

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

"Science is not done scientifically, since it is mostly done by non-scientists ..."

Anonymous

“Science is nowadays not done scientifically, since it is mostly done by ... scientists ...”

Anonymous

“Physics is too important to be left only to physicists ...”

Anonymous

“Is the claim about the validity of the so called ‘physical intuition’ but a present day version of medieval claims about the sacro-sanct validity of theal revelations ?”

Anonymous

“A physical understanding is a completely unmathematical, imprecise, and inexact thing, but absolutely necessary for a physicist ...”

R. Feynman

“I am looking forward very much to getting back to Cambridge, and being able to say what I think and not to mean what I say: two things which at home are impossible. Cambridge is one of the few places where one can talk unlimited nonsense and generalities without anyone pulling one up or confronting one with them when one

says just the opposite the next day.”

Bertrand Russell, Letter to Alys Pearsall Smith; published in *The Selected Letters of Bertrand Russell, Volume 1: The Private Years (1884-1914)*, edited by Nicholas Griffin.

Conditio Humana

Evidently, the world is never given to us directly but only as it appears on our inner screen. This trivial fact, which in philosophical terminology is just the phenomenal character of the world, when taken seriously, has far reaching consequences. Everything we sensually or intellectually conceive of our world is shaped and conditioned in a categorial way by the mode of our existence as conscious individuals. Naive realism asserts that the world appears to us more or less "like it really is". Sometimes our categorial cognitive structure is compared to a pair of colored sunglasses, which can be taken off to allow a look at the real world. But also this optimistic belief underestimates the inexorable phenomenality of our existence, which must be the starting point of every reflection about the way we orient ourselves in our world. In particular, physics cannot lay its own foundations but has to be aware of the categorial prerequisites imposed by our cognitional system and our mode of existence. In this spirit we mention that a measurement should not entirely be conceived as a physical process but also as an act of cognition. This also prevents a complete causal closure of physics. Of course, the physical process accompanying measurement has to be investigated and consistency

with the possibility of cognition must be guaranteed. A strict physical reductionism, trying to reduce "everything" to physics, is unaware of the phenomenal character of the world and, hence, of its own foundations. Moreover, it runs into the naive methodological mistake to identify the model with what is modelled. The main structural features of the phenomenal mode of human existence have already been mentioned in passing. We briefly collect them here :

- The figure of oppositeness. In every act of cognition we experience ourselves as an observer, different and set apart from what we observe. This is sometimes referred to as the egocentricity of human existence. The epistemic cut between observer and observed is never absent.
- Temporality. Human existence is inescapably temporal in the sense of a future directed time with a privileged "now".
- Factuality. We live in a world of facts rather than a world of potentialities. Everything which appears to us, primarily touches us in the form of a fact. In particular, the "now" carries the imprint of prototypic factuality.

These basic existential features are deeply encoded in the structure of quantum theory. The naturalness and, in a way, a priori structure of quantum theory has been observed by many :

- The epistemic cut is present in the very special and fundamental role attributed to measurement in quantum theory. We saw that observables are located right on the epistemic cut. Standard reductive physicalism ignores the importance of the observer and the epistemic cut in favor of the outside world. In this sense, it is as one-sided and implausi-

ble as a solipsistic world view, which ignores the outside in favor of the inside world.

- Factuality is intimately related to quantum theoretical measurement, which basically amounts to a transition from potentiality to a measurement result of factual validity.

The categorial scheme of human existence is, of course, the product of a long development. The temporality of primitive animals is a total subjection to the undivided factuality of a simple "now". Memory and the possibility of preparing actions open up the horizon of temporality eventually resulting in a differentiation between past, present and future. Causality and personal freedom, which are often considered to be in contradictory relationship, actually rely on one another and are in fact offshoots of the same root of such a developed and differentiated temporality. This phylogenetic process is repeated in quick motion in the ontogenesis of every human individual. Related to the unfolding of temporality there is an emancipation from the close binding to primitive factuality. Free exploration of the of various possibilities comes into sight with the capacity for hypothetical and counterfactual thinking. Along with this emancipation goes a deepening of the epistemic cut. The precise form of human existence undergoes a process of varied cultural evolution and also shows large individual differences. Development goes on: Man is always rebellious against his categorial limitations. Philosophy, science and arts grant visions on timeless structures. Utopianism challenges factuality, while integrative world views by embedding man into a comprehensive universe try to alleviate the egocentricity of the epistemic cut.

Hartmann Römer, arxiv:1202.5748

“Pure mathematics consists entirely of assertions to the effect that, if such and such a proposition is true of anything, then such and such another proposition is true of that thing. It is essential not to discuss whether the first proposition is really true, and not to mention what the anything is, of which it is supposed to be true ... If our hypothesis is about anything, and not about some one or more particular things, then our deductions constitute mathematics.

Thus mathematics may be defined as the subject in which we never know what we are talking about, nor whether what we are saying is true. People who have been puzzled by the beginnings of mathematics will, I hope, find comfort in this definition, and will probably agree that it is accurate.”

Bertrand Russell, *Recent Work on the Principles of Mathematics*, published in *International Monthly*, vol. 4 (1901).

A “mathematical problem” ?

For quite sometime by now, American mathematicians have decided to hide their date of birth and not to mention it in their own academic CV. Why are they so blatantly against transparency in such an academically related matter ?

Can one, therefore, trust American mathematicians, or for that matter, any other professional who behaves like that ?

Amusingly, Hollywood actors and actresses have their birth date easily available on Wikipedia. On the other hand, Hollywood movies have also for long by now been hiding the date of their production ...

A bemused non-American mathematician

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 electrical 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...