} = z' - \beta'$	Optimal number of dimensionless FIQs inherent in a model, $\gamma_{\mathrm{mod}i} = z'' - \beta''$, i, 1, 2, 3	Number of dimensionless FIQs inherent in a formulated model*, $\gamma_{\mathrm{exp}i} = z'' - \beta''$, i, 1, 2, 3	The achieved experimental comparative uncertainty of the model**, ε_i	The comparative uncertainty of the model, theoretically justified for the selected GoP, $\varepsilon_{\mathrm{opt}i}$	Ratio of $\varepsilon_i/\varepsilon_{\mathrm{opt}i}$
[45]	LMT	91	$\gamma_{\mathrm{mod}1} \approx 0.2 < 1$	$\gamma_{\mathrm{exp}1} \approx 4$	$\varepsilon_1 = 0.0464$	$\varepsilon_{\mathrm{opt}1} = 0.0048$	≈9.67
[46]	LMTI	468	$\gamma_{\mathrm{mod}2} \approx 6$	$\gamma_{\mathrm{exp}2} \approx 10$	$\varepsilon_2 = 0.0336$	$\varepsilon_{\mathrm{opt}2} = 0.0245$	≈1.37
[47]	LMTI	468	$\gamma_{\mathrm{mod}3} \approx 6$	$\gamma_{\mathrm{exp}3} \approx 8$	$\varepsilon_3 = 0.0293$	$\varepsilon_{\mathrm{opt}3} = 0.0245$	≈1.20
[48]	LMTIθ	4247	$\gamma_{\mathrm{mod}4} \approx 471$	$\gamma_{\mathrm{exp}4} \approx 19$	$\varepsilon_4 = 0.0484$	$\varepsilon_{\mathrm{opt}4} = 0.2220$	≈0.22
[43]	LMTI	468	$\gamma_{\mathrm{mod}5} \approx 6$	$\gamma_{\mathrm{exp}5} \approx 3$	$\varepsilon_5 = 0.0186$	$\varepsilon_{\mathrm{opt}5} = 0.0245$	≈0.76
[44]	LMTI	468	$\gamma_{\mathrm{mod}6} \approx 6$	$\gamma_{\mathrm{exp}6} \approx 5$	$\varepsilon_6 = 0.0229$	$\varepsilon_{\mathrm{opt}6} = 0.0245$	≈0.93

*In scientific research, it is not common practice to explicitly state the number of variables considered in a model, although it is crucial for calculating the comparative uncertainty (2). In addition, scientists sometimes forget to define the variables used in formulas. In these articles, the author had to calculate the number of variables independently, leading to the sole responsibility for any inaccuracies in representing the number of variables considered. **ε_i is calculated according to Equation (2).

the model, γ, was determined to be $\gamma = z'' - \beta'' = 125$. Consequently, $\varepsilon_{\text{mod}}/\varepsilon_{\text{opt}} \approx 0.9$ (ε_{mod} closely approximates ε_{opt}). Despite the authors' unfamiliarity with the proposed information method, their work [49] yielded exceptional results, as evidenced by the numerous successful landings of automated vehicles on the Martian surface.

Recognizing the progress achieved in prior research [43] [45] [46] [47] [48], the adoption of an informational approach emphasizes the significance of incorporating a specific number of variables in models that closely align with the recommended guidelines. Specifically, regarding underwater electrical discharges, the model proposed in [44] takes precedence by encompassing several variables close to the optimal values.

4. Discussion

The escalating costs of research and development, coupled with the increasing number of researchers, have led to a surge in published articles across scientific disciplines. However, concerns have emerged regarding the accuracy, validity, and reproducibility of reported findings. Issues such as replication problems, fraudulent practices, and a lack of expertise in measurement theory and uncertainty analysis have raised doubts about the reliability and credibility of scientific research.

To address these concerns, there is an urgent need for a universally applicable criterion that can assess the acceptable deviation between a model and the observed phenomenon. This criterion, known as comparative certainty, aims to evaluate the model-phenomenon mismatch and provide a theoretically grounded framework applicable to all scientific disciplines adhering to the International System of Units (SI). By establishing this criterion, the reproducibility and reliability of scientific investigations can be enhanced, instilling greater confidence in published findings.

It is difficult to overestimate the importance of SI for scientific research. The International System of Units (SI) is essential for assessing the reliability and reproducibility of scientific research due to its role in providing a standardized framework for measurements. It ensures consistency, traceability, and comparability, enabling accurate and replicable experiments. The SI promotes interdisciplinary collaboration, quality control, and error analysis. By using SI units, researchers can communicate globally, enhance research impact, and uphold scientific integrity.

The informational approach to quantifying model uncertainty offers a new perspective in assessing and quantifying model uncertainty. Traditionally, uncertainty analysis has relied on statistical methods, but the informational approach considers the processes of information transmission, accumulation, and transformation in the formulation of a model. It captures the inherent smallest uncertainty associated with the qualitative and quantitative set of variables in the model, providing a holistic measure of the overall uncertainty.

The selection of a specific system of units, such as the SI, is crucial in the formulation of a model. The system of units comprises a finite number of physical dimensional variables that characterize the physical properties of the world. It serves as the basis for all accessible knowledge in science and establishes a framework for modeling phenomena. By considering the model as an information channel connecting the phenomenon with the observer, the concepts and mathematical tools of information theory can be applied to assess the model's accuracy and determine its threshold discrepancy.

The establishment of the comparative certainty criterion has implications for diverse experimental data. It offers a universal metric, ε, for quantitatively assessing the model's proximity to the object of study. This metric goes beyond statistical methods and provides insights into the fundamental nature of reality. By analyzing experimental data using relative uncertainty and considering the conditions and requirements of applying the informational approach, researchers can detect subtle deviations from widely accepted principles in modeling physical phenomena, potentially indicating new physics.

However, challenges and considerations arise in applying comparative uncertainty analysis to diverse experimental data. The informational approach requires careful consideration of the system of units, the selection of variables, and the assessment of distortion in transforming the source into a model. Researchers need to account for various sources of uncertainty and potential limitations to enhance the accuracy and reliability of their predictions.

The comparative certainty criterion based on the informational approach holds promise for advancing scientific rigor and addressing concerns about the reliability and credibility of scientific research. By quantifying model-phenomenon mismatch and providing a theoretically grounded framework, this criterion can enhance reproducibility and instill greater confidence in published findings. However, challenges in applying this approach to diverse experimental data require careful consideration and further research. Overall, establishing the comparative certainty criterion represents a significant stride towards ensuring the robustness and credibility of scientific research across disciplines.

At the same time, it is important to note the following. The term "comparative uncertainty" is used in the context of the developed model to all scientific disciplines that follow the SI. The article suggests that Equation (2) provides a means to calculate the absolute uncertainty of a model, denoted as Δ_Σ and representing the a priori absolute uncertainty of the model, due to the choice of GoP (Group of Phenomena) and the number of variables considered.

Advantages and implications of the concept of "comparative uncertainty" to all scientific disciplines that follow the International System of Units include:

Correspondence principle: Equation (2) is described as a correspondence principle for model development. It establishes a relationship between the level of detailed description of the test bench, the choice of phenomena group, the number of variables considered, and the comparative uncertainty.

Determining achievable accuracy limit: Equation (2) helps determine the achievable accuracy limit for a given group of phenomena. It establishes a relationship between comparative uncertainty, absolute uncertainty, and the interval of change for the studied quantity. By meeting the necessary conditions outlined in Equation (2), the model confirms the legitimacy of the measured value of the physical constant.

Equivalence across measurement systems: Equation (2) exhibits the property of equivalence, meaning it holds true for other measurement systems as well. Regardless of the units of measure used, models formulated in different systems must comply with Equation (2) to maintain consistent relationships between physical variables. This ensures the compatibility and reliability of physical models across different units of measurement.

Limitations and inherent uncertainty: The article mentions that the process of developing measuring equipment and improving measurement methods can increase knowledge about the studied object and decrease relative uncertainty. However, there is an inevitable "comparative uncertainty" that depends on the preferences, intuition, knowledge, and experience of the researcher. The magnitude of this uncertainty indicates the likelihood of personal philosophical inclinations influencing the outcome of the model-building process.

It's important to note that the specific context and application of "comparative uncertainty" mentioned in the provided article may not be widely recognized or established within the broader scientific community.

5. Conclusions

The informational method methodology enhances our understanding of the inherent characteristics of the phenomenon, paves the way for further investigation, uncovers hidden correlations, and broadens the scope of our knowledge.

Considering the escalating costs of research and concerns about the reliability of scientific findings, the development of a universally applicable criterion for assessing model-phenomenon mismatch is urgently needed. This criterion, called comparative certainty, aims to evaluate the acceptable deviation between a model and the observed phenomenon in a theoretically grounded manner applicable to all scientific disciplines adhering to the International System of Units (SI). By establishing this criterion, the reproducibility and reliability of scientific investigations can be enhanced, instilling greater confidence in published findings.

The informational approach to quantifying model uncertainty offers a comprehensive and reliable method for assessing the uncertainty associated with theoretical models. By considering the system of units and the selection of relevant groups of phenomena, this approach captures the qualitative and quantitative essence of physical phenomena. It employs information theory concepts and mathematical tools to assess the accuracy of models and determine their threshold discrepancy. This allows for the analysis and quantification of various sources of uncertainty, enhancing our understanding of the modeling process and its outcomes.

Applying comparative uncertainty analysis to diverse experimental data poses challenges and considerations. It requires the establishment of conditions and requirements for applying the informational approach effectively. These include selecting an appropriate system of units, considering the equiprobable selection of variables, and recognizing the model as an information channel. By addressing these challenges, researchers can improve the accuracy and reliability of their experimental data analysis.

In conclusion, the development and adoption of a universally applicable criterion for assessing model-phenomenon mismatch, grounded in the informational approach and adhering to the International System of Units, is crucial for advancing scientific rigor. This criterion can enhance the reproducibility and reliability of scientific investigations across disciplines, instilling greater confidence in published findings. By promoting rigorous assessment practices and objective evaluations, we can ensure the robustness and credibility of scientific research in an era of escalating research costs and increasing concerns about the accuracy of reported results.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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