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# **On Changing Patterns of Mathematical Communication**

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# On Changing Patterns of Mathematical Communication Breakdowns in Traditional Publication<sup>1</sup>

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## Abstract

The Internet and the new electronic means of information and communication are transforming scientific communication fundamentally. In particular, mathematicians, physicists and other natural scientists intensify, accelerate and extend their communication by the use of the Internet and its tools, from electronic mail up to the World Wide Web. In doing so, they also exchange scientific results of a new kind and quality yet unknown to traditional information providers such as publishers, libraries, and database suppliers (e.g. in the form of current research software, scientific data collections, observations and experimental data, visualizations, animations etc.). They, on the other hand, perceive the new ways, which are passing their own field of activity, as breakdowns of traditional publishing, as it was termed by the *Association of Computing Machinery*. In addition, scientific libraries find themselves caught in a structural crisis – not only because of budget restraints.

The *Deutsche Mathematiker-Vereinigung* (DMV), however, sees the new electronic means as an opportunity to master a crisis of this kind rather than a threat. By discussing concrete models, which may be - in a certain technical sense – realizable already today, the article gives an introduction into the subject of a *Distributed Information- and Communication System for Mathematics*, a project prepared and planned by the DMV for the years 1996 to 1998. In the context of possible realization variants it also deals with questions of costs, resulting load of network connections, and – showing the beginnings – the (absolutely essential) solution of problems related to quality, authenticity, archival and intellectual property rights, which arise with the employment of electronic means. Obviously (even if not discussed explicitly) also computing centers, whose tasks and position are also affected by the electronic revolution, have the chance to find a new and forward-looking role in this field - in particular by new forms of cooperation with scientific libraries.

## 1. The Transforming Power of the Internet

Scientists today distribute their work long before “publication”, in the form of preprints and even earlier – electronically – as preliminary scripts. They discuss and comment their results within special interest groups and in-groups by exchange of e-mail within the Internet, addressing peer groups or larger groups – via public mailing lists. To an increasing extent they offer preprints through preprint archives which can be searched (*Archie*, *Wais*, *Jughead*; for an introduction into the conceptions and notions of the Internet see [ACM 94], [Krol 94] and [Flynn 95]). The interactive *World Wide Web*, named Web for

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<sup>1</sup>excerpt from [Grötschel 95c] <http://elib.zib-berlin.de/Cmath.org.softinf.pub.aufbau>

short, has made the access to the Internet very easy. It has already begun to fundamentally transform the manner by which scientists communicate with each other. Theoretical high energy physicists and other physics groups distribute their preprints electronically nearly without exception and keep them – searchable and without costs – at the disposal of everybody with access to the Web<sup>2</sup> [Ginsparg 94] [Stix 95], a method that has found followers in other fields of science<sup>3</sup>; see [Grötschel 95a] for a more elaborate discussion. Today scientific work is almost inconceivable without Internet access. Whoever misses “connection” will soon be isolated.

Scientific associations, research institutions and university departments are now in a position to publish their own electronic journals without much effort and at low costs – and they do it. Within mathematics there are about 30 electronic journals<sup>4</sup> at present, all of them fully refereed, offering their articles Web-accessible in  $\text{\LaTeX}$  or in postscript form. Everybody with a browser like Netscape or Mosaic at his disposal can access them around the clock and without cost, straight from his workstation or PC. Some of these journals inform their subscribers by electronic mail on their new articles as soon as they are accepted; the *Electronic Journal of Combinatorics*<sup>5</sup> (EJC) is but one example. The technical integration of such publications into an e-journal takes only a couple of minutes, says N. Calkin, one of the editors of EJC. And the process of peer-

reviewing is also sped up by electronic mail. In Germany, the *Deutsche Mathematiker-Vereinigung* (DMV) prepares publication of a universal electronic mathematical journal, the *Documenta Mathematica*<sup>6</sup>, which is expected to appear at the beginning of the next year.

Special interest groups of various mathematical disciplines (in Germany the special interest groups Computer Algebra<sup>7</sup>, Optimization<sup>8</sup>, Scientific Computing<sup>9</sup> and Stochastics<sup>10</sup> of the DMV) operate their own electronic information systems with moderated discussion forums (so called *digests*) and Web servers, by which they distribute - world wide - current news and maintain “databases” specialized on their subject areas. They set up hypertext systems, which are very simple to use and which do not require extensive training; see [Nielsen 95], [Flynn 95] and [Graham 95] for an introduction. Their information offers not only comprise simple comments, but also – besides scientific articles and bibliographies – extensive software and data collections (test data, visualizations, animations) related to their current research. The internationally well known numerical network library *netlib*<sup>11</sup> contains more than 160 such libraries and collections [Dongarra 87], altogether more than half a gigabyte of programs, documentations and data. You may find there about 10,000 software sources and modules, to be searched, combined and retrieved according to various points of view [BrowneDGGMRW 94].

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<sup>2</sup><http://xxx.lanl.gov/> - TH-HEP Archive (P. Ginsparg's Server)

<sup>3</sup><http://eprints.math.duke.edu/archive.html>

<sup>4</sup><http://elib.zib-berlin.de:88/Math-Net/Links/math-web.pub.html>

<sup>5</sup><http://ejc.math.gatech.edu:8080/Journal/journalhome.html> - EJC

<sup>6</sup><http://www.mathematik.uni-bielefeld.de/DMV-J/> - Documenta Mathematica of the DMV

<sup>7</sup><http://www.uni-karlsruhe.de/~CAIS/> - CAIS

<sup>8</sup><http://moa.math.nat.tu-bs.de/opt-net/opt-net.html> - Opt-Net Archive

<sup>9</sup><http://www5.informatik.tu-muenchen.de/sci-comp/home.html> - GSCI-Archive

<sup>10</sup><http://elib.zib-berlin.de/Ceconf.st-net> - ST-Net Archive

<sup>11</sup><ftp://netlib.att.com/netlib/master/readme.html> - netlib

The World Wide Web has taken science by storm. Every institution with a sense of reputation “publishes” its own server in the Internet. Practically all mathematical university departments in Germany<sup>12 13</sup> (and, naturally, also in the U.S.) have built up Web servers by which they describe their projects and explain their tasks in research and teaching. Many scientists use these servers not only for offering simple address data, but also for showing their personal list of publications and even their professional *curriculum vitae*. The large scientific associations such as the *American Mathematical Society*<sup>14</sup> (AMS), the DMV<sup>15</sup>, the *European Mathematical Society*<sup>16</sup> (EMS) or the *International Mathematical Union*<sup>17</sup> (IMU) are equally present in the Web. Scientific congresses such as the *International Congress of Mathematicians*<sup>18</sup> (ICM’98) are also announcing themselves in the Web. Interested persons can stay informed around the clock and even register electronically for participation.

## 2. On the Significance of the Internet for Science

The Internet is growing at an incredible pace. Specialized journals and even the daily press are reporting extensively about that. What has made the Internet so attractive and popular? It is not only the simplicity of the approach of the Web, which today is a synonym for the Internet. Neither is it merely the exceptional attractiveness that was brought to the Internet by the Mosaic browser [BernersCGP 92] [AndreessenB 94] by using *hypertexts* with *hyperlinks* (URLs) and their colorful images and video clips (multimedia information). For scientists it is – above all – the possibility to communicate quickly with each other over large distances by electronic means and the very simple access to the vast amount of available information<sup>19</sup>, which has grown in the Internet over a long period of time. The integration of this kind of information, which had been somewhat complicated to handle with previous Internet tools (various different commands, protocols and access methods), into the Web from its very beginning (thus being accessible by simple mouse clicks) is one of the most important reasons for the persistent dynamic growth of the Web.

An important factor for the world wide spreading of the Internet is also its special conferencing system, the *UseNet News*, named *News* for short, which informs about novelties and allows a large community distributed over many countries and states an efficient and active cooperation. In this way not only the communication specialists have been able to share in the development of the Internet itself and its tools, but also its users with their special needs.

The News are not as important for the scientist as they are for the technical communication specialists and for the Internet community as a whole. They have often been criticized for their talkativeness and low quality. They serve, however, as an example for

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<sup>12</sup><http://esther.mathematik.uni-osnabrueck.de/imagemaps/karte.html>

<sup>13</sup><http://elib.zib-berlin.de:88/Math-Net/Links/math-net.html>

<sup>14</sup><http://e-math.ams.org/> - AMS (e-Math)

<sup>15</sup><http://www.dmv.math.tu-berlin.de/> - DMV

<sup>16</sup><http://www.EMIS.de/> - EMS

<sup>17</sup><http://elib.zib-berlin.de/Cimu> - IMU

<sup>18</sup><http://elib.zib-berlin.de/CICM98> - ICM’98

<sup>19</sup><http://www.w3.org/hypertext/DataSources/bySubject/Overview.html> - WWW Virtual Library

electronic discussion forums. Based on e-mail, they are currently being introduced into the community of mathematicians [DongarraR 91] [DalitzL 93]<sup>20</sup>. Whoever has a particular problem or a special question to discuss may *post* it into the News or an electronic forum and will obtain a commentary or an answer from somewhere. It is exactly this *interactivity of the net* which has led to its broad acceptance and, increasingly, its now emerging wealth of information and scientific material.

The Internet has triggered a world wide mass movement, where information and publication, documentation and archival, and communication are merging – resulting in completely new and unforeseen forms. The media report almost weekly about spectacular new applications, as for instance on *live transmissions* of scientific conferences and workshops in the *MBone* of the Internet, a world wide “carrier” for video broadcasting [Erikson 94] [Schult 95]. For science, above all, the manifold of particular initiatives are of importance, which have effect beyond all geographical borders, and the possibility to access the treasure of experiences and knowledge of a large number of people and institutions, which are active in the Internet. Here is a vivid example from the area of bibliographic work.

Many computer scientists and mathematicians maintain their private bibliographies within their research work, often using the BibT<sub>E</sub>X-format [Lamport 86]. A significant number of them offer these “personal” documentations to their particular colleagues through the Internet. A. Ch. Achilles, a research assistant of computer science at the university of Karlsruhe, has brought together – “single-handedly” and more or less in his free time – about 650 of those locally stored bibliographies into a large and integrated *Collection of Computer Science Bibliographies*<sup>21</sup>, which now (Oct. 1995) contains about 390.000 references to actual conference reports, articles in journals and technical reports. This collection presently comprises over 190 megabyte of BibT<sub>E</sub>X-data. More than 12,000 references also carry *hyperlinks* to an online version of the paper. Additionally there are more than 1,000 links (URLs) to other sites carrying bibliographic information. This database can be searched and retrieved in the Internet without any costs. Currently about 1,000 accesses are counted every day. In the meantime another 12 servers in various countries mirror this collection, each of them having a comparable number of accesses.

All this is based on personal activities and wide-ranging initiatives, without special governmental funding, at most in the interest of the related institute – but, without the possibility (nor the intention) to earn money. Achilles would hardly have been able to gain the support of the participating scientists if their data were to be used commercially. As they are not, he has obtained statements of consent from all (approximately 600) persons involved. Maintenance of these data takes about one day per week, says Achilles (development of his software not accounted for).

The data may not always be of the technical quality a professional librarian would expect. They have, however, their origins in current research and development, thus being highly topical. In addition, Achilles mirrors and maintains them on a weekly basis. And, by using BibT<sub>E</sub>X – these data are printable in typeset quality. Scientists are able to integrate them *as they are* into their own papers, there is no need to type such references again and again. This is highly appreciated by everybody who has spent his time with the tedious

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<sup>20</sup><http://elib.zib-berlin.de:88/Math-Net/Links/math-web.sigs.html>

<sup>21</sup><http://liinwww.ira.uka.de/bibliography/index.html> - Computer Science Bibliographies

work of composing bibliographic lists.

Initiatives of this kind are typical for the Internet. They are welcomed by the scientific world but feared by some professional information providers. This clearly reveals an unwillingness to adapt to changing conditions as well as a monopolistic price policy.

One technical characteristic of the Internet, and of packet switching networks in general, should be mentioned within this context. Once a physical line is installed (based on fiber optics or on copper technology) the theoretical maximum transmission rate depends mainly on the power of the communication facilities at its ends (and from the used protocol, of course). Thus the electronic revolution with its continually increasing power and decreasing prices will also induce a dramatic cost reduction for existing communication channels in the long term, by making higher and higher transmission rates possible at nearly constant costs.

It is acknowledged that the Internet started as an initiative of the American Army, but it also is true that it was developed by research laboratories, i.e., strictly within the context of *unfettered research* [Kahn 94], as we would like to term it. The American National Science Foundation (NSF) has supported the Internet with vehemence. Today it still bears all the characteristics of a scientific network. The Internet is – somewhat superficially expressed – a “broadcasting station for information quanta”, which are “on the air” world wide via this carrier. Everyone connected to this carrier can “receive” such messages. By this formulation it is intended to express that the Internet is very close to radio or TV – with consequences for commercial information providers. Many of them are now beginning to ask themselves if and how they can earn money with this medium. In such a world laws are different from those in a traditional information market.

### 3. The Crisis of the Libraries

The production of literature doubles every 16 years [AAU/ARL 94] [CummingsWBLE 92]. Within science and mathematics the doubling even takes place every 10 to 12 years [Odlyzko 95]. This enormous growth has been visible for the last 100 years [Wiiërs 94]. This will naturally come to end at some point, as any exponential growth does. This is, however, not likely to happen in the near future. The reasons are a raised “productivity” of the single researcher together with a continuous growth in the number of scientists. In addition, there is an increasing influence of mathematics on other areas of science and an ever stronger tendency towards interdisciplinary work.

These circumstances pose a serious problem for the large scientific libraries. On the one hand they make great demands to own all the relevant literature in order to place it at the disposal of their users. On the other hand their budgets stagnate or even decrease. The serial and monograph unit prices, however, escalate faster than the inflation rate [AAU/ARL 94]; for an analysis of the situation in Germany see [WinterZ 95]. As a matter of fact, library budgets should grow at the same speed as the production of literature and the costs for its purchase.

At present, for scientific libraries there still seems to be a way out by resorting to electronic document delivery. In Germany, this can be done within the framework of the SUBITO

project [DBI 95]. Document delivery, however, is no real solution in the long run, as we have argued extensively in another article [GrötschelL 95b]. It is not only by far more expensive, but also much too late for research, because it is rooted within the traditional – paper-oriented – publication framework. Document delivery is only possible for articles that have been published, i.e., that have been printed on paper before. This may be adequate for some older or rare documents. If seen as the medium of choice for the large mass of literature a vicious circle becomes apparent.

In the case that, say, a half of the libraries cancels the subscription of a journal, which they cannot afford any longer, but trusts in the possibility to order single articles on demand by electronic document delivery, the publisher of this journal will have to calculate with only half the number of subscribers, among which he now has to divide his expenditures. A great amount of his costs are, however, independent of the print run. So the remaining subscriptions will cost, at a rough guess, twice as much - always assumed that the publisher will preserve his earnings. Would this be different, it would be enough if the libraries order a single issue for the whole community. What would be the price of such an issue?

A. Odlyzko predicts in his landmark article “Tragic Loss or Good Riddance? The impending demise of scholarly journals” (which has influenced our own thinking to a great deal) the forthcoming death of traditional scientific paper journals [Odlyzko 95] – some time within the next 10 or 20 years. The whole system of the traditional publishing on paper is, so his opinion, extremely slow, costly and not up to date. It will totally break down in the near future. Already today there are oppressively high rejection rates in mathematics (up to 80%) and exorbitantly long waiting periods (2 to 3 years), often only because a journal limits its pages numbers (due to cost and marketing reasons).

The *Association for Computing Machinery* (ACM) regards the present way of publishing as undermined by a number of “breakdowns” of the kind described in the first chapters of this article. Scholars today utilize more and more different and faster methods to communicate. For this reason the ACM has made a plan (and the decision) of a complete transition into the electronic world – with all their journals and serials [DenningR 95]. By the way, the ACM is not only a large association of computer scientists, but also a large publishing house with an annual \$30 million dollar budget, one-third of which is resulting from publication sales.

The enormous growth of scientific literature will result in the fact that within the next 10 to 12 years – at least in mathematics and in science – about the same number of articles will be written as in the history of mathematics and science at all. During the next 20 to 24 years the number of mathematical publications will have quadrupled. Together with Odlyzko we hold the opinion that these circumstances inevitably will induce a broad based transition to electronic publishing [GrötschelL 95b] [GrötschelLZ 95]. Where else shall all the paper be put? And, how else can the ever widening publication gap be closed? Alreday today, the traditional publication market is no longer able to develop according to requirements. New journals are founded continuously, without, however, finding enough buyers.

To say it in a few words, it is suggested that sciences themselves take care of their interests, supported by libraries, which represent their very infrastructure. Centers of specialized information can play an important role in this context, too, if only they comprehend what

changes are going on, if they react flexibly and if politics do not counteract.

Scientific publications today are always available electronically, too – in one form or the other – so that they could and should be distributed electronically once they are completed. Long waiting periods are no longer necessary. With electronic means the “dream” of having everything available locally, which has nearly come out of reach, could indeed be realized. Today, this may seem as bitter irony to the proponents of traditional publishing on paper. But already tomorrow they may regard it as their own chance.

#### 4. Distribution of Mathematical Reports, Cost Comparison

In the good old days of mainframe computing nobody would have thought of using these machines for the distribution of reports, this would have meant misusing them. Unfortunately, this thinking is still prevalent today, although times have changed dramatically. In the course of the electronic revolution, computers have become extremely powerful and inexpensive, and digital networks are working with barely conceivable bandwidths. In contrast to the past, today human labour is regarded as the more valuable factor, and its optimal use is aimed at, for instance, by avoiding long waiting periods.

Those who want to keep up with top research will have to adjust to the pace, as otherwise their work could easily lose its value just because competitors have been faster. Long waiting for publications of other scientists in a traditional journal is completely out of question. In mathematics, the publication of a new results may easily take 2 to 3 years, which is far too late for any research. Mathematicians have therefore made use of other means for quite a number of years now, mainly by exchanging their manuscripts and preprints before publication. We have already given a rough sketch of the role the Internet and e-mail, in particular, play in this context. The way in which these new electronic means may additionally bring about considerable cost reductions and how this can be realized technically will be the subject of the following sections.

A mathematical research institute such as the *Konrad-Zuse-Zentrum für Informations-technik Berlin* (ZIB) produces an average number of 50 scientific reports per year, each of which is sent to approximately 300 partners. The ZIB spends about DM 125,000 annually for conventional copying and distribution (not accounting for copies for its own use).

These reports do not require a large amount of electronic resources. For the sake of simplicity, let us proceed on the assumption that a mathematical report requires 200 kilobyte on the average, about 60 kilobyte for the  $\text{\LaTeX}$ -file and 140 kilobyte for graphics and figures in postscript form (eps-files). Thus, a standard hard drive of 4 gigabyte storage capacity (in early 1995 such a disk for workstations cost DM 4,000) holds about 20,000 reports. Accordingly, the storage costs for one report are roughly DM 0.20. Based on an efficient workstation with hard disk, software and maintenance (approximately DM 24,000) and a depreciation over 3 years (i.e., DM 8,000 per year), this yields a price of DM 0.40 per copy and year, i.e., DM 20 proportional costs per year for the storage of the report production of one year and DM 120 for a period of 3 years (DM 20 in the first year, DM 40 in the second and DM 60 in the third). Similar cost calculations can be found in [Lügger 95] and [Rehmann 95].



This is, of course, a very rough estimate, nevertheless, it reflects the dimension correctly. And the calculation is sensible only if the workstation can be employed for other routine purposes (as it is done at the ZIB), because the storage of reports takes only a very small fraction of its capacity. (How would one count the costs of a couple of copy commands?) Therefore workstation costs are assessed at the same rate as disk storage. The next chapter, however, discusses a model for the distribution of preprints, where the computer system is estimated totally for distribution as well as for storage and retrieval.

Now, what are the proportionate costs for the electronic dissemination over a net? The Internet connection of the ZIB (via the *German Science Network* WiN) has a transfer rate of 2 MB per second. Thus it is capable of transferring roughly 100 “true” kilobyte per second, because a connection cannot be utilized at full 100% of its capacity<sup>22</sup>. That is a very conservative estimate – done in order to be on the safe side. The real transfer will take more time, of course, because the net will also be used otherwise. We are not so much interested in the waiting time of the user in this context, but only in the network demands. Let us speak of “net seconds” in the sense that the transfer of a report will utilize the connection (of the ZIB) for 2 seconds of its true capaci

ty.

The 2 MB Internet connection does cost (the ZIB) at present DM 410,000 per year (incl. tax; according to the current scale of charges of the *German Research Network* [DFN 95]). Thus the real costs of a net second are DM 0.013, because a year has 31,536,000 seconds and the network is available around the clock (potential down times are already accounted above). Strictly speaking it does cost only half as much, because the transfer is into both directions, 2 MBps from the outside into the local network (of the ZIB) and another 2 MBps for the reverse direction. But, let us work with this magnitude in the following, because you will not be able to hire “a half” connection. Additionally we are able to suppose that the costs of the receiver are already accounted in that way.

Thus the distribution of a whole report in  $\text{\LaTeX}$ - and postscript form does cost less than DM 0.03. All the 50 reports (10 megabyte) can be transmitted in about 100 net seconds. The distribution to all the 300 cooperation partners (3 gigabyte) takes about 30,000 net seconds. Consequently the dissemination of all reports (of the ZIB) shows DM 390 in the books.

To sum it all up: The electronic storage and dissemination does cost (the ZIB or an institute of comparable size) only DM 510 per year. This is in sharp contrast to the DM 125,000 necessary for traditional duplication and distribution of paper. This estimate is valid only for the year 1995 (and in Germany) though, because the DFN has lowered its prices in the meantime drastically. Furthermore, the cost for electronic distribution will decrease in the future - there is no reason to assume the same for the distribution of paper.

The costs for the necessary infrastructure are not included in this amount, because a mathematical university department or research institute today ought to provide that in

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<sup>22</sup>Let us take into account a “true” capacity of 1 MBps only, because of potential down times, and let us subtract an additional 20% due to overhead (connection time, communication protocol, potential defaults and delays etc.).

any case (e.g., the ZIB operates a local network with supercomputers, more than 160 workstations and about 25 PCs). Also the personnel costs for storing the reports (which are prepared by secretaries ready for press - in LaTeX) are not extra accounted. A regular archival has to be done in any case (also for the distribution of paper). The use of the workstation by the sending of e-mail could be accounted on top of that. But, let us skip this for the moment<sup>23</sup> and let us discuss it in one of the next chapters completely.

The trick is, of course, that the ZIB shifts the costs for the paper copying of its reports to the receiving institutions and readers in that way - but, isn't that only fair? And isn't it also correct in comparison to the traditional way of sending preprints on paper? These should be commonly available in a library as a rule (in reality they are often buried in some researchers desk). Now, whoever needs such a report, because he intends to work in it, will copy it for his own purposes. Furthermore, the receivers of electronic reports will not print out each and everything at once, but rather only those reports they intend to really read.

The aim of this discussion was to make plausible which dramatic costs reductions are possible for "suppliers" of scientific information in the case that they employ electronic means and digital networks - even if the Internet may appear to be expensive to many people at present. But, already today that is - viewed in that way - not the case for an independent mathematical research institute (like the ZIB). Within a university many departments are able to share a single connection.

## 5. A Massively-Distributed Mathematical Preprint Archive

This chapter discusses a preprint distribution model which was almost inconceivable not long ago. Could it be possible that all mathematical university departments and research institutes (within mathematics there are at present about 1,000 "functioning" institutions connected to the Internet) place their preprints at the disposal of all others by means of electronic mail, immediately, at the moment they are available.

Then each mathematical institute would soon have a highly current collection of the complete research literature, a mathematical preprint archive, stored within a hypertext system or a database, which can be searched and retrieved locally. Thus not only the *in-groups* would have access to the most topical research manuscripts, but all the faculty members and students too - even within the whole university. Additionally, it would be possible to enable access even to teachers and schools, and also to other persons within the region (even commercially-oriented ones). The required server would not be overloaded.

Each institute could decide according to its own needs on the best form in which to offer mathematical preprints prepared anywhere in the world, with or without a database, stored within hypertext- or document-systems of different kinds, isolated or open to the World Wide Web, integrated into or compatible with other local library systems. It would always be possible to use locally familiar procedures and systems.

This is the very central point for the acceptance of the proposed system. There is no

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<sup>23</sup>The e-mail distribution could be organized in such a way that it is performed at night times or at weekends only, when the workstation will not be used otherwise.

common agreement about the features such a system should have and about the user interface. It is much too early to set a final standard with that respect. All these systems are presently still subject to research and development. Institutes participating in such an enterprise should have the freedom to experiment with different functions and forms in order to let the best ones evolve and assert themselves. Furthermore, it is not without relevance to have the search facilities and a (full) document access locally - think of slow international lines, which may be a bottleneck at present.

From a technical point of view it would already be possible today to organize the massive electronic dissemination of preprints. A simple mailing list (maintained centrally) with 1,000 entries should be sufficient as a first basis for its realization. The model of a massively-distributed preprint archive is, however, a “stress model”. Initially it was merely meant to get first estimates for the necessary primary costs and of the network load (at Internet connections) resulting from a *Distributed Information System for Mathematics*, a project planned for the DMV for the years 1995 to 1998; see [DalitzGLS 94] [DalitzGHLS 95]<sup>24 25</sup>.

It is, however, informative to discuss its realization too. A massively-distributed preprint archive could be implemented a great deal easier than the more general distributed mathematical information system. The first one is specialized on literature whereas the latter one comprises software and data collections, project-related and organizational information, still pictures and visualizations, up to dynamic animations and multimedia information. Nevertheless some interesting conclusions can be drawn on the basis of the simpler model alone and it delivers solutions to some intricate organizational problems, which can barely be obtained in another way.

In this model the central e-mail distribution list would serve for copying purposes only (not for the distribution of the preprints). Every institution intending to distribute a report therefore obtains the most actual copy of the whole e-mail distribution list and carries out the dissemination itself. While doing so it keeps to a simple (but still to be defined more precisely) standardized procedure, such that a receiver will be able to identify the different components of the mail and to transform them into his own data structure. A central e-mail server where every report is distributed would not be appropriate, because the whole mass of preprints would have to be channeled through this server. Each report would be sent twice.

The e-mail format used by the theoretical high energy physics group (according to the model of P. Ginsparg [Ginsparg 94]) would be one possible choice. It allows for the extraction of author(s), title, abstract, and the full report from an e-mail message containing ASCII only code (in plain text or L<sup>A</sup>T<sub>E</sub>X form). But why should one not use a multimedia format (MIME form, according to [BorensteinF 92]). It comprises nearly everything that can be sent electronically, from plain text to L<sup>A</sup>T<sub>E</sub>X and HTML codes to (even colored) graphics.

The only task to be fulfilled centrally within this model is the maintenance of the addressing information, a simple task which can be implemented almost self-regulating. For that reason each institution defines exactly one e-mail address, by which the distribution

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<sup>24</sup><http://elib.zib-berlin.de:80/Cmath.rd.vismath.newpersp>

<sup>25</sup><http://elib.zib-berlin.de/Cmath.org.softinf.pub>

will be carried out, i.e. an address of the form

library@math.tu-berlin.de

where the *user-name* “library” is prescribed literally. Each institution makes its own entry into the distribution list. Centrally a simple check of the *IP-address* would be enough (in the example “math.tu-berlin.de”) in order to guarantee that only the acknowledged mathematical institutions may do so. The intention of this procedure is not to exclude the distribution of preprints to other entities or persons, but rather to ensure that this will not be done by means of this mathematical distribution list. Further redistribution is a matter of the participating institutions.

Each institution designates an *information coordinator*, who – by this address – sends out the preprints of his institute. He is responsible for sending out solely reports which are acknowledged by his institution.

## 6. Quality, Authenticity, Archival, Intellectual Property Right

Within the model of a massively-distributed preprint archive (as well as in the general distributed mathematical information system) the responsibility for the quality of the reports lies with the participating institution, and not the information coordinator or the author(s) alone. This accounts for the question of quality, which has always been topic of controversial discussions; for a somewhat deeper argumentation see below.

The E-print model of physics (using servers of Ginsparg style) allows each and every author to utilize the e-mail server if only he has access to a mailing box [Ginsparg 94]. For mathematics such a procedure is out of question; the related problems are discussed in [GrötschelL 95a]. It may be possible, however, that reality will surpass such a point of view. A couple of mathematical special interest groups are already experimenting with such servers <sup>26 27 28 29 30</sup>.

The question of authenticity would be solvable in this way. An information coordinator receiving a report from somewhere will then be able to check – by the list of registered addresses – whether the message is “legitimated” and to reject anything else – even automatically. This is expressed somewhat superficially, because a hacker with only a little knowledge of electronic mail could modify his message (containing a “strange” preprint eventually) in such a way, that it looks like an admitted one. He thus may beat the system technically, but he also leaves traces in the net and he makes himself liable to prosecution in trying to delude the information coordinator into thinking that a preprint is from somebody else. Preprints (all the more if unpublished) are subject to data privacy law (at least in Germany), because they contain the name and the address of an author, thus being personal data. Furthermore, today there is the possibility of electronic signatures, which might be an appropriate means fo

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<sup>26</sup><http://eprints.math.duke.edu/alg-geom/> - Algebraic Geometry Preprint Archive

<sup>27</sup><http://www.msri.org/preprints/auto-fms.html> - Automorphic Forms Preprint Archive

<sup>28</sup><http://www.msri.org/preprints/cd-hg.html> - Complex Dynamics and Hyperbolic Geometry

<sup>29</sup><http://www.msri.org/preprints/dg-ga.html> - Differential Geometry and Global Analysis

<sup>30</sup><http://eprints.math.duke.edu/q-alg/> - Quantum Algebra and Topology

With the object of unique identification of reports (if there is any doubt) the mathematical institutions could agree on a name pattern, maybe of the kind

[www.math.tu-berlin.de/library/reports/SC-95-02](http://www.math.tu-berlin.de/library/reports/SC-95-02)

where – here too – the strings “library” and “reports” are prescribed literally. The institutes are totally free in using their own name pattern for their preprints or serials (in the example: “SC-95-02”), and also in the choice of their WWW-address (in the example: “www.math-tu-berlin.de”) as long as these are made public (which can also be done by the distribution list mentioned above). But the institutions ought to guarantee that their reports are definitely accessible electronically in this manner (stored in a hypertext- or in an ftp-archive). Everybody would then be able not only to cite a report (the original version) adequately, but also (in the case of any error or doubt) to convince himself of the identity of the original with the version known to him.

The question of authenticity has yet another side which has constantly been discussed controversially in the context of the electronic offer of preprints, in particular by publishers, who intend to claim the privilege to certify authenticity for themselves and the traditional paper-oriented publishing. Sometimes they imply that authors want to change and modify their articles afterwards, e.g., if errors are detected. They fail to see, however, that electronically disseminated messages and documents can never be withdrawn, not even in the case that they are distributed to a small group of people only. Everybody who receives such an e-mail message is able to forward it easily – without giving the author a chance to know about that and to whom the forwarded mail goes.

Mathematics knows a classical example for this: On June 23, 1993 – after a series of lectures – a message about the proof of the famous Fermat conjecture by A. Wiles went around the world at lightning speed (*DMV-Mitteilungen 3/93, pp 3-6*). Within only a few hours the whole community of mathematicians was electrified, perhaps faster than the author really wanted, because he had only announced but not yet published his result. His proof was quite long (several hundred pages) and a bit complicated. But the general delight did not last long because the proof contained an error (*DMV-Mitteilungen 1/94, pp 22-23*). The message of the error soon was spread at the same speed. By the way: This example does not speak against the use of electronic means in publication, because A. Wiles did not disseminate the proof electronically. It demonstrates the effectiveness of electronic communication – be it positive or negative. Wiles has modified his proof in the meantime and the new method appears to be commonly accepted (*DMV-Mitteilungen 1/95, pp 12-14 and 2/95, pp 6-8*).

Electronically distributed documents not only have an exact time stamp, they “are” also published (widely), so to speak. Neither would it be the aim of this model if electronically offered reports could be changed or withdrawn. They would lose their identity in a way and they would not be citable unambiguously any more. In contrast to traditional preprints on paper, which are in limited supply only (for reasons of costs), you may copy electronic preprints just as often as you like and as long as you like. For that reason in offering their reports electronically mathematical institutes have a special responsibility, not only in their own interest but also with regard to the author(s). This question has not appeared

earlier with this sharpness, because the degree of dissemination of preprints on paper was potentially not that high.

The example “A. Wiles” demonstrates that the problem of ensuring correctness has nothing to do with publishing by electronic means. He did not publish his defective proof at all, thus, of course, not electronically either. The “problem” is simply given by the existence of electronic communication means today. Whoever wishes to avoid that his article is prematurely distributed electronically should neither use a computer for writing, let alone electronic mail. But who would seriously consider this. Today we are living “in an electronic world” – even the advocates of traditional publishing.

Also the question of archival would be solvable within the model of a massively-distributed mathematical preprint archive, in fact without the need for every institution, to employ its backup procedures. If 1,000 institutes scattered all over the world always maintain the complete collection, it certainly will be no problem to obtain (e.g. by automatic mirroring) a complete copy again in the case that a local storage medium breaks down.

Such a simple model for the distribution of reports and preprints, by which the mathematical information is being replicated at all participating institutions (as it already was successful for the News) would have some other advantages too, as e.g. for the question of guaranteeing intellectual property rights. Against the electronic distribution of articles it is often argued that they may be very easy to copy, modify and, possibly, disseminated by using a wrong name. This belongs to the more important arguments named by scientists facing the electronic world sceptically. From a pure technical viewpoint this may be possible of course, but it is also true, that a “thought-thief” exposes himself to an exceptionally high risk. The text stolen by him (in the Internet) would already be there at 1,000 institutes, because it was distributed before - via e-mail and affixed with a time stamp. It is highly inconceivable that nobody would notice it, if the plagiarist then distributes “his own” work in its turn –

which would have be later.

Thus, the reverse case is far more likely: The earlier an author makes his work public, the more safe he can be, that his intellectual property right is preserved (and that a “thought-thief” convicts himself). Exactly this circumstance is the main reason for the mathematical researcher to produce preprints. Today he is able to utilize electronic means for that purpose.

## 7. Considerations of Costs and Estimation of Network Load

Organization and technical equipment are not the problem, as has been shown. These means are available already today. What are the investments to be made by the single institution? Would the realization of such a model not be too expensive? Each institute ought to provide an adequate workstation. And, would the generated network load not exceed the capacity?

In the case that 1,000 mathematical institutes distribute their preprints (50 reports in 1995 and about 10% more every year) to all the other partners (we calculate with a

doubling of scientific output every 10 years), the following cost will arise over the next 10 years (for a detailed calculation see [GrötschelL 95c]):

primary costs for 145 gigabyte disk storage altogether	36,000 DM
modernization of disk storage - every 3 years	13,000 DM
workstation - and its replacement every 3 years	40,000 DM
maintenance, operating system and database software	30,000 DM
Sum – over 10 years	120,000 DM

As a result every institution would incur less cost in ten years than the ZIB spends for the paper-oriented copying and distribution of its preprints in the first year alone.

The basic reason for that is “Moore’s Law”, by which the capacity of storage media doubles every 18 months at constant costs - due to progresses in technology. This corresponds to a cost reduction by one third every year (having the area of workstations in mind, of course). These relations will last at least for the next 10 years, as specialists forecast. But the institutes are forced to modernize constantly and to buy disk storage of optimal (large) size in order to be able to realize the potential advantages in costs. It is interesting to note that the total costs for the disk storage (one institute has to buy 10% more every year) are decreasing in the medium term even under the circumstances of a replacement every 3 years. That gives us a hint on how to cope with the soaring “information explosion” on a technical level.

Now, in this light, is the employment of electronic means still a question? Or, isn’t it rather the opposite case? Would it not be much more expensive not to utilize them?

By a calculation analog to the earlier chapter on the distribution (and the receipt) of preprints we get (in Germany, and for the ZIB):

proportionate costs for network access in 1995 (2MB connection)	3,000 DM
proportionate costs for network access in 1996 (34MB connection)	300 DM
proportionate costs for network access in 1997 (34MB connection)	330 DM

This is so because the German Research Network has announced considerably higher bandwidths (34MB per second) in 1996 at a modest increase in prices, an offer which the ZIB will certainly accept.

Naturally, these considerations are correct only in the case that all mathematical university departments and research institutes will participate in the exchange of preprints and reports and, in doing so, will use bandwidths of a comparable magnitude. In Germany at the time of this writing 43 of 74 universities and mathematical research institutes are equipped with 2MB connections. In the U.S. the development of the “Datenautobahn” is far further advanced. The majority of the universities there are already provided with 34 MB connections (at substantially lower costs) and some of them are testing connections with a much higher capacity (155 MB and more).

A 2 MB connection is able to transfer about 288 gigabyte a month (in each direction, from “the outside” into a local network, and reverse); see [GrötschelL 95c] for a detailed estimation. This is true even under the conditions of heavy load (we have calculated with only 50% of the theoretical maximum capacity of a connection). Thus the distribution

of all its mathematical reports in 1995 (1.09 gigabyte a month) would load the connection of the ZIB only by 0.38% and the receipt (0.84 gigabyte per month) to an even less proportion. A 34 MB connection is capable of transferring the vast amount of 4,896 gigabyte per month. Thus the load of the network connection (of the ZIB) caused by the dispatch in 1996 (1.9 gigabyte a month) is lower than 0,025% and by the receipt (0.92 gigabyte a month) even lower again.

I do not intend to make a corresponding calculation on the network capacity and costs from 1998 on (for Germany). Then, in Europe, the Datenautobahn will be deregulated. I expect noticeably decreasing prices and, simultaneously, the availability of much higher bandwidths (in Germany). The reason for that will be the commercialisation of the Internet and of the global Information Super Highways, which will attract a much broader spectrum of users. Thus much money will go into the further development of the Datenautobahn, thereby dramatically accelerating the development of the related technology, which sciences will also profit from.

To give a longterm prediction let us discuss the distribution of movies over the net (*video on demand*), which is also of interest for science (multimedia information). A movie, digitalized and compressed (JPEG), takes about 3 gigabyte of storage. This is about the same amount as is necessary for the distribution of the annual scientific production of the ZIB to all its 300 cooperation partners. It corresponds to a proportional network cost of DM 390, as shown above. If video-on-demand proves to be a success, the costs for transmitting one video “on” the Datenautobahn cannot be higher than the price for the video itself – in the U.S. \$ 10 are calculated (at the most) and this is still quite high in relation to German circumstances. With a 34 MB connection we have done a first step in this direction. The transfer of a video via a 34 MB line would cost (in Germany in 1996) about DM 33.50. And these developments will continue in the future.

To give a final comparison: According to A. Odlyzko the whole annual mathematical (scientific) world production of publications (on paper) can be stored in only 10 gigabyte of a disk (using L<sup>A</sup>T<sub>E</sub>X or postscript) [Odlyzko 95]; see also the related estimation for preprints in the chapters above. That amount corresponds to the information of only 4 full (digitalized) movies. Would it not make sense to utilize the networks for the distribution of this valuable information to all persons interested in?

## 8. A Distributed Information System for Mathematics

The massive distribution of preprints is a highly debatable point. Will mathematicians not be overloaded by the wealth of available information? Is it appropriate at all to make available each and every report? Would it not be much better to put the main emphasis on quality and to offer only a limited selection [Hoffmann 95]? M. Grötschel and the author hold a clear standpoint in this controversy; see [Grötschel 95c], from which the paper in hand was excerpted. In the first place our concern is to restore mathematical communication on a broad basis and, simultaneously, to overcome the deficiencies of traditional publication – both, in the speed of information dissemination as well as regarding costs. In our view, the counterarguments mentioned speak against the utilization of preprints in general. Mathematics, however, cannot live without them – not even in a world without



electronic means, as it has been known so far.

Now that the electronic world has become reality we strongly advocate putting large emphasis on quality and on maintaining this position vehemently. Here we appeal to the participating institutes. They have to accept responsibility now, because it is without doubt that the former standards, which have been established for journals by peer-reviewing, cannot be transferred entirely to scientific reports. But for what reason should students not be “confronted” with the problem of information overload? They, in particular, grow into a world, in which they must be able to cope with that. And, given a good information structure, the problem in question can be reduced.

Let us assume that all authors classify their work by the world wide accepted *Mathematics Subject Classification* schema (MSC-index) which comprises about 4,000 categories today [FIZKA 94]. Under the condition of 50,000 reports per year, each category – representing a particular mathematical discipline – would have about 24 to 36 entries (if a report is classified by 2 to 3 indices). By means of an expensive reviewing procedure this part probably could be reduced a bit – but is this number really that high? Would the additional expenditure in person power be worthwhile?

The proposal of this article and of the according plan of the DMV [DalitzGHLS 95] [Lügger 95] is to create a system, which makes reports of interest available to everybody “subscribing” to a certain subject area (i.e. to an MSC-index or a set thereof). In the model of a massively-distributed preprint archive an according sub-distribution would be the matter of the local mathematical institution. In following the present state of the discussion, however, an instant realization of a massively-distributed mathematics archive is not very likely. The mathematical institutions ought to learn first to make their reports electronically available at all. The difficulties are not in the technical area, the problems are elsewhere (ability to learn and shift in thinking).

The project plan of the DMV therefore proposes to implement an electronic “news agency” at first. Every institution providing a preprint electronically sends not the whole report but rather a message only on its availability to the agency. Besides the WWW-address (URL) of the report this message contains approximately its first page informing about the author(s), the title, classifications and keywords and the abstract. These texts are substantially shorter than a full report. For that reason there is no need to limit the distribution to institutions. Every mathematician should have the possibility to subscribe and to receive the according messages related to a specific subject matter (or even a superset thereof) or to any combination of keywords and MSC-indices specifying his interests. The system shall not only distribute such messages though, but also – simultaneously – archive them electronically, in a database, which may be searched later on, and also in a hypertext, which provides for an easy access to all information available so far.

That is – in a terse form – the central technical idea of the distributed information system planned by the DMV. This system leaves the original information at the particular institution, but guarantees – world wide – both the information on news and the possibility to locate the relevant information in a storage scattered over many institutions (and for all persons not participating from the first start). Both is necessary: the notification and the facility to retrieve, because nobody is able to know his forthcoming areas of interests in advance. In connection with retrieval also two different modes of operation ought to

be envisaged. On the one hand traditional techniques (classical database retrieval) and, on the other hand, modern hypertext oriented means (for browsing the complete set of available information). Within the framework of the DMV-project we intend to explore the chances to integrate these quite different techniques a step further. For example you may think of helping a reader of hypertexts by letting him browse particular subsets of the distributed information, which he may specify – within query – by an arbitrary combination of keywords and MSC-indices.

The proposed model of a distributed information system can – in contrast to the model of a massively-distributed preprint archive – be generalized for other kinds of information, e.g., for software and data collections. Mathematical software systems are often very large and they also develop and change as long as they “live”, not seldom in extraordinarily short periods of time. For this reason they are not suited for a massive distribution by electronic mail, i.e. for a massively-distributed archive. There is, however, an internationally accepted standard for classification, the *Guide to Available Mathematical Software* (GAMS-index) of the *National Institute of Standards and Technology* (NIST) [BoisvertHK 91]. Thus it is possible to deal with software and data collections in a comparable way within the distributed information system for mathematics. The corresponding database, however, ought to allow the use of different classification systems and schemes, also, because software is to be described in another way than literature. Regarding software we think of a schema utilized by the *netlib* [BrowneDGGMRW 94]. Technically speaking, we intend to employ an object oriented database.

Mathematics has a great manifold of information to offer, not only for mathematicians, but also for physicists, chemists, and other scientists making use of it, to engineers, and other researchers from technical areas to scientists from psychology, the social sciences and humanities. All of them could profit from information offers of this kind. For mathematical research descriptions of current projects and their related institutes are of relevance, too. In this context also organizational informations, such as names and addresses of members of the institutes or projects are of interest – and a great deal more. For students and teachers scripts and teaching materials are of importance, which could be available electronically in the whole country. The DMV intends to integrate all of this into the distributed information system.

For users of such scattered and heterogeneous data a special problem arises, i.e., how to find one’s way in the information distributed over many locations? The user is looking for information on a particular subject matter as a rule and he does not intend to search in a great number of servers for that purpose. The news agency described above will not be able to help him in every case, because it does not make sense to announce each and every Web page. For that reason local information shall be arranged into collections of the same type, which are searchable by database means, and it shall be structured and classified into a manifold of hierarchic stages. These “vertical” information hierarchies shall be net-shaped, connected “horizontally” with each other by linking collections of the same type (e.g. all the preprints, all software, all the organizational data) into a structured hierarchy of hypertexts. By this horizontal structure a user shall be capable to search “across Germany” (or across larger regions) for specific items and topics – by applying an index search or by browsing alone. Furthermore we intend to explore in which

way Internet robots and indexers can be applied, as e.g. Lycos<sup>31</sup> or Webcrawler<sup>32</sup> or the Harvest system <sup>33</sup> [BowmanDMS 95] [BowmanDHMSW 95].

A topic of immense interest for the DMV is electronic publishing in view of the deficiencies of traditional information supply. By the foundation of a universal electronic mathematical journal, the *Documenta Mathematica*<sup>34</sup>, the DMV intends to make a contribution to both closing the threatening publication gap and counteracting the cost explosion in the area of scientific journals (which at present leads to cancellations by a great number of libraries; see e.g., [WinterZ 95]). The DMV hereby also tackles the subject of quality, which is of central importance for the new electronic medium.

Mathematicians from all over the world have been discussing this matter for some time and with particular intensity, for they fear a loss of quality by the transition into the electronic world. Their concern is the reliability of mathematical literature at first, which has achieved exceptionally high standards through the years; see [Quinn 95]. The more progressive of them rather see the opportunities than the dangers, and they propose to transfer the methods to ensure quality into the electronic world, too; see [Odlyzko 95] and the materials from the Math-Net Links collection on electronic publishing<sup>35</sup> and from [FMC 94]. The *Documenta Mathematica* will be equipped with a high-ranking board of editors and peer-reviewers for that reason.

The question of quality is of central importance for the acceptance of the distributed information system, too. It will probably not make sense to aim at the extremely high standards of journals. Some kind of quality control, however, should be done. Our proposal is, to let “moderators” take care of certain “critical” collections and subject areas (like preprints of a specific set of MSC categories, or software of selected GAMS-classes). They will perform a short verification of a message sent in, just before it is distributed and archived.

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<sup>31</sup><http://lycos.cs.cmu.edu/>

<sup>32</sup><http://webcrawler.com/>

<sup>33</sup><http://harvest.cs.colorado.edu/>

<sup>34</sup><http://www.mathematik.uni-bielefeld.de/DMV-J/> - Documenta Mathematica of the DMV

<sup>35</sup><http://elib.zib-berlin.de:88/Math-Net/Links/math-epubl.html>

# Literature

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