The sui generis ontologies of the patent system

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This is already the second time that I have the honour to be invited to speak at the Ionian University. Last year it was in the context of the Conference about Computer Ethical and Philosophical Enquiry, where we presented, together with the great Latin American thinker Laymert Garcia Dos Santos, different aspects of the contemporary battles around knowledge: geopolitical, technological, cultural and economical, in particular, how codified knowledge is generated, appropriated, controlled or shared [1].

The patent system is at the core of this big game. It became internationalised in 1883[2] and culminated a century later (in 1996) with the Trade Related Agreement on IP Rights, the so-called TRIPS, which introduced a detailed regulatory framework virtually all around the world, a singular success for an international normative undertaking[3]. In the same time, the corpus of patent-related, publicly available technical knowledge exploded to reach amounts and levels that are unprecedented in human history[4].

However, despite this success story, more and more people nowadays associate 'patent' with 'private', 'restricted', 'intransparent', 'unavailable'. This sounds much more like medieval times guild tradition than a post-renaissance state of mind. Moreover, it is an indictment for the *patent* system, the etymology of which derives from the Latin *patere* - which means to disclose, to lay open, to be clear - to be confused with *latent* (from *G*reek *λανθάνειν*), its exact antonym.

This tarnished reputation is the more surprising, as patent offices undertake very substantial efforts to make technical and legal information (e.g. legal status of patents) publicly available. They invest very significant resources in capturing, digitalising, classifying according to technical criteria, organising millions of documents every year in several collections[5] and putting this vast amount of technical information in public view, mostly free of charge. So where does this perception of intransparency come from ?

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[1] See: Scenarios for the Future, EPO, 2007
[2] The Paris Convention for the Protection of Industrial Property, signed in Paris in 1883, was one of the first intellectual property treaties. As a result of this treaty, intellectual property, including patents, of any contracting state are accessible to the nationals of other states party to the Convention
[3] Peter Drahos and John Braithwaite; Information Feudalism; who owns the knowledge economy ?; Earthscan, 2002
[4] Alone the EPO patent databases include some 60 million documents
[5] See EPO's numerous subscription DBs in http://www.epo.org/patents/patent-information/subscription.html

The transparency gap

Peter Drahos, a renown researcher of the patent system, expresses this societal unease and specifies it, when he says in a chapter titled "Taking transparency seriously" of his new book "The Global Governance of Knowledge"[6] that "...the patent system currently does a very poor job of making information available to downstream inventors". He argues that "The obligation of patent offices is not just simply to publish the patent specification. This would be to construe the obligation passively. The purpose of the patent social contract is to diffuse invention information, simply to publish invention information in a patent office gazette is not the same as working towards actively spreading invention information. **Turning patent offices from passive publishers into active diffusers of information requires patent offices to begin approaching their task much more like public libraries: finding creative ways to engage with very diverse user communities.** The diffusion obligation of the patent office is not an obligation that is owed to a few wealthy corporate users of the patent system, but rather it is an obligation to society and to the many groups that are affected by monopolies over invention information. Patent offices obtain invention information from inventors by virtue of the operation of law. Under the social contract they should provide it as a public good. Moreover they should provide that information in ways that are useful to different user groups, ways that do not depend on patent searching expertise but rather more generalized skills of database searching. To date efforts in this direction have largely remained symbolic." Assuming that "... In theory it should be possible to have a technology platform that searched all the world's patents, allowing users to organize that information in various ways (around ownership, technologies, countries etc.)", he underlines the strategic and sensitive nature of this 'service', by claiming that "Global patent transparency is the foundation upon which other reforms of the patent system have to be built." [7]

Whoever has tried to establish a comprehensive patent landscapes around HIV drugs or emerging environmental technologies, will have noticed how difficult is to get what you want. There are several reasons for this failure, in the following I will focus more on problems of a more structural nature. According to the present analysis, the fundamental problem is that this vast amount of information (several tens of millions of documents in the case of the EPO) is organised and structured in a way that it makes sense to the interior of the patent system, but not necessarily to its exterior. Why this ?

The role of classification schemes

Both libraries and patent offices use complex and sophisticated systems to classify and thus to store and retrieve information. According to Wikipedia: "A library classification is a system of coding and organizing library materials (books, serials, audiovisual materials, computer files, maps, manuscripts, realia) according to their subject and allocating a call number to that

[6] Peter Drahos; The Global Governance of Knowledge; Cambridge University Press, 2010 (Chapter 11: Reclaiming the patent social contract - Taking transparency seriously)

[7] See also argumentation by Konstantinos Karachalios and Shirin Elahi in: Transparency, Trust, and the Patent System; Journal of Intellectual Property Law & Practice, Sept. 2009

information resource. Similar to classification systems used in biology, bibliographic classification systems group entities together that are similar, typically arranged in a hierarchical tree structure. A different kind of classification system, called a faceted classification system, is also widely used which allows the assignment of multiple classifications to an object, enabling the classifications to be ordered in multiple ways."

The same source states that "A patent classification is a way the examiners of patent offices or other people arrange documents, such as patent applications, disclosing inventions according to the technical features of the inventions. They arrange documents using a patent classification so that they can quickly find a document disclosing the invention identical or similar to the invention for which a patent is claimed. The same document may be classified in several classes." A patent classification system is a multi-faceted one.

Patent Classification

Patent offices systematically classify patent documents as well as non-patent literature in order to assist with administration and patent searching. Patent classification systems are arranged in a hierarchical structure and provide different technologies with different alpha-numeric codes. This hierarchical structure is typically arranged into sections, subsections, classes, subclasses, groups and subgroups. Below is an example of how wind motors would be classified under the most commonly used classification system, the IPC.

Section F: Mechanical Engineering; Lighting; Heating; Weapons; Blasting

Subsections to Section F: Engines or pumps; engineering in general; lighting; heating; weapons; blasting.
Classes: E.g. F02: Combustion engines; F03 Wind, spring or weight motors.
Subclasses: E.g. F03D: Wind motors
Groups: FO3D 1/00: Wind motors with rotation axis substantially in wind direction.
Subgroups: F03D 1/02: With plurality of rotors

While the IPC system is the most widely used classification system, with approximately 70,000 subdivisions (covering documents published after 1968), it is not the most extensive. The European Classification system (ECLA) developed by the EPO builds on the IPC, includes up to 134,000 subdivisions and is made public via a multitude of databases, see e.g. the *esp@cenet* DB[8]. Internally, the EPO examiners also use further, much finer coding to organise the documentation in their field of expertise. Patent offices are thus, huge archiving and classification machineries, handling a vast amount of technical information daily, investing very significant resources to carry out this task. The classification and re-classification exercise alone costs

[8] http://www.espacenet.com/index.en.htm

EPO some 140 FTEs[9] per year. In the framework of cooperation of the 5 major patent offices in the world (Patent offices of USA, Japan, China, Korea and the EPO) re-classification projects for harmonisation purposes is estimated to cost 2000 FTEs in the course of 10 years.

The quality of classification is absolutely crucial for the overall quality of the patent system. The exacter the classification, the better the search results and thus the comparison of the invention with the state of the art, and thus, the less trivial patents are granted.

Comparing the two classification approaches

External similarities may sometimes conceal more than they reveal: although both systems follow a hierarchical tree structure, the rationale of how the tree branches are defined and grow are completely different. I assume, and please correct me if I am wrong, that librarians classify by grouping together entities that are similar, whereas the entities and the similarity should be defined in a way to make sense primarily to the users of the library and not to the librarians.

Unfortunately this is not always the case for existing patent classification systems. Patent examiners classify with the main purpose to help them carry out their own very specialised job. Patent classification is thus a priori an inwards looking process, the public perspective is not an important criterion. The result is that the complex ontologies[10] produced by the patent offices do not always make sense to the non-expert seeker of information. Although the existing publicly available patent information platforms and raw data collections[11] offer a significant potential service for skilled users, the system is often stretched to its limit. The service of delivering digital information to the public[12] entered the internet era with new technical tools, but without rethinking the basic concepts.

Let us try to use a metaphor. As we read above, libraries "group entities together that are similar", that means dogs are grouped together with wolves and crocodiles with other lizards. Patent offices group "according to the

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[9] FTE: full time employee, in EPO's case this is a fully trained examiner, our most precious asset

[10] According to Wikipedia: In computer science and information science, an **ontology** is a formal representation of the knowledge by a set of concepts within a domain and the relationships between those concepts. It is used to reason about the properties of that domain, and may be used to describe the domain. In theory, an ontology is a "formal, explicit specification of a shared conceptualisation". An ontology provides a shared vocabulary, which can be used to model a domain — that is, the type of objects and/or concepts that exist, and their properties and relations. Ontologies are used in artificial intelligence, the Semantic Web, systems engineering, software engineering, biomedical informatics, library science, enterprise bookmarking, and information architecture as a form of knowledge representation about the world or some part of it.

[11] For an overview of the free of charge information services of the EPO, see http://www.epo.org/patents/patent-information.html

[12] An example of how one can use classification systems to retrieve information is presented in EPO's *esp@cenet* assistant 'How do I use the Classification search?' http://v3.espacenet.com/eclasrch?classification=ecla&locale=en_EP

technical features" of an entity, that means they are rarely interested in the whole 'animal', they rather look at its specific use or fragment it into skin, nails, teeth, bones, meat etc. and group either according to this specific use or put these elements together with parts of other animals, the ingredients of which may be used for a similar purpose, whether the animals are similar to each other or not. Thus, the ontologies created by the patent system have very often nothing to do with lay-man's logic.

E.g., according to their utility, in Asia one would put dogs (more exactly, their flesh) in the food section, whereas in the West dogs would fall into the 'pet' category, together with canaries and cats. Similarly, crocodiles, because of their leather, would be classified together with bovines, goats, snakes etc. and all together arranged probably in the section 'shoes' or by 'handbags, suitcases, etc'. Further, in African patent offices, because of their white meat, crocodiles would be classified also in the section of poultry.

Now, imagine someone trying to understand how a dog or a crocodile looks like by putting together, piece by piece, such a heterogeneous, fragmented documentation landscape. You must guess where you have to search for and you may still miss important information, e.g. that crocodiles have a vertebra and teeth, if you do not know that crocodile teeth or bones are used for buttons or something else of use to human kind.

An example from the pharmaceuticals sector

You may think I am exaggerating and this is not a good example. Then, take instead of 'dog', 'Tamiflu' or '*oseltamivir'* and carry out a keyword search with *esp@cenet*: you would find some 72 patents classified in a variety of groups. I bet with you that the number of patents related to this drug and its variations is orders of magnitude bigger than this. To get them all one needs either a very high expertise or a lot of money for specialised patent information providers.

An example why this is an important issue: some years ago, the World Health Organisation tried to establish a list showing whether some essential drugs were patent protected in a given set of developing countries or not. They believed that the lack of this very basic information was hindering national and international procurement agencies and NGOs from buying and importing cheap generic drugs in these countries. Dealing with this problem has become an important aspect of the Global Strategy and Plan of Action on Public Health, Innovation and Intellectual Property of the World Health Organisation.

The EPO became involved in this project, and unsurprisingly, what soon became clear was that this was no simple task. Many patent offices in the target countries were not able to deliver a clear answer to what seems to be a simple question, namely: *“Is the patent application with publication/priority number X that was filed in your country on date Y still in force ?*”. It is hard to believe that a patent office is unable to deliver this information, which theoretically, should be simple. The main source of failure was the lack of adequate documentation systems, resulting in situations like this: "*Swiss drug major Roche has told the governments of Indonesia, the Philippines and*

Thailand that they are free to manufacture generic versions of its anti-influenza drug Tamiflu (oseltamivir) because it is not patented in their countries. Roche says it received "with surprise" the announcement that Taiwan planned to issue a compulsory license for Tamiflu …"[13]*.* Several years on, it is clear that there does not appear to be any easy way to resolve this complex tangled web, particularly with many small patent offices under-resourced, as transparency costs money.

The carbon capture example

You may say, drugs is a complex case, in engineering logic dogs would be with wolves, and crocodiles with lizards. Really ? Let's take instead of 'crocodile' the case of the important emerging technology characterised as CO2 capture, sequestration and storage (CO2 CSS). It means that CO2 is taken out of combustion gases and stored in the earth, instead of being released into the atmosphere.

Trying to get a complete list of patented technologies in this field via IPC is no mean feat. It is like looking for an unknown number of needles of unknown size in 8 different hay stacks. Caution: in the patent game you win only if you have found all needles. First, you have to decide in which of the eight IPC sections (hey stacks) you should look for:

	The eight main IPC and ECLA sections
A	Human necessities
B	Performing operations; transporting
C	Chemistry; metallurgy
D	Textiles; paper
E	Fixed constructions
F	Mechanical engineering; lighting; heating; weapons; blasting engines or pumps
G	Physics
H	Electricity

To cut a very long story short, technologies to capture and store CO2 are categorised in no less than 4 of these sections (B, C, E and F), and within each section in most cases in many 'branches' that are far from each other. The patent offices are therefore since February 2010 suggesting a list of categories as a first start (a so-called 'catchword index' service). So, if one enters the search words "carbon capture" in the classification search mask of *esp@cenet,* following 'help' is offered to the desperate information seeker

[13] 'Tamiflu compulsory license not necessary, Roche tells three Asian nations', Pharma Marketletter, 5-12-2005

Separation of gases or vapours; Recovering vapours of volatile solvents from gases; Chemical or biological purification of waste gases, e.g. engine exhaust gases, smoke, fumes, flue gases, aero....	**B01D53**
Arrangement of devices for treating smoke or fumes (treating smoke or fumes, see the relevant class for the treatment, e.g. B01D53/00)	**F23J15**
Supplying non-combustible liquids or gases, other than air, to the fire, e.g. oxygen, steam	**F23L7**
Separating dispersed particles from gases, air or vapours by liquid as separating agent (B01D45/10 takes precedence; fractionating colum....	**B01D47**
Hydrogen; Gaseous mixtures containing hydrogen; Separation of hydrogen from mixtures containing it (separation of gases by physical means B01D);....	**C01B3**
Equipment or details not covered by groups E21B15/00 to E21B40/00	**E21B41**
Compounds of calcium, strontium, or barium (C01F7/00 takes precedence)	**C01F11**
Electrolytic production of inorganic compounds or non-metals	**C25B1**
Carbonates of sodium, potassium or alkali metals in general	**C01D7**
Carbon; Compounds thereof ([N: C01B6/00] , C01B21/00 , ...	**C01B31**

I am not sure how encouraging this looks even to hard core experts. Moreover, since most categories do not deal specifically with CO2, but generally with gases and fluids, even if you wander through all these labyrinths and retrieve the related documents, you would still have to filter-out CO2 from all other gases and liquids, and - believe me - this is less than evident a procedure.

One of the best experts in the field, consulting US venture capitalists for investments in the carbon capture domain, told me[14] that it took him 8 months of iterative work through the hay stacks to find 6000 of them. He apparently still missed one third (EPO identified some 9000 patents related to CO2 CSS).

In my humble opinion, this cannot be seen as a serious attempt to help information seekers in such critical fields. But there are other, politically far more critical consequences from this failure.

UNFCCC negotiations around technology transfer and the role of patents

[14] Communication during a teleconference in January 2010

The incapacity of the patent system to deliver timely and meaningful sector-related information around technologies with a potential of reducing greenhouse gas emissions creates growing political tensions in the climate change debate. Radical proposals are being tabled and experts attending the UN conference maintain that patents have become the most polarised and controversial item on the agenda. In fact this is the only field where no progress has been achieved. On the contrary, as the battle lines are drawn up, there seem to be no zones of compromise between the growing number of black or white positions being taken. Governments, their negotiators, researchers, political analysts, industry and other stakeholders are expressing an urgent need for platforms to provide continuous and reliable, sector- and country-related information about relevant technologies, their ownership and the costs associated with their acquisition.

That things do not need to be like this, shows an example from a recent engagement by the EPO. The EPO first identified potential risks to the IP system posed by fallout from the climate change debate in 2006, during work on the above mentioned "Scenarios for the Future" study, which was a long time before IP was seen elsewhere as even a mild indicator of trouble on the horizon. However, it soon became apparent that the issue was too complex for a single institution to handle on its own and that broader alliances would be necessary with organisations which have access to complementary expertise.

In 2009, a formal agreement was reached on a programme of co-operation between the EPO, the UN Environment Programme (UNEP) and the International Centre for Trade and Sustainable Development (ICTSD), a leading NGO specialising in sustainable trade and technology transfer. The aim of this programme was to launch an empirical study to shed light on the role of patents in the transfer of climate change mitigation technologies. More partners soon joined in: the OECD Environment Directorate, leading business and industry associations *(such as the International Chamber of Commerce (ICC), the Licensing Executives Society International (LESI), the World Business Council for Sustainable Development, and the Fraunhofer Gesellschaft)*, specialised governmental agencies like the Energy Research Centre of the Netherlands, and other NGOs and intergovernmental organisations. It was a first step towards creating a unique alliance among very diverse partners. In parallel the EPO acquired observer status at the UN climate change conference.

Carrying out the study, technologies in the field of renewable energy, biofuels and so-called "clean coal" were mapped first. On the basis of this work, the EPO and external experts developed a new taxonomy of technologies and their applications, down to apparatuses and components. Patent examiners performed searches and retrieved worldwide patent data relating to these categories. Using this data, the OECD then carried out various statistical analyses, looking at development trends over time in specific sectors and countries. In this way, precise patent landscapes were established for the technologies under scrutiny. In parallel, a first-ever licensing survey was

carried out among technology developers and potential licensors in the field of environmental technologies[15].

One and a half years later, all project targets have been met and the final report is expected to be published in the autumn of this year. The study not only provides many politically and otherwise relevant findings, it also makes suggestions for further analysis and research in the field. However, it shares the same fate as all other analyses on the same or similar topics - it only constitutes a snapshot in a vast, dark space. We came to realise this, but also noted that the collection of patent data itself would constitute a very valuable asset for experts and other special interest groups alike. To match this need, the EPO decided to take advantage of the effort already invested and use it to produce a publicly available, continuous flow of patent information relating to the energy sector. A genuine new public good would thus be created for the benefit of the global knowledge economy.

The ideal solution proved to be a new, detailed classification scheme similar to others previously developed by the EPO to track and categorise new technological developments, such as nanotechnology. The scheme is designed to serve as an interface between the vast amount of technical knowledge contained in the patent documentation, and the information needs of society. To achieve this, the entire worldwide patent documentation had to be re-classified into more than 200 new categories[16].

Apart from being easily accessible to and understandable by non-experts, this new information tool will always be kept up to date and accurate. Embedding it in the EPO's classification scheme ensures that the collective intelligence of 4 000 patent examiners and classification experts maintains and improves it automatically on a daily basis. A better solution could hardly have been found.[17]

The **Y02** subclasses already available to the public relate to clean energy technologies, namely **Y02C** (greenhouse gases- capture and storage/ sequestration or disposal) and **Y02E** (greenhouse gases - emissions reduction technologies related to energy generation, transmission or distribution). The new ontology for the 'animal' carbon capture and storage looks now like this[18]:

SECTION Y - GENERAL TAGGING OF NEW TECHNOLOGICAL DEVELOPMENTS

ECLA Code	**Description**
Y02:	**TECHNOLOGIES OR APPLICATIONS FOR MITIGATION OR ADAPTATION AGAINST CLIMATE CHANGE**
Y02C:	Capture, storage, sequestration or disposal of greenhouse gases (GHG)
Y02C10/00:	CO2 capture or storage
Y02C10/02:	Capture by biological separation
Y02C10/04:	Capture by chemical separation
Y02C10/06:	Capture by absorption
Y02C10/08:	Capture by adsorption
Y02C10/10:	Capture by membranes or diffusion
Y02C10/12:	Capture by rectification or condensation

Thus, search work that required significant expertise, time and money can now be done by any interested person who knows that the system exists and what he/she is looking for. Of course,, there is another dimension, beyond technical details: in the era of the knowledge economy, making codified and pertinent information accessible to broader constituencies amounts to a genuine political act. It reduces the power and control of incumbent experts for the benefit of society.

You may go and convince yourself how easy is to retrieve what you want, by simply copying the code into the search mask[19]. Instead of erring into the labyrinthic galleries of the patent classification, you have an 'one stop-shop'. With one 'click' on the right side box one can copy this code into the *esp@cenet* search mask and would thus get all patents worldwide related to these technologies and only these. By adding a second criterion in the search mask (e.g. country code in third line) one can get all patents in a given technology field for a certain country. One could add also a company name, getting only patents submitted by this company, etc...

The Y02E subclass, for example, looks like this:

Code Y02E	**Description**	**Comment**
10/00	Energy generation through renewable energy sources	Geothermal, hydro, oceanic, solar (PV and thermal), wind
20/00	Combustion technologies with mitigation potential	CHP, CCPP, IGCC, synair, cold flame, etc.
30/00	Energy generation of nuclear origin	Fusion and fission
40/00	Technologies for efficient electrical power generation, transmission or distribution	Reactive power compensation, efficient operation of power networks, etc.

[19] http://v3.espacenet.com/eclasrch?classification=ecla&locale=en_EP&ECLA=y02c10

50/00	Technologies for the production of fuel of non-fossil origin	Biofuels, from waste
60/00	Technologies with potential or indirect contribution to GHG emissions mitigation	Energy storage (batteries, ultracapacitors, flywheels...), hydrogen technology, fuel cells, etc.
70/00	Other energy conversion or management systems reducing GHG emissions	Synergies among renewable energies, fuel cells and energy storage

And here is the breakdown for a particular group (solar energy):

Code Y02E	**Description**
10/40	Solar thermal energy
10/41	Tower concentrators
10/42	Dish collectors
10/43	Fresnel lenses
10/44	Heat exchange systems
10/45	Trough concentrators
10/46	Solar-thermal plants for electricity generation, e.g. Rankine, Stirling solar-thermal generators
10/47	Mountings or tracking
10/48	Mechanical power, e.g. thermal updraft
10/50	Photovoltaic (PV) energy
10/52	PV systems with concentrators
10/54	Material technologies
10/54B	CuInSe2 material PV cells
10/54D	Dye sensitized solar cells
10/54F	Solar cells from Group II-VI materials
10/54H	Solar cells from Group III-V materials
10/54J	Microcrystalline silicon PV cells
10/54L	Polycrystalline silicon PV cells
10/54N	Amorphous silicon PV cells
10/56	Power conversion electrical/electronic aspects
10/56B	for grid-connected applications
10/56D	concerning power management inside the plant, e.g. battery charging/discharging, economical operation, hybridisation with other energy sources
10/58	M.P.P.T. systems (maximum power point tracking)
10/60	TPV hybrids

This scheme was publicly released on 9 June 2010 at a side event of the 32nd Subsidiary Bodies meeting of the UNFCCC in Bonn. The question of accessibility

to and costs of such privately owned technologies is a matter of permanent friction for the ongoing (rather not ongoing) negotiations. The new scheme is meant as an offer to negotiating parties who explicitly express following need: *"A technology information platform should be developed and be continuously updated to collect information on sector-specific technologies and best practices on publicly and privately held technologies, including on IPRs and licensing, costs, abatement potentials, and manufacturers of technologies."*[20]

We are therefore confident that this work has the potential to accommodate a big part of the above mentioned claims of the UNFCCC for a continuous, transparent and reliable technology information platform**.** However, whether further technology sectors (buildings, transportation, industry, agriculture, waste management) could be dealt with as a follow-up of this project is still an open question. In particular, since the definition of the new categories is the most critical and politically sensitive point (to which questions should the new categories deliver answers and who is posing them?), it would be important to collaborate with experts from key developing countries and/or with the UNFCCC secretariat to co-shape the remaining sectors. The EPO may even apply this methodology to create similar ontologies for other politically critical technical fields (essential drugs, ICT standards). Finally, the process can be further improved, in particular by making the classification rules explicit and public[21].

Concluding, the platform created by the EPO offers to non-expert seekers of patent-related information in the clean energy field following services:

- Worldwide patent coverage (not only EP, US etc. patents).
- All relevant technologies gathered together in one place, i.e., no in-depth knowledge of IPC or ECLA necessary.
- Detailed break-down up to component level (for example: dye-sensitized solar cells, off-shore wind towers, IGCC, torrefaction of biomass, direct methanol fuel cells, smart grids etc. all have their own separate entries).
- Regularly updated with the newest patent publications.

For now, however, this successful effort is further evidence that the patent system has the potential to rise to the expectations according to the original meaning of its name by providing comprehensive, useful information to the public, starting from a very critical, strategically important field[22].

[20] See e.g. Paragraph 194, page 150 of UNFCCC FCCC/AWGLCA/2009/8

[21] E.g. via hypertext language; see Building a Companion Website in the Semantic Web. Timothy Miles-Board et al.; Proceedings of the 13th international conference on World Wide Web 2004; http://www.iw3c2.org/WWW2004/docs/1p365.pdf

[22] For an example of the resonance, see http://cleanip.com.au/2010/06/18/at-last-clasification-system-for-climate-change-technologies/