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Introduction

In less than a decade the Internet has become a real alternative to the well established means of information exchange. Electronic means of accessing information are rapidly gaining importance, thus increasing the speed of international and intercontinental information exchange. The use of the Internet has many advantages, since it grants online access from the own desktop to information distributed from anywhere else, without the hassle of visiting libraries, ordering and waiting for the ordered information or other restrictions.
The enormous advantages are clearly shown by the fact that the Internet is growing exponentially, both in the size of web sites, web pages and in the number of users. As shown in a study recently performed in the U.S. [17], in mid-1999 more than 100 million adult Americans used the Internet, which represents more than one-half of U.S. adults. Moreover, the Internet has become an important factor in their daily lives, which is clearly evidenced by the following statistics about their online-habits: daily use of the Internet has risen to 60 percent for home users and 69 percent for work users, clearly indicating the advantages linked with this medium. The average user sends 6.4 emails per day, and 77 percent of all users send emails with files or attachments weekly - an example of the even more sophisticated use of this tool. Also, more and more users are actively taking part in the process of information dissemination, with 22 percent of all users having created or updated a web page within the last three months.
An analogous development can be found in the amount of information offered in the Internet. The so-called network of the networks is growing exponentially, enclosing already more than 10 million web sites (Figure 1) with the publicly indexable web containing an estimated 800 million pages as of February 1999 (1997: 320 million pages), encompassing about 15 terabytes of information or about 6 terabytes of text after removing structural elements, comments, and extra whitespace [7]. This growth is even expected to continue in the future, with an estimated number of 8 billion web sites in 2002.
The immense growth of both the number of Internet users and web sites indicates clearly the advantages of this medium, which almost each new user or web site indicating the expectation of potential benefit for the individual or the company they are working for. Each new user and each new web site can therefore also be considered as a vote for these possibilities and the further use of this new medium.

The Internet - a short definition

According to a definition [4] unanimously agreed by the US Federal Networking Council, the term "Internet" refers to the global information system that

- is logically linked together by a globally unique address space, based on the Internet Protocol (IP),

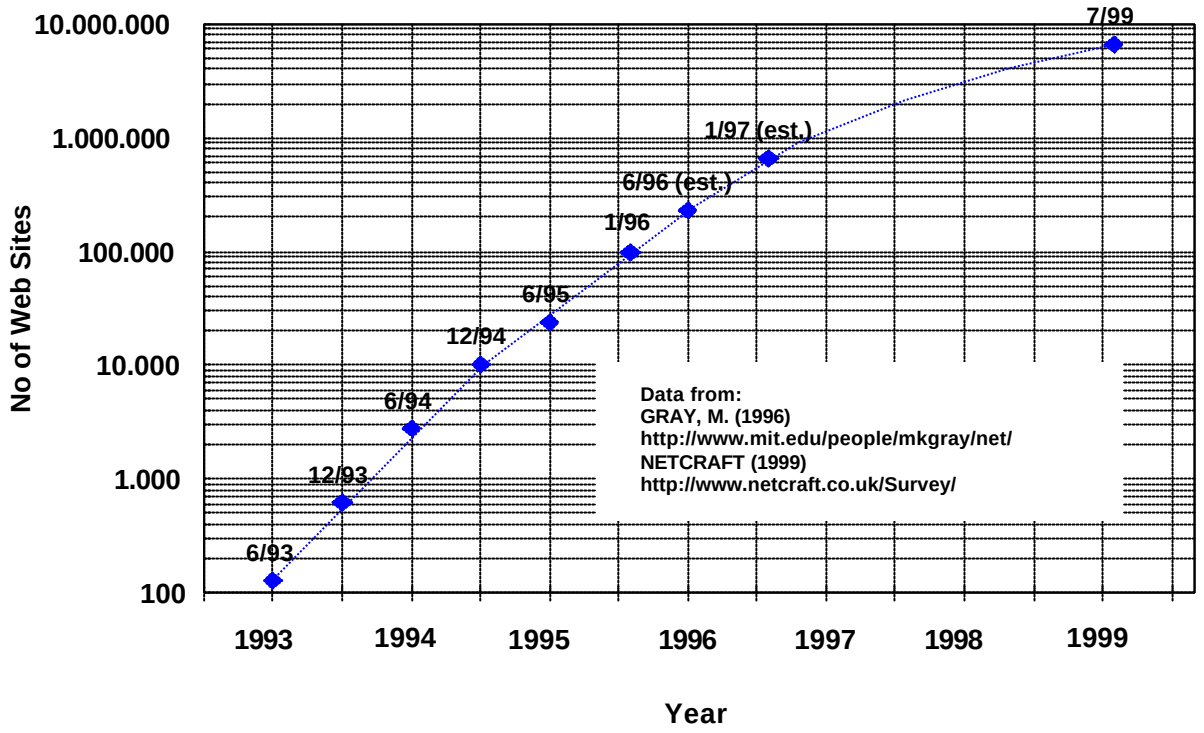

Figure 1: The world wide growth of web sites form June 1993 till August 1999. Graph derived form data published by GRAY (1996) and NETCRAFT (1999).

- is able to support communications using a specific transmission protocol (TCP/IP) and
- provides, uses or makes accessible, (...) high level services layered on the communications and related infrastructure described herein.

It is important to notice that each computer that is part of the Internet has an unique IP-address, which is an indispensable condition for utilising these services or serving requests from other machines. Furthermore information transmission is standardised by the TCP/IP protocol in a platform-independent manner, so that different computers with differing operating systems all can share the resources of the Internet.

Internet resources - Where to find information about irrigation?

World Wide Web (WWW)

Originally initiated by Tim Berners-Lee while working on a networked information project at CERN, the World Wide Web is nowadays surely one of the most important, if not the single most important high level service of the Internet. The WWW is specifically designed for the exchange of documents available to the Internet community. These documents are formatted in a language called HTML (HyperText Markup Language) that supports links to other documents, as well as graphics, audio, and video files. This means one can jump from one document to another simply by clicking on hot spots, also called *links*. There are several applications called web browsers that make it easy to access the World Wide Web; two of the most popular being Netscape Navigator and Microsoft's Internet Explorer.

Search engines and their deficiencies

With an estimated size of 800 million web pages, information retrieval can sometimes be quite difficult. Therefore, the proper use of search engines, which enable users to search for documents on the World Wide Web, plays a pivotal role. The database for the search engine can be either created by humans or by automated software tools, called spiders. An example of the human approach is Yahoo!, while Altavista or WebCrawler rely on an automatically created database. Beside these search engines, which were the very first at the time of their launch, numerous other engines have been installed since. A comprehensive list of search engines can be found at http://www.amdahl. com/internet/meta-index.html.

Unfortunately, the use of search engines can be quite tricky since finding the right information is not always easy. It can even be a very tough task - especially finding the engine that produces the output needed. Allegedly, the engines Google, DirectHit, and Northern Light are making use of some of the more innovative and best techniques used by search engines today, but even this does not guarantee good results. Furthermore, the use of search engines is generally subjected to some major restrictions:

A recent study about accessibility and distribution of information on the WWW indicated clearly that search engine coverage relative to the estimated size of the publicly indexable web has decreased substantially in the last two years, with no single engine indexing more than about 16 % of the estimated size of the publicly indexable and accessible web. To overcome this problem, the use of meta search engines, which submit a single inquiry to several different engines at the same time and then list the results grouped together, is encouraged. Table 1 lists some of these meta engines.

It should be remembered when using search engines that their databases might be out of date resulting in outdated search results. As showed in [7], indexing of new or modified WWW pages by just one of the major search engines can take months.

Despite being indispensable tools, search engines still remain tools with adherent deficiencies. A search for the mere expression "irrigation" produces more than 310.000 matches using "NorthernLight" and almost 11.000 matches using "Google". In order to prevent one from becoming entangled and frustrated due to this flood of information, the next chapter will give some hints on finding the most valuable sites within the area of irrigation.

World Wide Web Pages related to irrigation issues

A list of valuable WWW pages in the field of irrigation is shown in Table 2. Far from being complete, this list can serve as a starting point for retrieving professional and scientific information about irrigation on the Internet. Some of these sites are described in more detail in [8] and [11] (both sources can be accessed online). Especially valuable are search engines within a site, since the contents of their database are restricted to the visited web site. These tools can enormously facilitate the search for specific information since unlike the general search engines described above, they will narrow the search to irrigation specific contents.

Table 1: Meta-search engines for searching the WWW

Name	URL	Name (cont.)	URL
All4One	http://www.all4one.com/	Highway 61	http://www.highway61.com/
Ask Jeeves	http://www.askjeeves.com/	Metafetcher	http://www.metafetcher.com/
Copernic	http://www.copernic.com/	Metacrawler	http://www.metacrawler.com/
Cyber 411	http://www.cyber411.com/	Savy Search	http://www.savvysearch.com/

Table 2: Selected web sites dedicated to irrigation

Name/Category	URL	Maintained by	search engine
General overview, "portal sites"			
Virtual Library Irrigation	http://www.wiz.uni-kassel.de/kww/irrig_i.html	Thomas-M. Stein	yes
Microirrigation Forum	http://www.microirrigationforum.com	Richard Mead	yes
Soil water content sensors&measurement	http://www.sowacs.com	Bruce Metelerkamp	no
Research institutes / Other organisations			
Water Management Research Unit	http://www.cprl.ars.usda.gov/wmru.htm	Conservation & Production Research Laboratory Bushland, Texas USA	no
Water Management Research Laboratory	http://pwa.ars.usda.gov/fno/ wmrl/	USDA-ARS-WRML, Fresno, California, USA	no
FAO, Land and water development division	http://www.fao.org/ag/agl/aglw/aglw.html	Water resources, development and management service (AGLW), FAO	yes
Online Articles / Bibliographies			
Drip bibliography	http://asset.arsusda.gov/WMRL/dripbib.html	Richard Soppe, USDA, WMRL, Fresno, California	no
Journal of Applied Irrigation Science	http://www.wiz.uni-kassel.de/kww/zfb/	Thomas-M. Stein, Peter Wolff	yes
Software resources and other tools			
Irrigation Engineering Software	http://www.engineering.usu.edu/Departments/bie/software.html	Utah State University, Department of Biological and Irrigation Engineering	no
IRRISOFT - Database on Irrigation and Hydrology Software	http://www.wiz.uni-kassel.de/kww/irrisoft/	Thomas-M. Stein	yes
Professional / Industrial sector			
Irrigation Association	http://www.irrigation.org/	Irrigation Association, Fairfax, Virginia, USA	yes
Irrigation and Green Industry Network	http://www.igin.com/	IGIN: The Irrigation & Green Industry Network	no

Discussion lists dedicated to irrigation matters

The World Wide Web enables users to obtain information about many different subjects related to irrigation matters. However the situation may arise where, despite all efforts, the needed information cannot be found on the net. Or questions may arise, perhaps arising from the results of actual research work, or from reading an article. In such cases, the WWW will not help very much. An expert forum, where questions may be submitted in the hope that someone can answer these queries, may be the best approach in such a situation.

Email based Discussion lists are an ideal forum for discussions on a certain topic. Anyone with email access can participate in these discussions. The principle of such lists is as shown in Figure 2. Anyone who has subscribed to the list can contribute to the discussion, either in form of a new question or an answer, by sending an email message to the list-address (e.g. "irrigation-l") at the listserver (e.g. listserv@gmd.de") that hosts the discussion list. The listserver acts as a mere message duplicator and sends a copy of each incoming mail to each person who has subscribed to the list. With a few hundred experts in the field of irrigation as addressees, there is a high chance of getting an appropriate answer to one's request.
As listed in [8], there exist four discussion lists for irrigation that might be of interest.

The most general list is **irrigation-l** (http://www.wiz.uni-kassel.de/kww/ irrigation-_i.html), others are **trickle-l** [9], **salinity-l** [12] or **sowacs-l**. A comprehensive listing of discussion lists primarily concerned with topics related to water resources, comprising of 46 entries can be found at http://www.nal.usda.gov/wqic/lists.html. Subscribing to a list is fairly easy, and is achieved by sending an email message to the administrative address of the listserver that hosts the list, which can be found in Table 3. The subject must be left blank, the body of the email should only contain the command *subscribe* (or: *sign off* or *unsubscribe*). A confirmation of the subscription should be promptly received.

A slightly different version of an email based information service is the land-and-water-l newsletter published by the Land and Water Development Division of the F.A.O. This newsletter is a passive means for publishing information from that division rather than a discussion list, meaning that subscribers cannot send messages directly to the service.

From each contribution to the discussion list, a copy is stored in the archives of these lists. Since these discussion lists have existed for several years, these archives are a huge information pool and a major source of irrigation information, and they have the potential to be an invaluable help in many cases. Fortunately, for most of them a full-text search-engine has been implemented. The use of these engines is highly encouraged, both before placing a question to make sure it has not recently been subject of a discussion and as a general information source.

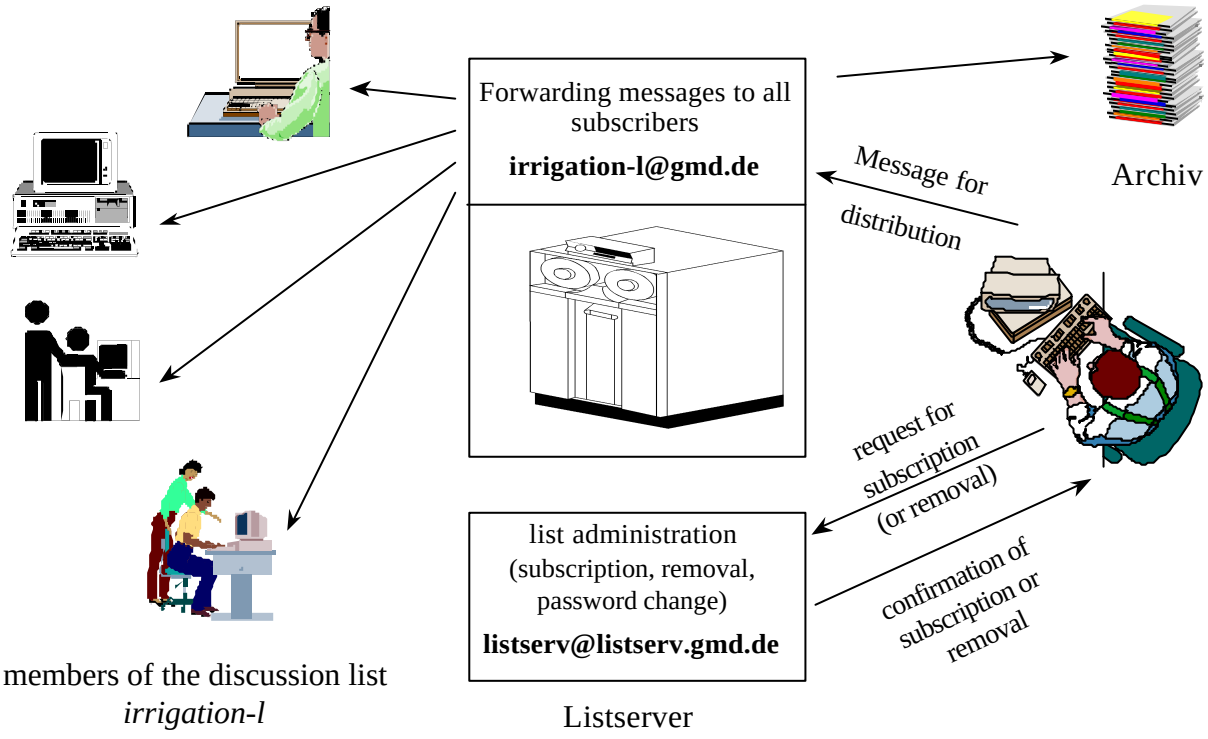

Figure 2: Schematic diagram of the functionality of Internet discussion lists (example for: irrigation-l)

Table 3: Email-based internet discussion lists and newsletters in the field of irrigation

List name	persons	list-owner	host	founded in	Online-Archives URL	searchable
Discussion lists						
irrigation-l	598	Stein, T.	listserv@listserv.gmd.de	Dec. 1994	http://www.wiz.uni-kassel.de/kww/sakia/sakia_i.html	yes
trickle-l	656	Mead, R.	listserv@crcvms.unl.edu	mid 1994	http://www.microirrigationforum.com/new/archives/	yes
salinity-l	251	Soppe, R.	listserv@crcvms.unl.edu	late 1995	http://crcvms.unl.edu/archives/salinity-l.html	yes
sowacs[1]	n. a.	Meteler-kamp, B.	majordomo@aqua.ccwr.ac.za	late 1995	http://www.sowacs.com/archives/index.html	no
Newsletter						
land-and-water-l	n.a.	AGLW, FAO, Hooge-veen, J	mailserv@mailserv.fao.org	June 1996	www.fao.org/ag/agl/lwissues.htm	no

[1] soil water content sensors

Newsgroups holding irrigation related information

Newsgroups are also an email based Internet service for online-discussions. Contrary to a discussion list, the messages sent to the newsgroups are distributed to other news servers rather than to the participants of the discussion itself. Each user can retrieve a list of the header lines from the emails sent to the newsgroup, and if he or she is interested, can request the whole document.

While newsgroups can be an extremely useful tool for solving computer hard and software problems, the chance of initiating a discussion about irrigation on a high level are pretty low. Some potentially suitable newsgroups are sci.agriculture, gov.us.topic.environment.water, sci.environment or alt.agriculture.

Irrigation Software on the Internet

Beside information about irrigation in written form, numerous software programs of different kinds have been written which can be valuable tools both in the research and the professional area.

Software Catalogues

As described in [6] and [16], various approaches have been undertaken to index and summarise the various known software programs in the field of irrigation, resulting in three major inventories:

- an inventory, published in form of a book (ILRI special report, [3]);
- LOGID, an inventory in form of a database which can be accessed via a software program for microcomputers. The software including the database is distributed at no cost and can be downloaded via ftp (file transfer protocol) from the anonymous ftp-server of the university of Kassel (ftp site: ftp://ftp.hrz.uni-kassel.de/pub/irrisoft/logid). Downloading instructions can be found at http://www.wiz.uni-kassel.de/kww/irrisoft/download.html.
- IRRISOFT [15] - a World Wide Web database on irrigation and hydrology software that has been established and is maintained at the University of Kassel, Germany. This database lists 105 programs which are described in detail in "software description pages". The database is fully text-searchable. A few freely available programs can be downloaded from the ftp-site set up together with the IRRISOFT catalogue (ftp site: ftp://ftp.hrz.uni-kassel.de/pub/irrisoft/).

From these three approaches, IRRISOFT [14] is certainly the most promising since it relies on the internet as medium of information interchange, thereby allowing the addition of programs and modify existing entries at any time. Even an user-interface to prepare entries for submission has been created, exonerating the maintainer from translating the contents into a format usable on the WWW. With the rapid development of software and hardware technologies in mind, one can imagine that static media like that of the ILRI report or the LOGID inventory, which have not changed their contents for years neither do depict the actual state of the software market for irrigation software, nor they do represent the state of the art for the dissemination of information in such a dynamic sector like software development.
In the long term, one should expect that software is partly made executable on the WWW using the platform independent language Java. Such Java programs can be executed directly inside a web browser on any platform, thus freeing one from creating software catalogues describing the programs and their hardware requirements.

Software programs
Not all software programs and tools are listed in the catalogues described above. A description of a choice of programs can be found at [10]. A variety of other web sites are also offering various software programs or tools or will present links to such applications. Surely one of the most comprehensive sites for software programs in the irrigation sector is maintained at the Department of Biological and Irrigation Engineering at the Utah State University, USA (http://www.engineering.usu.edu/Departments/bie/software.html). Altogether 24 programs are listed, 17 of them for DOS-platforms, the other seven are Windows programs. While five of the products are distributed at no cost, the prices for the other programs range between 15 and 3.500 US $.
The Water resources, development and management service of the Land and Water Development Division at the FAO offers various tools at their site http://www.fao.org/waicent/faoinfo/agricult/agl/AGLW/dss.htm, amongst them the software program CROPWAT (for DOS and Windows) and the climatic database CLIMWAT. The microirrigation research group at the New Mexico Climate Center offers links to various programs and Excel-Spreadsheets at the URL http://weather.nmsu.edu/w128/. The Water Management Research Lab inside the Agricultural Research Station of the USDA offers its products at http://pwa.ars.usda.gov/fno/wmrl/software/index.html.

How to offer irrigation related information at the Internet?

Having all the advantages of the new internet technologies in mind, one might think of getting actively involved in disseminating information on the web. All companies or organisations working in the field of irrigation which are already present on the Internet, are highly encouraged to register their institution to the Virtual Library of Irrigation. An online accessible form for the automated creation of an entry in the virtual library based on the user input is available at this site. It can be found at http://www.wiz.uni-kassel.de/kww/projekte/irrig/add/add_s.html. Applicants have to specify some data about the institution and what is offered on the web page and they can deliver a short abstract that describes their site and the information held there. After submission, applicants promptly will receive an email, indicating the temporarily URL of a created web page based on the contents that were submitted. If not content with the resulting page one can make proposals for corrections, otherwise the created page will be

added to the Virtual Library Irrigation after being approved by the maintainer of the site.
In order to publish own contents on the WWW, like findings of recently conducted research work, users should contact their system administrator. Designing own web pages and putting them on a server is not as complicated as it is thought to be. If there is no opportunity to publish on the servers of the institution one is working with, everyone has the opportunity to get free web space which is offered from several companies (have a look at http://freeweblist.freeservers.com/ for further information).

Global efforts to improve the access to the Internet

The "information world" is dramatically changing as electronic means become more and more widespread and it seems obvious that internet-based technologies will gain even more importance in the near future. This position is held by the Advisory Committee of the U.S. Federal Networking Council which firmly believes "that the Internet is a critical resource for the national research and education communities. This resource should be made available to the widest possible customer/user base with the highest possible level of service" [3].
As well as all the positive statements, some negative effects may also need to be considered like those stated by ARUNACHALAM (1998), i.e. that history has also shown that technology inevitably may enhance existing inequalities and thus widen the gap between industrialised and developing countries. Despite the enormous general growth of the Internet the availability of scientifically valid and approved information is disproportional low and far from being sufficient to meet the steadily increasing demand and growing expectations, especially concerning developing and less developed countries. Great efforts have been made over the last few years by international and national organisations, universities and individuals to improve the availability of information and access with several examples mentioned above. While there have been some impressive efforts, many users still have difficulty in accessing the full range of information on water conservation in agriculture.
As stated by SEIBEL et al. (1999), the private sector and international development agencies still appear to underinvest in information and communication technologies (ICT) in low income countries. For many developing countries the financial and technical constraints on accessing the Internet still form the major hindrances to accessing adequate and high quality information. To improve the communication and Internet facilities in developing countries, more than eight major programs funded by international organisations have been started. With regard to the African continent, for example, two major projects will establish a sound starting basis for an African wide connectivity which potentially covers the entire continent and should be established this year. The geo-stationary communication satellite above the area of Lake Victoria, which covers the entire African continent and the Indian subcontinent, and the laying of high speed and high capacity undersea fibre-glass cables surrounding the entire African continent allows 32 coastal countries to be linked up.
So we can expect that the situation in these countries will improve in the near future, giving them broader access to information that hopefully can be disseminated to allow the further development of their nations.

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