METHODS TO ACHIEVE ACCURATE PROJECTION OF REGIONAL AND GLOBAL RASTER DATABASES

OBJECTIVES/JUSTIFICATION

Need

Modeling regional and global activities of climatic and human-induced change requires accurate geographic data from which mathematical and statistical tabulations of attributes and properties of the environment can be developed. Many of these models depend on data formatted as raster cells or matrices of pixel values. Recently, it has been demonstrated that regional and global raster datasets are subject to significant error from mathematical projection and that these errors are of such magnitude that model results may be jeopardized (Steinwand, *et al.*, 1995; Yang, *et al.*, 1996; Usery and Seong, 2000; Seong and Usery, 2000). There is a need to develop methods of projection of these datasets which maintains accuracy to support regional and global analyses and modeling.

Objectives

Although recent research indicates that projection problems of raster databases at global and regional scales exist, there is little theoretical background for handling the relationships between the distortion due to projection methods and the raster representation of the distorted features. Also, little is theorized about reprojecting already-projected raster datasets. Currently, it is difficult to select the best projection in relation to raster pixel sizes, latitude, spatial pattern of categories, and the number of categories. Furthermore, it is even more challenging to understand the latent errors in already-projected raster databases and to fix them without further information loss. This research aims at building a decision support system (DSS) for selecting an optimum projection considering various factors such as pixel sizes, areal extent, number of categories, spatial pattern of categories, resampling methods, and error correction methods. Specifically, this research aims at investigating the following three goals theoretically and empirically and using the already developed empirical base of knowledge with these results to develop an expert system for map projection of raster data for regional and global database modeling. The three theoretical goals are:

1) The development of a dynamic projection which adjusts projection formulas for latitude based on raster cell size to maintain equal-sized cells.
2) The investigation of the relationships between the raster representation and the distortion of features, number of categories, and spatial pattern.
3) The development of an error correction and resampling procedure based on error analysis of raster projection.

Hypotheses

Regarding the first goal, we hypothesize that regional and global raster data can be accurately projected with appropriate equations which account for raster cell size and latitudinal position.

For the second goal, we hypothesize that scale factors explain the impact of distortion on raster representation, and that more categories and more complex spatial patterns cause more errors. Finally, we hypothesize for the third goal that error correction and resampling methods can be used for optimizing projection accuracy of regional and global raster datasets. This proposed research potentially has impacts on all USGS programs involving the use of large regional and global raster data such as Global Change Research and Place_Based Studies.

Background

With the advent of digital computers and their application to map projection problems from the early 1960's, one might think that all projection problems had been solved. It is true that when handling geographic data for small areas at high resolution and large scale, projection effects tend to be small compared to other sources of data error and inaccuracy. Renewed difficulties occurred in the late 1970's and 1980's with the introduction of a datum change in the United States from the North American Datum of 1927 (NAD 27) to the geocentric-based North American Datum of 1983 (NAD 83) (ACSM, 1983). In recent years this datum shift has plagued users of geographic information systems (GIS) and even with the current status of complete ellipsoid, datum, and projection conversions available in most commercial GIS software packages, the knowledge to use such conversions effectively is still lacking in the GIS user community (Welch and Homsey, 1997). Often approximations to projection equations are used resulting in error and comparing the results from various projections is difficult (Snyder, 1985; Tobler, 1986a; 1986b).

We are now entering a phase of GIS and digital cartographic use in which large datasets of high resolution are available for global and regional modeling applications. With these large areas and high resolution, data problems due to map projections again become significant. Although excellent reference works exist on the theory of map projections and the distortion resulting from map projection (such as Pearson II, 1990; Maling, 1992; Bugayevskiy and Snyder, 1995), little research has been conducted and even less applied to the projection of regional and global raster GIS databases. In particular, raster datasets suffer accuracy problems directly attributable to projection transformation (Snyder 1983; 1987; Steinwand, 1994; Steinwand *et al*., 1995).

Equal-area projections are generally better for raster datasets since preservation of the area characteristic yields pixel areas which are more correct and equivalent. The interrupted Goode homolosine projection has been recommended for global-raster GIS databases, particularly for products generated from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data (Steinwand, 1994; Steinwand *et al*. 1995). However, even the Goode homolosine projection results in replication of some pixel values and distortion of areas (Yang, *et* al., 1996). If a global GIS database is built using the vector data structure, an equal area projection will preserve most of original information such as the size of area, but research indicates that even projections designed to preserve areas, *i.e*., equivalent or equal-area projections, may distort original information when the database is built using the raster GIS data structure (Steinwand *et al.,* 1995; Seong, 1999; Usery and Seong, 2000).

As Steinwand *et al.* (1995) indicate, the loss and distortion of original information occur during image warping as well as during reprojection of raster data. In addition, the spatial resolution of a raster pixel can cause an inaccuracy along with the projection selected. Assuming a projection with minimum area distortion and allowing maximum angular distortion, the projection will be appropriate only when the raster pixel size is small enough not to be significantly affected by the angular distortion (Nyerges and Jankowski, 1989). As the pixel size is increased, the information for an area is affected significantly due to the distorted shape.

Seong (1999) and Usery and Seong (2000) investigated specific effects of raster cell size and latitudinal position on accuracy of thematic attributes. In both investigations the Goode homolosine projection was examined as well as three other equal area projections, the Lambert azimuthal equal area, the Mollweide, and the equal area cylindrical. The Robinson projection was included to determine the results with a non-equivalent projection. The results indicate that all of the equal area projections yield adequate accuracies with pixels of 8 km or smaller. From 8 to 16 km pixels, the Mollweide yields greater accuracy and at 50 km pixels, the equal area cylindrical projection gives better results. These results are averages for all latitudes and were verified mathematically by Seong (1999) and empirically by Usery and Seong (2000). Seong (1999) also examined the effects of latitude on accuracy of projecting raster data and found that the Mollweide retained accuracy better at all latitudes although with various discrepancies.

Results of Current Project

Title GRA Task 741 Projection Effects on Thematic Content of Maps and GIS Databases
Period FY 2000, Oct 1, 1999 to Sept 30, 2000.
Cost Salaries -- PI, 0.2 FTE; GS-9 Technician, ½ -FTE; GS-11 Computer Specialist, ½ FTE
Software $5,000; Travel $3,000; Training 2,000; Books, misc. $1,000
Results One paper submitted for publication, one in development; seamless global raster databases for elevation (5 min and 30 arc-sec), land cover (1 km), vegetation (1 degree), temperature (1 degree), precipitation (1 degree) in a variety of 10 map projections and geographic coordinates.

The project results indicate significant variation in tabulated areal statistics for land cover based on projection, raster cell size, and latitudinal position (Table 1). Positional information for elevation and other continuous datasets is under evaluation now. Table 1 illustrates the variance in areas of land cover for specific categories in Asia for 16 and 50 kilometer pixel sizes (from Usery and Seong, 2000). This table is typical of the variances in tabulating areas for land cover categories found among projections designed to preserve area. Similar tables for 1, 4, 8, 16, 25, and 50 km have been generated for these same projections and indicate the extent of this problem which increases with pixel size. Tabulation for the remaining projections and datasets is underway now.

In addition to the mathematical results of Seong (1999) and the empirical results illustrated in Table 1 and documented in Usery and Seong (2000), Seong and Usery (2000) have also developed a theoretical error model. Based on the concept of scale factor error in both horizontal and vertical directions, the model accounts for error resulting from pixel size distortion, pixel category replication, and skew of pixels. The model has been verified with the sinusoidal, Mollweide, and Lambert equal area cylindrical projections of raster data and accounts for greater than 99 percent of the theoretical error.

The research discussed above shows problems of raster database projection at global and regional scales. However, it does not provide a solution for the problems. This proposed research will extensively investigate the problem theoretically and empirically with various factors, and suggest the best projection depending on areal extent, pixel size, resampling and category characteristics.

Table 1
Asia Land Cover Percentages by Projection

Projection*

	16 km Pixels					50 km Pixels				
Land Cover Categories	Lam	Goode	Eq-Cyl	Mw	Rob	Lam	Goode	Eq-Cyl	Mw	Rob
Urban & Built-Up Land	0.16	0.17	0.16	0.16	0.15	0.14	0.17	0.21	0.15	0.09
Dryland Cropland & Pasture	12.36	12.70	12.13	12.47	11.97	12.24	13.16	12.48	12.57	11.76
Irrigated Cropland & Pasture	11.26	12.24	11.20	11.06	10.33	11.60	12.38	11.59	11.07	10.70
Cropland/Grassland Mosaic	5.89	5.78	5.91	5.79	5.83	5.95	5.81	5.66	5.78	5.84
Cropland/Woodland Mosaic	4.24	3.96	4.33	4.32	4.28	3.85	3.79	4.15	4.37	3.97
Grassland	17.12	14.82	17.05	17.00	17.65	17.14	14.55	16.61	16.96	17.57
Shrubland	14.27	11.69	14.45	14.25	14.31	13.94	11.96	14.19	14.44	14.62
Mixed Shrubland/Grassland	2.05	2.39	2.07	2.10	1.96	2.05	2.42	2.24	2.05	2.03
Savanna	4.49	5.23	4.39	4.55	4.58	4.54	4.96	4.64	4.65	5.03
Deciduous Broadleaf Forest	3.20	3.67	3.23	3.16	3.14	3.44	3.44	3.41	2.93	3.02
Deciduous Needleleaf Forest	1.87	2.86	1.92	1.89	2.23	1.88	2.94	1.86	2.04	2.08
Evergreen Broadleaf Forest	2.70	3.09	2.79	2.73	2.40	2.60	3.19	2.72	2.60	2.57
Evergreen Needleleaf Forest	0.83	0.94	0.86	0.85	0.81	0.85	0.76	0.86	0.96	0.85
Mixed Forest	8.56	9.46	8.52	8.64	9.25	8.63	9.53	8.25	8.45	9.01
Herbaceous Wetland	0.14	0.19	0.16	0.14	0.15	0.12	0.18	0.16	0.12	0.11
Wooded Wetland	0.11	0.13	0.11	0.09	0.14	0.17	0.10	0.12	0.11	0.11
Barren or Sparsely Vegetated	9.20	8.66	9.19	9.24	9.19	9.28	8.65	9.38	9.12	9.02
Herbaceous Tundra	0.16	0.06	0.17	0.16	0.17	0.17	0.07	0.12	0.21	0.17
Wooded Tundra	1.11	1.56	1.07	1.12	1.16	1.23	1.54	1.07	1.10	1.19
Mixed Tundra	0.04	0.11	0.05	0.05	0.07	0.03	0.11	0.04	0.04	0.02
Snow or Ice	0.25	0.28	0.24	0.25	0.25	0.15	0.30	0.24	0.28	0.25

*Lam = Lambert azimuthal equal area, Goode = Goode homolosine, Eq-Cyl = Equal area cylindrical, Mw = Mollweide, Rob = Robinson

PROCEDURES/METHODS

Based on the empirical knowledge base and results with commercial vendor projection software from GRA Task 741, a projection selection system will be developed. This DSS for projection selection for raster data will help users select the best projection based on data type, raster cell size, and specific region or global area. Additionally, three specific approaches will be used to develop methods to correct the errors resulting from the projection of raster datasets. One or more of these approaches may result in a complete correction system which can be added to the DSS. The approaches correspond to the three hypotheses listed in the objectives above, *i.e.*, 1) a dynamic projection which adjusts projection formulas for latitude based on raster cell size, 2) an error analysis between the raster representation and the distortion of features, number of categories, and spatial pattern of them, and 3) a resampling approach and an error correction procedure which adjust the resampling method to account for the error which occurs in a given cell location. Each of these approaches relies on previous projections research such as the empirical analysis to determine which projections are best at given latitudes and cell sizes (Usery and Seong, 2000), error analysis of raster data projection (Seong and Usery, 2000), and the development of the Goode projection for raster data (Steinwand, 1994). The procedures for each approach are detailed below.

Projection Selection System

Since certain projections work better for specific cell sizes, *e.g.,* of several equal-area projections, the Mollweide has minimum error for raster datasets with cell sizes between 8 and 25 km (Usery and Seong, 2000), and specific latitudes, a DSS tool to guide users to select the appropriate projection based on these characteristics can be developed. Such a tool can be used with commercial-off-the-shelf (COTS) software to guide users to select a projection which will minimize the error for a regional or global database. The system can also provide the user with the exact extent of error in specific locations on the globe. This tool can be developed primarily from the empirical knowledge base developed by Usery in GRA Task 741 “Projection Effects on Thematic Content of Maps and GIS Databases” in FY 2000 (described above). The results of this project are now being formulated for publication and include analysis of a range of databases, such as global vegetation, climate, land cover, and elevation at a range of resolutions from one kilometer to one degree raster cells. The project evaluated empirical errors resulting from 10 different projections. This empirical base can be used to establish the essential rules of the DSS to guide users to select the best projection available in a commercial software package for a given dataset.

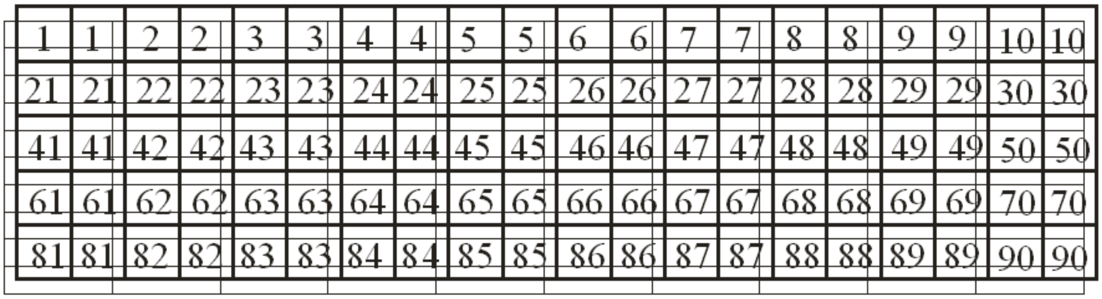
Dynamic Projection

The concept behind dynamic projection is to use the most appropriate mathematical formulation for the projection of a raster cell based on the cell size and the latitude of the cell. The development of a guidance tool or projection decision support system only allows users to select the best of currently available projection methods, all of which result in significant error. To obtain a solution without error, or at least a solution in which the error is significantly reduced from current projection methods for raster data, requires new developments. In a dynamic projection approach, a mathematical formulation will be developed based on empirical knowledge (from GRA Task 741) and theoretical considerations such as Tissot’s scale factor analysis of distortion effects. For example, a formulation similar to the Mollweide formulas (Snyder, 1987, p. 251) may be used for cells the 8 to 16 km range since the Mollweide projection produces minimal distortion at these resolutions. The equal area cylindrical (Snyder, 1987, p. 77) works better for 50 km cells, thus the dynamic projection may use formulas similar to those of the equal area cylindrical for 50 km cell size raster datasets. Since the best projection changes with latitude, adjustments of the formulation must be made on a dynamic basis to account for latitude changes. The key to this dynamic projection is to mesh the formulas which achieve high projection accuracies for specific cell sizes at given latitudes to form a continuous image. The Goode homolosine is an simple example of the application of this concept since it uses the Mollweide formulation for high latitudes and the sinusoidal formulation for lower latitudes (Steinwand, 1994). However, with dynamic projection, the potential to have a series of discrete transformations which do not join in a continuous image is great and must be avoided. Thus, one task of this research will be to develop a mathematical formulation which is dynamic to achieve accuracy of raster cell areas, but is continuous as latitude changes.

Error Analysis

The error correction approach is designed to use a single projection formulation, *e.g.*, the Mollweide or the sinusoidal, applied to the data with subsequent error correction procedures applied to adjust the raster cell area to the true value. Error analysis indicates that there are two types of errors for which adjustment is appropriate: 1) size errors which cause pixels to be portrayed at sizes larger or smaller than the original, and 2) categorical error which results from lost or gained pixels (Seong and Usery, 2000). Both types of error can be modeled with a scale factor model developed from the horizontal and vertical scale factors of the projection. An example of the error analysis approach is shown in Figure 1. With the model, corrections can be applied after projection to eliminate gained pixels.

An example analysis and application follows for the Mollweide projection which has been used frequently for world maps, especially for mapping oceans, because it represents oval areas at mid-latitude regions. In the Mollweide projection, all of the meridians are ellipses, except the central meridian which is a straight line and the 90-degree meridians which are circles. The main characteristics of the Mollweide projection are that the parallels are carefully spaced to maintain the equivalency so that the areal scale factor equals 1.0.



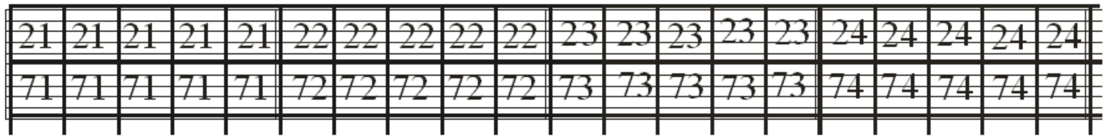
a) X scale factor = 2.0. Y scale factor = 0.5
Representation of original pixels = 50 pixels (50%)
Loss and gain = 100% (50% loss + 50% gain)

b) X scale factor = 5.0. Y scale factor = 0.2
Representation of original pixels = 20 pixels (20%)
Loss and gain = 160% (80% loss + 80% gain)

Figure 1. Scale factor error analysis.

Because the Mollweide projection uses straight parallels, the scale factor along the parallel can be used for examining raster representation accuracy. The horizontal scale factor in Mollweide projection is calculated as follows (Bugayevsky and Snyder, 1995):

$$n = (2\sqrt{2} / \pi) \cos(\alpha) \sec(\phi) \qquad \text{(Eq. 1)}$$

where, $2\alpha + \sin(2\alpha) = \pi \sin(\phi)$, and ϕ is the latitude. Because the $2\alpha + \sin(2\alpha) = \pi \sin(\phi)$ is a transcendental equation, the ϕ was calculated using the Newton-Raphson method that is an iterative solution with an equation which has a rapid convergence if the initial guess for α_n is given the value of ϕ (Pearson, 1990):

$$\alpha_{n+1} = \alpha_n + [\pi \sin(\phi) - 2\alpha_n - \sin(2\alpha_n)] / [2 + 2\cos(2\alpha_n)] \qquad \text{(Eq. 2)}$$

The horizontal local scale factor, n, becomes 1.0 at ±40° 44′. It is smaller than 1.0 at the latitudes between ±40° 44′ and larger than 1.0 beyond this latitude range reaching around 3.0. This means that pixels will be duplicated vertically at the latitude ranges between ±40° 44′, but horizontally beyond the range, which also implies that about 67 percent of the pixels may be duplicated in high latitude areas. Considering the maximum possible error, the minimum accuracy of raster representation in Mollweide projection can be calculated using the scale factor n and its reciprocal [1/n].

Figure 2 shows experiment results of raster representation in Mollweide projection. It shows that the accuracy is very high around the latitude of 40-degrees. Also, the accuracy is mostly the function of latitude as expected from the model. The average difference between model and experiment accuracies was 0.8%. This means the model, which uses horizontal and vertical scale factors, explains more than 99.2% of errors.

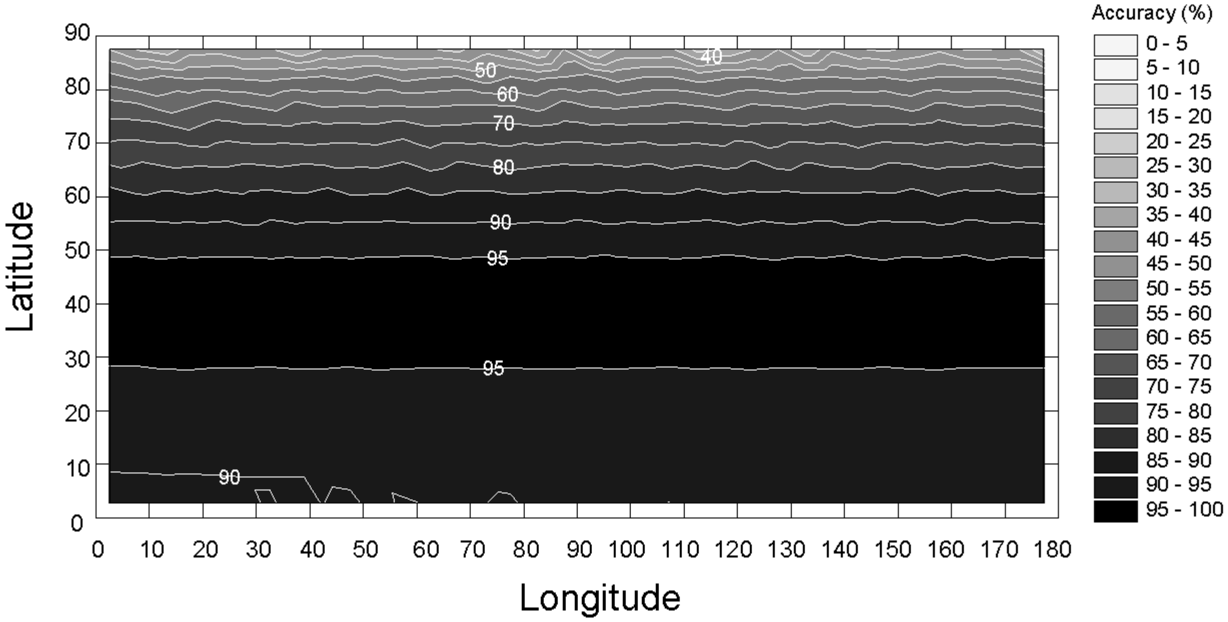


Figure 2. Accuracy results of scale factor error analysis applied to the Mollweide projection.

The scale factor model will be tested with various projections including equal area and conformal projections. In cylindrical and pseudo-cylindrical projections, it is relatively easy to calculate the horizontal and vertical scale factors with the assumption of parallelograms on hyperboloids. However, if parallels and meridians are curved, the accuracy of the raster representation of the scale factor model will be decreased. The extent of accuracy decrease will be modeled also.

In the cases of cylindrical projections such as Lambert equal area cylindrical, James Gall, Walter Behrmann, and Trystan Edwards projections, which use the standard parallel (ϕ_k) of 0°, 45°, 30° and about 51° respectively, the scale factor model may be applied with the horizontal scale factor and its reciprocal. Pseudo-cylindrical equal-area projections, such as Mollweide, Sinusoidal, Eckert VI, Wagner I, Wagner IV, and Urmayev projections, will be investigated using the same approach.

For conic equal-area projections in their normal aspects, the local linear scale factor along a meridian will be used for calculating the vertical and horizontal scale factors along with the difference of longitude. Albers conic equal-area projections and the polar azimuthal projections will be modeled with this approach. Also, the other conic and azimuthal projections will be modeled with the same approach using the deviation of graticule intersection from a right angle on the map.

Some conformal, equidistance, and arbitrary projections will be tested using the scale factor model. In the non-equal area projections, the error due to area change will be modeled. For those non-equal area projections, it is necessary to calculate the vertical and horizontal scale factors independently, because one is not the reciprocal of the other.

The scale factor model will be applied to monitor the raster representation errors due to reprojection. In this case, existing error in projected data and reprojection error will be modeled. The number of categories may affect the raster representation accuracy. Using experimental data that were labeled with various category numbers, the effect of the number of categories will be modeled. The total number of categories and the spatial pattern of categories will be analyzed in relation to the raster representation accuracy.

Finally, current global raster databases that are built on some projections will be used to empirically examine the scale factor model's validity. Also, the accuracy of raster representation of existing databases will be examined based on projections that are used, number of categories, and spatial pattern of categories.

Resampling

During the image warping and reprojection process, pixel values in the final image are determined by taking the original image pixel coordinate determined by the projection (mapping) transformation and rounding it to the nearest line/sample integer location; no interpolation of neighboring pixels is performed. This "nearest-neighbor" resampling is often used by scientists who work with class data because it does not create new classes in the image warping process.

This method of determining pixel values, when used in areas of high geometric distortion, can generate a data sampling that is not representative of the area in the original image and often results in blocky looking data. An interpolating resampler such as bilinear interpolation (Colwell, 1983), which uses the four neighboring pixels, or cubic convolution (Park and Schowengerdt, 1983), which uses the 16 neighboring pixels, produces a more geometrically accurate (but radiometrically smoother) result in large-scale, small-area studies (such as the scale and extent of a Landsat scene). However, in large-area, small-scale studies, the use of these small neighborhood interpolators does little to improve the type of errors seen in previous research (Steinwand, 1995). In addition, these interpolating resamplers are not typically used with class data, for the reasons stated earlier.

New interpolation techniques that take into account resolution and scale changes for a given data point or area are therefore needed. These resamplers need to be adaptable. They need to be determined for each pixel in the final image because the extent of resolution and scale distortion is often not constant throughout the warped image space. They also need to be selectable for the type of data used: "interpolative" for signal-based data, and "binned" for class-based data. A necessary by-product of this new resampling technique is an error map (image) indicating data lost and "created" by the scale and resolution changes.

Conclusions

The USGS user community is rapidly advancing in the use of large regional and global raster databases for modeling purposes. Those users are often unaware of the effects on areal and positional accuracy of projecting raster data. Since the USGS provides many of these databases, methods to insure accurate projection transformations are needed. This project offers the potential to address this problem from several perspectives. First, the development of an expert guidance system in the form of a projections DSS from the large empirical base available will provide users the capability to use COTS software for projection transformations effectively and wisely. Second, the development of a correction system offers the potential to solve this problem for users. Of the three approaches proposed, a dynamic mathematical projection specifically designed for raster data, error correction, and resampling, each offers a possible solution. All three approaches draw on an experience base in both empirical and theoretical work. Each of the approaches will be implemented through the most experienced researcher and the three approaches will be coordinated to achieve the best result for the USGS.

Contributions and Significance

This research offers the potential for the USGS to make a major new contribution to the theory and development of map projections, an area of historical significance to the organization. Specifically, this project offers the following contributions:

1) A system to support users in the selection of appropriate map projections for large regional and global raster databases.
2) Estimation of errors latent in existing global/continental raster databases.
3) Mathematical projection, error correction and/or resampling methods appropriate for large regional and global raster databases.
4) More accurate environmental models resulting from more accurate data at global/continental extents.

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EXPECTED PRODUCTS

Several specific products will be generated from this research. First, an DSS for selecting an optimum projection based on raster data cell size and geographic location and extent of the database will be developed. This tool will work with existing COTS software for raster data processing. Second, a new mathematical formulation for projecting raster data will be developed. This formulation may take one or more of the following forms: a new dynamic raster map projection, an error correction formula to be used with existing projections, and/or a new resampling method for raster data which accounts for projection errors. In addition, several publications are anticipated some in conference proceedings and one or more in refereed journals such as *Cartography and Geographic Information Science.*

TECHNOLOGY/INFORMATION TRANSFER:

The result of this proposed project will be distributed via the Internet. A WWW site will be developed at USGS and at Northern Michigan University. These sites will provide all data, analysis, and the published paper results from the project.

DATA MANAGEMENT

The provision of data and results to the public will be accomplished through the web sites describe in the section above on Technology/Information Transfer. All original data generated for the project will be managed in accordance with NMD policies.

PERSONNEL

PI – Dr. E. Lynn Usery, Research Geographer, USGS; Associate Professor, University of Georgia. Dr. Usery will coordinate the project and serve as primary investigator for the development of the expert system and for the development of the dynamic projection method. Dr. Usery will use a staff in MCMC of one programmer and one technician with a ½ time cartographer to support project management and development. Dr Usery will coordinate the research and support Dr. Seong and Mr. Steinwand as needed with project resources.

Co-PI – Dr. Jeong-Chang Seong, Assistant Professor, Northern Michigan University. Dr. Seong will be responsible for developing the error correction implementation. He will be supported by two full time students at NMU and will use the programmer assistance from MCMC under Dr. Usery's direction as needed.

Co-PI – Mr. Daniel R. Steinwand, Raytheon, EROS Data Center. Mr. Steinwand will be responsible for developing the resampling approach. He will be assisted by a fulltime student at EDC and will use the technician and programmer resources through MCMC under the direction of Dr. Usery.

COOPERATORS/PARTNERS

None

MANAGEMENT PLAN

Dr. Usery will provide the coordination. Since four separate subtasks exist, Dr. Usery will be responsible for Tasks 1 and 2, Dr. Seong for Task 3, and Mr. Steinwand for Task 4. Coordination of effort, sharing of results, and planning activities will be done primarily through email with at least three project meetings involving all Co-PI's and the support staff as needed. These meetings will facilitate the sharing of accomplishments, achievement of milestones, and resolution of major problems. Additional meetings of two or more of the project staff will be scheduled as required.

FACILITIES/EQUIPMENT/STUDY AREA(S)

The major facilities needed for the project include office and laboratory environments which include a suite of computers capable of handling large data volumes and processing at high speeds. Additionally COTS software for projecting geographic data is needed Since the data to support the project have been generated in GRA Task 741 in FY 2000, the need during FY 2001 is to process these data and conduct the DSS development, projection and error analysis and resampling. The needed environment and equipment exist in MCMC and EDC to accomplish most objectives, however, funds are requested to purchase a dedicated computer for the DSS development and to license COTS software packages (including Imagine, Arc/Info, and Blue Marble Transformer) for map projection. To support Dr. Seong and his students with the error analysis, funds are requested to purchase two high end microcomputers.

LEGAL AND POLICY-SENSITIVE ASPECTS

None

WORK AND REPORTING SCHEDULE

	FY 2001												FY 2002											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Tasks																								
Milestones																								
DSS																								
Database Completion	-	-	-																					
DSS design	-	-	-	-	-																			
Knowledge extraction			-	-	-	-	-																	
DSS knowledge entry				-	-	-	-	-	-	-	-	-												
DSS operational testing							-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dynamic Projection																								
Mathematical development	-	-	-	-	-	-	-	-	-															
Implementation								-	-	-	-	-	-	-	-	-	-	-						
Operational testing													-	-	-	-	-	-	-	-	-	-	-	-
Error Correction																								
Error analysis	-	-	-	-	-	-	-	-	-	-	-	-												
Corrections modeling								-	-	-	-	-	-	-	-	-	-	-						
Correction implementation and testing													-	-	-	-	-	-	-	-	-	-	-	-
Resampling																								
Interpolator development	-	-	-	-	-	-	-	-	-	-	-	-												
Implementation								-	-	-	-	-	-	-	-	-	-	-						
Operational testing													-	-	-	-	-	-	-	-	-	-	-	-

REPORTING REQUIREMENTS Progress reports will be developed quarterly by the Co-PI’s and integrated into a single project report by the PI. Annual reports will be compiled from the quarterly reports and scientific papers will be prepared as results are generated.

QUALIFICATIONS of PROJECT PERSONNEL

E. Lynn Usery
Research Geographer, USGS
Associate Professor, University of Georgia

Education
BS, University of Alabama, 1974; MA, University of Georgia, 1977; PhD, Univeristy of Georgia, 1985

Work experience
11 years with USGS as cartographer, geographer, research geographer.
5.5 years at University of Wisconsin-Madison, teaching and research in GIS, cartography, and remote sensing.
6.5 years at University of Georgia, teaching and research in GIS, cartography, and remote sensing.

Accomplishments
Tenured professor, University of Georgia.
Invited presentations in USA, Taiwan, Russia, Austria
Research grants from IBM, ERDAS, U.S. Department of Agriculture
Chair, Research Committee, University Consortium for Geographic Information Science
Working Group Chair, International Society for Photogrammetry and Remote Sensing
Editorial Board of *CaGIS*, *Applications and Advances in Remote Sensing, Remote Sensing Core Curriculum Peer Review Publication Series, ISPRS Journal of Photogrammetry and Remote Sensing* (1993-1997), editor UGA *Discussion Paper Series*

Selected Publications
Pocknee, S., E.L. Usery, C.Kvien, G. Vellidis, 2000. “Fundamental Changes in the Implementation of GIS and Remote Sensing for Agriculture,” *Journal of Cotton Science*, In press.

Seong, J.C. and E. L. Usery, 2000. “Fuzzy Image Classification for Continental-scale Multi-temporal NDVI Series Using Invariant Pixels and Image Stratification Method,” *Photogrammetric Engineering and Remote Sensing*, In press.

Mozolin, M., J.C. Thill, and E.L. Usery, 1999. “Trip Distribution Forecasting with Multilayer Perceptron Neural Networks: A Critical Evaluation.” *Transportation Research Part B*, Vol 34, pp. 53-73

Usery, E.L., 1996. "A Feature-Based Geographic Information System Model," *Photogrammetric Engineering and Remote Sensing*, Vol. 62, No. 7, pp. 833-838.

Usery, E.L., 1996. "A Conceptual Framework and Fuzzy Set Implementation for Geographic Features," In Burrough, P. A. and A.U. Frank, (eds.), 1996. *Geographic Objects with Indeterminate Boundaries*," Taylor and Francis, London, pp. 71-85.

Tang, A.Y.S., T. Adams, and E.L. Usery, 1996. "A Spatial Data Structure Design for a Feature-Based GIS," *International Journal of Geographical Information Systems*,Vol. 10, No. 5, pp. 643-659.

Jeong Chang Seong, Ph.D.
Assistant Professor
Geography, Northern Michigan University
Marquette, Michigan 49855

Education

BS, Seoul National University, 1988; MA, Seoul National University, 1994;
PhD, University of Georgia, 1999.

Work experience

2000 -	Authorized ArcView GIS Instructor. From ESRI.
1999 -	Assistant Professor, Northern Michigan University
1999	ERDAS, Inc. Program Engineer, ERDAS Headquarter, Atlanta, GA.

Accomplishments NMU Travel/Study Grant, NMU Faculty Research Grant, NAFSA: International Education, Korean Student Assistance Award Program (KSAAP)

Publications and Presentations

Seong, J. C., 2000. “Effect of Global Map Projections on Raster GIS Databases.” The 96th Annual Meeting of the Association of American Geographers. Pittsburgh, PA. 04-08-00. (Presented paper).

Seong, J. C. and E. L Usery, 2000. “Fuzzy Image Classification for Continental-scale Multi-temporal NDVI Series Using Invariant Pixels and Image Stratification Method.” *Photogrammetric Engineering and Remote Sensing.* In Press.

Seong, J. C., 2000. “An Urban GIS Database Design for Integrated Land Property Management in Seoul, South Korea.” 03-10-00. Michigan Academy of Science, Saginaw Valley State University. Submitted to *Michigan Academician*. 03-25-00.

Seong, J. C., 2000. “Characteristics and Application of Large-area Multi-temporal Remote Sensing Data.” *Journal of Korean Society of Remote Sensing*. In Press.

Seong, J. C., and Usery, E. L., “Regional Context of Land Cover Change: Asia, From East to South, 1983 - 1994.” Submitted to *Global Environmental Change - Human and Policy Dimensions*. 01-15-99.

Seong, J. C., Box, E. O., and Usery, E. L., “Spatio-Temporal NDVI Change Patterns and Their Implications for Global Land Cover Dynamics.” Submitted to *ISPRS Journal of Photogrammetry and Remote Sensing.* 12-25-98.

Usery, E. L., Seong, J. C., and Jun, B. W., 1998. “Implementing GIS Software over the World-Wide-Web.” *ASPRS-RTI 1998 Annual Conference Proceedings*, 623-629. Tampa, Florida.

Seong, J. C., 1998. “Estimation of General Systematic Errors Between Two Multitemporal Global NDVI Composite Images using the Polynomial Curve Fitting Method.” *ASPRS-RTI 1998 Annual Conference Proceedings*, 1021-1029. Tampa, Florida.

Mr. Daniel R. Steinwand, Raytheon, EROS Data, Sioux Falls, SD

Education

- B.A. Computer Science, 1983, Augustana College, Sioux Falls, SD.
  Principal subjects * Computer Hardware Interfacing, Software, and Physics.
- M.S. Engineering, 1992, South Dakota State University, Brookings, SD.
  Principal subjects * Signal Processing & Numerical Methods
  Thesis: "Algorithms for the Automated Matching of Remotely Sensed Imagery"

Skills & Research Interests

- Signal Processing, Compression, Numerical Methods, Visualization, and Parallel Computing
- Satellite Image Correlation and Resampling, Map Projection Transformations
- Software Development in C/C++, IDL, Java, Tcl/Tk, Perl, Delphi, and Fortran on UNIX, Linux, Win9x, and MacOS operating systems.

Relevant Experience (1983 * present)

- Developed geometric warping & resampling algorithms, ground control point matching software, & map projection transformation software for the Land Analysis System (LAS)
- Co-designer of geometry algorithms for the 1-km AVHRR Global processing system.
- Co-designer of a multi-resolution compression/decompression technique for the lossless compression of the Global 1-km AVHRR data products.
- Lead on a NMD/USGS-funded research project on Map Projection selection and data processing for raster image data of global and continental extent.
- Co-designer of geometry algorithms for the automated geometric rectification of space-based Synthetic Aperture Radar systems, including Seasat, ERS-1, and JERS-1.
- Lead EDC algorithm designer on Landsat Pathfinder projects (NALC & HTFIP) for co-registration and processing of Landsat data from the 1970's, 1980's, and 1990's.
- Team member, Landsat 7 Image Assessment System (geometry)

Related Publications

- Steinwand, Hutchinson, and Snyder, 1995, Map projections for global and continental data sets and an analysis of pixel distortion caused by reprojection, *PE&RS*, ASPRS, v. 61, no. 12, p. 1487-1497.
- Steinwand, 1994, Mapping raster imagery to the Interrupted Goode Homolosine Projection: *International Journal of Remote Sensing*, London, v.15, no. 17, p. 3463-3471.
- Wivell, Steinwand, Meyer, and Kelly, 1992, The evaluation of terrain models for the geocoding and terrain correction of synthetic aperture radar images: *IEEE Transactions onGeoscience and Remote Sensing*, v. 30, no. 6, p. 1137-1144.
- Kess, Steinwand, and Reichenback, 1996, Compression of the Global Land 1-km AVHRR data set: *International Journal or Remote Sensing*, v.17, no. 15, p. 2955-2969.
- Kess, Steinwand, and Reichenback, 1995, Compression of regions in the Global AVHRR 1-km data set in Science Information Management and Data Compression Workshop, NASA/GSFC, Sept. 1994, Proceedings: NASA Publication 3277, p.59-64.
- Wivell, Olmsted, Steinwand, and Taylor, 1993, An Earth Remote Sensing Satellite-1 synthetic aperture radar mosaic of the Tanana River Basin in Alaska: PE&RS, ASPRS, v. 59, no. 4, p. 527-528.