SOLSTICE:

AN ELECTRONIC JOURNAL OF GEOGRAPHY AND MATHEMATICS

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IMaGe

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The purpose of *Solstice* is to promote interaction between geography and mathematics. Articles in which elements of one discipline are used to shed light on the other are particularly sought. Also welcome, are original contributions that are purely geographical or purely mathematical. These may be prefaced (by editor or author) with commentary suggesting directions that might lead toward the desired interaction. Individuals wishing to submit articles, either short or full– length, as well as contributions for regular features, should send them, in triplicate, directly to the Editor–in–Chief. Contributed articles will be refereed by geographers and/or mathematicians. Invited articles will be screened by suitable members of the editorial board. IMaGe is open to having authors suggest, and furnish material for, new regular features.

The opinions expressed are those of the authors, alone, and the authors alone are responsible for the accuracy of the facts in the articles.

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Suggested form for citation. If standard referencing to the hardcopy in the IMaGe Monograph Series is not used (although we suggest that reference to that hardcopy be included along with reference to the e-mailed copy from which the hard copy is produced), then we suggest the following format for citation of the electronic copy. Article, author, publisher (IMaGe) – all the usual–plus a notation as to the time marked electronically, by the process of transmission, at the top of the recipients copy. Note when it was sent from Ann Arbor (date and time to the second) and when you received it (date and time to the second) and the field characters covered by the article (for example FC=21345 to FC=37462).

This document is produced using the typesetting program, TEX, of Donald Knuth and the American Mathematical Society. Notation in the electronic file is in accordance with that of Knuth's *The TEXbook*. The program is downloaded for hard copy for on The University of Michigan's Xerox 9700 laser- printing Xerox machine, using IMaGe's commercial account with that University.

Unless otherwise noted, all regular "features" are written by the Editor–in–Chief.

Upon final acceptance, authors will work with IMaGe to get manuscripts into a format well–suited to the requirements of *Solstice*. Typically, this would mean that authors would submit a clean ASCII file of the manuscript, as well as hard copy, figures, and so forth (in camera–ready form). Depending on the nature of the document and on the changing technology used to produce *Solstice*, there may be other requirements as well. Currently, the text is typeset using TEX; in that way, mathematical formulæ can be transmitted as ASCII files and downloaded faithfully and printed out. The reader inexperienced in the use of TEX should note that this is not a "what–you–see–is–what–you–get" display; however, we hope that such readers find TEX easier to learn after exposure to *Solstice*'s e-files written using TEX!

Copyright will be taken out in the name of the Institute of Mathematical Geography, and authors are required to transfer copyright to IMaGe as a condition of publication. There are no page charges; authors will be given permission to make reprints from the electronic file, or to have IMaGe make a single master reprint for a nominal fee dependent on manuscript length. Hard copy of *Solstice* is available at a cost of $15.95 per year (plus shipping and handling; hard copy is issued once yearly, in the Monograph series of the Institute of Mathematical Geography. Order directly from IMaGe. It is the desire of IMaGe to offer electronic copies to interested parties for free. Whether or not it will be feasible to continue distributing complimentary electronic files remains to be seen. Presently *Solstice* is funded by IMaGe and by a generous donation of computer time from a member of the Editorial Board. Thank you for participating in this project focusing on environmentally-sensitive publishing.

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TABLE OF CONTENT

1. WELCOME TO NEW READERS

Welcome to new subscribers! We hope you enjoy participating in this means of journal distribution. Instructions for downloading the typesetting have been repeated in this issue, near the end. They are specific to the TEX installation at The University of Michigan, but apparently they have been helpful in suggesting to others the sorts of commands that might be used on their own particular mainframe installation of TEX. New subscribers might wish to note that the electronic files are typeset files—the mathematical notation will print out as typeset notation. For example,

$$\Sigma_{i=1}^{n}$$

when properly downloaded, will print out a typeset summation as i goes from one to n, as a centered display on the page. Complex notation is no barrier to this form of journal production.

Many thanks to the members of the Editorial Board of *Solstice*. Some of them have refereed articles and offered suggestions, as have others. Thanks to all.

2. PRESS CLIPPINGS—SUMMARY

Brief write-ups about *Solstice* have appeared in the following publications:

1. **Science**, "Online Journals" Briefings. [by Joseph Palca] 29 November 1991. Vol. 254.

2. **Science News**, "Math for all seasons" by Ivars Peterson, January 25, 1992, Vol. 141, No. 4.

3. **Newsletter of the Association of American Geographers**, June, 1992.

4. **American Mathematical Monthly**, "Telegraphic Reviews" — mentioned as "one of the World's first electronic journals using TEX," September, 1992.

5. **Harvard Technology Window**, 1993.

6. **Graduating Engineering Magazine**, 1993.

If you have read about *Solstice* elsewhere, please let us know the correct citations (and add to those above). Thanks.

3. GOINGS ON ABOUT ANN ARBOR

1. ESRI, negotiating with IMaGe, has agreed to give a University Lab Kit to the University of Michigan, to be housed in the School of Education. All here are very happy and thank ESRI for their generosity. We look forward to pursuing the research projects that we explained to ESRI. Bob Austin, Sandy Arlinghaus, John Nystuen, Fred Goodman, and Bill Drake were all involved in various aspects of developing research and educational projects.

2. In the Fall of 1992, Bill Drake taught a course in "Transition Theory" (and invited Sandy Arlinghaus to co-teach it) in the School of Natural Resources and the Environment. It was quite popular, and this course that was experimental in nature in 1992-93 has just become part of the permanent graduate curriculum. A monograph written primarily by the students, and published by SNR and E, came from that course.

3. Book co-edited and co-authored by Bill Drake. *Population — Environment Dynamics*, edited by Gayl D. Ness, William D. Drake, and Steven R. Brechin, Ann Arbor: The University of Michigan Press, 1993.

This book has 15 chapters organized into four sections plus a final section "Summary, conclusions, and next steps" by the editors. It also has a Reference listing, information about the contributing authors, and an index. The book is 456 pages and costs $45. The titles of the four dominant sections are:

Global Perspectives: History, Ideas, Sectoral Changes, and Theories.

The State as Actor: Population — Environment Dynamics in Large Collectivities.

The State as Environment: Population — Environment Dynamics in Small Communities.

Emergent Ideas: Theory and Method.

4. Fred Goodman of the School of Education has been very helpful in finding space and resources so that IMaGe can give the software it's trying to line up to UM. Fred has been instrumental in providing constructive, diplomatic liason with other units within UM. We also welcome Fred to the *Solstice* Board with this issue.

4. ARTICLES

ELECTRONIC JOURNALS: OBSERVATIONS BASED ON ACTUAL TRIALS, 1987-PRESENT

Sandra L. Arlinghaus and Richard H. Zander.*

ABSTRACT

Electronic journals offer a 21st-century forum for the interchange of scholarly ideas. They are inexpensive, fast, easy to store, easy to search, and they have long-term archivability; these advantages easily justify the time spent learning to deal with the new technology. The authors, both editors of nationally-noted electronic journals, share with others their interdisciplinary experiences in dealing with this new medium for producing online, refereed journals.

During the past six years each of us has created and edited a successful electronic journal (E-journal) in our respective fields of geography (*Solstice: An Electronic Journal of Geography and Mathematics* first appeared in June of 1990) (Palca 1991; Peterson 1992) and botany (*Flora Online* first appeared in January of 1987) (Palca 1991). Both journals are peer-reviewed; both are available, free, over standard computer networks; and, both have editors who served as authors in early issues–to get the journal off the ground. E-journals provide an opportunity to share computerized information with others in an orderly and responsible fashion, within the context of current technology. They offer:

1. An inexpensive way to share information, quickly, with a large number of individuals;

   a. As direct, online, transmissions from editor to individual; in this case, the transmission should be free of charge, in much the way that a library card is free of charge. The editor/publisher bears the cost of journal creation and manufacture; the reader bears the cost of maintaining on online mail box;

   b. As direct transmissions to libraries – libraries should pay for diskettes, hard copy, online transmission, or whatever they desire. The cost to the library is generally greatly reduced from that of conventional journals, thereby freeing library funds for other useful projects. Funds generated from this source may make the E-journal(s) self-sustaining;

   c. As posted "messages" on an electronic bulletin board or files on an "anonymous FTP" server. The reader bears the cost of accessing the board or server and downloading the article.

2. When E-journals are highly specialized, they can serve as a more formal alternative to large (archived) data banks in the natural sciences and elsewhere. Indeed, when the E-journal is downloaded into a wordprocessor or a data manager, the content can be manipulated and edited carefully to fit the research needs of the individual user.

There are many systematic electronic communications already available and there are apparently more in the planning stages. The first edition of Michael Strangelove's "Directory of Electronic Journals and Newsletters" (1991) catalogues about 30 journals and over 60 newsletters. Major academic societies, notably the American Mathematical Society and the

American Association for the Advancement of Science, have announced far-reaching plans to produce other electronic journals; (Janusz 1991; Palca, 1991: 1480). A glance at a flyer for the Annual Meeting for the Society for Scholarly Publishing (July 1992) suggests that more than half of the four-day meetings will be devoted to issues related to electronic publication.

There are:

1. "Genuine" electronic journals.
2. Mere computerized versions of hardcopy titles.
3. Non-archived electronic databases that are not really citable in a scientific paper since the data used may have been changed or may no longer be available, even though these databases may be copyrighted.

What makes a systematic electronic communication a "journal" is a difficult issue (Nicholson 1992); concern for rigid, *a priori*, definition might better be replaced with open regard for all entries and suitable concern for the broad issues of journal production. For, an E-journal is first and foremost a "journal" that has simply been **modified** as "electronic," both linguistically and technologically, by the method of its transmission and production.

Thus, we offer a generalized summary of observations that have come from six years of actual trials with *Flora Online* and three years of actual trials with *Solstice*. It is useful to separate these results into three broad categories: content issues, production issues, and archival issues.

Content issues.

The most important concern is to obtain good manuscripts. And, to be acceptable as an outlet for scholarly publication, E-journals should approximate standard formats for professional journals, have high standards of scholarship, and be refereed. It does not matter how sophisticated the technological production becomes; if the journal does not have interesting and useful material of high quality, it will fail. This point should be obvious; however, it can become obscured, particularly in light of the exciting capability of the computerized format.

Thus, author perceptions of E-journals are critical; the most serious problem involves citation. Will others see the work? Will the work be taken seriously? The following strategies help:

1. the editor should see to it that the E-journal (and when necessary hard copy derived from it) is listed, housed, or otherwise recognized in

   a. standard reviews that are specific to the discipline of the journal;

   b. the usual indexing services (publications are often judged by the bibliographic and citation services that mention them — services that accept electronic files are particularly easy to deal with);

   c. news media, including field-specific conferences and meetings as well as mass media;

   d. standard book/journal registers of documents using conventional book/journal codes (such as ISBN and ISSN); and,

   e. library archives. Libraries apparently dislike the idea of downloading journals; they appreciate diskettes mailed to them. Archiving is important for E-journals so that data can be retrieved long after publication.

2. The editor should consider the unusual to boost regard and readership for this mode of journal transmission, such as:

   a. the use of reprints (with appropriate copyright permission) of hard-to-find works of field-leaders (prospective authors—of lesser fame—usually perceive some benefit-by-association and field leaders often are interested in participating in a different venture);

   b. the use of interactive review of material — post-publication review followed by online alteration of the original document as a later version (coded appropriately–original is version 1.0 and updates carry larger numbers according to the extent of change);

   c. the use of taxonomic, bibliographic, and other data sets consisting of long lists of records that can easily be downloaded and sorted according to user need. Several agencies are preparing monolithic data banks from which scientists can extract items of information using specialized data management programs. Unfortunately, such data banks usually employ in each different management system, complex and difficult for the scientist to learn, and the data banks give second-hand data (digested by those who run the data bank and who are not necessarily scientists). With the advent, however, of electronic publishing, information in the sciences developed by individual scientists can now be easily and directly shared;

   d. the use of novel typesetting or other electronic capabilities that display the power of the vehicle of transmission (Horstmann 1991); and,

   e. the sharing of experiences in E-journal editorship with others — through professional associations directly promoting electronic journal editorship (such as an E-journal editor's association) and with other organizations indirectly promoting it (such as the TEX Users' Group; "TEX" is a trademark of The American Mathematical Society).

Readers who are initial skeptics can become more receptive when they see actual output; hence, the early need for editor to become author. To increase E-journal availability, and to convert a wide variety of skeptics, E-journals should be distributed in more than one manner (e.g. diskette, File Transfer Protocol (FTP), Bitnet, on a listserv, U.S. mail, hardcopy).

When editor becomes author, then a mechanism for review is all the more important. Pre-publication peer-review by an editorial board or by other colleagues is effective and easy to achieve electronically; post-publication feedback in an open or closed forum is also simple electronically. In addition, it is important that the editor continue to publish in various other outlets held in high regard.

There are also a number of other reasonable, but less important, concerns that authors might have. These include:

1. Manuscript security; because E-journals can be forwarded easily, alteration of original manuscripts can occur. There are a number of ways to deal with this problem:

   a. Copyright a hard copy of the original transmission (thereby placing it in the Library of Congress);

   b. Advertise that the original computerized version or a hard copy of the original transmission is available (on-demand) to those wishing it–including libraries;

   c. Store single hard copies in selected libraries (including that of the author's institution);

   d. Transmit E-copies directly from editor to individuals, over standard electronic networks, using an electronic distribution list automatically marked with the sender's name and time;

e. Download from an electronic bulletin board. A persistent worry here is that a file made available for downloading is not "published" in the sense of being distributed. This worry underscores, again, the need for adequate reviewing and indexing of the document. However, the prospective author should note that a file made available for downloading is in fact published because

i. this is the same way hardcopy books are published — they are simply advertised as available for purchase, and

ii. in bibliographic research, the date of publication is the date advertised as available, since it is impossible to track down the date of first purchase or first mailing of the book.

f. Copy-protect diskettes (using some sort of seal unique to the journal) to prevent unthinking abuse.

2. Virus and other crank programming prevention. Downloaded FTP or regular phone modem files from other computers can spread electronic viruses if they are "executable," and only if they are actually run as programs. Downloaded text files cannot spread viruses: downloaded executable files (.EXE, .COM in MS-DOS) can be examined by commercial programs for viruses before they are run. When the E-journal is made available through a network server, the E-journal's health is simply transferred elsewhere; the network supervisor has considerable responsibility in this regard. Of course, good backup habits and a procedure in place for dealing with viruses if they happen are a must in all workplaces that use programs obtained from outside the workplace.

Production issues.

Production issues generally appear to fall into one of two categories: Document manufacture and editing, and transmission. Warehousing is not an issue of any significance, nor is the sort of marketing that requires a network of publishers' representatives to sell hardcopy documents.

Document manufacture and editing.

The manufacture involves creating, or being supplied, electronic files. Editing at this stage in journal computerization generally requires in-house manufacture and distribution of files and their media. It is useful to aim for the lowest common denominator: currently, that means ASCII text and .GIF or .PCX graphics files if needed — such files are easily read on a IBM PC clone, a Mackintosh, or Unix machine (Xwindows or whatever), by any wordprocessor and most graphic file viewers. It would be nice if the files could be set up with the format of one of the new GUI wordprocessors (e.g. WordPerfect, MSWord) but it seems prudent to wait until a multiplatform wordprocessor that creates text files incorporating graphics images becomes commonly used. Most prospective authors can provide "manufacture-ready" copy in the form of an ASCII file sent over the e-mail or provided on diskette. Indeed, for MS-DOS environments DCA or RTF (Document Content Architecture or Rich Text Format) are also standard file formats retaining formatting commands; these may be used to transfer a formatted text to any of most commercially available major word processors. It is thus an easy matter to ship the E-file to referees and to provide authors with E-proof to check prior to final production.

There are a number of issues, found also in conventional publishing, that remain difficult. For this reason (also), it is useful for editors to be experienced as authors of conventional articles; it is additionally desirable for them to have had editorial experience in dealing with a conventional publisher.

1. When the ASCII file is typeset using TEX, mathematical notation, tables, and figures that are rectilinear in shape are easy to handle: otherwise, complex mathematical notation is difficult even to approximate in ASCII. The typeset TEX file is itself an ASCII file with ASCII formatting commands, and so can be transmitted easily.

   a. The computerized typeset TEX file is not strictly "what-you- see-is-what-you-get"; however, the file is of traditional quality typesetting, and the file of electronic text and notation can now be downloaded and cheaply typeset or printed in hard copy by the journal receiver at his or her expense. To typeset the file, the receiver must first convert the transmitted TEX file to a .DVI file and then print it on any available downloading device (such as a Xerox 9700 series machine or an APS phototypesetter).

   b. The receiver can view the transmitted TEX file on screen (with the TEX commands visible). The editor can right-justify the TEX file in a word processor (prior to transmission), and bitstrip it to retain it as an ASCII file, in order to produce a journal-like electronic page in the transmitted E-file without interfering with (or influencing) the typesetting of the hardcopy. Right-justified electronic copy tends to reduce the visual impact of the unnatural looking typesetting commands that appear in the TEX file as it is viewed online.

   c. TEX produces device independent files; however, because different installations of TEX support different features it is good, at present at least, to keep the typesetting simple. To this end, the editor should consider supplying a set of TEX macros to authors wishing to do their own typesetting using TEX; these can be supplied over the electronic mail in much the way that the American Mathematical Society encourages the submission of abstracts for its meetings.

   d. Not all individuals have access to TEX even though their university has it; individuals in mathematics departments generally do have access to it and know how to use it.

   e. Figures, charts, and tables that can be considered as a matrix (such as a crossword puzzle) can be typeset using TEX. Maps and non-rectilinear figures generally cannot.

   f. One approach to dealing with figures, that works easily, is to scan complicated maps and figures and to incorporate the scanned file into any distributed hardcopy by electronic cutting and pasting. The Xerox DocuTech stores scanned images as electronic files on a hard disk and permits such electronic editing. Hardcopy, complete with figures, can be produced in an on-demand fashion for sale to standing orders and to others who inquire. Warehousing is thus converted to a "just-in-time" approach requiring virtually no extra space or cost. Hard copies can then be made available in a variety of bindings.

   g. If the scanned electronic files are downloaded as part of a text file, then the reader's electronic cutting and pasting is unnecessary. The capability of future word processors holds the answer to the possibility of shipping mathematical notation, maps, and photos in a single easy-to-read, typeset, transmission.

   h. Graphics transmission can be executed immediately by making available for distribution binary files of graphics images on an Internet server for downloading via FTP (File

Transfer Protocol) or from a standard bulletin board.

i. Yet another approach to the graphics issue might involve linkage to a Geographic Information System to provide a procedure for creating compatible transmittable map files directly from data managers into a TEX-ed file. Data files are likely to be quite large; compressed files should be used with instructions for decompression and recompression provided online in "help files."

2. As above, TEX can be used to create an ASCII file that is typeset, including diacritical marks. If, however, the editor chooses not to use TEX, publishers can convert the formatting codes of other software such as Microsoft Word, XyWrite (Signature), and other robust word processors. If straight ASCII, perhaps employing the upper IBM ASCII set whenever diacritical marks are important, is used to transmit the electronic files, then another set of issues, some similar to and some different from using TEX, confront the editor.

a. At present it is important never to right-justify straight ASCII files. Right-justified text introduces extra spaces in word processors that produce straight ASCII files. To mend this, users must do a number of search-and-replaces, replacing double spaces with single spaces. They need to do this to make the text look like their own text so they can add items from a bibliography to their own bibliographies or add to other downloaded lists of subjects that are searchable with a word processor or data manager.

b. Data-intensive text files, either those for which it is difficult to find a publisher in hardcopy or, in particular, those that are suited to searching and other computer text manipulation (such as bibliographies or checklists), are well-suited to journals employing the straight ASCII format. Data files take two forms: article format, similar to paper publications – searchable with a standard word processor or with "text management" software, and, data base format, appropriate for importing into a standard data base manager. The latter should have data presented with an equal number of lines per record and information entered on the appropriate line for each field, or in another "delimited" format.

c. Large text files should be divided into smaller files each less than 300 kb in size. These can be uploaded as is, or first converted into smaller compressed (e.g., .ARC, .ZIP, or .LZH) files. Split text files can be downloaded and reconnected (through DOS copy command) by the user. Very large files may, for now, be more appropriately distributed on disk.

d. Foreign language characters, symbols, and graphics. Authors should expect that downloaders will generally use 8 data bits and an error-checking protocol, so binary files and text files with the IBM upper ASCII character set (foreign and special characters and graphics) can be easily transmitted. If the text is prepared in something other than a MS-DOS, pure ASCII environment (non-ASCII texts are created by many word processors), authors need to remove all software-specific formatting codes and type-style codes, before uploading. These can, however, be suggested — underlining codes, for example, might be represented by symbols like @ or | so downloaders can re-underline through search-and-replace.

Users of operating systems other than MS-DOS generally do not have access to the upper IBM ASCII set, which has foreign characters and symbols such as the degree sign

(°) and simple graphics. Also, because all users may not have MS-DOS microcomputers or compatibles, some authors may wish to substitute special codes for the IBM upper ASCII set used in MS-DOS. It is recommended that instructions for translating (by search and replace) the codes into the actual character be given at the beginning of the publication. Any system can be used; however, a simple system, which can be easily interpreted even before translation and may be easily used by non-MS-DOS systems, is the "backspace and overstrike" method: many foreign characters may be easily manufactured by causing the printer to backspace and overstrike a diacritical mark. Since some wordprocessors cannot deal with the ASCII backspace character (ASCII 8), substituting an unused lower ASCII character such as @ or | for the backspace character will allow search and replace for (1) the backspace character itself, (2) for an acceptable printer code substitute for it, or (3) replacement of the three characters with an IBM upper ASCII character. Examples of backspace substitution: a|' = à ; A|o = Å, u|" = ü; and of direct substitution: deg. = °, u = μ (search for space-u-space and replace with μ). Graphics characters have little utility and cannot easily be coded for non-MS-DOS standard machines, so it is recommended that these be restricted to special applications.

There are a number of efforts at an enlarged ASCII set for foreign languages (Hayes 1992). The coming of Unicode or something similar will hopefully provide a complete set of multiplatform foreign characters.

e. In bibliographies, spell out all duplicate author's names (do not use a sequence of hyphens.) so that the author's names can be searched for. Begin each entry flush left and leave an empty line (two hard rights) between each entry.

f. Do not spell any words with all capital letters (this may make it difficult to search for them; it also looks bad).

g. If appropriate, present files in a "squeezed" form as an .ARC file or .ZIP or another 'archiving' utility file format. This allows faster and less costly downloading and keeps diskette files small.

3. File management seems to be relatively easy with an E-journal. Keeping track of manuscripts, and of who is refereeing them, and of their stage in the production process, is made simpler by the technology.

Transmission.

E-journals should have standard, and thus easy-to-use, modes of access. They should be transferable across different systems (e.g. various micro, mini and mainframe platforms). Alphabets should be standard (ASCII, ISO Superalphabet eventually) in order to be available to a wide number of users. Transmission can occur in a number of different ways and have various uses.

1. Issues may be obtained by "anonymous FTP" or downloaded via regular telephone lines by modem from an electronic bulletin board. An electronic bulletin board system is a computer and software system that can be accessed from outside by a caller, who likely has a number of options, including perhaps:

   a. Reading or leaving messages. These are typed while online and may be public or private (readable only by the addressee).

   b. Depositing or taking away data or text files. These are created with a word processor or data manager previous to calling and are "up-" or "down-loaded" as a unit.

c. Extracting information from a large data file. Authors can prepare compiliative publications that they use personally and wish to share. Then they may, if they wish, maintain the publications informally or formally as a series of versions in online data banks. Users of the bulletin board download online files, and use the files directly for searching for particular data or by copying portions to enlarge their own personal files, with due respect, of course, for copyright privileges of the original author.

2. A bulletin board can be of interest to scholars in the following ways:

   a. Messages - For exchange of ideas and information. Speed of contact is far greater than with regular mail. Special "Conference" sections allow public exchanges on single scientific topics that are equivalent to symposia at national meetings.

   b. Files — Electronic publications that may be cited in an author's curriculum vita. Such publications should be copyrighted. These include: original text material and computer programs; text or data files of an ephemeral or informal nature; and, previously published computer programs (of "reprint" value). With the eventual realization of a network of bulletin boards across the country, this method of transmission holds considerable promise.

3. Ship the E-journal across Bitnet or Internet to a distribution list of subscribers who ask to have the E-journal mailed to them. Some installations do not have the capacity to send files in excess of 25,000 characters. In that case, split the journal apart with instructions to the user to concatenate the files prior to downloading, printing, or typesetting.

Archival issues.

All journals are useful only for as long as they can be located in the holdings of some institution. As technological formats for producing journals change, it will be important to keep not only the new, but also the old — as back-up with a known life-span. Some of the issues that will confront archivists include those listed below.

1. Availability — the E-journal should be archived indefinitely in an institution willing to provide copies or the equivalent on request.
2. Durability — Archives should be maintained so as not to degrade with time, e.g. contents of diskette transferred to hard disk, then to optical disk, then to solid state or whatever future technology provides. Duplicates stored off-site, and EMF protection are also advisable in the long-term. Paper burns and degrades with age, but magnetic images can be maintained indefinitely if copied periodically onto new media (diskettes are said to have a maximum data retention life of 10-15 years).
3. Retrievability and salvageability - Standard operating system formats should be changed in a timely fashion: MS-DOS to Unix, etc. Standard word processing formats should be upgraded so they can be read decades hence. Database formats should be standard or also available in ASCII-delimited format. Any required programs (decompression programs, graphics viewing programs, special word processors) should be archived, too, along with necessary hardware platforms.

We have found that editorial and publishing problems can be overcome within the limits of existing technology such that electronic journals can be successful in transmitting and presenting information to scholarly readers. We foresee a significant upgrade in quality and flexibility of electronic presentations with the advent of standard cross-platform graphics-capable word processors, standard export-import formats, and standard multi-language character sets. The advantages of electronic publication: inexpensive, fast, easy to store, easy to search, long-term archivability, easily justify the time spent learning to deal with the new technology.

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WILDERNESS AS PLACE

John D. Nystuen *

Some conflicts are the result of people talking at cross purposes because they interpret identical empirical data in quite different ways. These differences can arise from deep seated differences in belief systems or from the knowledge systems (theories) applied to understanding a phenomenon. The conflict over the meaning of wilderness is an example.

Visual Paradoxes

The biologist Richard Dawkins in his book *The Extended Phenotype* uses the analogy of the Necker Cube (Louis Albert Necker, 1832) to illustrate the fact that the same empirical evidence can be interpreted in two or more perfectly accurate ways, each of which is valid but incompatible with the other. The Necker Cube is a visual paradox in which the mind perceives a flat plane drawing as a three dimensional transparent cube in which the orientation of the cube is arbitrary (Figure 1). At one moment it appears to be viewed from above but as one stares at it, a reversal occurs and in the next moment it seems to be viewed from below. The visual paradox arises when full information is available. Partial knowledge seems to favor one view or the other.

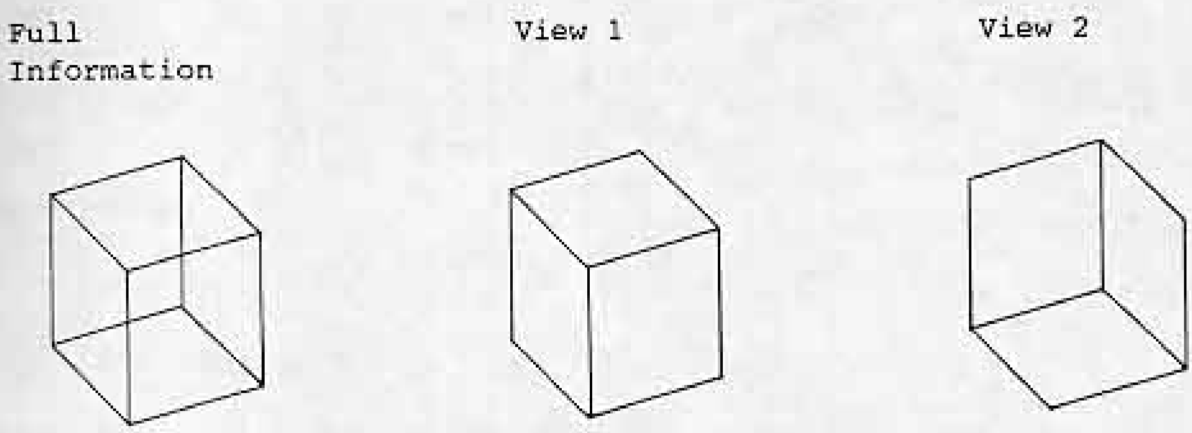

Figure 1. Necker Cube. A sequence of three cubes shown as line drawings. The reader unfamiliar with Necker's Cube would be well-advised to reconstruct this figure. The left hand cube is one with all edges showing; the center cube has three edges hidden so that it appears the reader is looking down at the cube from above; and, the right cube has three edges hidden so that it appears that the reader is looking up at the cube from below.

An additional set of views is available — that of a two dimensional plane figure which, of course, is what the drawings are. This set of views may become dominant by rotating the cube so that the many symmetries of the cube are emphasized (Figure 2).

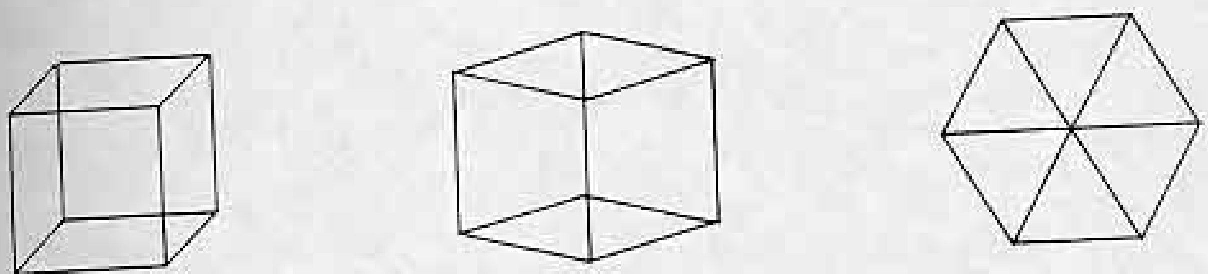

Figure 2. Views Along Axes of Symmetry of a Cube. This figure is also a sequence of three views of cubes shown as line drawings. The left cube is a full- information cube (no hidden edges) seen head-on, with a face of the cube closest to the face of the reader. The center cube is a cube with all edges showing viewed head -on with an edge closest to the reader so that the prominent edge, and the diametrically opposed edge appear to coincide for part of their length. The right cube is a view of the cube with one corner closest to the reader so that the plane view of the cube appears as a hexagon with three diameters.

Another well-known visual paradox, face/vase, was introduced by Edgar Rubin in 1915 (Figure 3). In this example additional knowledge seems to resolve the paradox — as a simple white, classical vase against a black background, both vase and profiles of faces at either side are evident. If baseball caps are put on the profiles, the faces dominate; if, instead, flowers are drawn in the vase, then the vase dominates.

Usually one has to plan how to seek additional knowledge about a problem. If only a certain type of knowledge is pursued because that is the way the problem is interpreted, then one view will likely prevail. If only economic evidence is admitted for consideration (for example), other views, other values, may remain invisible.

Past experience may bias one's interpretation beyond what seems reasonable to others with different points of view. Gerald Fisher's (1967) man-girl paradox is a sequence of eight progressively modified drawings — from man to nymph-like girl (Figure 4). The fourth drawing in the sequence was found upon empirical testing to have equal probability of being seen as a man's face or a girl's figure. However, by viewing the sequence successively from the top left to the bottom right one can maintain a bias towards seeing the man's face almost to the last drawing. There, only a faint, melting ghost of a face remains to be seen, if seen at all. The opposite is true if one starts with the girl's figure and moves in the reverse direction.

Wilderness Defined

The value of wilderness to society resembles a Necker Cube paradox. People of goodwill see the same empirical evidence in very different lights. The dominant American view of the environment is utilitarian and anthropocentric. The environment is for humans to use.

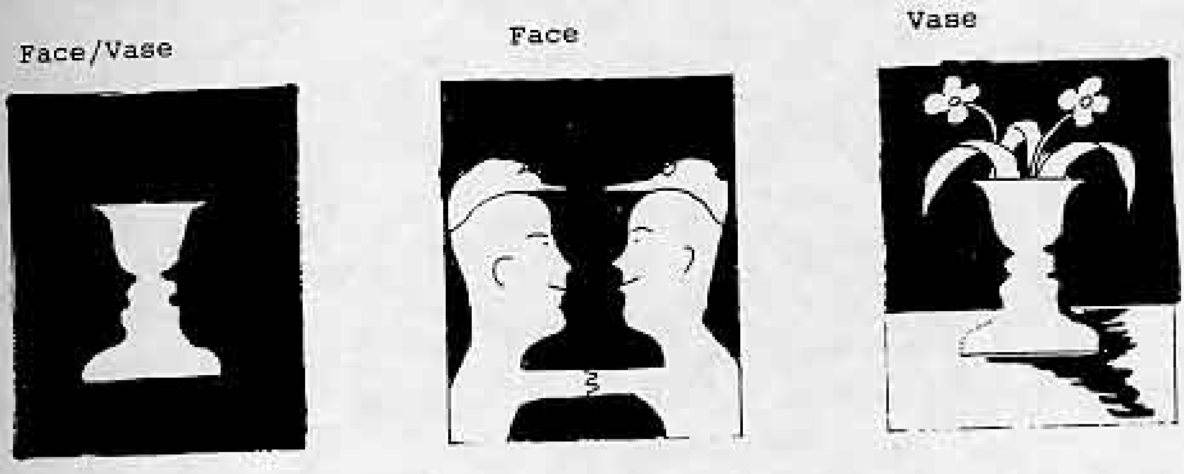

Figure 3. Face/vase paradox.

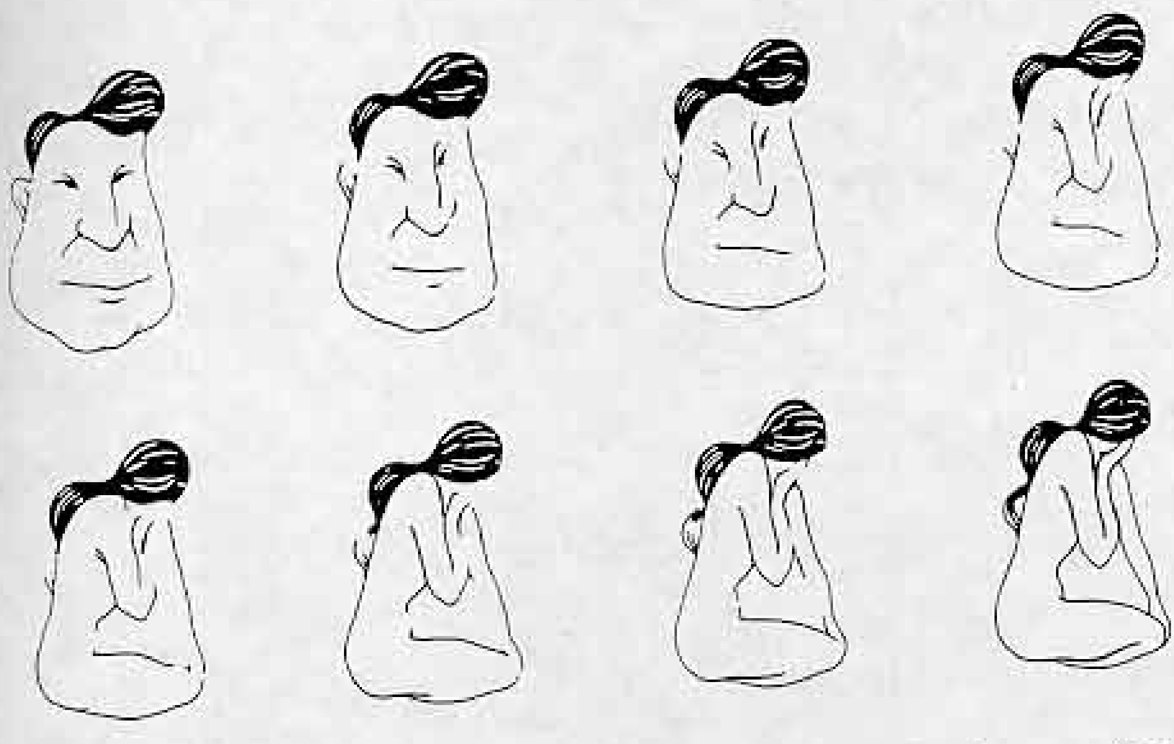

Figure 4. Man-Girl. Shows a sequence of eight line drawings–transforming a man's face to the profile of a girl's body.

Natural resources are cultural appraisals, more a matter of society than of nature. For something to be a resource we must want to use it, know how to do so, have the power to do so, and be entitled to do so. Nature offers only the opportunity for use.

A biocentric ethic imbues nature with intrinsic values independent of mankind. We are part of nature, not apart from it. In an anthropocentric view we are distinguished and especially favored by God. In a biocentric view all creatures, large and small, and plants too, have a right to exist. Most Native American cultures held to this belief. They apologized to their fellow life forms when consuming them to meet their own needs.

In Western Society the biocentric ethic is not well understood perhaps even by many of its advocates. Preservationists focus on symbols of wilderness rather than on wilderness in its full existence. Tactical reasons motivate this approach but then frequently wilderness advocates are outmaneuvered. Do preservationists really care about the snail darter and the spotted owl? Or are these species being used as focal points to preserve entire habitats? They embody or personify concern for more abstract values. Do we really want the habitat to be *preserved* unchanged?

I recall, when visiting Disneyland, a frontier scenario of "a settler's log cabin under attack and in flames." The logs were made of cement and the flames came from gas jets — they burn eternally for the tourists, daily during open hours, season after season.

The wilderness worth saving is the biosphere process. The wilderness ethic is to let wild habitats exist where human contact is slight and/or remote (outside–backdrop). Living wild habitats change and perhaps spotted owls or other species will vanish but not as a result of direct human action. Of value are natural processes remote and indifferent to mankind. John Muir said, "In Wilderness is the Preservation of the Earth." That phrase is the motto of the Sierra Club which Muir founded in 1892. Preservation of the earth as the home of life transcends societal concerns. Beyond a species imperative, it is life imperative.

Conflict or Synthesis

M. C. Escher, the artist noted for his depictions of the complexities of time and space, transcends the choice required by the Necker Cube. He gave the object some attention in his lithograph *Belvedere* (see *The World of Escher*, p. 229). The man seated in the foreground is holding an impossible cubic object while contemplating a drawing of it on the ground in front of him. In this scene Escher provides a drawing, a hand-held model, the embodiment of the concept in the structure of the castle building.

Escher simultaneously embraces two views of the cube with a model and a construction process that can only exist in the imagination. The paradox is in the images of physical things depicted. There are no paradoxes in nature. Nature exists. Paradoxes observed in nature mean that our understanding of phenomena is inadequate. This is what drives the imagination of physicists. Theory holds that nothing can exceed the speed of light — except human imagination; light bends; space is warped; black holes exist; time flows backward; light is both wave and photon. Deeper and deeper understanding of nature incorporates these constructs of our imagination. From the beginning many predictions of quantum mechanics were viewed as very strange. Now after many decades or resisting refutation, the theory yields new results that border on the surreal: that quantum phenomena are neither waves nor particles but are intrinsically undefined until the moment they are observed (John Hortgan, 1992). Yet nature exists. The problem is our mind set, the position of our understanding.

To understand Escher's impossible cube one must take into account the position of the observer. It is like a rainbow; it exists only for those who are in the proper position to appreciate it. There is no rainbow for the people who are being rained upon.

I remember talking to a Gurung woman (the Gurung are a highland people of Nepal) who, under a government program, had migrated to a lowland farm on the Nepalese portion of the Gangetic Plain (elevation 600 feet). I asked her if she missed the mountains for I had seen the breathtaking panoramas of her homeland in the high Himalaya. She said, "What is there to miss? We have four bega of good land here and we had only one half bega of very poor land in the other place."

We do not need to be articulate or self-conscious about things essential to our being. For example, food is so fundamental to our existence that we treat it very emotionally. Reasoned discourse is not the only or even dominant basis for thinking about food or debating public policy about entitlement to food. A sense of place is as deeply held and fundamental to our existence as food. We become attached to a place to the extent that we fill the place with meaning. A personal and deep attachment is made to the place called *home*. Home is familiar, safe, restoring, and controlled territory. We fight to protect it from invasion with deep feeling and energy. We will die for it.

Wilderness is a place that is *not home* for humans. It becomes real and important only to the extent that we fill it with meaning. To give it meaning it must become foreground (subject). Mere opposites of home values do not capture the essence. Is wilderness strange, dangerous, stressful, and wild territory? Strange and wild are nice but to me stressful and dangerous are the wrong emphasis, sometimes used by organizations that are trying to build self-confidence in adolescents by thrusting them into confrontation with wilderness. Recreation hunters whose intent is to achieve a kill reveal this sort of confrontational approach to wilderness as well. I believe that wilderness should not be taken as hostile, something to overcome, but rather one should enter a wilderness prepared, take prudent action and seek to experience the strange and the wild to be found there. Admittedly, some views of wilderness are going to be incompatible. But at least hunters and preservationists have visions of the meaning of wilderness, compatible or not. Certain vantage points must be assumed or wilderness will remain invisible. An alliance to build a public edifice is conceivable that might, like Belvedere, provide positions for people to calmly gaze in different directions.

Wilderness is like a rainbow. Existence depends, in part, on the position of the viewer. Do rainbows exist? Or are they only latent until observed in some fashion or another? Are they to be valued, if so, how is value assigned? Can you own one?

Wilderness As Place

The *Bureau of Land Management* (BLM) is a federal agency that controls 179 million acres of land mostly in the western states (over nine percent of the total land area in the coterminous USA). The bureau was created in 1946 through consolidation of two federal agencies, the *Land Sales Office* and the *Grazing Service*. The bureau inherited from these prior agencies the mandate to either sell off federal land to private owners as quickly and efficiently as possible or to make federal lands available for use by private individuals through issuing grazing permits. In 1976 Congress passed the *Federal Land Policy and Management*

Act which contained a mandate to the BLM to inventory, study, and make recommendations for wilderness designations for BLM lands. The bureau was to report back its actions by 1991.

The bureau people were somewhat at a loss for words. What exactly is wilderness? Is that a place with no conceivable human use; a place nobody wants? Wouldn't it be what is left over after we do our job? Could we address this mandate simply by subtraction? The answer was no, that would not do. Wilderness did not fit into a commodity based, 'I can own it,' philosophy. How could humans manage a wilderness? What would there be to do?

The bureau people were more than a little uncomfortable with their new task. In the past two decades a sea of change has occurred on how to view the environment and the BLM has been caught in its tide. Today, environmental groups are a political force with access to agency decisions through new avenues of public participation. It is not business as usual.

In the words of C. Ginger (1993):

"The philosophical challenge faced by BLM has, at its core, human perceptions of the value of land. These values are the same as those that were at the base of the disagreement between John Muir and Gifford Pinchot at the end of the nineteenth century. Muir and Pinchot debated the ideas of preservation of land versus conservation of land. Placed in the context of the wilderness protection, we might ask if we are saving wilderness for wilderness' sake or because it is a wise use of natural resources. These two perspectives (preservation and conservation) were a challenge to a third perspective that dominated the government institutions that oversaw public lands in Muir and Pinchot's time: exploitation of natural resources in the short run. All three points of view are present today in our approach to land and resources but it is Pinchot's view that provides the dominant ideal in the form of the multiple-use sustained -yield philosophy established by Congress for public land management in the United States. The debate over wilderness designations in the West illustrates that the idea of preserving a chunk of land is not just an administrative, legal or even political issue. The sometimes dramatic conflict reflects an underlying difference in values and perceptions of our relationship to the land. And the values are not simply held by individuals. They are reflected in and perpetuated by the institutions we have created to act collectively. We can find in the Bureau of Land Management how the debate over our relationship to the land is defined and pursued."

Human institutions are not natural phenomena. They are created by humans and some contain paradoxes and ambiguities. These ambiguities may be the source of conflict in circumstances where identical evidence is interpreted in different ways.

Human belief systems are mutable but they are also quite resistant to change even in the face of accumulating evidence. In the United States race relations and women's roles in society have changed in the second half of the 20th century to the extent that certain behaviors and attitudes accepted as commonplace in the first half of the century are disapproved and are illegal today. Equal access to places and roles is now an accepted ideal, not yet attained in many circumstances, but with many instances of success. *Justice* and *equality* are underlying moral imperatives driving these movements in particular directions.

Sustainability and ultimately, *survivability of life* are the imperatives underlying the shift from anthropocentric to biocentric views. As far as we know, we alone, among sentient beings, record history, and thus can be aware of long consequences of our actions. As humans gain capacity to control and to destroy we must take responsibility to sustain. We need goals in this regard. Sustaining life processes on earth is an acceptable goal to be placed on the balance scale along with other values.

Defining and managing wilderness by the agencies responsible for public lands is a skirmish in the paradigm shift over the position of humans in nature. Elements of nature must be given standing in human value systems in order that wilderness be recognized in human affairs. This is to be done by defining wilderness as a place apart, imbued with boundaries and rights, where humans behave in prescribed ways as if they were in someone else's home. For wilderness to be a place it must be filled with meaning that large segments of society understand and support, otherwise it will remain a backdrop in human affairs, invisible to policy makers.

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Clare Ginger, doctoral candidate, Urban, Technological and Environmental Planning Program, the University of Michigan. She is working on a dissertation about the meaning of wilderness in the eyes of BLM personnel and spent four summers collecting taped interviews from BLM employees at federal, state, and district levels. She asked them to describe wilderness and their responses to the wilderness mandate. Quotation in the text is from an unpublished document, 2/3/93.

Visual illusion authors

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Murray Eden, MIT

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THE EARTH ISN'T FLAT. AND IT ISN'T ROUND EITHER! SOME SIGNIFICANT AND LITTLE KNOWN EFFECTS OF THE EARTH'S ELLIPSOIDAL SHAPE

Frank E. Barmore *

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Abstract

The small difference between the shape of the earth and a sphere is usually thought to be negligible except for work of very high accuracy such as geodesy. This is not the case. There are some examples where this small difference in shape makes an easily apparent difference in what is observed. This paper will comment on three problems and evaluate the impact of the non-spherical shape of the Earth on the result: 1) the qibla problem of Islamic geography, 2) the center of area (geographic center) and 3) the center of population.

Introduction

I have noticed that some common considerations in geography are often treated without due regard for the Earth's ellipsoidal shape. This is surprising. The Earth is not spherical (round). It is, rather, very nearly an ellipsoid of revolution with equatorial radii, a and b, of 6378.2 km. and polar radius, c, of 6356.6 km. — a difference of 21.6 km. This difference is significantly larger than the next largest pervasive topographic feature, the continent — ocean basin dichotomy of 5 km. Also, this shape, an ellipsoid of revolution, is not intrinsic to terrestrial planets. Venus is nearly spherical, $a = b = c =$ ca. 6051.5 km. (Head, et al., 1981). Mars is reasonably well described as a tri-axial ellipsoid of $a = 3399.2$ km, $b = 3394.1$ km. and $c = 3376.7$ km. (Mutch, et al., 1976).

This departure of the shape of the Earth from a sphere is often given as the flattening,

$$f = (a - c)/a = 0.0034 \quad \text{or} \quad 0.34\%,$$

or the eccentricity, e, where

$$e^2 = (a^2 - c^2)/a^2 = 0.0068.$$

The departure from a sphere also results in a difference between geocentric and geographic latitude of (at 45° latitude),

$$0.195° = 0°11.7' = 0°11'42''.$$

While these are small quantities, they are not insignificant. For comparison, consider the following difference or ratios of similar magnitude:

a. one vacation day per year (which, in turn, is larger than the one day calendar adjustment every fourth or "leap" year),

b. a watch which gains or looses five minutes per day,

c. a two inch gap in a 50 foot brick wall,

d. a 1/6 inch crack in a 48 inch table top,

e. \$100 per \$30,000 of annual earnings,

f. an angle of 1/3 of the apparent diameter of the sun or moon.

We routinely concern ourselves with such small differences in daily life. We expect and receive better accuracy from craftsmen. Differences in direction of this magnitude are easily seen.

Consistency would require that we be as concerned with equally small quantities in geography as we are in other circumstances. Therefore, all but the simplest considerations in geography should routinely take into account the Earth's ellipsoidal shape. Often this is not done. This paper will consider the impact of the Earth's non-spherical shape on the results in three cases: 1) the qibla problem of Islamic geography, 2) the computation of a geographic center (center of area) and 3) the computation of a center of population.

The Qibla Problem

As I have previously commented (Barmore, 1985), a Koranic line which may be translated as "... wherever you are, turn your face towards it [the Holy Mosque — the Kaaba]" is often invoked to establish the correct orientation (the qibla) during the obligatory prayer (the salat), and hence the correct orientation for mosques. This requirement, in turn, is often considered as satisfied when a mosque is aligned with the direction of the Kaaba in Mecca. There is, in Islamic scientific literature, sufficient discussion of the direction of Mecca to indicate the usual definition of direction (King, 1979). The direction is that of the shortest arc of a great circle on a spherical Earth between the locality and Mecca. (But note that mediæval Islamic religious and legal scholars have often argued otherwise and, as a result, other orientation traditions have existed (King, 1972, 1982a, 1982b, and other work in preparation).) The direction is then specified by stating the azimuth of this arc of a great circle relative to the meridian.

Given the geographic coordinates of a locality and of Mecca the azimuth of Mecca is easily calculated with spherical trigonometry, **provided a spherical Earth is assumed**. Tables of such information, both historical and contemporary, exist in great number. These tables, as well as numerous individual calculations in the literature discussing the many facets of Islamic culture, often give their results to the nearest minute of arc (or even the nearest second of arc). The implication is that the results are correct to the same level of accuracy. But the Earth is not spherical. The Earth is ellipsoidal in shape. If qibla azimuths are calculated assuming a spherical Earth, they do not represent the real case with an accuracy approaching a minute of arc. In every case I have examined, the calculations were done as if the Earth were a sphere. In order to illustrate the errors that result, I have calculated the simple azimuth as well as the geodetic azimuth of the Kaaba in Mecca for a number of places. (The simple azimuth is calculated on a sphere while the geodetic azimuth more closely represents the correct case (See Appendix A).) The qibla error,

$$QE = az(S) - AZ(E),$$

is the amount that must be subtracted from the incorrect but more easily calculated simple azimuth, $az(S)$, in order to obtain the more accurate geodetic azimuth, $AZ(E)$, calculated on the ellipsoid representing the Earth. The locations of various places were taken from *The*

Times Atlas of the World (1990). The location of the Kaaba in Mecca was taken from a large scale map of Mecca (1970). The result, for Clarke's (1866) Ellipsoid, is displayed in Table 1 for selected localities and shown for the world in Figure 1.

Table 1

The error in the qibla azimuth for various places when calculated on a sphere. The results are given in decimal degrees and in minutes of arc. A tabulated value of the qibla error, $QE = az(S) - AZ(E)$, is the amount that must be subtracted from the incorrect but more easily calculated simple azimuth, $az(S)$, in order to obtain the more accurate geodetic azimuth, $AZ(E)$, calculated on Clarke's (1866) Ellipsoid representing the earth.

Place			**Qibla**		**Qibla Error**	
Name	Lat(N+)	Long(E+)	$az(S)$	$AZ(E)$	degree	min.arc
Baghdad	33.3333	44.4333	200.0637	200.1583	−.0946	−5.67
Cairo	30.0500	31.2500	136.2137	136.0561	.1576	9.46
Chicago	41.8333	−87.7500	48.5875	48.5209	.0666	3.99
Cordoba	37.8833	−4.7667	100.3041	100.1910	.1131	6.78
Damascus	33.5000	36.3167	164.7021	164.6278	.0743	4.46
Istanbul	41.0333	28.9500	151.5875	151.4770	.1105	6.63
Jakarta	−6.1333	106.7500	295.1509	294.9765	.1744	10.46
Jidda	21.5000	39.1667	97.2106	97.1680	.0426	2.55
Kabul	34.5167	69.2000	250.8290	250.9551	−.1261	−7.56
Khartoum	15.5500	32.5333	48.5631	48.7363	−.1732	−10.39
Marrakech	31.8167	−8.0000	91.5913	91.5139	.0774	4.65
Medina	24.5000	39.5833	175.8084	175.7846	.0239	1.43
Mombasa	−4.0667	39.6667	0.3437	0.3460	−.0024	−0.14
Riyadh	24.6500	46.7667	244.5752	244.7080	−.1328	−7.97
Tashkent	41.2667	69.2167	240.3127	240.4550	−.1423	−8.54
Tehran	35.6667	51.4333	218.5599	218.7030	−.1431	−8.59
Tombouctou	16.8167	−2.9833	76.4880	76.5301	−.0421	−2.53
Trabzon	41.0000	39.7167	179.6976	179.6962	.0013	0.08

When these results are considered it is clear that qibla errors on the order of 0.1 degrees ($0^\circ\ 06'$) will result when azimuths are calculated assuming a spherical earth. Not only is this true for qibla azimuths, but it is also true for azimuths calculated for any other purpose. Clearly, azimuths calculated assuming a spherical earth will not, in general, be accurate to a tenth of a degree and should not be given in a way that implies such accuracy.

It would not be appropriate to criticize historical works concerning the qibla problem for lacking such accuracy. However, knowledge of the ellipsoidal shape of the Earth is now widely known — clear descriptions are to be found in many texts on physical geography. I wish to

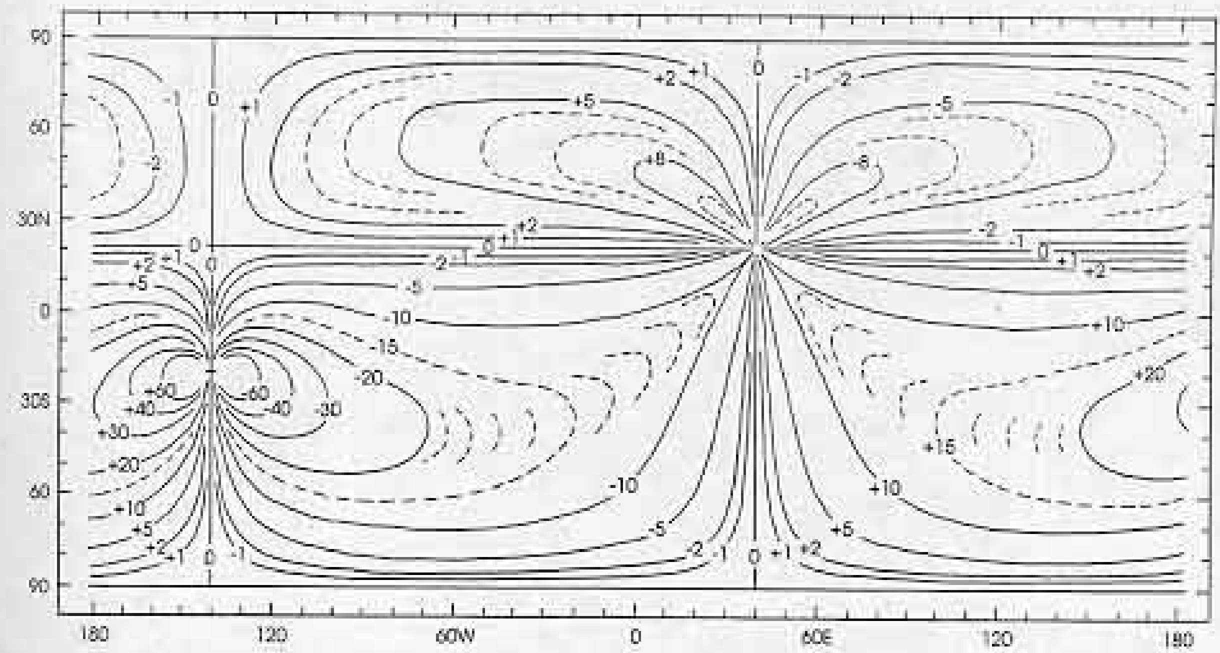

Figure 1. The error in the qibla azimuth for various places when calculated on a sphere. The results are given in minutes of arc. The plotted value of the qibla error, $QE = az(S) - AZ(E)$, is the amount that must be subtracted from the incorrect but more easily calculated simple azimuth, $az(S)$, in order to obtain the more accurate geodetic azimuth, $AZ(E)$, calculated on Clarke's (1866) Ellipsoid representing the Earth. The variations are complex near Mecca, located at 21.4 degrees N., 39.8 degrees E., and at the antipodes of Mecca. Note the non-uniform contour intervals, the incomplete contours in regions of high contour line density and some intermediate contour fragments, shown dashed.

raise two questions: 1) Is there an instance in recent or contemporary works concerning the "qibla problem" where the problem has been considered with due regard for the ellipsoidal (non-spherical) shape of the Earth? 2) Would Islamic legal, religious or geographic scholars have any interest in this small but noticeable correction to a traditional solution of the "qibla problem"?

The Geographic Center

There exists, in north central Wisconsin, less than 3/4 kilometer to the north and west of the very small community Poniatowski, a monument with the following text:

The location of Poniatowski near this unique geographic point has given it sufficient fame to be mentioned in newspaper articles, some tourist literature and even celebrated in song (Berryman, 1989).

If the Earth were spherical or much more nearly so, then the statements on the marker would be true enough. But, as a result of the Earth's ellipsoidal shape: a) the place marked is not halfway between the Equator and the pole, b) the place marked is well removed from the "center" and c) the halfway point and the center are well separated from one another.

GEOLOGICAL MARKER

This marker in Section 14, in the Town of Rietbrock, Marathon County is the exact center of the northern half of the Western Hemisphere. It is here that the 90th meridian of longtitude (sic) bisects the 45 parallel of latitude, meaning it is exactly halfway between the North Pole and the Equator, and is a quarter of the way around the earth from Greenwich, England.

MARATHON COUNTY PARK COMMISSION

(Note, however, the Earth's ellipsoidal shape not withstanding, the monument does mark the place, 90 W longitude, 45 N latitude, well enough.) The monument's failure in marking the halfway point and the center is substantial and each failure will be discussed in turn.

Halfway Point:

Because of the ellipsoidal shape of the Earth, the length (measured on the surface) of a degree of geographic (that is, geodetic) latitude varies with latitude. As a result, the point that is equidistant from the pole and the equator is not simply the midpoint in latitude. Using Clarke's (1866) ellipsoid and the various relationships in the geometry of an ellipsoid (Bomford, 1971, Appendix A) it is a straightforward calculus problem to find the equidistant point. It is at the geographic latitude $45.1447 = 45°08'41''$ (see Appendix B). The place with this latitude is about 16 km. from the one marked and sufficiently far from Poniatowski as to place it well into the next county to the north, Lincoln County.

Center:

The concept of the geographic center (center of area) for a curved surface is not as straightforward as when the area is flat. What is usually meant by the center is the average (or mean) location. The location coordinates used (latitude and longitude) are curvilinear rather than rectangular. Because of this, one **may not** average the latitude and longitude of the elements of area that make up the whole in order to find the center (average location) of the whole area. In order to make this point more clear, consider Figure 2. Shown shaded is the northwest quadrant of the Earth. On a sphere, this area shows a great deal of symmetry about the point at latitude 45° N., longitude 90° W. Surely the center of this quadrant on the surface of a sphere is at this central point. But, if one calculates the average latitude of the various area elements that make up the northwest quadrant on the surface of a sphere, the result is 32.7042 degrees or $32°42'15''$ N. Surely the center is not there. (Other statistics are no better when applied to latitude alone — the median latitude is 30° N. and the modal latitude is 0°.) What must be averaged is the location, **not** the coordinates of the location. Phrased differently, the latitude of the center of area is different from the average latitude of the same area.

Any satisfactory method of finding the center must take into account the curved surface of the Earth in a suitable way. One method is to calculate the center by assuming that the quantities spread over the two dimensional surface of a sphere are distributed in a three-dimensional Euclidean space (as indeed they are). One early geographical use (the earliest I have noted) of this "three-dimensional" method for finding centers of population (or area) on the surface of a sphere was derived by I. D. Mendeleev and used by his father, D. I.

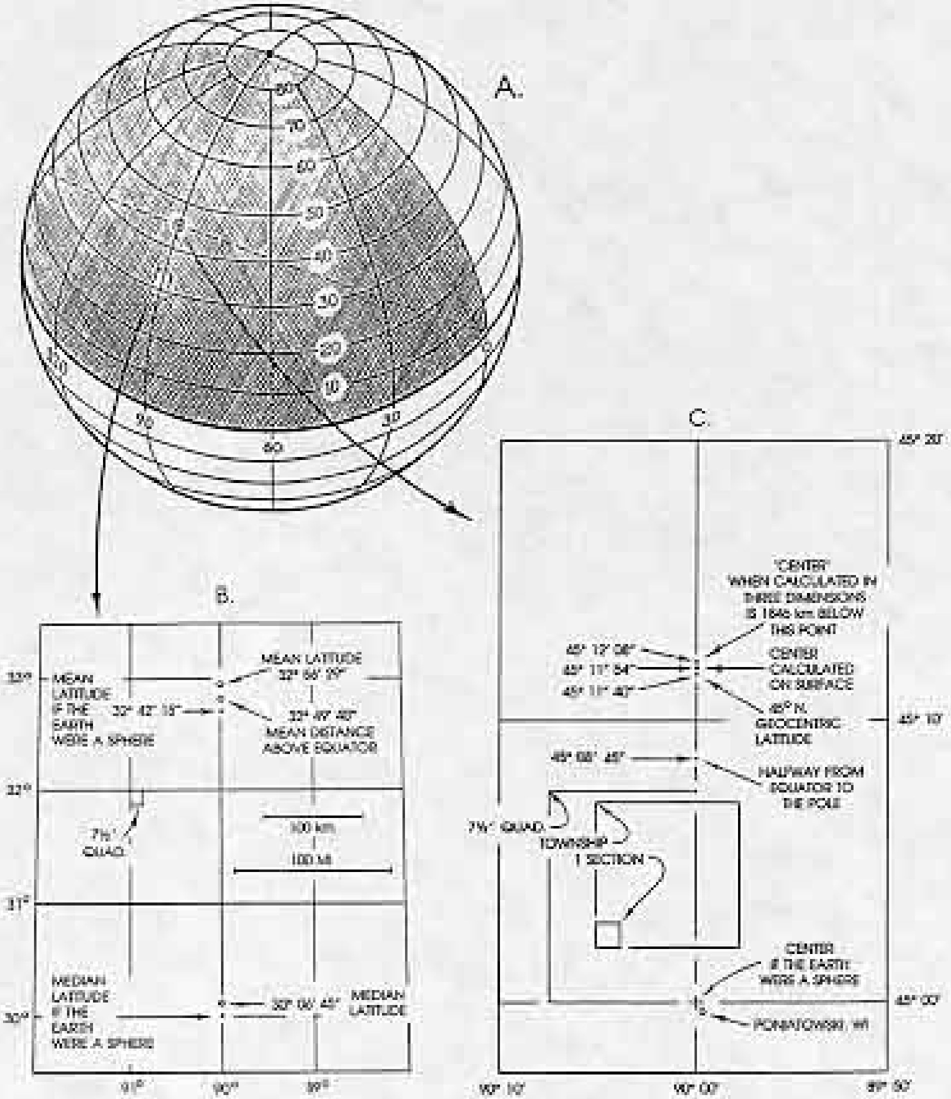

Figure 2. The geographic center (center of area) of the northwest quadrant of the Earth (or the upper left quadrant of a sphere or an ellipsoid) and other statistics. A) An oblique view of the Earth showing the northwest quadrant. B) The region of the northwest quadrant near the median and mean latitudes of the quadrant on the 90th meridian. C) The region of the northwest quadrant near the geographic center. The center was determined by the preferred method (Barmore, 1991); that is, calculated with the computations and the result restricted to the surface. The ellipsoid is Clarke's (1866) ellipsoid.

Mendeleev (1907 and earlier) to find the centers of area and population of Russia. Such a method is easily extended to calculating the center of area or population on the surface of an ellipsoid.

I believe an alternative method is preferable — a method that restricts the computations and the results to the surface of a sphere. We are largely confined to the Earth's surface and it is appropriate to adopt this provincial viewpoint when determining the center of population or geographic center. This is discussed elsewhere in some detail (Barmore, 1991). Whichever of the two methods is used (computations **in** the earth in three dimensions or computations **on** the surface in two dimensions) the geographic center (center of area) of the northwest quadrant of a spherical Earth is at 90° W. longitude and 45° N. latitude.

But the Earth is not spherical. The Earth is ellipsoidal in shape. When these computations are done for an ellipsoid, one finds that the geographic center is far removed from 45° N. latitude (though it remains on the 90th meridian). I have used both methods to calculate the geographic center of the northwest quadrant for Clarke's (1866) ellipsoid using the ellipsoidal geometry found in Bomford (1977) and find the center is about 22 km. to the north, well into the next county, Lincoln County, at about 45°12′ N. latitude. In addition to being far above the 45th parallel and far removed from Poniatowski, Wisconsin, the center is also far removed from the point midway between the equator and the pole (see Figure 2). Though the monument marks the intersection of the 45th parallel of latitude with the 90th meridian well enough, it marks **neither** the point midway between the equator and the pole **nor** the center of the northern half of the western hemisphere. The claims of the marker that it is at "the exact center of the northern half of the Western Hemisphere ... " and " ... is exactly halfway between the North Pole and the Equator, ... " are simply not true.

The Center of Population

When calculating the center of population of the United States, the Bureau of the Census explicitly states that it has assumed a spherical Earth (U.S. Bureau of the Census, 1973). But the Earth is ellipsoidal in shape, not spherical. The formulæ used by the Census Bureau for the center of population calculation are not particularly suitable for the computation of the center of populations on a sphere, let alone an ellipsoid. As has been previously pointed out in considerable detail (Barmore, 1991), the Census Bureau formulæ do not take the curvature of Earth's surface into account in an appropriate way. But, however the center of population is calculated for populations on the surface of a sphere, the questions remains: What will be the center of population for populations on the surface of an ellipsoid? As indicated in the previous section, there are two methods of computing centers on spherical surfaces and the procedures can be extended to the problem of calculating the center of population of the United States on the surface of an ellipsoid.

I have calculated the center of population of the United States for 1980 using Clarke's (1866) ellipsoid and the ellipsoidal geometry given in Bomford (1977) two ways: 1) in the Earth in three dimensions and 2) on the surface in two dimensions as outlined in a previous paper (Barmore, 1991). The same example data set was used in all cases. The results of these computations as well as previously derived results for the spherical case are shown in Table 2 and Figure 3.

When these results are considered it is clear that the difference between the center obtained with the Bureau of the Census formulæ and the center obtained using the preferred method (or the other reasonable alternative) is substantial. However, the error in ignoring the ellipsoidal shape of the earth is smaller — less than a minute of arc difference in the location of the center of population.

The Bureau of the Census gives the center of population to the nearest second of arc of latitude and longitude. If one wishes to pursue the location of the center of population of the United States to an accuracy of one second of an arc then the ellipsoidal shape of the

Table 2.

The Center of Population for 1980 for the United States calculated by various methods for the same example data set previously used (Barmore, 1991).

Center of Population

Method of computation	label	latitude	longitude	depth
Bureau of the Census formulæ	BC	38.1376	90.5737	—
In three dimensions for a sphere	s	39.1823	90.3477	165 km
In three dimensions for an ellipsoid	ϵ	39.1887	90.3469	165 km
On the surface of a sphere	COP	39.1980	90.4978	0
On the surface of an ellipsoid	$COP-E$	39.2045	90.4969	0

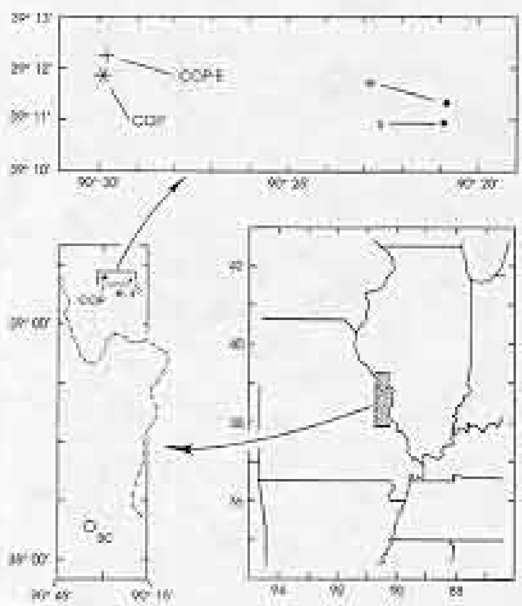

Figure 3. The "Center of Population" of the United States for 1980 calculated by various methods. The place shown as an open circle and labeled BC, is the center determined by the U.S. Bureau of the Census (1983). As discussed previously (Barmore, 1991) this place should not be called the center of population. The places shown as solid circles and labeled s and ϵ, mark the centers calculated in three dimensions assuming the population is on the surface of a sphere or on the surface of Clarke's (1866) ellipsoid, respectively. The calculated centers lie *ca.* 165 km below the places marked. The places shown as an asterisk or a plus and labeled COP or $COP-E$ are the centers calculated using the preferred method (Barmore, 1991) and assumes the population is on the surface of a sphere or on the surface of Clarke's (1866) ellipsoid, respectively. The preferred method restricts the computation and results to the surface (sphere or ellipsoid) containing the population.

Earth (and a host of other considerations) should be taken into account.

Summary

The Earth is not spherical. The Earth is ellipsoidal in shape. When computations are done without due regard for the ellipsoidal shape of the Earth they may be in error by amounts on the order of 1/10 degree. This paper points out: 1) that errors of *ca.* 1/10 degree result in qibla (and other azimuths calculated on a sphere, 2) that errors of *ca.* 1/10 degree result in the location of the geographic center of very large areas calculated on a sphere, but 3) that the error in the location of United States population center when properly calculated on a sphere is less than one minute of an arc.

Appendix A

Because the Earth is not a sphere (nor, for that matter, exactly an ellipsoid of revolution) a certain amount of care will be needed in using the terms **azimuth** and **distance**. This paper uses several terms (described below) which correspond closely to those defined and used by Bomford (1977). Also, several other concepts deserve additional comment.

ASTRONOMICAL AZIMUTH: For places on the physical surface of the Earth, the astronomical azimuth of one place from another corresponds to what would be measured with an accurate instrument located on the **surface of the Earth**.

GEODETIC AZIMUTH: For places on the surface of an ellipsoid representing the Earth, the geodetic azimuth of one place from another is what would be measured with an accurate instrument located on the **surface of the ellipsoid**, the instrument being "leveled" relative to the ellipsoid's normal at the instrument's location rather than the "gravitational field."

SIMPLE AZIMUTH: For places on the surface of a sphere, the simple azimuth of one place from another corresponds to what would be measured with an accurate instrument located on the **surface of the sphere**, the instrument being "leveled" relative to the sphere's normal at the instrument's location rather than the "gravitational field."

DISTANCE: For places on the surface of an ellipsoid, distances between places are often measured along the "normal sections" rather than along geodesics. For places on the surface of a sphere, distances between places are almost always measured along geodesics, called great circles.

On the sphere simple azimuths and great circle distances are easily calculated with spherical trigonometry. On the ellipsoid geodetic azimuths and normal section distances are determined by more complex calculations. In this paper Cunningham's formula was used for Geodetic Azimuth (Bomford, 1977, Eq. 2.23) and Rudoe's "9-figure" formula was used for distances along the normal section (Bomford, 1977, p. 136).

LOCATION: Places are located on a sphere, an ellipsoid or an accurate map according to their geographic (that is, geodetic) coordinates.

ACCURACY: Roughly speaking, calculations done on a sphere will represent distances and direction on the real surface of the Earth with an accuracy of one degree or more. Calculations done on a suitable ellipsoid will represent distances and direction on the real surface of the Earth with an accuracy of one minute of arc or more. For an accuracy of one second of arc or more, details such as the choice of the ellipsoid parameters, the Earth's gravitational field and heights of the various places must be taken into account. For the purposes of this paper (accuracy of one minute of arc) geodetic azimuths and distances in the normal sections represent the real case well enough. It is a rare case indeed that the difference between the geodetic and the astronomical quantities would be so large as one minute of arc (Bomford, 1977, p. 115, 528). In the main text of the paper results are often stated to the nearest second of arc (or 0.0001 degree). It should be kept in mind that these results are the geodetic results. This level of accuracy is justified for comparisons of similar results but it is not the absolute accuracy of quantities on the physical surface of the Earth.

ELLIPSOID: All the calculations involving the ellipsoid and discussed in the main part of the text used Clarke's (1866) Ellipsoid, $a=6378.2064$ km. and $e=0.08227185$. The geometry of the ellipsoid and various series expansions for some of the relationships were those given by Bomford (1977, Appx. A, C).

NOTATION: All azimuths are measured from the North toward the East and are always positive (i.e., SW = +225 degrees, never −135). Angles are given in degrees and decimal degrees (sometimes without the unit name or symbol) or in degrees and minutes of arc (and sometimes seconds of arc) and always with the symbols: dd°mm′ss″).

COMPUTATIONS: All computations were done on an Apple IIGS computer using the spreadsheet in AppleWorks 3.0 (Claris Corp.).

Appendix B
Half-way Point Calculation.

(added to this reprinting at the request of the Editor.)

If the distance from the equator to the pole measured along a meridian on the surface of the ellipsoid is s, then:

$$s = \int_{\text{equator}}^{\text{pole}} ds.$$

Rewriting this in terms of the radius of curvature, ρ, and the geographic (geodetic) latitude, ϕ, the latitude of the half-way point, Φ, is then given by:

$$\int_0^{\Phi} \rho \cdot d\phi = \frac{1}{2} \int_0^{\pi/2} \rho \cdot d\phi = \frac{1}{2}s.$$

Bomford (1977, eq. A.53)v gives the radius of curvature in terms of the semi-major axis a, the eccentricity e, and the geographic latitude. Then:

$$\int_0^{\Phi} \frac{a(1-e^2)d\phi}{(1-e^2\sin^2\phi)^{3/2}} = \frac{1}{2} \int_0^{\pi/2} \frac{a(1-e^2)d\phi}{(1-e^2\sin^2\phi)^{3/2}}$$

Cancelling common terms, using the binomial expansion (e is small), and evaluating the resulting series of definite integrals on the right hand side (RHS) one finds:

$$\text{RHS} = \frac{\pi}{4}[1 + \frac{3}{2} \cdot e^2 \cdot \frac{1}{2} + \frac{3 \cdot 5}{2 \cdot 4} \cdot e^4 \cdot \frac{1 \cdot 3}{2 \cdot 4} + \cdots].$$

The left hand side (LHS) integrals can be reduced (with a certain amount of algebraic and trigonometric manipulation) to:

$$\text{LHS} = \Phi + \frac{3}{2} \cdot e^2 \cdot (\frac{\Phi}{2} - \frac{\sin 2\Phi}{4}) + \frac{3 \cdot 5}{2 \cdot 4} \cdot e^4 \cdot (\frac{3}{8}\Phi - \frac{\sin 2\Phi}{4} + \frac{\sin 4\Phi}{32} + \cdots).$$

Ignoring the smaller terms — terms containing e^4, e^6 etc. (using the eccentricity for Clarke's 1866 ellipsoid) yields:

$$\Phi = 0.787923557 = 45.1447° = 45°08'41''.$$

Including terms containing e^4 and e^6 yields:

$$\Phi = 0.787945019 = 45.145924° = 45°08'45''.$$

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MICROCELL HEX-NETS?

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The ongoing revolution in electronic communications offers exciting opportunities to realize geographic ideas in perhaps unimagined electronic realms. It is well-known, throughout governmental, business, and academic communities, that the cartographer can make a map from hundreds of electronic layers in a Geographic Information System (GIS), in which the data behind the map work interactively with the map, so that upgraded data produces an upgraded map. GIS is certainly one exciting result of the interaction between traditional science and electronics.

Cordless telephones offer other prospects: networks of mobile terminals can be linked together in networks across city streets as well as within office skyscrapers. Chia (1992) notes that the Research on Advanced Communications for Europe (RACE) initiative of 1988, to study techniques to implement a third generation Universal Mobile Telecommunications System by the year 2000, is a significant step toward unifying communications and fixed networks.

The concept of a mobile telecommunication is straightforward (Chia 1992). Simply stated, a set of microcell base stations, each of which can transmit and receive electronic information, is spread across a geographic space as a network of stations, each with its own tributary area, a microcell, with which it communicates. Typically, one might think of the microcell base station as the center of a circular tributary area, with circular areas packed to cover a larger circular area. At the center of the larger circular area, a macrocell base station serves as an "umbrella" to relay information to the microcell base stations under it, and from one network of microcells to the next (Chia 1992). Within this sort of "mixed cell architecture," a vehicle carrying a terminal onboard passes through the microcells and receives information on a continual basis from the base station associated with the microcell it is currently traversing. This sort of hand-off of information in order to traverse a network is not new; indeed, the Rohrpost — an underground network of pneumatic tubes used for message transmission in Berlin in the early 1900s — was composed of energy regions in which pneumatic carriers were handed off from one region to the next in order to transmit messages across a fairly large geographic area (Arlinghaus 1986). More commonly, a relay foot race involves the handing off of a baton from one runner to a second, once the first runner has expended much energy to traverse some specified geographic space. There are a host of other illustrations of this sort.

There are apparently numerous engineering concerns associated with the optimal positioning of the base stations: antenna radiation patterns, natural terrain features, interference from tall buildings, and interference and signal attenuation of all sorts, including difficulties when the mobile unit turns a corner (Chia, 1992). The geometry of directional paths through Manhattan space (Krause 1975), based on number of vehicle turns can then also become of concern (Arlinghaus and Nystuen 1989).

It is the geographic issues of street patterns and building position that are fundamental to the engineering concerns in implementing these networks in which moving vehicles interchange information with a fixed network of base stations (Chia 1992). Even a brief glance at an atlas shows the range of variation in street pattern — from the predominantly rectilinear grid of Manhattan, to the polar-coordinate style of rotary and radial evident in Washington D.C. Thus, many studies involving microcell networks are done, initially, in an abstract environment (Chia, 1992) — as a benchmark against which to evaluate others in less than optimal environments. It is within this spirit that a microcell system, composed of layers of microcells of varying size, is viewed.

Lattices

Viewed broadly, microcell base stations are a set of lattice points. The way in which the lattice is constructed can affect all other considerations of the functioning of the consequent microcell network. There are an infinite number of "general" environments that one might use in which to construct benchmark networks. When the size of the microcells is sufficiently "large," the microcell tributary areas might be viewed as curved surfaces which when pieced together form a set of plates composing a broad continental (for example) surface. When the size of the microcells (or macrocells) is "local" rather than "large," curvature may not be an issue and the cells might be treated as plane regions. (What is "local," and what is not, is a significant problem for pragmatic implementation; at the abstract level it is of importance to note it, but not necessarily to deal with it directly.) And, if the line-of-sight geometry is one that excludes parallelism, or that permits more than one parallel, then it may be suitable to view microcell network architecture/geography from the non-Euclidean vantage point of elliptic or hyperbolic geometry (Arlinghaus 1990).

Within a plane region, there are two basic ways of creating an evenly-spread lattice: one with the lattice points lying in a grid pattern, and the other with the lattice points lying in a triangular / hexagonal grid pattern (Coxeter 1961). The differences between the two should be clear to anyone who has played the game of checkers on both a square board and on a "Chinese" board. What is not evident, though, is the sorts of patterns that emerge when one stacks layers of square or hexagonal cells of different sizes in varying orientations. When a square lattice is chosen, one style of space-filling by tributary regions emerges; when an hexagonal lattice is chosen, another appears.

Microcell hex-nets

Walter Christaller (1933, 1966) grappled with the problem of overlays of hexagonal nets; he did so in the German urban environment. One might question some of the interpretations of the patterns, but his analysis of the actual patterns of overlays is correct. There are numerous discussions of this problem, often under the heading of "central place theory" — or, how cities might share interstitial space (Christaller 1933, 1966; Dacey 1965). When the focus is on the extent to which space is filled by portions of the hexagonal outlines, as it might be when signal attenuation and interference of radio waves are an issue, then the fractal approach which permits the easy measurement of the extent to which an infinitely iterated overlay of nets will fill space is useful.

One way to look at the complicated issue of visualizing overlays of hexagonal nets is simply to think of a central hexagon surrounded by six hexagons of the same size — each of these is centered on a microcell base station. The central hexagon is also centered on a macrocell base station which serves the entire set of seven hexagons and has as its own larger tributary macrocell, a hexagon formed by joining pairs of vertices (separated by two intervening vertices) of the perimeter of this snowflake region. When these microcells and macrocells are iterated across the plane, a stack of two layers of hexagonal cells emerges, with the orientation of one relative to the other at an angle that insures that each of the macrocells contains the geometric equivalent of 7 microcells. If one zooms in or out, to generate other layers of larger or smaller hexagons, the stack may be increased; as long as the angle of orientation is fixed by the first two, the value of "7" will be a constant of the hierarchy —no matter which two adjacent layers of the hierarchy are considered, a large cell will contain the equivalent of 7 smaller cells. In the literature, this is often referred to as the "$K = 7$" hierarchy.

When one chooses different orientations of the nets, different K values emerge; indeed, there are an infinite number of possibilities. When it is also required that vertices of smaller hexagons coincide with those of larger hexagons, there are still an infinite number of hierarchies with the K values generated by the Diophantine equation $x^2 + xy + y^2 = K$ (Dacey 1965) where x and y are the coordinates of the lattice points arranged in a triangular lattice (and so relative to a coordinate system with the y-axis inclined at 60° to the x-axis).

A structurally identical process may be employed to make similar calculations for layers of squares centered on a square lattice. Relationships which show the number of small square microcells within a larger square macrocell are also constant between adjacent layers of a hierarchy formed from a single orientation criterion ("J" value).

Fractal geometry may be used to generate any of these hierarchies: hexagonal or square. All that is needed is to know the number of sides in a fractal generator and the self-similarity pattern desired (K- or J-value). From these, one can determine completely and uniquely the entire hierarchy–both cell size within a layer and orientation of layer (Arlinghaus, 1985; Arlinghaus and Arlinghaus 1989). The fractal dimension measures the extent to which parts of the boundary of the hexagons or squares remain under infinite iteration. When the results of the calculations are displayed in a table, it appears that hexagonal nets consistently fill less space (Arlinghaus, 1993).

This Table suggests that individuals actually implementing microcell systems might wish to first consider shape, size, and orientation of layers of a mixed cell architecture prior to superimposing any of the geographic concerns of street networks, or engineering concerns caused by interference and signal attenuation. A mixed cell architecture of low fractal dimension might be one that reduces interference, to some extent, just by the relative positions of microcells to macrocells.

Table: Comparison of fractal dimensions

Lattice coordinates of microcell base station adjacent to microcell base station at (0, 0)	Fractal Dimension	
	Squares	Hexagons
(1,1)	2.0	1.262
(1,2)	1.365	1.129
(0,2)	2.0	1.585
(0,3)	1.465	1.262
(0,4)	1.5	1.161
(0,5)	1.365	1.209
(0,6)	1.387	1.161
(0,7)	1.318	1.129
(0,8)	1.333	1.153
(0,9)	1.290	1.131
(0,10)	1.301	1.114

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SUM GRAPHS AND GEOGRAPHIC INFORMATION

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Abstract

We examine a new graph theoretic concept called a "sum graph," display a new sum graph construction, and prove a new theorem about sum graphs (sum graph unification theorem) verifying the construction. The sum graph is then generalized, ultimately as an augmented reversed logarithmic sum graph, so that it is useful in dealing with large sets of geographic information. The generalized form permits 1) the compression of large data sets, and 2) the simultaneous consideration of data sets at various levels of resolution.

The advantages of employing sum graph unification and the augmented reversed logarithmic sum graph to handle data sets are illustrated by hypothetical example; as a data structure, the various forms of sum graph data management provide compact handling of data and do so in a manner that permits variability of resolution, at multiple levels (unlike the quadtree), within a single layer of mathematical manipulation.

Our interest in creating, and exploring, this sort of data structure rests in searching for structures that are translation invariant. Data structures resting on geographic direction, such as the quadtree, seem destined not to be translation invariant; structures that are not tied to the ordering of the space in which they are embedded, but only to an ordering within the structure itself, have the potential to be translation invariant.

Geography and graph theory have a long history of interaction: the Four Color Problem (now Theorem) and the Königsberg Bridge Problem of graph theory arose as geographical questions. As geography has stimulated mathematical creation, so too has the body of theory developed by graph theorists stimulated careful analysis of various geographical networks. It is within this well-established spirit of interaction, and within the technological framework where electronic processing of data may be characterized using graph theory, that we examine a new graph theoretic concept, called a sum graph, as a theoretical data structure.

In this structure, the numerical pattern of the labels of the nodes in the "sum graph" will be dictated by the linkage pattern in the underlying data, rather than the other way around, which is more conventional. Thus, data that are "linear" (sequential), such as data streams in a raster mode, will be represented by a sum graph whose linkage pattern is linear, thereby forcing a certain style of label to be present on the associated nodes. We demonstrate the theoretical concepts in this paper using examples limited to the linear case because it is easy to express and because it has wide applicability.

Thus, the first section introduces the reader to elements of the abstract development of sum graphs, focusing only on those concepts that will actually be applied. The second section shows how to force "correct" labelling of "sum graphs" to permit the simultaneous consideration of data at multiple levels of resolution within subsets of a data set that is linear in character. The third section introduces the concept of "logarithmic sum graph," used to compress large data sets into subsets within bands of width of one unit — a critical strategy as the length of the linear sequence (data stream) increases. The fourth section introduces the "reversed sum graph" which also permits simultaneous consideration of data at more than one scale and does so with optimal labelling within bands of one unit. The fifth section introduces the "augmented reversed logarithmic sum graph," a graph combining the desirable elements of previously considered structures augmented by a set of linkages, induced by the numerical labelling of subsets, that permits inclusion of data at variable levels of resolution and offers a means to link that data between, in addition to within, subsets. Throughout, we show how to use these concepts in a small application derived from a set of data concerning North American cities.

1. Sum Graphs

Definition 1 (Harary, 1989)

Let S be a set of n distinct positive integers. Define *the sum graph* $G^+(S)$ as follows:

1. $G^+(S)$ has n nodes, each labelled with a different element (number) of S;
2. there is an edge between two nodes labelled a and b if and only if $a+b \in S$.

Example 1

Figure 1 shows the sum graph of $S_1 = \{1, 4, 5, 7, 8, 9\}$. S_1 is a set of arbitrarily chosen labels for the nodes. Because the label "9" is an element of S_1, it follows that the edge linking 4 and 5 ($4+5=9$) is present in the graph. Because the label "6" is *not* an element of S_1 there is an edge linking 1 and 5 ($1+5=6$). A number of theorems concerning sum graphs appear in the mathematics literature (Harary, 1990; Bergstrand *et al.*, 1990, 1991). We state those results without proof; others wishing to employ these methods should read with understanding the proofs in the mathematics literature, lest the methods be inappropriately applied in different situations. First note that the largest number in S cannot be the label of a node joined to any other node.

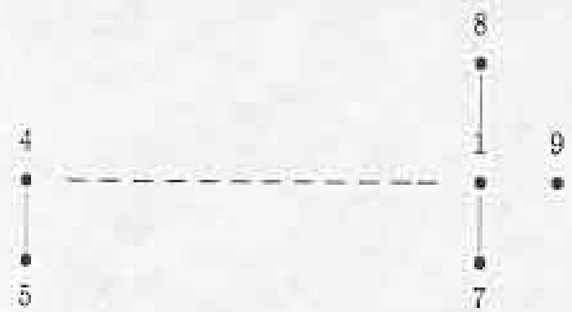

Figure 1.
$G^+(S_1)$: the sum graph of $\{1, 4, 5, 7, 8, 9\}$.
Reader is to solidify any dashed lines with a pencil

Lemma 1 (Harary, 1990)

Every sum graph contains at least one isolated node.

Example 2:

The sum graph of $S_2 = \{2, 3, 5, 6, 10\}$ is displayed in Figure 2.

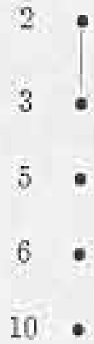

Figure 2.
$G^+(S_2)$: the sum graph of $\{2, 3, 5, 6, 10\}$.

Lemma 1 assures that the node labelled 10 is isolated. Example 2 illustrates that more than one isolated node is possible: hence, the phrase "at least" in the statement of Lemma 1.

Definition 2 (Harary, 1969)

Two graphs G_1 and G_2 are *isomorphic* is there is a one-to-one correspondence f between their node sets such that, for any two nodes a and b in G_1, (a, b) is an edge in G_1 if and only if $(f(a), F(b))$ is an edge in G_2. Thus two graphs are isomorphic not only when they look the same, but perhaps have different labellings of the nodes, but they are also isomorphic when the graphs do not look alike but have the same connection pattern — as are views of the same digital terrain model from different vantage points. Figure 3 illustrates this phenomenon for the graph of the octahedron. Isomorphic structures are invariant under geometric translation.

Notation Given a set S of positive integers, write $kS = \{kx : x \in S\}$.

Theorem 1 (Harary, 1990)

If $G^+(S)$ is a sum graph and $S' = kS$, k a positive integer, then $G^+(S)$ and $G^+(S')$ are isomorphic.

Example 3

Consider the sum graph of Example 1, $G^+(S_1)$ with $S_1 = \{1, 4, 5, 7, 8, 9\}$. When $k = 3$, we have $S_1 = \{3, 12, 15, 21, 24, 27\}$. The distributive law of algebra guarantees that exactly the same edges will appear in $G^+(S_1')$ as in $G^+(S_1)$. For example, because $5 \in S_1$, 1 and 4 are adjacent in $G^+(S_1)$; because $3 \cdot 5 \in S_1'$, $3 \cdot 1$ and $3 \cdot 4$ are adjacent in $G^+(S_1')$, since $3 \cdot 1 - 3 \cdot 4 = 3 \cdot (1 + 4)$. Thus, $G^+(S_1)$ and $G^+(S_1')$ have the same edge structure (but different node labellings, hence, perhaps, different geographic positions), so they are isomorphic.

One interesting structure a sum graph might have is a graph-theoretic path (Harary, 1969).

Definition 3 (Niven and Zuckerman, 1960)

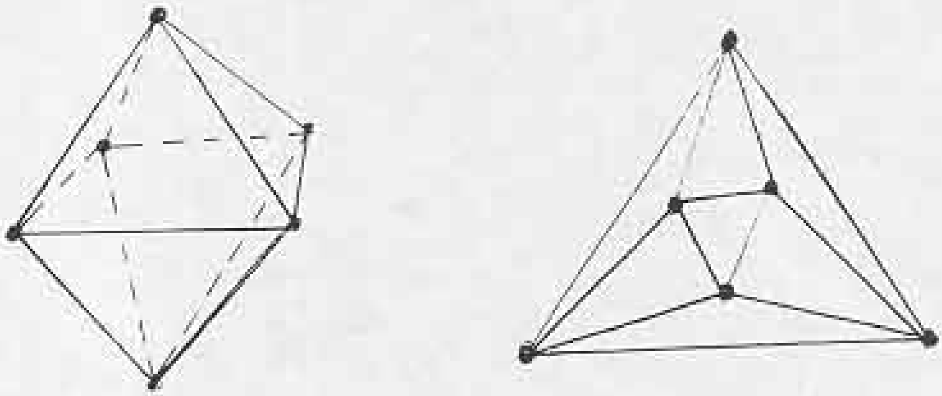

Figure 3.
The octahedron in two different views (View A on the left; View B on the right)
The reader should draw it

The sequence of Fibonacci numbers F_n is defined as follows: $F_1 = 1$, $F_2 = 2$, $F_n = F_{n-2} + F_{n-1}$ when $n \geq 2$. For example, the first nine elements of this sequence are 1, 2, 3, 5, 8, 13, 21, 34, 55.

Theorem 2 (Harary, 1990)

If $S = \{F_1, F_2, \ldots, F_p\}$ is the set consisting of the first p Fibonacci numbers, then $G^+(S)$ consists of a path connecting F_1 and F_{p-1} and the isolated node F_p.

Example 4

Let $S_3 = \{1, 2, 3, 5, 8, 13, 21, 34, 55\}$. Then $G^+(S_3)$ is the graph of Figure 4.

2. Sum Graph Unification: Construction

One of the characteristics that distinguishes a sum graph from other graphs is that the algebraic rule assigning edges forces the sum graph to have at least one isolated node. Thus, in aligning this graph-theoretic concept with geographic notions, one might, at the outset, be tempted to look for applications that require "isolating" one geographic location from a set of others, as in site-selection for toxic waste sites, for prisons, or for other similar societally-obnoxious facilities.

Further reflection suggests, however, that the power behind this "isolation" might be best exploited by considering the isolated node as one with linkages not visible at the graph-scale shown, much as inset maps generally do not reveal linkages to the larger-scale maps they modify. Thus, this cartographic conception of the isolated node as a node with invisible edges will provide a systematic method for shifting scale, or varying resolution, without disturbing the associated spatial structure. The isolated node acts as a "cataloging" node functioning at a scale different from the content it catalogues (the term "isolated" will therefore be reserved for the graph-theoretic case; when viewed in a geographic context, the "isolated" node will be referred to as a "cataloging" node to emphasize this role).

Consider three disjoint sets of nodes, A, B, and C, with a linear linkage pattern joining each (Figure 5). The linear linkage pattern of each path is based on some serial arrangement of data, such as data ordered by longitude from east to west.

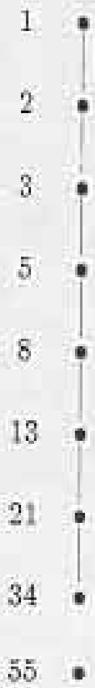

Figure 4.
$G^+(S_3)$: A Fibonacci sum graph containing a path and an isolate

It is not difficult to obtain the paths, P_3, P_4, P_5 of Figure 5 as three distinct sum graphs using Theorem 2. Fibonacci labelling of the nodes of Figure 5, shown in Figure 6, generates (as sum graphs) exactly the path-patterns of Figure 5; e.g., the edge joining 2 to 3 in A is present because $2+3=5$ is also a node label. An additional node, a cataloging one, is necessarily introduced in each sum-graph, A, B, and C of Figure 6. When the label of a cataloging node is used as a label for an entire configuration, this sum graph represents not only the linear linkage within the path, but also, at the same time, represents information (as a label) for the entire path. Information at different cartographic scales is displayed simultaneously.

In Figure 6, the simple Fibonacci labelling scheme of Theorem 2 produced three distinct sum graphs. Because the same labels are re-used, it would not be possible to compare information concerning these distinct sum graphs. Stronger theoretical results follow: results that will permit such comparison, while retaining the desirable asset of simultaneous display of data at different cartographic scales.

Consider, as a whole, the set of twelve nodes from Figure 5. Find a strategy for labelling these nodes that will produce exactly the three paths of Figure 5 as subgraphs of a single sum graph. Viewing the three parts of Figure 5 as subgraphs of a *single* sum graph will guarantee distinct labels for distinct nodes while retaining scale-shift characteristics.

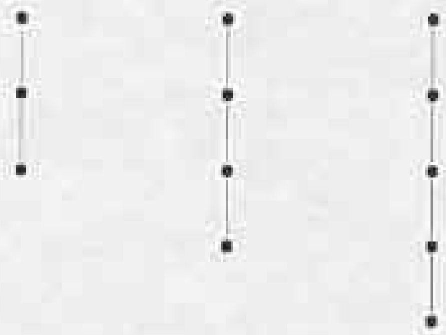

Figure 5.
Three graphs, Left, Middle, and Right, representing serial linkage of data.

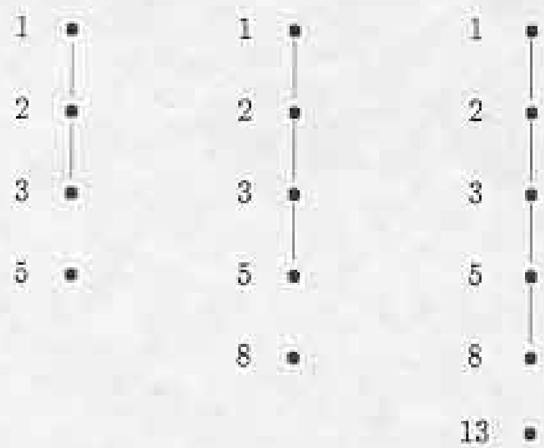

Figure 6.
The three distinct Fibonacci sum graphs showing the paths
P_3 (on the left), P_4 (middle), and P_5 (right).

One way to achieve such a labelling is as follows. Assign Fibonacci numbers consecutively (starting with 1) to the nodes of one subgraph (A, in Figure 7). Continue this scheme to a node of subgraph B; thus, in Figure 7, A has nodes with labels 1, 2, 3 and one node in B has label 5. It might be natural to label the next node in B with the next Fibonacci number — 8. However, this would introduce an unwanted edge between 3 and 5. So, label the next node with one more than the next Fibonacci number — in this case 9 — to remove the possibility of introducing unwanted edges. Label the remaining nodes in the Fibonacci-style with 5 and 9 as the first two elements. Continue this scheme through to one node of subgraph C (labels 14, 23, and 37 are thus introduced). The second node in the third subgraph must not be labelled 60, or else an unwanted edge is introduced linking 23 to 37. Call the label of the second node "61". Continue labelling in the Fibonacci style using 37 and 61 as the first two elements of a Fibonacci-style label-generating scheme. In the case of Figure 7, all nodes are now labelled; a single extra node, which is a cataloging one, is also labelled. All paths of this single sum graph are exactly those desired. The label associated with the cataloging node, 416, is the catalogue number for the entire configuration; other labels describe the local, linear linkage patterns. Distinct labels correspond to distinct nodes in such a way that only desired paths are introduced between nodes. A single added cataloging node permits associating information with a label for this node at the scale of the entire configuration — in the manner of object-oriented data structures.

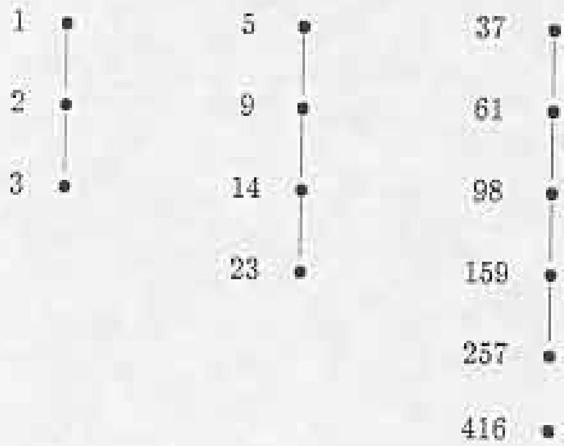

Figure 7.
A Fibonacci-style of labelling for a sum graph with one cataloging node (416) showing the paths P_3 (on the left), P_4 (middle), and P_5 (right) as subgraphs.

Thus, two levels of variability in resolution are displayed — that of the linkage pattern within individual subgraphs, and that of the weight of the entire graph, reflecting to some extent on the size of the data set, and the style of its subgraphs and their pattern of internal connection (had the subgraph in the middle terminated at 14, the subgraph on the right (with an added edge) would have begun with 23 and had an isolated node with label 419).

Stronger yet would be to construct a single sum graph from which desired paths would emerge (as in Figure 7) and in which distinct paths would correspond to distinctly-labelled cataloging nodes as in Figure 6. The notion of wanting one cataloging node per desired path, in order to ensure greater variability in resolution, motivates the following definition.

Definition 4

Suppose a set of n nodes is partitioned into t subsets. Further suppose k of these subsets contain more than one node. To each of these k subsets add a node. The resulting t subsets will be called "constellations" (Figure 8).

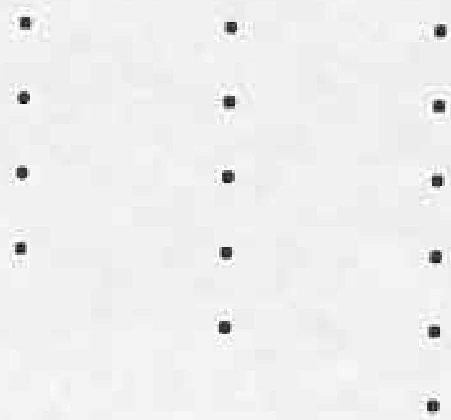

Figure 8.
Three constellations, Left, Middle, and Right, partition a distribution of nodes.

Now we return to the example of Figure 5, with three nodes added to make three constellations (all with more than one node, as in Figure 6). We seek some labelling for the entire set of constellation nodes (Figure 8), as nodes of a single sum graph, that will

1. produce the paths P_3, P_4, P_5;
2. produce cataloging nodes within the subgraphs containing P_3, P_4, P_5;
3. make retrieval of path structure simple.

Because there are paths that are to be retrieved as subgraphs of a single sum graph, some sort of Fibonacci or Fibonacci-style labelling will be needed (Theorem 2). The labels from Figure 5 cannot be chosen because under that circumstance distinct nodes do not have distinct labels. Theorem 1 suggests that distinctness in labelling as well as retention of path structure is achieved by multiplying Fibonacci numbers by constants. Thus, the issue is to know what values to choose as these "multipliers" so that distinctness of node labels (required by Definition 1) is ensured. Example 5, below, suggests a general construction that will satisfy these conditions. It will be proved in full generality in Theorem 3.

Example 5

1. To ensure path structure, give the underlying Fibonacci label pattern of 1,2,3,5; 1,2,3,5,8; 1,2,3,5,8,13 to, respectively, the left, middle, and right constellations (Definition 4) in the node pattern of Figure 8. To produce a set of suitable multipliers for these nodes, proceed to step 2.

2. Choose the smallest prime number greater than the sum of the largest and next largest

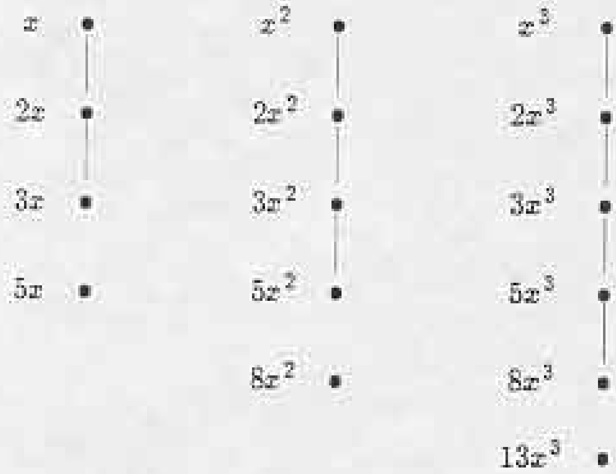

Figure 9.
Sum graph derived from Figure 6 using the base multiplier and its powers, writing $x = 23$ for brevity.

numbers used in the underlying Fibonacci pattern. In this case, 13 is the largest number in the underlying Fibonacci pattern and 8 is the next largest, so choose 23, the smallest prime number larger than 13+8=21 (choosing 21 would introduce an unwanted edge). This number will be the multiplier for one constellation (in this case, we arbitrarily choose to use it for the left-hand constellation).

3. Use successive powers of 23 (23 functions therefore as a base-multiplier) to label the nodes of successive constellations. In this case, 23^2 is used as the multiplier for the right-hand constellation. The nodes are now labelled as shown in Figure 9.

When this set of nodes is used as the set S of Definition 1, the resulting sum graph is isomorphic to the union of the three sum graphs in Figure 5. The fact that three cataloging nodes are introduced by this procedure gives an indication from each coefficient of the cataloging nodes of size, shape, and connection pattern of the subgraph it represents (as did the single cataloging node of 416 for the entire graph in Figure 7). The set of steps in Example 5 may be stated more generally as in the Construction below.

3. Cartographic Application of Sum Graph Unification

The following application will show how the labelling produced by the Sum Graph Unification Construction might be used. Consider a set of seven North American cities together with selected suburbs of those cities (Table 1.1). Column 1 in Table 1.1 lists these cities and suburbs in seven groups as metropolitan areas (the latter named in all upper case letters): constellations. To consider the east-west extent a proposed metropolitan mass transit system might need to cover, the longitude is also associated with each location (in column 2 of Table 1.1). The sequential ordering of cities and suburbs, by longitude from east to west, describes a path within each constellation linking these nodes. The metro area node is a cataloging

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Construction: Sum Graph Unification

Given a set of nodes partitioned into constellations. To ensure a prescribed path structure linking the nodes, that can be retrieved electronically entirely (only) from the numerical characteristics of the labels for the nodes, assign labels in the following manner.

1. Label the nodes of each constellation with Fibonacci numbers, in order, beginning with the label "1" in each constellation.

2. Find a base multiplier for each Fibonacci label. Form the sum of the two largest labels from step 1. The smallest prime number greater than this sum will serve as a multiplier. Use this prime base multiplier as the multiplier for labels of the nodes in one constellation.

3. Use successive powers of the prime in step 2 as multipliers for labels of the nodes in successive constellations.

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node not hooked into the path. Column 3 associates a Fibonacci number with each node of the entire distribution of nodes (step 1 in the Construction). Column 4 shows weights for the nodes by constellation; 37 is the base multiplier because it is the smallest prime greater than 21+13 (steps 2 and 3 in the Construction). Column 5 shows the product of columns 3 and 4; distinct nodes have distinct labels.

Suppose the entire list is rearranged by longitude, independent of constellation; positions of data within all but the New Orleans constellation remain the same. In the New Orleans constellation, the suburb of Metairie is shifted from the New Orleans constellation to the St. Louis constellation (between E. St. Louis and Lemay). That Metairie jumps metropolitan area is evident from the factored weight associated with it: it belongs to constellation 7, that of New Orleans, as its exponent in the factored weight shows (Table 1.2). Thus, the sum graph node label shows that it is out of regional order and provides a direct means to re-sort it back into regional order. Rank-ordering or other conventional means would not do so; rank ordering does not show which city belongs in which constellation. These sum graph node labels offer a way to organize data and to retrieve predetermined sequential order of information from a jumbled data set. The node labels are somewhat large in magnitude, but that is irrelevant in this particular application. It may be important in others, and thus it is to this issue and to the related one of data compression that the remainder of the material is directed.

4. Sum Graph Unification: Theory

The example above may prove a useful source of mental reference points on which to base the formal proof of the following lemmas needed to probe Theorem 3 below. The first Lemma will prove that there are no unwanted edges linking nodes within constellations and the second one will prove that there are no edges linking nodes between constellations.

For the most part, Theorem 3 is just a formalization of the method developed in the example based on Figure 9. However, additional details are necessary to allow for constellations of a single node (in these cases no new node is added). One might interpret such a node as a small city with no suburbs. (Readers wishing to examine the rigor of this method should read Theorem 3 and associated material with care; others might wish to skip to the next section.)

Lemma 3a

Let a, b, c, i, j be positive integers. If $p > a + b$, and $p > c$, it is impossible for $a \cdot p^i + b \cdot p^i = c \cdot p^j$ if $j \neq i$.

Proof

Note that $a \cdot p^i + b \cdot p^i = (a+b)p^i < p^{i+1} \leq c \cdot p^j$ if $j > i$. Similarly, if $j < i$, $c \cdot p^j < p^i < a \cdot p^i + b \cdot p^i$. Thus, in either case, the equation of the lemma is impossible.

NOTE: We will want to choose p greater than the sum of the largest two occurring Fibonacci numbers. For example, suppose 21 is the largest occurring Fibonacci number. Then $21 \cdot 23^a + 2 \cdot 23^a = 23^{a+1}$, so using 23 as the base multiplier would introduce an edge between the nodes $21 \cdot 23^a$ and $2 \cdot 23^a$.

Lemma 3b

Let a, b, c be positive integers, $p > a + b$. Let x, y, z be positive integers, $x \neq y$. Then $a \cdot p^x + b \cdot p^y = c \cdot p^z$ is impossible.

Proof:

Without loss of generality, assume $x < y$. Then, $p^y < a \cdot p^x + b \cdot p^y < (a+b)p^y < p^{y+1}$. Thus, for the equation to be possible, $z = y$. But then $a \cdot p^x \equiv 0 (\mathrm{mod} p)$, which is impossible, since $ap^x < p^{x+1} \leq p^y$.

We now formalize the ideas exhibited in the construction of Example 3.

Definition 5 (Harary, 1970)

A linear tree is a path. A linear forest is a union of disjoint linear trees.

Theorem 3 (Fibonacci sum graph unification)

Suppose we are given a set of n nodes, which are partitioned into t subsets, k of which contain more than a single node. Then there is a set S of $n + k$ suitably chosen positive integers whose sum graph $G^+(S)$ consists of t isolates (k additional nodes and $t - k$ nodes from single-node subsets) together with a linear forest of k nontrivial paths.

Proof:

Suppose that the n original nodes are $a_1, a_2, \ldots, a_n$. Divide these into the t desired subsets

$$\{x_{11}, x_{12}, \ldots x_{1n_1}\}$$

$$\{x_{21}, x_{22}, \ldots x_{2n_2}\}$$

$$\ldots$$

$$\{x_{t1}, x_{t2}, \ldots x_{tn_t}\}$$

where $n_1 + n_2 + \cdots + n_t = n$. Let $N = 2 + \max\{n_1, n_2, \ldots, n_t\}$. Let p be the smallest prime greater than F_N, the Nth Fibonacci number. Now label $n + k$ nodes as follows:

1. If $n_i = 1$, label x_{i1} with p^i (subsets with exactly one node).
2. If $n_i \neq 1$, label x_{i1} with p^i, x_{i2} with $2p^i, \ldots x_{in_i}$ with $p^i F_{n_i}$, and a new node y_i with $p^i F_{(1+n_i)}$ (subsets with more than one node).

Follow this procedure for all i, $1 \leq i \leq t$. Let S consist of the original nodes together with the new y_is. Now consider constellations consisting of the nodes labelled x_i if $i = 1$ and the nodes $\{x_{i1}, \ldots, x_{in}, y_i\}$ is $i \neq 1$. Then Theorems 1 and 2 assure that there are Fibonacci paths $x_{i1}, x_{i2}, \ldots x_{in}$ and that y_i is not adjacent to x_{ia} for any a $(1 \leq a \leq n_i)$. Lemma 3a assures that there are no edges within a constellation other than the Fibonacci path. Lemma 3b assures that there are no edges between constellations. Thus, the theorem is proved.

5. Logarithmic Sum Graphs

The procedure displayed in the Construction, and proved in Theorem 3, meets the criteria of producing desired paths, from the labelling scheme alone, each with a corresponding cataloging node, as subgraphs of a single sum graph. In cases based on large data sets, the multipliers get very large very quickly. However, if the logarithm (using the base multiplier, x, as the base of the logarithm) of each label is taken, this issue of apparent significance vanishes (Table 2). In the example on which Figure 9 was based, the values of the multipliers transformed by the log base 23 display clearly the constellation structure. The nodes associated with all entries with integral part "1" are grouped in a constellation, all with integral part "2" in another, and all with integral part "3" in yet another. The integral values serve as a data "key" to this data structure. The fractional values are, of course, the same from subset to subset, exhibiting the same underlying Fibonacci linkage pattern from subset to subset. The largest value in each subset is the cataloging node; if other nodes were to be included in, for example, the third constellation, those also would have a logarithmic value greater than 3.8180367 but less than 4. Thus, independent of how many nodes there are in a single constellation, all the logarithmic labels are contained in a band of real numbers one unit wide: 3 is a greatest lower bound (which is attained), and 4 is an upper bound for labels in the third constellation. Further, the logarithmically - transformed labels increase additively: there are only as many different data keys as there are different constellations.

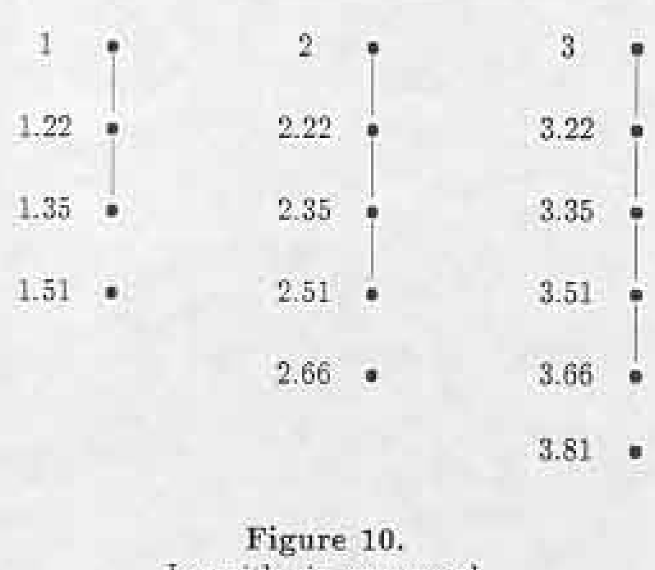

Figure 10.
Logarithmic sum graph

When these logarithmic labels are attached to the nodes of the graph in Figure 9 we refer to the resulting graph as a "logarithmic sum graph" (Figure 10). Note, however, that even though this graph is isomorphic to the sum graph of Figure 9, it is not itself a sum graph (in much the way that a truncated cone is not itself a cone, even though it is derived from a cone).

From a purely theoretical standpoint, it is possible to identify the constellation to which a node belongs very simply from its assigned multiplier. For, if p is the base multiplier, a node whose multiplier is $N = a \cdot p^k$ has $k \leq \log_p N \leq k+1$, since $a < p$. Thus, a node with multiplier N belongs to constellation k if and only if $[\log_p N] = k$ (where brackets denote the greatest integer function). (From a computer standpoint, one must be careful, since occasionally computational error might make $\log_p p^k < k$ computationally. Adding a suitably small amount to $\log_p N$ before determining its constellation should avert this difficulty.) In fact, it seems easier computationally to store $\log_p N$ rather than N as a multiplier, since then much smaller numbers can be stored. This motivates the following formal characterization of logarithmic sum graphs.

Definition 6

Let S be a set of n distinct positive integers, p a prime. Define the *logarithmic sum graph*, relative to p, $G^+(\log_p S)$ as follows:

1. $G^+(\log_p S)$ has n nodes, labelled with the n different labels $\{\log_p x \mid x \in S\}$.
2. there is an edge between two nodes labelled a and b if $p^a + p^b \in S$.

Logarithmic sum graphs retain all the advantages afforded by Theorem 3, and they make it possible to handle large data sets more easily.

6. Reversed Sum Graphs.

In the procedure of Theorem 3, and in the logarithmic modification of that procedure to accommodate large data sets, the cataloging nodes all have the largest labels within their subgraph. It might be useful, in some situations, for the cataloging nodes to have the smallest labels within their subgraphs. For this purpose, we define the notion of a "reversed" sum graph.

Definition 7

Let S be a set of positive integers such that the sum graph $G^+(S)$ [logarithmic sum graph $G^+(\log_p S)$] is partitioned into constellations such as those of Theorem 3. Define the *reversed sum graph* $^+G(S)$ [*reversed logarithmic sum graph* $^+G(\log_p S)$], isomorphic to $G^+(S)$ [$G^+(\log_p S)$], as follows. If the nodes in a given constellation have labels $a_1 < a_2 < \ldots < a_p$, relabel them $a_p, a_{p-1}, \ldots, a_1$. That is, the node labelled a_i is given the new label a_{p+1-i}. (Note that single-node constellations are not affected.)

Example 6

Let $S_4 = \{1, 2, 3, 5, 8, 13\}$. The graphs $G^+(S)$, $^+G(S)$ are displayed in Figure 11. (As in the case of the logarithmic sum graph, note that a reversed sum graph (Definition 7) is not itself a sum graph.)

As Definition 7 suggests, logarithmic sum graphs may also be reversed. Figure 12 shows the logarithmic sum graph of Figure 10 and its reversed logarithmic sum graph. Reversed sum graphs, logarithmic or not, always assign an integer, the data key, to the cataloging node.

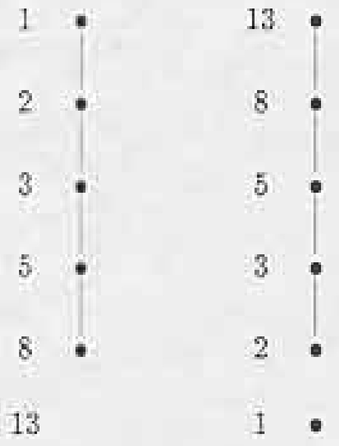

Figure 11.
A Fibonacci sum graph $G^+(S)$ (left)
and its reversed sum graph $^+G(S)$ (right).

This feature is particularly important in the case of the logarithmic representation, when data might be added to or deleted from a single subgraph, all with integral part of their labels identical to that of the cataloging label.

7. Augmented Reversed Logarithmic Sum Graphs

Reversed logarithmic sum graphs single out cataloging nodes as the only nodes with integral labels. It may be useful to consider linkages within the set of cataloging nodes and to "augment" the reversed logarithmic sum graph with edges displaying these linkages (Figure 13).

Definition 8

The *augmented reversed logarithmic sum graph, ARL sum graph*, denoted $^+A(\log_p S)$, consists of the nodes and edges of $^+G(\log_p S)$ together with all edges linking the nodes with integer labels in $^+G(\log_p S)$. Thus, $^+A(\log_p S) = {}^+G(\log_p S) \cup \{$ complete graph on nodes with integer labels in $^+G(\log_p S)\}$.

If m is the number of nodes with integer labels in $^+G(\log_p S)$, this augmentation adds $\binom{m}{2}$ edges to the reversed sum graph $^+G(\log_p S)$. The ARL sum graph is not itself a sum graph. Augmented reversed logarithmic sum graphs retain all the characteristics of Theorem 3, have the computational advantage of logarithmic sum graphs in handling large data sets, permit the reverse sum graph strategy of integral labelling of the cataloging node, and have the added feature of displaying the complete linkage pattern among cataloging nodes. Linkage patterns emerge both at the local scale and at the more global cataloging scale.

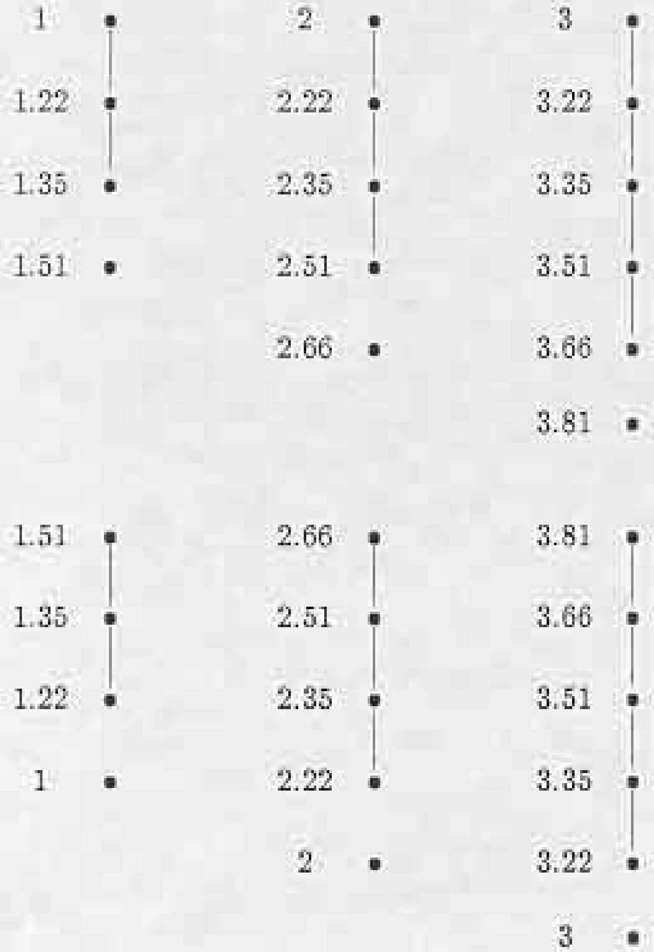

Figure 12.
Logarithmic sum graph (top) and reversed logarithmic sum graph (bottom).

8. Cartographic Application of ARL Sum Graphs

The labels of Table 1.1, derived from the Sum Graph Unification Construction, offer a way to organize data and to retrieve predetermined sequential order of information from a jumbled data set. The relative sizes of the weights for the nodes in Table 1.1 are, however, awkward. A simple way to overcome this awkwardness is to take the logarithm of the node weights (to the base of the base multiplier). Thus, in Table 3, column 6 shows the $\log_{37}$ of each node weight determined in Table 1.1 (listed in column 5 of Table 3). The constellation number is easily read off as the integral part of the logarithm and all entries for a single constellation are contained within a band of values one unit wide. When the labels are reversed, the integral label corresponds to the cataloging node. This reversed logarithmic sum graph (represented by Table 3) retains the favorable characteristics of Table 1.1 for

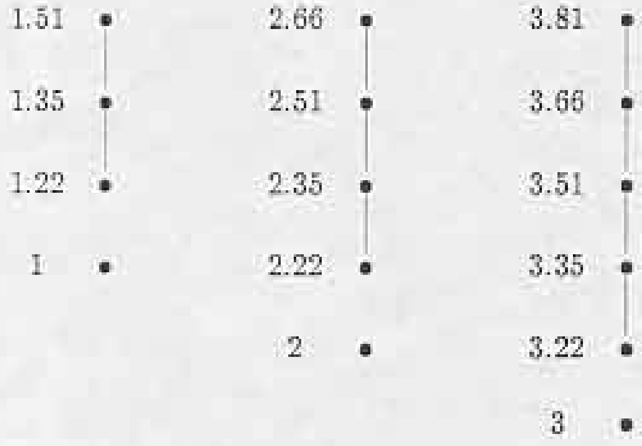

Figure 13.
ARL sum graph derived from a reversed logarithmic sum graph
Reader should draw edges joining nodes 1 and 2, 2 and 3, and 1 and 3

sorting of data; the node labelling scheme of Table 3 is, however, easy to handle.

The augmentation afforded by ARL sum graphs permits significant compression of data, particularly in large data sets, as it retains the favorable characteristics of the reversed logarithmic sum graph noted above. To illustrate this capability, we present the following application.

Consider the set of 39 cities and metropolitan regions labelled in Table 1.1. One set of data that is often stored is distances between places ("distance" is used as an example). Generally this set is stored in a square array, or better, sometimes in an upper- or lower-triangular matrix.

Sum graphs can reduce greatly the number of entries that need to be stored. Table 4.0 shows a complete set of great-circle distances between metropolitan areas. Each metropolitan area is assigned the latitude and longitude of the city for which it is named. Thus, particular sets of geographic coordinates are viewed simultaneously at two different scales. Tables 4.1 to 4.7 show complete sets of great-circle distances among the cities in each of the seven metropolitan areas (constellations).

The distance between Livonia and Scarborough (for example), which does not appear directly in any of the set of Tables in Table 4, may nonetheless be obtained by summing the distances from Livonia to DETROIT, from DETROIT to TORONTO, from TORONTO to Scarborough (Figure 14). The algorithm displayed in Figure 14 shows how to use the reversed logarithmic node label of two arbitrary nodes to determine the distance between them using only the entries in Table 4.0, between metropolitan areas (constellations), and in Tables 4.1-4.7 (showing local linkages within each constellation). The distance so-obtained is not itself a great-circle distance but it may well be a distance more realistically representing current air-travel circumstances.

Figure 14.

Commutative diagram showing distance calculation scheme using Table 4; algorithm showing how to find distance within Table 4 using the data key provided by the reversed logarithmic sum graph label.

Algorithm

1. Assumption: the cataloging city is also the city with the lowest non-integral label in its constellation.
2. Find the distance from a city with a node with reversed logarithmic sum graph label $j.x$ to one with label $k.y$, $j \leq k$ (and $x < y$ if $j = k$)

a. If $j = k$, use Table $4.j$ to find the distance from $j.x$ to $j.y$.

b. If $j < k$,

  i. use Table 4.0 to find distance between cataloging cities j and k.

  ii. use Table $4.j$ to find distance from j.lowest to $j.x$.

  iii. use Table $4.k$ to find distance from k.lowest to $k.y$.

Add the results of i, ii, and iii to find the required distance.

There are 32 different cities in this example. An upper-triangular 32 by 32 matrix of $\binom{32}{2} = 496$ different entries would normally be required to find between-city distances. Using the sum graph method, shown in the algorithm of Figure 14, requires the use of 8 smaller Tables: Table 4.0 for distances between cataloging node cities and Table $4.i$, $1 \leq i \leq 7$, for distances of cities in constellation i from cataloging city i. The latter procedure, composed of smaller matrices, requires storing (from each matrix) a total of

$$\binom{7}{2} + \binom{6}{2} + \binom{4}{2} + \binom{5}{2} + \binom{6}{2} + \binom{5}{2} + \binom{3}{2} + \binom{3}{2}$$

$= 21 + 15 + 6 + 10 + 15 + 10 + 3 + 3 = 83$ separate entries. In this case, sum graph methods afford a compression ratio of about 6 to 1 over traditional methods.

With larger data sets, the compression ratio becomes much more substantial. Given a data set of 10,000 entries to be partitioned into 100 constellations of 100 entries each, traditional methods using an upper triangular matrix would require that $\binom{10{,}000}{2} = 49,995,000$ entries be stored. Sum graph methods would require storing $\binom{100}{2}$ entries for Table 4.0 and $\binom{100}{2}$ entries for each of Tables $4.i$, $1 \leq i \leq 100$, for a total of $101 \cdot \binom{100}{2} = 499,950$ entries.

In this case the compression ratio is 100 to 1. If instead the 10,000 entries are partitioned in a different manner, different compression ratios result. If 1000 constellations of 10 entries each are used, the corresponding compression ratio is 91.8 to 1; if 10 constellations of 1000 each are used, the compression ratio is 10.09 to 1. Clearly the manner in which the partition is selected is important. Larger data sets bring even larger compression ratios: if 1,000,000 data points are considered, and are partitioned into 1000 constellations of 1000 each, the corresponding compression ratio is 1000 to 1.

Any process of this sort also needs to accommodate the insertion of new data; when it does so without having to alter existing structure, it is "dynamic." The Sum Graph Unification Construction is dynamic to an extent. Table 5 shows part of the data set of Table 3 with Ann Arbor added to the Detroit metro area. Only the one constellation needs relabelling; all others remain undisturbed. If, however, enough new entries had been added to force an increase in the prime base multiplier, then a global change would have been required for that single entry (generally easy to achieve electronically). None of the formulæ would have required alteration.

"Dynamic" tables of this sort might see application as on-board mapping systems in cars or buses giving optimum route displays in an interactive mode (so-called IVHS or other commonly-used acronyms). So data becomes accurate more quickly in response to changing traffic patterns transmitted to the vehicle in some sort of interactive fashion. Advances in theory can bring advances in technology to the level of affordable cost and widespread application. The application of sum graphs might be one effort in that direction.

9. Summary

We have taken a tool from graph theory and specialized it in a number of directions in order to deal with various types of problems that often arise with data structures. Table 6 organizes these specializations in capsule format. Independent of how the sum graph is specialized to adapt to various difficulties in data management, however, the linkage pattern between nodes in a sum graph is determined by node weight alone, which is derived from whether or not one node is linked to another. There is no reliance on geographic direction or on any sort of other relative ordering based on the underlying space in which the nodes are embedded. Hence, the sum graph data structure has a theoretical base free from directional bias and is perhaps therefore, translation invariant. Determining whether or not this theoretical data structure offers a graphical application at the level of GIS theory–as in the quadtree) that permits translational invariance of the structure (independent of pixel shape) under GIS constraints, appears a significant next step in bringing theory into practice.

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TABLE 1.1:
Analysis according to sum graph unification construction

City Suburb METRO	LONG-ITUDE west	FIBO-NACCI LABEL	BASE MULTI-PLIER	FACTORED WEIGHT	NODE WEIGHT	RANK ORDER
Salem	70 54	1	37	$1 \cdot 37$	37	1
Lynn	70 57	2	37	$2 \cdot 37$	74	2
Quincy	71 00	3	37	$3 \cdot 37$	111	3
Brockton	71 01	5	37	$5 \cdot 37$	185	4
Cambridge	71 07	8	37	$8 \cdot 37$	296	5
Boston	71 07	13	37	$13 \cdot 37$	481	6
BOSTON		21	37	$21 \cdot 37$	777	7
Longueuil	73 30	1	37^2	$1 \cdot 37^2$	1369	8
Verdun	73 34	2	37^2	$2 \cdot 37^2$	2738	9
Montreal	73 35	3	37^2	$3 \cdot 37^2$	4107	10
Laval	73 44	5	37^2	$5 \cdot 37^2$	6845	11
MONTREAL		8	37^2	$8 \cdot 37^2$	10952	12
Camden	75 06	1	37^3	$1 \cdot 37^3$	50653	13
Philadelphia	75 13	2	37^3	$2 \cdot 37^3$	101306	14
Upper Darby	75 16	3	37^3	$3 \cdot 37^3$	151959	15
Norristown	75 21	5	37^3	$5 \cdot 37^3$	253265	16
Chester	75 22	8	37^3	$8 \cdot 37^3$	405224	17
PHILADELPHIA		13	37^3	$13 \cdot 37^3$	658489	18
Scarborough	79 12	1	37^4	$1 \cdot 37^4$	1874161	19
Toronto	79 23	2	37^4	$2 \cdot 37^4$	3738322	20
North York	79 25	3	37^4	$3 \cdot 37^4$	5622483	21
York	79 29	5	37^4	$5 \cdot 37^4$	9370805	22
Etobicoke	79 34	8	37^4	$8 \cdot 37^4$	14993288	23
Mississauga	79 37	13	37^4	$13 \cdot 37^4$	24364093	24
TORONTO		21	37^4	$21 \cdot 37^4$	39357381	25
Windsor	83 00	1	37^5	$1 \cdot 37^5$	69343957	26
Warren	83 03	2	37^5	$2 \cdot 37^5$	138687914	27
Detroit	83 10	3	37^5	$3 \cdot 37^5$	208031871	28
Dearborn	83 15	5	37^5	$5 \cdot 37^5$	346719785	29
Livonia	83 23	8	37^5	$8 \cdot 37^5$	554751656	30
DETROIT		13	37^5	$13 \cdot 37^5$	901471441	31
E. St. L.	90 10	1	37^6	$1 \cdot 37^6$	2565726409	32
St. Louis	90 15	2	37^6	$2 \cdot 37^6$	5131452818	33
Lemay	90 17	3	37^6	$3 \cdot 37^6$	7697179227	34
ST. LOUIS		5	37^6	$5 \cdot 37^6$	12828632045	35
New Orleans	90 05	1	37^7	$1 \cdot 37^7$	94931877133	36
Marrero	90 06	2	37^7	$2 \cdot 37^7$	189863754266	37
Metairie	90 11	3	37^7	$3 \cdot 37^7$	284795631399	38
NEW ORLEANS		5	37^7	$5 \cdot 37^7$	474659385665	39

TABLE 1.2:
Analysis according to sum graph unification construction
Two constellations ordered from east to west by longitude

City Suburb METRO	LONG-ITUDE west	FIBO-NACCI LABEL	BASE MULTI-PLIER	FACTORED WEIGHT	NODE WEIGHT	RANK ORDER
New Orleans	90 05	1	37^7	$1 \cdot 37^7$	94931877133	36
NEW ORLEANS		5	37^7	$5 \cdot 37^7$	474659385665	39
Marrero	90 06	2	37^7	$2 \cdot 37^7$	189863754266	37
E. St. Louis	90 10	1	37^6	$1 \cdot 37^6$	2565726409	32
Metairie	90 11	3	37^7	$3 \cdot 37^7$	284795631399	38
St. Louis	90 15	2	37^6	$2 \cdot 37^6$	5131452818	33
ST. LOUIS		5	37^6	$5 \cdot 37^6$	12828632045	35
Lemay	90 17	3	37^6	$3 \cdot 37^6$	7697179227	34

TABLE 2:
Multipliers and their logarithms to the base of the base multiplier of 23 for the example of Figure 7.

Multiplier	Logarithm, base 23
$1 \cdot 23 = 23$	1
$2 \cdot 23 = 46$	1.2210647
$3 \cdot 23 = 69$	1.3503793
$5 \cdot 23 = 115$	1.5132964
$1 \cdot 23^2 = 529$	2
$2 \cdot 23^2 = 1058$	2.2210647
$3 \cdot 23^2 = 1587$	2.3503793
$5 \cdot 23^2 = 2645$	2.5132964
$8 \cdot 23^2 = 4232$	2.6631942
$1 \cdot 23^3 = 12167$	3
$2 \cdot 23^3 = 24344$	3.2210647
$3 \cdot 23^3 = 36501$	3.3503793
$5 \cdot 23^3 = 60835$	3.5132964
$8 \cdot 23^3 = 97336$	3.6631942
$13 \cdot 23^3 = 158171$	3.8180367

TABLE 3:
Table 1.1 labelled as a reversed logarithmic sum graph

City Suburb METRO	LONG-ITUDE	FIBO-NACCI LABEL	BASE MULTI-PLIER	FACTORED WEIGHT	NODE WEIGHT	LOG BASE 37 NODE
Salem	70 54	21	37	$21 \cdot 37$	777	1.746657
Lynn	70 57	13	37	$13 \cdot 37$	481	1.629043
Quincy	71 00	8	37	$8 \cdot 37$	296	1.509974
Brockton	71 01	5	37	$5 \cdot 37$	185	1.394708
Cambridge	71 07	3	37	$3 \cdot 37$	111	1.269430
Boston	71 07	2	37	$2 \cdot 37$	74	1.169991
BOSTON		1	37	$1 \cdot 37$	37	1
Longueuil	73 30	8	37^2	$8 \cdot 37^2$	10952	2.509974
Verdun	73 34	5	37^2	$5 \cdot 37^2$	6845	2.394708
Montreal	73 35	3	37^2	$3 \cdot 37^2$	4107	2.269430
Laval	73 44	2	37^2	$2 \cdot 37^2$	2738	2.169991
MONTREAL		1	37^2	$1 \cdot 37^2$	1369	2
Camden	75 06	13	37^3	$13 \cdot 37^3$	658489	3.629043
Phil.	75 13	8	37^3	$8 \cdot 37^3$	405224	3.509974
U. Darby	75 16	5	37^3	$5 \cdot 37^3$	253265	3.394708
Norris.	75 21	3	37^3	$3 \cdot 37^3$	151959	3.269430
Chester	75 22	2	37^3	$2 \cdot 37^3$	101306	3.169991
PHILADELPHIA		1	37^3	$1 \cdot 37^3$	50653	3
Scar.	79 12	21	37^4	$21 \cdot 37^4$	39357381	4.746657
Toronto	79 23	13	37^4	$13 \cdot 37^4$	24364093	4.629043
NYork	79 25	8	37^4	$8 \cdot 37^4$	14993288	4.509974
York	79 29	5	37^4	$5 \cdot 37^4$	9370805	4.394708
Etobicoke	79 34	3	37^4	$3 \cdot 37^4$	5622483	4.269430
Missi.	79 37	2	37^4	$2 \cdot 37^4$	3748322	4.169991
TORONTO		1	37^4	$1 \cdot 37^4$	1874161	4
Wind.	83 00	13	37^5	$13 \cdot 37^5$	901471441	5.629043
Warren	83 03	8	37^5	$8 \cdot 37^5$	554751656	5.509974
Detroit	83 10	5	37^5	$5 \cdot 37^5$	346719785	5.394708
Dearb.	83 15	3	37^5	$3 \cdot 37^5$	208031871	5.269430
Livonia	83 23	2	37^5	$2 \cdot 37^5$	138687914	5.169991
DETROIT		1	37^5	$1 \cdot 37^5$	69343957	5
ESLou	90 10	5	37^6	$5 \cdot 37^6$	12828632045	6.394708
SLou	90 15	3	37^6	$3 \cdot 37^6$	7697179227	6.269430
Lemay	90 17	2	37^6	$2 \cdot 37^6$	5131452818	6.169991
ST. LOUIS		1	37^6	$1 \cdot 37^6$	2565726409	6
NOrl	90 05	5	37^7	$5 \cdot 37^7$	474659385665	7.394708
Marr	90 06	3	37^7	$3 \cdot 37^7$	284795631399	7.269430
Meta	90 11	2	37^7	$2 \cdot 37^7$	189863754266	7.169991
NEW ORLEANS		1	37^7	$1 \cdot 37^7$	94931877133	7

TABLE 4.0: Distances between all metro areas

	BOS	MONT	PHIL	TOR	DET	SL	NO
BOSTON	0	255	263	429	615	1034	1349
MONTREAL		0	388	312	523	974	1394
PHIL			0	331	444	808	1086
TORONTO				0	211	662	1112
DETROIT					0	452	936
ST LOUIS						0	596
NEW ORLEANS							0

TABLE 4.1: Boston-area cities

	Salem	Lynn	Quincy	Brock.	Cambr.	Boston
Salem	0	4.29	19.1	31.6	15.3	21.4
Lynn		0	15.1	27.8	10.2	17.2
Quincy			0	12.6	10.9	5.96
Brock.				0	22.4	13.6
Cambr.					0	9.21
Boston						0

TABLE 4.2: Montreal-area cities

	Longue.	Verdun	Laval	Mont.
Longueuil	0	6.6	11.3	4.64
Verdun		0	9.29	3.54
Laval			0	7.35
Montreal				0

TABLE 4.3: Philadelphia-area cities

	Camden	Chester	U Darby	Norris.	Phila.
Camden	0	15.2	9.12	18.3	7.7
Chester		0	9.64	18.4	13.0
Upper Darby			0	11.2	3.5
Norristown				0	10.7
Philadelphia					0

TABLE 4.4: Toronto-area cities

	Scar.	Miss.	N. York	York	Etob.	Tor.
Scarborough	0	24.3	11.0	14.8	19.5	10.8
Mississauga		0	17.9	10.4	6.27	13.5
North York			0	7.66	11.8	8.23
York				0	4.75	5.12
Etobicoke					0	9.23
Toronto						0

TABLE 4.5: Detroit-area cities

	Windsor	Warren	Dear.	Livonia	Detroit
Windsor	0	16.3	12.8	20.7	9.18
Warren		0	20.0	19.3	13.9
Dearborn			0	10.5	6.27
Livonia				0	11.5
Detroit					0

TABLE 4.6: St. Louis-area cities

	E St. L.	Lemay	St. Louis
E. St. Louis	0	6.29	4.49
Lemay		0	1.79
St. Louis			0

TABLE 4.7: New Orleans-area cities

	Met.	Mar.	New O.
Metairie	0	7.61	5.98
Marrero		0	5.84
New Orleans			0

TABLE 5:
New data added — Ann Arbor

City Suburb METRO AREA	LONG-ITUDE	FIBO-NACCI LABEL	BASE MULTI-PLIER	FACTORED WEIGHT	NODE WEIGHT	LOG BASE 37 NODE
Wind.	83 00	21	37^5	$21 \cdot 37^5$	1456223097	5.746657
Warren	83 03	13	37^5	$13 \cdot 37^5$	901471441	5.629043
Detroit	83 10	8	37^5	$8 \cdot 37^5$	554751656	5.509974
Dearb.	83 15	5	37^5	$5 \cdot 37^5$	346719785	5.394708
Livonia	83 23	3	37^5	$3 \cdot 37^5$	208031871	5.269430
Ann Arbor	83 45	2	37^5	$2 \cdot 37^5$	138687914	5.169991
DETROIT		1	37^5	$1 \cdot 37^5$	69343957	5
ESLou	90 10	5	37^6	$5 \cdot 37^6$	12828632045	6.394708
SLou	90 15	3	37^6	$3 \cdot 37^6$	7697179227	6.269430
Lemay	90 17	2	37^6	$2 \cdot 37^6$	5131452818	6.169991
ST. LOUIS		1	37^6	$1 \cdot 37^6$	2565726409	6
NOrl	90 05	5	37^7	$5 \cdot 37^7$	474659385665	7.394708
Marr	90 06	3	37^7	$3 \cdot 37^7$	284795631399	7.269430
Meta	90 11	2	37^7	$2 \cdot 37^7$	189863754266	7.169991
NEW ORLEANS		1	37^7	$1 \cdot 37^7$	94931877133	7

TABLE 6:
Specializations of sum graphs

Type of graph	Characteristics
Sum graph (Figure 7)	Variable resolution at local and global scales, only. Shape, size, and connection pattern of parts to whole suggested by global label.
Sum graph with base multiplier (Figure 9)	Variable resolution at intermediate and global scales. Relative shape, size, and connection pattern of parts to whole suggested by multiple labels associated with split regions.
Logarithmic sum graph (Figure 10)	Confines sum graph labels to a single unit for each subgraph. Deals well with split regions; is not itself a sum graph. Label on cataloging node suggests relative shape, size, and connection pattern of parts to the whole
Reversed sum graph (Figure 11)	Not itself a sum graph. Sole function is to assign an integral value to the cataloging node of each subgraph.
Augmented reversed logarithmic sum graph (Figure 13)	Combines characteristics of logarithmic and reversed sum graphs. Added edges join cataloging nodes. Linkage patterns are suggested at local, intermediate, and global levels of resolution.

5. SAMPLE OF HOW TO DOWNLOAD THE ELECTRONIC FILE BACK ISSUES OF *SOLSTICE* NOW AVAILABLE ON FTP

This section shows the exact set of commands that work to download *Solstice* on The University of Michigan's Xerox 9700. Because different universities will have different installations of TEX, this is only a rough guideline which *might* be of use to the reader. (BACK ISSUES AVAILABLE using anonymous ftp to open um.cc.umich.edu, account GCFS; type cd GCFS after entering system; then type ls to get a directory; then type get solstice.190 (for example) and download it or read it according to local constraints.) Back issues will be available on this account; this account is ONLY for back issues; to write Solstice, send e-mail to Solstice@UMICHUM.bitnet or to Solstice@um.cc.umich.edu . Issues from this one forward are available on FTP on account IEVG (substitute IEVG for GCFS above).

First step is to concatenate the files you received via bitnet/internet. Simply piece them together in your computer, one after another, in the order in which they are numbered, starting with the number, "1."

The files you have received are ASCII files; the concatenated file is used to form the .tex file from which the .dvi file (device independent) file is formed. The words "percent-sign" and "backslash" are written out in the example below; the user should type them symbolically.

ASSUME YOU HAVE SIGNED ON AND ARE AT THE SYSTEM PROMPT, #.

create -t.tex

percent-sign t from pc c:backslash words backslash solstice.tex to mts -t.tex char notab

(this command sends my file, solstice.tex, which I did as a WordStar (subdirectory, "words") ASCII file to the mainframe)

run *tex par=-t.tex

(there may be some underfull (or certain over) boxes that generally cause no problem; there should be no other "error" messages in the typesetting–the files you receive were already tested.)

run *dvixer par=-t.dvi

control *print* onesided

run *pagepr scards=-t.xer, par=paper=plain

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TABLE OF CONTENT

1. WELCOME TO NEW READERS

Welcome to new subscribers! We hope you enjoy participating in this means of journal distribution. Instructions for downloading the typesetting have been repeated in this issue, near the end. They are specific to the TEX installation at The University of Michigan, but apparently they have been helpful in suggesting to others the sorts of commands that might be used on their own particular mainframe installation of TEX. New subscribers might wish to note that the electronic files are typeset files—the mathematical notation will print out as typeset notation. For example,

$$\Sigma_{i=1}^{n}$$

when properly downloaded, will print out a typeset summation as i goes from one to n, as a centered display on the page. Complex notation is no barrier to this form of journal production.

THANK YOU NOTES AND GOOD WISHES

Many thanks to the members of the Editorial Board of *Solstice*. Some of them have refereed articles and offered suggestions, as have others. Thanks to all. We send our very best wishes to Michael Goodchild.

In this issue, we announce the availability of *Solstice* on a GOPHER. Many thanks to Bruce Long of the Department of Mathematics of Arizona State University for his initiative in putting this journal on their GOPHER (PI.LA.ASU.EDU). It was kind of him to think of *Solstice* and his constructive actions are greatly appreciated.

So, too, are those of Eugene Fosnight of The University of Michigan, School of Natural Resources and Environment, for his aid in technical matters. Thanks, Gene!

2. PRESS CLIPPINGS—SUMMARY

Brief write-ups about *Solstice* have appeared in the following publications:

1. **Science**, "Online Journals" Briefings. [by Joseph Palca] 29 November 1991. Vol. 254.

2. **Science News**, "Math for all seasons" by Ivars Peterson, January 25, 1992, Vol. 141, No. 4.

3. **Newsletter of the Association of American Geographers**, June, 1992.

4. **American Mathematical Monthly**, "Telegraphic Reviews" — mentioned as "one of the World's first electronic journals using TEX," September, 1992.

5. **Harvard Technology Window**, 1993.

6. **Graduating Engineering Magazine**, 1993.

7. **On Internet**, 1994.

If you have read about *Solstice* elsewhere, please let us know the correct citations (and add to those above). Thanks. In addition, *Solstice* is an object of study in at least one Ph.D. dissertation. We are happy to share information with concerning electronic journal production and are delighted when others share with us, as well.

Publications of the Institute of Mathematical Geography have, in addition, been reviewed or noted in

1. *The Professional Geographer* published by the Association of American Geographers;

2. The *Urban Specialty Group Newsletter* of the Association of American Geographers;

3. *Mathematical Reviews* published by the American Mathematical Society;

4. *The American Mathematical Monthly* published by the Mathematical Association of America;

5. *Zentralblatt* fur Mathematik, Springer-Verlag, Berlin

6. *Mathematics Magazine*, published by the Mathematical Association of America.

7. *Newsletter* of the Association of American Geographer.

8. *Journal of The Regional Science Association.*

9. *Journal of the American Statistical Association.*

Villages in Transition: Elevated Risk of Micronutrient Deficiency

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ABSTRACT

Some researchers have suggested that as villages move from traditional living patterns emphasizing self-sufficiency, to ones featuring economic development, there is a vulnerable transition period in which families of the community are at greater health risk. This elevated risk results from many factors such as employment volatility, changes in food consumption patterns, composition of the extended family, temporary migration, and child rearing behavior. Elevated risk, if present, would strike hard at children who are most vulnerable and readily reflect adverse changes in family status.

Analysis of data from the Eastern Islands of Indonesia supports this hypothesis of elevated risk during transition. Villages in the study area were ranked by a classification system used in Indonesia to measure level of development ranging from traditional agricultural villages, to modern, market-oriented villages. This ranking system not only is related to the amount of infrastructure available in the community, but also includes many other factors. The approach followed takes advantage of the multitude of parameters measured in this study by portraying joint risk of vitamin A deficiency, iodine deficiency disorders, iron deficiency

anemia as well as other health indicators such as measles, worm infestation, and diarrheal diseases. By examining community-level prevalences for all three micronutrient deficiencies this methodology offers unique opportunity to study how the risk for these conditions covary at the community level, and thus provides important information for targeting communities with integrated control program activities. Amongst all villages with high prevalences of any of the three micronutrient deficiencies, there is about a 70% 'overlap' in risk between at least two of the three micronutrients, with 22% of the villages being at high risk for all three micronutrient deficiencies.

Villages in transition are shown to have higher prevalences of total goiter rate, lower mean hemoglobin levels, higher helminthic infection rates, and higher prevalences of wasting and underweight malnutrition, all at statistically significant levels. They also tend to have slightly higher prevalences of low serum retinol, although not statistically significant within the sample sizes in this study. While focusing upon villages in transition is but one type of targeting, there is a qualitative difference between this one and other targeting strategies. In this instance the targeting can be based upon *anticipating* the risk rather than reacting to risk estimates based on surveys. Because the government is both planner and resource allocator for its development programs, difficulties experienced during movement through a transition period can be monitored and dampened by allocating special integrated activities to the region receiving development assistance.

INTRODUCTION

Objectives of Study

As governments strive to maximize the effectiveness of their limited resources, the issue of identifying and targeting those most in need of health and nutrition assistance becomes paramount. This paper presents a unique approach to determining these needs for assistance. The approach combines recent theoretical developments in the field of population-environment dynamics with general resource allocation strategies to suggest a method for identifying high-risk population groups. As part of this inquiry, measurements of the extent of overlap among risk factors is made which can be utilized to improve the efficiency of program implementation. Perhaps most important, the methodology which is proposed permits governments to anticipate difficult problems so that preventive rather than solely curative measures can be taken in a timely manner.

This paper begins by describing the setting in which the study was undertaken. Next, the theoretical model is presented along with the possible applicability of the model to real world situations at hand. Third, data is used to determine whether the model has predictive capacity, and finally conclusions and policy implications stemming from the analyses are presented.

The Setting: The Eastern Islands of Indonesia

In 1990 the Government of Indonesia commissioned the Center for Nutritional Research and Development of Bogor, Indonesia to undertake a study on the health conditions of the Eastern Islands. Community Systems Foundation of Ann Arbor, Michigan was asked to provide technical assistance through the A.I.D. VITAL Field Support Project. The Government was especially concerned with deficiencies in micronutrients that were expected to be a strong contributing factor to poor health status of the children in those islands.

A cross-sectional prevalence study was carried out in October 1990 through June 1991. The purpose of the study was to gather data on the prevalence and distribution of specific micronutrient deficiencies, including vitamin A deficiency (VAD), iron deficiency anemia (IDA), iodine deficiency disorders (IDD), and protein energy malnutrition (PEM). It was planned that this information would be used for assistance in the targeting of specific nutrition and health interventions in these remote islands. The study provides the first substantial body of information regarding the prevalence of these conditions in the Eastern Islands.

The Eastern Island provinces of Indonesia include the islands east of Java and Kalimatan (Borneo), the island of Sulewesi (the Celebes), the islands of the province of Maluku, the islands of Irian Jaya, Nusa Tenggara Barat (NTB), Nusa Tenggara Timor (NTT), and Timor Timur (Tim Tim). However, only Maluku, NTT, Tim Tim, and Irian Jaya were selected for this study as these provinces were not fully represented in earlier surveys.

Most of the provinces are culturally distinct from the rest of Indonesia, as well as from each other. Dietary patterns, terrain, and climate also differ, leading to a belief that causes of malnutrition may differ from the rest of the country and among the four provinces.

Irian Jaya, the easternmost island, is populated by subsistence hill tribes whose intertribal warfare has kept development efforts at a minimum until they were released from Dutch Colonial domination in the early 1960s. In the last thirty years, the development of roads, communication networks, construction of schools and health centers have done much to bring this province more into the mainstream of Indonesian life. However, the population and their lifestyle is still quite different from most of the country. Through the transmigration of groups from Java to Irian Jaya, the population is now quite diverse representing a wide range of socioeconomic and cultural backgrounds.

Timor Timur (Tim Tim) is an even more recent addition to the Republic of Indonesia. Until 1974 it was under the jurisdiction of Portugal. In that year, Portugal divested itself of all its colonial possessions, including Tim Tim. Tim Tim was then integrated into the Republic of Indonesia, and for several years specific pockets of resistance to this integration made the expansion of governmental social welfare programs problematic. Under the Portuguese, very little effort was made to educate the rural population, and semi-feudal political systems kept power in the hands of a few rich Portuguese families living in the capital, Dili. The results of this survey suggest that Tim Tim has made progress and is in the process of expanding its rural social welfare systems.

The province of Maluku is the location of the original spice islands for which the European countries originally set sail to the Orient. Nutmeg and mace originated from the island of Banda (which is in this province), and cloves were found on the island of Ambon. During the 16th century this area was a site of confrontation between the Portuguese, the first Europeans to settle in the area, and the Dutch. Different islands in the province still display characteristics which have been adopted from these two western European nations.

Nusa Tenggara Timor (NTT), like Maluku, is one of the original provinces of Indonesia. It has a dryer climate than most of the country. Unlike the other eastern provinces, it has characteristics which are similar to those of the rest of the country, and its level of participation in social welfare programs is the highest of all the provinces in the survey.

Nutritional problems of the area

Vitamin A deficiency — Vitamin A deficiency has long been known to occur in Indonesia. Consequently, Indonesia has been one of the leaders in the world in research of this important problem. Blindness due to xerophthalmia had been the primary justification for these investments. However, in 1985, studies provided some evidence that sub-clinical VAD, even when not associated with nutrition blindness, leads to increased risk of mortality, thereby introducing and additional impetus for its control.

The island of Ambon in Maluku was included in the 1978 National Nutritional Blindness Survey, but the other four provinces were not surveyed because of logistic and cost constraints. The island of Biak was recognized as having high levels of xerophthalmia in 1981, due to the energetic efforts of the head of Kabupaten medical services. It was suggested that xerophthalmia might also be a problem in NTT in the early 1980s.

Nutritional Anemia — Of all the micronutrient deficiencies, nutritional anemia is undoubtedly the most widespread. However, its distribution and magnitude is least known throughout the country. Young children and pregnant and lactating women are the most likely to be at risk. Nutritional anemia has been associated with impaired cognitive and motor development of children, low birthweight, and increased risk for mortality in pregnant women as well as reduced productivity in adult males. Data generated from the present study provides the first population-based prevalence information on anemia available in the country.

Protein Energy Malnutrition — Protein Energy Malnutrition (PEM) is a problem associated with poor food availability and excessive infection. It is identified in children who are short for their age (stunted) and/or underweight for their age, and in some cases with diminished body mass for their stature (wasted). The method by which PEM has been assessed in this study is through anthropometry. The primary measurements taken were the height, weight, and age of preschool children. These different measures were then combined to form three indices: weight-for-age, height-for-age, and weight-for-height. Height-for-age is generally considered a measure of food availability and overall socioeconomic conditions during the development of the child, while weight-for-height (body mass on the frame of the child) is considered to better reflect insult to the child either due to illness or recent acute food shortage. Weight-for-age is a combination of these two indices, although limited since it fails to distinguish, thin children from short children with adequate muscle and fat in the classification of the undernourished.

Iodine Deficiency Disorders — Iodine deficiency disorders are a group of health and developmental problems associated with inadequate iodine intake. Historically, the magnitude of this problem has been measured by palpable goiter rates, which is the most obvious and specific symptom associated with low iodine intake. Among the other symptoms of IDD, cretinism (mental and developmental sub-normalcy) is found in areas in which iodine deficiency is endemic, and a whole spectrum of more subtle symptoms also have been attributed to insufficient iodine nutriture. These include reduced IQ, deafness, and delayed motor skill development. Several biochemical parameters are sometimes used to assess the magnitude of IDD including: urinary iodine, thyroid stimulating hormone (TSH), and levels of other thyroid hormones (T3 and T4).

The Study

The study focuses on vitamin A deficiency (VAD) in children in the age group 0 to 6 years. Ophthalmological examinations were carried out to look for clinical eye signs of VAD Blood collections were performed for the measurement of serum vitamin A in a 11% subsample. From blood samples taken, hemoglobin levels were also assessed. This same group of children were examined for protein energy malnutrition.

Pregnant women in the same communities were tested for anemia. Iodine deficiency disorders (IDD) were studied in elementary school children through examination for palpable goiter as well as through assessing iodine levels in urine specimens collected from a 10% subsample. From each sub-province (kecamatan) surveyed, two elementary schools were chosen which were located close to the village and census unit (wilayah) in order to examine children 0-6 years along with pregnant women.

Every pregnant woman chosen in the survey area was examined for general health conditions, goiter, and hemoglobin. Urine samples to check for iodine levels were not taken.

Data Processing and Analysis

The data was converted to electronic form using a customized computer and entry program equipped with built-in checks to minimize data entry error. In addition, several thorough rounds of data checking and cleaning were carried out, to ensure the internal validity of the data.

Table 1 lists the variables used in the present analysis. Using FoxPro Version 2.0 and SPSS-PC Version 3.0, these variables were created by aggregating household data up to the village level to derive community-level variables. From the 245 villages, 56.3% were accepted with loss due to missing values, leaving a total of 138 villages included in the analysis. Most of this data loss is due to the fact that iodine deficiency in schoolchildren was measured only in those villages with schools.

These continuous variables were chosen from the dataset to depict the nutrition and health of the sample population. The first two variables, MN-VITA and MN-HEMO represent sera data collected in preschoolers in Eastern Island villages from which the serum vitamin A levels and serum hemoglobin levels were assayed. These data were aggregated to the village level as mean serum vitamin A and hemoglobin levels.

MOVING FROM TRADITIONAL TO MODERN VILLAGE LIFE: RISKS DURING TRANSITION

Relative Health Risks at the Community Level

The determination of the prevalence of nutriture deficiency in the Eastern Islands marks the first stage in devising an effective intervention. Another critical element is the determination of the extent to which assistance can be targeted to high-risk populations. The findings of this survey show wide variation in health status among provinces and, more important, within each province. Such variation implies that considerable benefits might accrue from targeting – provided that a practical method could be devised. If the actual identification of high risk groups for targeting is costly, the relative gains from targeting

TABLE 1
All data were gathered for preschool children unless otherwise indicated.

Variable	Description
MN-VITA	Mean Serum Vitamin A Levels
MN-HEMO	Mean Serum Hemoglobin Levels
CASES	Prevalence of Xerophthalmia (X1B)–clinical sign of VAD
MEAS	Prevalence of Measles in the last 3 months
POX	Prevalence of Chicken Pox in the last 3 months
DIA	Prevalence of Severe Diarrhea in the last 3 months
WORM	Prevalence of Parasitic Infestation in last 3 months
MN-WHZ	Mean Weight for Height z-score (wasting)
STUN	Prevalence of moderate Stunting
UNDERWT	Prevalence of moderate Underweight
WAST	Prevalence of moderate Wasting
TGR	Total Goiter Rate (among schoolchildren)
VGR	Visible Goiter Rate (among schoolchildren)
MN-BMI	Mean Body Mass Index (among pregnant mothers)
TGR-M	Total Goiter Rate (among pregnant mothers)
VGR-M	Visible Goiter Rate (among pregnant mothers)
ED-HH	Mean Education level of head of household
ED-MOM	Mean Education level of mother

are lost. For example, in most settings, it is not practical to conduct a careful household survey to determine relative risk. Other less expensive means must be found which can act as a reasonable surrogate for these rigorous but expensive approaches. Thus, the Eastern Islands Prevalence Survey was designed, in part, to test the effectiveness of using variables collected at the desa (village) level to estimate *household* health risk. The question is not whether perfect correspondence exists between village and household but rather, are there easily gathered village-level variables which do a reasonable job in ranking regions. If village estimates can be used to indicate *relative* risk, then a targeting strategy, at the sub-province (Kabupaten or Kecematan) level may be practical. On the other hand, if there is not a strong correspondence, practical targeting is less likely.

A sequence of steps was undertaken to examine this question. First, variables gathered at the community level were related to the average nutritional status for individuals and other health indicators of households in the desa. Next, the strength of association between household and desa-level data was assessed using Pearson correlation coefficients and analysis of variance. The final objective was to select a subset of variables which could be gathered at the desa level and which would relate to household health conditions. A wide range of variables gathered at both the household and community level were analyzed for their targeting effectiveness. These results are presented elsewhere (*Eastern Islands Micronutrient Deficiency Prevalence Study*, Center for Research and Development in Nutrition, Nutrition Directorate, Ministry of Health, Republic of Indonesia, October 1991). In this paper we will explore an alternative (or supplementary) scheme for determining relative risk – one based on emerging theoretical developments in the field of population-environment dynamics.

Elevated Risk for Villages in Transition

Recent research suggests that there is a special vulnerability as a community moves from relative traditional living patterns emphasizing self-sufficiency, to ones featuring economic development (see Drake, W. D. "Toward Building A Theory of Population Environment Dynamics: A Family of Transitions," *Population-Environment Dynamics*, University of Michigan Press, Ann Arbor, 1993). The theory asserts that movement from traditional to "developed" status is characterized by the region passing through a series of transitions in each of many sectors of its society. For example, one well known transition is the demographic transition. At the onset of this transition, births and deaths are both high and are in relative equilibrium with each other. Historically, births exceed deaths by small amounts so that the total population rises only very gradually. Occasionally, famine or epidemic forces a decline in total population but in general, changes in rates are slow. During the transition, however, death rates drop dramatically, usually due to improvement in the health condition of the population. This change in health is caused by many, often interrelating factors. After some time lag, the birth rate begins to drop and generally declines until it is in approximate balance with the death rate again.

But there are in fact many similar transitions each related to different sectors of the community. This dynamic is visualized as a **family** of transitions. That is, not only has demographic and epidemiologic transition been described but also deforestation, toxicity, agricultural, energy, education, and urbanization transitions as well as many others. It is argued that for each transition there is a critical period when society is especially vulnerable. During that period, rates of change are high, societal adaptive capacity is limited, in part due to this rapid change, and there is a greater likelihood that key relationships in the dynamic become severely imbalanced. The trajectory that a community takes through a transition varies, depending upon many factors operating at local and national levels. Transitions not only are occurring in many different sectors but also at different scales, both temporal and spatial. At times, a community experiences several transitions simultaneously, which can raise social vulnerability as they amplify the effects of each other.

It is beyond the scope of this paper to describe the details of these dynamics except to note that for any given location experiencing rapid modernization, such as a village in one of the Eastern Island Provinces of Indonesia, it is reasonable to conjecture that there might be special vulnerability (for a comprehensive description of the transitions existing in a community, see *ibid.* 301-355). If this were true, then health indicators of *at-riskness* might indicate magnified problems in those villages experiencing an overall transition from traditional self-sufficiency to relative modernity. This elevated risk, it is argued, results from many factors such as employment volatility, changes in food consumption patterns, composition of the extended family, temporary migration, and child rearing behavior. Elevated risk, if present, would strike hard at children who are most vulnerable, and readily reflect adverse changes in family health status.

It follows then, if transitional communities are experiencing vulnerability which then translates into heightened child health at-riskness, a targeting strategy might be devised based on some readily available community-level indicator. Such a targeting strategy might provide a practical policy tool.

Classifying Villages According to Their Transition Status

Fortunately, in Indonesia the government has for years maintained an up-to-date record of the "transitional" status of villages throughout the country. Villages in the study area, like all other parts of the country, have been ranked by a classification system used to measure level of development. This ranking system is related to the amount of infrastructure available in the community but also includes many other factors. The village scale ranged from traditional self-sufficiency (Pradesa) to modern market oriented communities (Swasembada) (formal village classification of villages was provided by the Indonesian Government). Pradesa villages (pre-villages) are generally located in remote regions and have relatively little contact with the national economy. The main occupation is agriculture, and education levels are very low. Traditional custom has a dominant influence and these villages are considered "traditional." The next level of development is classified as Swadaya, and is still characterized by very strong influence of traditional custom, "... strong relations among villagers and social control based on the family system." Infrastructure, while more advanced than Pradesa villages, is still relatively basic. Average education is low, communication and transportation are minimal, production methods traditional, and facilities for social activities rarely observed. The third level of development in villages, Swakarya, shows traditional customs further in transition. Influences from outside are observed in the village which are deemed to "... be changing ways of thinking." Job opportunities are shifting from primary to secondary sectors. Secondary sector here is defined as small industry and crafts. Traditional custom and religion is in transition, education and skill levels are judged to be medium, communication and social facilities increasing to a "... medium level," and institutional and governmental tasks functioning in a more developed manner.

The highest development classification level is Swasembada. "Traditional custom and religion is not influencing development ...," education and skill of the villagers is high, and members take initiatives and responsibility for local action. Communication, productivity, marketing, and social facilities are above standard. Village output/yield in all sectors is high and job opportunities are mainly in the "third sector" (commercial and service).

In order to maximize the generality of the results of this study, the balance of this paper will use generic terminology when labelling villages. Pradesa villages will be called traditional, Swadaya and Swakarya called transitional and Swasembada, modern or developed.

TESTING FOR ELEVATED RISKS IN TRANSITION VILLAGES

If there is validity to the hypothesis that there is elevated risk during the time villages are going through a transition from traditional to developed status, then one might expect at least some health status indicators to change unfavorably during this period (it is quite possible that, due to low measurement specificity and sensitivity, indicators could show no heightened at-riskness during transitional periods when, in fact, there were risks but the opposite is less likely to be true.) Analysis of Eastern Islands data supports this hypothesis of elevated risk.

However, as is true for any study, association does not necessarily mean causation. There are always possible alternative or competing explanations for the cause of the observed outcome. In the case of this analysis, the most probable competing explanation for elevated risk in transitional villages would be inherent differences among villages which are unrelated to their level of development. For example, does village topography have an effect upon the outcome, especially for health indicators known to be related to geography such as iodine deficiency?

Other competing explanations know to be related to child health risk, such as educational level of the head of household or of the mother are part of the fabric of a transitional village and, for our purposes, do not need to be separated. In fact, to a large degree, they define the heightened at-riskness of transitional villages. Whenever possible, we shall attempt to provide what evidence there is for refuting this competing explanation. But regardless of the causes, the fact still remains that is associations exist, then an intervention strategy can be proposed which reflects this elevated risk, regardless of its cause.

Table 1 in an earlier section, provides a listing of the available health indicators which, while gathered in some cases at the individual household level, in all instances have been aggregated to the village level. This section presents the results of analysis for the major indicators available, organized by village transitional status. It should be remembered that due to data gathering protocol, the number of villages available for analysis, varies by each indicator variable.

Undernutrition

A sample of the nutritional status of preschool children in each of 138 villages was taken during the course of this study. Height, weight, and age were measured and key anthropometric indices of child nutriture were calculated and standardized using the NCHS reference standard. Village prevalence estimates were determined from these samples and related to village transition status. Both weight-for-height (wasting) and weight-for-age showed statistically significant association with village type. Weight-for-height (a measure of stunting) was also at a higher rate in transitional villages although not statistically significant. Figure 1 presents the prevalence of wasting by village type. Both types of transitional villages (early and late) showed statistically significant higher malnutrition. For the purposes of presentation in the figures that follow, both transitional types have been combined into one category.

Figure 2 shows the prevalence of underweight malnutrition for preschool children in the same 138 villages. Transitional villages again show a higher risk for malnutrition. Using the NCHS standard and a cut-pint of less than two standard deviations from mean values, transitional villages experienced 48% malnutrition while traditional and modern villages showed 35% and 41% respectively. These differences were statistically significant at the p=.01 levels (p=.0065 and .0009 respectively).

Vitamin A Deficiency

Two indicators of vitamin A deficiency were measured during this study; mean serum

FIGURE 1

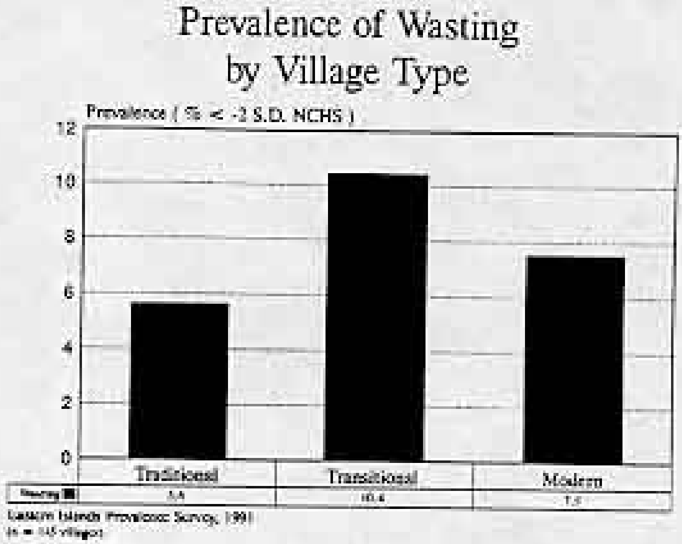


Figure 1. Prevalence of Wasting by Village Type (145 villages). Three bars are displayed in this chart: one for traditional, one for transitional, and one for modern villages. The height of the bar measures the percentage of prevalence (% < -2 S.D. NCHS). Traditional shows wasting of 5.6%; transitional at 10.4%; and, modern at 7.5%. The source is 1991 Eastern Islands Prevalence Survey.

vitamin A level and prevalence of xerophthalmia as indicated by detection of bitot's spots (X1B). Because of an extremely low prevalence of xerophthalmia, the only variable amenable to analysis of transitional villages is vitamin A serum levels. Figure 3 presents the prevalence of low serum retinol in preschool children by village type. The cut-point used to define community at-riskness is the WHO recommended 5% of the population with serum retinol levels < 10 mcg/dl. Although all village types showed prevalences of low serum VA well above the cut-off for being a public health risk, transitional villages experience the highest prevalence of low serum retinol although not at statistically significant levels.

Iodine deficiency (IDD)

Iodine deficiency disorders (IDD) is used to define a group of functional disabilities associated with inadequate levels of iodine ranging from impaired thyroid function to debilitating cretinism. Iodine is normally ingested in water or plants which have extracted it from soil. IDD is most likely to occur in isolated rural areas that are ecologically deficient in iodine and have little contact with food products from areas with higher iodine availability. Three different measures were used to assess iodine deficiency in this study; visible goiter rate, to-

FIGURE 2

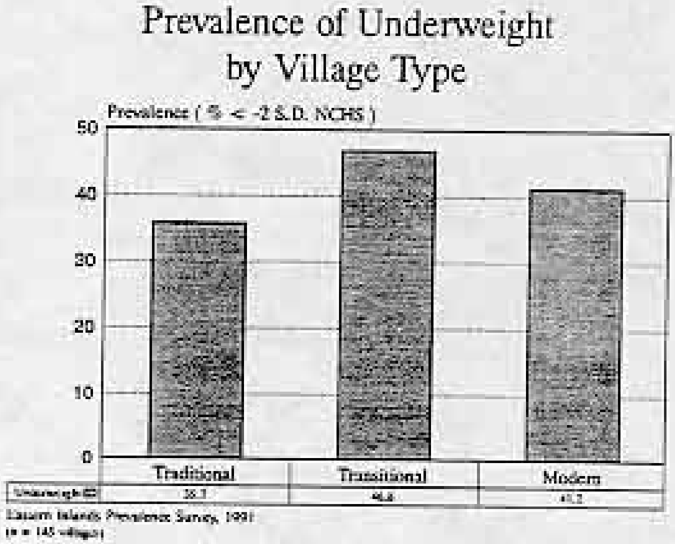


Figure 2. Prevalence of Underweight by Village Type (145 villages). Three bars are displayed in this chart: one for traditional, one for transitional, and one for modern villages. The height of the bar measures the percentage of prevalence (% < -2 S.D. NCHS). Traditional shows underweight of 35.7%; transitional at 46.8%; and, modern at 41.2%. The source is 1991 Eastern Islands Prevalence Survey.

tal goiter rate, and percent of villages with total goiter rate above the WHO defined at-risk prevalence rate of ten percent.

Figure 4 shows the visible goiter rate classified by village category. Again, risk was shown to be highest in transitional villages. Figures 5 and 6 also show much higher risk rates in transitional villages using the other indicators of deficiency, total goiter rates, and percent of villages with high total goiter rates (p=0.0045).

Because there is often correspondence between topography and iodine deficiency, an attempt was made to refute this competing explanation for the observed outcome. Figure 7 shows the relationship between topography and village transitional status. Topography was categorized as lowlands, mountainous, and coastal. If the competing explanation for high risk in transitional villages is, in fact, their mountainous topography, one would expect mountainous villages to be overrepresented in the transitional village category. The data in Figure 7 indicate exactly the opposite. Fewer transitional villages lie in mountainous areas than in either the low land or coastal village categories. While this observation does not fully refute the competing explanation, it strongly supports transitional villages as the underlying explanation for high risk.

FIGURE 3

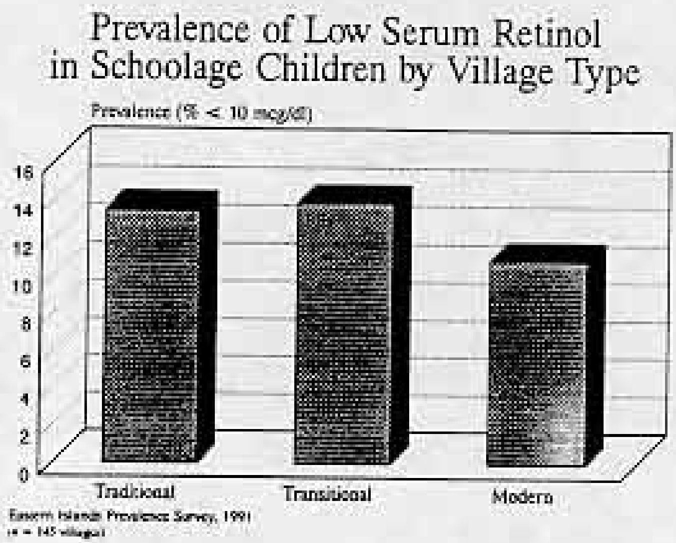


Figure 3. Prevalence of Low Serum Retinol in Schoolage Children by Village Type (145 villages). Three bars are displayed in this chart: one for traditional, one for transitional, and one for modern villages. The height of the bar measures the percentage of prevalence (% < 10 mcg/dl). Traditional shows low serum retinol of about 12.5%; transitional at about 13%; and, modern at about 10%. The source is 1991 Eastern Islands Prevalence Survey.

Iron deficiency

Anemia is the most widespread micronutrient disorder in the world. It has profound consequences on adult productivity, impaired cognitive and motor development in children, and in pregnant women can significantly complicate the risk of intrauterine growth, low birthweight, and perinatal mortality. As many as fifty percent of all maternal deaths in developing countries may be associated with anemia and may be the exclusive cause in as many as twenty percent of all maternal deaths (ACC/SCN Workshop; Preventing Anemia; SCN News 6:1-6). In addition to an inadequate intake of iron in the diet, anemia may be brought on by exposure to certain infectious diseases. Malaria, hookworm, schistosomiasis, and other infections are related to the etiology of anemia. In the Eastern Islands of Indonesia, the role that malaria plays in the etiology of anemia cannot be ignored. However, regardless of cause, nutritional anemia must be reckoned with.

Figure 8 indicates the relationship between nutritional anemia in preschool children and village type. Using the WHO cut-off for iron anemia of eleven gm/dl, the mean values of both categories of transitional village fell below the cut-off while traditional and modern villages were above the cut-off. There is a statistically significant difference between village

FIGURE 4

Visible Goiter Rate in Schoolage Children by Village Type

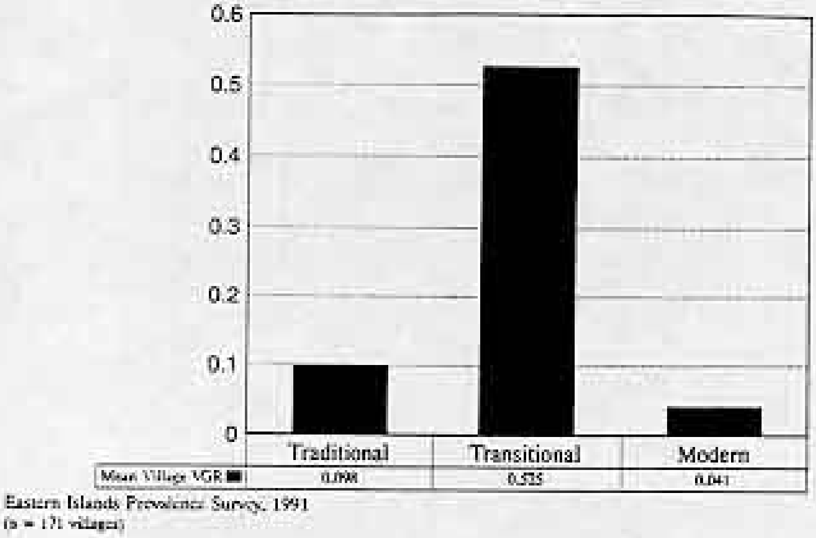


Figure 4. Visible Goiter Rate in Schoolage Children by Village Type (171 villages). Three bars are displayed in this chart: one for traditional, one for transitional, and one for modern villages. The height of the bar measures the mean village visible goiter rate. Traditional shows visible goiter rate of 0.098%; transitional at 0.525%; and, modern at 0.041%. The source is 1991 Eastern Islands Prevalence Survey.

types with p=0.043 for between group differences.

Intestinal worms

Intestinal parasites (helminthic infection) can significantly contribute to malnutrition in adults and even more in children. Reduction in such infections usually requires a multifaceted approach to public health including family education, improved waste disposal, safe water, and proper food preparation. Figure 9 presents evidence on the prevalence of helminthic infection by village type for 169 villages in the Eastern Islands. Again, both early and late transitional villages show a higher mean village worm rate although not at statistically significant levels.

Not all measured variables showed at-riskness in transitional villages. Prevalence of diarrhea, chicken pox, and measles did not show measurably higher rates during the study period. Difference in seasonality of high-risk periods depending on topography and the

FIGURE 5

Total Goiter Rate in Schoolage Children by Village Type

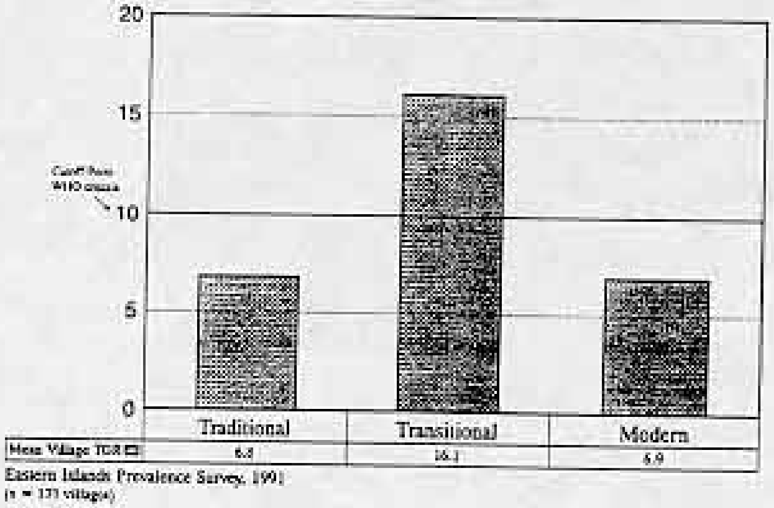


Figure 5. Total Goiter Rate in Schoolage Children by Village Type (171 villages). Three bars are displayed in this chart: one for traditional, one for transitional, and one for modern villages. The height of the bar measures the mean village total goiter rate. Traditional shows total goiter rate of 6.8%; transitional at 16.1%; and, modern at 6.9%. The source is 1991 Eastern Islands Prevalence Survey.

episodic character of some of these diseases may be factors which preclude indication of heightened risks by village type.

TESTING FOR RISK OVERLAP WITHIN THE HEALTH SECTOR

While this dataset provides evidence of the vulnerability of transitional villages to micronutrient deficiencies, and supports the targeting of micronutrient control programs to these villages, it is also pertinent to investigate the general "overlap" in micronutrient deficiency prevalences in all village types. This analysis addresses the issue of integrating VAD control activities with IDD and IDA control programs. As governments examine the possible benefits gained from the integration of VAD control activities with IDD and IDA programs, and a strategies that target high risk populations appear most cost-effective, the examination of the extent to which villages at high risk for one micronutrient deficiency is at the same time at high risk for another micronutrient deficiency becomes a logical research question

FIGURE 6

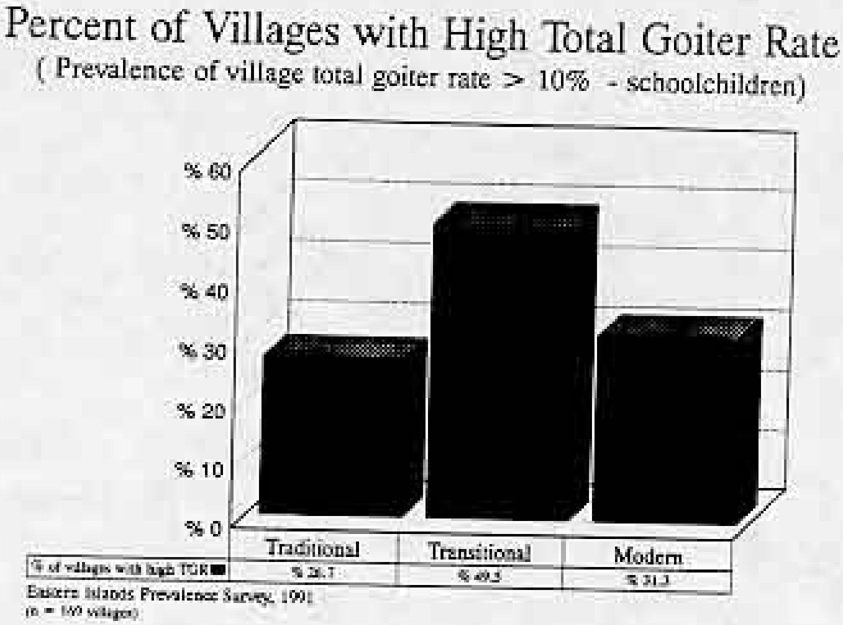


Figure 6. Percent of Villages with High Total Goiter Rate (169 villages). (Prevalence of village total goiter rate ¿ 10% – schoolchildren.) Three bars are displayed in this chart: one for traditional, one for transitional, and one for modern villages. The height of the bar measures the percentage villages with high total goiter rate. Traditional shows percentage of villages with high total goiter rate at 26.7%; transitional at 49.5%; and, modern at 31.3%. The source is 1991 Eastern Islands Prevalence Survey.

with direct programmatic implications. The data gathered from the Eastern Islands Prevalence Survey, provides a unique opportunity to investigate this measurement of the degree of covariance, or "overlap," between these deficiencies.

Methods

In order to address this issue, two types of analyses were carried out. The first set of analyses focused on measuring the correlations between the prevalence of the three micronutrients. Statistical procedures included formulation of a correlogram and multidimensional scaling. (These methodologies are not included in this paper but are available through the primary author in a separate paper presently in draft form.) The second type of analysis was aimed at presenting the relative "overlap" in high prevalences for all three micronutrient deficiencies, and Venn diagrams were constructed to allow for visualization of this

FIGURE 7

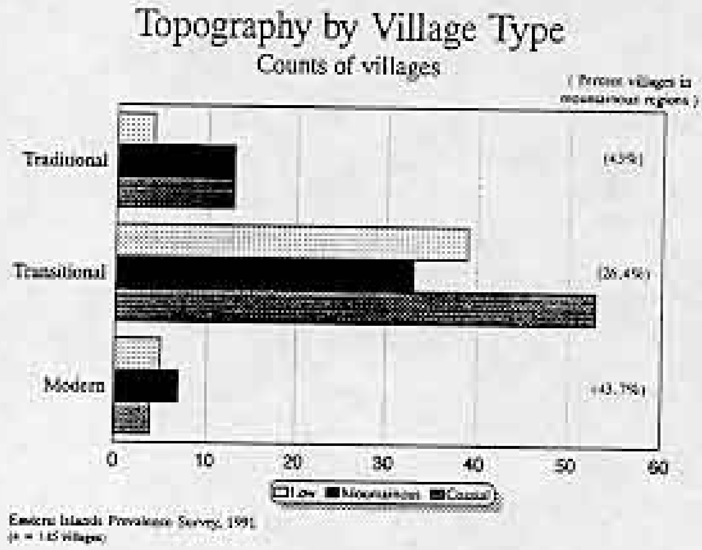


Figure 7. Topography by Village Type: Counts of Villages. (145 villages). (Percent villages in mountainous regions.) Three sets of three bars each are displayed in this chart: one for traditional (low, mountainous, and coastal topography), one for transitional (low, mountainous, and coastal topography), and one for modern (low, mountainous, and coastal topography) villages. The length of the bar measures the percentage of villages in mountainous (or coastal or low) regions. 43% of the traditional villages are mountainous; 26.4% of the transitional villages are mountainous; and, 43.7% of the modern villages are mountainous. The source is 1991 Eastern Islands Prevalence Survey.

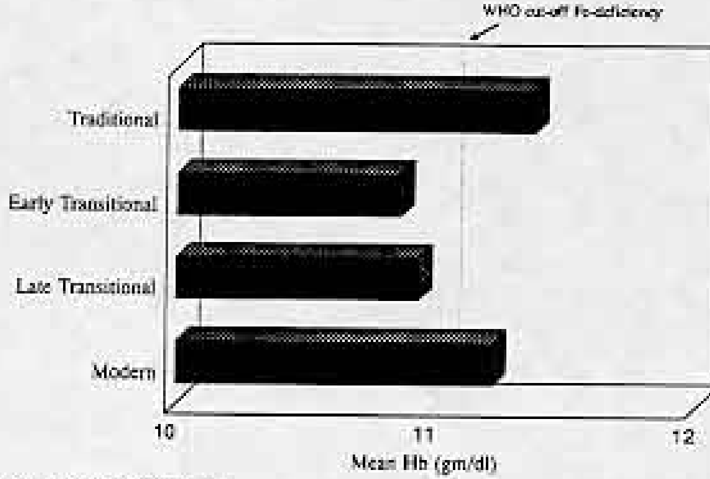
phenomenon.

Determination of Overlap in Risk

Figure 10 is a Venn diagram which shows the overlap in risk for micronutrient malnutrition. It represents aggregated data from 138 villages. VAD, TGR, and IDA are shown to have a substantial overlap among the villages. This overlap, like the broader overlap among different sectors in the community, has important implications for intervention strategies which will be discussed further in the concluding section of the paper.

Figure 11 presents the overlap in risks for the same micronutrient deficiencies in transitional villages and Figure 12 shows these overlaps for traditional and modern villages. It is interesting that the pattern of overlap does not change between transitional and non-transitional villages.

FIGURE 8
Nutritional Anemia in Preschool Children
by Village Type



Eastern Islands Prevalence Survey, 1991
(n = 145 villages)

Figure 8. Nutritional Anemia in Preschool Children by Village Type. WHO cut-off Fe-deficiency is at a value of 11 (measuring mean HB (gm/dl)). (145 villages). Four bars are displayed in this chart: one for traditional, one for early transitional, one for late transitional, and one for modern villages. The length of the bar measures the mean Hb (gm/dl). The bars for the early and late transitional villages fall short of the WHO cut-off line at 11. The bars for the traditional and modern village go beyond the WHO cut-off line. The source is 1991 Eastern Islands Prevalence Survey.

CONCLUSIONS AND POLICY IMPLICATIONS

Summary of Evidence for Elevated Risk in Transitional Villages

The forgoing analysis presents a rather compelling picture of heightened health risk in villages experiencing transition from traditional self-sufficient living patterns to more developed market-oriented economies. Almost every health indicator examined in this study shows that households in villages experiencing transitions were worse off — whether the measure be child malnutrition (PEM), anemia (IDA), vitamin A deficiency (VAD), iodine deficiency (IDD), or helminthic infection. Further, this heightened risk was evident in spite of apparent "improvements" in community infrastructure, both physical and organizational.

Theoretical developments and the first stages of empirical work elsewhere suggest that this heightened risk during transition may be attributable to the vulnerability created by rapid rates of change in each of many sectors of the community especially when they occur simultaneously. Old and often useful patterns of interaction among sectors are damaged or

FIGURE 9

Prevalence of Helminthic Infection by Village Type

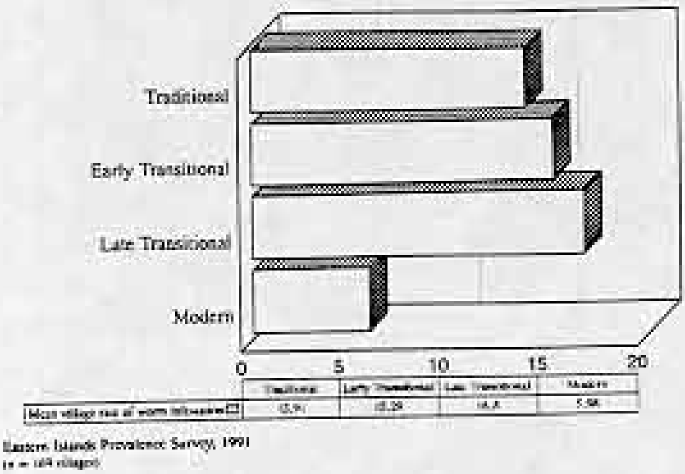


Figure 9. Prevalence of Helminthic Infection by Village Type (169 villages). Four bars are displayed in this chart: one for traditional, one for early transitional, one for late transitional, and one for modern villages. The length of the bar measures the mean village rate of worm infestation. The bar for traditional villages has length 13.91; that for early transitional has length 15.29; that for late transitional has length 16.8; and, that for modern has length 5.98. The source is 1991 Eastern Islands Prevalence Survey.

destroyed and new adaptive patterns have not yet developed. Changes within one sector result, often harmfully, in changes in another. And, perhaps most important, these changes occur so rapidly that societal adaptive capacity is limited during the transition.

Societal vulnerability due to rapid rates of change deserves recognition and, if possible, remediation. Risks are brought about by changes in employment patterns, education levels, more abundant supplies of water, altered waste disposal systems, increased transportation alternatives (and costs), disruption in food production, storage, preparation and consumption, and changes in population density. These overlapping risks call for a community-wide strategy of remediation which explicitly recognizes their interaction. The strategy need not be complex; only conceived broadly enough to explicitly embrace interaction among sectors.

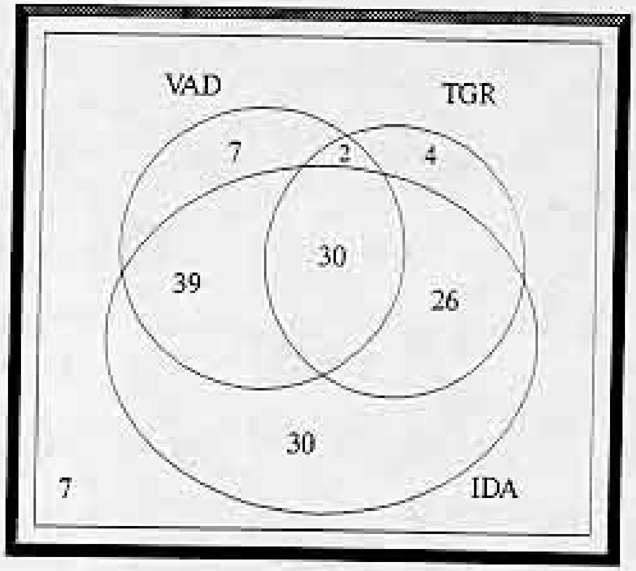
Policy implications

A possible policy implication from the findings of this study suggests planning for special emphasis and corresponding resources devoted to health care activities during periods of rapid social or economic change. Especially when government-sponsored development efforts

FIGURE 10

Overlap in risk for Micronutrient Malnutrition

in the Eastern Islands of Indonesia



n = 145

Figure 10. Three-circle Venn diagram: two circles on top, one below, intersecting to form eight disjoint regions. The circle on the upper left represents VAD; the one on the upper right, TGR; and, the one on the bottom, IDA. Overlap in Risk for Micronutrient Malnutrition in the Eastern Islands of Indonesia (number of villages is 145). Breakdown of the partition by Venn region: 1. VAD and TGR and IDA: 30; 2. VAD and TGR and not-IDA: 2; 3. VAD and IDA and not-TGR: 39; 4. VAD and not-IDA and not-TGR: 7; 5. IDA and TGR and not-VAD: 26; 6. IDA and not-TGR and not-VAD: 30; 7. TGR and not-VAD and not-IDA: 4; 8. not-VAD and not-TGR and not-IDA: 7.

are being implemented, it may be helpful to schedule higher levels of service delivery in order to overcome the anticipated higher risk for children during transition periods.

While focusing upon villages in transition is but one type of targeting, there is a qualitative difference between this and other targeting strategies discussed earlier. In this instance, targeting can be based upon **anticipating** the risk rather than reflecting current or historical risk estimates. Because government is both planner and resource allocator for its development programs, difficulties experienced during movement through a transition period can be dampened by allocating special activities to the region receiving development assistance.

FIGURE 11

Overlap in risk for Micronutrient Malnutrition

in Transitional Villages

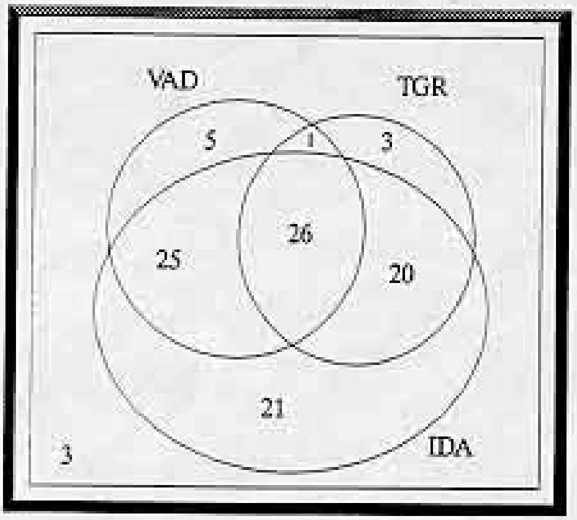


Figure 11. Three-circle Venn diagram: two circles on top, one below, intersecting to form eight disjoint regions. The circle on the upper left represents VAD; the one on the upper right, TGR; and, the one on the bottom, IDA. Overlap in Risk for Micronutrient Malnutrition in the Eastern Islands of Indonesia in Transitional villages. Breakdown of the partition by Venn region: 1. VAD and TGR and IDA: 26; 2. VAD and TGR and not-IDA: 1; 3. VAD and IDA and not-TGR: 25; 4. VAD and not-IDA and not-TGR: 5; 5. IDA and TGR and not-VAD: 20; 6. IDA and not-TGR and not-VAD: 21; 7. TGR and not-VAD and not-IDA: 3; 8. not-VAD and not-TGR and not-IDA: 3.

At the very least, government can monitor local conditions more closely and be prepared to act quickly if problems should arise.

Because this is the first study showing these elevated risks for transition villages and because the results from this analysis should not be extended to other settings without further confirmation, it also might be useful to explore more fully the nature of societal vulnerability in transition communities. A pilot project incorporating a research design which focuses upon this question could be far more robust than was possible in this study and consequently capable of stronger conclusions regarding the strategy's usefulness. If such

FIGURE 12

Overlap in risk for Micronutrient Malnutrition

in Non Transitional Villages

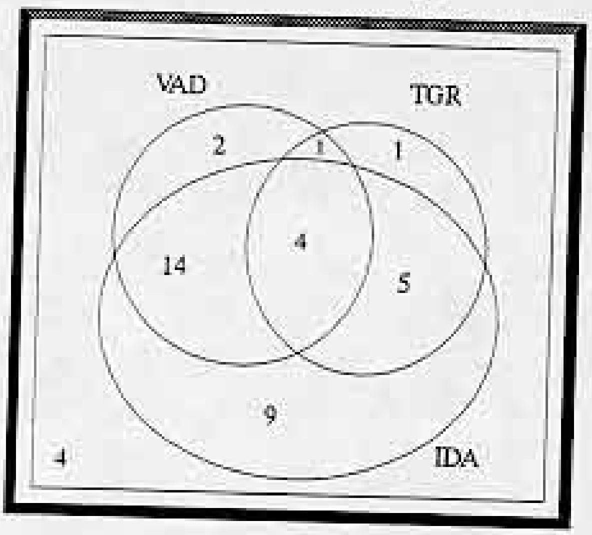


Figure 12. Three-circle Venn diagram: two circles on top, one below, intersecting to form eight disjoint regions. The circle on the upper left represents VAD; the one on the upper right, TGR; and, the one on the bottom, IDA. Overlap in Risk for Micronutrient Malnutrition in the Eastern Islands of Indonesia in Non-transitional villages. Breakdown of the partition by Venn region: 1. VAD and TGR and IDA: 4; 2. VAD and TGR and not-IDA: 1; 3. VAD and IDA and not-TGR: 14; 4. VAD and not-IDA and not-TGR: 2; 5. IDA and TGR and not-VAD: 5; 6. IDA and not-TGR and not-VAD: 9; 7. TGR and not-VAD and not-IDA: 1; 8. not-VAD and not-TGR and not-IDA: 4.

a pilot study is implemented, it would be useful to install a simple monitoring component capable of measuring the gains from this approach.

Implementing a targeting strategy

Implementing a targeting strategy has many practical elements. Ease of gathering data necessary for targeting is crucial. As discussed earlier, data requirements which are too costly or time consuming usually are not useful. One strength of the strategy suggested in this paper is the use of simple village-level variables which are easy to gather but which do a good job of identifying average household at-riskness. But there is another practical dimension which is less easy to quantify. That is, how to blend analytic evidence of at-riskness in a particular sector of a community with local judgment of those closest to the setting. Experience elsewhere indicates that a targeting strategy based only upon analytic considerations is less than optimal. Furthermore, risks organized by type of problem or sector in the community can be less useful than combining risks into one composite. Often it is most practical to allocate resources to the entire community rather than to each component or sector. While it is helpful to keep each risk category separate for analysis purposes, there is also benefit in being able to aggregate risk across sectors. Assessing and acting on at-riskness based on village transitional status permits such a strategy.

4. SAMPLE OF HOW TO DOWNLOAD THE ELECTRONIC FILE
BACK ISSUES OF *SOLSTICE* ON A GOPHER

Solstice is available on a GOPHER from the Department of Mathematics at Arizona State University: PI.LA.ASU.EDU port 70

BACK ISSUES OF *SOLSTICE* AVAILABLE ON FTP

This section shows the exact set of commands that work to download *Solstice* on The University of Michigan's Xerox 9700. Because different universities will have different installations of TEX, this is only a rough guideline which *might* be of use to the reader. (BACK ISSUES AVAILABLE using anonymous ftp to open um.cc.umich.edu, account GCFS; type cd GCFS after entering system; then type ls to get a directory; then type get solstice.190 (for example) and download it or read it according to local constraints.) Back issues will be available on this account; this account is ONLY for back issues; to write Solstice, send e-mail to Solstice@UMICHUM.bitnet or to Solstice@um.cc.umich.edu . Issues from this one forward are available on FTP on account IEVG (substitute IEVG for GCFS above).

First step is to concatenate the files you received via bitnet/internet. Simply piece them together in your computer, one after another, in the order in which they are numbered, starting with the number, "1."

The files you have received are ASCII files; the concatenated file is used to form the .tex file from which the .dvi file (device independent) file is formed. The words "percent-sign" and "backslash" are written out in the example below; the user should type them symbolically.

ASSUME YOU HAVE SIGNED ON AND ARE AT THE SYSTEM PROMPT, #.

create -t.tex

percent-sign t from pc c:backslash words backslash solstice.tex to mts -t.tex char notab

(this command sends my file, solstice.tex, which I did as a WordStar (subdirectory, "words") ASCII file to the mainframe)

run *tex par=-t.tex

(there may be some underfull (or certain over) boxes that generally cause no problem; there should be no other "error" messages in the typesetting–the files you receive were already tested.)

run *dvixer par=-t.dvi

control *print* onesided

run *pagepr scards=-t.xer, par=paper=plain