A Guide to Available Mathematical Software

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We have come to rely on a wide variety of tools to help us mine large research libraries for useful nuggets of information. Among these tools are cross-indexes such as the card catalog, Mathematical Reviews, Current Index to Statistics, the ACM Guide to Computing Literature, Science Citation Index, and the various classification systems upon which these are based. Today we are seeing explosive growth of the so-called information super-highway, a network-based resource whose size and complexity will far surpass any existing library. In spite of this, the networks still lack many of the navigational aids common in library settings.

As a concrete example, consider an average computer user searching for software for solving a Sturm-Liouville eigenvalue problem. A number of good software packages exist for solving problems like this. They might be installed in commercial libraries setup for use at a local computing site, or they might be research-grade public-domain packages available for downloading on the Internet. (Network-based distribution of such mathematical software was pioneered by the *netlib* project [4], and today there are substantial collections accessible in this way.) Unfortunately, our user has a difficult time dealing with this bounty. Even with the knowledge of where and how to traverse the labyrinthine computer network to a software repository, it is still a tedious and error-prone process to determine what is actually applicable to the problem at hand. Each repository may have a different access mechanism and directory services are usually primitive at best. Our user would be greatly helped by an easily accessible centralized information resource (i.e., a cross-index) with problem-oriented directory services, and facilities to retrieve software and related items once they are located. Fortunately, systems with these characteristics are beginning to emerge.

Math software cross-index

The Guide to Available Mathematical Software (GAMS) is one such service. GAMS currently contains information on some 9000 problem-solving software modules from about 80 packages distributed over four physically distributed software repositories (three at NIST, and *netlib*). The system supports search for software by problem classification, keyword, or name, as well as retrieval of items such as abstracts, documentation, examples and source code. (Some 32,000 objects can be retrieved in this way.)

GAMS performs the function of an inter-repository and inter-package cross-index, as well as the functions of a repository itself (i.e., retrieval). However, instead of maintaining the cataloged software itself, GAMS provides transparent access to multiple repositories managed by others. We use the term *virtual repository* to describe such a system.

The GAMS project started in the early

80's as an effort to catalog software supported for use on NIST's central computing facility (several printed catalogs were produced, the last in 1990). As a result, both public domain and commercial software was cataloged. Although the scope of the system has broadened, we continue to index commercial software in use at NIST. GAMS does not redistribute the source code for commercial software; however, items such as documentation and example programs are often available thanks to the support of vendors such as Visual Numerics, NAG, and Cray Research.

Public use of GAMS is now being supported by NIST to demonstrate the possibilities afforded by community resources of this type. This service was officially announced to the public in the spring of 1994, and since then it has seen roughly 2800 uses each month. (See sidebar.)

An important feature of GAMS is a taxonomy of mathematical and statistical problems which is used to classify software. The GAMS problem classification system [2] [3] is a 736-node tree-structured taxonomy extending to seven levels (see Figure 1). This taxonomy has been adopted for use by many library developers and scientific computing centers (see, e.g., [5] [7] [6]). Each software module within GAMS is assigned one or more problem classifications. The taxonomy can then be used as a rudimentary decision tree to help focus in on a group of software modules for a particular problem.

We also maintain a thesaurus of mathematical terminology. These terms are mapped to the problem taxonomy, allowing one to translate alternate terminology into that used by the taxonomy. This provides the basis for keyword searching in GAMS.

Another useful concept supported by GAMS is that of *filters*. With more than 9000 problem-solving software modules classified by a 736-node taxonomy one expects many classes to be populated by a large number of modules, and hence even plowing through the modules in a single class can often be a chore. Filters allow users to specify their preference in a number of areas : language (e.g., Fortran, C), precision (e.g., single, double, multiple), access (e.g., free, proprietary), package, and repository. When browsing a particular problem class, GAMS only presents modules that satisfy the current filters.

Architecture

The GAMS system is based on a client-server architecture; see Figure 2. The GAMS server runs continuously at NIST, listening for TCP/IP-based socket connections from remote clients. When a client connects to the server, it uses a simple ASCII protocol (*gamsp*) to request and receive information from the server. The interactions are at a fairly high level, corresponding to queries like the following : *What classes are related to the keyword "regression"? What are the subclasses of class D2? What modules are classified at class D2a1? What are the retrievable components of module 7754? Send Source of module 7754.* Recently, some 30,000 transactions of this type have been processed per month.

The server has a small database that contains items such as module and package names, brief descriptions, classifications, and other data. In addition, it knows what retrievable components are associated with each module and package, and how to retrieve them from external repositories. When asked by a client to retrieve a component, the GAMS server connects to the external repository in real time (i.e., it becomes a client also), downloads the

How to Use GAMS

Local clients. The GAMS Unix clients (*gams* and *xgams*) can be obtained by anonymous FTP from enh.nist.gov (129.6.16.1) in the directory [GAMS].

Guest login. Guest logins are available for those who wish to try out the GAMS clients. To do this, telnet to gams.nist.gov (129.6.80.11) and log in as user gams (for the command line interface) or xgams (for the X windows interface).

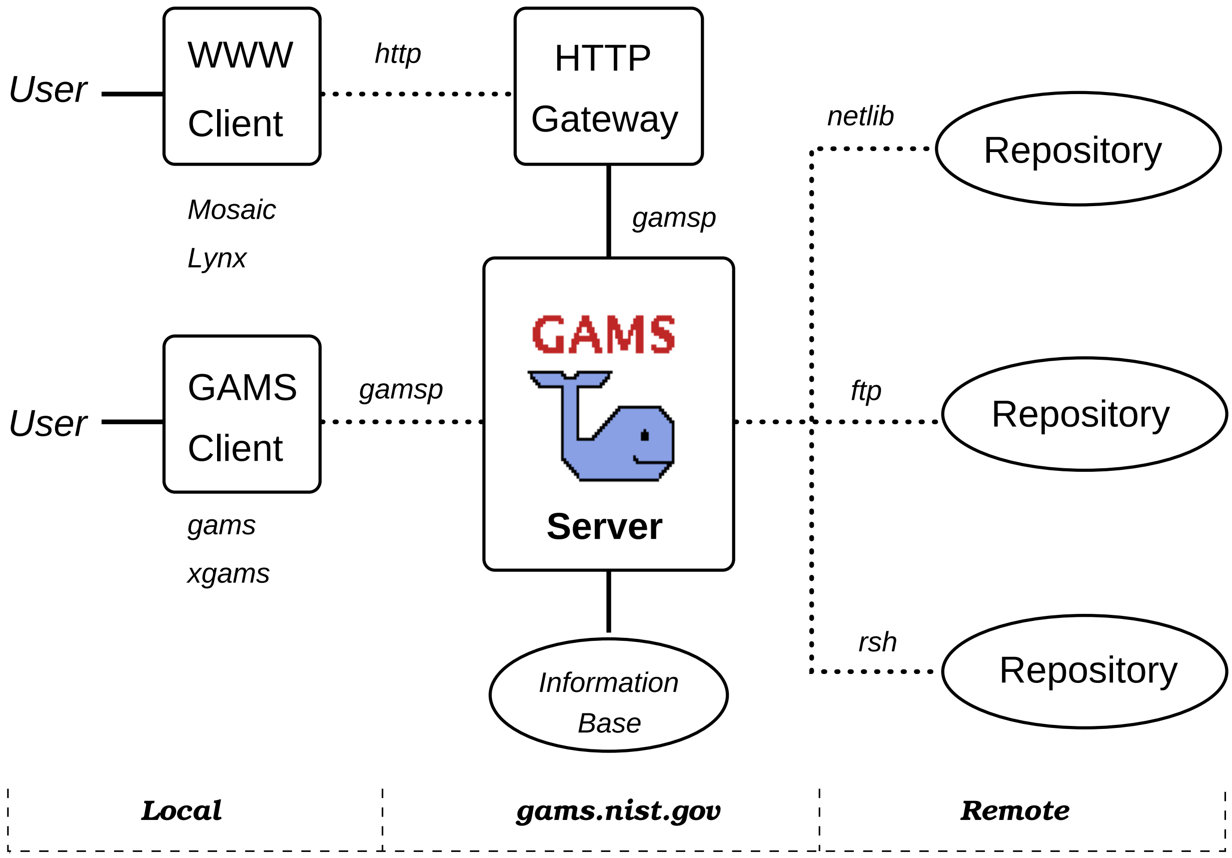
Gopher. A gopher gateway to the GAMS guest logins is provided on gams.nist.gov.

World Wide Web. GAMS can be accessed by World Wide Web browsers like Mosaic or Lynx by specifying the URL http://gams.nist.gov/. Mosaic can be obtained by anonymous FTP from ftp.ncsa.uiuc.edu.

Figure 1: Topmost level of the taxonomy, with problem F expanded.

A.	Arithmetic, Error Analysis	G.	Optimization
B.	Number Theory	H.	Differentiation, Integration
C.	Elementary and Special Functions	I.	Differential and Integral Equations
D.	Linear Algebra	J.	Integral Transforms
E.	Interpolation	K.	Approximation
		L.	Statistics, probability
F.	Solution of Nonlinear Equations	M.	Simulation, stochastic modeling
F1.	Single equation	N.	Data handling
F1a.	Polynomial	O.	Symbolic computation
F1a1.	Real coefficients	P.	Computational geometry
F1a2.	Complex coefficients	Q.	Graphics
F1b.	Nonpolynomial	R.	Service routines
F2.	System of equations	S.	Software development tools
F3.	Service routines	Z.	Other

Figure 2: The architecture of the GAMS system.



requested object, and forwards it to the GAMS client.

The GAMS clients manage the interface with the user, connecting to the GAMS server to obtain data as needed. Several such clients, including a simple command-line client (*gams*) and an Motif-based X windows graphical user interface (*xgams*), have been developed for use on Unix systems. Recently a World Wide Web gateway to the GAMS server was developed, which means that popular Web browsers like Mosaic and Lynx can also be used to access GAMS. This provides a means of access for PC and Macintosh users.

The future

The next step for systems like GAMS is to provide expert-level advice on software selection, and within the context of GAMS we are concentrating on more intelligent schemes for selecting software in a given class. To do this we are focusing on extensions to the filtering mechanism that support both simple knowledge representations and effective user interactions [1].

We are also beginning work on a substantial revision to the GAMS problem classification system. Much of the current taxonomy is more than 10 years old, and the emergence of software for new problems, the accumulated experience of using the system, and our expert advisory system goals all provide compelling reasons to start anew. We are very interested in having experts in mathematical and statistical software in a variety of subdomains involved in this project. Please contact us if you are interested!

Although we expect that it will be a much slower evolution than one might expect from recent media hype, we believe that experiences in the research sector with systems like GAMS demonstrate that the information superhighway indeed provides a promising means of disseminating useful information that can increase the productivity of its users.

References

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[4] J. J. Dongarra and E. Grosse. Distribution of mathematical software via electonic mail. *Comm. ACM*, 30:403–407, 1987.

[5] eLib is the electronic library of the Konrad-Zuse-Zentrum fuer Informationstechnik Berlin (ZIB). To use eLib, telnet to elib.zib-berlin.de (130.73.108.11) and login as user elib. eLib can also be reached via the ZIB Web page at URL http://elib.zib-berlin.de/.

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