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The Evolution of Information Systems: From the Big Bang to the Era of Globalisation

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Abstract

The aim of this paper is to show the importance of the evolution of information systems to the emergence of life and the trajectory of human history. It locates this development in the widest possible context, that is, the history of the Universe as a whole. One can view the development of the Universe from the Big Bang to the present social existence of our species as a series of revolutionary/evolutionary stages, with each stage associated with the development of a new information system. The present form of globalization is made possible, in part, by the development of modern Information and Communications Technology (ICT). In this context, the change in character of the working class will be examined. It will be argued that information workers are the dominant category in advanced economies, and that one of their sub-groups, the knowledge workers, can play an especially important role in the resolving the crises of both the socio-economic system and the environment.

The Big Bang and the Quantum Physics Information System

After the Big Bang, as the Universe cooled, stable matter particles (such as electrons, protons and neutrons) were formed from the high energy fields, as determined by the special relativity law of equivalence for matter and energy. The baryonic matter particles (protons and neutrons) condensed out of a precursor plasma about 10 micro-seconds after the Big Bang. This plasma consisted of quarks, leptons and force carrier particles like photons (Electromagnetic force), W and Z bosons (Weak force), and gluons (Strong force). This is sometimes referred to simply as the 'quark soup'. Neutrons and protons, for instance, are each composed of a combination of three different quarks that are held together by gluons (Turner 2009).

During the interval 0.01 to 300 seconds after the Big Bang, further cooling allowed the formation of the light nuclei of Helium, Heavy Hydrogen (Deuterium), and Lithium. About 380,000 years later, the Universe was sufficiently cool to allow the formation of electrically neutral atoms from electrons and the nuclei. This released the electromagnetic radiation previously trapped in the plasma, which then increased its wavelength with the expansion of the universe to become the cosmic microwave background radiation that was first detected in 1965 by Arno Penzias and Robert Wilson (Penzias and Wilson 1965: 419–421). This background radiation has been extensively studied with increasing accuracy ever since. After 13.7 billion years, it now has a temperature of about 2.7 Kelvin and wavelengths of several millimetres. It provides important evidence for the Big Bang model of cosmology (Turner 2009).

About 300 million years after the Big Bang, the first stars and galaxies formed, as a result of the action of gravitational forces. Because of the mass of the stars, these forces were sufficiently strong to initiate nuclear fusion of hydrogen and its isotopes, which resulted in the emission of electromagnetic radiation in the visible spectrum – in other words, the first stars lit-up. It is this radiation that carried and still carries important information about the structure of the stars, galaxies and the Universe itself, and thus made possible the science of Astronomy. This radiation also created the energy source for the evolution and continuation of life on Earth, as well as stimulating the evolution of visual sensors in higher animals. These sensors contributed to the evolution of the ultimate information processor, the human brain.

The laws of quantum physics decide on how particles of matter interact with various types of fields, most importantly, the electromagnetic field. In fact, quantum physics can be thought of as the first and fundamental information system in that it allows matter particles to be aware of or ‘know’ about each other's presence even when there is no physical interaction between them. The ‘wave-function’ of quantum physics carries statistical information about the possible states of the particle, that is, the probability for its being in each of its different possible states of energy, motion and location. *It also makes possible the many subtle processes that allow particles of matter to act collectively to form higher levels of organisation in atoms and molecules, including, eventually, the possibility of life itself.*

For example, the laws of quantum physics allow different elements to be synthesised in dying stars through nuclear fusion processes. These elements then combine together into molecules and crystalline material also due to the laws of quantum physics. This resulting type of matter, under the influence of gravity, eventually aggregated to form planets, such as our own.

It should be noted that work by physicists Stephen Hawking and Jacob Bekenstein, using an ad-hoc combination of quantum physics and General Relativity, has shown that the information content of a black hole (matter so concentrated that light cannot escape from it) is encoded on its surface (Hawking 1988). This result has recently been applied to the Universe as a whole by Gerard t'Hooft, Leonard Susskind and other physicists, using the holographic principle. From this point of view, all physical processes in the bulk of the Universe are seen as a holographic projection of information stored in quantum fields on a distant boundary. Each unit of information (bit) is contained in an area of 10^{-70}m^2, that is, the Planck length (10^{-35}m) squared.[1] This means that 1m^2 of this boundary surface contains 10^{70} bits of information! Thus, these recent theories, in effect, describe the universe itself as a giant quantum information processor (Greene 2011: ch. 9).

The Molecular-Genetic Information System of Life

It is still by no means clear in detail how life emerged, but obviously an important step was the evolution of molecules that could trap and store energy through quantum processes. Initially, perhaps this energy was derived from thermal sources, but later from sunlight, and was then utilised to promote the chemical synthesis of more complex molecules such as proteins and the poly-ribonucleic acids, such as RNA and especially DNA. Both these types of molecules are linear polymers made of a number of different structural units (or monomers). For proteins, these are the twenty possible different amino acids that form the monomers in chains containing several hundred or more monomer units. For DNA, there are four organic bases – A, T, G, C – adenine, thymine, guanine, and cytosine. These are the possible monomer 'letters' linked together on a sugar-phosphate backbone in groups of three, called triplets. There are thus 64 (= 4^3) possible triplets. Each of the 20 amino acids is coded by one or several of these triplets. Whereas the proteins have both a structural and a functional role (such as enzymes), the DNA molecules form a molecular-genetic system that codes the information to make the proteins. This led to the possibility of organisms reproducing themselves by reproducing copies of their DNA information molecules, which act as a 'blueprint' to create a new generation.

The emergence of this molecular information system was obviously a crucial step that enabled evolution itself to take place. It allowed living forms to adapt to changing environments. It is even possible to show, using information theory, that the protein-DNA system itself would have been that selected as optimal by evolutionary processes (Davies G., Lt-Commander, Royal Navy, retired, private communication, 1996).[2] Organisms can differ slightly in their structure and properties due to random changes (mutations) in the information 'letters' of their DNA. Those variations that allow the organism to survive in changing environments would pass on these survival properties to the next gen-

[1] The Planck length is the smallest length that can be consistent with physical laws. It can be thought of as the size of an 'atom' of space so that space is no longer continuous at this scale.

[2] This is referred to by Gareth Davies as a G (20, 4, 3) structure coding system – 20 structural units, coded by 4 letters, with code word length of 3 letters.

eration. Mono-cellular organisms combined to form multi-cellular organisms to survive in certain environments and so on up the evolutionary ladder. The development of information-gathering organs such as touch, smell and sight, together with an associated information processing organ – like a brain – were also crucial for survival and the eventual emergence of different levels of consciousness, including that of our own species.

So, in short, the emergence of living systems depended on the complex interplay of matter, energy and information. But the development of a molecular genetic information system was the crucial and revolutionary step that made possible the long evolutionary process that led to human kind.

Information Systems and Homo Sapiens

Speech

Similarly, a crucial step in the emergence of the genus *Homo* from our near primate relatives was the evolution of the capacity for language. This was, first, perhaps, a system of non-verbal signs that later developed into a full verbal system. This information system meant that it was possible to form cohesive social groups that had vastly improved survival chances. It also meant collective defence against predators and more effective communal hunting and gathering.

The development of the brain as an external and internal information and communication organ, through the stimulus of language, also meant the capacity for more abstract thought. This was most probably also closely linked to the development of a tool culture. In this way, the functionality of a tool could be abstracted from its material embodiment. Knowledge about suitable materials and the effectiveness of tool design could be shared more effectively and more rapidly through the use of language. And, of course, the use of tools also improved chances of survival.

Writing

The movement from hunter-gatherer societies to settled, agrarian societies in some regions occurred between 12,000 and 7,000 years BP, and distinct towns and cities were created, circa 7000–6000 BP. Some time later the early urban settlements turned out to be connected to the next stage in the evolution of information systems, namely, the invention of writing. Living in much larger settled groups required a more complex system of group rules of behaviour that could be unambiguously understood by every member of the group. Within such a context the writing must have been helpful since the existence of a multiplicity of purely verbal interpretations of the rules would have been somewhat disruptive. Writing also allowed for the accurate transmission of all sorts of useful knowledge between generations, thus improving group chances for survival.

The surpluses produced by more productive agrarian settlements could then support a literate priestly caste that was in charge of knowledge production and transmission, as well as the encoding of superstitious beliefs about, and explanations for, natural phenomena – namely religious beliefs. The latter gave the priesthood social and political power, as it does even today in some advanced capitalist countries, such as in the United States and in less advanced societies such as Iran.

The invention of writing must have also helped to promote the exchange of goods and services within settled groups and between such groups. This is because it was then possible to communicate information reliably about the amount and conditions of labour, raw materials and techniques of production, so as to establish an agreed equivalence between different amounts of various goods and services.

Money

Monetary systems arose to facilitate the exchange of goods and services between communities. It was also closely associated with the emergence of writing information system, even preceding it somewhat in some areas. The monetary system is essentially an information system that allows the representation of value of goods and services. This monetary form contains information about the amount and quality of labour needed to create goods or services, the cost to transport them to locations of exchange, and the scarcity of materials used in the creation of goods or services. The development of different forms of money information systems greatly facilitated the trade in goods and services between the early human settlements. It solved the 'coincidence of needs' problem associated with other forms of exchange, such as barter systems. Early writing systems were used to codify the laws governing the use of money, for example, the Code of Hammurabi in ancient Babylon circa 1760 BCE.

There are many forms of money, such as commodity money (crops, animals, precious metals, cowry shells, or beads); fiat money (created by and guaranteed by the power of a state body); and fiduciary money (a promise pay the bearer of the fiduciary money in commodities or fiat money). In effect, most currencies today are a form of fiat money, since they are no longer linked to the dollar, which itself was taken off the gold standard in 1971. Fiduciary money is by far the most common form of money used by banks in relationship to their customers. This form of money is now stored as digital information on credit cards and computer systems, thus clarifying its role as an information carrier system.

As Adam Smith pointed out, money itself can also be a commodity, one that is bought and sold in the market place (Smith 1776: Book 1, ch. 4). This is most characteristic of late capitalism, when finance capital dominates over production capital. For instance, on any given day in the City of London, 90 % of the transactions deal with financial instruments rather than with capital for production. Production investment forms only the remaining 10 % of transactions. This makes money an object of speculation, which can lead to destabilization of whole economies. It also leads to massive debt/credit bubbles as a result of the detachment of money from the value-creating system of labour producing useful goods and services. This is certainly the root cause of the present instabilities in the global financial system.

Printing

As I discussed in a previous paper, the invention of printing with moveable type was a critical development necessary for the emergence of the capitalist system in its first phase, which was called 'mercantilism' (Hookes 2003). Printing allowed for the mass production and dissemination of information about markets, the means of production, and improvements thereof, and most importantly, the spread of scientific knowledge and its method. Thus, the Age of Reason and Enlightenment in the 18th century, as well as the Industrial Revolution and the modern bourgeois state, were long-term consequences of this information revolution.

The emergent social classes, capitalist and worker, become distinct classes as a result of the ability of the members of each class to act together, cooperatively, in defence of their collective interests. This process required a communication system, that is, exchange of information. The existence of printing greatly enhanced this emergence of class behaviour and, eventually, of class consciousness.

Thus, we can view printing as the first Information and Communication Technology of the modern age initiated by the birth of capitalism. The industrial phase of capitalism was associated with the controlled release of energy, firstly from hydraulic systems and then, most importantly, from steam power, and later electromagnetic forms of energy derived from steam power. The control technology for energy release made it possible to vastly increase the productivity of labour within a factory system. In this system, each worker had his/her labour enhanced by availability of energy in a parallel network of supply from a centralized energy plant.

Electromagnetic Communication

The development of other powerful electromagnetic information technologies that proliferated in the 20th century, such as the telephone, radio, and television helped to strengthen the bourgeois state through increased political and social control, as demonstrated by Edward Herman and Noam Chomsky in *Manufacturing Consent* (Herman and Chomsky 1994). These developments also led to intensifying of commodity production, and the consequent temporary stabilisation of the capital system, through the creation of artificial needs by mass-media advertising that was in turn based on information technologies.

Digital ICT

Most importantly, this process includes not only the Internet but all other digital technologies used by information processing and for control of productive processes. In the present epoch, the modern computer-based ICT is also a control technology, which syntheses the two stages of capitalist technological development. To some extent, this was anticipated by the development of electromagnetic power and the early electromagnetic communications systems, but it achieves it full synthesis in the computer-control of information production, processing and communication, as well as control of the instruments of production themselves, such as machine tools and power plants.

It should also be noted that the solid state-based technology, on which modern ICT component devices are largely-based, depends on quantum processes. This illustrates the important role of quantum physics in many information systems. There is also much research being carried out to develop purely quantum information processors based on quantum bits (q-bits). These are based on the property of quantum superposition and entanglement, such that a q-bit can contain a mixture of '0' and '1' binary states. Although the arrival of quantum information processors is still some distance in the future, they are expected to make present processors appear pedestrian in comparison. Thus, quantum physics is again centre stage, as it was at the time of the Big Bang.

Information Systems, the ICT Revolution, Globalisation and the Labour Process

The character of work has changed considerably during the 20th century. The classical proletariat, namely, manual factory workers, have gone from a decisive majority of 60–70 % of the workforce a century ago to 10–20 % in advanced capitalist countries today. Those members of the workforce who provide services, especially information processing and delivery, now form the majority.[3] Members of a sub-group of this 'information proletariat' are sometimes called 'knowledge workers', those whose jobs require high levels of education obtained from advanced schooling.

Overall, these knowledge-workers now constitute about 40 % of the workforce in the United States, more than twice as numerous as the manual factory proletariat (Drucker 2001). Information workers form the core of the proletariat in an information-based society, but the membership is a mixed group: it in-

[3] In advanced capitalist economies, roughly 70 % of the active working population are engaged in providing services, 27–28 % in industry, and 2–3 % in agriculture. In Russia, in 1996, the service sector predominates at about 48 %, industry at 36 % and agriculture at 16 %.

cludes many highly exploited workers, such as those in call-centres and data-input offices, alongside highly privileged workers, such as university teachers and researchers, whose level of alienation is, let us say, tolerable, as well as some privileged technical workers.

The modern manual factory workers are themselves also affected by this new information society, producing considerably more goods per worker than when they were the majority of the workforce. This is due to the increased use of automation, especially intensified by the recent and on-going ICT revolution, based on micro- and nano-engineering. This technology also involves the parallel work of the information proletariat in the production process: writing computer programs, in-putting data, operating computers, answering telephones, operating reprographic machines, *etc.*

The numerical dominance of the information proletariat over the manual factory workers should give Marxists, for instance, cause to rethink their political agenda and strategy, but, sadly, in most cases it has not. There is a persistent and unthinking attempt to continue to celebrate manual work over ‘brain’ work, even when most manual workers today mainly use their brains rather than their muscles. Why should this be so? – especially since Marxists claim to be scientific materialists?

Perhaps the answer is related to the character of the information proletariat itself. For instance, they are less likely to behave as willing followers of a Marxist vanguard party and its ‘correct program’ than even the manual factory proletariat ever was. In fact, such workers tend to reject hierarchies (political or otherwise) and often embrace the concept of a non-hierarchical network society, the nature of which has been exhaustively discussed by Manuel Castells and others (Castells 1996, 2004).

The Nature of Work or Labour

The dominance of the information proletariat means that it also necessary to re-evaluate the nature of labour as such. Traditionally, labour has been considered to be closely associated with the physics definition of work: *Work is said to be done when a force displaces itself in its own direction.*

So, it is easy to identify manual labour with this definition of work. During manual labour, forces are applied to a material body. These forces are displaced while changing the shape, position and/or composition of the body.

But such work also involves considerable activity of the brain: Processing sensory information about the location of objects and the effectors whether the latter are bare hands or most usually a tool operated by the hands; making judgments about when to change the position of material objects with the effectors; consulting past experience about the appropriate degree and pattern of force to apply; the correct orientation and position of the effector relative to the material object; deciding when sufficient force(s) has been applied by judgments about the effects on the material object. The chemical energy expended by the brain during even simple unskilled manual labour is comparable with that consumed by the muscles. In the case of skilled manual labour using machine tools, the amount of mechanical work done by a worker is a small fraction of the energy consumed by the brain. Only in the case of heavy, unskilled manual labour the energy is expended by the muscles significantly greater than that expended in the brain.

So, in any human labour process, energy is expended both to do mechanical labour (work in the physics sense) and also in a mental labour that we can loosely refer to as internal 'information processing and control'. The proportions of each type of energy consumption during a labour process will vary depending on the nature of the labour process itself. For many types of labour, very little mechanical work is necessary, such as in operating a machine tool or a powered mechanical excavator, computer operating and programming, or teaching.

A Definition of the Working Class

From the above discussion the working class can be defined as follows: *The working class is that group in society that lives, principally, by earning wages in exchange for the expenditure of their own energy. The latter process is called 'labour'.*

This energy is stored in the form of chemical energy derived from food and drink, which, in turn, is derived from solar energy captured through the quantum processes involved in photosynthesis. The molecule that actually stores the energy in its final form before use is identical for muscles and for the neurons that compose a brain, namely, adenosine triphosphate (ATP). Most of this aggregate chemical energy is expended in peoples' brains or keeping them at the correct temperature, rather than in their muscles.

This means one must reject 19th century mechanistic interpretations of 'labour', as the purely manual application of forces, that is, as physical work. Even in most forms of manual labour, the majority of energy expended is in mental labour processes. The excess value, or the surplus value, created by the labour of the working class is appropriated by capital, either as a reward to capital-owners for lending the capital, or else to strengthen and extend the capitalist system by maintenance or increased investment.

The Working Class, Globalisation and the Environmental Crisis

Most workers, especially the new information proletariat, tend to work in small groups, making large-scale collective action more difficult through increased isolation. In the extreme case, ICT allows an individual to carry out information creation and processing labour in the confines of the home. There is the example of the computer programmer who is woken up in the night in his remote Scottish Highland cottage in order to allow him to fix the computers controlling the harbour traffic in Hong Kong, without leaving his cottage.

The vastly improved standard of living of the working class in advanced societies is heavily dependent on the availability of *cheap* fossil fuel energy in the form of oil, gas and coal (Kunstler 2005). This era, especially for oil and gas, is coming to an end, with acute shortages expected in 2–3 decades... if not sooner (McKillop 2005). Although there is much discussion amongst environmentalists, it would appear that capitalist economies largely ignore this reality. It is similar to being in a container under conditions of free fall, under gravity, in which one would appear to be weightless, that is, until one hits the ground. It is unclear, and probably unlikely, that the capitalist system can make a smooth transition to a distributed, sustainable renewable energy system before this contact with reality occurs.

The emerging climate crisis and the end of cheap fossil fuel means that there will have to be a reduction of consumption by those sections of the working class in advanced economies and thus a convergence of living standards with those of the newly formed proletariat in the developing world. This may be difficult to sell politically, but it also presents an opportunity to establish, in practice, the universal character of labour as a concrete historical reality.

Since the Industrial Revolution, manual labour has been amplified by applying new sources of energy so as to enormously increase the productivity of labour. Recently, the ICT revolution has produced a similar amplification of information processing, and of thinking processes in general, and has lead to automation in almost all spheres of work. One should also note that ICT has also had a major impact on the productivity of manual labour by considerably reducing the cost of automation. For instance, computer-controlled machine tools are commonplace even in small workshops, and can produce a complex machined object in a few minutes, which would take hours with a manual machine tool. Thus, there is a gain in productivity by a factor of the order of a hundred.

These developments underlie the phenomenon of 'globalisation'. One important contribution of this process is that money, which contain information about value, can be transmitted electronically and therefore almost instantaneously, to any part of the globe. The production and exchange processes themselves can also be globally integrated through these information systems. It is now possible to design a product in one country, transmit the design via the internet to machines operated by low-wage workers in a second country, and then market the product in a third country. It is even cheaper (more 'efficient' to use a current euphemism) to process data in developing countries, data that has been generated in advanced capitalist countries.

One important series of events that has contributed to the intensification of globalisation is the collapse of the pseudo-socialist regimes in Russia, Eastern Europe and China, along with their transition into a market economy. In the case of China, it has occurred without a political regime change. This has made vast reserves of skilled and unskilled labour accessible to capital, as well as new sources of raw materials. Russia, for instance, has the largest reserves of natural gas and now seeks to dominate this global market. One can even say that the long term consequence of the Bolshevik revolution was to create a very large army of new proletarians disciplined, either by circumstance (Russia) or state power (China), to submit themselves to exploitation by private and state capital.

Conclusion: Modern Information Systems and the Survival of our Species

We are now entering a critical era for the survival of our species. The next few decades will decide whether we have a future on this tiny speck of matter, rotating around an average star – the Sun – towards the edge of the moderately sized galaxy of the Milky Way, containing about 200 billion stars. Our galaxy is one of perhaps 150 billion or so galaxies in the known Universe. At first glance, matters do not seem very promising.

The capitalist system now has no competitors to its hyper-expansionist ‘growth for growth's sake’ economic philosophy, with little or no consideration of the finite limit of resources and the finite capacity of the Earth to absorb the detritus of this process. Most critically, the age of cheap fossil fuel is coming to a close and the consequences of its profligate (mis)use are upon us, in the form of climate instability that threatens to ‘cook’ the planet and eliminate many species, including, possibly, our own. Urgent action is required – most climate scientists believe that the move from fossil fuel to carbon-neutral renewable energy technologies must begin within the next ten years.

The seeds of change are paradoxically contained in the ICT revolution. While capital has developed a qualitatively more powerful information system, one aspect of which is loosely referred to as the ‘internet’, capital has not yet been able to bring it under control, and possibly never will, due to its distributed, networked character. ICT represents a synthesis of the main technology elements of capitalist development and it has arrived at a time when a large-scale restructuring of the production system of capital – globalisation – is taking place. Indeed, it has made this restructuring possible. But it also makes possible the transcending of production relations of capital through an alternative form of globalization (alter-globalization), which is based on cooperation, mutuality and sustainability. This alter-globalization is required to solve the multiaspect social and environmental crises confronting the world socio-economic system, due to the anarchic character of the market system of capital.

There is the need to switch to renewable energy technologies: largely solar. These will generally have the character of distributed, small-scale energy production units, whose output can be networked to overcome problems of supply intermittency. ICT can enable this networking of energy production to take place. It can also be used to replace blind market forces by the conscious production of necessary use-values, but without the need for a dominant role of centralized state planning bureaucracy with its attendant self-interested inertia, corruption and privileges.

Most significantly, the majority of proletarians in advanced economies is now information workers who expend most energy using their own information organ, the brain, rather than their muscles. The dominant sub-group of this information proletariat, the knowledge workers, deal in a universal quantity – knowledge – especially scientific knowledge. Because of their unique position, they form the group most aware of the impending climate and environmental crises. In addition, they also possess the skills and knowledge to create the technologies for alter-globalisation. In order to implement such a program, they must form alliances with all other sections of the working class (Hookes 2003, 2009).

Although the new information technologies were created to increase exploitation and social control they also can lead to the exact opposite. They can be the basis of a new system of production on the planet based on the principle of cooperation to meet human needs. Digital ITC can now make possible true social control of production and, at the same time, lead to the global enlightenment of the vast majority of humanity as part of this process.[4]

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[4] Some images (in the form of a diagram) illustrating the main ideas of the present article can be found on the Almanac homepage (URL: http://www.socionauki.ru/almanac/issues/evolution_2_en/#hookes).

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