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Letter to Editor

HOMO ANALITICUS OR HOMO COMPUTICUS?

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Abstract. *A rapid development of computer aided sciences forced us to give our point of view for traditional "analytical" approach and today's "numerical" one.*

Key words: *asymptotic approaches, computations, simulations, analysis.*

"The purpose of computing is insight, not numbers" - this idea given by R. W. Hamming (1975-1998), the author of the famous book [1], has motivated us to write this paper.

1. INTRODUCTION-ASYMPTOTIC APPROACHES IN THE INFORMATION AGE

The end of the century and close birthday of a new millennium focused an attention of many researchers on a future of relations between analytical and numerical strategies in applied sciences and engineering.

The fundamental impressions can be summarized in the following way. A possibility of getting required information has significantly increased in recent years. This implies high quality tools for its safe keeping and a transformation in a manner to be understandable by a human being. The last requirement is related to: a) construction of low dimensional models; b) extraction of high dimensional information; c) extraction of the most important singularities in a system's behaviour (for instance, the bifurcation points), and so on. The most suitable tools to realize the mentioned requirements are related to analytical, and in particular, to asymptotic methods.

On the other hand, it has been observed that in recent years asymptotic approaches have been highly developed from both qualitative (an increase of number of possible applications) and quantitative points of view.

2. SOME PROBLEMS

It is evident that thousands of papers and books (for instance see [1-9] and the cited references therein) are devoted to this subject, and it is regularly discussed either on special scientific conferences and in a general public way. We would like to address one aspect of the

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problem, not clearly stated in the cited references. Because due to computer simulation a new virtual world is created, and the same rules hold for both real and virtual worlds, therefore a particular attention must be paid to application of asymptotic methods.

Such phrases as "Nowadays computers expand very widely human being's possibilities", "Computers are needed but they cannot fully substitute experts", and so on, are well known and many times repeated in numerous journals and books. However, this issue becomes more interesting if somebody tries to read more carefully papers by J. Guckenheimer [2,3], M. Gromov [4], I. Elishakoff [5] and others [6-8]. We are going to present our point of view on the subject of computers versus the traditional analytical approach on the basis of the cited scientists opinions as well as our own understanding.

A social response to the new phenomenon is characterised by three steps: unlimited optimism, a reaction showing strong criticism with an emphasis on disadvantages, and, finally, a partial inclusion of a new process in a cultural paradigm.

It seems that an influence of computers on our life is still in the first phase. Obviously, the number of books, papers, talks, TV shows, etc. devoted to advertising the power of computers is extremely high. On the other hand, many scientists are fully confident that serious estimation of limits of computer oriented sciences is needed [1-8]. A belief in unlimited possibilities of computers leads to manipulation and control of the social behaviour of a human being. Real complex processes like a climate change caused by a thermal effect or a nuclear war, or a state of economics, depend on extremely high numbers of parameters. Very often a priori model of the process is not known but it depends on the chosen parameters. For instance, according to one group of researchers, a thermal effect leads to a temperature decrease on the Earth, whereas another group predicts its increase. Simulation models also lead to prediction of the duration time of a "nuclear winter" either within tens (or even hundreds) of years or within weeks (or months). Both groups accuse each other of a juggling with initial data or an improper choice of essential parameters, and so on. A dangerous illusion is introduced when one assumes that an accuracy can be improved by increasing the number of parameters, which are sometimes not easy to define or the price of their estimation is high. Computer algorithms should be stable against unknown parameter changes, but one can observe a lack of the corresponding theories in this field [2,3].

According to Hamming, a good theoretical researcher should estimate a result a priori and should behave rather in a sceptic way as far as the obtained results are concerned. The main problem occurs not due to potential wrong results introduced by the subroutines used, but due to a formulation of the problem and due to the fact that the expectations are different. This observation corresponds with the paradoxical phrase of Hamming "It is better to solve a problem properly formulated in an improper way than to solve an improperly formulated problem using a proper way" [1].

Furthermore, even if a problem is properly stated, one should recognise advantages as well as disadvantages of the numerical algorithms used. "When we bundle exacting algorithms into libraries and wrap them into packages to facilitate easy use, we create de facto standards that make it easy to ignore numerical analysis. We regard the existing base as static and invest in the development of problem-solving environments and high-level languages. This is needed, but we also need to maintain our investment in continuing research on algorithms themselves" [3]. An increase of the number of program packages developed on the basis of unknown for users principles results in an increase of chance of omitting the existence of their limitations and principal systematic errors.

One of the psychological problems of human being is a tendency to avoid responsibility, which fits well with the virtual world and computers. "Computer programs have made to many people believe that all technical problems are readily solvable" [6]. P. R. Halmos reminded us

about "permanent human opposite to a creative work" [9], and computer users have a "lucky" possibility to "replace ideas by computations" (instead "replace computations by ideas" [10]).

Finally, the following psychological problem appears. Large computer projects (demographic, genetic, synergetic, climate modelling, etc.) need extreme efforts due to identification, unification, verification of the number of parameters, and so on. It means that a share of uncreative activities is also extremely high. An individual influence and responsibility of a researcher becomes washed out, but prise of his mistake may be very high!

3. FRANKNESS IS THE BEST POLICY

It is clear that for computer science oriented researchers it is rather difficult to be totally honest: grants and funds as well as the advertisements are needed. But compromise between honesty of a researcher and the battle for money should be achieved. It seems to us, position of famous mathematicians concerning using of mathematics must be cited as an example.

This matter has been discussed by J. Schwartz [11] and N. Wiener [12]. In particular, Wiener wrote: "One of the fundamental responsibilities of a mathematician is to persuade to other scientists not to many expecting from mathematics".

In his turn, Schwartz notes [11, p.358]: "Related to deficiency of mathematics, and perhaps more productive of rueful consequence, is the simple-mindedness of mathematics - its willingness, like that of a computing machine, to elaborate upon any idea, however absurd; to dress scientific brilliancies and scientific absurdities alike in the impressive uniform of formulae and theorems. Unfortunately however, an absurdity in uniform is far more persuasive than an absurdity unclad. The fact that a theory appears in mathematical form somehow makes us more ready to take it seriously".

I. Gelfand wrote even more sharp "An experience of collaboration with physicians and biologists shows that a new mathematics is needed which does not exist up till now" [13].

It seems that in published papers with computer simulation results stronger emphasis should be put on a choice of parameter sets and the rules for negligibility of other parameters should be exhibited (if there is a lack of such rules, it should be clearly stated) [14]. The alternative approaches and results should also be added. A honesty of the computer programs creators is required also because: "The engineers who can "stand up to" a computer will be those who understand that software incorporates many assumptions that cannot be easily detected by its users but that affect the validity of the results. There are thousand points of doubt in every complex computer program" [6]. A user must know from the programmer about all "dangerous" places, limitations and weak points of a program. On the other hand a program possesses its own life, and even not everything, in some sense, is clear to its creators. The experienced programmers believe that each "complex programs has errors", and a testing and improvement of a program belong to most complex and expensive parts of this task. "That what is fully under control is never real. That what is real is never controlled in full" (V.V.Nabokov [15, p.136]). And therefore a "successful computer-aided design requires vigilance and the same visual knowledge and intuitive sense of fitness that successive designers have always depended on when making critical design decisions" [6].

4. COMPUTATIONAL MECHANICS, COMPUTATIONAL FLUID MECHANICS…

One can see a lot of "new sciences": Computational Physics, Computational Biology, etc. (reader can himself to add word "Computational" before any science title). Are there really "new sciences"? Why one can not see "Algebraic Biology" or "Geometrical Geography?". We refer some opinions of word-known experts.

Batchelor et al. [20] wrote: "This debate was motivated by the increasing importance of CFD (Computational Fluid Dynamics) in research and applications, which makes some people believe that in the foreseeable future CFD will dominate fluid mechanics, relegating analysis and experiments to a peripheral role. Has the idea of a "numerical wind-tunnel", replacing real ones, any validity? Does fluid dynamics differ from other physical science centred around experiments and observations? ...

The conclusion of the debate was that experiment, analysis and computation are of comparable importance and, ideally, one would like to see them interact in the same laboratory. None of these can flourish without the other two".

Novoshilov et al. [21]: "The authors are firm opponents of exchanging the fundamental domain - the theory of shells – for one of the chapters of applied sciences. This regrettable tendency is a side effect of implementation of numerical methods. On journals (and monographs) pages there were flowing avalanches of works with the opinions of numerical experts, realised sometimes with the use of standard packets of applied programmes. Unfortunately (or perhaps fortunately) there cannot be a pattern set for all life cases. At the same time the most important thing is the understanding of the penetrated problem, and not the number. As for the numerical methods, then when the complicated problems are set, the introductory analytical solutions may turn out to be very useful, and sometimes they are even necessary to quicken the realisation of numerical algorithm. In the domain of mechanics of deformed solid body it is primary to accept initial hypothesis and assumptions based on deep understanding of work of the material in construction.

The estimation of errors in the accepted hypothesis and assumptions – the formation of the set of equations adequately describing the construction working.

The position of the authors: sensible combination of analytical and numerical methods with the understanding of the mechanical side of the considered problem".

Is that so that there is an insurmountable precipice between the "analysts" and the "computer experts"? We are sure that this is not the case. We know from our own experience that it is much easier to reach an agreement with a clever and extensively educated "computer expert" than with a limited "analyst". Moreover it can be assumed that the boundary between the analysts and the "followers of the numbers theory" will violently obliterate together with the implementation of the programme packets of the "Mathematics" type, which allow to form symbolic explanation, and also the packets giving the possibility of analytical presentation of the bulk of numerical data.

5. BRAVE VIRTUAL WORLD

> The speed of computation as a limiting factor in simulating physical systems has largely been replaced by the difficulty of extracting useful information from large data sets.
>
> J. Guckenheimer [2]

Wide using of computer models creates to the world new reality, and we need experts for analysis this world. The situation is similar to that of the status of experimental and theoretical physics: an expert of computer information analysis (further referred to as an analyst) should translate the simulation results into a language of human oriented science (Figs. 1, 2).

The fundamental goal of an analyst working in a virtual world is the same as in the real one. First of all we must remember, that "The grand aim of all science is to cover the greatest number of empirical facts by logical deduction from the smallest number of hypotheses or axioms"[16,p.256]). That's why "the search for symmetries and regularities" [3, p. 846] (as well as evident asymmetry and irregularity!) plays the key role for any researcher. Here is an important place for asymptotical methods, based on decreasing dimensions and decompositions, multiple scale analysis, and homogenization [17-19]. In our opinion, analyst of virtual world must be in the first place an asymptotic analyst.

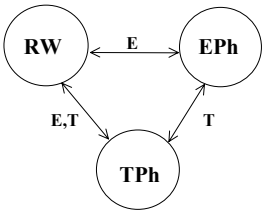

Fig. 1. The internal problems of Eph (Experimental Physics) and TPh (Theoretical Physics) are solved by experimentalists (E) and theorists (T). A link between the RW and EPh is realised via E; a link between the EPh and TPh, as well as the RW and TPh, via T.

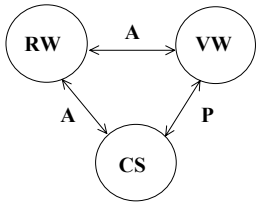

Fig. 2. Internal problems of the VW (Virtual World) are solved by programmers (P); the links between the RW (Real Word) as well as between the CS (Conventional Science) and VW are realised by analysts (A).

Naturally, the asymptotic analyst and the programmer users should work in close collaboration. An advantage of computer models lies in a possibility of quick verification of hypotheses, detaching small (large) parameters, estimation of validity of different characteristics, etc. A role of an analyst is to formulate important and properly stated questions as well adequate conclusions on the basis of the obtained results.

6. CONCLUSION

Of course, the connections between the world of computer modelling, the world of conventional science and the real world need a separate discussion. We conclude that the methods of the real world analysis are fully applicable to the world of computer modelling. However, their actual application needs a different kind of intuition and different habits which require computer models (asymptotic) analysts.

Naturally, we can use all tools from the store of mathematical modelling (see, for example, Fig.3).

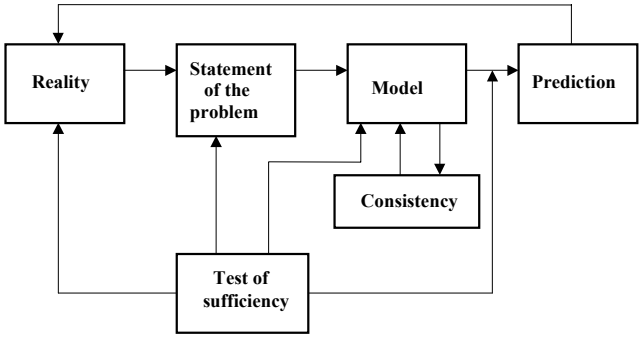

Fig. 3. Changing "Reality" to "Virtual Reality", one can use a scheme of mathematical modelling to analysis of computer models [23].

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