AMO - Advanced Modeling and Optimization, Volume 19, Number 2, 2017

Analysis and utilization of knowledge acquisition within the framework of ubiquitous technologies

Georgios Constantine Pentzaropoulos[1]

Mathematics and Information Technology Unit,
Department of Economics, University of Athens,
1 Sophocleous Street, 10559 Athens, Greece.

Knowledge is inherently limited.
Imagination encircles the world.
- Albert Einstein

Abstract

Life in the 21st century is characterized, amongst other developments, by the proliferation of new technologies. These technologies are now everywhere, surrounding our lives and work, hence the name *ubiquitous.* In this article we examine the importance of *knowledge* acquired via our interaction with these new technologies. We first introduce the concept of *Infoworld,* i.e. a world of information from which knowledge can be extracted and used appropriately. Then, we focus our attention on the opportunities from the use of technologies within our still evolving information society.

Keywords: Internet; man-machine communication; codification of information; knowledge; Infoworld; reliability; entropy.

MSC Classification: 03A10, 60G07, 68P30, 37F99, 94A17.

1. Introduction

The so-called new technologies of our time, also formally known as information and communication technologies (ICTs), are everywhere. They permeate almost every human activity: in working environments, at home, and on the go (mobile). ICTs are now considered essential elements of many contemporary information economies and societies. Because of their *ubiquitous* nature, they are seamlessly integrated into virtually all human activities. Support of their function is provided by large-scale computer networks and sophisticated man-machine interfaces. All of these elements facilitate the process of *knowledge* acquisition and utilization.

---

[1]*Professor of Information and Communication Technologies. Email: gcpent@econ.uoa.gr.*

Recent research shows that ICTs are now calling into existence a new, inclusive, economic and social order [1]. Many contemporary researchers, e.g. most notably Manuel Castells [2], have focused on the so-called network or Internet societies. Their work shows the implications of the Internet and the diffusion of an enormous range of ICT applications and services. The World Summit on the Information Society (WSIS), actively supported by the United Nations, is a prime example of the current discussions about the opportunities as well as limitations of ICT usage within public and private organizations, in an ever globalizing world [3].

The present article is structured as follows. After this brief introduction to ICTs, we examine the scope and use of ubiquitous technologies in the "internet age". Thereafter, we discuss the problem of information codification and its transformation into "know-how" or else *actionable knowledge* [4, 5]. The important role of the *Infoworld* is also stressed in these proceedings, which brings about issues of opportunities as well as concerns in the utilization of knowledge. The article ends with a summary of our conclusions.

2. The ubiquity of information and communication technologies

ICTs are now everywhere surrounding almost every human activity. Their ubiquity makes them "invisible" to us; yet we use them every day, as a new commodity like the electrical power grid and the telephone service. Researchers from IBM expect that *Cloud Computing* (see below) will become a mega-utility service within the next few years [6]. Also, the European Commission has announced its strategy for this technology within the framework of its *Digital Agenda for Europe.* This agenda is aimed at enhancing Europe's economy by delivering sustainable economic and social benefits from a digital single market [7].

Likewise, the so-called *Internet of Things* (see below) presents a tremendous potential for many economic and social activities. The Organisation for Economic Co-Operation and Development (OECD) recently reviewed the state of affairs with this technology [8]. It concluded that ICTs now permeate countless aspects of the world economy. It also acknowledged that ICTs are transforming the ways social interactions and personal relationships are conducted. Further, it is stated that devices and objects are increasingly connected to form the *Internet of Things* (IoT).

The trend towards an all-round connectivity in everyday life is already evident. Portable computers and tablets are widespread and the same is true of smart TVs. Mobile phones, digital cameras, light bulbs, and many home appliances all have built-in intelligence. E-book readers have WiFi, WiMax or 4G connections, and cars are now fitted with navigation systems. The so-called "smart life" is already here [9].

The driving forces behind the pace towards a “ubiquity of technology” can be identified as follows [10] (see also Figure 1):

A. *Nanotechnology.* Physical matter on atomic and molecular scale. Structures are about the size 100 nanometres. Electronic elements such as gates are then constructed according to that size.

B. *Fiber Optics.* The basis of all modern telecommunication infrastructures. Internet-based services like electronic governance, commerce and business, distance learning, and telemedicine require the power and reliability of fiber optics technology. Notable is the trend towards fiber to the home (FTTH).

C. *Big Data.* Digital content produced by human interaction with ICTs, e.g. via the social media. Then, a variety of communication systems, sensors and mobile devices may transmit considerable volumes of such data. Processing is accomplished mainly by means of analytics.

D. *Autonomous Systems.* Electronic systems able to search and perceive their environment, translate perceptions into actions, without human supervision. Examples are intelligent robots for the monitoring of production.

E. *Cloud Computing Systems.* Large computing installation enabling access to resources across the Internet. Storage of data and information processing take place in a “cloud” located far away from the users’ premises. Services are fully configurable according to users’ needs.

F. *Internet of Things.* A technology utilizing the concept of machine-to-machine communication (M2M). A new technological paradigm in which end-to-end communication is accomplished without human intervention. The so-called “things” are entities of either physical or virtual nature. They use the available infrastructure seamlessly via built-in intelligent interfaces.

G. *The Semantic Web.* An extension of the world-wide web that allows network computers to understand demand of running applications *a priori.* Semantic Web technologies help increase the efficiency of organizations and provide services based on virtual operating systems.

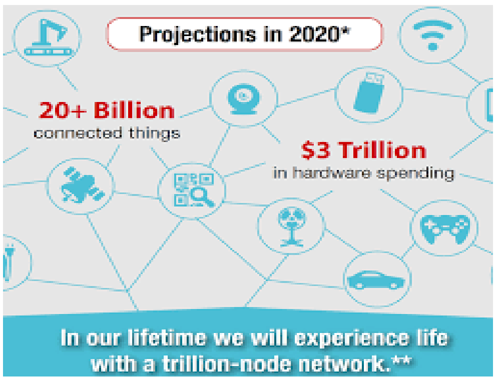

Figure 1: Possible expansion of computer networks (OECD)

The above developments gradually alter our perception of the world. The first point to note comes under the heading of "digital convergence". This is the result of the successful merge of previously separate technologies, such as voice, text, audio, and video forms all of which are now converted into digital form and transmitted through global networks. A second point concerns the "ubiquity of technology", as noted. This is nowadays promoted via the so-called *ubiquitous digital networks,* a grand vision expected to remove remaining barriers between fixed and mobile networks. Finally, a third point concerns world-wide reforms presently taking place in both the electronics and telecommunications industries.

Therefore, the forces of Information and Communication Technologies (ICTs) influence modern life. Within the concept of the *Infoworld,* as explained below, data are the building blocks of information. Semantic information is regarded in this work as a *prerequisite* for knowledge. Then, new knowledge can always be created from existing knowledge by the application of logical inference.

3. Encoded information and knowledge

Information processing typically refers to the acquisition, display and dissemination of information stored in databases. Of course, the term information is much older than the more modern term "information age". In popular usage, information refers to a multitude of facts and opinions of daily life conceived regardless of the medium involved in such exchanges. For the purpose of this work, we limit the meaning of the term "information" to that entity obtained via *human-computer communication.* Further, we consider such communication to take place within a so-called *Infoworld,* the meaning and structure of which is explained below.

3.1. *The Infoworld*

For the purpose of this study, we consider that any information comes from data distributed across an entity named *Infoworld.* Our view here includes randomly distributed groups or else clusters of people who interact with his world. This is defined as a *ubiquitous* world of information which is provided by the convergence of new technologies (ICTs).

The above sketch of the *Infoworld* is, in our view, compatible with the principles of Epistemology as these are briefly discussed below. In that context, what the users of the *Infoworld* perceive as something new is connected to what they already know, i.e. to their background knowledge. There is a cyclic arrangement between what is new and what is already known. Information is then assumed to be transferred via bit-streams the content of which is eventually converted into user's perceptions. These perceptions can be *transformed* into knowledge by means of logical inference.

However, it must be understood that such knowledge acquisition often contains elements of *uncertainty.* Hence, any knowledge gained via interaction with sources within the *Infoworld* should always be the subject of inspection.

Any person interacting with other persons or systems is assumed to be capable of acquiring some kind of *knowledge.* Then, information organized according to logical relationships can be said to constitute a *body* of knowledge. [Knowledge can, in certain cases, lead to wisdom; but we will not pursue this matter here.] Skills are very important in this discourse. They are the means by which the exploitation of information can lead to practical or "know-how" knowledge. Information has the ability to permeate both the physical and mental worlds, thus creating "images" familiar to many of us, the ordinary users.

The existence of an *Infoworld* is taken for granted in this study. Such existence is in accordance with known empirical evidence from the discipline of information systems and networks. A similar name for the *Infoworld,* namely *Infosphere,* was recently proposed by Floridi from the Oxford Internet Institute [11]. In Chapter 3 of his book *"The Fourth Revolution",* Floridi writes that the *Infosphere* is neither entirely virtual nor only physical; and that it is a good reminder of how influential ICTs are becoming in shaping our identities.

3.2. *Epistemological and mathematical considerations*

Epistemology is a branch of philosophy which, in our view, is more closely related to the natural sciences than any other theoretical subject. Its main purpose is the study of the nature and scope of knowledge [12, 13]. It analyzes the nature of knowledge and also examines the means for the production of knowledge, e.g. skills required in our information age. Epistemology addresses important issues pertinent to the creation and diffusion of knowledge in many areas of human inquiry. It is concerned with many fundamental questions some of which appear below:

- What is knowledge and by which means can it be acquired?
- Can knowledge and its entropy be modelled mathematically?
- How can knowledge be used for profit, e.g. in organizations?

The above questions are of central importance within this study, and thus we try to address them below.

3.2.1. *Knowledge Acquisition*

As mentioned already, knowledge can be viewed as the processing of information by means of logical inference. The source of information is the *Infoworld.* This complex structure looks like a large network with many nodes. Thus, we may write:

Data (forms of bit-streams) **[plus]** *Codification* **[plus]** *Processing (e.g. by means of computer languages and algorithms)* **[plus]** *Control and Renewal of Content* $\Rightarrow$ *Information* $\Rightarrow$ *Knowledge.*

This is, of course, a technical explanation compatible with the scope of this article. But, as it happens, knowledge acquisition is a much more complex matter involving *cognition* and the notion of *consciousness.* Perception, and thus practical knowledge, are intrinsically linked with the notion of consciousness. However, as recently shown by Hameroff and Penrose [14, 15], the mechanism by which consciousness occurs in the human brain is still unknown. These two eminent scientists proposed that human consciousness depends strongly on a series of biologically "orchestrated" coherent *quantum processes* in collections of microtubules within brain neurons. Their theory is known as "orchestrated objective reduction" (Orch OR). Microtubules couple to and regulate neural–level synaptic functions, and as such they may be an ideal model of future quantum computers.

However, there are several questions here. For instance, as elaborately noted by Susan Blackmore [16]: "How on earth can the electrical firing of millions of tiny brain cells produce my private, subjective, conscious experience?" Let us remember that the human brain as a kind of neural network with very complex circuitry. Modern biology has shown that the human brain contains several billion neurons and trillions of synapses. Artificial neural networks (from AI research) come nowhere near those figures. Further, we must consider changes in memory. As Nobel laureate Daniel Kahneman writes [17]: "A general limitation of the human mind is its imperfect ability to reconstruct past states of knowledge or beliefs that have changed. Once you adopt a new view of the world, you immediately lose much of your ability to recall what you used to believe before your mind changed."

3.2.2. *Steady-State Analysis*

When communication with the *Infoworld* is within normal range, i.e. there are time intervals in which users experiences match their expectations, we may indicate those intervals to be in steady-state. Expressed mathematically, we may have:

$$\textit{Time Intervals: } T_{S1} \Rightarrow T_{S2} \Rightarrow T_{S3} \quad (\ldots.) \qquad (1)$$

where the above are random time intervals of user-system communication.

The exponential distribution with parameter α and probability density function $f\,(T, t)$ is commonly used in such communications. The above p.d.f. is always a strictly decreasing function of t. Hence, we may write:

$$P\ \{\ 0 \leq T \leq \Delta t\ \} > P\ \{\ t \leq T \leq t + \Delta t\ \} \qquad (2)$$

for any positive values of t and Δt .

The exponential distribution also has the so-called memoryless property:

$$P\ \{\ \Delta t > t + \Delta t\ \mid \Delta t > \Delta t\ \} = P\ \{T > t\} \qquad (3)$$

again for any positive values of t and Δt .

Stochastic analysis shows that the minimum of a series of independent exponential random variables also has an exponential distribution. Let $T_{\min}$ be the the random variable representing the minimum of the values of time intervals. Then, $T_{\min}$ also has an exponential form with parameter α as follows:

$$\alpha = \sum_i \alpha_i \quad (i = 1, 2, 3, \ldots.) \qquad (4)$$

Let us also assume that the interarrival times have the exponential distribution with parameter $\lambda > 0$. Therefore, arrivals occur according to a Poisson input process with parameter $\lambda > 0$. In this case, $\lambda\alpha$ is the mean arrival rate and T (t) is the number of arrivals in elapsed time (t). Therefore, for all positive values of t and for a small Δt we may write:

$$P\ \{\ T\ \leq t + \Delta t\ \mid T > t\ \} = \alpha\Delta t \qquad (5)$$

If there are (n) different types of users with parameter λ_i, then their aggregated input is also a Poisson process with parameter $\lambda_i\ = \lambda_1 + \lambda_2\ +\ \lambda_3 + \ldots. + \lambda_n$. Assuming that each user has a probability p_i with parameter $\lambda_i\ =\ p_i\,\lambda$, we can see that:

$$\sum_i p_i = 1 \quad (i = 1, 2, 3, \ldots.) \qquad (6)$$

3.2.3. *Entropy Analysis*

Entropy has its roots in physics, particularly in thermodynamics. In physics, the entropy of a system is defined as a measure of its intrinsic *uncertainty.* This notion has become familiar in our times thanks to the pioneering works of Claude Shannon [18] and Norbert Wiener [19]. Practically speaking, entropy is a measure of system disorder which signals a clear deviation from its steady-state. Following a recent work of ours on the modelling of knowledge acquisition via content-related Internet sources [20] we may initially express *information entropy* as a measure associated with a set of possible system states. Then, the following formula:

$$S = \sum_{i} p_i \log p_i \qquad (7)$$

measures the average entropy of a system in the presence of probabilities $\{p_i\}$ that correspond to a series $\{i\}$ of system states.

When user communication with the *Infoworld* takes place, information entropy underpins this activity. Also, from previous discussions, we may think of entropy as a measure of the amount of uncertainty about a possible outcome. Similarly, we may consider information as a measure in the reduction of uncertainty after observing some kind of logical connection or *hint* related to the same outcome. Having a hint helps the observer to form an opinion about the chance a specific outcome has to occur given a number of possible outcomes. Such an opinion can then be described quantitatively in terms of probabilities.

Let us consider a system S and an associated hint h. Then, we may express the entropy $E(S)$ of system S as follows:

$$E(S) = -\sum_{s} p(s) \log p(s) \qquad (8)$$

where $p(s)$ is the probability of observing state s.

We can also express the information acquired with the help of hint h by classical arguments such as those found in information theory. This acquired information is quantitatively the reduction in uncertainty within the system. Further, we can express the conditional entropy $E(S|H)$ of system S after the observation of hint h as:

$$E(S|H) = -\sum_{h} p(h) \sum_{s} p(s|h) \log p(s|h) \qquad (9)$$

where $p(h)$ is the probability of observing hint h and $p(s|h)$ is the conditional probability that system S is in state s, after the observation of hint h. $E(S|H)$ measures the residual uncertainty of system S. Therefore, the difference:

$$A(S) = E(S) - E(S|H) \qquad (10)$$

shows the extent by which hint h reduces the uncertainty. $A(S)$ is named here the *acquired information* and its measured value extends from zero - when the elements in the right-hand part of the above equation are equal - up to some positive number.

4. Knowledge utilization

Interest in the study and utilization of information has shown an exponential growth in recent years. The subject of "information", in many variants, can today be found in a number of diverse scientific disciplines: mathematics, philosophy, physics, biology, computer science, communications and networks, and management. Particularly, in economics information is nowadays considered as a *resource* with economic value which is comparable with the traditional resources of material, capital, and labour. Thus, information is regarded as a significant and valuable non-material resource. The end-result of this remarkable development is the emergence of what we now call the *Information Society.*

Within the European Union, as well the OECD, knowledge has in recent years become a key element in forming policies for a better economy and quality of life. According to Eurostat the digital economy is growing at seven times the rate of the rest of the economy and much of this growth has been fuelled by broadband Internet. Launched in May of 2010, the European Digital Agenda is aimed at enhancing Europe's economy by delivering sustainable economic as well as social benefits from a digital single market (see Figure 2).

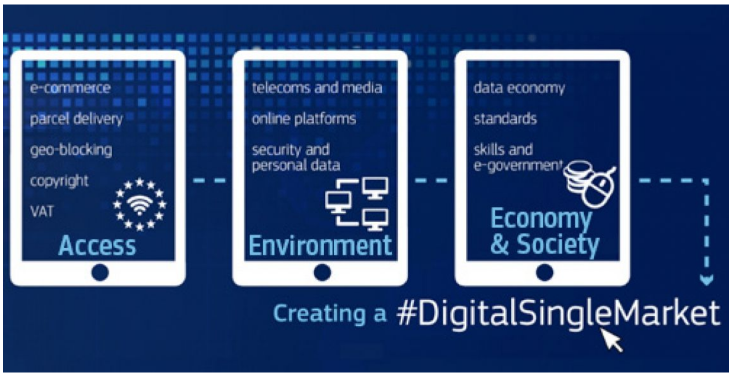

Figure 2: Vision of the European Digital Single Market (European Commission).

Another important point, which follows from the recent exponential increase of information-intensive activities, is that information can also be seen as a *commodity.* Economists, when they talk about commodities, typically think of such utilities as electricity, telephony, natural gas, and so on. But recent developments in electronic communications and computer networks suggest that newer technologies, such as Cloud Computing and the Internet of Things, can also become significant *utilities* in the near future, in addition to the above-mentioned ones.

In this new environment, perhaps the most important element for a developed or developing economy is no longer the material or labour, but *actionable knowledge.* This is a kind of knowledge with a practical flavour as well as purpose. The new economy of our times needs knowledge workers who can create wealth using their own *intellectual capital* as the main asset. Traditional money capital is still important but its value is becoming less significant in the networked world of ours. However, there a problem here. Because knowledge is - by its nature - an intangible asset it cannot be measured with traditional methods. Knowledge is still not sufficiently understood and, thus, its value as a commodity remains unclear.

Knowledge can also be regarded as awareness of the surrounding reality. In this work we are more concerned with “know-how” knowledge as this is better suited to the characteristics of the *Infoworld,* as described previously. Many of the features of “know-how” knowledge are now central within the world’s economy. They enable organizations to disseminate knowledge across their employees and other partners. Knowledge is considered the key to competitive advantage.

Knowledge of empirical facts in the context of “know-how” involves perception, i.e. use of the senses. Further, it requires *reasoning,* i.e. the analysis of information involved as well as inference. Logic is a major part of this process as is memory. Memory allows us to retain a fact that we knew in the past and use it subsequently. The successful use of practical knowledge also requires that the original information acquired be reliable. Empiricism emphasizes the role of experience; this role is particularly useful in our study, as we focus on perceptions from the *Infoworld.*

5. Concluding Remarks

The concepts and results introduced in this article focus on the subject of knowledge, and in particular *actionable knowledge,* within a new framework made possible by the so-called ubiquitous technologies. Within this framework the important role of the *Infoworld* has been shown. Especially in the realm of business and organizations, knowledge has been shown to be the key for competitive advantage.

Know-how knowledge is often ignored in traditional epistemology; however, it is very important in the context of the so-called “new economy”. Nowadays, we see a shift from the established term information society to the term *knowledge society* which, of course, includes the world’s economy. Also, the term *knowledge economy* appears frequently in the economics and management literature.

Our regular interaction with the external world creates a new kind of information environment named *Infoworld* in this study. This new world is the “product” of information systems and networks, which together create a web of new knowledge. We have already stressed that knowledge should be the logical “product” of reliable online information. In a world of *ubiquitous* knowledge, we need to look beyond the uses of networks and ICT applications; we should rather focus on the conditions that encircle these uses for the benefit of world’s economy and society.

Acknowledgements

The work described here has been financed by grant "elke/70/11698" awarded by the Research Committee of the University of Athens, Greece. Also, many thanks are due to Dr. Neculai Andrei, Chief Editor of AMO, for his excellent cooperation.

References

[1] Mansell, R., Avgerou, C., Quah, D. and Silverstone, R. (2007). *The Oxford Handbook of Information and Communication Technologies.* New York: Oxford University Press.
[2] Castells, Manuel (2001). *The Internet Galaxy: Reflections on the Internet, Business and Society.* Oxford: Oxford University Press.
[3] UNESCO (2005). *Towards Knowledge Societies.* UN World Report, Paris.
[4] Argyris, Chris (1996a). "Actionable knowledge: design causality in the service of consequential theory". *Journal of Applied Behavioural Science,* 32 (4), pp. 390- 406.
[5] Argyris, Chris (1996b). "Actionable knowledge: intent versus actuality". *Journal of Applied Behavioural Science,* 32 (4), pp. 441-444.
[6] Walker, Grace (2014). "Cloud computing fundamentals: A different way to deliver computing resources". *IBM publication.*
[7] European Commission (2014). *The EU explained: Digital Agenda for Europe.* Luxembourg: Publications Office of the European Union.
Link: http://ec.europa.eu/digital-agenda
[8] Organisation for Economic Co-Operation and Development (2015). *Digital Economy Outlook 2015.* OECD Publications, France.
[9] Botta, Alessio; de Donato, Walter; Persico, Valerio; Pescapé, Antonio (2016). "Integration of Cloud computing and Internet of Things: A survey". *Journal of Future Generation Computer Systems,* Volume 56, pp. 684-700.
[10] Pentzaropoulos, Georgios C. (2016). "New technologies, the Infoworld, and the need for actionable knowledge", *E-Logos Electronic Journal of Philosophy,* Volume 23(2), pp. 51–61.
[11] Floridi, Luciano (2014). *The Fourth Revolution: How the Infosphere is Reshaping Human Reality.* Oxford: Oxford University Press.
[12] Pritchard, Duncan (2008). *What is this Thing Called Knowledge?* London: Routledge.
[13] Klempner, Geoffrey (2007). *The Possible World Machine*. E-book available at: [http://www.philosophypathways.com/download/Possible_World_Machine.pdf]

[14] Hameroff, S. and Penrose, R. (1998). “Quantum computation in brain micro tubules? The Penrose–Hameroff Orch OR model of consciousness”. *Philosophical Transactions of The Royal Society A,* Volume 356, Issue 1743, pp. 1869-1896.
[15] Hameroff, S. and Penrose, R. (2014). “Consciousness in the universe: A review of the ‘Orch OR’ theory”. *Physics of Life Reviews,* Volume 11(1), pp. 39-78.
[16] Blackmore, Susan (2005). *Consciousness.* Oxford University Press.
[17] Kahneman, Daniel (2011). *Thinking, Fast and Slow.* Penguin Books.
[18] Shannon, Claude E. and Weaver, Warren (1998). *The Mathematical Theory of Communication.* University of Illinois Press, Reprint.
[19] Norbert, Wiener (1988). *The Human Use of Human Beings: Cybernetics and Society.* Da Capo Press, 1988, Reprint.
[20] Pentzaropoulos, G.C. (2014). “Conceptual framework for modelling knowledge acquisition via content-related Internet sources”. *Advanced Modelling and Optimization,* Volume 16(1), pp. 199-210.

Author Information

Georgios Constantine Pentzaropoulos
Professor of Information and Communication Technologies in the Department of Economics, University of Athens, Greece. Formerly: Research Associate at UMIST, Manchester (UK). Subsequently, Honorary Research Fellow at UCL, London (UK). Research areas: human-computer interaction, analysis and modelling of information systems, knowledge economy and society, philosophy and technology.