An improved method of assigning spatial characteristics in a raster environment

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AN IMPROVED METHOD OF ASSIGNING SPATIAL CHARACTERISTICS IN A RASTER ENVIRONMENT.

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Presented to the
Faculty of the Graduate College
and the
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University of Nebraska at Omaha
In Partial Fulfillment
of the Requirements for the Degree
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By
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THEESIS ACCEPTANCE

Accepted for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Arts, University of Nebraska at Omaha.

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CHAPTER I

INTRODUCTION

This thesis will attempt to develop an improved method of handling spatial characteristics in a raster GIS environment. The possibility of assigning multiple variables to a single location in a raster map will be explored. This will be done by developing a non-traditional Geographic Information System (GIS) called the Advanced Raster Analysis Subsystem (ARASS). ARASS will constitute one step in the continuing evolution of GIS.

This system will be unique because it can create maps with one or more spatial characteristics without actually overlaying map files. ARASS will query on spatial attributes rather than pixel values. It will also have an advanced neighborhood analysis capability for studying the relationship between adjacent areas. Because there will always be a need to overlay some maps, ARASS will have a simplified overlay function as well.

The final step of this thesis will be to apply the system to an urban study of Omaha using 1970 census data. This will involve producing maps displaying single geographic variables as well as areas with specific spatial characteristics. The relationship between neighboring areas with different characteristics will be analyzed as well.
LITERATURE REVIEW

Overview of Geographic Information Systems

Geographers are ultimately concerned with understanding spatial interaction, especially man’s interaction with the environment. Computerized systems to store, manipulate, analyze and display geographic and spatial data have been shown to be very useful in studying such spatial relationships as well as mapping cartographic data and studying man’s impact on the environment (Dangermond, 1983). Although geographic information systems have only been around for about 25 years, their importance as geographic tools continues to grow and their ultimate potential may have only been partially realized.

A major problem with studying GIS is that not all their uses are fully understood. It is a relatively new technology and all its applications to geographic analysis have not been explored. Despite its relative infancy, numerous applications have been identified so far. For example, it has been used for natural resource management by keeping an inventory of mineral resources, wetlands, wildlife habitat and hydrologic data. A GIS also has applications in an urban environment such as maintaining census data, conducting traffic analysis, land use planning and managing city resources. It is frequently used in network and corridor analysis as well as in route planning (Dangermond, 1983). Two of its most critical applications are in geographic modeling as well as land use and land cover analysis.
There are two different classes of GIS, vector and raster. A vector system stores data as a list of X,Y coordinates (Fig 1). Features are represented as points, lines or polygons. Vector systems are fairly simple to understand because they use a traditional approach to cartographic processing. They are, however, limited in their capability to perform certain types of data analysis because they have difficulty showing spatial relationships between polygons. It is also very difficult to integrate other technologies such as remote sensing into a vector GIS (Marble, 1978).

A raster GIS stores spatial data as grid cells or pixels in a matrix format (Fig. 2). These systems have advantages and disadvantages associated with them. Raster data requires a lot of storage space and as a result, the size of the study area may be limited. Also, usually raster maps have a lower spatial resolution than vector maps because of its matrix format. On the other hand, raster algorithms tend to be simpler and more efficient than algorithms used with vector data. A raster systems biggest advantage, though, is that it is very well suited for file manipulation, geographic analysis, modeling and especially map overlaying (Marble, 1978).

The Map Analysis and Processing System (MAPS) is a sophisticated raster GIS that was developed at Yale University in conjunction with the Defense Advance Research Project Agency (DARPA). It has an integrated database that can store raster and vector maps as well as imagery files (Autometrics, 1987). This gives it the capability to
VECTOR SYSTEMS STORE DATA AS POINTS, LINES AND POLYGONS

(Jack Dangermond, 1983)

<table>
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<th>FEATURE NUMBER</th>
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<tr>
<td>POINT</td>
<td>X, Y (SINGLE POINT)</td>
</tr>
<tr>
<td>LINE</td>
<td>$X_1 Y_1, X_2 Y_2, \ldots, X_n Y_n$ (STRING)</td>
</tr>
<tr>
<td>POLYGON</td>
<td>$X_1 Y_1, X_2 Y_2, \ldots, X_1 Y_1$ (CLOSED LOOP)</td>
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Raster systems store data in a matrix format.

(Jack Dangermond, 1983)

FIG 2
perform spatial queries that can overlay map and remote sensing data. MAPS uses an interactive command language with English-like phrases to perform its map manipulation and queries (McKeown, 1987).

At the other end of the GIS spectrum is IDRISI which was developed at Clark University to run on microcomputers. It uses a series of independent program modules that are linked by a simple data structure. This system allows new modules to be created using a variety of computer languages. It is even capable of using and creating files in MAPS format. Because it is extremely inexpensive, can be used on a personal computer and can be modified fairly easily, it is ideal for use in business and academic environments.

The Raster Geographic Information System for Mapping (RGISM), developed at the University of Nebraska at Omaha, has similarities to both MAPS and IDRISI. Like MAPS, it consists of a series of Fortran 77 programs and a subroutine library that runs on a mainframe computer. In many ways, though, it is closer to IDRISI because it uses a large number of independent modules that can be easily modified and allows new functions to be added with a minimum of difficulty. RGISM, however, does not have some of the more sophisticated data manipulation functions found on the other systems.

Recently, there have been attempts to upgrade GIS capabilities by integrating them with artificial intelligence (AI). In the past, AI was more associated with remote sensing and pattern recognition rather than geographic
analysis. One application of AI in geographic systems has been in improving how spatial queries are performed. The intent was to find an alternative method of querying for spatial attributes rather than on pixel values alone. One example was CONCEPTMAP, which was developed by modifying MAPS's programs and database structure. This system allows users to query a database for regions using a spatial entity name, by describing some of its properties, using spatial relationships, and by shape description (McKeown, 1987).

Another application of AI in geographic systems was the development of an automated helicopter flight planning system for the U.S. Army. Using a variety of sources such as imagery, maps and intelligence reports, it was possible to plan the safest and most efficient route for a helicopter by taking into account both terrain and threat location (Garvey, 1987).

The Function Of a Raster GIS

In raster based systems such as RGISM, each map file is superimposed over the terrain in such a way that attribute information is stored as a systematic array of grid cells (Jensen, 1986) (Fig. 3). By superimposing a grid cell pattern over a geographic study area, a map value can be associated with each pixel value to characterize a geographic location on a map (Autometrics, 1987). Each raster map file generally represents a single map variable. To depict an area with multiple variables, numerous map files need to be created (Monmonier, 1982) and a data bank of map layers must be built to provide the required multivariate information (Jensen,
A conventional GIS has to overlay multiple maps to sort out the desired information.

(John Jensen, 1986)
Creating numerous raster files is both very difficult and time consuming.

Raster systems have several methods of converting vector data into a grid cell format. The most common method assigns a specific category value to an area enclosed by a polygon, a multi-sided figure. Areas with the same characteristics are given the same grid cell values in the matrix file (Monmonier, 1982). The RGISM program that performs this function is called POLYFILL. Another type of conversion program performs a weighted distance interpolation using a numerical approximation algorithm. It is mostly used to do terrain modeling and to create elevation maps.

Most raster systems such as RGISM, MAPS, and IDRISI all have numerous programs to do data manipulation and data analysis operations. Data analysis operations are those operations that create a new map by combining or transforming values of existing maps. There are four classes of data analysis (Autometrics, 1987).

1) Reclassifying maps is the simplest operation. It creates a new map by reassigning pixel values to an existing map file. This involves substituting one pixel value for another (Autometrics, 1987). Some systems can condense a range of values to a single value. Values above or below a certain threshold can be mapped out as well.

2) The second class is the overlaying of two or more raster files. A new map is created by assigning a pixel value based on its relationship to grid cells on the overlayed maps. Map
overlaying can be done using arithmetic or boolean operations (Dangermond, 1983). Arithmetic operations enable users to add, subtract, multiply and divide pixel values in two separate files. Boolean operations can be used to display pixels that have the same or different values for each grid cell location.

3) The third class of data analysis, measuring distances, relates proximity to spatial data (Autometrics, 1987). It can involve finding the optimum corridor between two points, calculating area of grid cell values and doing circle searches for a given radius around a point (Dangermond, 1983).

4) The final class of data analysis is spatial neighborhood analysis. This involves creating new maps where pixel values are determined by their association with neighboring cells. New pixel values would be calculated based on the values of contiguous grid cells (Autometrics, 1987).

RGISM is only able to do the first two classes of data analysis. It has no software to measure distances or to do neighborhood analysis. These functions can be added but RGISM would still have the same limitations as other raster systems.

Geographic information systems generally have two types of output: statistical reports and maps. Statistical reports usually show the percent of area for each type of land use in the map. This report displays the pixel values representing land use as a percent of the total map file.

The most important output is the various types of maps that can be produced. The simplest map is the choropleth map. It
uses the various grid cell values to differentiate between areas (Tomlinson, 1976). For example, a choropleth map displaying census tract population would show each census tract as having a pixel value equal to its population. A 3-dimensional map can also be created. The third dimension is represented by the cell value. Examples of this type of map include contour, viewshed and watershed maps (Dangermond, 1978).

These are the common features found in most GIS's. More advanced systems can do network analysis as well. Some GIS, such as MAPS, can use remote sensing data as another map level that can be overlayed. Both MAPS and IDRISI have a 'Zoom' capability to more closely study a small portion of the map. Despite RGISM's simplicity, its inherent limitations are found in all other raster GIS's as well.

Limitations Of A Raster GIS

Most raster systems perform data manipulation rather than actual data analysis. This is because the geographic property of the region is stored in the pixel value. Changing the pixel value changes the areas characteristics (Lillesand, 1987). A user overlaying raster maps has to know what each value represents in order to do any type of analysis. Presently, most geographic systems are very limited in their ability to do functions such as land use/cover analysis because of the difficulty associated with computer-assisted geographic analysis. Conventional GIS are dependent on overlaying single variable maps to do any type of analysis.
There are several significant problems with most raster systems: 1) Spatial characteristics can not be easily assigned to a geographic area. Arbitrary pixel values are used to represent variable data. 2) These systems have only limited software to do neighborhood analysis. It is often difficult to show any type of relationship between pixel values that are adjacent. 3) To create map files with multiple variables requires a great deal of data manipulation. For example, to show those census tracts in Omaha that are single family, upper middle income and predominantly black would require the creation and overlaying of several different map files. 4) The quality of the analysis is dependent on the expertise of the person who is doing it. Very few people have the technical expertise required to use a conventional GIS. This is one reason that their use is generally limited to universities and government. 5) Raster map files often can only be used by the person who created them. A user would have to know what each pixel value represented in the map file. The drawbacks associated with traditional systems show the need for a new method of performing geographic analysis.

PURPOSE OF THESIS

It is the intention here to develop an alternative system for performing geographic analysis in a raster environment. A methodology will be devised for assigning an unlimited number of geographic variables to a single raster location and thereby attempt to address some of the shortcomings of current
raster systems. This methodology will be incorporated into the Advanced Raster Analysis Subsystem (ARASS).

The ARASS system will have five significant advantages over conventional geographic systems: 1) Users will be able to query on multiple spatial characteristics rather than a single pixel value. 2) Proximity analysis can be used to produce maps showing relationships between regions with differing characteristics and their neighboring areas. 3) Improved software will greatly simplify overlaying and comparing map files. 4) A variety of outputs can be produced including a statistical report or a choropleth or surface map. 5) The incorporation of trinary map files will show spatial relationships more clearly than the traditional binary files.

ARASS will be unique because it will not be dependent on overlaying files to create maps with multiple characteristics. A conventional raster map usually just shows a single geographic variable. In traditional systems, like RGISM, multiple maps are overlayed and several programs are run to produce a map showing more than one variable. Since they have no query capability, these systems often require extensive training. ARASS simplifies geographic processing by performing spatial analysis without overlaying many single variable maps.

**METHODOLOGY AND ORGANIZATION**

This thesis proposes to test a methodology of assigning multiple variables to a single raster location by developing a GIS using this system. ARASS requires the development of four separate components. 1) A method of assigning one or more
attributes to pixel values in a raster map file. 2) A system for querying raster maps for areas with specific characteristics. 3) Software to show relationships between contiguous regions. 4) An output capability to show the data as a statistical report, choropleth map or 3-dimensional surface map. These choropleth maps include single variable maps as well multiple variable trinary maps. (Fig. 4)

Developing ARASS involves modifying the current RGISM system while retaining as much of its structure as possible. It will have two separate subsystems. The main subsystem will allow users to query raster maps for regions with specific characteristics. It also allows users to create single variable raster files for each geographic variable in the attribute file. These files can create choropleth maps that can be used with RGISM. There will be a capability for neighborhood analysis as well. One option displays areas with specific characteristics that are contiguous to tracts with other attributes. The second neighborhood analysis option will display an area and its contiguous districts that have unique features. The query and neighborhood analysis functions can do statistical analysis or create maps showing the areas of interest using the RGISM mapping programs.

The second subsystem performs overlaying functions. Unlike most GIS's which have a large number of overlay programs, ARASS only has three. The subsystem can compare map files and show the areas that are the same, that are different or it can add maps together.
Once the software is developed, the next step will be to test the system and apply the methodology. This will be done by doing an urban study of Omaha. This application will allow a user to produce maps showing census tracts that have special geographic characteristics as well as their relationship to contiguous tracts with different attributes.
CHAPTER II

DESIGN & IMPLEMENTATION OF ARASS

DESIGN CONSIDERATIONS

ARASS was designed to address the shortcomings of traditional raster based Geographic Information System. It had to have at least the same capabilities as RGISM. It also had to be able to use map files created by RGISM as well as create maps for RGISM. The need for more user friendly software resulted in a scrolling menu system that allows a user to pick specific GIS options. It was important that the system be simple enough so that a user does not need to understand how geographic systems work.

The most difficult problem was developing a method of assigning multiple characteristics to a single area. A user had to be able to change area characteristics without modifying the map file. He also had to be able to run a query against these attributes. Since grid cells would not represent variables, another method of assigning geographic characteristics was needed.

A Data Base Management System (DBMS) was considered as a means of storing map data but it was rejected because it could not show spatial relationships. For this reason, it would be very difficult for it to perform neighborhood analysis. The other difficulty would be in integrating a Fortran based system such as RGISM with an existing DBMS. A great deal of software would have to be written to make the two systems interact. Despite these difficulties, a commercial system
using the ARASS methodology would most likely need a DBMS.

ARASS also required a method of performing proximity analysis. A user had to be able to show the relationship between an area with one set of attributes to its neighboring tracts that may have a different set of characteristics. For example, the software had to be able to display areas with a high black population that were contiguous to areas with a high population density. This involved relating spatial proximity to area attributes.

ARASS would also need an overlay capability since it is not possible to do away with overlaying maps completely. For example, the only way to compare 1970 and 1980 Omaha census data would be to overlay maps. This would require building two separate maps and their associated attribute files. With ARASS, there is no need for a large number of overlay programs to do pixel manipulation. Instead, one program with several options could compare the two maps and produce an output file.

The final consideration was to develop an efficient method of displaying the geographic data. ARASS had to be able to create and use map files showing just a single variable. In other words, there had to be a capability to produce and display choropleth and surface maps showing one spatial characteristic for an entire area. It must also be capable of creating maps displaying regions with special characteristics. RGISM produces binary maps that only show areas of interest and areas of non-interest. There is no way to differentiate those areas that are part of the map from 'empty space'. A
special type of map was needed to show areas of interest and non-interest and to distinguish them from those areas that do not have valid data.

IMPLEMENTATION OF ARASS

Implementing ARASS involved modifying RGISM while trying to retain as much of its structure and subroutines as possible. Like RGISM, ARASS was written in FORTRAN 77. It is a structured programming language that is very efficient at manipulating matrices such as raster files. The main program in ARASS is called the driver module. It calls all the other subroutines that perform specialized processing. The software was designed using structured programming techniques for easy maintenance and modification. It is also well commented to simplify future changes.

ARASS is organized to enable the users to perform a number of GIS functions. It can do statistical analysis by showing the percent of area by land use as well as the percent by area characteristics. Its primary function, though, is to allow a user to show areas with unique characteristics without having to overlay maps. After running a query, the user has the option to perform several types of neighborhood analysis. This allows him to study relationships between adjacent areas with different characteristics.

In ARASS, the characteristics of each area are stored in an attribute record in the attribute file. These attribute records are maintained in a sequential data set so that they
can be easily updated. Modifying the attribute file changes the characteristics of a region without creating a new map. ARASS relates pixel values in the map file to a specific attribute record containing the characteristics of each tract.

The Category value is the key field for the attribute record. It is a four character field that uniquely defines a geographic area. The category value corresponds to a pixel number in the raster map file. The first two characters define land use and land cover for that area. All these land use categories are defined in the land use category file. Within each general land use/cover category there can be up to 99 subdivisions. For example, a census tract with a grid cell value of 1011 indicates that it is the 11th census tract that is predominantly single family housing. This method allows a great deal of flexibility. For each individual project, the user can develop his own system of assigning land use or land cover to a geographic area.

The Characteristic fields are the actual geographic variables that are stored in the attribute file. For this study they include Population, Population Density, Average Housing Value, Ethnic Group, Percent of Population of that ethnic group, Average Family Income, and Average Education Level. All these fields may not be filled in for an individual record. For other studies, these fields can be changed with very minor modifications to the software.
Developing the query system was the most challenging part of this project. A separate query subroutine was written for each variable in the attribute file. The query package would identify regions with specific attributes. These subroutines search the attribute file for records with variable fields that matched the query. This identified those pixels with the characteristics the user requested. A special subroutine was written to associate that pixel values and its spatial characteristics. This subroutine was called after each query subroutine was performed.

A query can be run against one or more variable fields stored in the attribute file. A query consists of a relationship and a value. For example, the user can ask for all areas with a family income greater than $7500 and less than 10.3 years of education. During a query, the software will read in the attribute file and the raster map file. The system will then find those attribute records containing the requested characteristic data and their associated grid cells. These pixel values will be mapped out into a trinary file.

To do this with the current RGISM system would require creating two separate maps. One map would show family income and the other average education. A program called Above would be run against each file producing a binary file as output. One map would show areas with an income greater than $7500 and the other education levels greater the 10.3 years. Another program called SAME would overlay the two files and produce a binary file showing those areas that matched.
To simplify this process, two types of statistical subroutines were written. One showed each land use as a percent of the total map area. It calculated this by summing the total pixels for each land use and dividing by the total number of non-zero pixels. ARASS also showed the percent of total area that had the characteristics the user requested. During a query, the system keeps track of all grid cell values that had the requested attributes assigned to them. The total number of these pixels were then divided by the number of pixels in the map.

Software was developed to do the four steps in a neighborhood analysis: 1) The primary query subroutine sifts out those tracts that the user is interested in. 2) Another performs proximity analysis by identifying all adjacent regions to those areas identified by the primary query. 3) The query subroutines are called again to further isolate areas with unique characteristics. 4) In option one, a subroutine is called to match the areas from the first query with those in the second. This identifies those areas from the primary query that are adjacent to tracts identified in the secondary query.

A separate overlay subsystem was developed by modifying three RGISM programs called; SAME, DIFFERENCE and ISOLATE. These programs were modified and made into subroutines that can be called from a main menu. This gave the user the ability to compare two trinary maps by showing where they match or differ. It can also combine the areas of interest from the two maps and put them together on the output map.
There are two types of raster files created by the ARASS system. Software had to be developed to create single variable raster files for each variable in the attribute file. The subroutine would substitute the data in the variable field with the grid cell value in the raster map. For example, it is possible to produce a map showing the average family income by census tract in Omaha. This would be done by replacing the pixel values with the family income field of the attribute record assigned to it. A census tract with a population of 7500 will have a grid cell with the same value. These files could then be used with all RGISM programs. Implementing software to read and write trinary files was more difficult.

RGISM uses binary maps to represent areas that have multiple variables that are of interest to the user. These binary files are created by overlaying several single variable raster maps. In ARASS, RGISM software was modified to use trinary files. A trinary map is similar to the binary map except that instead of storing data as 1's and 0's, it stores data as 0's, 1's and 2's. A binary file can only show areas of interest and noninterest. In a trinary file, pixel values of '0' represent areas not on the map as well as missing or invalid data. Grid cell values of '1's represent areas on the map that the user is not interested in and 2's are areas with special characteristics. Trinary files display data more clearly but require more sophisticated software to produce and use them.
ARASS Matches Pixel value in the Raster Map with the Category : Value in the Attribute to assign spatial characteristics

Figure 4
THE CAPABILITY AND FUNCTIONS OF ARASS

ARASS was designed to simplify geographic analysis by using a non-traditional approach to spatial processing. It uses a scrolling menu system that gives users the option to perform selected geographic processes. This simplifies geographic analysis and allows the user to make a hardcopy of a session so that he has a record of the map files created. The menu tells the user everything they need to know to use ARASS.

When ARASS is first run, it displays an option to produce a report or a map. The report option just shows the percent of total area that meets the users query. The map option also produces a trinary map displaying all areas with the characteristics that were requested. Users have the option to look at the attribute file which contains all the geographic characteristics assigned to each tract in the map file.

ARASS uses a raster map file as input. This is the matrix file produced when the POLYFILL program does a vector to raster conversion. The size of this file is not a factor and it is possible to have a map with several different scales, depending on the need. The map file is then compared with the land use/cover file to show each land use by percent of total area.

Creating Single Variable Raster Maps

Using ARASS, it is possible to create a single variable map file. This is done by replacing the pixel value with one of its geographic variables. Choropleth maps can be created showing population, population density, average family income,
average housing price, land use and percent of population for a specific ethnic group.

This option allows users to create standard raster files that can be used with RGISM. RGISM then has various programs to convert it into binary files. These single variable map files can be used to produce a choropleth map or a 3-dimensional surface map showing the distribution of each geographic variable.

Querying A Map file

The most important function in ARASS is the capability to query a raster map on specific geographic characteristics. The query by field system used in ARASS gives the user the option of querying on each of the variables in the attribute file or bypassing them. The query system works by putting in a boolean relationship (GT=Greater than, LT=less than or EQ=equal to) and a numeric variable. The program then goes out to the attribute file to find those records that meet the users parameters. For example, if the user asks for a population greater than 2500, the program will look for those attribute records that have a value in the population field greater than 2500. The associated pixel values are then passed to the next query subroutine. This subroutine then tests if any of these pixels have the characteristics specified by the current query. ARASS continues to sift out the grid cells until only those tracts that have all the requested characteristics remain. Putting in a '0' bypasses a query and no match against the attribute field is performed.
The first query is on land use. The operator puts in a two character land use value that matches one of those in the land use file. The subroutine then compares this number with the first two characters of the pixel value in the map. For example, inputting a '15' will extract all census tracts that are predominantly single and multifamily housing.

The next query subroutine looks at the population field in the attribute record. The user puts in a boolean relationship and a value to compare with. Entering a LT3000 will list all tracts with a population less than 3000 that also meets the specification from the previous query. It is then possible to show all single and multifamily tracts with a population under 3,000. The same methodology is used to query on population density, family income and average education level. Running a query on ethnic composition requires a slightly different process.

To do an ethnic query, the user puts in a 2 character variable representing either a specific or general ethnic group. General ethnic groups such as Hispanics would be represented as a '30' while a specific subgroup such as Mexicans would be represented as '31'. A user has the option of viewing the ethnic file that describes each ethnic category. After inputting a specific ethnic group, the next step is to input a boolean relationship. For example, using a GT23 will show those areas where over 23% of the population is of a specific ethnic group. More than one ethnic group can be assigned to an area. This is done by having multiple attribute
records define the same location. The only difference would be in the ethnic group and ethnic percent field. There is no limit to the number of ethnic groups that can be assigned to a specific tract.

By going through this procedure, all the tracts with certain characteristics are identified. From this point, the user has two choices. He can produce a map showing those regions with the attributes he has requested or he can perform a neighborhood analysis.

Neighborhood Analysis

The neighborhood analysis function has two separate options. The first identifies areas with specific characteristics that are also adjacent to regions with other attributes. For example, it is possible to display those census tracts with over 10% black population that are adjacent to tracts with an average family income of over $12,000 and greater than 12.0 years of formal education.

The second option enables the user to identify tracts with specific characteristics and their contiguous districts. Out of these, only those areas with the required attributes would be displayed. The first step would be to identify those census tracts with over 10% black population and all adjacent tracts. From these, only those areas with an income over $12,000 and 12.0 years of education would be displayed. The difference between the two options is very subtle but it is also very important. One option will display areas depending on its relationship with neighboring tracts. The other takes
certain regions and their neighbors together and does a secondary query to sort out those districts with special characteristics.

ARASS produces a statistical analysis showing the percent of the total map that the user is interested in. If the map option was selected, the user can specify the name of the output file to be created. Comments can also be added to describe the map.

Overlaying Map Files

The overlay subsystem has three options: 1) It can show the difference between two map files. It overlays two trinary files by doing a pixel by pixel comparison and identifying those areas where the values don't agree. 2) It also can show areas of interest that are the same. The overlay program looks for areas with matching grid cell values. 3) The final option allows users to add two maps together. If an area of interest is on at least one map, it will be displayed. In other words, if either file has a pixel value of '2' it will be mapped as a '2' in the output file. These capabilities greatly simplify the overlay process and significantly reduce the number of overlay programs needed.

Displaying Map Files

There are two programs for displaying map data. The SCREEN program creates a choropleth map on a special graphics screen. The user assigns a specific alphanumeric or special character to represent a pixel value. In trinary files, spaces are used
to represent 0's, '.' represents 1's and '@' are used to display 2's.

The second program is called TRIDGG. It creates a surface map on the screen. The third dimension is represented by the pixel value. It is generally used to show single variable raster files as a 3-dimensional image but it can also be used with trinary files. The user can specify the altitude and azimuth of the map on the screen.

The final step in implementing ARASS was applying it to a geographic problem. This was the only way to confirm the effectiveness of ARASS and its methodology. In this case, it was used to perform urban analysis although it also could have applications in such areas as land use management and agricultural planning.
CHAPTER III
EVALUATION & APPLICATION OF ARASS

DATA INPUT

One of the most difficult portions of this thesis was evaluating and testing ARASS. The purpose of this was not only to test the software but also to use the methodology developed in a practical application. ARASS was used to do a limited urban study of Omaha with 1970 census data. It provided an alternative method of doing urban analysis by assigning multiple population variables to each census tract in the city. Users could then run a query to create maps displaying census tracts with special characteristics.

Building The Maps

The Vector map of Omaha showing all the census tracts was stored in a sequential file on the VAX computer. It was originally created by digitizing each of the census tracts. Digitizing involves tracing each tract and creating a record that shows the boundary coordinates for that polygon. This file was modified and a land use category value was assigned to each of the 102 census tracts in Omaha. The final step was to convert the vector file into a raster map file.

An RGISM program, POLYFILL, was used to convert the vector map into a matrix. Each census tract was assigned a unique pixel value representing its land use category. The user had the option of specifying the size of the raster file to be created. The larger the file, the larger the scale of the map.
Two maps of Omaha with different scales were created for this test. The first map file was 80 columns by 60 rows and the other was 60 columns by 40 rows. Map scale was irrelevant although the overlay system could not compare map files of different sizes and smaller files would be processed faster. There also was a limit on the size of the maps that could be displayed on the computer screen, although larger maps could be sent to a printer.

DATA TESTING
Building The Files

In addition to creating the maps, data for each census tract had to be gathered to build the attribute file (Fig. 5). This data included land use, population, population density, average family income, average level of education and percent of population for each ethnic group. Some of this data was not in the 1970 census and had to be gathered from the Metropolitan Area Planning Agency (MAPA). For example, land use for each tract was established using a map showing land use by block rather than by census tract. Thus, the one or two predominant land uses per tract were used to assign that land use value. The average housing cost was also gathered from MAPA data.

In this project, only two ethnic groups were shown for Omaha. This was because the census data only showed the black and hispanic populations. For other ethnic groups, it only counted foreign born people and not ancestry. For this study, only ethnic groups making up over 1% of the population of a
THIS IS THE ATTRIBUTE FILE. IT CONTAINS THE CHARACTERISTICS FOR A GEOGRAPHIC AREA. IT MATCHES THE CATEGORY VALUE WITH THE PIXEL VALUES IN THE RASTER MAP FILE. IT THEN ASSIGN CHARACTERISTIC DATA WHERE PIXEL VALUES MATCH CAT CODE.

A RULE OF 'A' ASSIGNS CHARACTERISTICS TO AN AREA.
A RULE OF 'O.' ASSIGNS CHARACTERISTICS TO PIXEL VALUES BEING OVERLAYERED.
A RULE OF 'N' ASSIGNS CHARACTERISTICS TO A PIXEL VALUE BASED ON THE VALUE OF ADJACENT PIXEL VALUES.

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| A2   | 1502      | 2538      | 5942      | 4513     | 9.8      | 10    |

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| A2   | 1401      | 399       | 2551      | 2300     | 9.6      | 10    |

| A1   | 1503      | 1308      | 4333      | 3203     | 9.7      | 10    |

FIG. 5
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FIG 5

- 37 -
tract were shown. The default ethnic group was white.

Testing The Files

After all the files had been created, the next step was to test the software. The first test was to ensure that the attribute, ethnic and land use files were read correctly. For the ethnic and attribute files, ARASS just read the files and displayed them. Testing the land use file was a little more difficult because the system only showed those land use categories that were in the map file. The category value and its description had to be properly matched and displayed.

Testing The Statistical Analysis Procedures.

There were two subroutines that performed the statistical analysis. The first showed the percent of area for each land use in the map file. This was tested by creating a single variable map showing land use. It was possible to compare this with ARASS to see if the land use percent roughly matched. In other words, it was used to test if the total area for each land use approximately matched the systems statistical output. The other method of testing statistical integrity was to run a query showing each land use and then comparing it with the displayed land use statistics. This was possible because the system showed the percent of total area that matched the users query. There were slight discrepancies between the two because of truncation while calculating the statistics. For this reason as well, the total land use statistics did not add up to 100%.
Testing The Query Programs

The most critical aspect of testing the query system was ensuring that the pixel values and their characteristics stayed properly associated during a query. The first test was fairly general, maps were created with specific characteristics such as high income levels or a high concentration of an ethnic group. By comparing these with maps obtained from MAPA, it was discovered that pixel values were being disassociated from their attributes. Several maps created by ARASS showed North Omaha having a very high black population but also having a very high education level, family income and cost of housing as well. This conflicted with other data that indicated that this area was fairly poor. This error was corrected by writing a special subroutine to relink the pixel with its attributes after each query.

Another method of testing involved using known geographic relationships. For example, there is a direct relationship between family income, education and housing costs. Thus, census tracts with a high income often overlap with tracts having a high education level or high housing cost. Areas with these characteristics are often concentrated together. There is also often a relationship between ethnic composition and other variables such as education, income, housing value and land use. Areas with a high black population often have a lower income, education level and housing cost. These areas also have a high concentration of multifamily housing and industrial buildings. By creating maps with
specific variables and comparing them with maps showing other characteristics, it was possible to determine if pixels and their attributes were staying associated.

The final method of testing the query procedure was the most precise. During a query, ARASS would display the grid cells and its associated variable fields that had been selected. If the user asked for all census tracts with a population over 2,000, ARASS would display the area pixel values as well as its population field. It was possible to check that only population fields with over 2,000 were displayed. In addition, the pixels were manually compared with their associated population field. The final evaluation was to test all remaining pixels to ensure that they had all the requested characteristics. After testing the query software, the next step was to evaluate the neighborhood analysis system.

Testing Neighborhood Analysis Functions

The first step in testing the neighborhood analysis software was to ensure that all adjacent census tracts were identified. A special subroutine was developed to identify those areas contiguous to the census tracts passed to it. This subroutine was tested by passing a group of tracts and listing out all adjacent census tracts. This was then compared with a map of Omaha census tracts.

The next step was to run a secondary query to pull only those adjacent tracts with special characteristics. This query used the same subroutines that performed the primary query.
The first neighborhood analysis option showed all tracts with certain attributes and their neighbors that had special characteristics. This was tested by: 1) performing a query to pull census tracts with specific characteristics (primary tracts). 2) Identifying all adjacent tracts. 3) Running a secondary query against the primary and contiguous tracts. 4) Comparing the remaining tracts with census data to ensure that they have the characteristics identified in the secondary query.

Testing the second option was slightly more difficult because adjacent areas were not mapped. Only primary tracts that were contiguous to areas identified in the secondary query were displayed. This option was tested by: 1) Performing a query to pull census tracts with specific characteristics; 2) Identifying all adjacent tracts; 3) Running a secondary query against the contiguous tracts. 4) Identifying the neighboring tracts selected by the secondary query (secondary tracts); and 5) Comparing the tracts from the first query with those in the second. Only those primary tracts that were bordering the secondary tracts should be displayed.

Testing The Overlaying Functions

Overlaying trinary files was more difficult than overlaying binary files because the system has to deal with three variables instead of two. On the other hand, ARASS only needs to overlay two trinary files to achieve the same result as RGISM overlaying three files. ARASS was able to process
trinary files by ignoring pixel values of 0's since they represented non-valid data. If the two maps of Omaha were the same scale, the zeros pixel values would correspond. The overlay software was mostly concerned with differentiating between areas with pixel values of 1's and 2's.

Testing the overlay functions involved creating several maps of Omaha with different characteristics and comparing them. ARASS would produce a map showing areas that were the same, that were different or just show any areas of interest on either map. These maps were then manually compared to confirm that the correct relationship was displayed.

Overlaying was used to test the ARASS neighborhood analysis capabilities as well. Two map files were produced, one showing the primary tracts and the other showing the primary and adjacent tracts. If the 'same' overlaying option was selected, only the primary census tracts would be displayed. If the 'different' option was used, only adjacent areas would be mapped out. If the 'total' overlay option was tested, both the primary and neighboring tracts would be displayed. It was not necessary to test the output programs SCREEN and TRIDGG because both were part of the original RGISM system and were well tested.

URBAN APPLICATION OF ARASS

The final step in testing ARASS was to apply it to an urban analysis of Omaha. One application entailed studying the ethnic composition of Omaha by census tract. This involved looking at the distribution of the black and hispanic populations.
The first type of map created using SCREEN was a single variable choropleth map showing the distribution of the hispanic population in Omaha (Fig. 6). The hispanic population by census tract varied from zero to 17 percent. The highest concentration of hispanics was found in south-eastern and central Omaha. The concentration decreased toward the north and western part of the city. Another choropleth map was created showing the distribution of the black population in Omaha (Fig. 7). This percentage ranged from 0% to 97% with the highest concentrations in eastern Omaha, especially in the North Omaha area. TRIDGG was then run to give a 3-dimensional map showing the black and hispanic population density.

The next step was to run a query and identify all census tracts with over a 1% hispanic population (Fig. 8). ARASS produced a multivariable trinary map which confirmed that most of the hispanic population is in eastern and central Omaha. A second query was then run to identify those tracts with greater than a 2% hispanic population (Fig. 9). This trinary map indicated that most of the census tracts in east central Omaha have less than 2% hispanic population. These two files were then overlayed to show those areas having between a 1% and 2% hispanic population. Trinary maps were also created showing districts with over a 10% black population (Fig. 10). This map identifies the black population as largely concentrated in the North Omaha area.
Concentration of Hispanic Population in Omaha
Concentration of Black Population
In Omaha

FIG 7
CENSUS TRACTS WITH OVER 1% HISPANIC POPULATION

CHOROPLETH MAP

Enter desired symbol for value 0:
Enter name of file: MAP.OUT

Notes from the file: MAP.OUT

CENSUS TRACTS WITH GREATER THAN 2% HISPANIC POPULATION

CHOROPLETH MAP

Enter desired symbol for value: 0:

--- Diagram of Choropleth Map ---

FIG 9
Enter name of file: MAP1.OUT
Notes from the file: MAP1.OUT

CENSUS TRACTS WITH GREATER THEN 10% BLACK POPULATION

FIG. 10

- 48 -
The trinary map files showing the Hispanic and Black concentrations were then overlayed. The maps created showed those areas that were over 2% Hispanic or 10% Black (Fig. 11) as well as showing those areas with greater than 2% Hispanic and 10% Black populations (Fig. 12).

These first set of queries were fairly simple and could even have been done with RGISM. The next set of queries looked at the ethnic composition of an area and its relationship to the income and education levels of neighboring tracts. The first query identified areas with over a 10% Black population and their adjacent regions and then mapped those tracts that had an average income over $12,000 and an average education level greater than 12 years (Fig. 13). Another query was run to show areas with a 10% Black population that were adjacent to census tracts with a family income of over $12,000 and more than 12 years of formal education (Fig. 14). Although the two queries were similar, they produced two distinctly different maps. This capability to work with multiple variables in conjunction with adjacency is what sets ARASS apart from many other geographic systems.

ARASS's ability to perform extremely complex queries allows very specific maps to be created. This was illustrated by a map showing the single census tract with a population of over 3000, that has single and multifamily housing, an average family income over $10,000 and 10 years of education that is near a commercial district as well as adjacent to tracts with over 3% Hispanic population (Fig. 15). Creating this map
Enter name of file: MAP2.OUT
Notes from the file: MAP2.OUT

CENSUS TRACTS THAT ARE OVER 2% HISPANIC OR 15% BLACK BUT NOT BOTH
Enter name of file: MAP2.OUT
Notes from the file: MAP2.OUT

CENSUS TRACTS OVER 2% HISPANIC & 10% BLACK

FIG 12

- 51 -
CENSUS TRACTS WITH OVER 10% BLACK POPULATION AND ADJACENT TRACTS WITH A FAMILY INCOME OVER $12,000 AND OVER 12.0 YEARS OF FORMAL EDUCATION.

CHOROPLETH MAP
CENSUS TRACTS WITH OVER A 10% BLACK POPULATION THAT ARE ALSO ADJACENT TO TRACTS WITH AN AVERAGE FAMILY INCOME OF $12,000 AND OVER 12.0 YEARS OF FORMAL EDUCATION.

CHOROPLETH MAP

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FIG 14
SINGLE & MULTIFAMILY HOUSING NEAR COMMERCIAL DISTRICTS IN CENSUS TRACTS WITH OVER 3000 PEOPLE, AN AVERAGE FAMILY INCOME GREATER THEN $12,000, GREATER THEN 10.0 YEARS OF EDUCATION THAT IS ADJACENT TO CENSUS TRACTS WITH OVER 3% HISPANIC POPULATION

CHOROPLETH MAP

Enter desired symbol for value 0:

.................

FIG : 15

- 54 -
required using ARASS's query and neighborhood analysis functions as well as overlaying two trinary files. In contrast, RGISM probably could not create this type of map and most other GIS would require overlaying numerous map files.
CHAPTER IV

CONCLUSION

COMPARING ARASS AND CONVENTIONAL GIS

A conventional raster-based GIS, such as RGISM, overlays a series of single variable maps to produce a binary map showing specific area characteristics. A separate map must be built for each geographic variable. Geographic systems generally have many programs that can add, subtract, multiply and divide the pixel values of one or two map files. It is necessary to have all these programs because all spatial data is represented as a pixel value. In ARASS, only one raster map is necessary to show all the characteristics. This is because the area attributes are stored in the attribute file and so a large number of pixel manipulating programs are not needed.

To sort out areas with unique characteristics, programs are usually run to identify specific pixel values. RGISM searches for areas that have grid cells that are equal to, greater than or less than a given value. Several binary files can be built this way. These maps are then overlayed to create multivariable files showing areas that the user has identified.

ARASS does the same function by querying on each variable in the attribute file. Each query identifies only those pixels that have specific characteristics assigned to it. This assigning of multiple variables to a grid cell avoids the need to overlay so many map files. ARASS still does have an overlay capability but it is greatly simplified. It compares two maps.
and shows areas that are the same, different or combines the areas of interest on each map.

RGISM has no neighborhood analysis functions and most other systems can only perform proximity analysis using a single variable at a time. ARASS can do proximity analysis against multiple variables. It can show an area and its contiguous regions even when they have different characteristics. For example, it can show tracts with single family houses and adjacent tracts with a population greater than 2500. It can also show tracts with specific attributes that are adjacent to regions with other characteristics. This can include single family homes that are bordering on regions with a population over 2500. Conventional systems can not show these types of relationships without great difficulty, if at all.

Since RGISM uses binary files, it is impossible to tell those areas that are part of the map and those areas that are just 'empty space'. Areas not part of the map, having invalid data or of being no interested to the user, all have the same value. A trinary file differentiates between areas containing invalid data and those regions with good data but not having the characteristics the user wants.

ARASS can greatly simplify spatial processing by dividing up the work. One person can digitize and create the map files and another can update the attribute data files as the information changes. The end-user does not need to worry about these processes. This is quite a contrast with traditional systems which required an extensive understanding of
geographic systems before being used.

IMPACT OF ARASS

ARASS was not developed to be a commercial geographic information system. Rather, it was developed as a prototype of a new generation of geographic systems. There are two major modifications that could make it commercially viable. The first would be to integrate ARASS with a Data Base Management System (DBMS). Instead of storing attribute data in a sequential data set, it could be stored on a database. A DBMS would make querying a database more efficient. Instead of having to do a separate query on each variable, it would be possible to do a single query against one or more variable fields. With a DBMS, the database could be updated very quickly. Attribute fields could be modified and records added and deleted with minimum difficulty.

There are problems, however, with integrating a DBMS with a system such as ARASS. It would be easy to list all areas with specific characteristics using a simple query language such as SQL. The difficulty is that it is not possible to perform neighborhood analysis using a database. A DBMS has no capacity to show geographic relationships such as adjacency. This was why I did not integrate ARASS with a relational DBMS such as ORACLE. Integrating ORACLE with a structured language such as Fortran would be extremely difficult. Software would have to be developed to allow ARASS to extract data from the database using a special query language. ARASS would then perform the spatial analysis and produce the maps.

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Despite these difficulties, one possible method to integrate the two systems might be to have the DBMS pass a data file to ARASS with a set of grid cells that meet the users query. ARRAS could read the file and do the geographic analysis. It could even be possible to overcome the DBMS's limitation on neighborhood analysis by having ARASS identify adjacent pixel and pass it back to the database for a secondary query.

Another important step for ARASS would be to put it on a personal computer (PC). This would make the system available to a larger number of users. One reason that GIS are not used extensively in business is because they are often difficult to use and require extensive training. Also, they are often located on large mainframe computers that limit users accessibility. By making GIS more available to users, geographic analysis could become an important tool for making business decisions. It would further isolate users from the technical aspects of building, maintaining and updating a GIS. The person who created the maps does not need to be the person who maintains the attribute files. The end-user does not even really have to understand how ARASS works. All he has to do is be able to pick a map and run a query asking for areas with the characteristics he wants. Putting ARASS on a PC would make performing geographic analysis as simple as using a word processor or a spreadsheet.
SUMMARY

The Advanced Raster Analysis Subsystem represents an alternative approach to performing geographic processing. The system is unique in that multiple variables can be assigned to the same location without having to overlay maps. This is a more realistic concept because in the 'real' world, all spatial locations have numerous attributes describing them. ARASS allows users to query on specific characteristics rather than pixel values. This greatly simplifies the process of geographic analysis. It also has a neighborhood analysis function that is unusual because it can work with several variables together. It can show all adjacent areas or only those with specific characteristics. It can also display those specific tracts that are adjacent to areas with unique attributes. Most other GIS can not do this because they generally work with single variable raster maps.

ARASS seems to require less technical training than most other geographic systems. It is possible to divide jobs so that end users do not need know how geographic systems or ARASS works. The users should be able to get on to a computer and simply ask it to display those areas that meet his query parameters. Functions such as digitizing maps and updating the attribute file can be performed by people who are not end-users. This type of specialization will make geographic systems more freely available and increase their usefulness.
The concepts developed by this thesis may be applicable to future GIS's. It seems that spatial scientists need to get away from building and overlaying single variable maps. These maps seem to be very difficult to create and to use. Geographers are responsible for constantly thinking of new ways to improve the capabilities of geographic information systems. In addition, they must constantly search for new applications of geographic systems for geographic, cartographic and spatial analysis.
GLOSSARY

Advanced Raster Analysis Subsystem (ARASS): A raster GIS developed as a result of this thesis. It allows users to query on area characteristics rather than pixel values.

Binary Map File: A raster map file that stores data as 1's and 0's.

Data Analysis: Operations that provide for generation of new maps by combining and/or transforming values of existing maps.

Data Base Management System (DBMS): A software tool that is used to simplify file management and data retrieval.

Fortran: An early computer language commonly used in mathematical and scientific programming. Both ARASS and RGISM are written in Fortran.

Geographic Information Systems (GIS): Computerized systems to store, manipulate, analyze and display geographic and spatial data.

IDRISI: A raster GIS developed at Clark University for use on a Microcomputer.

MAPS: A raster subsystem of the vector Map Overlay and Statistical System (MOSS).

Maryland Automated Geographic Information System (MAGI): A Raster GIS used by the Maryland Department of State Planning to do state wide land use planning.

PIXEL or Grid Cell: An element of a digital map that represents a square portion of the Earth's surface.

Raster GIS: A GIS that stores and uses geographic data in a matrix or cellular format.
RGISM: A raster GIS developed at the University of Nebraska at Omaha. It consists of a series of Fortran Programs to manipulate and display raster map files.

Trinary Map File: A file similar to a binary map file. A '0' is used to represent areas not included in the map. A '1' represents map data while a '2' is used to represent an area of interest. It is superior to binary map files because it can display map information more clearly.

Vector GIS: A GIS that stores and manipulates geographic data in an X-Y coordinate structure.

Vector to Raster Conversion: A process for converting X-Y coordinates into a matrix format. Polyfil is an example of software that does this conversion.
APPENDIX A

MAPS CREATED BY ARASS

This appendix shows various examples of single variable choropleth maps, multivariable trinary maps and 3-dimensional surface maps created by ARASS. (The vertical distortion was the result of POLYFILL’s vector to raster conversion)
MAP OF OMAHA SHOWING LAND USE GROUPS

CHOROPLETH MAP

Enter desired symbol for value 0:

Enter desired symbol for value 100:

Enter desired symbol for value 110:

Enter desired symbol for value 120:

Enter desired symbol for value 130:

Enter desired symbol for value 140:

Enter desired symbol for value 150:

Enter desired symbol for value 170:

Enter desired symbol for value 180:

Enter desired symbol for value 200:

Enter desired symbol for value 260:

Enter desired symbol for value 270:

Enter desired symbol for value 280:

Enter desired symbol for value 290:
CENSUS TRACTS CONSISTING OF SINGLE & MULTIFAMILY HOUSING IN OMAHA
Enter name of file: MAP.OUT
Notes from the file: MAP.OUT

SINGLE & MULTIFAMILY HOUSING NEAR COMMERCIAL DISTRICTS WITH OVER 3000 PEOPLE IN THE CENSUS TRACT, WITH AN AVERAGE FAMILY INCOME OVER $12,000 AND GREATER THAN 10.0 YEARS OF EDUCATION

CHOROPLETH MAP

Enter desired symbol for value 0:

@
SINGLE, MULTIFAMILY AND COMMERCIAL PROPERTY IN CENSUS TRACTS WITH OVER 3000 PEOPLE, AN AVERAGE FAMILY INCOME GREATER THAN $12,000, OVER 10.0 YEARS OF EDUCATION AND ADJACENT AREAS WHERE THE TOTAL HISPANIC POPULATION IS GREATER THAN 1%

CHOROPLETH MAP

Enter desired symbol for value 0:

 Enter name of file : MAP2.OUT
 Notes from the file : MAP2.0UT
AVERAGE FAMILY INCOME IN OMAHA

AZ ALT NC NR
120. 35. 80 80
AZ ALT NC NR
130 35 80 80

--------> AVERAGE EDUCATION LEVEL IN OMAHA
AZ ALT NC NR ---->> BLACK POPULATION IN OMAHA
120. 35. 90 60
APPENDIX B
EXAMPLES OF ARASS FUNCTIONS

This appendix shows how ARASS would look to a user. The dialog includes all of the functions found in the ARASS system.
DO NOT CREATE RASTER MAP

(1) MAP POPULATION
(2) MAP POPULATION DENSITY
(3) AVERAGE FAMILY INCOME
(4) AVERAGE HOUSING PRICE
(5) AVERAGE EDUCATION LEVEL
(6) GROUP LAND USES TOGETHER
(7) % OF POPULATION BY ETHNIC GROUP

Do you wish to query on specific areas? "Y" or "N"

Y

Fill in the land use category or put a "C" in for the value.

Fill in the 2 digit category value or put a C to bypass this query.

Fill in the population or put a "C" in for the value.

Fill in the relationship (GT, LT, EQ or O) then fill in the population to be mapped.

GT3000

<table>
<thead>
<tr>
<th>Code</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>2801</td>
<td>5142</td>
</tr>
<tr>
<td>2802</td>
<td>4004</td>
</tr>
<tr>
<td>2804</td>
<td>3472</td>
</tr>
<tr>
<td>2806</td>
<td>3244</td>
</tr>
<tr>
<td>2807</td>
<td>3004</td>
</tr>
<tr>
<td>2811</td>
<td>5522</td>
</tr>
<tr>
<td>2812</td>
<td>5559</td>
</tr>
<tr>
<td>2814</td>
<td>6689</td>
</tr>
<tr>
<td>2815</td>
<td>7551</td>
</tr>
<tr>
<td>2818</td>
<td>4232</td>
</tr>
</tbody>
</table>

Fill in the income level or put a "C" in for the value.

Fill in the relationship (GT, LT, EQ or O) then fill in the income level to be mapped.

GT12000

<table>
<thead>
<tr>
<th>Code</th>
<th>Income Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2814</td>
<td>21017</td>
</tr>
<tr>
<td>2815</td>
<td>13144</td>
</tr>
</tbody>
</table>

Fill in the average housing value or put a "C" in for the value.

Fill in the relationship (GT, LT, EQ or O) then fill in the housing value to be mapped.

0

<table>
<thead>
<tr>
<th>Code</th>
<th>Housing Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2814</td>
<td>48702</td>
</tr>
<tr>
<td>2818</td>
<td>0</td>
</tr>
</tbody>
</table>

Fill in the average population density or put a "C" in for the value.

Fill in the relationship (GT, LT, EQ or O) then fill in the pop density to be mapped.

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INTERACTIVE QUERY FOR THE IMPROVED RGISM SYSTEM

WILL THE OUTPUT BE A STATISTICAL REPORT OR A CHOROPLETH MAP?
ENTER OPTION (1) REPORT OR (2) MAP
2

DO YOU WANT TO SEE THE ATTRIBUTE LIST
(1) YES OR (2) NO
2

ENTER THE RGISM MAP FILE: OMAHA.OUT
Notes from the file: OMAHA.OUT
OMAHA BY CENSUS TRACTS

POLYGON FILL PROGRAM OUTPUT

LAND USE CATEGORIES IN RGISM FILE:
11 SINGLE FAMILY HOMES AND AGRICULTURE
12 SINGLE FAMILY HOMES AND COMMERCIAL
13 SINGLE FAMILY HOMES AND INDUSTRIAL
14 MULTIFAMILY HOUSING
15 MULTIFAMILY AND SINGLE FAMILY HOUSING
17 MULTIFAMILY HOUSING AND INDUSTRIAL
18 MULTIFAMILY HOUSING AND COMMERCIAL
20 INDUSTRIAL AND COMMERCIAL
26 AGRICULTURE
27 SINGLE, MULTIFAMILY AND AGRICULTURE
28 SINGLE, MULTIFAMILY AND COMMERCIAL
29 SINGLE, MULTIFAMILY AND INDUSTRIAL

LAND USE CATEGORY BY % OF TOTAL AREA
11 19.1
12 4.4
13 1.7
14 1.7
15 1.3
17 1.5
18 0.8
20 2.7
26 21.2
27 10.2
28 11.3
29 4.9

THIS ALLOWS USERS TO CREATE CONVENTIONAL RASTER MAPS FOR EACH SPATIAL CHARACTERISTIC. THIS CAN BE USED TO CREATE 3 DIMENSIONAL MAPS BY Viewing SPATIAL DATA USING TRIGGS.
(0) DO NOT CREATE RASTER MAP
(1) MAP POPULATION
(2) MAP POPULATION DENSITY
(3) AVERAGE FAMILY INCOME
(4) AVERAGE HOUSING PRICE
(5) AVERAGE EDUCATION LEVEL
(6) GROUP LAND USES TOGETHER
(7) % OF POPULATION BY ETHNIC GROUP

DO YOU WISH TO QUERY ON SPECIFIC AREAS? "Y" OR "N"

Y

FILL IN THE LAND USE CATEGORY OR PUT A "C" IN FOR THE VALUE

FILL IN THE 2 DIGIT CATEGORY VALUE OR PUT A 0 IN TO BYPASS THIS QUERY

FILL IN THE POPULATION OR PUT A "0" IN FOR THE VALUE

FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0) THEN FILL IN THE POPULATION TO BE MAPPED

GT3000
2801  3142
2802  4004
2804  3472
2806  3244
2807  3004
2811  5522
2812  5559
2814  6689
2815  7551
2818  4232

FILL IN THE INCOME LEVEL OR PUT A "0" IN FOR THE VALUE

FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0) THEN FILL IN THE INCOME LEVEL TO BE MAPPED

GT12000
2814  21017
2818  13144

FILL IN THE AVERAGE HOUSING VALUE OR PUT A "0" IN FOR THE VALUE

FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0) THEN FILL IN THE HOUSING VALUE TO BE MAPPED

0
2814  48702
2818  0

FILL IN THE AVERAGE POPULATION DENSITY OR PUT A "0" IN FOR THE VALUE

FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0) THEN FILL IN THE POP DENSITY TO BE MAPPED
FILL IN THE EDUCATION LEVEL OR PUT A "0" IN FOR THE VALUE

FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0)
THEN FILL IN THE EDUCATION LEVEL TO BE MAPPED
GT 10.0

2814 13.80000
2818 12.70000

DO YOU WISH TO SEE THE ETHNIC CLASSES?
(1) YES OR (2) NO

2

FILL IN THE ETHNIC CATEGORY TO BE MAPPED OUT

0

2814 0
2818 0

THIS PART OF THE QUERY ALLOWS YOU TO DO NEIGHBORHOOD ANALYSIS
(1) SHOW QUERIED REGIONS THAT ARE ADJACENT TO AREAS WITH USER REQUESTED CHARACTERISTICS
(2) SHOW QUERIED REGIONS AS WELL AS ALL ADJACENT AREAS THAT HAVE REQUESTED CHARACTERISTICS
(3) DO NOT DO NEIGHBORHOOD ANALYSIS

1

1016
1017
1203
1517
1701
2003
2813
2814
2815
2818
2907

FILL IN THE LAND USE CATEGORY OR PUT A "0" IN FOR THE VALUE

FILL IN THE 2 DIGIT CATEGORY VALUE OR PUT A 0 IN TO BYPASS THIS QUERY

0

FILL IN THE POPULATION OR PUT A "0" IN FOR THE VALUE

FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0)
THEN FILL IN THE POPULATION TO BE MAPPED

0

1701 1395
1203 5087
2813 1759
2814 6669
1016 3595
1017 1120
1017 6834
FILL IN THE INCOME LEVEL OR PUT A "0" IN FOR THE VALUE

FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0) THEN FILL IN THE INCOME LEVEL TO BE MAPPED

0

1701  6224
1701  6224
1203  25090
2813  20296
2814  21017
1016  20979
1017  12345
1517  18142
2907  11343
2815  10341
2003  9174
2818  13144
1701  11997
1701  11997

FILL IN THE AVERAGE HOUSING VALUE OR PUT A "0" IN FOR THE VALUE

FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0) THEN FILL IN THE HOUSING VALUE TO BE MAPPED

0

1701  12500
1701  12500
1203  74831
2813  56869
2814  48702
1016  50190
1017  27644
1517  43752
2907  23177
2815  20169
2003  0
2818  0
1701  33587
1701  33587

FILL IN THE AVERAGE POPULATION DENSITY OR PUT A "0" IN FOR THE VALUE

FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0) THEN FILL IN THE POP DENSITY TO BE MAPPED

0

1701  0
1701  0
1203  0
2813  0
2814  0
1016  0
1017  0
1517  0
- - - - -
FILL IN THE EDUCATION LEVEL OR PUT A "0" IN FOR THE VALUE

FILL IN THE RELATIONSHIP ( GT, LT, EQ OR 0 )
THEN FILL IN THE EDUCATION LEVEL TO BE MAPPED

<table>
<thead>
<tr>
<th>ID</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>1701</td>
<td>3.400000</td>
</tr>
<tr>
<td>1701</td>
<td>9.600000</td>
</tr>
<tr>
<td>1203</td>
<td>14.000000</td>
</tr>
<tr>
<td>2813</td>
<td>13.000000</td>
</tr>
<tr>
<td>2814</td>
<td>13.800000</td>
</tr>
<tr>
<td>1016</td>
<td>14.100000</td>
</tr>
<tr>
<td>1017</td>
<td>12.600000</td>
</tr>
<tr>
<td>1517</td>
<td>14.900000</td>
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<tr>
<td>2807</td>
<td>12.500000</td>
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<tr>
<td>2815</td>
<td>11.800000</td>
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<tr>
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</tr>
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<td>12.700000</td>
</tr>
<tr>
<td>1701</td>
<td>12.300000</td>
</tr>
<tr>
<td>1701</td>
<td>12.300000</td>
</tr>
</tbody>
</table>

FILL IN THE ETHNIC CATEGORY TO BE MAPPED OUT

<table>
<thead>
<tr>
<th>ID</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2815</td>
<td>4</td>
</tr>
</tbody>
</table>

FILL IN THE RELATIONSHIP ( GT, LT, EQ OR 0 )
THEN FILL IN THE ETHNIC PERCENT TO BE MAPPED
GT3

Enter name of OUTPUT file: MAPI.OUT
Enter upto 5 lines of text ( a '.' in column 1 means quit)
You may enter 80 characters per line.
SINGLE & MULTIFAMILY HOUSING NEAR COMMERCIAL DISTRICTS IN CENSUS TRACTS WITH OVER 3000 PEOPLE AND AN AVERAGE FAMILY INCOME GREATER THEN $12,000 AND GREATER THEN 10.0 YEARS OF EDUCATION ADJACENT TO CENSUS TRACTS WITH OVER 3% HISPANIC POPULATION

THE % OF TOTAL AREA THAT MEETS YOUR QUERY PARAMETERS IS : 0.9068239
FORTRAN STOP
APPENDIX C

ARASS PROGRAMS AND DATA FILES

This appendix contains all the programs developed for ARASS as well as the Category file, Land Use file and the Ethnic file.

ARASS was designed using structured programming techniques thus allowing easy modification for new projects. To do this only requires changing the Attribute file and its Fortran read statement. New subroutines can easily be integrated with ARASS because they are all stored in a separate subroutine library. The overlay programs are also stored in a separate library. This allows minor modification to be made to parts of ARASS without impacting the whole system. In addition, the program is very well commented for easy maintenance. A copy of the software is kept on UNO's Vax on the disk Perm$4:[Geolib,Rgism,ARASS].
PROGRAM QUERY 1
THIS SYSTEM QUERIES A RASTER FILE FOR NONSPATIAL CHARACTERISTICS.

CHARACTER*80 DATA(100)
CHARACTER*80 GDATA(100)
CHARACTER*80 DATAl(500)
CHARACTER*80 DATA2(500)
CHARACTER*80 IRELl(500)
CHARACTER*80 IREL2(500)
CHARACTER*80 IREL3(500)
CHARACTER*80 IREL4(500)
CHARACTER*80 IREL5(500)
CHARACTER*80 IREL6(500)
CHARACTER*80 BLANK(500)
CHARACTER*80 DATAA(500)
CHARACTER*80 IRULE(500)
CHARACTER*80 IRULE2(500)
CHARACTER*1 DOQRY
DIMENSION ICAT(1000)
DIMENSION ICATl(1000)
DIMENSION IGCATl(1000)
DIMENSION ILNDCT(1000)
DIMENSION ILAND(1000)
DIMENSION ICATA(1000)
DIMENSION ICAT2(1000)
DIMENSION IVALS(1000)
DIMENSION IVALS1(1000)
DIMENSION IATTl(1000)
DIMENSION IATT2(1000)
DIMENSION IATT3(1000)
DIMENSION IATT4(1000)
DIMENSION IATTB(1000)
DIMENSION IPRI(1000)
DIMENSION IPOL(1000)
DIMENSION IPOPDL(1000)
DIMENSION IPOPPL(1000)
DIMENSION ILNDSL(1000)
DIMENSION IEDCAT(1000)
DIMENSION ITMP1(1000)
DIMENSION EDCAI(1000)
DIMENSION IETHN1(1000)
DIMENSION IPRECT1(1000)
DIMENSION IPERCl(1000)
DIMENSION IPOPDI(1000)
DIMENSION IPOPPLl(1000)
DIMENSION ILNDVI(1000)
DIMENSION IATTAl(1000)
DIMENSION IEDCAT(1000)
DIMENSION IETHN(1000)
DIMENSION IPERCl(1000)
DIMENSION IPOPCT(1000)
WRITE (6,*) 'INTERACTIVE QUERY FOR THE'
WRITE (6,*) 'IMPROVED RGISM SYSTEM'

C
WRITE (6,*) ',
WRITE (6,*) ',

C.. SET OUTPUT TO A MAP FILE OR STATISTICAL REPORT
WRITE (6,*) 'WILL THE OUTPUT BE A STATISTICAL REPORT OR'
WRITE (6,*) 'A CHOROPLETH MAP?'
WRITE (6,*) 'ENTER OPTION (1)REPORT OR (2)MAP'
READ (5,*) IMAP
C.. OPEN INPUT / OUTPUT FILES
WRITE (6,*) ',
WRITE (6,*) ',
WRITE (6,*) ',
WRITE (6,*) ',

C.. READ IN THE CATEGORY FILE.
C.. OPEN (UNIT=7,FILE=FOR007,STATUS='OLD')
READ(7,('//////')
DO 100 K=1,100
   READ (7,18,END=2000) ICAT(K), DATA(K)
18 FORMAT (IX,14,4X,A60)
   ICAT1(K) = ICAT(K)/100
100 CONTINUE
CLOSE(UNIT=7)
WRITE(6,*) ',
OPEN (UNIT=8,FILE=FOR008,STATUS='OLD')
READ (8,('///////////////')
C.. READ IN THE ATTRIBUTE FILE WITH
C.. PIXEL VALUES AND AREA CHARACTERISTICS
DO 170 N=1,100
   READ (8,24,END=4000) BLANK(1)
24 FORMAT (IX,A1)
   READ (8,25,END=4000) IRULE(N), IATT1(N), IATT2(N), IATT3(N),
   * IPRI(N)
25 FORMAT (IX,A2,13X,I4,8X,I4,8X,I4,11X,I1)
   READ (8,26,END=4000) IRL2(N), IREL1(N), IPOPL(N),
   * IREL2(N), IPOPDN(N), IREL3(N), IPERC(N),
   * IREL4(N), INDV(N), IREL5(N), EDCAT(N), IETH(N),
   * IREL6(N), IPERC(N)
26 FORMAT (IX,A2,2X,A1,I5,4X,A1,I5,3X,A1,I5,4X,A1,I5,
   * 5X,A1,F4.1,5X,I2,4X,A1,I2)
170 CONTINUE
C.. THE USER HAS THE OPTION TO LOOK AT THE ATTRIBUTE
C.. FILE WHICH RELATES PIXEL VALUES WITH NONSPATIAL
C.. DATA
CLOSE(UNIT=8)
WRITE (6,*) 'DO YOU WANT TO SEE THE ATTRIBUTE LIST'
WRITE (6,*) '(1)YES OR (2)NO'
READ (5,*) IALIST
C.. IF (IALIST.EQ.1) THEN
   DO 185 J=1,N-1
      WRITE (6,31) IRULE(J), IATT1(J), IATT2(J), IATT3(J),
      * IPRI(J)
31 FORMAT (IX,A2,13X,I4,8X,I4,8X,I4,11X,I1)
WRITE (6,32) IRUL2(J),IREL1(J),IPOPL(J),
* IREL2(J),IPOPDN(J),IREL3(J),IPERCP(J),
* IREL4(J),ILNDVL(J),IRELS(J),EDCAT(J),IETHN(J),
* IREL6(J),IPERCT(J)
32 FORMAT (1X,A2,2X,A1,15,4X,A1,15,3X,A1,15,4X,A1,15,
* 5X,A1,F4.1,5X,I2,4X,A1,I2)

CONTINUE
ENDIF
5000 WRITE (6,*) ',
C... READ IN THE RASTER MAP FILE...
CALL IMOPEN (1,' ENTER THE RGISM MAP FILE : ','OLD')
C
C.. READ SIX LINES OF COMMENTS FROM INPUT FILE(S)
CALL INQUIRE (1)
C
C.. DETERMINE SIZE OF WORKING MATRIX
CALL SIZE (NROW,NCOL)
C
C.. PROCESS FILE(S)
IZOLD = IMREAD (1,1,1)
IVALS(1) = IZOLD
ICOUNT = 1
ITOT = 0
C
C.. DETERMINE THE GENERAL LAND USE CATEGORY BASED
C.. ON 1ST 2 PIXEL VALUES
DO 200 J = 1, NCOL
    DO 200 I = 1, NROW
        IZ = IMREAD (J,I,1)
        IX(J,I,1) = IZ
        ISAME = 1
        IF (IZ .NE. IZOLD) THEN
            IZOLD = IZ
            ISAME = 0
            DO 110 L = 1, ICOUNT
                IF (IZOLD .EQ. IVALS(L)) ISAME = 1
                110 CONTINUE
        ENDIF
        IF (ISAME .EQ. 0) THEN
            ICOUNT = ICOUNT + 1
            IVALS(ICOUNT) = IZOLD
            IVALS1(ICOUNT) = IVALS(ICOUNT) / 100
        ENDIF
    200 CONTINUE
C
WRITE(6,*) ',
WRITE(6,*) ',
WRITE(6,*) 'LAND USE CATEGORIES IN RGISM FILE:'
C
C.. sort ivals array
CALL LOWHIGH (IVALS1,ICOUNT)
C
IOLDCT = 1
C
C.. SHOWS THE GENERAL LAND USE AND LAND COVER
C.. CATEGORIES IN THE RASTER MAP FILE.
C.. DO 300 I=1,ICOUNT
DO 300 L=1,K
IF (ICAT(L).NE.0) THEN
  IF (IVALS1(I).NE.10DCT) THEN
    IF (IVALS1(I).EQ.ICAT1(L)) THEN
      IOLCT = IVALS1(I)
      IGCAI1(L) = ICAT1(L)
      GDATAL = DATA(L)
      WRITE (6,250) IGCAI1(L), GDATAL
      IF (ICAT(L).NE.0) THEN
        IF (IVALS1(I).NE.10DCT) THEN
          IF (IVALS1(I).EQ.ICAT1(L)) THEN
            IOLCT = IVALS1(I)
            IGCAI1(L) = ICAT1(L)
            GDATAL = DATA(L)
            WRITE (6,250) IGCAI1(L), GDATAL
          END IF
        END IF
      END IF
    END IF
  END IF
END IF
END IF
CONTINUE
CALCULATE STATISTICS BY LAND USE CATEGORY
CALL STATS(NROW, NCOL, IX, IGCAI1, L)
WRITE (6,*) ' THIS ALLOWS USERS TO CREATE CONVENTIONAL'
WRITE (6,*) ' RASTER MAPS FOR EACH SPATIAL CHARACTERISTIC'
WRITE (6,*) ' THIS CAN BE USED TO CREATE 3 DIMENSIONAL'
WRITE (6,*) ' MAPS SHOWING SPATIAL DATA USING TRIDG'
WRITE (6,*) ' (0) DO NOT CREATE RASTER MAP'
WRITE (6,*) ' (1) MAP POPULATION'
WRITE (6,*) ' (2) MAP POPULATION DENSITY'
WRITE (6,*) ' (3) AVERAGE FAMILY INCOME'
WRITE (6,*) ' (4) AVERAGE HOUSING PRICE'
WRITE (6,*) ' (5) AVERAGE EDUCATION LEVEL'
WRITE (6,*) ' (6) GROUP LAND USES TOGETHER'
WRITE (6,*) ' (7) % OF POPULATION BY ETHNIC GROUP'
READ (5.*) ITRID
IF (ITRID.GT.7) GO TO 33
CREATE A RASTER MAP FILE SUBSTITUTING VARIABLE DATA IN
THE ATTRIBUTE FILE FOR PIXEL VALUES
IF (ITRID.EQ.1) THEN
  CALL TRIDG(NROW, NCOL, IX, IATT1, N, IPOPL)
END IF
IF (ITRID.EQ.2) THEN
  CALL TRIDG(NROW, NCOL, IX, IATT1, N, IPOPDN)
END IF
IF (ITRID.EQ.3) THEN
  CALL TRIDG(NROW, NCOL, IX, IATT1, N, IPERC)
END IF
IF (ITRID.EQ.4) THEN
  REDUCE THE HOUSING VALUE SIZE SO THAT THE ARRAY CAN HANDLE IT
  DO 55 I=1,N
    ITMP1(I) = IATT1(I)
    ILAND(I) = ILNDVL(I) / 10
  CONTINUE
  CALL TRIDG(NROW, NCOL, IX, ITMP1, I, ILAND)
END IF
IF (ITRID.EQ.5) THEN
  CONVERT EDUCATION LEVEL TO AN INTEGER
  DO 65 I=1,N
    ITMP1(I) = IATT1(I)
    IEDCAT(I) = EDCAT(I) * 10
  CONTINUE
CALL TRIDG(NROW,NCOL,IX,ITMP1,I,IEDCAT)
ENDIF
IF (ITRID.EQ.6) THEN
CALL TRIDG1(NROW,NCOL,IX)
ENDIF
C.. ALLOW USERS TO CREATE A RASTER FILE SHOWING AN ETHNIC GROUP
C.. AS A % OF THE POPULATION
IF (ITRID.EQ.7) THEN
IP=0
C.. INPUT A SPECIFIC ETHNIC GROUP NUMBER
75 WRITE (6,*) 'WHICH ETHNIC GROUP WOULD YOU LIKE TO SEE?'
   READ (5,*) IGRP
   IF (IGRP.GT.99) GO TO 75
DO 95 I=1,N
   IP = IP + 1
   ITMP1(IP) = 0
   ILAND(IP) = 0
C.. IF AN ATTRIBUTE RECORD HAS THIS ETHNIC % PASS IT ON
   IF (IETHN(I).EQ.IGRP) THEN
      ITMP1(IP) = IATT1(I)
      ILAND(IP) = IPERC(I)
   END IF
95 CONTINUE
CALL TRIDG(NROW,NCOL,IX,ITMP1,IP,ILAND)
ENDIF
C.. WRITE (6,*) 'DO YOU WISH TO QUERY ON SPECIFIC AREAS? "Y" OR "N"'
   READ(5,255) DOQRY
255 FORMAT (A1)
   IF (DOQRY.NE.'N') THEN
C.. SUBROUTINE RES1 IS USED TO KEEP TRACK OF VARIABLE DATA
C.. SO THAT IT STAYS ASSOCIATED WITH THE CORRECT CATEGORY VALUE
C..
   CALL RES1 (IATT2,J,IATT1,IPOL1,IPOLD1,IPERC1,
   * ILNDV1,EDCAT,IETHN,IPERC,N,IATT,IPOL1,IPOLD1,
   * IPRCP1,ILNDV1,EDCA1,IETH1,IPERC1,K)
C..
C.. QUERY BASED ON CENSUS TRACT POPULATION
C.. CALL QUERY3 (IRL1,IPOL1,K,IATT1,IATT2,J)
C..
C.. QUERY BASED ON CENSUS TRACT POPULATION
C.. CALL RES1 (IATT2,J,IATT1,IPOL1,IPOLD1,IPERC1,
C.. * ILNDV1,EDCAT,IETHN,IPERC,N,IATT,IPOL1,IPOLD1,
C.. * IPRCP1,ILNDV1,EDCA1,IETH1,IPERC1,K)
C..
DO 13 I=1,J
   WRITE (6,*) IPOPCT(I), 'CCCCCCCC'
13 CONTINUE
C..
C.. QUERY BASED ON AVERAGE INCOME
C.. CALL QUERY5 (IRL3,IPRCP1,K,IATT1,IATT2,J)
C..
C.. QUERY BASED ON AVERAGE HOUSING VALUE
C.. CALL QUERY6 (IRL4,ILNDV1,K,IATT1,IATT2,J)
CALL RES1 (IA TT2, J, IAT T1, IPOP L, IPOP DN, IPERCP, 
* ILN DVL, EC CAT, IE THN, IPERCT, N, IAT TA, IPOP L1, IPOP D1, 
* IPRCP1, ILND VL1, EDCA1, IETHN1, IPERC1, K) 

C.. 

QUERY BASED ON POPULATION DENSITY 
CALL QURY6A (IREL2, IPOP D1, K, IATTA, IATT2, J) 

C.. 

CALL RES1 (IA TT2, J, IAT T1, IPOP L, IPOP DN, IPERCP, 
* ILN DVL, EC CAT, IE THN, IPERCT, N, IAT TA, IPOP L1, IPOP D1, 
* IPRCP1, ILND VL1, EDCA1, IETHN1, IPERC1, K) 

C.. 

QUERY BASED ON AVERAGE EDUCATION LEVEL 
CALL QURY7 (IREL5, EDCA1, K, IATTA, IATT2, J) 

C.. 

THE USER HAS THE OPTION OF SEEING THE ETHNIC CLASSES 
THAT CAN BE QUERIED ON 

WRITE (6,*) 'DO YOU WISH TO SEE THE ETHNIC CLASSES?' 
WRITE (6,*) ' (1) YES OR (2) NO' 
READ (5, *) IELIST 

IF (IELIST .NE. 2) THEN 
OPEN (UNIT=10, FILE='FORO10.DAT', STATUS='OLD') 
DO 270 I=1,1000 
READ (10,35,END=5500) DATA2(I) 
35 FORMAT (A80) 
270 CONTINUE 
5500 CLOSE(UNIT=10) 
DO 285 M=1, I 
WRITE (6,40) DATA2(M) 
40 FORMAT (A80) 
285 CONTINUE 
ENDIF 
WRITE (6,*) '' 
C.. 

QUERY BASED ON ETHNIC COMPOSITION OF CENSUS TRACT 
CALL QUERY8 (IREL6, IETHN1, IPERC1, K, IATTA, IATT4, L) 

C.. 

CALL RES1 (IATT4, L, IAT T1, IPOP L, IPOP DN, IPERCP, 
* ILNDVL, EDCA1, IE THN, IPERCT, N, IAT TA, IPOP L1, IPOP D1, 
* IPRCP1, ILNDVL1, EDCA1, IETHN1, IPERC1, K) 
EN DIF 
C.. 

WRITE (6,*) '' 
C.. 

WRITE (6,*) ' THIS PART OF THE QUERY ALLOWS YOU TO DO 
WRITE (6,*) ' NEIGHBORHOOD ANALYSIS' 
C.. 

WRITE (6,*) ' (1) SHOW QUERIED REGIONS THAT ARE ARE ADJ 
WRITE (6,*) ' AREAS WITH USER REQUESTED CHARACTER' 
WRITE (6,*) ' (2) SHOW QUERIED REGIONS AS WELL AS ALL 
WRITE (6,*) ' AREAS THAT HAVE REQUESTED CHARACTER' 
WRITE (6,*) ' (3) DO NOT DO NEIGHBORHOOD ANALYSIS' READ(5,*) DOADJ 
C.. 

TRANSLATE CATEGORY VALUES 
C..
IF (DOADJ .NE. 3) THEN
  CHECK FOR ADJACENT PIXEL VALUES
  CALL ADJAC (NROW, NCOL, IX, IATT4, L, IATT2, J)
  CALL QUERY2 (J, IATT2, IATT1, IATT1, IATT2, J)
  CALL RES1 (IATT3, IATT2, IATT1, IATT2, J, IATT1, IPOPL, IPOPL, IPOPDN, IPOPD1,
  * ILNDVL, EDCAT, IETHN, IPERCT, N, IATT1, IPOPL, IPOPD1,
  * IRCPI, DNDVL, EDCA1, IETHN, IPERCT, K)
  CALL QUERY3 (IREL1, IPOPL, K, IATT1, IATT2, J)
  CALL RES1 (IATT2, J, IATT1, IPOPL, IPOPDN, IPOPD1,
  * ILNDVL, EDCAT, IETHN, IPERCT, N, IATT1, IPOPL, IPOPD1,
  * IRCPI, DNDVL, EDCA1, IETHN, IPERCT, K)
  CALL QUERY5 (IREL3, IRCPI, K, IATT1, IATT2, J)
  CALL RES1 (IATT2, J, IATT1, IPOPL, IPOPDN, IPOPD1,
  * ILNDVL, EDCAT, IETHN, IPERCT, N, IATT1, IPOPL, IPOPD1,
  * IRCPI, DNDVL, EDCA1, IETHN, IPERCT, K)
  CALL QUERY6 (IREL4, IRCPI, K, IATT1, IATT2, J)
  CALL RES1 (IATT2, J, IATT1, IPOPL, IPOPDN, IPOPD1,
  * ILNDVL, EDCAT, IETHN, IPERCT, N, IATT1, IPOPL, IPOPD1,
  * IRCPI, DNDVL, EDCA1, IETHN, IPERCT, K)
  CALL QUERY6A (IREL2, IPOPD1, K, IATT1, IATT2, J)
  CALL RES1 (IATT2, J, IATT1, IPOPL, IPOPDN, IPOPD1,
  * ILNDVL, EDCAT, IETHN, IPERCT, N, IATT1, IPOPL, IPOPD1,
  * IRCPI, DNDVL, EDCA1, IETHN, IPERCT, K)
  CALL QUERY7 (IREL5, EDCA1, K, IATT1, IATT2, J)
  CALL RES1 (IATT2, J, IATT1, IPOPL, IPOPDN, IPOPD1,
  * ILNDVL, EDCAT, IETHN, IPERCT, N, IATT1, IPOPL, IPOPD1,
  * IRCPI, DNDVL, EDCA1, IETHN, IPERCT, K)
  CALL QUERY8 (IREL6, IETHN1, IPERCT, K, IATT1, IATT3, M)
C.. FIND PIXELS WITH NEIGHBORING PIXELS THAT MEETS
C.. THE USERS QUERY PARAMETERS
C.. IF (DOADJ .EQ. 1) THEN
C..  CALL REACT (NROW, NCOL, IX, IATT4, L, IATT3, M, ILNDCT, I)
C.. ENDF
ENDIF
ENDIF
C.. IF (IMAP .EQ. 2) THEN
  CREATE OUTPUT MAP
  IF (DOADJ .EQ. 1) THEN
    CALL MKMAP1 (NROW, NCOL, IX, ILNDCT, I)
  ENDF
  IF (DOADJ .EQ. 2) THEN
    CALL MKMAP1 (NROW, NCOL, IX, IATT3, M)
  ENDF
  IF (DOADJ .EQ. 3) THEN
    CALL MKMAP1 (NROW, NCOL, IX, IATT4, L)
  ENDF
ENDIF
ENDIF
C.. STOP
END
subroutine lowhigh(S,n)

C**************************************************************************
C IMPLICIT INTEGER (A-Z)
dimension S(n)
nl=n-1
C.. SORTING THROUGH THE VALUES COMPARING EACH VALUE TO ALL OTHER VALUES.
do 100 k=1,nl
C.. COMPARING THE FIRST VALUE TO ALL OTHER VALUES.
do 100 j=k,n
   if (s(k) .lt. s(j)) goto 100
   save=s(k)
   s(k)=s(j)
   s(j)=save
100 continue
C.. write out ranked values
   write(*,900) (i,s(i),i=1,n)
900 format(5x,'The ranked data values',//,(2x,i4,2x,f10.2))
C return
end
SUBROUTINE QUERY2(K,IATT1,IPOPC,T,M)
C.. THIS SUBROUTINE ALLOWS USERS TO QUERY A
C.. RASTER MAP FILE AND AN ATTRIBUTE FILE FOR
C.. CENSUS TRACTS WITH A CERTAIN LAND USE OR LAND COVER.
C************************************************************
C..<.
DIMENSION IPOPC(1000)
DIMENSION IATT1(1000)
DIMENSION ILNDCT(1000)
INTEGER ILNDCT
WRITE (6,'(A)') 'FILL IN THE LAND USE CATEGORY OR PUT '
WRITE (6,'(A)') 'A "0" IN FOR THE VALUE'
C.. THE USER WILL FILL IN THE LAND USE OR LAND COVER CATEGORY
C.. TO BE MAPPED
WRITE (6,'(A)') 'FILL IN THE 2 DIGIT CATEGORY VALUE OR'
WRITE (6,'(A)') 'PUT A 0 IN TO BYPASS THIS QUERY'
M = 0
READ (5,75) ILNDCT
75 FORMAT(I2)
C.. ONLY THOSE PIXEL VALUES THAT MATCH THE QUERY
C.. PARAMETER WILL BE MAPPED OUT
DO 100 J=1,K
   IF (IATT1(J).NE.0) THEN
      IF (ILNDCT.EQ.0) THEN
         M = M + 1
         IPOPC(M) = IATT1(J)
      ENDIF
      IF (ILNDCT.NE.0) THEN
         IPIPCT(J) = IATT1(J)/100
         IF (ILNDCT.EQ.IPIPCT(J)) THEN
            M = M + 1
            IPOPC(M) = IATT1(J)
         ENDIF
      ENDIF
   ENDF
100 CONTINUE
125 WRITE (6,*) 'RETURN
END
C******************************************************************
SUBROUTINE QUERY3(IREL1,IPOL, K, IATT1,IPOPC,M)
C.. THIS SUBROUTINE ALLOWS USERS TO QUERY A
C.. RASTER MAP FILE AND AN ATTRIBUTE FILE FOR
C.. CENSUS TRACTS WITH A CERTAIN POPULATION.
C******************************************************************
C..<
CHARACTER*2 POPREL
CHARACTER*80 IREL3(1000)
INTEGER IRDPON
DIMENSION IPOL(1000)
DIMENSION IATT1(1000)
DIMENSION IPOPC(1000)
WRITE (6,'(A)') 'FILL IN THE POPULATION OR PUT '
WRITE (6,'(A)') 'A "0" IN FOR THE VALUE'
C.. THE USER WILL FILL IN THE RELATIONSHIP AND THE POPULATION
C.. TO BE MAPPED
WRITE (6,*) '
WRITE (6,*) 'FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0)'
WRITE (6,*) 'THEN FILL IN THE POPULATION TO BE MAPPED'
M = 0
READ (5,75) POPREL,IRDPOP
75 FORMAT(A2, I5)
C. ONLY THOSE PIXEL VALUES THAT MATCH THE QUERY
C. PARAMETER WILL BE MAPPED OUT
DO 100 J = 1, K
   IF (POPREL.EQ.'LT') THEN
      IF (IRDPOP.GT.IPOP(J)) THEN
         M = M + 1
         IPOPCT(M) = IATT(J)
         WRITE (6,*) IPOPCT(M), IPOP(J)
      END IF
   END IF
   IF (POPREL.EQ.'0') THEN
      IF (IPOP(J).NE.') THEN
         M = M + 1
         IPOPCT(M) = IATT(J)
         WRITE (6,*) IPOPCT(M), IPOP(J)
      END IF
   END IF
   IF (POPREL.EQ.'GT') THEN
      IF (IRDPOP.LT.IPOP(J)) THEN
         M = M + 1
         IPOPCT(M) = IATT(J)
         WRITE (6,*) IPOPCT(M), IPOP(J)
      END IF
   END IF
   IF (POPREL.EQ.'EQ') THEN
      IF (IRDPOP.EQ.IPOP(J)) THEN
         M = M + 1
         IPOPCT(M) = IATT(J)
         WRITE (6,*) IPOPCT(M), IPOP(J)
      END IF
   END IF
100 CONTINUE
125 WRITE (6,*)
RETURN
END
C.. C.. C.. C..**********************************************************************
C. SUBROUTINE QUERY5(IREL,IPEL,K,IATT,IPCCT,M)
C. THIS SUBROUTINE ALLOWS USERS TO QUERY A
C. RASTER MAP FILE AND AN ATTRIBUTE FILE FOR
C. CENSUS TRACTS WITH A CERTAIN INCOME LEVEL.
C..**********************************************************************
C. CHARACTER*2 INCREL
CHARACTER*80 IREL(1000)
INTEGER INCLVL
DIMENSION IPEL(1000)
DIMENSION IATT(1000)
DIMENSION IPCCT(1000)
M = 0
WRITE (6,*) 'FILL IN THE INCOME LEVEL OR PUT'
WRITE (6,*) 'A "0" IN FOR THE VALUE'
WRITE (6,*) 'FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0)'
WRITE (6,*) 'THEN FILL IN THE INCOME LEVEL TO BE MAPPED'
READ (5,75) INCREL,INCLVL
75 FORMAT(A2,15)
DO 100 J = 1,K
  IF (INCREL.EQ.'0') THEN
    M = M + 1
    IPCPCT(M)=IATT1(J)
    WRITE (6,*) IPCPCT(M), IPERC(P)
  ENDIF
  IF (INCREL.EQ.'LT') THEN
    IF (INCLVL.GT.IPERCP(J)) THEN
      IF (IPERCP(J).NE.0) THEN
        M = M + 1
        IPCPCT(M)=IATT1(J)
        WRITE (6,*) IPCPCT(M), IPERC(P)
      ENDIF
    ENDIF
  ENDIF
  IF (INCREL.EQ.'GT') THEN
    IF (INCLVL.LT.IPERCP(J)) THEN
      M = M + 1
      IPCPCT(M)=IATT1(J)
      WRITE (6,*) IPCPCT(M), IPERC(P)
    ENDIF
  ENDIF
  IF (INCREL.EQ.'EQ') THEN
    IF (INCLVL.EQ.IPERCP(J)) THEN
      M = M + 1
      IPCPCT(M)=IATT1(J)
      WRITE (6,*) IPCPCT(M), IPERC(P)
    ENDIF
  ENDIF
100 CONTINUE
125 WRITE (6,*) '
RETURN
END
C.. C.. C.. SUBROUTINE QUERY(IREL4,ILNDVL, K, IATT1,ILNDCT,M)
C.. THIS SUBROUTINE ALLOWS USERS TO QUERY A
C.. RASTER MAP FILE AND AN ATTRIBUTE FILE FOR
C.. CENSUS TRACTS WITH A CERTAIN HOUSING VALUE.
C..**************************************************************************
C..
CHARACTER*2 INCREL
CHARACTER*80 IREL2(1000)
INTEGER INCLVL
DIMENSION ILNDVL(1000)
DIMENSION IATT1(1000)
DIMENSION ILNDCT(1000)
M = 0
WRITE (6,*) '
WRITE (6,*) 'FILL IN THE AVERAGE HOUSING VALUE OR PUT'
WRITE (6,*) ' A "0" IN FOR THE VALUE'
WRITE (6,*) '
50 WRITE (6,*) 'FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0)'
WRITE (6,*) ' THEN FILL IN THE HOUSING VALUE TO BE MAPPED'
READ (5,75) INCREL, INCLVL

DO 100 J=1,K
   IF (INCREL.EQ.'0') THEN
      M = M + 1
      ILNDCT(M) = IATT1(J)
      WRITE (6,*) ILNDCT(M), ILNDVL(J)
   ENDIF
   IF (INCREL.EQ.'LT') THEN
      IF (INCLVL.GT.ILNDVL(J)) THEN
         IF (ILNDVL(J).NE.0) THEN
            M = M + 1
            ILNDCT(M) = IATT1(J)
            WRITE (6,*) ILNDCT(M), ILNDVL(J)
         ENDIF
      ENDIF
      IF (INCREL.EQ.'GT') THEN
         IF (INCLVL.LT.ILNDVL(J)) THEN
            H = H + 1
            ILNDCT(M) = IATT1(J)
            WRITE (6,*) ILNDCT(M), ILNDVL(J)
         ENDIF
      ENDIF
      IF (INCREL.EQ.'EQ') THEN
         IF (INCLVL.EQ.ILNDVL(J)) THEN
            M = M + 1
            ILNDCT(M) = IATT1(J)
            WRITE (6,*) ILNDCT(M), ILNDVL(J)
         ENDIF
      ENDIF
   ENDIF
100   CONTINUE
125   WRITE (6,*) '',
RETURN
END

***************************************************************************************

SUBROUTINE QUERY6A(IREL2, IPOPDN, K, IATT1, IPDNCT, M)

THIS SUBROUTINE ALLOWS USERS TO QUERY A RASTER MAP FILE AND AN ATTRIBUTE FILE FOR CENSUS TRACTS WITH A CERTAIN POPULATION DENSITY.
-------------------------------------------------------------------------------

CHARACTER*2 INCREL
CHARACTER*80 IREL2(1000)
INTEGER INCLVL
DIMENSION IPOPDN(1000)
DIMENSION IATT1(1000)
DIMENSION IPDNCT(1000)
M = 0
WRITE (6,*) '',
WRITE (6,*) 'FILL IN THE AVERAGE POPULATION DENSITY OR PUT A "0" IN FOR THE VALUE'
WRITE (6,*) '',
WRITE (6,*) 'FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0)'
WRITE (6,*) 'THEN FILL IN THE POP DENSITY TO BE MAPPED'
READ (5,75) INCREL, INCLVL
75 FORMAT(A2,15)
DO 100 J = 1, K
  IF (INCREL.EQ.'0') THEN
    M = M + 1
    IPDNCT(M) = IATT1(J)
    WRITE (6,*) IPDNCT(M), IPOPDN(J)
  ENDIF
  IF (INCREL.EQ.'LT') THEN
    IF (INCLVL.GT.IP0PDN(J)) THEN
      IF (IP0PDN(J).NE.0) THEN
        M = M + 1
        IPDNCT(M) = IATT1(J)
        WRITE (6,*) IPDNCT(M), IP0PDN(J)
      ENDIF
    ENDIF
  ENDIF
  IF (INCREL.EQ.'GT') THEN
    IF (INCLVL.LT.IP0PDN(J)) THEN
      M = M + 1
      IPDNCT(M) = IATT1(J)
      WRITE (6,*) IPDNCT(M), IP0PDN(J)
    ENDIF
  ENDIF
  IF (INCREL.EQ.'EQ') THEN
    IF (INCLVL.EQ.IP0PDN(J)) THEN
      M = M + 1
      IPDNCT(M) = IATT1(J)
      WRITE (6,*) IPDNCT(M), IP0PDN(J)
    ENDIF
  ENDIF
100 CONTINUE
125 WRITE (6,*) ' ',
RETURN
END

C..******************************************************************************
C..******************************************************************************
C.. SUBROUTINE QUERY7(IREL5,EDCAT, K, IATT1,IEDCAT,M)
C.. THIS SUBROUTINE ALLOWS USERS TO QUERY A
C.. RASTER MAP FILE AND AN ATTRIBUTE FILE FOR
C.. CENSUS TRACTS WITH A CERTAIN EDUCATION LEVEL.
C..******************************************************************************
C.. CHARACTER*2 INCREL
C.. CHARACTER*80 IREL5(1000)
C.. REAL ENCLVL
C.. DIMENSION EDCAT(1000)
C.. DIMENSION IATT1(1000)
C.. DIMENSION IEDCAT(1000)
M = 0
WRITE (6,*) ' ', FILL IN THE EDUCATION LEVEL OR PUT' 
WRITE (6,*) ' ', A "0" IN FOR THE VALUE' 
WRITE (6,*) ' ', FILL IN THE RELATIONSHIP (GT, LT, EQ OR 0)' 
WRITE (6,*) ' ', THEN FILL IN THE EDUCATION LEVEL TO BE MAPPED' 
READ (5,75) INCREL,ENCLVL 
75 FORMAT(A2,F4.1) 
DO 100 J = 1, K
  IF (INCREL.EQ.'0') THEN
M = M + 1
IEDCAT(M) = IATT1(J)
WRITE (6,*) IEDCAT(M), EDCAT(J)
ENDIF
IF (INCREL.EQ.'LT') THEN
IF (ENCLEVEL.GT.EDCAT(J)) THEN
M = M + 1
IEDCAT(M) = IATT1(J)
WRITE (6,*) IEDCAT(M), EDCAT(J)
ENDIF
ENDIF
IF (INCREL.EQ.'GT') THEN
IF (ENCLEVEL.LT.EDCAT(J)) THEN
M = M + 1
IEDCAT(M) = IATT1(J)
WRITE (6,*) IEDCAT(M), EDCAT(J)
ENDIF
ENDIF
IF (INCREL.EQ.'EQ') THEN
IF (ENCLEVEL.EQ.EDCAT(J)) THEN
K = K + 1
IEDCAT(M) = IATT1(J)
WRITE (6,*) IEDCAT(M), EDCAT(J)
ENDIF
ENDIF
100 CONTINUE
125 WRITE (6,*) 
RETURN
END

C..*****************************************************************************
C.. SUBROUTINE QUERY8(IREL6,IETHN,IPERC1KT,K, IATT1, IETCAT,M)
C.. THIS SUBROUTINE ALLOWS USERS TO QUERY A RASTER MAP FILE AND AN ATTRIBUTE FILE FOR CENSUS TRACTS WITH A CERTAIN ETHNIC %.
C..*****************************************************************************
C..
CHARACTER*2 INCREL
CHARACTER*80 IREL5(1000)
INTEGER INCLVL
DIMENSION IETHN(1000)
DIMENSION IATT1(1000)
DIMENSION IETCAT(1000)
DIMENSION IPERC1KT(1000)
M = 0
WRITE (6,*) 
WRITE (6,*) 'FILL IN THE ETHNIC CATEGORY TO BE MAPPED OUT'
READ (5,60) IETCT
60 FORMAT(12)
WRITE (6,*) 
WRITE (6,*) 'FILL IN THE ETHNIC CATEGORY TO BE MAPPED OUT'
READ (5,75) INCREL,INCLVL
75 FORMAT(A2,12)
ENDIF
DO 100 J=1,K
IF (IETCT.EQ.0) THEN

M = M + 1
IETCAT(M) = IATT1(J)
WRITE (6,*) IETCAT(M), IPERCT(J)
ENDIF
IF (IETCT.EQ.IETHN(J)) THEN
  IF (INCREL.EQ.'LT') THEN
    IF (INCLVL.GT.IPERCT(J)) THEN
      M = M + 1
      IETCAT(M) = IATT1(J)
      WRITE (6,*) IETCAT(M), IPERCT(J)
    END IF
  END IF
ELSE
  IF (INCREL.EQ.'GT') THEN
    IF (INCLVL.LT.IPERCT(J)) THEN
      M = M + 1
      IETCAT(M) = IATT1(J)
      WRITE (6,*) IETCAT(M), IPERCT(J)
    END IF
  END IF
ENDIF
ENDIF
END IF
100 CONTINUE
125 WRITE (6,*) '
RETURN .
END
** Subroutine MKMAP1(NROW, NCOL, IX, IATCAT,K)

** Open input/output files

** Process file(s)

** This relates pixel values with the categories with

** The requested population level

** Write the output file

** Close output file

** Return

---

** Program MAKETRID

** Produces a raster map that can be used with TRIDGG.
IT SUBSTITUTES SPATIAL DATA FOR GRID CELL VALUES.

SUBROUTINE TRIDG(NROW, NCOL, IX, IATCAT,K,IPOPL)
DIMENSION IX(300,300,1)
DIMENSION IATCAT(200000)
DIMENSION IPOPL(200000)

C.. OPEN INPUT / OUTPUT FILES
CALL IMOPEN (3,' Enter name of OUTPUT file: ','NEW')
CALL COMMENTS (3,'IRGISM CHOROPLETH MAP',0,' ',0,' ',0,' ',)

C.. PROCESS FILE(S)
DO 100 J = 1, NCOL
   DO 100 I = 1, NROW
      IZ0 = IX(J,I,1)
      ICT = 0
      IF (IZ0.NE.0) ICT=1
      DO 90 L = 1, K
         IF (IZ0.EQ. IATCAT(L)) THEN
            ICT = IPOPL(L)
         ENDIF
      90 CONTINUE

C.. WRITE THE OUTPUT FILE
CALL IMWRIT(J,I,3,ICT)
100 CONTINUE

C.. CLOSE OUTPUT FILE
CALL IMCLOSE (3)

RETURN
END

C**********************************************************************

C RASTER GEOGRAPHIC INFORMATION SYSTEM AND MAPPING
C R G I S M
C
C PROGRAM MAKE TRID
C PRODUCES A RASTER MAP
C THAT CAN BE USED WITH TRIDG.
C IT SUBSTITUTES 1ST 2 CHARACTERS OF PIXELS VALUES
C FOR GRID CELL VALUES. ALL LAND USE TYPES ARE
C THEN GROUPED TOGETHER.
C**********************************************************************

SUBROUTINE TRIDG1(NROW, NCOL, IX)
DIMENSION IX(300,300,1)

C.. OPEN INPUT / OUTPUT FILES
CALL IMOPEN (3,' Enter name of OUTPUT file: ','NEW')
CALL COMMENTS (3,'IRGISM CHOROPLETH MAP',0,' ',0,' ',0,' ',)

C.. PROCESS FILE(S)
DO 100 J = 1, NCOL
   DO 100 I = 1, NROW
      IZ0 = IX(J,I,1)
      C.. GROUP LIKE LAND USE AREAS TOGETHER
      IZ = IZ0/100
      C.. EASIER TO SHOW THE DIFFERENT LAND USES FOR CONTRAST
      IZ1 = IZ * 10
C WRITE THE OUTPUT FILE
   CALL IMWRITE(J,I,3,I21)
100 CONTINUE
C
C CLOSE OUTPUT FILE
   CALL IMCLOSE(3)
C
RETURN
END

C*************************************************************************
C RASTER GEOGRAPHIC INFORMATION SYSTEM AND MAPPING
C
C PROGRAM STATS
C...  CALCULATES THE LAND USE
C...  STATISTICS
C*************************************************************************

SUBROUTINE STATS(NROW,NCOL,IX,IVALS1,ICNT)
CHARACTER*40 GDATA(100)
DIMENSION IX(300,300,1)
DIMENSION IVALS1(20000)
DIMENSION ICTOT(20000)
DIMENSION IDTOT(20000)
REAL ICTOT
REAL ITOT,IDTOT

IZ0=0
ITOT = 0

C PROCESS FILE(S)
C READ RASTER MAP FILE & CALC % OF AREA BY FIRST
C 2 DIGITS OF PIXEL VALUES
C
DO 100 J = 1, NCOL
   DO 100 I = 1, NROW
      IZ = IX(J,I,1)
      IF (IZ.NE.0) THEN
         ITOT = ITOT + 1
         IZ0 = IZ/100
      DO 75 K = 1, ICNT
         IF (IZ0.EQ. IVALS1(K)) THEN
            ICTOT(K) = ICTOT(K) + 1
      ENDIF
    75 CONTINUE
   100 CONTINUE
WRITE (6,*)
WRITE (6,*)
WRITE (6,*) 'LAND USE CATEGORY BY % OF TOTAL AREA'
C WRITE PIXEL VALUES AND % OF AREA
C
DO 200 L=1,K
   IF (ICTOT(L).NE.0) THEN
      IDTOT(L) = (ICTOT(L)/ITOT)*100
      WRITE (6,88) IVALS1(L), IDTOT(L)
   88 FORMAT(1X,I2,4X,F4.1)
ENDIF
200 CONTINUE
**RETURN**
**END**

*C RASTER GEOGRAPHIC INFORMATION SYSTEM AND MAPPING*
*C RGI S M*
*C*
*C PROGRAM ADJAC*
*C DETERMINE ADJACENT LAND USE CATEGORIES*

SUBROUTINE ADJAC(NROW, NCOL, IX, IVALS1, ICNT, IADJCT, N)
DIMENSION IX(300,300,1)
DIMENSION IXL(300,300,1)
DIMENSION IXR(300,300,1)
DIMENSION IXU(300,300,1)
DIMENSION IXD(300,300,1)
DIMENSION ITOT(20000)
DIMENSION IVALS1(20000)
DIMENSION IACAT(20000)
DIMENSION IADJCT(20000)

N = 0

PROCESS FILE(S)
READ RASTER MAP FILE AND DETERMINE ALL ADJACENT PIXEL VALUES.

DO 100 J = 1, NCOL
   DO 100 I = 1, NROW
      IZ = IX(J,I,1)
      IZL = IX(J-1,I,1)
      IZR = IX(J+1,I,1)
      IZU = IX(J,I-1,1)
      IZD = IX(J,I+1,1)
   C.
   DETERMINE PIXEL VALUES AROUND A PIXEL
   DO 50 L = 1, ICNT
      IF (IZ.EQ.IVALS1(L)) THEN
         N = N + 1
         ITOT(N) = IZL
         N = N + 1
         ITOT(N) = IZR
         N = N + 1
         ITOT(N) = IZU
         N = N + 1
         ITOT(N) = IZD
      ENDIF
  50 CONTINUE
  100 CONTINUE
  M = 0

GET RID OF 0'S FROM CATEGORY LIST
DO 125 K=1,N
   IF (ITOT(K).NE.0) THEN
      M = M + 1
      IACAT(M) = ITOT(K)
   ENDIF
  125 CONTINUE
C.. THIS SORTS THE CATEGORIES
M1 = M - 1
DO 150 I = 1, M1
   DO 150 J = I, M
      IF (IACAT(I) .GT. IACAT(J)) THEN
         SAVE = IACAT(I)
         IACAT(I) = IACAT(J)
         IACAT(J) = SAVE
      ENDIF
   CONTINUE
N = 0
K1 = 0
C.. THIS GETS RID OF DUPLICATE CATEGORY VALUES
DO 200 K = 1, M
   K1 = K - 1
   IF (IACAT(K) .NE. IACAT(K1)) THEN
      N = N + 1
      IADJCT(N) = IACAT(K)
      WRITE (6,*) IADJCT(N)
   ENDIF
CONTINUE
WRITE (6,*)
 WRITE (6,*),
RETURN
END
C******************************************
C R A S T E R  G E O R G I C  I N F O R M A T I O N  S Y S T E M  A N D  M A P P I N G
C R G I S M
C P R O G R A M  R E A C T
C D E T E R M I N E  P R I M A R Y  L A N D  U S E  C A T E G O R I E S
C BASED ON NEIGHBORING PIXEL VALUES
C******************************************************************************
C SUBROUTINE REACT(NROW, NCOL, IX, IVALS1, ICNT, IADJCT, N, IATT1, I)
DIMENSION IX(300,300,1)
DIMENSION IXL(300,300,1)
DIMENSION IXR(300,300,1)
DIMENSION IXU(300,300,1)
DIMENSION IXD(300,300,1)
DIMENSION ITOI(20000)
DIMENSION IVALS1(20000)
DIMENSION IATT1(20000)
DIMENSION IADJCT(20000)
C M = 0
C.. PROCESS FILE(S)
C.. READ RASTER MAP FILE AND DETERMINE ALL ADJACENT PIXEL VALUES.
C.. DO 100 J = 1, NCOL
   DO 100 I = 1, NROW
      IZ = IX(J,I,1)
IZL = IX(J-1,I,1)
IZR = IX(J+1,I,1)
IZU = IX(J,I-1,1)
IZD = IX(J,I+1,1)

C.. DETERMINE PIXEL VALUES AROUND A PIXEL
DO 50 L = 1,ICNT
  IF (IZ.EQ.IVALS1(L)) THEN
    DO 125 K = 1,N
      IF (IZL.EQ.IADJCT(K)) THEN
        M = M + 1
        IACAT(M) = IVALS1(L)
      ENDIF
      IF (IZR.EQ.IADJCT(K)) THEN
        M = M + 1
        IACAT(M) = IVALS1(L)
      ENDIF
      IF (IZU.EQ.IADJCT(K)) THEN
        M = M + 1
        IACAT(M) = IVALS1(L)
      ENDIF
      IF (IZD.EQ.IADJCT(K)) THEN
        M = M + 1
        IACAT(M) = IVALS1(L)
      ENDIF
    125 CONTINUE
  ENDIF
50 CONTINUE
100 CONTINUE

C.. THIS SortS THE CATEGORIES
M1 = M - 1
DO 150 I = 1,M1
  DO 150 J = I,M
    IF (IACAT(I).GT.IACAT(J)) THEN
      SAVE = IACAT(I)
      IACAT(I) = IACAT(J)
      IACAT(J) = SAVE
    ENDIF
  150 CONTINUE
C.. THIS GETS RID OF DUPLICATE CATEGORY VALUES
I = 0
DO 200 K=1,M
  K1 = K - 1
  IF (IACAT(K).NE.IACAT(K1)) THEN
    I = I + 1
    IATT1(I) = IACAT(K)
    WRITE (6,*) IATT1(I)
  ENDIF
200 CONTINUE
WRITE (6,*) '
WRITE (6,*) '
C C RETURN
END
SUBROUTINE RES1

THIS SUBROUTINE KEEPS CATEGORY VALUES AND THEIR ASSOCIATED SPATIAL DATA LINKED TOGETHER

SUBROUTINE RES1(IATTA,L,IATT1,IPOPL,IPOPDN,IPERCP,ILNDVL, EDCAT,IETHN,IPERCT,N,IATT2,IPOLP1,IPOLP2,IPERCP1, ILCV1,EDCA1,IETHN1,IPERC1,M)

DIMENSION IATTA(N)
DIMENSION IATT1(N)
DIMENSION IPOPL(N)
DIMENSION IPOPDN(N)
DIMENSION IPERCP(N)
DIMENSION ILNDVL(N)
DIMENSION EDCAT(N)
DIMENSION IETHN(N)
DIMENSION IPERCT(N)
DIMENSION IATT2(N)
DIMENSION IPOPL1(N)
DIMENSION IPOPD1(N)
DIMENSION IPERCP1(N)
DIMENSION ILNDV1(N)
DIMENSION EDCA1(N)
DIMENSION IETHN1(N)
DIMENSION IPERC1(N)
REAL EDCAT EDCA1
INTEGER M
M = 0
DO 100 I=1,N
   DO 100 J=1,L
   IF (IATTA(J).EQ.IATT1(I)) THEN
      IF (IATTA(J).NE.IATT1(J-1)) THEN
         M = M + 1
         IATT2(M) = IATT1(I)
         IPOPL1(M) = IPOPL(I)
         IPOPD1(M) = IPOPDN(I)
         IPERCP1(M) = IPERCP(I)
         ILNDV1(M) = ILNDVL(I)
         EDCA1(M) = EDCAT(I)
         IETHN1(M) = IETHN(I)
         IPERC1(M) = IPERCT(I)
      ENDIF
   ENDIF
CONTINUE
100 CONTINUE
RETURN
END
C*****************************
C RASTER GEOGRAPHIC INFORMATION SYSTEM AND MAPPING
C RGIS
C
C PROGRAM OVERLAY
C THIS PROGRAM OVERLAYS 'TRINARY' FILES
C AND SHOWS THOSE AREAS THAT ARE THE SAME, DIFFERENT
C OR ADDS THE AREAS IN THE TWO MAP FILES TOGETHER
C
C*****************************
C
C.. OPEN INPUT / OUTPUT FILES
CALL IMOPEN (1,' Enter name of first file : ', 'OLD')
CALL IMOPEN (2,' Enter name of second file : ', 'OLD')
CALL IMOPEN (3,' Enter name of OUTPUT file : ', 'NEW')

C.. ADD COMMENT TO SIXTH LINE OF OUTPUT FILE
CALL COMMENTS (3,'PROGRAM OVERLAY',1,'DIFFERENT',2,'=',3,'0')

C.. READ SIX LINES OF COMMENTS FROM INPUT FILE(S)
CALL INQUIRE (1)
CALL INQUIRE (2)

C.. DETERMINE SIZE OF WORKING MATRIX
CALL SIZE (NROW, NCOL)
WRITE (6,*), 'THIS PROGRAM ALLOWS YOU TO OVERLAY FILES CREATED'
WRITE (6,*), 'BY THE IRGISM PROGRAM'
WRITE (6,*), '1) DO YOU WISH TO SEE THOSE AREAS THAT ARE THE'
WRITE (6,*), 'SAME IN BOTH FILES?'
WRITE (6,*), '2) DO YOU WISH TO SEE THOSE AREAS THAT ARE'
WRITE (6,*), 'DIFFERENT IN THE FILES?'
WRITE (6,*), '3) DO YOU WISH TO SEE THE COMBINED AREAS OF'
WRITE (6,*), 'BOTH FILES?'
READ (5,*), IQRY
IF (IQRY.GT.3) GOTO 50
IF (IQRY.LT.1) GOTO 50

C.. PROCESS FILE(S)
DO 100 J = 1, NCOL
  DO 100 I = 1, NROW
    IZ1 = IMREAD (J,I,1)
    IZ2 = IMREAD (J,I,2)
    IF (IQRY.EQ.1) THEN
      C.. PLOT GRID CELL VALUES THAT MATCH IN THE TWO FILE
      IF (IZ1.EQ.IZ2) IZ=IZ1
      IF (IZ1.NE.IZ2) THEN
        IZ = 1
        IF (IZ1.EQ.0) IZ=0
        IF (IZ2.EQ.0) IZ=0
      ENDIF
      ENDF
    IF (IQRY.EQ.2) THEN
      C.. PLOT GRID CELL VALUES THAT DON'T MATCH IN THE 2 FILES
      IF (IZ1.EQ.IZ2) THEN
        IZ = 1
        IF (IZ1.EQ.0) IZ=0
      ENDF
    IF (IQRY.EQ.3) THEN
      C.. PLOT GRID CELL VALUES THAT ARE THE SAME
IZ = 1
IF (IZ1.EQ.2) IZ=2
IF (IZ2.EQ.2) IZ=2
IF (IZ1.EQ.0) IZ=2
IF (IZ2.EQ.0) IZ=2
ENDIF
ENDIF
IF (IQRY.EQ.3) THEN
  C.. ADD THE GRID CELL AREAS TOGETHER
  IF (IZ1.EQ.IZ2) IZ=IZ1
  IF (IZ1.NE.IZ2) THEN
    IF (IZ1.GT.IZ2) IZ=IZ1
    IF (IZ2.GT.IZ1) IZ=IZ2
  ENDIF
  ENDIF
  CALL IMWRIT(J,I,3,IZ)
100 CONTINUE
C.
C.. CLOSE OUTPUT FILE
  CALL IMCLOSE (3)
C
  STOP
END
**** THIS FILE CONTAINS THE ETHNIC CATEGORIES FOR
**** THE IMPROVED RGISM SYSTEM.

10  BLACK
20  WHITE
21  POLISH
22  ITALIAN
23  SLAVIC
24  IRISH
30  HISPANIC
31  MEXICAN
32  CUBAN
33  PUERTO RICAN
40  ASIAN
41  CHINESE
42  JAPANESE
43  KOREAN
 THESE ARE THE LAND USE AND LAND COVER CATEGORIES
 THEY SHOULD MATCH THE PIXEL VALUES IN THE RGISM
 MATRIX FILE.

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<th>Land Use</th>
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<td>1000</td>
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