SEMANTIC INFORMATION - A SURVEY OF THE FIELD

A fundamental change in the scientific conception of physical reality is silently but busily afoot at the international level. This change is poised to usher in turn revolutionary changes in the development of all other sciences, as well as engineering and technology.

The central idea in the emerging conception of reality is that the world of objects we perceive in our experience, are made of, *not* matter characterized by mass/energy but *information.* This idea was sufficiently anticipated and clearly articulated by the famous physicist, John Archibald Wheeler in 1989:

> The physical world has at bottom an immaterial source and explanation. All things physical are information-theoretic in origin.[1]

Wheeler accordingly coined the succinct slogan, ―it (matter) from bit (information)". For recent work in reformulating our physical theories in accordance with his idea, see the *Physical Review A* paper by Chiribella et al.[2] However, Wheeler's idea was still born becuase he was limited to classocal bits. Whereas information that can account for appearance for matter needs quantum bits, an idea that had not emerged yet during Wheeler's time.

This quantum information turn in our conception of the very stuff of physical reality will be quite different from the classical information technology that has been revolutionizing the world for the past several decades, although it too will further revolutionized by this new informational turn.The notion of information as reality has been long in coming within physics. In 2013, the Fundamental Questions Institute had announced a $3 million grants competition for best research projects on physics and information, and wrote:

> The past century in fundamental physics has shown a steady progression away from thinking about physics as a description of material objects and their interactions, and towards physics as a description of the evolution of information about and in the physical world. Moreover, recent years have shown an explosion of interest at the nexus of physics and information…by developments in quantum information theory and computer science.[3]

Classical mechanics dealt with the dynamics of objects in space and time. While conscious experimenters certainly obtained "information" subjectively about the world, the theory itself seemed to have nothing to do with information as any part of objective reality. The incorrectness of this idea already became clear in statistical mechanics, where even though the gas molecules are taken to obey classical deterministic mechanics, probabilities became necessary for adequate description of thermodynamic phenomena. This raised the question whether information as a physical concept was already indicated even within the classical physical framework.[4]

With an even more fundamental and ontological role of probabilities, quantum theory gave rise to the possibility whether "the fundamental laws of nature concern — not waves and particles — but *information*."[5]

The nexus between physical reality and information is so keen within quantum theory that despite open conceptual questions about whether the wave function represents physical reality at all in a one-to-one manner, theoretical and experimental efforts to put quantum information to practical use abounds at the present juncture.

In 2010, the Chinese government has invested $554 million toward funding five scientific satellites, one of which will be for testing very-long distance quantum information communication technologies.[6] In 2016, European Union anounced €1 billion investments in quantum technologies.[6a] Other nations too are investing highly in this field.[7]

The information turn has hardly been restricted to physics. The Nobel Prize award in 1962 to James Dewey Watson, Francis Harry Crick and Maurice Hugh Frederick Wilkins - for their work in discovering the chemical structure of the DNA molecule - credited them with bringing in the notion of information within biology. The Nobel citation read, in part: ″for their discoveries concerning the molecular structure of nucleic acids and its significance for *information transfer* in living material″.[8]

By 1970s, Crick had already enunciated the "Central dogma of molecular biology", which accorded a central role for "information flow" in the observed one-way process, DNA -> RNA -> Protein synthesis. Indeed, the idea of DNA as carriers of "genetic information" took root within biology and spawned the whole area of multi-billion dollar genetic engineering. As Sydney Brenner wittily remarked, DNA makes, RNA, RNA makes proteins, and proteins make money."[9]

Nevertheless, the genuineness of the notion of information as introduced by Crick within biology has been questioned,[10,11,12] and also defended.[13,14,15] Very recently, the failure of the program to account for human complexity on the basis of the corresponding hoped-for complexity of the human genome – it is now known that we share 90% of our genes with the common fruit fly – has led to a call for a more sophisticated notion of information to be brought within biology than the one advocated by Crick in the ~~–e~~entral dogma". [16,17]

The informational turn in physics is indeed connected with the felt need for *semantic* information.[18] At the level semantic information is being currently dealt with, the word "semantic" certainly refers to meaning. However, the program of InSIST goes beyond to introduce the notion of *objective* semantic information (OSI), which does not directly relate to meaning. It connotes a state of matter that underlies and gives rise to our experience. For its full realization, OSI entails a full marriage between quantum physics with statistics and information theory to model processes in the *macro*scopic world in a new, non-classical manner. Classical physics and even current quantum physics, can only view physical states as data, and the idea that they carry information is a superimposition by us over data. This is because current physics interprets all individual observations as corresponding to localized physical events in space and time of the external world. Information belongs to our subjective experience. The semantic information turn begins by *reversing this:* treating the observations as localized events in *phenomenal world* and corresponding to objective information status in the external world. It is semantic by virtue of accounting for our experience directly. The work of InSIST pioneers this new approach. [19,20,21,22]

The essence of the "semantic" turn in information within sciences and technology revolves around integrating the notion of information in physics, and the emergence of primacy of observations qua experience in quantum theory. However, it must be emphasized that the notion of quantum information is still not properly established in the West. As recently as in 2013, one of the founding figures of quantum information, David Deutsch admitted to the following:

> Quantum information theory, as it stands, never gets round to specifying what it is referring to as 'quantum information', nor its relation to classical information. It is not, despite the name, a theory of a new type of information. A new theory of information is needed within physics but at a deeper level than both [present] quantum theory and Shannon's theory.[22a]

Our work at InSIST, offers indeed such a new approach to quantum mechanics at the macroscopic level, and presents Objective Semantic Information as the appropriate new notion of quantum information.

Indeed, such a new idea about information established within physics, the most fundamental of all sciences, can only be expected to impact all other sciences, as well as engineering and technological applications. From Semantic web[23] to Semantic biology[24,25] and even Semantic medicine[26] the *semantic informational turn* is actively in play. However, as already remarked these are based on conventional idea of physical information, and semantics in only introduced vai big data analytics etc.

The OSI- based approach, however, will *store* information semantically and also process it. Therefore, it is a different and superior approach.

Current estimates in quantum theory based technologies are about one-third of world GNP. That is about $9 trillion. Information-based technologies account for 30% of the GNP in the USA. It is reasonable to conclude that these two sectors will contribute in the same ratio to the world GNP, which is 3 times that of USA. The new semantic informational turn can be expected only increase the economic impact.

India cannot afford to be totally left out of this development. In fact, with proper foresight and effort, India can become a world leader in this world even without extravagant investments to the tune of hundreds of millions of dollars being made around the world. The Institute for Semantic Information Sciences & Technology (InSIST), recently established in Mumbai, can arguably said to be the leading, if not the only centre, in India for advanced research in this emerging field of semantic information sciences and technology.

One of the important ways in which such advanced research work can be consolidated and furthered is to introduce it within the education. In this regard, InSIST has taken major step to float PhD and 4 Year B. Tech Program in Semantic Information Science and Technology (SIST). It will be the first such degree program in the world. We have developed a full curriculum for the proposed B. Tech program

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