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# John von Neumann and Self-Reference ...

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*Dedicated to Marie-Louise Nykamp*

## **Abstract**

It is shown that the description as a "frog" of John von Neumann in a recent item by the Princeton celebrity physicist Freeman Dyson does among others miss completely on the immesnely important revolution of the so called "von Neumann architecture" of our modern electronic digital computers.

"There have been four sorts of ages in the world's history. There have been ages when everybody thought they knew everything, ages when nobody thought they knew anything, ages when clever people thought they knew much and stupid people thought they knew little, and ages when stupid people thought they knew much and clever people thought they knew little. The first sort of age is one of stability, the second of slow decay,

the third of progress, and the fourth of disaster.

Bertrand Russel, "On modern uncertainty" (20 July 1932) in *Mortals and Others*, p. 103-104.

"History is written with the feet ..."

Ex-Chairman Mao, of the Long March fame ...

"Of all things, good sense is the most fairly distributed : everyone thinks he is so well supplied with it that even those who are the hardest to satisfy in every other respect never desire more of it than they already have." :-) :-) :-)

R Descartes, *Discourse de la Méthode*

"Creativity often consists of finding hidden assumptions. And removing those assumptions can open up a new set of possibilities ..."

Henry R Sturman

"A physical understanding is a completely un-mathematical, imprecise, and inexact thing, but absolutely necessary for a physicist ..."

R. Feynman

## **Was indeed John von Neumann a mere "frog", as Freeman Dyson classifies him ?**

Let us give an example of gross omission of self-reference in a recent publication by an assumed Princeton celebrity, Freeman Dyson (b. 1923).

Originating from England, Dyson started with mathematics, and then switched to physics.

His claim to fame comes from his contribution to quantum electrodynamics which he made back in 1949.

Since 1953, he has been at the Institute for Advanced Study, Princeton, New Jersey, USA.

In the February 2009, Vol. 56, No. 2, pp.212-223, of the Notices of the American Mathematical Society, he has the item Birds and Frogs. The item is the written version of Dyson's AMS Einstein Lecture of October 2008, a lecture which in fact was cancelled.

In it, more or less appropriately, he segregates mathematicians into two sharply different categories, namely, bird, and on the other hand, frogs.

Among the birds who are supposed to have a wider vision he mentions at the beginning Descartes, while as frogs who are supposed to live in the mud below and see only the flowers that grow nearby he starts with Francis Bacon (1561-1626).

And with some apparent modesty, Dyson classifies himself as a frog...

What is amusing, however, is that he labels John von Neumann as a frog, too...

And here, assuming naturally that Dyson is fully honest, one can only see this classification of von Neumann as an utter lack of even a mere elementary understanding by Dyson of the truly revolutionary and fundamental use of self-reference by von Neumann.

But before going into some detail, it is worth mentioning that, ever since the Paradox of the Liar in ancient Greece, Western civilization has had nothing short of a horror of self-reference. And that horror was further entrenched into our modern times when, in 1903, Bertrand Russell reformulated that ancient paradox in terms of Set Theory, thus further helping in creating an immense problem in the Foundations of Mathematics.

Consequently, it may simply happen that Dyson never came to give any thought to the issue of self-reference, considering that it had been settled for good, ever since ancient Greece...

Be it as it may related to Dyson, the fact is, and so it is ever since ancient times, that in the Old Testament - not a less important pillar of Western civilization, than ancient Greek art, science and philosophy, or the ancient Roman legal, political and military systems - there is no trace whatsoever of the least reservation regarding self-reference. And on the contrary, in Exodus 3:14, it is nothing less than the name of God, in the formulation I am that I am.

The above, needless to say, should not be construed as placing any obligation upon Dyson. After all, modern mathematicians, physicists, or for that matter, other practitioners of hard sciences, do not usually excel in their deeper knowledge of the roots of Western civilization...

Not so with von Neumann, however.

Indeed, one of by far most important novelties in our times is the introduction of electronic digital computers. And nowadays, there is a near universal dominance in the construction of such computers of what is called the von Neumann architecture.

This, briefly means the following.

Two inputs are introduced in every such computer, namely, the program and the data. And the computer is supposed to process the data according to the program, and then give as an output the results.

Well, before the present day computers built according to the von Neumann architecture, there have been some rather sophisticated electri-

cal computers, among them the one built by the American Herman Hollerith (1860-1929). This computer did in 1890 process the whole American census in only one year, while in 1880, and prior to the Hollerith computer, the census took no less than eight years to be processed.

The massive success of the Hollerith computer is shown among other by the fact that in 1924, under the presidency of Thomas J Watson, the IBM, that is, International Business Machines Corporation was founded in order to produce and spread such computers.

And then, what was the truly revolutionary novelty, one of a massive practical advantage, which the von Neumann architecture introduced in the world of computers ?

Simple indeed :

All the earlier computers, including the Hollerith, operated only and only upon the given data, and did so according to the given program which remained the same during the whole computation.

The essence of the von Neumann architecture, on the other hand, is that the computer can operate both on the data and the program itself, before obtaining the results. And the way the computer operates on the program is dependent on the data.

It follows therefore that here we have a clear and rather simple example of self-reference : the program acts upon itself, and does so according to its own structure, as well as the information in the data.

And this simple self-reference was perfectly sufficient in order to unleash all the miracles of modern computation...

At the same time, it seems nevertheless to escape completely the awareness of Dyson...

But the story does not stop here :

A few years later, von Neumann showed that one can construct finite

cellular automata which can reproduce themselves. Thus they may be used in spreading civilization beyond Planet Earth.

Here, however, one should note from the beginning that at first sight - the issue is highly nontrivial. Indeed, a self-reproducing automaton must, among others, contain the program of its own self-reproduction. And then, this program of self-reproduction must on its turn contain a program of its own self-reproduction, that is, a program of self-reproduction of the program of self-reproduction...

And so it comes that we are facing an infinite sequence of such programs...

Well, von Neumann showed that a rather simple finite cellular automaton can avoid the need for such an infinite construction...

And again, Dyson happened to miss on that, too...

Last, and not least, one should note the following :

The so called von Neumann architecture makes our electronic digital computers not quite perfectly self-referential, since the way any given program acts upon itself depends not only on the respective program, but also on the given data.

On the other hand, the self-referentiality of self-reproducing automata is indeed a pure and perfect self-referentiality, since it has nothing else involved in it, except for itself.

Back to Dyson, however...

Well, having missed utterly on both self-referentialities above, not to mention on their immense importance, be it actual or potential, he manages to find one of the many lectures von Neumann gave, a lecture to which allegedly von Neumann went unprepared...

Yes indeed, Dyson seems to be a frog...

And how much can a frog understand a bird... ?

Anyhow, von Neumann, in a research career of about a mere quarter of century, from which his other engagements during WW II took a lot of time, managed to obtain fundamental contributions to Game Theory, Foundations of Set Theory, Quantum Mechanics, Operator Theory, among others...

Quite some frog, one would say...

But then, Dyson's handicap is not only the fact that he is indeed a frog, having done very little remarkable in physics, except for his 1949 breakthrough, but he is also a physicist...

And as such, he is not supposed to understand much enough about mathematics, and thus, about mathematicians...

Yes, honesty seems not to be enough, not even when coming from a physicist...

But until he may reach next year the venerable age of ninety, he may hopefully have some time to ponder about such issues...