Why Weren't Ants the First Astronauts?

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ABSTRACT

Ants are fantastic animals. For 40 millions years they have developed cultural skills such as joint parental care, joint hunting, cooperation and labor division, cattle husbandry, and agriculture. In biological terms, they form *superorganisms* where individual ants act like cells in an organism. Based on their cooperative skills they are the pre-dominant life form in their ecological niches and resemble roughly the same total biomass as humans do. What impresses on the one hand, can also look very disappointing on the other. *Humans* developed large-scale collaborative skills significantly later; for example human agriculture evolved around 10 000 years ago. That being said, it is humans who have invented telephones, computers, and the Internet, and who have visited the Moon. In this article we use our insights on Internet and Web technology to explain this anomaly. We also project forward from this proposed explanation to consider the potential further developments embodied in a perceived new superorganism, a 'brain for all mankind' which humans are developing for the first time in their history.

Keywords: Internet, World Wide Web, Web 2.0, Semantic Web, ICT development.

1. INTRODUCTION

For most of the time that humans have existed, communication has been only local. Communication beyond the boundaries of small social habitats was minor and notably slow and unreliable. During the last 200 years we have seen the explosive development of Information and Communication Technology (ICT) – telegraphy, telephones, radio, televisions, mobiles, computers, PCs, laptops etc. have begun to significantly re-shape our daily life. ***Fast communication*** on a ***global scale*** starts to become a ***mass phenomenon***. In this paper, we analyze this trend and its impact on the human society. We focus particularly on the development of the Web, which is an infrastructure for fast global information sharing. We discuss its original shape and its development through so-called Web 2.0 and Web 3.0 technology. Finally, we speculate about future trends by drawing analogies from the organization principles of super organisms such as ants based on millions of individuals, and from "super organs" such as brains based on interwoven networks of billions of neurons.

2. WEB 1.0 – AN INFRASTRUCTURE FOR GLOBAL INFORMATION SHARING

The Internet was introduced approximately 45 years ago as a means to interconnect computers. Slowly an application layer, based on applications to share files and exchange emails, etc., evolved. It took 30 years before it became a mainstream trend. Around this time, the Web arose as a means for global information sharing. Within a few years, it grew from a small in-house solution for some thousands of users, and some tens of thousands of pages, into a worldwide mass medium. The breakthrough was achieved via the *Netscape* browser, which quickly achieved a large user community, making it attractive for others to present their information on the Web. Consequently there occurred a 'network effect', as in Metcalfe's law,[1] governing its impressively rapid growth. In the meantime, more than 2 billion people make use of the Web, and in 2008 *Google* indexed more than 1 trillion pages.[2]

The success of the Web is based on three simple principles:

1. a simple and uniform addressing schema to identify information chunks;
2. a simple and uniform representation formalism to structure information chunks allowing browsers to render them;
3. a simple and uniform protocol to access information chunks.

As *Netscape* was fundamental for the breakthrough of the Web, *Google* is generally given credit for its enormous growth. In the early days of the Web people exchanged URLs and built bookmark lists in order to gain access to interesting information. Soon, with the introduction of search engines like

[1] http://en.wikipedia.org/wiki/Metcalfe%27s_law
[2] http://googleblog.blogspot.com/2008/07/we-knew-web-was-big.html

Google[3], it became possible for a piece of information to be found more quickly on the Web than in an individual's own bookmark list. For the first time in human life, information became, in principle, subject to global and near-instant access. Information about a topic written by a person in Japan is two mouse clicks away from a reader in Austria.[4]

A shortcoming of Web 1.0, as it is described here, is that most users were consumers of information and only a small fraction were actually providers of information. Turning consumers into *prosumers* is the underlying principle of Web 2.0.

3. WEB 2.0 – EMPOWERING THE MASSES

Tim Berners-Lee stated once that there is no real difference between Web 1.0 and Web 2.0. And he is right, especially given that the term was coined for marketing purposes: to justify re-invigorated valuations after the crash in the market for tech stocks up to 2002. Still, there are differences in emphasis between Web 1.0 and Web 2.0 that may cause a qualitative change. With Web 1.0 technology, a significant level of software skills and investment in software was necessary in order to publish information. Web 2.0 technology changed this dramatically. The four major breakthroughs of Web 2.0 are:

- blurring the distinction between content consumers and content providers;
- moving from media for individuals towards media for communities;
- blurring the distinction between service consumers and service providers;
- integrating human and machine computing in new ways.

Wikis, blogs, and *Twitter* turned the publication of text into a mass collaborative phenomenon, while *Flickr* and *YouTube* did the same for multimedia content. In place of individual publishers, entire communities started to publish and exchange information. Social web sites such as *Delicious*, *Facebook*[5], *LinkedIn*, *MySpace*, and *Xing* allowed communities of users to smoothly interweave their information and activities. This weaving of communities is obviously a new quality of Web 2.0. Sites promoting and facilitating *mash-ups*[6] allow Web users to easily reuse in their Web sites services implemented by third parties. They are not limited to just reusing existing services, but can also easily generate new combinations of existing services. Finally, approaches such as *Amazon*'s Mechanical Turk[7] allow access to human services through a Web service interface, blurring the distinction between manually and automatically provided services. In conclusion, with Web 2.0 technology the billions of people now on the Web not only consume content but also produce the content available on it. In this way the Web has become a true instant communication channel for mankind on a global scale.

Wikipedia[8] is an excellent example of this. Within a short period of time it has become the World's leading encyclopedia and one of the most useful on-line information sources when hunting for high-quality background information on a given concept or domain. A community of volunteers has built it up through the use of a structured process model that enforces consensus. Wikipedia has turned the access to valuable and broad encyclopedic knowledge into a commodity available for instant, cheap, and global access based on the effort of a structured community of volunteers. If only for this, Web 2.0 is a gift to human kind.

4. WEB 3.0 – A MANKIND'S BRAIN

> *"Imagine a Web that contains large bodies of the overall human knowledge and trillions of specialized reasoning services using these bodies of knowledge. Compared to the potential of the Semantic Web, the original AI vision seems small and old-fashioned, like an idea of the 19th century. Instead of trying to rebuild some aspects of a human brain, we are going to build a brain of and for mankind."[2]*

The simplicity of Web and Web 2.0 technology is also generating a major obstacle for its future development. Computers are only used as devices that transmit and render information — they do not have access to the actual content, i.e., all their computational power is restricted to delivery and layout of otherwise non-processed information. In the end, computers have become devices that do not compute anything. Thus, they can only offer limited support in accessing, extracting, merging, and processing this information. Therefore, the main burden not only for accessing and processing information, but also for extracting and interpreting it, is on the human user.

"Tim Berners-Lee first envisioned a Semantic Web that provides automated information access based on machine-processable semantics of data and heuristics that use these metadata. The explicit representation of the semantics of data, accompanied with schema definitions, will enable a Web that provides a qualitatively new level of service." [2]. The Web weaves together an incredibly large network of human knowledge. The Semantic Web complements this with machine processability. Automated services help to achieve goals based on information provided in a machine-understandable form. Machine processability is achieved by metadata that allow machines to make "sense" out of data. The Resource Description Framework (RDF)[9] is the first layer in adding semantics to the Web, enabling semantic information to be added to Web resources.

"<http://www.fensel.com/me, firstName, "Dieter">"

states that the resource referred to by a URI has the first name "Dieter". These triples are interwoven to form a labeled directed graph. RDF Schema[10], the Web Ontology Language (OWL)[11], and the Rule Interchange Format (RIF)[12] provide means to add

[3] It soon became a generic "*Sésame, ouvre-toi*".
[4] Assuming that both use a global language such as English.
[5] The number of users of *Facebook* is larger than the population of the third world largest country.
[6] http://www.programmableweb.com/
[7] https://www.mturk.com/mturk/welcome
[8] http://www.wikipedia.org/
[9] http://en.wikipedia.org/wiki/Resource_Description_Framework
[10] http://en.wikipedia.org/wiki/RDF_Schema
[11] http://www.w3.org/TR/owl-features/
[12] http://www.w3.org/TR/rif-bld/

ontological information (schema definitions) to this instance data. For example, it is possible to add that "*www.fensel.com*" is an instance of the concept Scientist, and the fact that each Scientist is also a Person, as well as that each Person has a birth date and therefore so does "*http://www.fensel.com/me*".

Adding this type of information to Web resources allows computers to reason about the content available on the Web. Instead of only rendering Web pages, a computer can be used to accurately retrieve, extract and combine information. When using the computer to plan a vacation, it is currently capable of retrieving thousands of pages that are highly and moderately-highly relevant for this task. Based on Semantic Web technology, a computer can "understand" the meaning of the data, and is able to retrieve, extract, and aggregate available information in order to derive a number of alternatives based on preferences defined for the journey. Eventually, this will generate an extremely knowledgeable system with various specialized services that support us in nearly all aspects of our life. It will become as necessary to us as access to electric power.

The Semantic Web started as a means to annotate content that was meant for human consumption: text, pictures, videos, etc. It provided metadata for human readable documents, providing in addition machine-processability of this content. The next natural step in the evolution of the Semantic Web is to directly publish data and their schema information (i.e., metadata) for machine consumption. In the first scenario, computers improve the access to information provided in human readable documents. In the second scenario, machines process information to provide valuable services to humans. Instead of requiring the human reader to extract information from various heterogeneous information sources, the computer is able to provide this service and aggregate such data into meaningful service offers. As a consequence data is published on the Web that is intended for direct machine consumption. Humans only access this data through services implemented on top it. This *Web of Data* [1] started to grow explosively over the last year. By November 2009 it had already grown to 13.1 billion RDF triples, interlinked by around 142 million RDF links.[13] The major technical elements of this Web of Data are:

- the export of data from proprietary databases as RDF statements on the Web;
- the use of global identifiers (URIs) to refer to this data;
- the use of standard approaches – such as RDF, HTTP, and SPARQL[14] – to access this data;
- the interweaving of this data via links to data from other exported resources generating a network of information.

Wikipedia lists a number of these interwoven datasets (see Figure 1):[15]

- DBpedia[16] – a dataset containing data extracted from Wikipedia; it contains about two million concepts described by 200 million triples;
- DBLP Bibliography[17] – provides bibliographic information about scientific papers; it contains around one million articles, 400 000 authors, and is represented as approximately 15 million triples;
- GeoNames[18] – provides RDF descriptions of more than 7 million geographical features worldwide;
- Revyu[19] – a dataset containing user-submitted reviews about any kind of "object";
- FOAF[20] – a dataset describing people, their individual properties and relationships; and
- the OpenPSI project[21] – a community effort to create UK government linked data services.

This development enables the evolution of the Web from a collection of documents for direct human consumption to a global information integration platform for applications. A huge amount of interlinked data becomes available to applications, with endless possibilities for combining them in order to create new services. For example, FOAF data could be used as a basis by any social networking application, without the need to manually redefine one's personal connections for each and every service. A real estate service could combine the usual data about apartments coming from owners with external data about the district, for example location of shops and services, or statistics about crime coming from government agencies. Mobile services are another interesting area for this kind of applications, especially with GPS-enabled sensors, producing positioning data, becoming more and more common on mobile devices. DBPedia Mobile[22] is an interesting example: the usual map shown on the mobile device is enriched with information about nearby places coming from DBPedia, pictures coming from Flickr, and users' comments and opinions coming from Revyu.

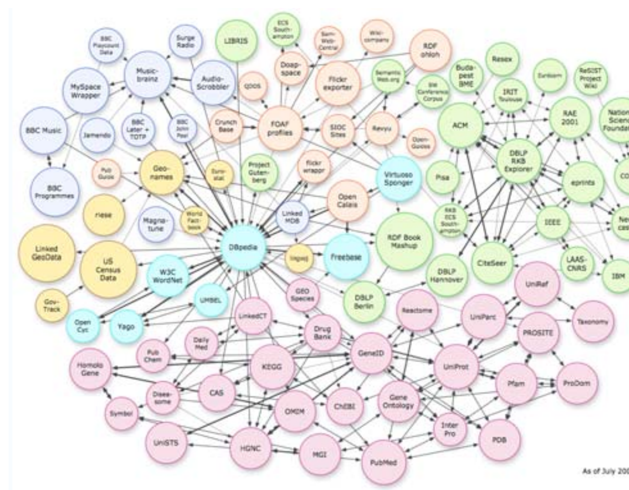

Figure 1: Instance linkages within the Linked Open Data datasets[23]

[13] http://esw.w3.org/SweoIG/TaskForces/CommunityProjects/LinkingOpenData
[14] http://www.w3.org/TR/rdf-sparql-query/
[15] http://en.wikipedia.org/wiki/Linked_Data
[16] http://dbpedia.org/About
[17] http://www.informatik.uni-trier.de/~ley/db/
[18] http://www.geonames.org/
[19] http://revyu.com/
[20] http://www.foaf-project.org/
[21] http://code.google.com/p/jiscri/wiki/openpsi
[22] http://wiki.dbpedia.org/DBpediaMobile
[23] http://upload.wikimedia.org/wikipedia/en/8/8c/Lod-datasets_2009-07-14_colored.png

In these ways the seamless integration of data, which use different conceptual models and resources, becomes feasible. Ultimately, the initiatives around the Semantic Web build a global networking of knowledge, which is understandable for and processable by a global network of computers. Some 30 years ago, AI researchers coined the slogan "*knowledge is power*"[24]. They realized that their vision of implementing the reasoning power of a human brain cannot be achieved simply by applying generic search or reasoning methods. Knowledge is required to solve problems not only in principle but in practice, i.e., at the scale of complexity that is provided by actual usage scenarios. However, this insight generates a new problem: how to acquire this knowledge. Extracting it from humans through knowledge elicitation and knowledge acquisition techniques has neither worked properly, nor been scalable and economic in any sense. Expert systems developed with this approach have therefore been costly, brittle, and small solutions for minor problems.

With the Web and the Semantic Web, this situation has changed drastically. In *Wikipedia* we have millions – and in general we have billions – of people providing information on-line. Based on semantic technology, this information can be made accessible for computers, i.e., formal reasoning engines. Basically, it is hard to imagine a topic on which information cannot be found on the Web. The Web resembles a large and significant fraction of the human knowledge. Based on semantic annotation, *the global Internet-based computer network can evolve as a brain for mankind based on the whole knowledge of mankind*, rather than a human brain based on the limited fraction of global knowledge that an individual is able to collect. Just compare your personal knowledge with the combined knowledge of *Wikipedia*, and consider for a moment what it will imply if a network of billions of computers starts to understand it.

5. WEB 4.0 – A NEW SUPER ORGANISM ORGANIZED AS A SUPER ORGAN

With Web 3.0 we are generating a brain for mankind. It collects the totality of human knowledge and makes it accessible to computers. This is not a conscious result. It is a side product of improving the speed and quality of information access and dissemination on a worldwide scale and another step in what started around 200 years ago with the explosive development of Information and Communication Technology.

For example, according to *The Guardian*, the amount of information provided on the Internet was around 500 billion gigabytes in 2009, or around 0.5 zettabytes[25]. It is expected that this amount of information will double every 18 months; i.e., by the end of 2010 we can expect around one zettabyte of digital information to be accessible via the Web. If the World's rapidly expanding digital content were printed and bound into books it would form a stack that would stretch from Earth to Pluto 20 times[26]. Nobody really understands where this process will finally lead.

[24] First Francis Bacon and later Ed Feigenbaum.
[25] http://en.wikipedia.org/wiki/Zetta-
[26] http://www.guardian.co.uk/business/2009/may/18/digital-content-expansion

At the beginning of this article we mentioned ants as a highly successful life form. For 40 millions years they have developed cultural skills such as joint parental care, joint hunting, cooperation and labor division, cattle husbandry, and agriculture [4]. Humans developed such skills significantly later. For example, human agriculture evolved only 10 000 years ago. Still, within the last 10 000 years the human race has made significant progress compared to the nearly stagnant development of ants in the last 1 million years. Therefore, it may be helpful to compare the essentials of ant and human communication and reasoning, as a means to understand the difference of mankind both with and without access to global, instant mass communication. This latter phenomenon seems to increase the speed of human development roughly as much as the overall speed of human development outnumbers the development of ant societies.

Statistics concerning ants are truly impressive [4]; they form the World's largest superorganisms (i.e., colonies with cooperative structures). Certain species have colonies with more than two million individuals. In total, they constitute a biomass which is roughly equal to the current weight of all humankind. They dominate their ecological niches and are the predominant insect life form. Their success is based on human-like behavior. A single man in the jungle has little chance to survive, nor power to change this. An organized group of humans, on the other hand, can kill the jungle's largest predators, and in the long term change it into an area for agriculture and prolonged human habitation.

Ants "invented" the principles of cooperation in parental care and hunting, labor division, cattle husbandry, and agriculture around 40 million years ago. That is to say that, compared to humans, they started the race with an advantage of nearly 40 million years. Therefore, a very natural question is why we have bypassed them so easily. Why did our species visit the Moon and not the ants, and why did they not do so 39 million years before us? Moreover, why did *we* visit the moon only 50 years ago and not 2000 years ago? Our explanation is simple and consistent: humans develop faster than ants since their neurons are better connected, allowing fast communication and reasoning speed. Modern humans are developing faster than their predecessors due to an extension of the same reason.

Information processing at an individual level

Let's start with comparing information processing capabilities of ants and humans. A human brain is implemented by a network of around 100 billion neurons. These neurons implement information processing through complex chemical and electrical interactions. Compared with this, the brain of an ant is rather simple, resembling a network of around ten thousand neurons. However, a colony of around one million inhabitants sums up to around 10% of the neurons of a human brain, which is still less, but quite close in number. The ***plain number of neurons*** is obviously not enough to explain a significant difference in the two species.

The numerical complexity of the ***human brain*** is awesome [6][7]. A hundred billion neurons per brain are the basis of its complexity. These billions of neurons can have, between them, many trillions of connections and orders of magnitude greater interaction resonance patterns. Neurons can interact ***locally*** with surrounding neurons through the exchange of chemical neurotransmitters. A second kind of interaction is implemented through a network of dendrites connecting the neurons and enabling ***global*** interaction. Neurons can interact over great distances with other neurons via instant exchange of electrical signals along these dendrites. Furthermore a given neuron can participate in a number of distinct exchange processes via differences in the frequencies of the exchanged electrical signals. Metaphorically, a thought can be described as a pattern of self oscillation and resonance among connected neurons. The numerical complexity involved in describing the potential states of a system, based on billions of nodes where every node can in principle interact with every other node in a nearly infinite spectrum of frequencies, is beyond the (current) state of Science.

Ants have essentially the same brain structure in principle, however possess only 0.0000001% of the number of neurons. This is clearly a significant difference in complexity. We mentioned earlier the fact that these disadvantages are partially obviated through the number of individuals within a colony. There is, however, still a marked difference between the instant and potentially global interaction of neurons within one brain and neurons distributed over two ants' brains. Communication between ants is based on exchanging chemical pheromones and therefore ***local***. As a result, the freedom of interaction in these networks of neurons is severely restricted and notably slow. Small chunks of 10 000 neurons interwoven with high speed interactions networks are hidden behind "Chinese walls" only allowing very slow and locally scattered interaction with other neuronal network chunks. In the end, it is not a surprise that not much happened in such a fragmented network of neurons. Its architecture drastically reduces speed and complexity of the network through localization of interaction. *Actually, finding ants stemming from Earth on the Moon would have been the big surprise!*

Information processing at a global level

Our argument as to why human development speed, as well as the amount of available information, has suddenly explosively increased follows the same argument. Human intelligence, and development of mankind, is based on a 'super organ', the human brain. It interweaves 100 billion neurons in a network of instant and global interaction as a mass phenomenon. It should come as no surprise that a species with such a powerful information processing unit quickly outranges competing ones. Evolution, which is usually observed at the level of periods of millions of years, started to happen in intervals of a hundred thousand, ten thousand, and then thousands of years. This is a result of the fact that these powerful reasoning engines are engaged in interaction patterns based on symbolic language beyond intrinsic given meaning defined by instinct and inherited by genes. The "slow" biological inheritance mechanism based on genes becomes replaced by inheriting ***memes***,[27] units of cultural ideas, symbols, or practices, which can be transmitted from one mind to another through writing, speech, gestures, rituals, and other imitable phenomena.

Replacing a biological mechanism of interpreting and inheriting information with a cultural one allows for a significant speed up in development. Still, this process is seriously limited if communication is limited to local and slow interaction channels. Like ants, humans were only able to slowly communicate and interact locally. Networks of billions of neurons were ready to interact with other neuronal networks based on symbolic interactions. However, chunks of 100 billion highly interwoven and interactive neurons are hidden behind Chinese walls that allow only very slow and local interaction with other such chunks. From this perspective it is not a surprise that Information and Communication Technology (ICT) development over the last 200 years releases the power to a new hype of explosively growing development speed, based on relieving billions of 100 billions of neuronal networks from these prisons. With ICT advances we have quickly achieved a communication and interaction pattern, where these billions of 100 billion neural networks can communicate and interfere (i.e., establishing a stable pattern of oscillations) at an instant and global scale as a mass phenomenon. The resulting interaction possibilities, whose complexity is several orders of magnitude higher, should lead to quantitative and qualitative revolutions (see Table 1). *It is not a surprise that development speed increases explosively during the last 200 years of Information and Communication Technology development. Anything else would be a surprise!*

Humans		Ants	
–	–	10 000 high-speed connected neurons	Individual level
Individual level	100 billion high-speed connected neurons	1 million individuals connected locally and slow	Colony level
Global level	10 billion first locally and slow and finally high-speed connected individuals	–	–

Table 1. Humans versus Ants

As a result of this Information and Communication Technology revolution a new kind of superorganism arises: a world where soon 10 billion of individuals are interconnected through a network of cultural interactions. Besides becoming a global superorganism, this network can also be described as a new super organ. Soon 10 billion human brains will be interconnected in a global reasoning engine. Not only the edges of this network (the human brains) but also the connectors through semantic technology enabled computational infrastructure interpret information and derive new such. Now recall for a moment that each of these 10 billion nodes is again implemented by a network of 100 billion neurons, and that the computational power of the connecting IT infrastructure rapidly increases too. Clearly, no single human brain can fully understand nor control this new evolving living form based on global information processing in the same way as a single neuron in our brain cannot fully understand and govern our human brain. It is actually the network that decides which neurons are interrelated in interaction patterns and grow and which ones simple degenerate and disintegrate [6].

[27] http://en.wikipedia.org/wiki/Meme

6. CONCLUSIONS

Viewing oneself as a minor node in a global information processing life form based on billions of other “natural” nodes and increasing “artificial” reasoning through mechanical interpretation of semantics may not be a very romantic view of the World. On a personal level we may believe we extend and improve this Information and Communication Technology network to fulfill our personal or professional pleasure. In fact, we just help to build a new life form through this as a transcendental aspect of our activities. Science Fiction literature is full of warnings. The warnings that we humans are just a means to implement powerful Information and Communication Technology infrastructures hidden behind illusionary projections of individual worldviews and desires are there. Just take [3], adapted as the two-part German television play “*Welt am Draht*”[28], or the Matrix trilogy as examples for this. And finally, what is new about this? Since Kant, at the latest, we have known that reality is either only a simulation created by our perceptive system or the magic “*Ding an sich*” beyond the means of any rational discourse.

Simply stated, this paper only scratches the surface and leaves the most important questions unanswered. First of all, is Information and Communication Technology about communication or computation, i.e., ***is the Internet a network of computers or a human communication device?*** Clearly it is somehow both, but how to understand this monster properly? Second, ***is this monster really confined to the virtual world?*** The Internet is growing its own perceptual system via *Google Maps*[29], *Google Street View*[30], millions of webcams, billions of sensors and RFID chips, and automatic building and face recognition provided by smartphones in 2010. And it is not only ‘eyes’! With all the massively increasing number of devices controlled through the Internet, ‘hands’ and ‘feet’ are growing. Within just ten years most combat airplanes will fly without a human pilot. *Cyborgs* [5] that have a brain living in the Internet are just around the corner.

This brings us to the third and final question. ***Why have we failed to find another intelligent civilization in a cluster of 100 billion stars in our milky way multiplied by around another visible 100 billion galaxies?*** *This is the real and frightening surprise*. Does evolution provide a kind of inheritance mechanism for the self-destruction for monkeys daring to eat an apple from the “tree of knowledge”? In any case, ants will most likely survive in a more stable and less oscillating pattern of computation and interaction. Are we just a kind of “*neuronal brain cancer*”?

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