Annals of the Academy of Romanian Scientists
Series on Science and Technology of Information
ISSN 2066-8562 Volume **3**, Number **1**/**2010**

STUDY OF THE PRESENT PROBLEMS OF THE SCIENTIFIC INFORMATION PROCESSING AND TRANSMISSION

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Rezumat. *Pentru a evalua calitatea informației, această lucrare își propune să indice criterii pentru studiul compatibilității a)informației cu parametrii fizici reali; b) diferitelor corelații (și a modelelor lor teoretice) cu datele experimentale. Au fost de asemenea studiate posibilitățile evaluării riscului de eroare la respingerea compatibilității cu datele experimentale, ca și trăsăturile fundamentale ale transmisiei informației (de exemplu clopotele de rezonanță etc.). Este insistent subliniată necesitatea folosirii procedurilor matematice riguroase, atât ale Analizei numerice cât și ale Statisticii matematice.*

Abstract. *In order to evaluate the quality of the information, this work aims to point out some criteria for the study of the compatibility of: a) information with the true physical parameters, b) different correlation (and of their corresponding theoretical models) with the experimental data. The possibilities to evaluate the error risk to the rejection of the compatibility with the experimental data, as well as the basic features of the information transmission (i.e. resonance bells, etc) were also studied. The necessity to use both the rigorous mathematical procedures of the Numerical Analysis and of the Mathematical Statistics is strongly underlined.*

Keywords: Mathematical Analysis, Data Processing, Numerical Physics, Mathematical Statistics, Numerical Methods

1. Introduction

The field of Sciences presents an extremely fast development. According to the published data of *the Institute for Scientific Information (ISI, Philadelphia – US),* only the number of Physics papers published and indexed in the interval 1981-1996 was of about 77350 ISI indexed works/year, being frequently necessary the use of indices formed by 4 figures and a letter (e.g. the symbol 4281W corresponds to the field of *optical fiber sensors; fiber gyros*).

For this reason: a) there intervene sometimes certain errors (as those in the cases of: (i) “anomalons” [1], or of the: (ii) assumed nuclear fusion at low temperatures (starting from some palladium compounds), b) some important works (from the

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fields of the Nuclear Physics or of Superconductors) have sometimes 30…50 authors, in order to avoid the possible errors! High quality solutions of these difficulties are given by the Numerical Analysis, which ensures the scientific study of all theoretical models. The main stages of the modern processing of the experimental results are presented in the frame of Diagram 1, their achievement being accomplished by means of the methods of Statistical Mathematics and of the Numerical Analysis, together with its correspondent in Physics – the Numerical Physics [2].

2. Present possibilities and limits of the scientific information processing

The outstanding development of the computation techniques allowed not only the description of the physical systems in different conditions, the analysis of its compatibility relative to experimental data, and also the simulation of some physical and technical processes in special conditions (difficult to be reached in laboratories). Because this method is considerably cheaper and it allows the simulation of certain phenomena produced in inaccessible conditions, it presents a considerable interest both from the technical point of view and from the didactic one [3]. Taking into account the considerable future increase of the computation abilities due to the use of parallel computers, there appeared some special simulation techniques, as the Local Interaction Simulation Approach (LISA) [4], mainly intended to such techniques. The main difficulty met by the simulation techniques refers to the appearance of some numerical phenomena: instabilities, divergence [5], dispersion, distortion [6], etc, which lead sometimes to considerable errors of the obtained numerical simulations.

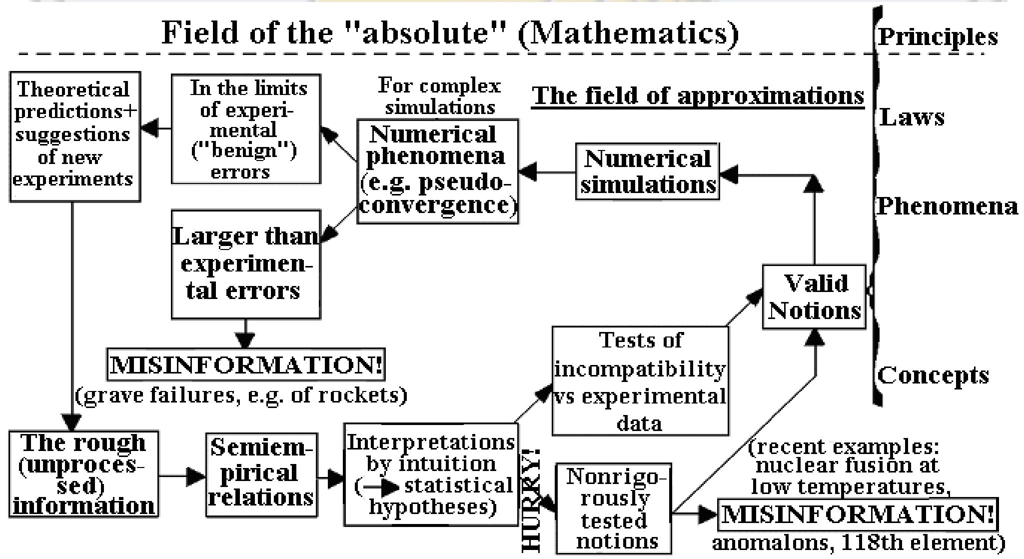

Diagram 1. Basic Stages of the present Scientific Information Processing.

The most misleading numerical phenomenon is that of pseudo-convergence [5], because it leads to some apparently correct simulations (their shape being qualitatively correct, usually), but erroneous from the quantitative point of view.

For this reason, the present work considers that the numerical simulations have to be studied in strong connection with the basic results of the experimental data processing.

3. Evaluation of the Error Risk at the Rejection of the Compatibility of a Theoretical Model with the existing Experimental Data

Given being the huge volume of the experimental results, at beginning it is wanted their synthesis by means of some *semi-empirical relations*, in order to associate them finally to (or to obtain) some corresponding *laws*. Because any physical relations or laws represent only some approximations of the empirical truth, all these relations will be found as incompatible for higher accuracy of considered measurements, the basic decision in the statistical studies of the experimental results being so *the rejection of the compatibility of some relations (or theoretical models) relative to the experimental results.* As for any statistical hypothesis, it is associated also to the hypothesis of compatibility rejection a certain error risk, which has to be known always, but which is … rarely studied!

As it is well-known [7], to any set of experimental results referring to N different parameters corresponding to the same state of the studied system (let be $x_{1mp} \ldots x_{Nmp}$ – the most probable values of these parameters) it is associated a confidence domain, which – in the frequent case of a normal distribution – has the shape of a N-dimensional ellipsoid:

$$\varepsilon^T \Gamma^{-1} \varepsilon = f_N(N_i)\,, \tag{1}$$

where ε is the errors "column" vector ($\varepsilon_i = x_i - x_{i,mp}$), ε^T is its transposed (“row”) vector, $\mathbf{\Gamma}$ is the matrix of co-variances (each its element being equal to the statistical average of the product of corresponding errors: $\mathbf{\Gamma}_{ij} = <\varepsilon_i\,\varepsilon_j>$), and $f_N(L_i)$ is a certain function on the confidence level L_i corresponding to the considered confidence domain. In the frequent case of the study of a pair of physical parameters X and Y, the confidence domain corresponding to the normal (2-dimensional) distribution will correspond to the internal part of the ellipse:

$$\left(\frac{x_k - x_{k,cmp}}{s(x_k)}\right)^2 + \left(\frac{y_k - y_{k,cmp}}{s(y_k)}\right)^2 - 2r_k\left(\frac{x_k - x_{k,cmp}}{s(x_k)}\right)\left(\frac{y_k - y_{k,cmp}}{s(y_k)}\right) = f_2(L_{ik})\,, \tag{2}$$

where $s(x_k)$, $s(y_k)$ are the square mean deviations corresponding to the values of the parameters X and Y for the state k, r_k is the correlation coefficient of the values of these parameters for the indicated state:

$$r_k = \frac{\Gamma(x_k, y_k)}{s(x_k)\cdot s(y_k)} = \frac{<(x_k - x_{k,cmp})(y_k - y_{k,cmp})>}{s(x_k)\cdot s(y_k)}, \text{ and: } f_2(N_{ik}) = -2\left(1 - r_k^2\right)\cdot \ln\left(1 - L_{ik}\right). \quad (3)$$

Usually, the correlation coefficient r_k is considered as the main criterion for the appreciation of the compatibility of some relations $y = f(x)$ relative to certain sets of experimental data. In fact, this coefficient "evaluates" only the nearness degree of the confidence domains centers relative to the studied regression line (curve); e. g. despite that $|r_a| > |r_b|$, the ensemble of experimental values from Fig. 1.a is not compatible with relation $y = f(x)$, while the set from Fig. 1.b is compatible with this relation, because the corresponding confidence domains are crossed by the regression line (function) $y = f(x)$. Obviously, the solution of such problems, of high importance for the experimental data processing can be achieved only by means of computers. Particularly, the too small values (e.g., less than 0.01) of $q_k = 1 – N_{ik}$ [obtained from relations (2) and (3b) for $x_k = x_{tk}$, $y_k = y_{tk}$, where x_{tk}, y_{tk} are the coordinates of the tangency point of the confidence ellipse to the regression line (function) $y = f(x)$ (see the broken ellipse from Fig. 1.b)] can justify the hypothesis of incompatibility of the studied $y = f(x)$ relation relative to the considered ensembles of experimental data [7]. As the error risk $q_k = 1 - L_{ik}$ at the rejection of the compatibility of experimental results for the state k relative to the studied theoretical relation $y = f(x)$ is less, or it is larger than a certain threshold (chosen usually between 0.001 and 0.2), the studied compatibility is rejected, or it is accepted, respectively.

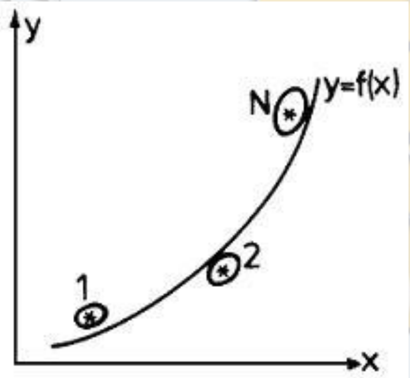

Fig. 1.a. Incompatible theoretical relation relative to the considered confidence domains.

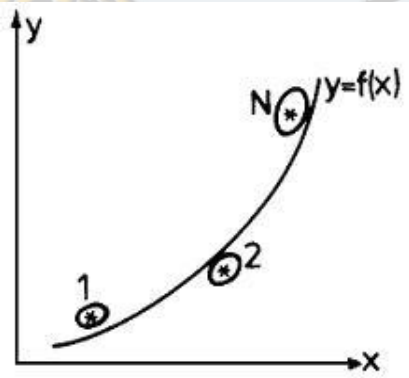

Fig. 1.b. Theoretical relation compatible with the considered confidence domains.

The accomplished studies (see e.g. [2a], p. 44) pointed out the possibility to appreciate the global (for all existing experimental data and confidence domains) compatibility of a theoretical relation versus these experimental data, by means of the global compatibility criterion λ ($\lambda > 1$ means compatibility), defined as:

$$\lambda = \frac{V_N(r_N)}{\left(1 - |r_N|\right)^2}, \quad (4)$$

where $V_N(r_N)$ is the variance of the correlation coefficient corresponding to all N considered confidence domains centres ($\lambda \ll 1$ corresponds to incompatibility).

4. Description Possibilities of the Apparent and True Information Amounts obtained by Measurements and Transmitted by Publications, respectively

As it is well-known, the main target of the usual determinations is represented by the physical parameters, whose individual values are statistically distributed, due to the presence of fluctuations.
The most frequently met distribution of the individual values (of fluctuation) of a parameter X is the one-dimensional (Gauss) normal distribution, described by the probability density:

$$p(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(x-\tilde{x})^2}{2\sigma^2}\right] \tag{5}$$

4.1. Information amounts corresponding to Shannon's definition

Starting from the Shannon [8] – Hincin [9] expression of the *uncertainty degree* associated to a discrete statistical set of physical events:

$$H\left(P_i \mid i = \overline{1,n}\right) = -a\sum_{i=1}^{n} P_i \log_b P_i \ , \tag{6}$$

where: $a > 0$ and $b > 1$, one finds the uncertainty degree associated to a continuous statistical ensemble, described by the probability density *p(x)* using the relation:

$$H(p(x)) = -a \int_{-\infty}^{\infty} p(x) \log_b (p(x)\Delta x) \cdot dx \ , \tag{7}$$

where Δx is the suitably chosen "quantum" of the variable *x*.

From relations (5) and (7), one obtains (see also [10]) the expression of the uncertainty degree for the one-dimensional normal (Gauss) distribution:

$$H\left(p_{Gauss}(x)\right) = \frac{a}{\ln b}\left(\frac{1}{2} + \ln\left(\frac{\sigma\sqrt{2\pi}}{\Delta x}\right)\right) . \tag{8}$$

Starting from certain measurements, it is found the confidence interval associated to the true value:

$$D_n \equiv \left[\tilde{x}_n - z_L \cdot \sigma(\tilde{x}_n), \tilde{x}_n + z_L \cdot \sigma(\tilde{x}_n)\right], \tag{9}$$

but the accurate localization of the true value ("mathematical hope") inside the confidence interval is not possible. That is why the uncertainty degree for this interval will be calculated assuming a uniform repartition inside this interval:

$$p(a_X) = 0 \ pentru \ a_X \notin D_n, \quad p(a_X) = C(const.) \ pentru \ \ a_X \in D_n . \tag{10}$$

Using the normalization condition:

$$1=\int_{-\infty}^{\infty} p(a_X)\cdot da_X = \int_{\tilde{x}_n - z_L\cdot\sigma(\tilde{x}_n)}^{\tilde{x}_n + z_L\cdot\sigma(\tilde{x}_n)} C\cdot da_X = 2C\cdot z_L\cdot\sigma(\tilde{x}_n),$$

one obtains the expression of the uncertainty degree corresponding to the uniform statistical distribution associated to the confidence interval of the true value:

$$H(p(a_X)) = -a\int_{-\infty}^{\infty} p(a_X)\log_b(p(a_X)\Delta x)\cdot da_X = a\cdot\log_b\left[\frac{2z_L\sigma(\tilde{x}_n)}{\Delta x}\right]. \qquad (11)$$

One finds that both the uncertainty degree associated to the normal one-dimensional distribution, at that associated to the uniform distribution inside the confidence interval of the true value, involve the logarithm of the square mean value corresponding to the individual, and to the true value, respectively.

4.2. The apparent Information amount

The apparent information amount obtained by means of the *n-th* determination of a certain set of measurements is defined as difference of the residual uncertainty degrees after the $(n-1)$-*th* and after the *n-th* determination, resp.

Taking into account the expressions (7) and (10) of the uncertainty degree for the individual, and the true values of the studied parameters, it results that the apparent information obtained by means of the *n-th* determination can be expressed starting from the mean square deviations for the sets of results obtained after the $(n-1)$-th and after the *n-th* determination, respectively, as:

$$I_{app.n} = H_{n-1} - H_n = a\cdot\log_b\frac{\sigma_{n-1}}{\sigma_n}. \qquad (12)$$

4.3. Modeling of the true Information amount

In order to understand the difference between the apparent and true information amounts, we will consider the example of a series of determinations of a (physical, particularly) parameter, the first n (≥2) individual values being (by chance, excessively near, while the $(n+1)$-*th* is compatible with the previous ones, but rather far from them. Due to the increase of the square mean deviation of the individual and average values after the $(n+1)$-*th* determination, the apparent information amount will be [see also relation (12)] negative, while in fact this $(n+1)$ - *th* determination brings an important amount of true information.

A possible definition of the true information amount starts from the finding that the description of complex systems (of the physical parameters, particularly) is strongly connected to certain probability distributions. As it concerns the experimental findings (or communications) about the values of the studied parameter of the considered complex object, they correspond to a certain 1D distribution, of course somehow different than the true one. As it results from the examination of Figure 3, there is indeed an overlapping zone of these distributions, whose magnitude increases for more accurate descriptions of the studied parameter (object). In conditions when both these one-dimensional distributions are normalized to 1, it is possible to define the true (physical) information amount by means of the expression (see also [11]):

$$\Im = 2 \cdot Overlapping\ Area\ - 1\ . \tag{13}$$

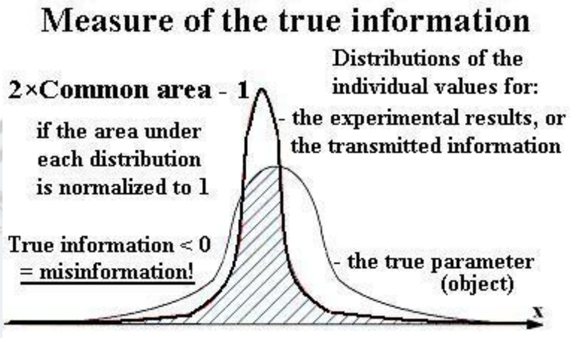

Fig. 2. Definition of the true information amount.

Because the obtainment of an additional true information amount assumes the reduction of the mean square deviation of the average value s(<*x(C)*>), one finds that the achievement of this goal is considerably more difficult when the existing knowledge correspond already to a reduced square mean error s(<*x(C)*>). Particularly, this is the case of the "consolidated" disciplines (mathematics, technical sciences, theoretical physics, etc). This could be a cause of a more reduced of the *rationalized individual impact factor*, defined as a ratio of the total number of citations/number of specialists from the studied (sub)domain.

Unlike the above situation, the works elaborated in the scientific fields with a reduced consolidation degree could present rather high values of the true information amounts and of the rationalized impact factor, but could present also rather frequently negative values (hence *misinformation*) of the true information amounts, especially in the frame of domains of high complexity [11] (examples: the works referring to the: a) *N*(ancy) rays [12] (53 favorable papers published in the first part of 1904 by the Sciences Academy of France and the Leconte price awarded in December 1904 to their "discoverer" (March 1903) – the correspondent fellow of the French Academy – prof. René Blondiot), b) the "giant" elementary particles (anomalons, see [1] and table 1), c) "nuclear fusion" in very simple conditions: (i) at cold, starting from the electrolysis of some palladium salts, or: (ii) "in bubbles" (dr. Rusi Taleyarkhan, Univ. Purdue, publications during the 2002-2006 [12], pp. 59-60), d) trans-uranium element 118 (dr. Ninov, Lawrence Berkeley National Laboratory, [12], p. 67), etc.). We have to underline here also that the "boarder" between the negligent experimental data processing and the scientific frauds is rather "narrow" (e.g., dr. Ninov did not recognized never to be used some frauds). Taking into account that (unlike the works on *N* rays) the investigations referring to the existence of anomalons were accomplished in several different countries and they were beyond any fraud suspicion, it results that this situation was due to the particular difficulty of the corresponding data processing. For this reason, we believe as interesting to present (in the frame of Table 1) the “oscillations” between the favorable and negative opinions of specialty researchers up to the final rejection of the hypothesis of these particles (anomalons) existence.

First author	*The review*	*Volume*	*Page*	*Year*	*The result*
1. E. M. Friedlander	Phys. Rev. Lett.	**45**	1084	1980	*Favorable*
2. P. L. Jain	Phys. Rev. Lett.	**48**	302	1982	*Favorable*
3. H. B. Barber	Phys. Rev. Lett.	**48**	856	1982	*Favorable*
4. T. M. Liss	Phys. Rev. Lett.	**49**	775	1982	*Yes; indirectly*
5. M. H. Mac Gregor	Phys. Rev. Lett.	**49**	1815	1982	*Review*
6. P. L. Jain	Phys. Rev. C	**25**	3216	1982	*Negative*
7. E. M. Friedlander	Phys. Rev. C	**27**	1489	1983	*Favorable*
8. H. A. Gustafsson	Phys. Rev. Lett.	**51**	363	1983	*Yes; indirectly*
9. M. L. Tincknell	Phys. Rev. Lett.	**51**	1948	1983	*Favorable*
10. R. J. Clark	Phys. Rev. D	**27**	2773	1983	*Negative*
11. J. D. Stevenson	Phys. Rev. Lett.	**52**	515	1984	*Negative*
12. T. J. M. Symons	Phys. Rev. Lett.	**52**	982	1984	*Negative*
13. A. Z. M. Ismall	Phys. Rev. Lett.	**52**	1280	1984	*Negative*
14. W. Heinrich	Phys. Rev. Lett.	**52**	1401	1984	*Negative*
15. M. El-Nadi	Phys. Rev. Lett.	**52**	1971	1984	*Favorable*
16. P. L. Jain	Phys. Rev. Lett.	**52**	2213	1984	*Favorable*
17. A. A. Kartamyshev	JETP Letters	**40**	1105	1984	*Favorable*
18. H. Drechsel	Phys. Rev. Lett.	**54**	30	1985	*Negative*
19. D. Ghosh	Phys. Rev. Lett.	**54**	396	1985	*Favorable*
20. R. Bhanja	Phys. Rev. Lett.	**54**	771	1985	*Negative*
21. M. M. Aggarwall	Phys. Rev. C	**32**	666	1985	*Favorable*
22. G. Dersch	Phys. Rev. Lett.	**55**	1176	1985	*Favorable*
23. H. Drechsel	Phys. Rev. Lett.	**55**	1258	1985	*Negative*
24. G. Baroni	Nucl. Phys.	**A437**	729	1985	*Negative*
25. B. P. Bannik	Zeit. für Phys.	**A321**	249	1985	*Negative*
26. M. Aguilar-Benitz	Phys. Lett.	**160B**	217	1985	*Negative*
27. P. L. Jain	Phys. Rev. C	**34**	726	1986	*Negative*
28. M. Okashi	Phys. Rev. C	**34**	764	1986	*Negative*
29. B. Judek	Phys. Rev. C	**34**	890	1986	*Favorable*

Table 1. The main experimental works referring to “anomalons” (according [1])

4.4. Description of the received information

The accomplished study pointed out that presently: a) the best technical manner for the information transmission uses the optical communications [13], [14], as well as: b) the most important features of the basic components: laser sources [15], optical fibers [16], optical amplifiers [17], use of solitons for signals multiplexing [18], etc of the modern optical communications systems.

As it concerns the information transmission by publications, we will consider that it is a resonant process, somewhat similar to the forced oscillations. It is well-known that the dependence on the frequency ω of the external periodic excitation of the energy transmitted to an oscillator with the characteristic (eigen) frequency ϖ is described by the expression (see also Fig. 3,b):

$$W(\omega) = \frac{W(\varpi)}{1 + \frac{1}{B^2}\left(\omega - \frac{\varpi^2}{\omega}\right)^2} . \tag{14}$$

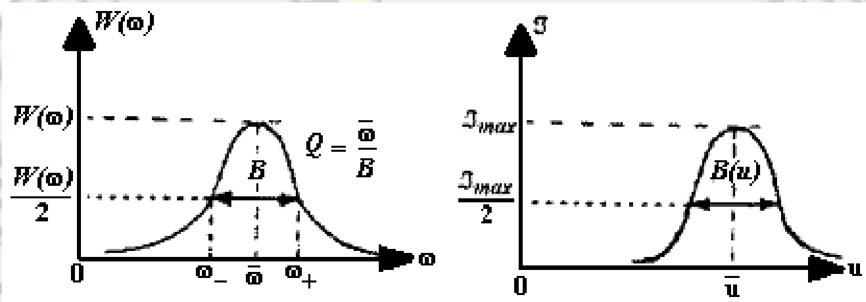

Fig. 3,a. Resonance bell of a forced oscillator. **Fig. 3,b.** Similar bell at information transmission.

For frequencies to whom the transmitted energy reduces to half of the maximum value *W*(ϖ), we have:

$$\frac{1}{B}\left(\omega_{\pm} - \frac{\omega^2}{\omega_{\pm}}\right) = \pm 1, \text{ hence: } \omega_{+} - \omega_{-} = B \; ; \tag{15}$$

it results that the physical meaning of the parameter *B* is that of "half-width" of the resonance bell (the width of the pass band). We mention also that the width of the pass band and the merit factor *Q* for the resonance selectivity are related by the relation:

$$Q = \frac{\varpi}{B} . \tag{16}$$

Similarly, the plot of the transmitted information amount by means of publications in terms of the ensemble of the uniqueness parameters corresponding to the readers knowledge will present the shape of a "bell" with a certain width *B(u)* of the pass band (see fig. 3,b).[1]

[1]It results that – in order to ensure a high impact factor – it is necessary to achieve a sufficiently high accessibility of the published work, by means of a friendly (hence not too rigorous) presentation of the approached matters.

4.5. Scientometric evaluations

Because the experimental making evident and description of some narrow distributions *p(x)* requires some special knowledge, it results that the "bell" $\Im(u)$) corresponding to such information description will be also narrow.

For this reason, the impact factors corresponding to some works from unconsolidated scientific domains (broad *p(x)* distributions and $\Im(u)$ “bells”) will be usually considerably larger than the corresponding values for the usual works belonging to some consolidated scientific fields.

One finds so that the impact factors are inversely proportional to the consolidation (hence of involved mathematics content) degree of the considered scientific (sub)field.

Because the science amount involved by a certain domain increases with its quantitative (mathematics) content [the trend of all scientific fields being to involve more quantitative (mathematics) elements, as it can be found also from the cover page of Mathematical Reviews, including the majority of domains of Physics, Chemistry, Biology, Economical and Social sciences, etc], it results that - paradoxically - the citations number and the impact factor are (usually) larger for the scientific works with a reduced degree of quantitative (mathematics) elements.

For these considerations, we will cite also the opinion of the mathematician Jean-Pierre Bourguignon, director of the « *Institut des hautes études scientifiques* » and president of the Ethics Committee of CNRS (*Conseil National de Recherche Scientifique*) of France:

> « *Ce qui est le plus inquiétant, à mon sens, c'est que les comités d'évaluation – au lieu de lire les travaux des chercheurs – s'en tiennent à une sorte d'analyse de leur impact. Pourtant, le fait qu'un article soit très cité par d'autres chercheurs n'est pas forcément positif! Il peut être au contraire pointé pour ses faiblesses. La massification nous fait dépendre de plus en plus de systèmes très automatisés; or moins les gens auront lu les articles, les auront critiqués, auront une opinion réelle, plus la situation deviendra fragile* » [12], p. 69.

We can find so that the impact factors can be used for scientometric classifications only for:

a) scientific sub-domains with a comparable quantitative (mathematics) content,

b) published works in scientific reviews of the same type [2c], resp.

Conclusions

The accomplished study led to the following conclusions:

(1) The quality of an information can be appreciated by means of some statistical criteria referring to its compatibility with the existing experimental data for:

a) a given state, using the error risk criterion: $q_k = 1 - L_{ik}$,

b) a set of experimentally obtained confidence domains, by means of the global compatibility criterion:

$$\lambda = \frac{V_N(r_N)}{\left(1 - |r_N|\right)^2},$$

c) the entire distribution of the individual values of a considered parameter, using the true information amount [see relation (13)]:

$$\Im = 2 \cdot \mathit{Overlapping\ Area} - 1$$

(2) The use of computer simulations is often useful, but it has to be tested in order to point out and predict the features of the possibly existing numerical phenomena.

(3) The most efficient present technical procedure for the information transmission is that of optical communications, involving the optical fibers, amplifiers, lasers (as sources), solitons (for signals multiplexing), etc.

(4) The efficiency of the information transmission by means of publications depends strongly on the "resonance bell" of the readers' knowledge, hence the impact factors can be used for scientometric classifications only for:

a) scientific sub-domains with a comparable quantitative (mathematics) content,

b) published works in scientific reviews of the same type, respectively.

(5) Because the scientometry objectives are political essentially, we consider as useful to calculate the impact factors as a geometrical average of the cited works in the frame of:

a) ISI reviews, proceedings or scientific monographs of the scientific works published abroad,

b) ibid., for the scientific works published in the frame of some scientific reviews from Romania,

c) some PhD dissertations.

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