WITH INFORMATION TECHNOLOGY ON THE THRESHOLD OF THE NETWORK AGE

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Abstract - The third civilization wave is characterized by the development of information society. In future, a high information availability and knowledge are conceived as prominent accelerators of economy. Under the third wave, the community of computer experts understands the network age. The attribute 'network' expresses current trends, i.e. e-business, virtual organizations, virtual teams, etc. better than the attribute 'information'. The year 2000 is often designed as the start of the network age. This paper shows some interested features of the current state of Information Technology (IT) that have consequences for the society in the network age. It explains some quantitative aspects of the information explosion (how much information there is in the world) and shows one its possible consequence, the so-called digital immortality. Increasing significance of the practice-oriented research as well as the number of information system problems requiring a long-term research are also mentioned. We also discuss new features of the IT profession and achievements in the vision of the so-called intellectual networks.

Keywords - Network Age, Third Wave, Digital Immortality, Practice Driven Research, Profession IT, Semantic Web.

INTRODUCTION

In the 1980 IFIP Congress Series Gotlieb [1] compared computers to the 'gift of fire', likening them to the legend of Prometheus who stole it from the god to give it to man. Researchers like [2] talk about cyberspace as a new continent-equivalent to the discovery of the America 500 years ago. Informatics is the ideology and language of this continent.

One of the most significant world futurists, Toffler, explains the *third wave*[1] in his book [3] and characterizes its essence by the development of information society. He mentions knowledge and a high information availability in the future as prominent accelerators of economy. In an alternative terminology it is possible to talk about the society oriented at knowledge and digital economy. Only the development of computing in the 90s, particularly the convergence of information and communication technologies, prepared ground for the real third wave. Internet, more generally 'Net', makes feasible information availability and the needed communication. The development of the knowledge management contributes to the development of new economy.

We are witnesses of processes that split the world system into three different civilizations. The third wave comes after the agrarian age and the industrial age, which obviously overlap each other in the history. In fact, in some countries like India and Brazil they coexist. By the third wave, we mean today the 'network age' in the world of IT. The attribute 'network' expresses current trends, e-business, virtual organizations, virtual teams, ... better than the attribute 'information'. Even the globalization itself would hardly exist without networks. The network age puts the start of the third wave in 2000.

The network age has carried up information systems (IS) and information technology (IT). Biotechnologies and IT are two driving forces of economic changes. The development of IT influences:

- the amount of stored digital information
- production and use of information
- profession of IT
- research in arbitrary area

The network age influences us whether we like it or not. Therefore, it is necessary to explore its principles, generalize them and successively and suitably react with other more systematic changes. Most of the previous long-term prognoses and outlooks to future about economy, science, and society have to be reformulated today. Namely, they are based on past notions and knowledge of the industry age.

The goal of the paper is to show some interesting features of the current status of IT that will have an impact on society in the network age. In Section 2, we discuss the quantitative features of the information explosion: how much information is there in the world? how large is the web? and what is its structure? We will also discuss one of its possible, not yet well-known, aspects the so-called 'digital immortality'. In Section 3, we will mention the increasing significance of practice driven research. Following twelve problems of Gray from the area of systems, we will show what is possible for investigating concerning long-term research. Further, we emphasize some new features of profession of IT. Some aspects of the vision of the so-called 'intellectual networks' are discussed in Section 4. In the concluding part, we formulate some problems concerning the society in the network age.

INFORMATION EXPLOSION

Despite a long discussion about the information explosion, this notion has gained importance only with the Net development. Today, the main problems connected with the Net are how to approach the data it offers and how to search and use the data quickly as well as in a targeted and intelligent way. Although the current ways of searching give us a chance of gaining much interesting information, it is often done for a long time and with a low precision.

In this connection, we must recall famous papers like [4] and sources like [5] for the notion of the World Encyclopedia from 1937, which covered a vision of certain 'planetary memory for all mankind'. As mentioned in [4], the intelligent machine Memex makes it possible to gather and search data. Books, and even speech, should be recorded and searched in an associative way. All is mechanized in such a way that consultations are fast and feasible. An important necessary condition is the associative searching. It is no remote dream, no fantasy, as is affirmed by today's similarity algorithms for searching full texts. Wells [5], influenced by the technology of microfilms, was not satisfied by storing all human knowledge. He sees teams of people who index text manually. They create abstracts and summaries, i.e. metadata in today's notions. Possibilities of the Net, although often criticized, and recent successes of IT mean the first real steps towards achieving such visions.

When on August 19-21, 1998, a group of 16 database system researchers from academia, industry, and government met at Asilomar, California, they faced the problem to access the database system research agenda for the next decade. As a ten-year goal for the database research community, they recommended the *information utility*: make it easy for everyone to store, organize, access, and analyze the majority of human information online [6]. For all undoubted successes achieved in IT till now, this problem requires a long-term research. Today, the entire informatics tries to deal with it.

HOW MUCH INFORMATION IS THERE IN THE WORLD?

Some years ago, researchers tried to estimate how much information, or rather more modestly data existing in various media, was in the world. Assuming traditional (text) information, cinema, images, broadcasting, sound, telephone, and conversation, we get numbers about 12.000 PB[2] [7]. In comparison, the total size of the Library of Congress is about 3 PB. These numbers are certainly astronomic and somewhat above our understanding. However, the estimates for the last years are considerably higher [8]. The world produces between 1 and 2 exabytes of unique information per year, which is roughly 250 megabytes for every man, woman, and child on earth. If the current trends continue, the amount of data generated in the next three years will be more than that generated during the recorded history.

In IT, we should now reach the production of disks with the total disk space greater than 13.000 PB. By the way, the total memory of all people now alive is estimated about 1.200 PB. So, this suggests that we will be able to save all information in the world, at least technically, in the digital form on computer storage space. By decreasing the price of disks 100 times within 10 years, digital stores will be even cheap and open to the public.

On the other hand, other information sources are appearing, e.g. biological information, business information and web. The growth of the former is astonishing. The information stored in GenBank imitates Moores's law, i.e. being doubled every 18 months or so. In business, the real problem is that the data growth, per year, is 100% and even more and the database search indexing capabilities have not been able to manage it.

It is only partially possible to estimate the amount of texts placed in the Net. Authors of [9] mention 6 TB of directly assessable text. The estimates for year 2000 speak about 21 TB of static HTML pages, and are growing at a rate of 100 % per year [8]. Such estimates are formed only on the basis of the work of index machines, like Google, HotBot and others, which automatically index web pages and documents referred to from these pages. Other documents, the so called 'hidden web' or 'deep web', are stored and accessible in other ways, for example, as databases with paid services.

DIGITAL IMMORTALITY

Cheap storage media and a simple way of gathering and storing data make it possible to create personal (external) digital memory (*personal Memex*). Technically, such Memex seems feasible today. It offers storing digitally all the information production of a person throughout his/her entire life and even 'forever'. This includes letters, photos, essays, videos, papers, speeches (written or spoken), music records, etc. To record conversations during one's personal and professional life in a sufficient form will require 1 TB and less than 25 GB per year. Such memory can even be distributed, i.e. its parts can be stored anywhere in the Net. Everybody can store his/her personal data into such 'digital crypt' (obviously for a fee) today[3].

Personal video Memex seems to be beyond our technology today. Video of a high quality would require 80 TB per year, 8 PB per lifetime. How to achieve it is a good theme for long-term research.

What does it mean for the human life or society? Great ideas in a written or verbal form as well as images and writings are preserved for a whole human history. Their prompting is traditional for immortality. Immortality, given by endless experience and learning, is of a higher form. If part of a person is digitalized and stored in more durable media, it is possible to preserve it for future. The processing will not copy the current searching techniques known from text or multimedia databases. The output of a conversation of the resultant avatar[4] will be spoken. Such avatars will 'learn' from the conversation. They will enable the person to appear to 'live forever'.

In the network age, such type of immortality is becoming to be real (see project CyberAll developed in [10]. An intermediate stage of this vision is to develop a system, the so called 'World Memex', which is able to answer summarization questions about the topic of a given corpus of texts as well as a human expert in that field. Observe that we do not use the notion of machine intelligence. In comparison, there was the optimistic estimate of [11], who predicted in 1950 that computers should become intelligent within the following 50 years.

HOW LARGE IS THE WEB?

Recent research directions include a study of quantitative properties of web viewed as an oriented graph [12]. The web graph is the graph of the web pages together with the hypertext links between them. Consider a *strongly-connected component* (SCC) of a graph as a set of pages S such that for all pairs of pages (u,v) in S, there exists a directed path from u to v. The measurement from an Altavista crawl from May 1999 showed that the largest SCC in this crawl had 56 million nodes and the second largest 50 thousand meaning three orders of magnitude smaller than the former. The whole graph contained 200 million pages and 1,5 billion links[5].

A *weekly-connected component* of a graph is a set of pages *S*, each of which is reachable from the other one if the hyperlinks can be followed either forwards or backwards. For example, (*a*,*b*), (*b*,*c*) and (*a*,*c*) make up such a component. In the same experiment, the largest strongly-connected component contained 186 million nodes, i.e. more than 90 of the crawl.

The map of the web has a bow-tie structure (Figure 1). The rest of Figure 1 contains isolated components. The knot of the bow-tie represents the giant SCC. The left side of the bow-tie, IN, represents 44 million pages. They are defined to be all pages not in the SCC but from which a path leads to some node of the SCC. These 'new pages' are linked to interesting destinations on the web, but they have not yet been discovered by the core of the web and are, therefore, not reachable from the SCC. If a page of IN became reachable from the SCC, it would become part of the SCC. The set OUT has also 44 million pages. Any page of OUT can be reached from any page of the SCC by the following hyperlinks, but no page of the SCC can be reached from a page of OUT by the following hyperlinks. There we find well-known pages from enterprise intranets, in which linking is rather internal. Tendrils consist of pages with no link to the knot, and which are not reachable from the knot. They make up a significant fraction of the web, approximately 44 million pages. Only 10 of the whole graph do not belong to one of these four parts that compose the bow-tie.

A deeper analysis of the bow-tie has revealed a surprising property of web connectivity:

- For most pages *u*, *v* *S*, there does not exist a path from z *u* to *v*.

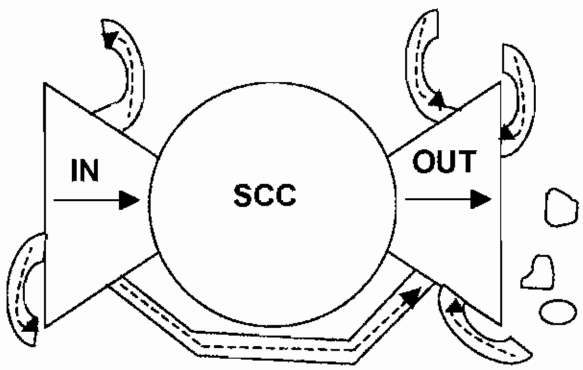

Figure 1: Topology of the web

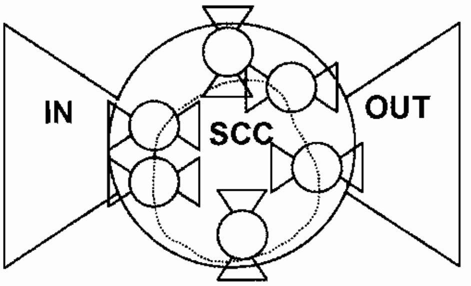

Figure 2: Self-similarity in the web

Self-similarity is an interesting finding in the web. Consider Thematically Unified Clusters (TUC) of pages, i.e. according to a set of key words, an intranet, etc. TUC can be associated with a community. Experiments have shown that each TUC has the same structure as the whole web (Figure 2), i.e. it has a bow-tie structure that mirrors the structure of the web at large. These cohesive collections are tightly and robustly connected via a certain *navigational backbone* (the dotted line in Figure 2) into SCC. The extent to which each TUC exhibits the bow-tie structure and the extent to which its SCC is integrated into the web as a whole indicate how well-established the corresponding community is.

These measurements can be beneficial for quantitative estimates in query processing over web in the case when the web is conceived as a database. Obviously, the notion of a query has to be changed. To the basic query type 'Find relevant pages for topic T', we have to add others, e.g. 'Find a community'. By a *community,* we mean a set of *authoritative pages* that describe a topic sufficiently, e.g. aircraft manufactures, and a set of *hub* pages, e.g. travel agencies. There are mutual references among the hub-like pages but not among the authoritative ones (due to their mutual competition). The goal is to find such implicit communities. This is significant for:

- automatic web portals and focused search engines, content filtering and complementing text-based searches
- analysis of the entire web and the objective study of relationships within and between communities

It seems that web opens up both fascinating possibilities in its own right and immensely promising and, hitherto, unsuspected possibilities that facilitate information processing that is beyond the traditional solution-to embed a distributed database into Net and use usual web services for getting access to it.

IT RESEARCH AND PRACTICE

The existence of useful information in the Net and its high availability contribute to accelerating the scientific production and to more precise considerations about goals both of IT RD and practice.

PRACTICE-DRIVEN RESEARCH

The network age shortens time to solve both scientific and technological projects. Short-term projects bringing immediate applicable results have a high priority. The same holds for projects having roots in practice. In this connection, [13] emphasizes a *practice-driven research* in IT and discusses it using examples in ISs. There is a difference between this approach and other approaches with regard to conducting relevant research, i.e. applied research. In the practice-driven research, the problems require also new models, new tools and experiments to be solved. The Net supports a quick absorption of these issues by scientific community, successive generating of other problems and, thus, other research as well. Practice-driven research has other specific attributes, e.g. it can be dependent on business decisions. It is often not the best solution that is used but only a possible one requiring less funding. The direction of the development in a given area can change according to the experience gained from the life-cycle of a product, a new standard or a new protocol.

Due to the Net, more researchers and developers can be joined into teams. Open consortia are a very appropriate organization structure for such research in comparison with the traditional grant agencies. Such a style of research eliminates very quickly those of its branches that are not innovative, despite the fact that they are interesting for a researcher. On the other hand, sometimes the scientific community offers a concept that practice is not yet able to appreciate and that, possibly, a long-term research is necessary.

A nice example of IT is the language XML first designed as a standard format for text exchange in the Net. No doubt, it is of significance for e-business or various communities working with the texts of a certain type. Then a consortium W3C (composed of firms, companies, research institutions, and particular persons) was established, which produced other, recommended or standardized, subsequent tools and languages. New scientific conferences, journals, and web sites have appeared. An active researcher in this area has practically all relevant information put on one place. He/she can also recognize which subjects are challenging and which are not. The accelerated extending of the XML research community has caused a development in which this language becomes a new web data model. On the other hand, effective products reminding XML databases are expected in 10 years. Thus, a long-term research is again necessary.

LONG-TERM RESEARCH

From time to time each research needs to answer the question 'what to investigate in a large-term perspective'. In IT, for example [2] offers a dozen examples of long-term systems research projects.

1. **Scalability:** Devise a software and hardware architecture that scales up by a factor for 10^6. That is, application storage and processing capacity can automatically grow by a factor of a million, doing jobs faster (10^6 speedup) or doing 10^6l larger jobs in the same time (10^6 scale-up), just by adding more resources
2. **The Turing Test:** Build a computer system that wins the imitation game at least 30% of the time
3. **Speech to Text:** Hear as well as a native speaker
4. **Text to Speech:** Speak as well as a native speaker
5. **See as Well as a Person:** Recognize objects and motion
6. **Personal Memex:** See Section 2.1
7. **World Memex:** See Section 2.1
8. **TelePresence:** Simulate being some other place retrospectively as an observer (TeleObserver): hear and see as well as actually being there, and as well as a participant and simulate being some other place as a participant (TelePresent): interacting with others and with the environment as though you are actually there
9. **Trouble-Free Systems:** Build a system used by millions of people each day and yet administered and managed by a single part-time person
10. **Secure System:** Assure that the system of problem 9 only serves authorized users; service cannot be denied by unauthorized users and information cannot be stolen (and prove it)
11. **Always Up:** Assure that the system is unavailable for less than one second per hundred years (and prove it)
12. **Automatic Programmer:** Devise a specification language or user interface that: makes it easy for people to express designs (1,000×easier) and can compile and describe all applications. The system should reason about application, asking questions about exception cases and incomplete specification. But it should not be onerous to use.

Without doubt, the most natural solution is to support long-term research at universities. The well-known report [14] to the American president recommends the government to double the university IT research funding and the funding agencies to shift the focus to long-term research. In most of the IT industry, we observe an investment in long-term IT research. The leading IT companies spend between 5-10% of their revenues on Research and Development. About 10% of this is not product development, and there is an estimate that about 10% of that, i.e. 1% of the total, is pure long-term research.

PROFESSION OF IT

The network age is characterized by a radical departure from mass-production towards an individual, i.e. a particular customer. This phenomenon is observable in IT, where a mere product (e.g. software) is not enough, rather it is necessary to do its personalization according to the requirements of a particular customer. This will apply to most production in future. Generally said, adaptive technologies are mentioned ther main feature of which is that they are able to re-organize themselves. These technologies are distinguished from engineering technologies that do not have this property in [15].

There is a prediction that the IT profession will be the first profession in the third wave. What is a profession? Five criteria are distinguished for a profession in [16]:

- A durable domain of human concerns
- A codified body of principles (conceptual knowledge)
- A codified body of practices (embodied knowledge)
- Standards for performance
- Standards for ethics and responsibility

Profession of IT is very diversified. In three usual categories, we find many specializations (Table 1).

Table 1: Specializations in profession of IT

Profession of IT		
IT-Specific Disciplines	**IT-Intensive Disciplines**	**IT-Supportive Occupations**
Artificial intelligence	Aerospace engineering	Computer technician
Computer science	Bioinformatics	Service technician
Computer engineering	Cognitive sciences	Network technician
Theory of algorithms	Digital libraries	Professional trainer IT
Data engineering	E-commerce	Security specialist
Computer graphics	Financial services	System administrator
Human computer interaction	Genetic engineering	Web services designer
Network engineering	Information science	Web master
Operation systems	Information systems	Database administrator
Performance engineering	CAD. CAM	
Robotics	Knowledge engineering	
Scientific computing	Management information systems	
Software engineering	Multimedia design	
System security	Telecommunications	

Examining the items from Table 1, we find that the profession of IT fulfils the general features of profession only partially. For example, it is still not clear how to write programs or entire systems without bugs. Reliable methods or principles (let alone standards of IT qualification!) are not complete either. An expected development of ethics in the network age should also influence the ethics of the profession of IT.

In the network age, we will need a rather modified IT professional than we know, and mainly educate, him today. Today's IT professional is educated too technically. To function effectively in the network age, every professional, whether in IT or not, must deal with customers through value-generating relationships. By value, we mean: a value for a particular customer, as e.g. capabilities to ensure coordination and customer relations; to be able of doing teamwork; to absorb the idea of lifelong learning; to have capabilities for business and entrepreneurship, etc. Many engineers and developers use the term 'soft skills' for the value skills. These skills will be preferred in the network age and value-generating skills will distinguish professionals from technicians.

TOWARDS INTELLECTUAL NETWORKS

In the network age, most information will be born, live and die in a computer system. Recent concepts of electronic journals include new functionality in knowledge interaction, organization and presentation as well as in technology and the way of its creation. Differences between a journal and an information source in the Net are missing.

Electronic journals and other information sources are usually parts of a digital library. Other semantic structures can be added to the texts in such a library, e.g. subject trees, glossaries, thesauri, etc., which enrich the possibilities of the search process. Presentation of information includes not only browsing journals, or a given information source but also powerful filtering mechanisms, possibilities of connections to other sources. and services in a context-driven framework. We can observe that scientific papers appear usually in the Net earlier than they are accepted and published in traditional journals. They appear on home pages of their authors or as parts of specialized information sources. This trend can be characterized by 'everybody is a publisher'. Unfortunately, such information sources imply a not well-organized store rather than a library. Systematically built electronic journals still have an increased chance today.

New entities, the so called 'intellectual networks', are appearing. We can conceive them as a generalization of digital libraries. In their nodes, there will be not only today's usual structures like digital libraries or information centres, but also single persons or companies[6] that produce data, information, or knowledge. Managers of many institutions are already aware of these aspects of IT. To be 'in the Net' is usual in the day-to-day life of scientific communities that work in virtual teams, organize conferences, publish their results, etc.

The future of a (distributed) intellectual network, where knowledge or information creates a new quality on which a new society or culture has to be based, is undeniable in the Net and will be distinguished from today's web and its services. Not only specialists, e.g. academics, engineers and artists, but also most people will produce, use and share information in the Net. In [17], we mention issues concerning heterogeneous sources and shared experience. The problem lies in understanding the inside of one application domain. Ontology is now a popular approach in this context. Ontology typically consists of a hierarchical description of important concepts in a domain, along with a description of the properties of each concept. Ontology begins to play a pivotal role in the so called Semantic web. Such a web provides an environment for real web services.

The resultant system architecture consists of repositories, mediators and ontologies. Each user will choose an ontology for his/her query framework that fits his/her requirements as best as possible.

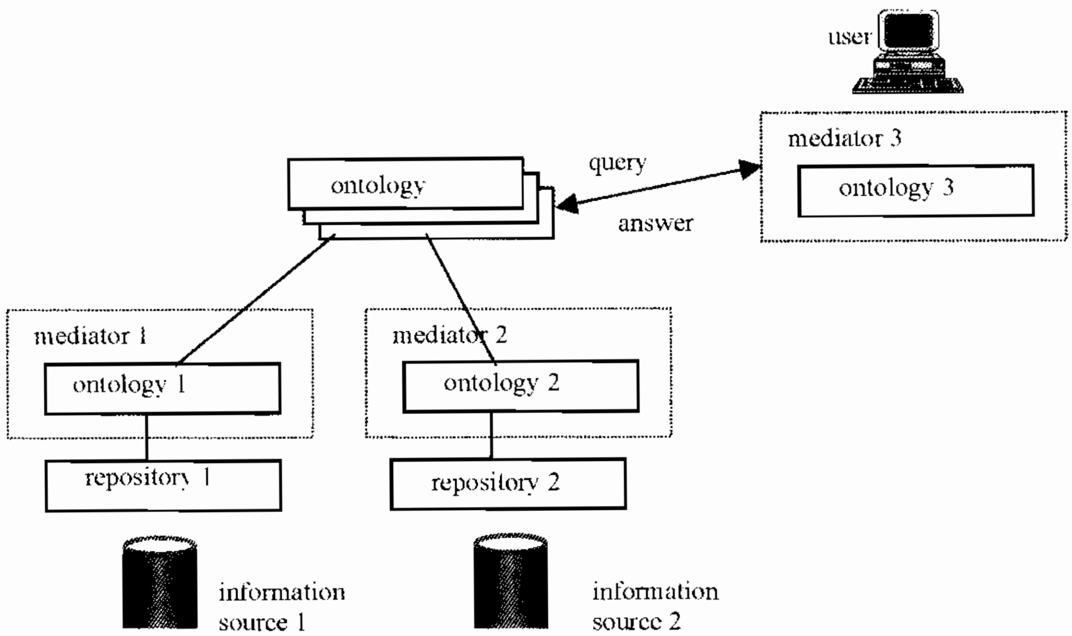

Figure 3: Architecture of mediated IS

CONCLUSIONS

We have tried, rather non-systematically, to characterize the network age and the role of IT in it. However, many issues remain to be dealt with. While the network age could enhance the quality of life for people, it is a challenge for social sciences and ethics [18]. In view of the fact that not only technology but also entire culture and civilization are changing, social sciences will develop, and their significance increase, at a faster pace than natural sciences and engineering.

The authors of [19] cite an important passage from the materials of the European Commission from 1996. Despite the indisputable benefits of the creation of wealth and increased standards of living, there are many concerns still to be reckoned with about the impact of information society on the quality of life. Two key questions are framed:

- Will these technologies not destroy more jobs than they create? and will people be able to adapt themselves to the changes in the way they work?
- Will the complexity and the cost of the new technologies not widen the gaps between

the industrialized and the less developed areas, between the young and the old and between those in the know and those who are not?

Despite the seeming absolute benefit, computers also make complex the reality. Owing to the bounded man's capability of decision speed, it is necessary to avoid creating complicated systems, where the justification of a computer decision can be so complex that the system is becoming non-verifiable, or forces people to make a premature decision. These problems can be approached also by a science. Let us recall in this connection the new role of science (here IT), as is formulated in [20]: it should help society make good decisions. And this is a challenge for IT in the network age as well.

ENDNOTES

1. People often talk about *post-modern* culture or society, Poster calls this *the second media age* [21].
2. PB is the abbreviation of petabyte. In the sequence of units kilo, mega, giga, tera, peta, and exa, each of which is thousand times larger than the previous one.
3. For example, http://www.forevernetwork.com/.
4. An avatar is an interactive representation of a human being in a virtual world.
5. In July 2000, it was estimated that the web graph contains about 2.1 billion nodes and 15 billions of links. Today, the web graph might contain more than 6 billion nodes.
6. Kumon calls these elements of intellectual network 'netizens' and 'intelprises' in [15].

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