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Informatics for Environmental Protection, Sustainable Development, and Risk Management

20 Years Technical Committee on Environmental Informatics

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Abstract

After its launch more than two decades ago, Environmental Informatics has become a somewhat fuzzy movement in applied informatics and computer science dealing with environmental matters to give rise to a professional society. Today, Environmental Informatics constitutes a scientific community with numerous tools, studies, publications, and resources of research. On the intellectual level, the GI TC 4.6 Environmental Informatics community with its academic background has a growing impact on government agendas, business applications in industry, and higher education programmes. As it has developed such a degree of institutionalisation, it is the right time to trace back its history (section 2), outline the current state of the field with its different forms of institutionalization (section 3), describe the emerging disciplinary contours (section 4), and illustrate major results and impacts of the field (section 5).

1. Introduction

Environmental Informatics has its roots in two world-changing developments: In environmental science and research and in Information and Communication Technology (ICT). In the status nascendi, these two fields seemed to be completely independent. Computer science with its technical and technological origin was and is opposed to the diverse scientific, ecological, social, and political environmental movements in many respects. Nevertheless, the increasing performance of computers and the need for solutions to respond to environmental stress made these different areas amalgamate.

On the basis of environmental indicators, information and knowledge, a broad spectrum of environmental plans and legislative measures were established in the last two decades.

In Europe, the right to access environmental information improved the public's insight into environmental information and led to the adoption of the updated Directive 2003/4/EC on "Public Access to Environmental Information". A further step was the "Århus Convention" on Access to Information, Public Participation in Decision-making, and Access to Justice in Environmental Matters (1998, Denmark), ratified by 39 signatories (until Jan. 2006). General strategies, such as the currently re-focused Lisbon strategy (COM(2006) 30, 25 January 2006) bring more "investment in knowledge and innovation" and "response to globalization and aging" to the agenda.

Programs like the European Strategy for Sustainable Development (COM(2001) 264 final; COM(2005) 658 final) need a sound basis for decisions. For these reasons, the Research Framework Programme of the European Commission (FP7: 2007-2013, with a focus on sustainability) directed the attention to specific

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information, resulting in an environmental legislation e.g. on waste management (WEEE Directive), protection of air (fine particulate matter PM 2.5) and water (Water Framework Directive WFD). Other areas of directives have been soil, nature, biodiversity and emission trading. In the meantime, most politicians in the EU, member states, cities, and on the regional level admit the need to reconcile the three objectives of wealth creation, social cohesion, and environmental protection.

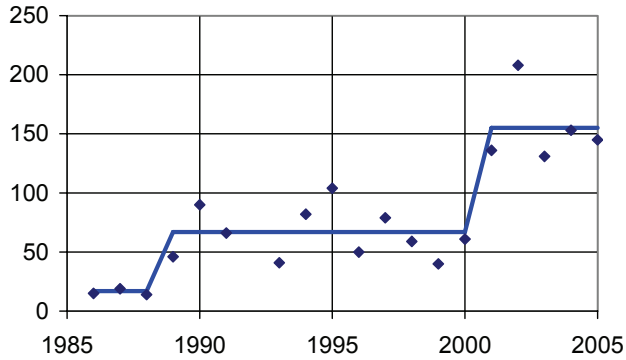

Figure 1: Number of presentations in EnviroInfo Conferences

Anyhow, we are confronted with "unsustainable trends" like climate change, armed conflicts, partly counterproductive transports, progressive land use, depletion of natural resources, an ageing society in Europe as well as social exclusion and poverty. Hence, information for a sound environmental management is one of the pillars of sustainable development. The annual EnviroInfo Conferences on Environmental Informatics represent a platform to disseminate information and methods, using the strength of informatics and the dissemination potential of Information and Communication Technologies.

2. History of Environmental Informatics and the Technical Committee's Role

40 years ago, both environmental science and computers were in the starting blocks of a world-changing evolution. Prospering industrialization and increasing wealth in developed countries resulted in an escalating energy consumption, resources and land use, transport density, and consumption in general. The problems of this development resulted in an increasing demand of information on the environment. Measurements of air and water pollution incited the media to report on them soon and, thus, boosted environmental awareness and the corresponding political response despite the opposition from many established interest groups (Pillmann, Geiger and Voigt 2006).

Environmental Informatics originates from application needs in engineering, e.g. data acquisition, computer-based process control, operation of measurement stations, data transmission, pollution modeling, and image processing in remote sensing. At the same time, developments e.g. in landscape ecology, biosciences, identification, model building, system science, and environmental policy enriched the structural understanding of scientists working in this interdisciplinary areas. It also was the time of changes in governments, the establishment of national Environmental Protection Agencies, and the foundation of new non-governmental environmental organizations (NGOs). E.-U. von Weizsäcker dated the emergence of Environmental Informatics back to the time when no specialist area and no identifier for this activity existed (Hilty 1997). Today, the overall objective of Environmental Informatics is to process data, analyze information, support information management, and develop information systems related to the environment in its broadest sense, while using methods, techniques, and tools of computer science. With this, it is hoped to contribute to environmental protection, support risk management, and finally to approach a more sustainable future.

In the course of existence of the Technical Committee (TC) 4.6 Environmental Informatics of the German Informatics Association (GI)[4], three phases of development can be distinguished: A pioneer phase, a phase

[4] Gesellschaft für Informatik, Fachausschuss FA 4.6: Umweltinformatik, http://www.iai.fzk.de/Fachgruppe/GI/
TC 4.6 Executive Committee (2006):
W. Geiger, A. Gnauck, L.M. Hilty, St. Jensen, G. Knetsch, R. Kramer, B. Page, W. Pillmann, U. Rey, W.-F. Riekert,

of continuous work, and the maturity of this discipline at present. A sound indicator of these phases is the number of refereed papers submitted to the main conferences (fig. 1). Illustrated by the topics of the main conference, the development of Environmental Informatics shall be demonstrated.

2.1 Early Efforts

In principle, time in the mid-1980s was ripe for applications of information systems in the emerging field of environmental protection. The nucleus of the upcoming field of "computer application for environmental protection" was the 1st Symposium held at the Karlsruhe Research Center in 1986 and the foundation of the Technical Committee "Informatik im Umweltschutz" (Environmental Informatics). By the way, this year brought a lot of different incidents, e.g. the Chernobyl nuclear reactor disaster, the establishment of the Ministry of the Environment (Germany), the Emergency Planning and Community Right to Know Act (USA), and the signature of the Vienna Convention for the Protection of the Ozone Layer.

Since 1980	Independent working groups in Hamburg, Karlsruhe, and Vienna (e.g. Hilty and Page 1985; Pillmann 1981; Pillmann and Stefanich 1980)
1986	1st symposium and WG meeting "Informatik im Umweltschutz" at the Karlsruhe Research Center
1987	2nd symposium and proposal of the foundation of a Technical Committee (TC)
Jan. 1988	GI board accepts the proposal to establish the TC 4.6 "Informatics for Environmental Protection"
May 1988	1st Technical Newsletter (Rundbrief) of the TC
1989	3rd symposium "Informatik im Umweltschutz" at the Karlsruhe Research Center (organizers: Jaeschke, Geiger), in cooperation with GIL (Gesellschaft für Informatik in der Land-, Forst- und Ernährungswirtschaft)

Table 1:Foundation of the Technical Committee

The growing interest in informatics applications in all fields of environmental protection led to a continued series of annual symposia and conferences later on (fig. 2).
Exchange of information in this emerging scientific field of Environmental Informatics was enhanced by A. Jaeschke and B. Page, who organized the 1st symposium. The bibliography "Status of computer and informatics applications in the environmental sector (Page 1989) and the paper "Angewandte Informatik im Umweltschutz" (Page et al. 1990) reflected the developing self-image of the group.

M. Schreiber, H. Streuff, J. Wittmann, K. Voigt.
Appointed members: U. Freitag, F.-J. Radermacher, Th. Ruddy, F. Scholles, A. Susini

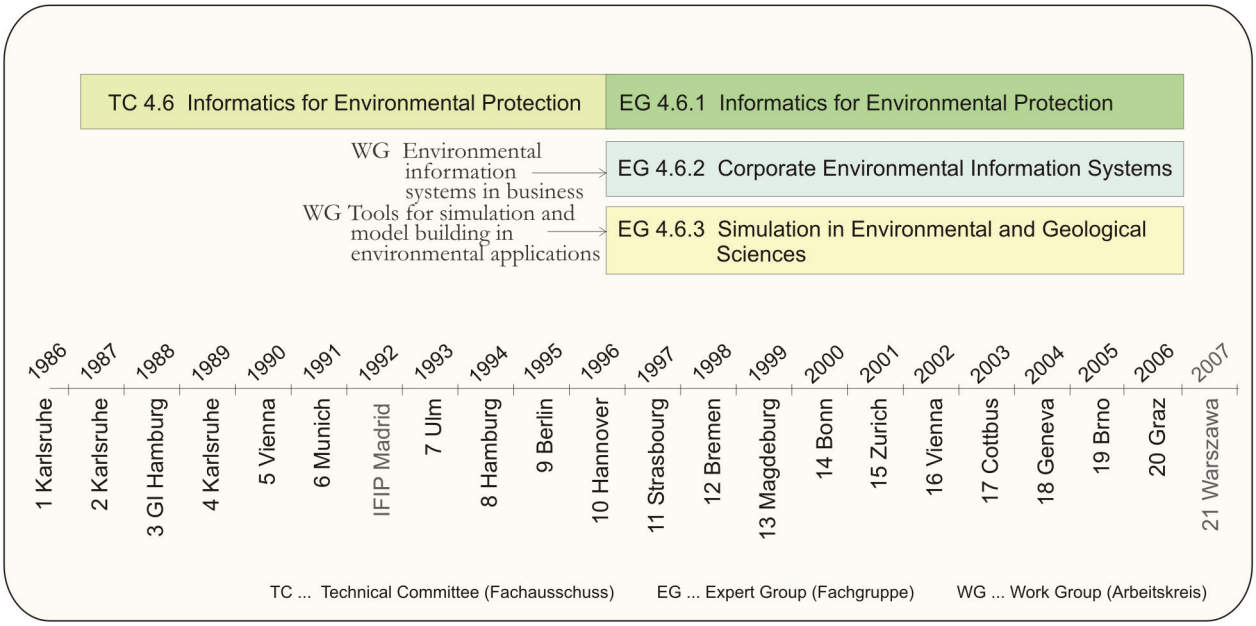

Fig. 2: Development of the TC 4.6 structure and annual conferences

Due to the activities of several TC members, in 1996 the TC formed two additional branches: TC 4.6.2 *Corporate Environmental Information Systems* and TC 4.6.3 *Tools for Simulation and Model Building for Environmental Applications*. This name was changed in 2000 to *Modeling and Simulation in Environmental Applications*.

2.2 Establishing the Field of Research

Increasing interest in computer applications for the analysis of environmental impacts is reflected by the doubled number of presentations at the 5th Symposium. Amicable cooperation and mutual support within the TC was a convenient framework for the following conferences. Since 1989, each Symposium has been divided into sections like specific environmental issues, environmental research, progress in applied informatics, modeling and simulation, database applications, geographic information systems, and specific issues of computer science.

Due to the preference and expertise of the symposium organizers, each event had its own profile and specific subjects. In 1990 for example, a session on "Prospects, effects, risks, and limits of information processing" shaped the discussion culture in the TC concerning the Janus face of "Informatics and Ecology" (Rolf EI 1990 683)[5].

The **1991** Munich symposium was coined by the organizer Siemens AG. Air pollution control, municipal information, and presentations of industrial applications were combined with presentations of early GIS, expert systems, and knowledge-based developments. Embedded in the 12th IFIP World Congress (Madrid 1992), the expert meeting on EI was rather isolated in the diverse topics of this event. The topic "sustainable development" emerged in presentations especially after the 1992 UNCED Conference.

[5]References to the EnviroInfo symposia (Informatik für den Umweltschutz, Umweltinformatik and since 2002 EnviroInfo) were identified simply with author, EI year/volume (if applicable), and first page, e.g. (Weizsäcker EI 1987 1) or (MacDonell EI 2002/II 174). The EI volumes 1986-2005 can be found in the reference list.

1990	Vienna	Pillmann, Jaeschke	Informatik für den Umweltschutz
1991	Munich	Hälker, Jaeschke	Informatik für den Umweltschutz Computer Science for Environmental Protection
1992	Madrid	Expert Session within the 12th IFIP World Congress	
1993	Ulm	Jaeschke, Kämpke, Page, Radermacher	Informatik für den Umweltschutz
		Hilty L., Page B. (1993): Handbook ”Environmental Informatics“ Oldenbourg Verlag	
1994	Hamburg	Hilty, Jaeschke, Page, Schwabl	Informatik für den Umweltschutz
1995	Berlin	Kremers, Pillmann	Raum und Zeit in Umweltinformationssystemen Space and Time in Environmental Information Systems
1996	Hannover	Lessing, Lipeck	Informatik für den Umweltschutz
1997	Strasbourg	Geiger, Jaeschke, Rentz, Simon, Spengler, Zilliox, Zundl	Informatique pour l'Environnement '97
1998	Bremen	Haasis, Ranze	Networked Structure in IT, the Environment and Business
1999	Magdeburg	Rautenstrauch; Schenk	Umweltinformatik zwischen Theorie und Industrieanwendung
2000	Bonn	Cremers, Greve	Umweltinformation für Planung, Politik und Öffentlichkeit

Table 2: Symposia 1990 - 2000: Organizers and main topics

In the 1993 symposium, a comprehensive interim report presented the Environmental Information System Baden-Württemberg (UIS BW) as a central tool of the state for providing environmental information and its efficient access (Mayer-Föll EI 1993 313). As requirements increased, so did the potential costs of development of environmental information systems. In an effort to work out powerful economically efficient solutions, a cooperation for the development of software for Environmental Information Systems (KoopUIS) was initiated by the State Ministry of the Environment Baden-Württemberg and the German Federal Ministry of the Environment (BMU). This cooperation was gradually joined by all German state ministries of the environment (Mayer-Föll et al. EI 2005/I 146; Keitel et al. EI 2002/II 23).

In 1993, B. Page and L. Hilty edited the handbook of Environmental Informatics. In 16 chapters, a comprehensive survey of tools and methods for environmental protection was given, covering applied informatics, monitoring, visualization, environmental communication, business informatics, etc. The 2nd edition appeared in 1995. Also in 1993, A. Gnauck became the head of the first university chair of “Environmental Informatics” in Cottbus. In Germany, several working groups and later on institutes and organizations attended to this cross-cutting issue, e.g. in Kiel, Göttingen, Kassel, and Bayreuth.

The focus “Environmental information systems in business” started at the **1994** Hamburg Symposium. High-level keynote speakers, e.g. F. Schmidt-Bleek, K. Fedra, H. Bossel, and A. Rolf (EI 1994 13-80) enriched the program. Public access to databases of the UBA Berlin, the Web application CEDAR (Central European Environment Data Request Facility) in cooperation with UNEP/Infoterra (Pillmann EI 1994/I 219), and progress in meta information (Lessing and Schütz EI 1994/1 159) continued this development.

In the **1995** Berlin symposium, an increasing number of papers - and a growing fraction of participants from non-German-speaking countries - made this event exceptional. H. Kremers in particular promoted presentations from eastern European countries in this 1995 conference. In the light of the enlargement of the EU, this was an early step to foster the transboundary exchange of environmental information.

The presentation of E. U. v. Weizsäcker “Data Demand and Factor 4” (EI **1996** 13) and main topics like meta information and transport modeling introduced new strategic research fields in the discussion.

Important steps towards the internationalization of the TC were the symposia in Strasbourg and Bremen. In **1997** (Strasbourg), a mixed French-German program included topics like telematics and Web applications, substance flow management, and environmental information systems in administration. In an impressive keynote, Radermacher (EI 1997/I 27) pointed out the topics of resource use and the rebound effect and their consequences.

In Bremen **1998**, the two additional conferences of Artificial Intelligence (KI-98) and Informatics in Medicine in the conference week enriched the topics of Environmental Informatics.

In **1999**, the symposium was held in Magdeburg, for the first time in the New Laender (Neue Bundesländer) of Germany. The conference was organized by an institute of business informatics and celebrated "one decade of environmental information systems in business".

At the end of the millennium, the **2000** Bonn Symposium "Environmental Information for Planning, Politics, and the Public" topped off the main issues of the century. Agenda 21, spatial planning, regional and urban development, GIS, and environmental communication prepared the development of the next phase.

Looking at this middle development phase of Environmental Informatics with a bird's eye view, it was found that early developments of GIS application were fully operational (e.g. best paper award: Pecar-Ilic and Ruzic EI2005/I 207), while expert systems did not develop appropriately. Information in the fields of environment and health (Keune and Theisen EI 1991 546) needed three further ministerial conferences to implement ENHIS, a European ENvironmental and Health Information System.

2.3 Emerging Discipline and Consolidation

With the Zurich Symposium in **2001**, a new phase in the TC development was reached. The discussion on opening the "German conference" to an international scale was completely put into practice. It was the first annual conference held fully in the English language. A best paper award and a student's price were introduced. The title "Sustainability in the Information Society" perfectly outlined the direction of the TC strategy, a critical study of effects of conferences from an environmental point of view was completed (Hilty, Gilger EI 2001 Preface), and guidance for an "Ethical Framework for Environmental Informatics" was presented (Isenmann EI 2001/I 127).

2001	Zurich	Hilty, Gilgen	Sustainability in the Information Society
2002	Vienna	Pillmann, Tochtermann	Environmental Communication in the Information Society
2003	Cottbus	Gnauck, Heinrich	The Information Society and Enlargement of the EU
2004	Geneva	Minier, Susini	Sharing

Memorandum Nachhaltige Informationsgesellschaft (2004). Authors: M. Dompke, J. von Geibler, W. Göhring, M. Herget, L.M. Hilty, R. Isenmann, M. Kuhndt, St. Naumann, D. Quack, E. Seifert

2005	Brno	Hrebícek, Rácek	Networking Environmental Information
2006	Graz	Tochtermann, Scharl	Managing Environmental Knowledge

Table 3: EnviroInfo conferences 2001 - 2006 and their main topics

In some respects, this "innovative new phase" was trend-setting for the subsequent conferences. The name "EnviroInfo" was introduced for the 2002 annual conference in Vienna. The title "Communication in the Information Society" considered environmental information from an informatics and social perspective. This conference was held in cooperation with the Eco-Informa Foundation (USA) and the European Environment Agency (EEA), which hold its eEIONET workshop (EI 2002 70-132). A broader view to a "sustainability perspective" gave Radermacher (EI 2002/I 58) and Schmidt-Bleek (EI 2002/I 1).

The conference sessions were organized in a systemic manner. The conference structure was designed as a dynamic system embedding specific fields of environmental protection like air, water, soil, waste, landscape, and informatic applications in a societal, economic, technical, and political context (Pillmann EI 2002/I 11; EI 2005/I 1).

The second EnviroInfo in a former east European country was held at the University of Cottbus. The topic of the **2003** Cottbus EnviroInfo was "Enlargement of the European Union". Shortly before the joining of the EU by ten states, the conference close to the Czech Republic and Poland brought sustainable development up to the agenda.

The **2004** Geneva EnviroInfo was linked with the celebration of CERN's 50th anniversary. The principal topic "Sharing technologies, knowledge, and data" comprised issues related to e-Government (Lahser et al. EI 2004/I 33), know-how transfer (Tochtermann et al. EI 2004/I 172), decision support in developing countries (Göhring et al. EI 2004/I 97), data sharing for risk assessment (Susini et al. EI 2004/I 363), and sharing environmental data and services (Bandholz EI 2004/I 324).

The **2005** EnviroInfo in the Masaryk University in Brno emphasised the "Networking Environmental Information" with a large contingent of speakers of the new EU member states. An outlook on the 7th Framework Programme was given and in the Workshop "Tools for Emergencies and Disaster Management" speakers from South America to Indonesia enriched the discussion.

Since 1993, the Thesaurus of the Environmental Data Catalogue Austria and Germany (UDK-Thesaurus) had been developed based on the German environmental thesaurus UMTHES® of EPA (Umweltbundesamt) Berlin/Dessau, now available in Vers. 8. The software "SuperThes" had been used for the construction and maintenance of the thesaurus (Batschi, Legat, Plini and Stallbaumer EI 2004/I 492).

From 1995, a General Multilingual Environmental Thesaurus (GEMET) for 19 languages of the EU member states had been developed within the working program of the EEA "European Topic Centre for Catalogue of Data Sources & Thesaurus" (ETC/CDS). Also in 2004, several contributions of EIONET partners on the progress in *Reportnet* and the *Ecoinformatics initiative* (Jensen, Fitzwater EI 2004/II 208) were presented.

3. Institutionalization of Environmental Informatics

Over the years, special interests led to the establishment of specialized Expert- and Working Groups (EGs, WGs). Below, a short descriptions of Expert Groups (Fachgruppen, FG) and working groups (Arbeitskreise, AK) are given.

3.1 Expert Groups (Fachgruppen)

In the early stages, the TC 4.6 comprised one Expert Group, called Technical Committee or "Fachausschuss". After the foundation of new EGs this first and largest group with its annual conference EnviroInfo was renamed to Expert Group 4.6.1 "Umweltinformatik".

Industrial Environmental Information Systems (FG 4.6.2)

The WG Corporate (or Industrial) Environmental Information Systems (CEIS; Fachgruppe FG 4.6.2 Betriebliche Umweltinformationssysteme, BUIS) was founded 1993 in Hamburg, where L. Hilty and C. Rautenstrauch organized the first workshop. This WG was very successful in transferring experiences with Environmental Information Systems from the public to the private sector, as well as in structuring various approaches to extend Corporate Information Systems or Enterprise Resource Planning (ERP) Systems to include environmental, health and safety aspects. Since 1993, 13 annual workshops have been held at

many places in Austria, Germany and Switzerland. Most of the work has been documented in the book series "Umweltinformatik aktuell" by the Metropolis publishing house (in German).

Modeling and Simulation in Environmental Applications (FG 4.6.3)

The Working Group *Werkzeuge für Modellbildung und Simulation in Umweltanwendungen* founded in 1992 changed its status in 1996 to the Expert Group 4.6.3 and cooperates with ASIM, the GI-TC 4.5. The speaker of this group was R. Grützner, who organised 9 high quality workshops between 1992 and 1999. Since 1999 the EG continued Grützner's activities in parallel with a yearly track in spring *Simulation in den Umwelt- und Geowissenschaften* guided by J. Wittmann, and with a yearly track in fall *Modellierung und Simulation von Ökosystemen* guided by A. Gnauck.

3.2 Working Groups (Arbeitskreise)

In the early phase of the TC, topics like environmental impact assessment, expert systems, and visualization were of practical interest. Especially the integration of environmental data and environmental information systems in municipalities were discussed intensively. After an intermission, these topics now are again included in the agenda of the TC. In Figure 3 the active periods of WGs are depicted.

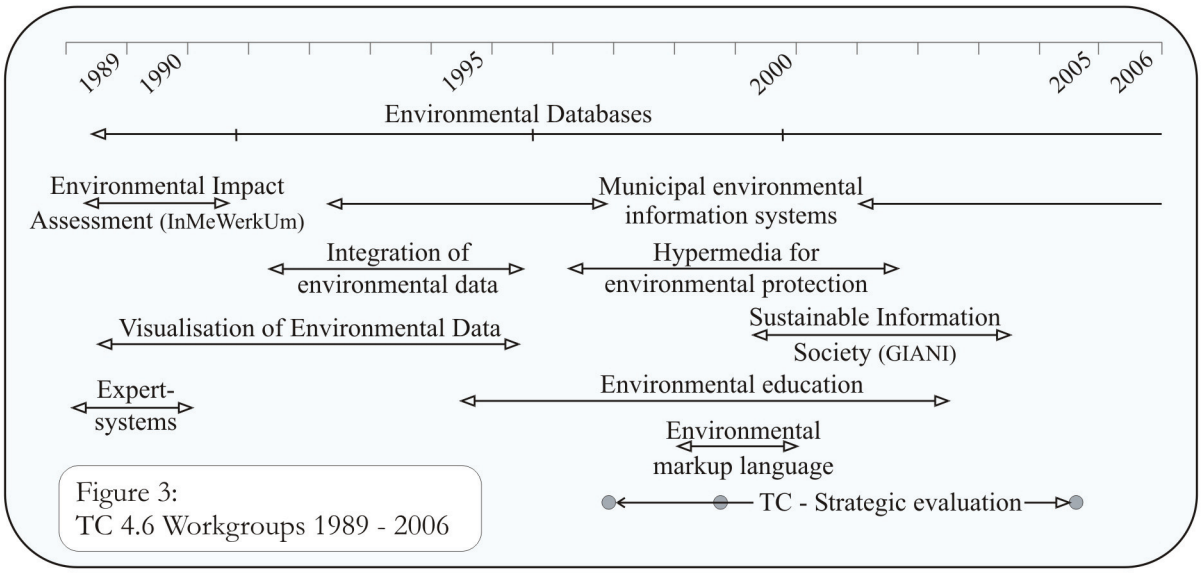

Figure 3:
TC 4.6 Workgroups 1989 - 2006

Environmental Databases (Umweltdatenbanken)

The WG "Environmental Databases" is a long-standing group that has been restructured three times during two decades. A first outstanding contribution was presented in 1990 with an analysis of the structure of environmental data and requirements on databases (EI 1990 1).

Since 2001, U. Freitag and G. Knetsch guide the working group, which publishes results in printed form and on the Web http://www.umwelt.schleswig-holstein.de/ (search for "Umweltdatenbanken") and under http://www.umweltbundesamt.de/uba-info-medien/dateien/3015.htm, …/2854.htm and …/2388.htm.

Hypermedia for Environmental Protection (Hypermedia im Umweltschutz)

The WG "Hypermedia for Environmental Protection" was founded in 1998 based on a joint initiative of the TCs "Computer Science for Environmental Protection" and "Hypertext Systems" of the German Informatics Association. The WG investigated the innovative potential of hypertext and multimedia, also referred to as Hypermedia, in environmental applications.

Between 1998 and 2001, four workshops took place, on the average, about 80 attendees participated in each event. 116 peer-reviewed contributions, including tutorials and invited keynotes, made up the programs of these workshops. A mailing list was installed that finally comprised more than 250 members.

The idea behind the WG was to stimulate hypermedia research by challenges encountered in environmental applications. Vice versa, latest hypermedia research results were pushed in application-oriented projects. In 2002, when it was felt that the objectives had been achieved successfully, the WG finished its work with a workshop embedded in the 16th EnviroInfo (Riekert and Tochtermann EI 2002/II 2).

Sustainable Information Society (GI Arbeitskreis Nachhaltige Informationsgesellschaft)

Right before the World Summit on the Information Society (Geneva 2003), the "Memorandum Nachhaltige Informationsgesellschaft" was released by the WG GIANI. The memorandum expresses concern about the trend to interpret exponential growth in digital data as a growth of information or knowledge. The information society offers great, but very unevenly distributed opportunities for education, participation in markets, and intercultural understanding. The substantial increases in efficiency in the ICT sector by process optimisation and product substitution through information services do not reduce resource depletion. In addition, the Memorandum points out that material and energy consumption of ICT and the amount of electronic waste are shifted into the focus. In an appendix, some aspects of the memorandum - lifecycle of ICT infrastructure, computer and education, and the precautionary principle - are deepened. The memorandum addresses scientists, teachers, students, the communication media, the interested public, economists, and the respective politicians. (http://www.giani-memorandum.de)

Environmental Education (Umweltbildung)

The WG Environmental Education started in 1994. In conjunction with the TC 4.6, workshops were organized e.g. in Bremen 1995, Zurich 2000, and in Cottbus 2003. The topics covered results from university research and IT methods in real-life applications. A large-scale German-Czech example of the activities was the support of about 200 environmental schools in the river Elbe basin (Bosler and Schreiber, EI 2001/II 987). Another activity referred to international computer-supported learning (CSL) for collaborative inquiry learning.

Environmental Markup Language (XML/EML)

Shortly after the eXtensible Markup Language XML had been developed by the SGML Editorial Review Board (under W3C), two XML workshops were organized in Berlin (1999 and 2000) and an additional WG Session was held in Ulm in 2001. EML was to be used for the description of marked-up electronic text. An in-depth discussion of advantages of XML databases, how they can be delimited from sql databases, and how data models can be better represented in XML-defined structures can be found in Weihs (EI 2005/II 773).

3.3 Conferences Related to EnviroInfo

Worldwide seen, some few other platforms exist, which provide a knowledge exchange in Environmental Informatics; some of them are very new:

- Envirosoft conferences started in 1986 and were held biannually till 2004.
- EcoInforma conferences were held between 1992 and 2001. Since 2002, the EcoInforma organizers M. MacDonell, K. Morgan and L. Newland join the EnviroInfo conferences.
- ISESS, the International biannual Symposium for Environmental Software Systems, started in 1995 (http://www.isess.org).
- ISEIS annual International Conference on Environmental Informatics 2002-2006.

- iEMSs, the International Environmental Modelling and Software Society (conferences in 2002, 2004 and 2006).
- ITEE Information Technologies in Environmental Engineering. Conferences in 2003 and 2005.
- ECOinformatics initiative (2004). Jensen and Fitzwater EI 2004/II 208 http://ecoinfo.eionet.europa.eu/.

Furthermore, two IFIP working groups deal with environmental applications. WG 5.11 "Computers and Environment" and the quite recently established WG 9.9 "ICT and Sustainable Development".

4. Disciplinary Contours of Environmental Informatics

The various developments in the field seem to be converging to a unifying "self-image". In terms of epistemology, a scientific profile or architecture of Environmental Informatics is emerging. Such an epistemological exploration sets the scene for implementing practical applications, supports the field's further developments, and opens a window for intellectual reflection and conceptual clarity. An approach to "what makes a field distinctive" usually requires the consideration of its philosophical basis, common language, definitions and goals, concepts, tools for applications, and aspects of institutionalization, among others. Setting the boundaries is crucial to any field of research, be it established entities like physics, ecology, and economics, but it is of major importance to fields with roots in different disciplines, be it engineering sciences, computer sciences, and management sciences. Of course, this is also true for Environmental Informatics (Page et al. 1990; Page, Hilty 1995; Möller, Bornemann 2005).

As a rather young discipline, the discourse on a unifying "self-image" in Environmental Informatics must certainly be a continuous process, covering various perceptions from different intellectual backgrounds. This process was stimulated nearly a decade ago among others by Page, Jaeschke and Pillmann (1990) providing two journal publications in the "Informatik Spektrum" and Page and Hilty (1995) editing the first comprehensive textbook on Environmental Informatics in German. It is the merit of Hilty (1997) who traced this ongoing process of reflection with the help of a historical analysis and current literature in the field. Among other factors to be considered, he identified and discussed two major forces driving the evolution of Environmental Informatics, i.e. cybernetics as a conceptual foundation and environmental policy as a practical starting point. The various implications that influence identity and uniqueness could be illustrated by four factors (fig. 4).

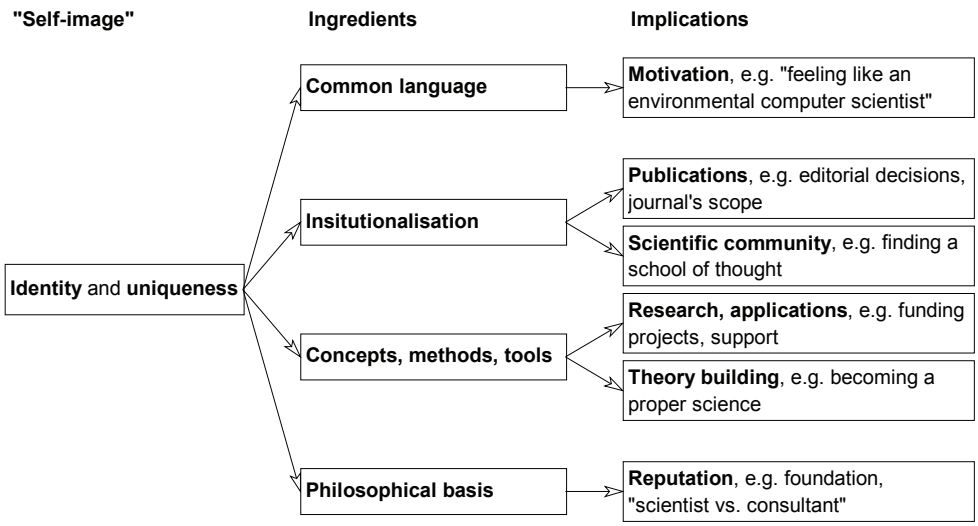

Fig. 4: Implications on identity and uniqueness, examples

An epistemological analysis of Environmental Informatics provides a proper method for making clear its emerging theory and describing the characteristics of the field. Usually, all research fields share a common "perspective" which in terms of epistemology represents a specific way to treat and deal with problems. For Environmental Informatics, the pyramid (in fig. 5) describes a basic architecture along four basic layers or contexts: (I) context of statements, (II) context of phenomena, (III) context of instruments, and (IV) context of basics. This epistemological architecture has its methodological basis in the philosophy of science (Zwierlein 1994) and sociology of science (Krüger 1987). Such a general framework especially illustrates the "inter-disciplinary" common ground of various disciplines and is particularly useful when analyzing different fields of research, comparing different schools of thought, or analyzing higher educational programs in terms of interdisciplinarity (Isenmann 1999).

In the case of Environmental Informatics, the architecture (fig. 5) highlights distinctive characteristics of the field in terms of epistemology, compared to other fields of applied informatics and computer science like business information systems, bioinformatics, computational biology, and geoinformatics. Such architecture can also help to further discuss matters of identity, differentiation, and uniqueness. Moreover, it supports the description of the intellectual heritage of the Environmental Informatics' proponents and the development of the community as a whole.

The epistemological architecture of Environmental Informatics has been conceptualized through certain issues that have been widely discussed in the community so far. Hence, these issues can be taken as prototypical of the current state of the field. For example, data analysis, visualization, geographic information systems, environmental databases, and modeling and simulation are some of the methods of Environmental Informatics and make up the Environmental Informatics toolbox (Page and Hilty 1995; Rautenstrauch and Patig 2001). All issues used to conceptualize the general architecture were identified by a document analysis covering oral and poster presentations of the international EnviroInfo conferences or extracted from current literature in the field, including the online resources of the Technical Committee (TC) 4.6.1 "Computer Science in Environmental Protection" (2006), comprehensive text books, and journal publications. The issues again have been clustered according to the four levels above (i.e. statement, phenomena, methods, and basics).

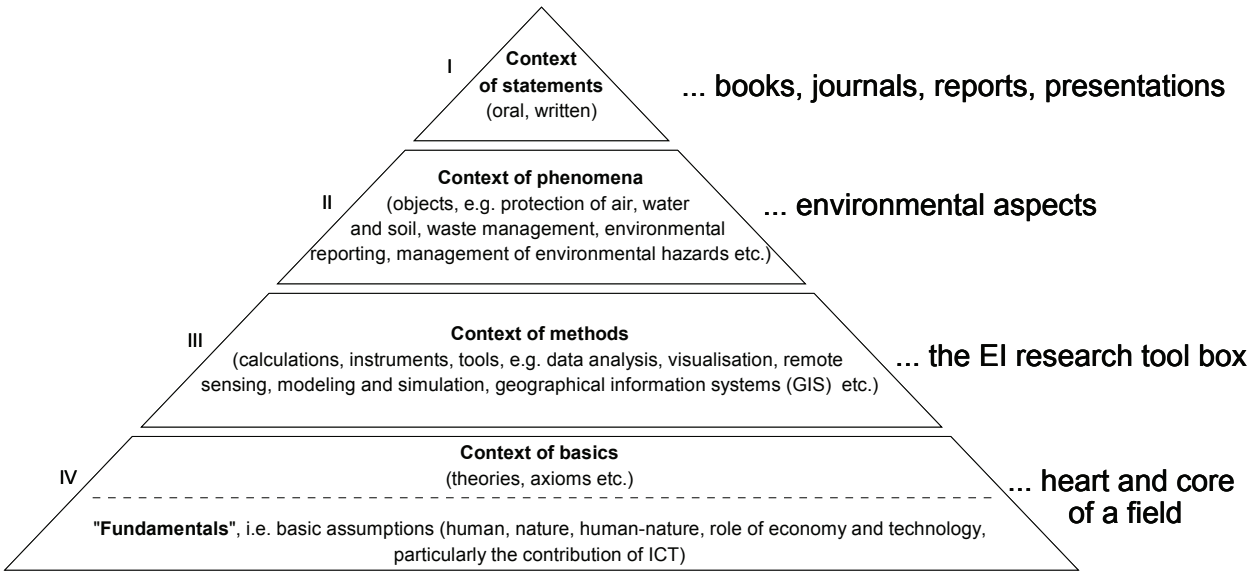

Fig. 5: Scientific profile of Environmental Informatics, illustrated by a pyramid

In addition to "real research" like software development, design of ICT applications, and empirical studies, epistemological exploration and discussion of a unifying "self-image" are crucial, as these issues have consequences for both theory and practice: At least, they shape concepts, instruments, and vocabularies that are used to approach environmental research problems, and they may help to obtain a deeper understanding in tasks which arise in Environmental Informatics or could emerge in the near future at least. Approaching a more sustainable development definitely requires bridging the apparent difference in world view and methodology and, thus, overcoming the fundamental difference between the natural and engineering sciences on the one hand and the social sciences and humanities on the other. In this respect, Environmental Informatics might be a good example.

5. Results and impacts of Environmental Informatics

The authors have attempted to highlight some of the essential findings, efforts, merits and completion within 20 years of the network of excellence in Environmental Informatics. Quantitative results are: 3.000 referred papers in 20 EnviroInfo conferences and approximately 50 TC 4.6 workshops, documented on 30.000+ pages. Let us argue that the networking between scientists, persons from administration, business, industry and NGOs, engineers and politicians in regular time intervals supported the way towards a sustainable development in Europe. Involved in this specific TC 4.6 network were some 7.500 authors, wich have professional contacts within their departments, to project groups, to other scientific bodies, to contractors, to students and to environmental administrations and came also in contact with politicians. Not taking into account the Web-marketing effect, we estimate that some 50.000 persons came in touch with one of the worldshaking questions: how can we act so that we give chances also to future generations.

Unable to enter in all the details of Environmental Informatics applications, let us address only one representative development. PortalU is a new Web portal with latest software and search engine technology (Vögele, Klenke, Kruse and Groschupf EI 2005/I 30). Access to environmental information has been made possible through the Meta-information System UDK (Umweltdatenkatalog), (Lessing and Weiland EI 1990 410) and later through gein® (Bilo and Streuff 2000). The Federal Ministry of the Environment and the environmental administrations of the German Laender operate the coordination office UDK/GEIN (Hannover) where the team opened PortalU on-line in May 2006. In addition, an innovative service of the Federal Environment Agency (Dessau) is the Semantic Network Service (SNS), which provides support for all questions concerning environmental terms (Angrick, Bös, Rüher and Bandholtz EI 2002/I 78). SNS contains a bi-lingual (German/English) semantic network, the Geo-Thesaurus-Environment (GTU) and an Environmental Chronology of current or historical events that affected the environment (http://www.semantic-network.de/; Rüther EI 2004/II 293). Here, EnviroInfo built the platform for a fruitful exchange of ideas, results and knowledge within 15 years, including the EEA activities with its ETC/CDS Topic Center *Catalogue of Data Sources* (Pick et al. EI 2000/II 665) and the *Reportnet* (Jensen et al. EI 2002/I 29).

6. Conclusions

The past 20 years TC 4.6 conferences show a well-balanced composition of participants from universities, research institutions, government, companies and consulting firms from Europe and also from other continents. This complex participant structure stimulated the marketplace for exchange of information between users and suppliers of environmental information. A growing number of national research contracts, EU programmes participations and product developments like information systems, databases and Web tools can be stated. In many aspects, the TC 4.6 workshops and conferences resulted in an

increasing knowledge in comprehensive handling of complex environmental information. The TC 4.6 established a sound basis for a lively forum of discussion and exchange of knowledge within the European Research Area at the launch of the EU's 7th Framework RTD Programme.

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