Applying Measurement Theory and Information-based Measure in Modeling Physical Phenomena and Technological Processes

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Abstract—In this paper, we compare the features of the application of the theory of measurements and the measure of the similarity of the model to the phenomenon under study on the basis of calculating the amount of information contained in the model. An experimental estimate compared with the standard model’s uncertainty calculation procedure shows that this measure is preferable to the traditional approach to calculating the threshold discrepancy. The article presents an algorithm that is used to calculate the minimum achievable uncertainty in the resolution of the model’s fuzziness, as well as experimental results demonstrating its effectiveness.

Index Terms—Computational Modeling; Information Theory; Theory of Measurements; Theory of Similarity.

I. INTRODUCTION

“There is nothing new to be discovered in physics now. All that remains is more and more precise measurement.” This statement (worldview statement) was by Lord Kelvin in 1900, which was shattered only five years later when Einstein published his paper on special relativity.

In the 21st century, it can be safely asserted that absolutely all modern achievements in the field of science are based on the successes of the theory of measurements, on the basis of which the practical recommendations useful in physics, engineering, biology, sociology, etc. are extracted. In addition, this is because the application of the principles of the theory of measurements in determining the fundamental constants allows us to verify the consistency and correctness of the basic physical theories. Complementing the above, quantitative predictions of the basic physical theories depend on the numerical values of the constants involved in these theories: each new sign can lead to the discovery of a previously unknown inconsistency or, conversely, can eliminate the existing inconsistency in our description of the physical world. At the same time, scientists came to a clear understanding of the limitations of our efforts to achieve very high measurement accuracy.

The proposed information approach [1], to assess the model’s noncompliance with the physical phenomenon under study, has introduced an additional measurement accuracy limit that is more stringent than the Heisenberg uncertainty principle. And it turned out that the “fuzziness” of the observed object, strangely enough, depends on the personal philosophical prejudice of scientists, which are based on their accumulated life experience, acquired knowledge and intuition. In other words, when modeling a physical phenomenon, one group of scientists can choose variables that will differ fundamentally from the set of variables that are taken into account by another group of scientists. The fact is that the same data can serve as the basis for radically opposite theories. This situation assumes an equally probable accounting of variables by a conscious observer when choosing a model. A possible, though controversial, example of such an assertion is the consideration of an electron in the form of a particle or wave, for the description of which various physical models and mathematical equations are used. Indeed, it is not at all obvious that we can describe physical phenomena with the help of one single picture or one single representation of our mind.

The purpose of this paper is to compare the application of measurement theory and the information-based method to specific physical and technical problems. This will allow scientists and engineers to clarify the limits of their applicability, while their practical value in various fields of science and technology is already evident.

II. PRELIMINARIES

To begin with, the first task of the scientist studying the phenomenon is usually to determine the conditions under which the phenomenon can be repeatedly observed in other laboratories and can be verified and confirmed. For an accurate knowledge of the physical variable, you need to measure it. And for its measurement, a certain device is always required (this presupposes the existence of a physical-mathematical model already formulated), which somehow affects this value, as a result of which it becomes known with some degree of accuracy. In turn, the amount of information obtained by measurement can be calculated by reducing the uncertainty resulting from the measurement. In other words, the uncertainty about a particular situation is the total amount of potential information in this situation [2].

The foregoing reduces to the following postulates of measurement theory [3]:

- There is a true value of the measured quantity;
- In every dimension there is one true value;
- The true value of the measured quantity is constant;
- True value cannot be found due to the existence of an inevitable discrepancy between the parameter of the model and the real property of the object, called the threshold discrepancy.

In addition, there are other inevitable limitations on the approximation of the true value of the measured quantity. For example, the accuracy of measuring devices is inevitably limited. For this reason, we can formulate the

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statement: the result of any measurement always contains an error. Thus, the accuracy of the measurement is always limited, and in particular, it is limited by the correspondence between the model and the phenomenon. We add that the achievable measurement accuracy is determined by a priori information about the measurement object.

The trait that unites measurement theory and the information-oriented approach is that they study in physical theory only what can be observed directly, excluding such a thing as unobservable quantities.

One can realize the fundamental difference that exists between measurement theory and the information-based approach. To do this, we note that the measured variables, the simultaneous knowledge of which is necessary in the theory of measurements, in order to strictly predict the measured value, are precisely those whose definition of quantity is precisely calculated by the information approach in the process of model formulation. Areas of their application are delineated by a threshold discrepancy. The error caused by the threshold discrepancy between the model and the object must be less than the permissible error in the measurement. If the predetermined measurement error exceeds this limit, then the main variable cannot be measured with the required accuracy. This result shows that the model is inadequate. To implement the experiment, the model must be redefined.

Unusual in the information-based approach is that the amount of information in the model is directly related, on the one hand, to the existing de-facto system of primary units (SPU), for example, SI-International system of units, and on the other hand, the number of variables chosen in the model. SI includes primary and secondary variables constructed on their basis, which are used to describe the observed phenomenon from a qualitative and quantitative point of view. SI includes seven main units: L is length, M is mass, T is time, I is current, θ is temperature, J is light intensity, F is amount of substance. Within the framework of the SPU, each analyst chooses a specific class of phenomena (COP) to study the observed process. COP is a collection of physical phenomena and processes described by a finite number of primary and secondary variables characterizing certain features of the phenomenon under investigation from quantitative and qualitative aspects [4]. So, for example, to describe the heat transfer processes in SI, usually, four primary units L, M, T, θ are used, then COPSI = LMTθ.

Summarizing this idea, the information-oriented approach raises the following basic postulate, which can be called the principle of limitation: the value of any physical variable can be found only with a minimum absolute uncertainty, depending on the chosen class of the phenomenon and the number of variables considered in the model.

For classical physics, quantum mechanics, and technical applications, this postulate is not trivial. Any theorist or experimenter, based on his life experience, knowledge and intuition, determines the design of the test stand or theoretical model, thereby limiting (decreasing) the number of variables reflecting the observed phenomenon, compared with the total number of variables contained in the SPU. Thus, this intangible disturbance of the system is primordial, although much smaller in comparison with the errors considered by the theory of measurements and including inaccuracy of the initial data, boundary conditions, differential and integral equations with their subsequent computerization, etc. Therefore, any model significantly distorts the phenomenon under investigation.

Is this information approach, although very beautiful and very clear, somewhat arbitrary? Why its concepts are relatively complex and so contradictory to the usual notions of the scientific community (it is meant the equally probable accounting of variables by a conscious observer when choosing a model)? It turns out that equally probable interpretation is the only possible one for today. This means that today it alone allows us to explain within the information-based approach, reasonable boundaries of expedient accuracy before carrying out any theoretical or experimental research. None of the attempts made in any other directions has led to success: absolutely all the methods now developed are aimed at reducing the a posteriori errors associated with the optimization of an already constructed / formulated model. So, we can say that the above fundamental postulate is justified by the fact that it is possible to build on its basis a consistent theory consistent with all the experimental facts. Unlike the traditional theory of measurements, the new information-based approach provides a theoretically substantiated and reasonable estimate of the minimum achievable measurement absolute uncertainty of any developed model.

III. TRACING THE IDEA

Absolutely all physicists and engineers try to describe the observed phenomena with the help of concepts inculcated with everyday experience, acquired knowledge and, not infrequently, intuition. At the same time, despite 90-year efforts, until now it has not been possible to combine classical determinism with the probabilistic laws of quantum mechanics. The only characteristic that unites all modern physics so far is that scientists use so-called SPU, such as the International System of Units (SI), to realize their ideas. The concept of SPU is taken from our everyday experience and is valid only for the momentary perception of the observed phenomena. It would be surprising if it would be possible someday to exclude from the physical theory concepts that are the very foundation of our daily life. True, the history of science reveals the amazing fruitfulness of human thought and one should not lose hope. However, until we have succeeded in spreading our ideas in this direction, we should try with greater or less difficulty to squeeze the observed phenomena into the framework of the concept of SPU. Although we will always be troubled by the feeling that we are trying to put a huge human foot in a diamond small shoe that does not suit her.

SPU, in its essence, is some new element in scientific knowledge, completely alien to classical concepts. It exists only because of the consensus of the researchers, although SPU is absent in nature. By default, the use of the dimensional variables contained in the SPU to describe the micro- and macro-cosmos implies a certain framework that limits our knowledge. It can be shown that SPU contains the finite number of variables [1]. Each variable carries a certain amount of information about the object under study. Since the number of elements in the SPV is finite, insofar as the total amount of information contained in the SPV is finite. Thus, we come to the conclusion that there exists an objectively existing limit of knowledge of the surrounding
researcher. This limit is due not to any really existing physical laws, but to the presence of collective human consciousness.

The mere fact of the measurement process presupposes the existence of a physical-mathematical model of the researched object that has already been formulated, including equations and boundary conditions. In this case, it is already possible to compile a list of the registered dimensional variables and calculate their number in advance. Most importantly, calculate the entropy change between the initial state corresponding to the maximum number of variables in the SPU, and the number of variables considered in the model. Since only a thought experiment is carried out at the stage of model formulation, and no material disturbance is introduced into the observable system and does not distort the investigated phenomenon, the effectiveness of such an action is equal to one (100%).

All of the above allows us to formulate the \( \mu \)-hypothesis [1]:

Let the system of primary units with the total number of dimensional physical variables \( \Psi, \xi \) of which have an independent dimension be chosen in the process of model formulation. Within the chosen class of phenomena (\( z \) is the total number of dimensional variables, \( \beta \) is the number of primary dimensional variables), there exists a dimensionless main variable \( u \) varying in a given range of values of \( S \). Then the absolute uncertainty \( A_{\text{mm}} \) of calculation \( u \) (for a given number of physical size variables \( z, \xi \), written in the model, of which \( \beta \) is the number of selected primary physical dimensional variables), can be determined from relation:

\[
A_{\text{mm}} = S \left( (z - \beta') / (\Psi - \xi) + (z'' - \beta'') / (z' - \beta') \right),
\tag{1}
\]

where \( A_{\text{mm}}/S = \varepsilon \) is the comparative uncertainty; \( \mu_{5\%} = \Psi - \xi = 38,265 \) corresponds to the maximum amount of information contained in SI. Equation (1), surprisingly, is very simple. Absolute and relative uncertainties are familiar to physicists. As for the comparative uncertainty, it is rarely mentioned. Nevertheless, the comparative uncertainty is of great importance for the application of information theory in physics and engineering [5].

The total uncertainty of the model, including inaccurate input data, physical assumptions, an approximate solution of integral-differential equations, etc., will be greater than \( A_{\text{mm}} \). Thus, \( A_{\text{mm}} \) is the primary and least component of the possible inconsistency between the real object and the simulation results.

Equation (1) is the conformity principle (uncertainty relation) for the model development process. Namely, any change in the level of a detailed description of the observed object (\( z', \beta' \); \( z', \beta' \)) causes a change in the minimum absolute uncertainty of the model \( A_{\text{mm}} \) and the achieved accuracy of each main variable characterizing the internal structure of the object. In other words: the conformity principle is a fundamental consideration, which establishes the accuracy limit (for a given class of phenomena) of simultaneously defining a pair of variables observed by a conscious researcher, in particular, the absolute uncertainty in the measurement of the investigated variable and the interval of its changes. Thus, it turns out that the fuzziness (inaccurate representation) of the object in the eyes of the researcher depends both on the chosen class of phenomena and on the number of variables taken into account by the conscious observer. The latter directly depends on the knowledge, the accumulated life experience and intuition of the researcher. Objectively, these factors allow the possibility, already stated above, of considering the choice of a variable as a random process with an equally probable account of a particular variable.

The \( \mu_{5\%}\)-hypothesis has a physical meaning. It shows that in nature there is a fundamental limit to the accuracy of measurement of any process that cannot be surpassed by any improvement in the tools, methods of measurement and computerization of the model. The magnitude of this limit is much higher and stronger than the Heisenberg uncertainty relation. In addition, this fundamental limit imposes serious limitations on microphysics.

In the examples below, we compare the possibilities of applying the theory of measurements and the information-based approach in various branches of science and technology.

**IV. EXCITING USES AND CONTROVERSIAL RESULTS**

**A. Ice Slurry**

First of all, we were interested in how the principles of measurement theory are widely used by researchers to confirm the developed model and to compare the experimental results with the theory. As the field of research was chosen “Ice slurry”, in which the author has 27 years’ experience. At the first stage the articles were filtered by the following keywords: ice slurry + cooling + model + slurry ice generators + error + research + article +2010...2017 (https://goo.gl/pWDejn), and publications of International Institute of Refrigeration including articles of International Journal of Refrigeration on English (https://goo.gl/MlT7QJ).

According to these criteria 1,820+719 publications were selected. At the second stage, the articles were sorted out by four criteria simultaneously: period of 2010-2017; the presence of a comparison of experimental results with theoretical calculations or computer simulations; the representation of numerical values of the absolute or relative uncertainties of calculation or measuring the value of the main researched variable; the presence of charts with declared measuring ranges or computer simulations. According to these criteria 81 articles were selected. The most of authors declared the satisfactory results like “model predictions are confirmed by experiments”, “model captures the trends found in experimental investigations”, “comparison showed a very good agreement between these data”, “it can supply plentiful parametric information in the interested region” and so on.

According to the results of the analysis, one thing is puzzling: no one compares the gap between the numerical predictions (NP) and the experimental results (ER) with the calculated absolute uncertainty (AU) of the main variable realized in field tests. If AU is greater than NP-ER, then the statement about the proximity of NP to ER is meaningless, and the model must be redefined. Probably, the measurement uncertainties were not inferior in magnitude to the measured effect. The coincidence of the measurement results with the theoretical calculations could be a fortuitous accident, and, probably, the developers knew in advance. Therefore, the NP-ER quantitative indicator without taking
into account AU can be misleading and, ultimately, counterproductive to evaluate scientific research. In the worst case, it is known that one in 50 scientists admit to misconduct (fabrication, falsification, and/or modifying data) at least once [6].

In general, analyzing the results of these studies cannot explain the neglect of validation and verification methods, as well as methods of measurement theory including uncertainty analysis [3], [7], [8]. Ultimately, these methods help scientists/engineers to better understand physical principles and technical nuances of the researched object. The most surprising thing, according to the author’s opinion, is that the described situation is in complete contradiction with what happens, for example, when researchers develop global climate models, scientists determine the values of fundamental physical constants, engineers predict the extraction of oil or calculate heat- and mass-transfer characteristics of water vapors. In these areas, special attention is paid not only to calculating the total achieved absolute uncertainty, but the clarification of all components of the measurement relative uncertainty of the main variable. Thus, from the position of measurement theory, the presented analysis of published papers related to ice slurry, revealed a situation that is currently critical and very undesirable in the future. From the position of the information approach, summarizing the above-stated results it should be noted that factually none of the studies defined or declared a possible changes interval of the main variable.

B. Freezing

Freezing a thin layer of paste material posted onto a moving cooled cylinder wall has been investigated [9]. A study of the developed model by computer simulation using the random balance method has been conducted. As the objective function, the final dimensionless temperature of the outer surface of the material \( \theta_{ss}\) was selected, where \( \theta_{ss}, \theta_{ss}, \theta_{ss} \) are the dimensionless temperature differences of the freezing point of a material, outer surface of a material layer and evaporation point of the refrigerant, respectively. \( \Delta \theta_{ss}, \Delta \theta_{ss}, \Delta \theta_{ss} \) are the dimensional uncertainties of measurement of these temperatures. Their declared values were: \( \theta_{ss} = 272 \, ^\circ \text{C}, \theta_{ss} = 259 \, ^\circ \text{C}, \theta_{ss} = 243 \, ^\circ \text{C}, \Delta \theta_{ss} = 0.1 \, ^\circ \text{C}, \Delta \theta_{ss} = 0.5 \, ^\circ \text{C}. \) The declared achieved discrepancy between the experimental and computational data in the range of admissible values of the similarity criteria and dimensionless conversion factors did not exceed 8%. There were recorded 18 (\( z^* \)) input dimensional variables and 5 (\( \beta^* \)) primary physical variables, such that we obtain \( z^* \)\( \beta^* \)=18-5=13 for the dimensionless criteria.

Into the frame of the measurement theory, taken into account was the fact that the direct measurement uncertainties are much smaller than the measured values, accounting for a few percent or less of them. The uncertainty can be considered formally as small increments accounting for a few percent or less of them. The uncertainties are much smaller than the measured value of an absolute total dimensionless uncertainty of the indirect measurement \( \Delta \theta_{ss} \) reached in the experiment:

\[
\Delta \theta_{ss} = (\theta_{ss} + \Delta \theta_{ss})/((\theta_{ss} - \theta_{ss}) + |\theta_{ss} - \theta_{ss}|/((\theta_{ss} + \Delta \theta_{ss} - \theta_{ss})/|\theta_{ss} - \theta_{ss}|)^2) \approx 0.066. \quad (3)
\]

In order to apply the information approach, we analyze the recorded variables dimensions, and verify that the model is classified by COP_{SI} \( \equiv LMT \Theta \). Further, we need to calculate the minimum comparative uncertainty inherent to this COP. For this purpose, we take into account the following:

1. The dimension of any secondary variable \( q \) can only be expressed as a unique combination of dimensions of the main primary variables to different powers [4]:

\[
q \sim L \cdot M^n \cdot T^m \cdot \Theta^o \cdot J^f \cdot F^l. \quad (4)
\]

2. \( l, m... f \) are exponents of the variables, the range of each has a maximum and minimum value; according to [11], integers are the following:

\[
-3 \leq l \leq +3, \quad -1 \leq m \leq +1, \quad -4 \leq i \leq +4, \quad -2 \leq j \leq +2, \quad -4 \leq l \leq +4, \quad -1 \leq j \leq +1, -1 \leq f \leq +1, \quad (5)
\]

3. The exponents of variables can only take integer values [11], so the number of choices of dimensions for each variable, according to (XX), is the following:

\[
e_i = 7; \quad e_m = 3; \quad e_i = 9; \quad e_l = 5; \quad e_p = 9; \quad e_j = 3; \quad e_f = 3 \quad (6)
\]

In order to formulate the conditions for achieving the minimum comparative uncertainty of a model \( (e_{\text{min}})_{LMT} \), it is required to equate its partial derivative with respect to \( z^* \beta^* \) to zero. Thus we can obtain:

\[
(z^* \beta^* = [e_i e_m e_i e_p e_j - 1]/2 - 4 = 846, \quad (10)
\]

\[
(z^* \beta^*)^2 / \mu_{ss} = 846^2 / 38, 265 \approx 19. \quad (11)
\]

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where "-1" corresponds to the case when all the primary variable exponents are zero in formula (6); dividing by 2 indicates that there are direct and inverse variables, e.g., $L^1$ is length, $L^{-1}$ is run length. The object can be judged knowing only one of its symmetrical parts, while others structurally duplicating this part may be regarded as information empty. Therefore, the number of options of dimensions may be reduced by 2 times; 4 corresponds to the four primary variables $L, M, T, \Theta$.

Substituting (10) and (11) into (1) we find

$$\left(\varepsilon_{\text{sys}}\right)_{\text{LMT}} = \Delta_{\text{sys}} / S = 0.0446.$$  \hfill (12)

From (1), using calculated values $\mu_N, z^* - \beta = z^- - \beta^- = 13, z^- - \beta^- = 0$ (10), and $(z^- - \beta^-)$ (11), with the help of a calculator one obtains a dimensionless absolute uncertainty value $(\Delta \beta)_\text{num}$ of the chosen model:

$$(\Delta \beta)_\text{max} \leq \beta_{\text{max}} \cdot (z^* - \beta^*) / \mu_N + (z^- - \beta^-) / (z^- - \beta^-) = 0.93 \cdot \left[ \frac{846}{38.265 + 13.846} \right] = 0.038,$$  \hfill (13)

where $\beta_{\text{max}} = 0.93$ is the dimensionless given range of changes of the dimensionless final temperature allowable by the chosen model [9].

From (3) and (13) we get $(\Delta \beta)_\text{exp} > (\Delta \beta)_\text{num}$, i.e., an actual uncertainty in the experiment is 1.7 times (0.066/0.038) larger than the possible minimum. It means, at the recorded number of dimensionless criteria the existing accuracy of the dimensional variable’s measurement is insufficient. In addition, the number of the chosen dimensionless variables $z^* - \beta^* = 13$ is less than the recommended $\approx 19$ (11) that corresponds to the lowest comparative uncertainty at COP_{SI} $\equiv \text{LMTI}$. That is why, for further experimental work it is required to use devices of a higher class of accuracy sufficient to confirm/clarify a new model designed with many dimensionless variables.

In this example we introduce a full explanation of the required steps for analyzing experimental data and its comparison with results obtained from a field test or computer simulation model in the frame of the measurement theory. On other hand, there were given the required steps of reviewing results by the information-based approach principles.

C. Proton Magnetic Moment in Nuclear Magnetons $\mu_p/\mu_N$

The international team of scientists used high-precision methods to identify the most accurate measurement of the proton magnetic moment in nuclear magnetons [12] and declared that their result improved the previous best measurement by a factor of 11. This was achieved with the use of an optimized double-Penning trap technique.

Let’s check how a methodology of the measurement theory was applied and principals of the information-based approach could be realized for analyzing last measurements of the proton magnetic moment in nuclear magnetons made during 2005-2017.

In order to apply the stated approach, as the estimated interval of $\mu_p/\mu_N$ changes, we choose the difference of its value that was reached by the experimental results of two projects: $(\mu_p/\mu_N)_{\text{max}} = 2.79284735623$ [13] and $(\mu_p/\mu_N)_{\text{min}} = 2.79284734462$ [12]. In this case, the possible observed range $S_\mu$ of $\mu_p/\mu_N$ variation is equal to:

$$S_\mu = (\mu_p / \mu_N)_{\text{max}} - (\mu_p / \mu_N)_{\text{min}} = 1.161 \cdot 10^{-8}.$$  \hfill (14)

The choice of the author of $(\mu_p/\mu_N)_{\text{max}} - (\mu_p/\mu_N)_{\text{min}}$ seems subjective and arbitrary. However, as already noted in the remarks to formula (1), the magnitude of the product of absolute uncertainty in the measurement of the investigated variable and the interval of its changes is fixed for a specific CoP. Therefore, the choice of the interval of observation of the measured variable will not affect the final calculation of the recommended relative uncertainty. That is why, it can be argued that an objective, mathematically sound statement is given.

We studied several scientific articles from the perspective of the achieved relative and comparative uncertainty values. The data are summarized in Table I [12]-[16]. By analyzing the theoretical methods and the experimental schemes, one can declare that the results were obtained using COP_{SI} $\equiv \text{LMTI}$.

<table>
<thead>
<tr>
<th>Year</th>
<th>Proton magnetic moment in nuclear magnetons $\mu_p/\mu_N$</th>
<th>Achieved relative uncertainty $\varepsilon_{\text{sys}}$</th>
<th>Absolute uncertainty $\Delta_{\text{sys}}$</th>
<th>$\mu_p/\mu_N$ changes range $S_\mu$</th>
<th>Comparative uncertainty $\Delta_{\mu} / S_\mu$</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>2.79284735128</td>
<td>1.0 \times 10^{-8}</td>
<td>2.792847 \times 10^{-8}</td>
<td>1.161 \times 10^{-8}</td>
<td>2.4056</td>
<td>[14]</td>
</tr>
<tr>
<td>2012</td>
<td>2.79284735623</td>
<td>8.2 \times 10^{-9}</td>
<td>2.290135 \times 10^{-8}</td>
<td>1.16E-08</td>
<td>1.9726</td>
<td>[13]</td>
</tr>
<tr>
<td>2014</td>
<td>2.79284735076</td>
<td>3.3 \times 10^{-9}</td>
<td>9.216396 \times 10^{-9}</td>
<td>1.61E-08</td>
<td>0.5724</td>
<td>[15]</td>
</tr>
<tr>
<td>2016</td>
<td>2.79284735088</td>
<td>3.0 \times 10^{-9}</td>
<td>8.378542 \times 10^{-9}</td>
<td>1.61E-08</td>
<td>0.5204</td>
<td>[16]</td>
</tr>
<tr>
<td>2017</td>
<td>2.79284734462</td>
<td>3.4 \times 10^{-10}</td>
<td>9.495681 \times 10^{-10}</td>
<td>1.61E-08</td>
<td>0.0590</td>
<td>[12]</td>
</tr>
</tbody>
</table>

In the frame of the measurement theory principals, authors of each article [12]-[16] explained with details and calculate different sources of relative uncertainties. A careful discussion of the input data and the justification and construction of tables of values sufficient for the direct use of the relative uncertainty are conducted using modern advanced statistical methods and powerful computers. It must be mentioned that this problem is very serious. At the same time, this, in turn, allows one to check the self-consistency of the input data and the output set of values. However, at every stage of data processing researchers must rely on common sense, i.e. an expert conclusion, which is based on intuition, accumulated knowledge and the cumulative life experiences of scientists (one’s personal philosophical leanings [17]). The fundamental difference of the CODATA technique to determine the recommended
value of the relative uncertainty of this or that fundamental physical constant in comparison with the information-based method is the following. Within the framework of the presented approach, a theoretical and informational grounding and justification are carried out for calculating the relative uncertainty. A detailed description of the data and the processing procedures do not require considerable time.

In order to apply the information approach, we need to calculate the lowest comparative uncertainty $\varepsilon_{\text{LMTI}}$ for electromagnetic processes ($\text{COP}_{\text{SI}} \equiv LMTI$) at the following conditions:

\[
(z^\prime - \beta^\prime) = \left(e^l_e \cdot e^{-1} \cdot e^r_e \right) / 2 - 4 = 468, \quad (15)
\]

\[
(z^\prime - \beta^\prime) = (z^\prime - \beta^\prime)^2 / \mu_{\text{SI}} = 468^2 / 38, 265 = 5.723873. \quad (16)
\]

where "-1" corresponds to the case when all the primary variable exponents are zero in formula (1); dividing by 2 indicates that there are direct and inverse variables, e.g., $L^1$ is the length, $L^{-1}$ is the run length, and 4 corresponds to the four primary variables $L, M, T, I$.

Then, one can calculate the minimum achievable comparative uncertainty $\varepsilon_{\text{LMTI}}$

\[
\varepsilon_{\text{LMTI}} = \left( A_{\text{min}} / S \right)_{\text{LMTI}} = 0.0244. \quad (17)
\]

At the next step we can argue about the order of the desired value of the relative uncertainty of $\text{COP}_{\text{SI}} \equiv LMTI$, which is usually used for obtaining measurements of $\mu_{\text{SI}}/\mu_{\text{SI}}$. For this purpose, we take into account the following data: $\left( A_{\text{min}} \right)_{\text{LMTI}} = 0.0244$ (17) and $S = 1.161 \cdot 10^{-8}$ (14). Then, the lowest possible absolute uncertainty for $\text{COP}_{\text{SI}} \equiv \text{LMTI}$ equals:

\[
\left( A_{\text{min}} \right)_{\text{LMTI}} = \left( A_{\text{min}} \right)_{\text{LMTI}} \cdot S = 2.8328 \cdot 10^{-10}. \quad (18)
\]

In this case, the lowest achievable relative uncertainty $(r_{\text{min}})_{\text{LMTI}}$ for $\text{COP}_{\text{SI}} \equiv \text{LMTI}$ is as follows:

\[
(r_{\text{min}})_{\text{LMTI}} = \left( A_{\text{min}} \right)_{\text{LMTI}} / \left( \left( ( \mu_{r} / \mu_{r} )_{\text{min}} + ( \mu_{s} / \mu_{s} )_{\text{min}} \right) / 2 \right) = 1.014 \cdot 10^{-10}. \quad (19)
\]

Three value (19) is in excellent agreement with the recommendation $(3.4 \cdot 10^{-10})$ mentioned in [12], and it can be used to significantly revise the International System of Units. It should be mentioned that the author of these lines is not an expert in the field of measuring fundamental physical constants. This, at the same time, allows us to state, taking into account the presented results, that the proposed information-based method is very accessible to highly qualified specialists in experimental and theoretical physics, as well as in applied engineering sciences.

V. DISCUSSION AND CONCLUSIONS

In fact, we understand that any physical theory can serve as a basis for the application of measurement theory. On the other hand, the information theory is very important to guide the methods of design and ideas in measurement process. As for the information-based approach, its practical application can cause an uneven response in the scientific community. At the same time, we wanted to show why the general principles of the information-oriented approach given above do not contradict the firmly established conclusions of modern physics, but, on the contrary, allow us to consider them as an opportunity for purposefully increasing the accuracy of calculations and experiments, and, on the whole, maximize the predictive power of model.

It can no longer be assumed that the accuracy of the model of any physical phenomenon can be brought to the boundaries determined by the Heisenberg uncertainty relation. There is only the initially known value of the threshold discrepancy of the model, which is determined by the $\mu$-hypothesis and depending on the volitional choice by the researcher of the class of the phenomenon and the number of the variables considered. This allows us to consider (1) as a kind of watershed between, possible in the future, the limit for improving measuring devices, mathematical calculation methods, increasing the power of computers, including quantum ones, and fine, accurate in its perfection, the universe around us.

From the point of view of the constructive development of modern theories, the $\mu$-hypothesis can in some sense play a guiding role, limiting the number of variables considered in the models, but without specifying, of course, this or that particular model structure. More precisely, since the $\mu$-hypothesis considers only the general properties of systems without going into the details of individual processes, it does not risk falling into error, which often threatens more "courageous" theories, claiming a detailed description of the process. In fact, at this point, the $\mu$-hypothesis is a Black swan [18] among existing theories that have to do with checking the discrepancy between the model and the observed object.

Assuming that all the results of the $\mu$-hypothesis follow from information theory, it follows that the formulas obtained are of the strict requirement type. At the same time, they describe only the actual process of modeling by a conscious observer (epistemic entity). This concept is not an element inherent in nature, or, in other words, it is not a fundamental principle of nature. Indeed, it is not at all obvious that we can describe physical phenomena with the help of one single picture or one single representation of our mind. Our pictures and representations we form, drawing inspiration from our everyday experience. From it we extract certain concepts, and then, starting from them, we invent, by simplification and abstraction, some simple pictures, clear concepts, which then we try to use to explain the phenomena.

The fundamental conclusion of the $\mu$-hypothesis confirms that the observer creates reality. As observers, we are personally associated with the creation of our own reality. What changes the way we perceive reality? Information is as physical substance [19], however, information does behave differently than other physical properties, like space-time. When new information arises, it changes the way we look at things, and as a result our reality changes, we gain new experience and we are open to a wider view of reality. The $\mu$-hypothesis actually reveals the connection between the consciousness of the observer and the physical world under investigation. Thus, the information approach forces...
physicists to recognize that the universe is a "mental" construction [20].

Finally, it should be noted that the basic principles of the theory of measurements remain in force, but they can be used separately in the further stage of computerization of the model.

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REFERENCES


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