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The two main processes of technological convergence[1]

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Abstract

From a systemic point of view, technological convergence can be considered a consequence of the progressive formation of technological systems. Furthermore, it could also be compared with the composition of individual and collective human actions, which broaden the respective scope of capabilities and activities (A. Sen). This paper applies these three philosophical hypotheses: on the one hand to convergence between several information and communication technologies (ICTs) and, on the other, to NBIC (nano-bio-info-cogno) convergence, in both cases focusing on the social appropriation of these convergent technologies and on the role of users in processes of socio-technological appropriation. Consequently, technological convergence depends on social convergence among users of different technological systems.

Key words

Philosophy of technology, Converging Technologies, social appropriation.

Resum

Des d'un punt de vista sistèmic, la convergència tecnològica es pot considerar una conseqüència de la formació progressiva de sistemes tecnològics. A més, també es podria comparar amb la composició d'accions humanes, individuals i col·lectives, que expandeixen els corresponents espais de capacitats i acompliments (A. Sen). Aquest article aplica aquestes tres hipòtesis filosòfiques a la convergència entre algunes tecnologies de la informació i la comunicació, d'una banda, i a la convergència NBIC (Nano-Bio-Info-Cogno), de l'altra. En ambdós casos se subratlla la importància de l'apropiació social d'aquestes tecnologies convergents i del paper dels usuaris en els esmentats processos d'apropiació sociotecnològica. Per tant, la convergència tecnològica depèn de la convergència social entre usuaris de diferents sistemes tecnològics.

Paraules clau

Filosofia de la tecnologia, tecnologies convergents, apropiació social.

1. Technological systems and human actions

Human techniques have very different origins and are usually studied separately, according to the atomist paradigm that has predominated for decades in the studies of science and technology. However, a systemic approach has been adopted more recently and this article is based within such a context. In his book *Tecnología: un enfoque filosófico* (1989), Quintanilla established the foundations of the systemic conception of technologies, which states that they shape technological systems rather than working in isolation. Throughout technology's history, examples abound of techniques that have continued to come together and link up, therefore resulting in mixed artefacts. The cart is a good example of this because it combines the wheel, the box or body of the vehicle and the action of the animal, but so are a ploughman's tools, the objects needed to make a stable, the tools for basic carpentry or mining, or the equipment of a fishing boat. These technological items, each with their own particular job, unite to form technical systems in which technologies from different origins combine. Some of these technical systems have been around for a long time and have characterised entire cultures, helping to ensure survival in certain environments. However, many inventions have come about because ideas or technical resources have been transferred from one system to another (Edgerton 2007, p. 270). For example, electricity proves that, once something is invented and becomes established as a technological system (electric power stations, transport systems, accumulators, voltage regulators, power plugs, connections, etc.), many innovations will be generated as a result, from the light bulb to an oven's electrical element, electrical engines and trolley buses and trams and other methods of transport that rely on electrical energy. Combining has always been a rich source of invention, as Leibniz realised, and the history of technology is no exception.

A second idea proposed by Quintanilla is also of great importance, because it forms the basis of this integration of different tools into long-lasting and stable technological systems. According to him, technologies are "systems of human actions intentionally orientated towards transforming concrete objects

in order to efficiently achieve valid results."[2] Therefore, it is not tools that are important but what human beings do with them that matters.

Once technologies have been defined in this way, it is very easy to explain why they converge and how they shape technological systems. Because they are human actions, insofar as such actions can be combined and integrated into one activity, either individual or collective, then the corresponding technologies will converge into technological systems. As a single person or various people coordinate their own actions and compose complex actions (cooperation, collaboration), the tools that facilitate these actions will gradually become integrated as mixed complex objects and, ultimately, technological systems.

As a second hypothesis, we can say that technological convergence occurs because human actions can be combined and give rise to complex actions. In particular, human actions generate collective actions, insofar as they synchronise their individual actions in such a way that a joint action results, something that has often occurred since prehistoric times (hunting cultures). There are technological systems for individual use (a carpenter), but also for collective use (a team or a group of workers). Some of these collective systems have significantly influenced the make-up of specific methods of production, distribution, supply, usage or storage of different types of goods and, therefore, the shaping of stable economic, cultural and social systems. Even opponents of technological determinism must acknowledge that technological systems form an important part of many other systems, including scientific, artistic, literary and educational, as well as military, legal and administrative systems, which also function with the help of specific technological systems. A laboratory, an orchestra, a book, a classroom, a bomber aircraft, a courtroom and an office can be seen and analysed by how their technological systems operate in the aforementioned spaces, which require specific tools and skills, both on an individual basis (know-how) as well as knowing how to integrate them into a joint action or project. We can therefore say, rephrasing Quintanilla, that *the composition of human action forms the basis of various processes of technological convergence, which end up generating technological systems*.

We can also add a third to these two hypotheses (the system approach and the conception of technologies as human action). For this, we can look to Amartya Sen's idea of wealth and poverty relating to areas of capabilities and functionings. Reinterpreting this author's theses, it can be seen that technologies broaden human beings' capabilities and, depending on the extent to which these capabilities are possessed and how they are used, they also increase and enrich people's ability to function. In simple terms, many technologies have been designed precisely to increase and improve human abilities; for example, their ability to move about (cart, canoe, bicycle, motorbike, car, lorry, train, aeroplane, boat, etc.), or perceive (glasses, hearing aids, microscopes, telescopes, etc.). Whoever has a car or uses buses or the underground can work at distance from their home, as millions of people do every day in large cities. These technologies, which are in part industrial and in part social (organisation of the service, signposting, etc.) increase people's ability to move about and, ultimately, other basic ways of avoiding poverty, as they can earn a living through paid work. Urban and industrial culture is based on a range of technical systems that the majority of city-dwellers use on a daily basis: for example, the transport subsystem. This does not just mean cars, trains, roads or rail networks. What's important are the human actions that can be carried out thanks to this multiplicity of intricately linked technical systems and, particularly, the increase and improvement of human abilities that, as a whole, make it possible. This hypothesis works not only for individual abilities and activities but also for collective ones.

This justifies both the usefulness and the importance of technological convergence which, in the first instance, consists of the linking-up of two or more different objects in such a way that the increases brought by each to the area of capabilities add together. When a chain, a pedal and a wheel are joined together, a new technological system emerges based on the convergence and integration of earlier technologies. Once other technical problems have been resolved (balance, direction, braking, etc.), convergence leads to a breakthrough, the bicycle, which afterwards continues to improve thanks to accumulative improvements (tyres, lights, mudguards, etc.). The convergence and integration of several previously existing technologies into a new technological system is one of the main sources of technological innovation, and that is because such combining enables new compositions of human capacity.

Technological convergence deals with systems, actions and human capabilities, both individually and collectively. Certain great social changes have been accompanied by parallel technological changes. Technology is never the cause of social change in terms of objects and tools, but when these are part of systems brought about by both individual and collective human action, it is easier to understand why technological changes are of considerable importance in many processes of social change.

2. Convergence of information and communication technologies

Today, information and communication technologies constitute one of the main examples of technological convergence that has brought about profound social change, normally summarised as the emergence of a new type of society, the *informational society* (Castells 1995-97).

The informational society is often identified with the internet but, in our opinion, it is vital to distinguish between them. Firstly, because the internet is a remote space made up of interconnecting networks and computers and is not a society. Secondly, because the ICT (information and communication

technology) technological system is much more extensive than the internet. Television, radio and digital sound (MP3, MP4, electronic music), electronic money, videogames, multimedia technology, digitalised databases and metabases, virtual reality objects, telecommunication towers and satellites and, of course, remote networks that are integrated within and connected to the internet, go to make up a *new technological system*, the ICT system. This has radically transformed the production, distribution, supply, use and storage of information, facilitating the emergence of a new form of society, the information society, in which information flows become a new kind of wealth. The ICT technological system is not only the internet, although the web is deployed throughout the world. It goes without saying that the network per se is based on the functioning of a highly complex technological system that interconnects computers and flows of information worldwide, and, subsequently, individuals, institutions and different social and economic agents. Both the internet and the ICT system have enormously increased human capability in the fields of information and communication, and their success stems from this, both individually and collectively.

The different technologies integrated into this system have very different origins and functions. What is important is that they have all gradually become compatible with each other over the last few decades. Nowadays, it is possible to watch television on a computer screen or on a mobile telephone, to edit texts and digital photographs, carry out bank transactions through an electronic cashpoint or on a home computer, play videogames, visit virtual museums, attend concerts, chat and access the great depositories of scientific and humanistic knowledge of our age (magazines, digital libraries, etc.). The origins of all these technologies are very different. Many had a military beginning, which has not stopped them from evolving and becoming useful in many areas of civil life. The creation of symbolic technologies (HTML, URL codes, Unicode, jpg, compression, zip, etc.) has played a vital role in these technologies becoming mutually compatible in spite of their heterogeneous origins and designs. Both the internet and the ICT system are the result of many technological convergence processes.

The emergence of an information society has therefore been accompanied by a complex technological convergence that has managed to integrate and make compatible the most relevant information and communication technologies, such as film, photography, radio, television, computing and telecommunications. Each of these was an economic sector in itself and had significant presence in society. Consequently, convergence has not only affected the design of devices but has also involved a process of convergence among many different economic and social agents that have now placed themselves in the same social space, an electronic space or third environment (Echeverría 1999). The media, for example, strenuously resisted the internet in the last decade of the 20th century, giving the web negative publicity. Nowadays, they almost all have their own digital versions and, in particular, many different forms of journalism have arisen (blogs) maintained by individuals and small groups of *communicologists*. ICT technological convergence has therefore not only generated a technological system but also a new social space; this is our basic thesis. In the electronic field, human capacity for action has grown thanks to the fact that long-distance and internet actions are possible, something that earlier technological systems were not capable of achieving.

In short, ICT convergence has all the characteristics we discussed in the previous section: on the one hand, it generates a new technological system, and on the other it broadens the space of human capabilities, on both an individual and collective level, and, finally, it generates a new social space in which no less than a new kind of society emerges and develops. Technological convergence is in direct correlation with a social convergence that has been occurring all over the world and has ended up consolidating a new space for individual and collective relationships. This process is entirely comprehensible if we see technologies as systems of human action, in this case as new capabilities for individual and collection action regarding information and communication.

When the United Nations organised the World Summit on the Information Society (Geneva 2003 and Tunisia 2005) and managed not only to get all the countries of the world to participate but also to agree on an extensive joint declaration and action plan, technological convergence was defined as a process of social convergence of international importance but of slow and difficult development, even though it continues to occur. ICT convergence has many different aspects: it is clearly technological but is also economic, social, cultural, legal (it is necessary to make internet legislation compatible) and political.

3. Technological convergence and civil society

As an instrument is used over and over, we can verify whether it's suitable for the function for which it was intended and think of improvements. Many experienced users of certain tools have come up with different ways to ensure these tools fulfil their function more quickly, with greater accuracy or efficiency, with greater ease or at a lower cost. Using technological objects means that users not only evaluate the advantages provided by these instruments but also the potential inconveniences and faults (bugs). Some of these users, the 'experts', come up with possible improvements and, in some cases, design them, implement them and put them to the test. This shows how important users are in processes of technical innovation, particularly expert users (leading users). According to Von Hippel (*Democratizing Innovation*, 2005), and as a fourth hypothesis, we can say that technological innovation is not just generated by factories and R&D departments. Suppliers, distributors and users are also sources of innovation and the latter in particular generate a very important type of social innovation, 'distributed

innovation'. In other words, once technological convergence has been accepted by society, it is users who will improve the system and generate different forms of social innovation (e.g. SMS messages, Linux, Wikipedia, social networks, etc.).

Since technologies are systems of human action and not just objects, cooperation and interaction between people lead to new actions and therefore new technological instruments to carry them out. Society not only receives and accepts (or rejects) the innovations proposed by firms and other R&D actors, it also generates innovations itself. The small or large improvements introduced are tested by many users and innovations spread very quickly because users themselves make them fashionable. As a result of these *human processes of technological convergence*, new tools and new practices ultimately appear, some of which become standards in the corresponding social or professional sector. For an innovation to be accepted socially and become a instrument of current use, it must be widely used, so that its usage becomes generalised and the corresponding object becomes a social norm. We can therefore say that *users themselves give rise to technological convergence*. Moreover, users of technology that has been previously tested through habitual use can be sources of technological innovation. This has been the case with the internet, as Manuel Castells has often highlighted, and it continues to be the case at the end of the first decade of the 21st century, as Web 1.0 gives way to Web 2.0 (Benkler 2006). The latter is characterised by a strong impulse called bottom/up, since users contribute the content and generate particularly active social networks.

We won't insist on this point, preferring instead to merely point it out, but it could be said that ICT convergence is entering a new phase in which users are the ones who promote convergence. This involves an important step towards the democratisation of the information society, although a lot still remains to be done, which can be summarised in one: it is necessary to build a "telepolis" in electronic space, affirming the primacy of *res publica* (public property) in remote networks as a whole. Web 2.0 users have started generating authentic civil spaces where a lot of people converge on the internet to meet one another and this is the beginning of constructing a global remote city. As systems of governance arise in these public networking spaces, the "telepolis" will gradually adapt.

4. Nano-bio-info-cogno technological convergence

Inherent to the start of the 21st century is a new process of technological convergence that primarily affects nanotechnologies (*nano*), biotechnologies (*bio*), information technologies (*info*) and cognitive sciences (*cogno*). One of the novelties of this new integration of technological systems concerns the scale at which the aforementioned convergence can be achieved: in a nanocosmos, that is to say, at a nanometric scale. The technological system we hope to develop, namely the NBIC (nano-bio-info-cogno) system, will not only be microcosmic but also nanocosmic and, therefore, imperceptible to view. The nano-objects/tools that go to make up the NBIC system cannot be manipulated by just any human being, since it acts at a scale of the world that, albeit real, only very recently became accessible to human perception. And this is due to the invention of tunnelling and atomic force microscopes, which have improved our perceptive capacity and enabled the representation of phenomena taking place at a nano level, as well as being able to handle small particles, altering the structure of atoms, molecules, DNA and cells by engineering materials in the nanocosmos. These two microscopes, and other complementary technologies, have made it possible to manipulate material at both an atomic and molecular level, something which no other technological system had managed. Nanotechnology has therefore broadened human capabilities, expanding them from the usual mesocosmos, where we normally perceive and act, to this nanocosmos we could not perceive before and now we can, and where we could not intervene before and now we can. NBIC convergence supposes a new example of expansion in the scope of human capabilities. Needless to say that nanotechnologies offer huge possibilities for innovation since different types of matter, both alive and inert, can be artificially reinvented on this scale.

Technologies don't just try to understand the world (observing, analysing and explaining it, and predicting phenomena and events...), as has always been the objective of modern science. They also try to transform it. The North American NBIC programme clearly states this in the title: *Converging Technologies for Improving Human Performance*.[3] What we want to understand is what the world is like at a nano level and, to do so, much basic research is required. That said, the ultimate aim is not knowledge but the improvement of human performance. "Converging technologies could produce enormous improvements in human abilities, such as social benefits, improving the nation's productivity and also the quality of life".[4] Therefore, supporters of NBIC convergence intend, right from the start, to increase human capabilities (e.g. perceptive, cognitive, communicative), as well as corporate productivity and competitiveness.

The overall aim is to modify the atomic, molecular and cellular structure of various already inert or alive materials and generate nanoparticles and nanotools that carry out functions that can be biological (attacking the DNA of carcinogenic cells), informative (to store gigas of information on a nanochip) or cognitive (using nanosensors and nanotransmitters, without giving up on improving more complex cognitive abilities). For this, a lot of basic research is necessary, since the laws of quantum mechanics apply on a nano scale and the properties of nanomaterials and nanoparticles are therefore very different to those of their counterparts at a meso- and microcosmic level. Some of these properties can be beneficial for people, while others can be harmful. It is a matter of exploiting this knowledge that must be generated and produce technological breakthroughs and innovations. On our part, we can say that the society will

always have the last word, either accepting or rejecting the innovations proposed. At the moment, there are signs of a lack of confidence and the first risks from NBIC convergence have been noted. In any case, and without exaggeration, nanotechnologies have allowed us to discover new dimensions of the material world, so that NBIC convergence will have a similar or greater importance than the aforementioned ICT convergence.

Nanotechnologies allow us to modify the basic properties of matter (cohesion, weight, duration, electrical conductivity, light absorption, etc.). The way in which they converge with biotechnologies means that the structure and properties of cells and organisms are modified, with implications for medicine, pharmacology, genetics and life sciences in general. Nano-info convergence opens up the possibility of numerous innovations in the ICT sector: quantum chips, nanosensors, nanodetectors, etc. The programme's final objective, related to cognitive sciences, consists of no less than the *conquest of the brain*, by implementing, among others, perceptive, cognitive, communicative and mnemonic capabilities of the human brain. If it were possible to implement neurone capabilities by inserting nanodevices to stimulate them, the different abilities of the human brain would be modified and, hypothetically, improved. NBIC convergence is one of the great objectives of contemporary technoscience because, if it is accomplished, it will bring radical changes to the capabilities of human action, as well as new objects and tools resulting from such convergence. NBIC convergence from the US is particularly Faustian. The ideology of transhumanism can be found everywhere but we will analyse these aspects here.

The technological convergence programmes that have been developed in different countries since 2001 have *innovation* as their general goal. The innovations promoted by the North American NBIC have governments as their ultimate goal (defence, administration), markets (efficiency, productivity), nation (worldwide leadership), society (improvement of different services) and people (better sensory and cognitive capabilities, direct communication between brains, increased life expectancy, treatment for physical and mental decline, etc.). It is not about investigating how the world is but rather transforming and improving it. On a global level, the NBIC programme has been designed to radically change markets and societies, introducing innovations that are extremely competitive and acceptable for all clients and consumers. Ultimately, the aim is to modify the habits and behaviours of individuals so that they incorporate the innovations generated by the different NBIC programmes into their daily lives. It is in this area that a new difference between science and technoscience lies. The latter surpasses the Baconian programme, which merely advocated the control and command of nature. Technoscience, however, is aimed at the transformation of people and society. That is why the relationships between technoscience and society are complex. Some technoscientific innovations are well received, others not. It is vital to identify, analyse, assess, prevent and manage risk in technoscientific policies. It is especially important to pay attention to users' criteria. Since they use NBIC technologies, much knowledge will be gained and social innovations will appear in the corresponding sector, as was the case with the ICT technological system.

The European report on NBIC convergence (2004) also leans towards a deep social transformation, but of a different nature. It has been called "Converging technologies for the European Knowledge Society"[5] (CTEKS) , already highlighting the main goal that must be attained to promote technological convergence: to contribute towards the construction of a European knowledge society that, in line with the strategy *e-Europe 2003*, *e-Europe 2005* and *i2010*, converts the European Union into a worldwide leader of knowledge in 2010 (Lisbon Agenda 2000). Irrespective of the difference in their ultimate objectives, the EU and the US share this basic thesis: innovation is essential. In the document entitled: "Towards a European strategy for nanotechnologies"[6] it clearly states that "European excellence in nanosciences must finally be translated into commercially viable products and processes." [7]

Despite innovation being the priority, the European documents, more than the North American ones, insist on the need to investigate the risks:

"Nanotechnology must be developed in a safe and responsible manner. Ethical principles must be adhered to and potential health, safety or environmental risks scientifically studied, also in order to prepare for possible regulation. Societal impacts need to be examined and taken into account."[8]

Many other countries are promoting similar initiatives: Japan, Korea, Taiwan, China, Russia, Australia, Canada, India, Israel, some Latin American countries, New Zealand, the Philippines, Singapore, South Africa, Thailand, etc. Each country has its own strategies. The same can be said of the companies that fund research, development and innovation in the NBIC sector. *Converging Technologies programmes* not only try to revolutionise scientific and technological activity but also scientific policies and business and industrial activity. To carry out these programmes, a large dose of interdisciplinary work in the research teams, as well as the intervention of many other economic, political, social and legal agents, not forgetting the military, is necessary. The Nanotechnology National Initiative, approved by the US in 2000, had been requested by various US defence agencies that had been at the forefront of research, technological advances and innovation throughout the 20th century. In this case, technological convergence requires the integration of very different social and economic agents into a same technoscientific agenda, which is clearly defined in the US and EU's Converging Technologies programmes.

5. Conclusions

The hypotheses we proposed at the beginning are valid for interpreting these two great processes of converging technologies that are already in full development: the ICT system,

already consolidated, and the NBIC system, which has provided us with significant results but whose medium- and long-term future still remains to be seen. It is necessary to analyse each of these technological systems, the majority of which have appeared in converging processes and many of which have been promoted by the same users. It is also necessary to study the converging processes among technologies and existing systems, as will be the case with ICT (YouTube and digital television, for example), or what NBIC convergence will be like. From the above comments, although too brief and succinct in many cases, we may conclude that, in general, technological convergence always has other facets (e.g. social, economic, culture, of companies and institutions, of users, etc.), because technologies do not limit themselves to being merely tools and objects but also consist of systems of human action. Converging technology entails a convergence of human action and therefore a collaboration or cooperation between corresponding agents, be they individuals or collectives.

Technologies are never separate from the societies that promote or use them. In fact, many of the changes, improvements and innovations of technological systems come from society itself, in particular from users. With ICT and NBIC technologies, what is important is the social appropriation of the aforementioned technologies, i.e. their incorporation into people's daily lives. When this happens, a technological system integrates into a culture and influences it, but without determining it at any point. Because they are systems of human action through which the aim is to achieve valuable results, technologies and their future depend on the value that human beings apply to these actions, both in carrying them out and also in assessing their results. Ultimately, the essence of the different converging technologies consists of a confluence of opposing values and, if necessary, the integration and generation of new value systems. Each technological system has an underlying system of human values, both individual and collective. Technologies are therefore social entities. In terms of social technologies and technosciences.

Notes

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2 Quintanilla, *op. cit.*, p. 34.

3 M. C. Roco and W. S. Bainbridge (ed.), 2001.

4 M. C. Roco and W. S. Bainbridge, *op. cit.*, p. IX.

5 A. Nordmann (coord.), 2004.

6 Brussels, 12.5.2004, COM(2004) 338 end.

7 *Ibid*., pàg. 3.

8 *Ibid*.

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