From Human-Environment Interaction to Environmental Informatics (I): Theoretical and Practical Implications of Knowledge-Based Computing

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Abstract: *During recent decades the stirring up of the processes of globalization, practically in all spheres of present day civilization, has aggravated the society and brought numerous problems resulting from human-environment interactions. To overcome these problems, it is necessary to develop and adopt new concepts and techniques to manage the changes occurring on the Earth's ecosystem. For this, application of information and communication technology via Environmental Information Systems (EISs) - as integrated part of Environmental Informatics (EI) - is the best option. This paper deals with new and interactive approach to process, analysis and synthesis of environmental systems using various IT applications, so we could underline that environmental science and technology are therefore a vital component of productive knowledge and thus a high priority for the mankind sustainable fraternity with nature.*

Keywords: *Human-Environment interaction, IT&C applications, Environmental Information Systems*

1. Introduction

During recent decades the stirring up of the processes of globalization, practically in all spheres of society (as presented in Fig. 1), has aggravated and brought numerous problems resulting from *Human-Environment Interactions* (HEI). To overcome these problems, it is necessary to develop and adopt new concepts and techniques to study, understand, evaluate and manage the changes occurring on the Earth's ecosystem [1, 2].

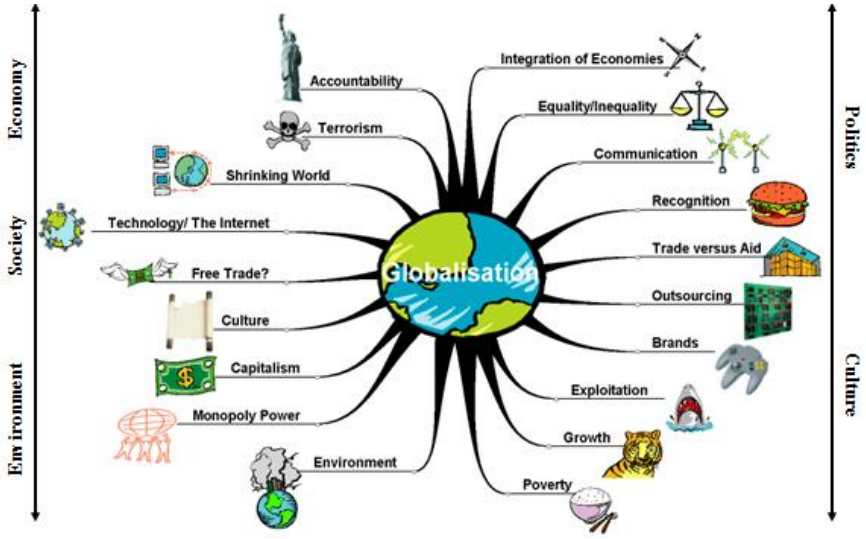

Fig. 1. Contemporary globalization - conceptual determinations [2]

For this, application of information and communication technology (IT&C) via *Environmental Information Systems* (EISs) - as integrated part of *Environmental Informatics* (EI) - is the best option; much more, understanding this complexity through interactive applications will develop new strategies and ideas to manage and protect ecosystem's values [1, 3].

Ever since "the environment" gained its place in the public international and national agenda (environmental legislation, sustainable development or disaster and hazard management), as well as in the globalization context (Fig. 2), it has been bundled with *data*, *information*, *knowledge* and *information systems* [3, 4, 24]; *Environmental Monitoring Systems* (EMSs), *Environmental Monitoring and Analyzing Systems* (EMASs) and especially *Environmental Information Systems* (EISs) [20, 21] are integrated part of *Environmental Informatics* (EI) platform [3, 4, 22-24].

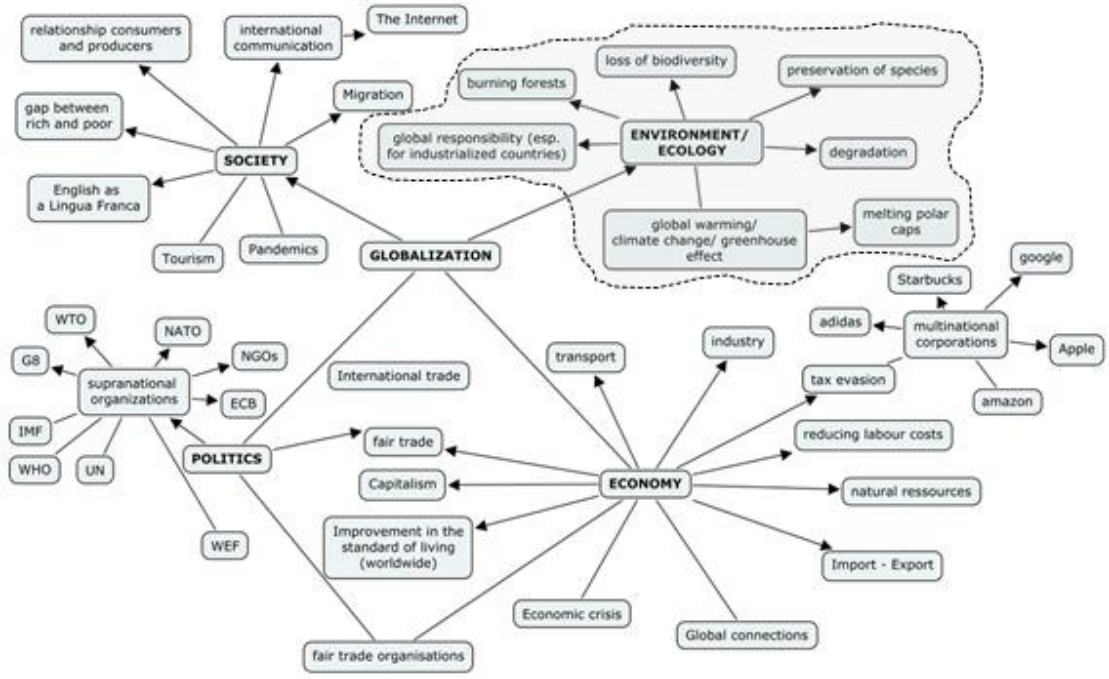

Fig. 2. Contemporary globalization - by reference to Human-Environment Interactions [3]

As we speak the area of Environmental Informatics (EI) is becoming more complex due to the current context and trend of making the EISs available to the public and end-users access (Fig. 3); this phenomena is based on the assumption that public and environmental information end-users awareness, participation and acting is improved by the rate of access to the environmental information to solve the complex problematic covered by the research, engineering and environmental protection fields; in this sense, Environmental Informatics (EI) plays a major role in environmental protection, planning, management and, of course, decision making [4]

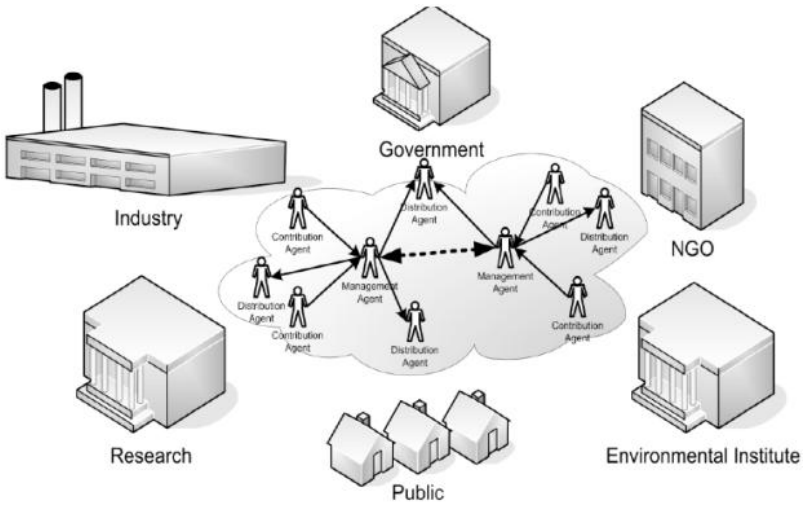

Fig. 3. General perspective according the environmental informatics societies: the main actors interested and involved in Environmental Informatics issues [4, 17]

The communication triangle of *Human-Computer-Environment interaction* (Fig. 4) - presenting the explicit and implicit types of communication - shows that the communication is possible on all levels, between each pair of the involved entities: *human* (users), *computer* (computing devices) and *environment* (context).

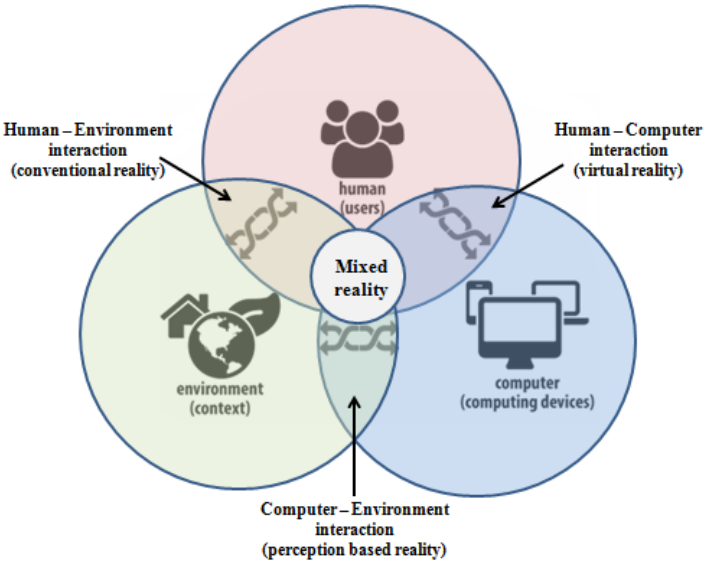

Fig. 4. The communication / existential reality triangle of Human-Computer-Environment interaction

Fields concerned with some aspect of this interaction triangle are, but not limited to, as follows:

- *Intelligent User Interfaces (IUI)* - aim to improve the efficiency, effectiveness, and naturalness of human-machine interaction by representing, reasoning, and acting on models of the user, domain, task, discourse, and media (e.g., graphics, natural language, gesture); as a onsequence, this interdisciplinary area draws upon research in and lies at the intersection of human-computer interaction, ergonomics, cognitive science, and artificial intelligence and its subareas [5];
- *Ubiquitous Computing (UBICOMP)* - is the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user [6];
- *Pervasive Computing* - can be a portal into an application-data space, by which a user performs a task, not software written to exploit a device's capabilities [7];
- *Physical Computing* - in the broadest sense, means building interactive physical systems by the use of software and hardware that can sense and respond to the analog world;
- *Ambient Intelligence* (AmI) - is about sensitive, adaptive electronic environments that respond to the actions of persons and objects and cater for their needs, this approach includes the entire environment and associates it with human interaction - being the way for us to re-immerse ourselves in life, and not in technology;
- *Everyware* - show us that all information we now look to our phones or web browsers to provide becomes accessible from just about anywhere, at any time and this is delivered in a manner appropriate to our location and context [8];
- *Internet of things (IoT)* - show us that the pervasive presence around us of a variety of things or objects which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbours to reach common goals [9].

This paper suggest new and interactive approach to process, analysis and synthesis of environmental issues using various IT&C applications, so we could underline that environmental science and technology are therefore a vital component of productive knowledge and thus a high priority for the mankind sustainable fraternity with nature. Since years, environmental scientists and computer experts are working on different and innovative computer-based modeling techniques to study the environmental problematic and hazards system and to provide the maximum accuracy in decision making or in elaborating sustainable strategies of community development [3].

Specialists working in the environment protection and engineering or related fields (agriculture, horticulture, forestry, zootechnics, landscape architecture) [10] need a great deal of information and knowledge at each stage of the management and assessment of environmental processes if they want the functioning of society and, implicitly, the economy to be in line with the principles of sustainable development and in favor of a healthy environment; also, for the preparation of a project and its implementation, they must know and understand, after a systematic analysis, the conditions under which these processes are carried out [3, 17].
The analysis carried out should be based on the best available data, methods and techniques and on the acquired knowledge, experience or expertise from other specialists [10]. Traditionally, this information and knowledge is obtained according to the requirements of the moment, through direct access to databases, reports and documents, by transferring information and knowledge among specialists (managers, practitioners, researchers) and by contacts established during the training sessions, workshops, congresses, conferences and symposiums (Fig. 5) [3, 16, 17].

Fig. 5. Different knowledge acquiring techniques specific to environmental management

In order to improve environmental management and assessment capacities, it is necessary for the specialists concerned to be able to manage and implement the concepts of effective and efficient assessment of environmental components and conditions, that can be achieved through environmental information software via EI applications; they also need to have simple and effective access to updated knowledge, in order to be able to take the best decisions, to shape sustainable development strategies, policies and actions for both developed and emerging economies.

2. Regarding ocurrences of environmental information culture

2.1 Documentary information and current society

Lately, as a result of the facilities offered by the new information and communication technologies in all sectors of society and in all aspects of the activities carried out [12, 16], expressions such as the *information society*, *informational era*, *communication society* were imposed, to designate, in fact, a new existential reality - mixed reality (as presented in Fig. 4) [17].
In today's society, defined by this new reality, the success and survival of many businesses, institutions, or people with political or social responsibilities depend on their ability to locate, analyze and use information resources efficiently and intelligently; in fact, the effectiveness to which it refers is intimately linked to the achievement of the proposed goals of documentation, information and knowledge, as well as the existence of concrete situations of making a particular decision, optimizing processes or applying different methodologies [3, 16].

The competence of any kind of individuals is given by the ability to search, retrieve, evaluate, use and understand fully the information resources, regardless of their support and presentation form. In this sense, the new information and communication technologies, which are in the process of developing, through the contribution of knowledge, have led to overcoming and dismantling the separating barriers - the time and space are no longer insurmountable obstacles to communication and relationship - as references to the Super Smart Society, composed by Information, Knowledge and Consciousness Society (Fig. 6) [3, 4, 12-14].

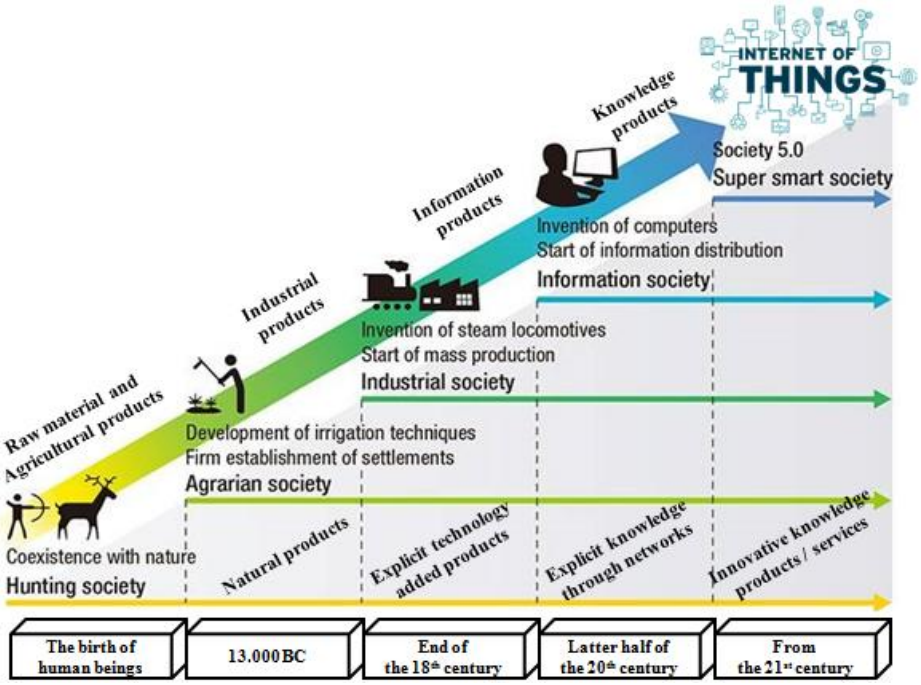

Fig. 6. Evolution of societies from the Hunting Society to Super Smart Society

In line with the extraordinary development of means of access to information, documentary training is at the heart of the global movement of forming an "information culture" irrespective of the field of interest. Documentary training, even the one specific to environmental sciences and individuals closely involved in this vast field, aims at the use and understanding of information and documentation tools and techniques in relation to the principles of sustainable development.
In addition, documentary training was defined as "the acquisition of documentation gathering techniques, integrated into a set of research procedures"; thus, documentary training is regarded as an element of the general research methodology, which includes cognitive and processing and communication activities - dissemination of information elements of interest to the user [12, 15].

2.2 Documentary information as a preoccupation of the university environment

The practice of collecting documents of any kind in collections and further research of their content has existed for a very long time and is regarded as an almost natural appropriation of humanity in its path to the formation of a culture (Fig. 7). The 20th century scientific evolution and the need for information from the 21st century have imposed information and documentation as an independent research area, which has pushed the human will to the frontiers of knowledge as far as possible and has generated an extraordinary documentary mass [12].
New technologies facilitate intimate, direct and immediate proximity to user information without the need for other mediation systems; moreover, because of the particular needs of information needed at a certain point in time, the user has to prove the knowledge of the specific information and documentation methods and techniques, which implies the existence of the formation of an informational culture. The acquisition of knowledge specific to new information and communication technologies expressively grafted on the information culture of each individual is in an effervescent process of development and restructuring as a result of various research environments, one of the most striking, far from being the university [2, 3].

The university environment is the space where the changes generated by New Informatics and Communication Technologies are felt with extraordinary force and represent at the same time the space where the most information needs intersect and the most diversified areas of interest are quantified. The university, equally educated, but also research oriented, is open to all the novelties, ready to assimilate the recent research results, but also to propose and promote new alternatives of knowledge, which is why for such a medium documentary training becomes indispensable [12].

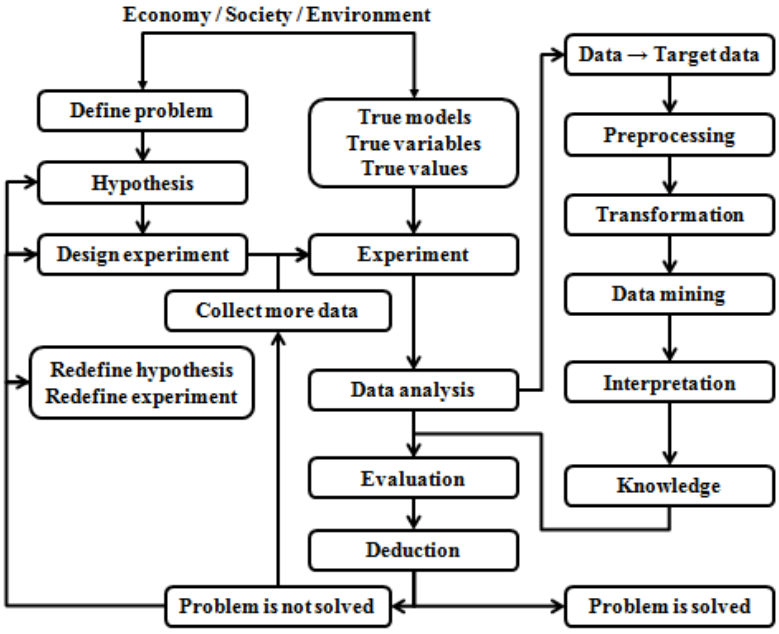

Fig. 7. Specific steps for obtaining environmental information and developing EISs [1, 11]

The educational process specific to the university, for example, is based on three pillars:

- passing the knowledge from the teacher to the student;
- observation and practical-applicative experiments;
- acquiring knowledge by consulting written or electronic documents.

Information and telecommunication technologies have produced unprecedented changes in society in all its aspects, comparable to the transformations produced by the invention and the wide use of printing; tending towards a transformation of the economic life, of the social life and implicitly a cultural transformation, mentality and, last but not least, the everyday life of each individual, the information mediated by the new information technologies penetrated and directs, with or without our will, activities in the universe of each.

The amount of information, the variety of forms of expression, the diversity of tools and information mediation technologies have produced major changes in people's way of communicating, learning, doing business, solving various problems, and reporting to peers and environment. The university environment, through education at all levels, must under these circumstances provide students with information literacy, an informational culture and the skills needed to use information resources, in order to further support the framework of the Society of Consciousness [13, 14].

One of the modern trends in the educational process in general and the environmental protection and engineering in particular is to approach the training of future environmental specialists on the basis of the legal system and policies specific to the field so that future specialists can make decisions and take actions based on their own knowledge and experience [15]. To improve environmental management and assessment capacities, specialists need to be able to manage and implement effective and efficient environmental assessment concepts that can be achieved through environmental information software. Under these conditions, information technology is a fundamental support for all components of fundamental scientific and applied scientific research in the field of environmental protection, being used for numerical simulation of complex interdisciplinary processes, for supervising and conducting experimental processes in laboratory installations, as well as in all applications in the field of environmental information transmission.

3. Environmental Informatics as a result of the info-environment culture

Environmental Informatics is a new research field, which is constantly developing within the wider framework of the confluence of environmental sciences and applied informatics, based on the application of IT&C to environment-specific issues closely studied by specialists [19]. Environmental Informatics applies methods and technologies for the collection, analysis, interpretation, dissemination and use of environmental information. It also includes a broad range of tools that can be used in conjunction to understand environmental issues: *Artificial Intelligence*, *Neural Networks*, *Geographic Information Systems* (Fig. 8), *Global Positioning Systems*, *Remote Sensing*, *Surveillance and Mapping Services*, *data storage* (data banks), *software engineering*, *mobile technology* and *the internet* [3, 16].

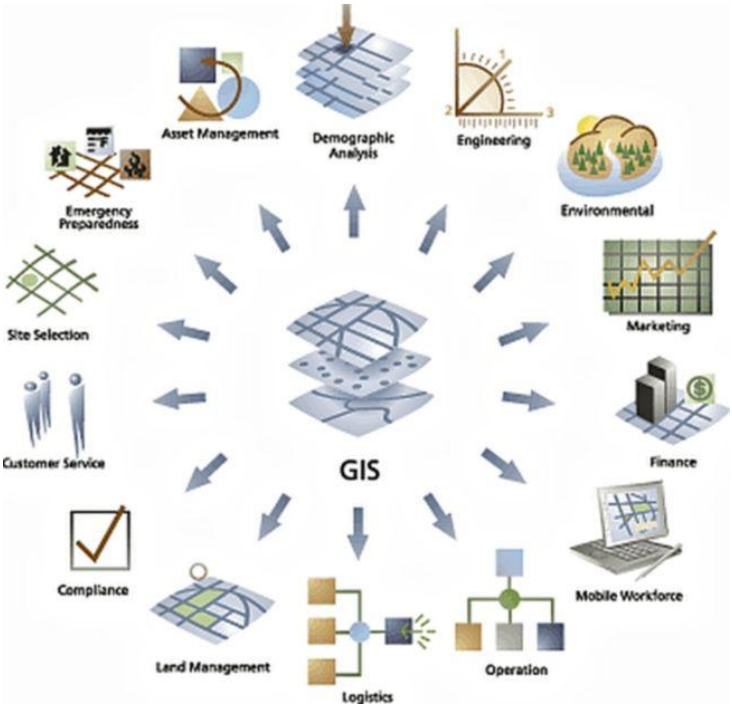

Fig. 8. Geographic Information Systems tools used to understand environmental issues [3, 18]

In Romania, although the activities that want to emphasize the bending towards the subject of environmental informatics are only in the beginning, there is some interest in alignment with the international standards in the field. Thus, a Laboratory of Environmental Informatics was set up at the Faculty of Power Engineering of the Polytechnic University of Bucharest and in the same sense it was acquired the most efficient computing system in Southeastern Europe at that time at West University of Timisoara, where an Institute for Advanced Environmental Research is being created; all this is dedicated to integrating IT&C applications for understanding and possible resolving environmental issues at national level [3]. As far as problems are concerned, they can be at any time or space scale, depending on this, their treatment is based on computational reasoning, mathematical modeling or monitoring, to ensure and allow a better understanding [3].
The main goal of the Institute for Advanced Environmental Research in Timisoara is to create a strategic research infrastructure, of excellence, at international standards that:

- to focus and develop the existing research potential in research centers;
- allow research to be addressed in an inclusive and multidisciplinary manner;
- ensure, through space, adequate endowment and training, international competitiveness and visibility of research results by members of the academic community;
- to contribute to the stimulation of technology transfer based on cooperation between the research institute and the productive enterprises;
- to support and participate in the development of poles of excellence focusing on technological science and environmental research via different IT&C tools (Fig. 9).

It is also intended, as an estimated strategic outcome, to meet the following requirements related to the integration of project research results from major areas of academic activity and scientific research [15, 16]: *environmental science* (geology, geophysics, meteorology etc); *chemistry* (environmental chemistry, biochemistry, biotechnology, enzymology, technological chemistry, analytical chemistry etc); *biology* (ecology, ethology, biomonitoring, ecotoxicology etc); *physics* (environmental physics, biophysics, bioinformatics, solid body physics etc); *mathematics* (mathematical modeling, biostatistics, applied mathematics etc); *computer science* (Fig. 9) (artificial intelligence, parallel and distributed computing, computational mathematics, bioinformatics etc) and *socio-human sciences* (bioeconomy, sustainable spatial planning, ecotourism and marketing, environmental management), which will then provide optimal channels for transfer to the effective beneficiaries - economic and institutional actors (Fig. 4).

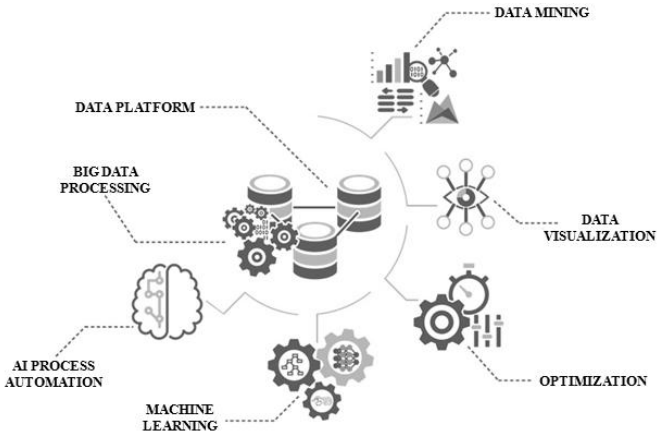

Fig. 9. A broad range of IT&C tools used to understand environmental issues

The research carried out within the Environmental Informatics Laboratory focuses on the implementation of information and communication technology in the field of environmental monitoring and evaluation and the determination of its impact on the health of the population; have as their main objective the application of new, innovative approaches to solving specific problems by focusing on the use of environmental information systems (Fig. 10).

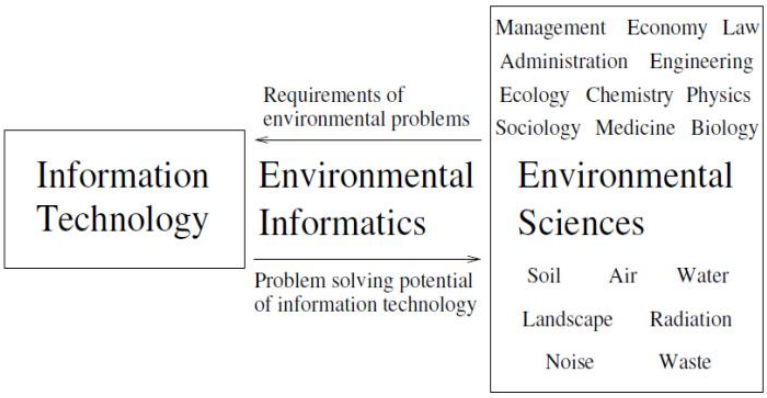

Fig. 10. Environmental Informatics - a bridge-science between IT&C and Environmental sciences [3, 17, 18]

The research team serving the laboratory must be specialized in: *monitoring of environmental factors* - water, air, soil, biodiversity; *use of automatic data acquisition systems* to monitor environmental factors, previously specified; *process management* with the help of industrial computers and programs for this purpose; *implementation of innovative systems* in environmental applications; *development and management of environmental databases*; *use of geographic information systems* for the collection, processing, analysis and visualization of environmental data, information and knowledge; *performing statistical analyzes* and creating databases, and *environmental knowledge management*.

The support of the research activity carried out within the Environmental Informatics Laboratory is the modern endowment with hardware and software, which allows the efficient approach of any research topic. A significant variety of environmental research themes have been addressed so far, most of them being framed and being oriented in several directions, among which we can mention:

- *integrated environmental monitoring* and *pollution control*, which is the basic instrument of environmental decision support systems, both for the recording of environmental changes and especially for understanding and defining the causes of these changes;
- *the use of Geographic Information Systems* (GIS) to monitor environmental factors has become an essential tool in understanding the process of global environmental change;
- *environmental data base management* is defined as one of the fundamental elements that generate and control environmental information flows.

Addressing issues specific to environmental protection, environmental management and research in this area is based, exclusively at least in the last period, on the effective use of environmentall information; this information, collected in different ways and from different sources (Fig. 5), can take the form of biological, physical, chemical, geological, meteorological information. Environmental data, as the first phase of knowledge in the field, describe the status and dynamics of the environment at a given time and for a particular area, and are commonly organized in technical, temporal and space databases or databases covering virtually all environmental domains. By appropriate management, the latter can meet waste, noise and vibration requirements, hazardous substances and products, fauna and flora quality.

Environmental problems which imply one or more decisional steps are more common in engineering and environment protection areas of expertise, and especially common in durable development strategies on a local level [3]. Developing the mathematical apparatus specific to financial and managerial mathematics and more specifically greater use of computers have made scientists take on the decisional problem on a more advanced manner; optimal decision making and optimising took as refference an objective, computational mathematics and technology focused way using this knowledge towards modern techniques regarding inventorying charting and management approaches.

Distribution of information and knowledge over the internet must be in close collaboration with intense preocupation regarding natural resources available for human need satisfaction. Rational allocation of those resources imposes politically influenced decisions but rationally fundamented on scientific needs and opinions and orchestrated by acess towards such scientific knowledge; the decisional support for durable development of communities is given by EISs. With help from Environment Informatics the efficency of identification of new solutions for problem solving regarding environment is greatly enhanced, end users being provided with higher levels of acess to information and so they can develop and maintain an environmental informational culture [3]. We are setting the premises of efficient training in environmental research, based on complete analysis of environment specific issues ,knowing up to date technologies and generating decisions in regards with the personnel needs and specific situations found in field research.

Environment represents the essential foundation of human existence, being the result of human made and natural elements interacting with each other; all of those factor into conditions of existance of society and development prepositions of the before mentioned society. Taking this into consideration, environment protection is a public priority which targets obtaining and mantaining a healthy environment, conservation of resources in concordance with durable development requirements. Fulfilling those objectives neccesitates a raising in levels of education and conciousness among population, in regards to globalisation of information in society which creates a need for producing and for utilisation of information coroborated with knowledge gaining regardless of field of expertise.

Knowledge is meaningful information and information that drives to action, in regards of decision making being influenced by knowledge and sharing of such knowledge among interest groups.

Informational society based on knowledge means more than inevitable progress of technology and IT&C contextualised in the so called new economy based on intellectual dependent activities that characterise an advanced society. Considering this approach, Informational and Knowledge Societies include a series of multilateral developed sub-societies which cover the following dimensions [13, 14]:

- *social* - applies to healthcare and social security, social democracy (e-Health systems, remote workflow systems, remote ensurance systems etc);
- *educational* - develops competences regarding concieving and working in fully informatical workspaces, intelligent management of work-processes (e-learning, virtual libraries etc);
- *ambiental* - with impact on environmental research and protection;
- *cultural* - with impact on developing and maintaining the cultural wealth of a community, and its industrial developments, (online museums and art galleries, digitalisation of coursebooks, international and local cultural wealth digitalisation etc);
- *economic* - develops new approaches to digital economy and knowledge-based economy (e-Commerce, e-Banking, e-Learning, e-Currencies, e-Trading, online payments etc).

First steps into the knowledge society are triggered by a minimal number of technological vectors. We take into consideration the following technological vectors for both the informational and knowledge-based societies [3, 13, 14]: *extended interconnectivity* by geographical extension of bandwith transsmision up to all reachable areas of the globe, taking into it every household, company, and individual; *e-book technologies*; *intelligent agents* which are specialised systems with artificial intelligence implementations embedded in them, used for data mining, intelligent agents will be used for defining most of the technological vectors; *informatised environment* and *nanoelectronics*, which will become the main physical support for processing information.
Analysis methods play a significant role in adding to the environment knowledge base taking into consideration the significant amount of data measurable and measured, amount which is in continuous growth and adaptive to user requests (Fig. 11). Major fields of environmental research which converge towards assuring knowledge neccessary are environmental informatics and statistics. Such fields of research undertake different and multiple variations regarded to informatics providing different systems to analyse specific environmental data.

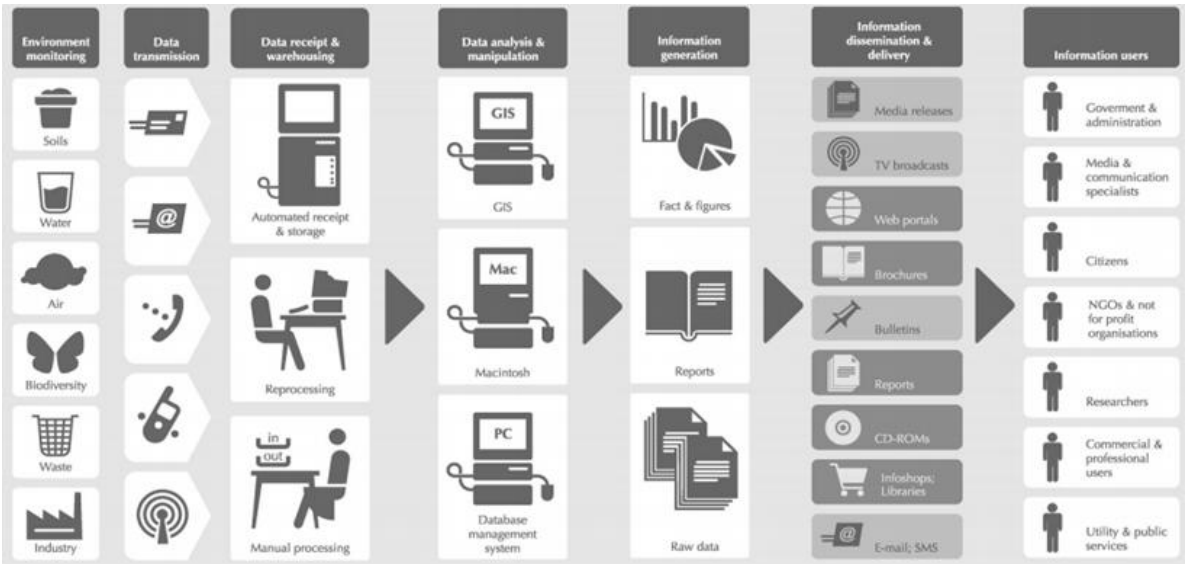

Fig. 11. Schematic diagram for a "complete" Environmental Information System [3, 17, 25]

In contemporary society social, cultural, economic and ecologic dynamics are on of the dominant constants of the 21st century; such transformations of society represent challenges that humankind and its academic structure are called to take on and manage accordingly. The answers to those requirements worked towards changing educational priorities, by going from manually operating the data to automatically operating the data with help from environment softwares.
The use of computers in schools and universities and educational software in the teaching-learning-evaluation process is the solution provided by the informational educational system for the progress of society and environmental protection. The possibilities of processing the collected data from the field and the ones with the help of specific computer environments come together with the traditional teaching and acquiring knowledge system to identify the student motivational resources needed to manage the daily challenges and problems of the environment.

As a result of the "environmental informatics" learning system (Fig. 11) [20-24], which has a solid theoretical base and depending on the version of the environmental software, several research sub-domains are detached, of which we review the following [3]:

- *bioinformatics* - involves the application of IT&C in the field of biology and medicine; is based on specific algorithms, databases, web technologies, artificial intelligence, applications dedicated to the exploitation of biological data, image processing, modeling and simulation of various processes, as well as biostatistics concepts etc.
- *chemioinformatics* - is a mixture of information resources from two different fields of computer science and chemistry, which encompass many of the applications that currently underlie chemical engineering and modern genetics.
- *geoinformatics* - addresses geoscience related issues and related branches of geological engineering, including cartography, geodesy, GIS, photogrammetry, remote sensing etc.
- *hydroinformatics* - has a strong interest in using techniques stemming from artificial intelligence and recognizes the social nature of water management issues.
- *ecoinformatics* - defined as discipline and self-standing science, outlined by the integration of mathematical applications, computer science, statistical and engineering sciences for ecosystem research and management, is an increasingly evolving area.

4. Conclusions

The environment is the essential framework of human existence, being the result of the interaction between natural elements and elements resulting from human activity; all of these influence the existence conditions of society and its development possibilities. As a result, the protection of the environment is a public priority aiming at achieving a healthy environment and the preservation of natural resources, in line with the requirements of sustainable economy and social development. Achieving these goals requires raising the level of education and awareness of the population, as part of the global computerization of today's society. Computer technologies are currently the support of all fundamental and applied scientific research components in the field of environmental protection, being used for numerical simulation of complex interdisciplinary processes, for monitoring and conducting experimental processes in laboratory installations, as well as for all applications in the field of information processing and transmission environmental specific.
It is also of greather importance that the communication and relationship, as well as knowledge and awareness - as contextual references of the Information Society, Knowledge Society and Society of Constitution - are to be supported by the idea and the merits that they can bring the altar of science information systems for the collection, processing and dissemination of environmental information. As an integral part of environmental informatics, the computer systems in question come to outline, in the most direct way possible, to associate and complement the cognitive apparatus of users with new aspects of the environmental information culture that is indispensable for the outcome of the educational act itself.
Nowadays, IT&C systems have a well-defined place in all areas of activity: production, service provision, management, monitoring, research, public involvement in decision-making and in almost all states of the world. Environmental Information Systems become mandatory environmental science tools and can be defined as a collection of packet data and information, described by a number of specific indicators relevant for the study, monitoring and exploration of the environment. Every decade brings new problems, but also new applications in the field of environmental protection, SIM being more involved in the foresight activity, selecting a development alternative, diminishing possible and / or real negative effects.
As a conclusion, it can be said that modern data analysis methods are useful tools in environmental informatics and environmental statistics. Good methods are understandable for the environmental scientists and at the same time reliable, robust and helpful for discovering important relationships in the data. In cooperation between environmental and information scientists, what takes the relationship flourish is the knowledge of both sides about their field and efficient communication concerning the specific needs of a certain problem, and the properties of the methods. Without these ingredients, the results of cooperation projects may not be satisfactory.

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