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The design and development of a prototype Peri-Urban Demonstrator for Spatial Data Integration (PUDSI)

Author

GDS Ltd

Organisation

Geographic Data Support Ltd.
11 Fir Tree Close
Flitwick
Beds MK45 1NY
UK

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DFID Natural Resources Systems Programme

NRSP, HTSPE, Thamesfield House, Boundary Way, Hemel Hempstead, HP2 7SR, United Kingdom

t: +44 (0) 1442 202447
f: +44 (0) 1442 219886
e: nrsp@htspe.com
w: www.nrsp.org.uk

The Design and Development of a Prototype Peri-Urban Demonstrator for Spatial Data Integration (PUDSI)

Contract No: R 6347

Final Technical Report

April 1996

Geographic Data Support Ltd.
11 Fir Tree Close
Flitwick
Beds. MK45 1NY
United Kingdom

Glossary

ArcView Terminology

Project
A Project is the file ArcView creates so that you can organise your work. Projects make it easy to keep any combination of related ArcView components- views, tables, charts layouts and scripts- together in one convenient location.

Document
Documents are the different means of interacting with your data. These include views, tables, charts, layouts and script editors.

View
One of ArcView's document types which displays a map and its legend. A View is made up of layers of geographic information for a particular area.

Table
One of ArcView's document types which displays information in rows (or records) and columns. In theme attribute tables, such as the "Attributes of Soils" table, the rows correspond with individual geographic features and the columns correspond to fields, named at the top of the columns. A table lets you work with data from various tabular data sources.

Chart
One of ArcView's document types. It is a dynamic, visual representation of data in a table. Charts may be drawn in a variety of formats such as bars, lines, pies and others.

Layout
One of ArcView's document types used to arrange maps, graphics, text and so on, in preparation for high-quality, full colour prints of plots of your work.

Theme
Layers of geographic information in a View are called Themes. A Theme represents one of the following sources of geographic data: a spatial data source such as an ARC/INFO coverage or ArcView shapefile, an image data source such as a satellite photo, or a tabular data source.

Feature Theme
If the spatial data source for a theme is an ARC/INFO coverage or ArcView shapefile, then that theme is referred to as a Feature Theme.

Image Theme
If the spatial data source for a theme is an ARC/INFO GRID or an image, then that theme is referred to as an Image Theme.

Table of Contents
Each view has a Table of Contents (TOC) that lists the themes in a view.

Active Theme
When a Theme is active it is highlighted in the Table of Contents.

Legend
Each theme has its own Legend which is displayed in the Table of Contents. A theme's legend controls how the theme is displayed on the view. A legend is changed by using the Legend Editor.

Shapefile
A shapefile is a simple non-topological format for storing the geometric location and attribute information of geographic features.

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Appendices

Technical Note

The PUDSI system has been installed at NRI in a directory location which is referenced by the value of the PUDSHOME environment variable.

The value of PUDSHOME at the time of installation (April 1996) was *c:\jane\pudsi*.

Any reference to PUDSHOME in this report should assume the directory location *c:\jane\pudsi*, unless changed by the PUDSI data manager since installation.

Executive Summary

The NRI (Natural Resources Institute) is currently conducting research on the development of methodologies for integrating spatial data of varying scales and resolutions, principally remotely-sensed data with map/tabular data. Environmental management activities are typically based on a wide range of information sources, differing in terms of scale and resolution, data format, information content and reliability. It is anticipated that a tool which allows local decision-makers and planners to examine these sets of data in a sensible, integrated manner would not only lead to a better understanding of the information content of the data and the spatial relationships between them, but also enable better decisions and plans to be made regarding the environment.

The purpose of this project is to design and develop a prototype user-friendly browse and analysis system to assist researchers in exploring with local decision-makers and planners the integration and coherent use of spatially-related data. The datasets for the development of this prototype are taken from the peri-urban area around Kumasi, Ghana.

The system design is sufficiently flexible to allow it to be used for other study sites or production systems such as intensive agriculture.

The research has thus focussed on developing a user-interface for the Kumasi peri-urban area, enabling users of the system to integrate a number of different data types and providing a range of data input, query and analysis functions.

Outputs from the project include:

- a range of diverse datasets relevant to Kumasi which have been installed in a well organised directory structure;
- an Access database which stores all metadata relating to the spatial datasets;
- a GIS user interface, based on ArcView2, for displaying, querying and analysing the spatial and non-spatial datasets;
- a better understanding of what potential users may like to see incorporated into such a system; and
- a final technical manual and report.

Part One

General OverView of PUDSI

1. Introduction

The NRI (Natural Resources Institute) is currently conducting research on the development of methodologies for integrating spatial data of varying scales and resolutions, principally remotely-sensed data with map/tabular data. Environmental management activities are typically based on a wide range of information sources, differing in terms of scale and resolution, data format, information content and reliability. It is anticipated that a tool which allows local decision-makers and planners to examine these sets of data in a sensible, integrated manner would not only lead to a better understanding of the information content of the data and the spatial relationships between them, but also enable better decisions and plans to be made regarding the environment.

Most currently available Geographical Information Systems (GIS) allow the simultaneous display, query and analysis of diverse datasets, but the operation and sensible use of these systems requires considerable knowledge, experience and training in concepts of spatial data management and GIS. For users with little or no GIS understanding, it would be more appropriate to develop a specially-tailored, yet simpler, user-friendly browse and analysis system. Such a system would not only enable simple data integration and querying, but also incorporate a number of specific functions to support known requirements defined by local planners and decision-makers. It is important that before such specific functions can be developed and implemented, the end users are identified and their needs and requirements clearly defined.

GDS (Geographic Data Support) Ltd. has thus been awarded a contract to develop a prototype system to assist in research into the rational management and understanding of patterns and processes in peri-urban areas. This is called the **Peri-Urban Demonstrator for Spatial Data Integration (PUDSI)** system. As an initial case study, work is being focused on the Kumasi peri-urban area in Ghana. NRI is currently conducting a baseline study there which should not only identify specific problems in terms of peri-urban resource allocation and management but also provide a range of additional information sources for integration in PUDSI.

Terms of Reference/Objectives

1 To design and develop a prototype user-friendly browsing and analysis system to assist researchers in exploring with local decision-makers and planners their needs in the integration and coherent use of spatially related data.

2. The system will allow users to examine the available data qualitatively (as it appears on the screen) and also perform a limited range of quantitative analysis (land use change measurements, *etc.*).

3. The datasets for the development of the prototype will be from the peri-urban area around Kumasi, Ghana. The system design, however, should be sufficiently flexible to allow it to be used elsewhere for other production systems or applications.

Data Needs and User Requirements

It has already been mentioned that an essential component of any user interface system is the establishment of clearly defined user needs and requirements. Equally important is the availability of data to support the development of functions to meet these requirements. However, it has been unfortunate that the Kumasi baseline study commenced after this contract began and, more importantly, had not reported before the final submission date.

As a result, only a limited range of data has been available to place on the system, including some hypothetical datasets prepared by GDS. Accordingly, only a limited range of possible functions can presently be demonstrated. To be fully effective as a research tool, additional and authentic datasets must be made available and incorporated into the system.

In terms of user requirements, the ways in which PUDSI is to be used in research will need to be more clearly specified by the research managers and the design and operation of the system reviewed and revised accordingly. Section 3 addresses in more detail some of the issues which need to be considered.

This final report describes the work carried out by GDS Ltd. in the 11-week period following the briefing meeting at NRI on Thursday 11th January 1996. The report is structured into several parts with Part One intended as a complete report in its own right, designed to give a general overview of the system from a non-technical point of view. Our conclusions and recommendations for further development are included at the end of Part One.

Part Two considers the technical aspects of the system in more detail, such as system requirements, database design and directory organisation. Those who will be actively involved in the further development of PUDSI will find this invaluable. PUDSI developers should also consult the Technical Details section of section 2.3.

Part Three has been added to enable someone who is not very familiar with ArcView to demonstrate the functionality of PUDSI to interested users.

The report is thus structured as follows:

Part Three: PUDSI Demonstration

Section 8 PUDSI Demonstration

2. Functionality of the PUDSI Interface

2.1 Introduction

PUDSI is based on ArcView2, a low-cost desktop GIS (Geographical Information System) which enables the display, query and manipulation of geographic information. The standard ArcView interface is comprised of menus, buttons and tools which enable the user to interact with the display and perform a range of different functions. GDS does not intend to explain all ArcView concepts and terminology in this report so the user is advised to first become familiar with ArcView by referring to official manuals and documentation. As a source of reference, we have included a short glossary of ArcView terminology at the beginning of the report.

ArcView is made up of five *document* types: Views, Tables, Charts, Layouts and Scripts. Each of these document types has an associated Graphical User Interface (GUI) with its own set of menus, buttons and tools. Appendix C shows the standard ArcView GUIs for View and Table documents.

The standard ArcView interface may be customised by using an object-orientated programming language called *Avenue*. GDS has thus modified this standard interface to create the PUDSI interface, designed specifically for peri-urban analysis. As well as removing some of the standard ArcView menus, buttons and tools, we have added a number of our own to each of the View and Table documents we have created. The GUIs of these View and Table documents are shown in Appendix D.

Section 2.2 gives a brief summary of the capabilities of the system from a non-technical point of view. There are various accompanying figures to illustrate the Views and Tables which are accessed at different stages of running the system (Appendix D).

Section 2.3, on the other hand, is much more detailed, describing in turn each function which GDS has developed and added to the standard ArcView interface for a particular View or Table. The format of the description for each function is as follows:

View or Table: Button/Tool/Menu 

Purpose:

What this particular function (activated by a tool, button or menu choice) does, described(as far as possible) in non-technical terms.

Example:

Expands on the general description above by giving a specific example.

Technical Details:

> More technical detail on how the function operates, including an account of all the options and user inputs which are required. ArcView/Avenue technical terms are used here.

Comments:

Any comments (if any) on the limitations or further potential of this particular function.

Note that some ArcView terminology has been adopted, even in the general description section. A *theme* is synonymous with a dataset and an *active theme* is one which has been selected by the user, simply by clicking on its name in the legend.

2.2 General Description of Interface Functionality

The PUDSI user interface has been created by simplifying the standard ArcView interface and adding some new menus, buttons and tools to provide specific functionality. Although this prototype system focuses on the Kumasi peri-urban area it has been designed in such a way that the user may add data and functionality relating to any number of other sites around the world.

On opening the system, the user is first presented with the *World View* (Appendix D, Figure 1). This shows the countries of the world and the distribution of study sites such as Kumasi. The user is then able to press a button which will zoom him to a continent or region where the study sites are labelled by name. The current version of PUDSI only enables the user to zoom to Africa. The View which is then opened is called *Africa* (Appendix D, Figure 2).

The user may then select any of the study sites shown on the Africa View and this automatically opens a new window where topographic datasets relevant to that study site are loaded. Figure 3 (Appendix D) shows *Kumasi View* which is opened when the user clicks on the Kumasi study site shown on the Africa View.

When the Kumasi View is initially opened the Digital Chart of the World (DCW) and 1:50,000 topographic layers are automatically loaded. A circular area of radius 50km is displayed around Kumasi city. However, only the DCW layers are shown at this point and it is only when the user zooms to larger scales that the 1:50,000 layers become visible.

The various menus, buttons and tools added to this View enable the following operations:

- query of the Access database to retrieve and display vector datasets which are relevant to the Kumasi study area;
- input of user-defined vector or raster datasets which have not been catalogued in the Access database. These datasets may be inserted directly into the View for display and analysis,
- importing of georeferenced text files to create a point theme;
- importing of text files with no georeferencing to create a table which may then be joined to the attribute table of an existing theme;
- the ability to zoom to a rectangle or a point defined by the user in terms of latitude/longitude co-ordinates,

- limited spatial analysis routines relating point data to other point, line or polygon features *e.g.* selecting all villages which fall within the 1000-3000ft elevation zone;

- display of data description and data processing history text files for any dataset;

- display of hotlinked features (*e.g.* text files, scanned photographs or images, *etc.*) for any point, line or polygon feature;

- creation of side-by-side bar symbols to show the attribute data for selected features;

- creation of pie-style spot symbols for (selected) polygon features;

- the ability to zoom to a special View for displaying and interpreting the Bath College high resolution imagery for SE Kumasi.

If the users decide to display and analyse the Bath College high resolution image data then they choose a menu option from the Kumasi View which opens another View called *Bath Aerial Video Images* (Appendix D, Figure 4). Here there are options to load and display the separate datasets which represent the image interpretations for buildings, vegetation, and linear features (roads, railways, rivers). The user may also display the raw images which formed the basis of the interpretations. As these images currently have no georeferencing they are displayed in a separate View which we refer to as the *TIFF View* (Appendix D, Figure 5).

The TIFF View enables the user to display the image data for a particular image site and to digitise features from the screen *e.g.* the location of buildings.

In addition to the functionality summarised above for each View, the user also has access to the standard ArcView functions such as: pan and zoom, editing the legend, and querying of selected features. The user is advised to consult the ArcView manual for additional information.

2.3 Specific Functionality

Appendix E summarises all the menus, buttons and tools which have been programmed as part of the PUDSI interface by GDS Ltd. These are now described in turn.

2.3.1 World View: Zoom to Africa Button [A]

Purpose:

This enables the user to zoom to the extent of Africa in order to select a study site.

Technical Details:

On opening PUDSI, the user is first presented with the World View. This shows the distribution of study sites on a generalised world map derived from ArcWorld 1:25M.

In order to create a point theme of study sites to add to the TOC (Table of Contents) of the World View, the system first retrieves all the records from the Access table called *Sites* and creates a table document called *Study Sites Table*.

A point theme is then created from this table document (script: *WorldViewOpen*) which basically generates, for each record, a point shape from the x and y co-ordinates. All study sites are displayed with a red point symbol.

Comments:
Other buttons may be added here at a later stage to enable the user to zoom to other continents or regions.

2.3.2 Africa View: Hotlink Tool

Purpose:
This enables the user to select a study site with the mouse. This operation automatically opens another window for displaying datasets relating to that site and performing a number of data input, query and analysis functions.

Example:
If the user clicks on the Kumasi study site then a window specifically for the display and analysis of datasets relevant to Kumasi is opened. This is called the Kumasi View (Appendix D, Figure 3).

Technical Details:

On the Africa View the study sites are displayed with random colour assignment and their names are shown in the legend. The main objective of this View is for the user to click on one of these study sites with the hotlink tool (which must first be made active). This in turn opens another View for displaying datasets relevant to that study site.

When the Africa View is opened, hotlinks are set up for each study site (script: *AfricaViewOpen)*. The attribute table for the Study Sites feature theme has a field called Hotlink which is used to store the name of the View which is opened when that study site is selected. The script which is run when the hotlink tool is used is called *OpenHotLinkView*.

Comments:
Users are currently only able to use the hotlink tool to open a window for the Kumasi study site. If they click on any of the other sites (all hypothetical) then no action is initiated *i.e.* no window is opened.

2.3.3 Kumasi View: Overview

Purpose:
The main function of this View is to enable the user to select and display datasets which are relevant to the Kumasi peri-urban environment.

The user interface has therefore been modified by GDS and several menus, buttons and tools have been added to perform a variety of functions such as data selection and display, input of text files, representation of attribute data with the use of histograms and pie-charts, spatial analysis, and zooming to user-defined locations.

Technical Details:

The current version of PUDSI assumes that all datasets added to Kumasi View are held in geographic (unprojected) co-ordinates. No provision has been made for datasets which are held in a projection system such as Mercator. Once the Kumasi baseline study is complete and relevant datasets have been identified and collected, then a re-evaluation of the issue of projections and how they may be handled in PUDSI should be made. If it transpires that many datasets are held in a common projection system then the interface could be programmed to first, retrieve the dataset projection (held in a field in the *Datasets* table), then open a special View to display only those datasets held in that projection.

When users move the cursor around the Kumasi display, their geographic location at any point is recorded in units of decimal degrees. This is because the *map units* have been set to decimal degrees. However, we have set up the View properties so that the *distance units* are recorded in kilometres. The distance units are used by ArcView to report any measurements made using the Measure tool and for distance tolerances used in spatial analysis routines (such as the SPATIAL ANALYSIS menu described in section 2.3.14 below). However, the user may change the distance units, for example from kilometres to metres, by using the Properties option of the VIEW menu.

Comments:

We have assumed that all datasets accessed with PUDSI are held in geographic co-ordinates (latitude/longitude, units of decimal degrees). Datasets held in a projection system must first be transformed to geographic co-ordinates prior to display in PUDSI. This transformation may be carried out on an external system such as ARC/INFO. Future versions of PUDSI could, however, be easily adapted to cope with datasets which are not referenced by latitude/longitude.

We have deliberately retained many of the standard ArcView menus, buttons and tools on the Kumasi View interface for several reasons:
- they provide useful functionality for those users who are familiar with ArcView; and
- they will be needed for further development on PUDSI functionality.

2.3.4 Kumasi View: Set/Remove Thresholds option on the THEME Menu

Purpose:

This option either sets or removes scale thresholds for the active theme, depending on whether scale thresholds have already been set. Scale thresholds control whether that theme is drawn at a given display scale.

Example:
When Kumasi View is first opened all the 1:50,000 topographic datasets are added with a maximum scale threshold of 1:510,000. This means that they are not drawn until the display scale falls below 1:510,000. If users wish to display the 1:50,000 road theme when Kumasi View is first opened then they simply select the Remove Thresholds option from the THEME menu and the 1:50,000 roads are drawn.

Technical Details:

When Kumasi View is opened, DCW and 1:50,000 topographic datasets are added to the TOC. However, only the DCW layers are displayed. This is because we have set up the View so that the source of topographic data displayed is dependent on the scale of the View. DCW layers have been set with a minimum scale of 1:510,000 while the 1:50,000 layers have been set with a maximum scale of 1:510,000. This means that when the View is first opened at a default scale of approximately 1:900,000 only the DCW layers are drawn. However, as the user zooms to more detailed study areas the scale becomes larger and eventually, if it falls below 1:510,000, the DCW layers are switched off and the more detailed 1:50,000 layers are drawn. These minimum and maximum scale thresholds are set in the script *KumasiViewOpen* for each of the topographic themes added to Kumasi View.

The user may, however, overwrite the scale dependencies using the THEME PROPERTIES menu or disable/enable them for the active theme using the Set/Remove Thresholds option from the THEME menu. Whether the menu item is set to Remove Thresholds or Set Thresholds depends on whether scale thresholds already exist for the active theme.

Similarly, when new datasets are added to Kumasi View from the Vector Data Table any minimum or maximum scale thresholds are retrieved from the Access database. These may be disabled using the Remove Thresholds menu option or, if none exist, they may be set up using the Set Thresholds option.

Comments:
This facility to be able to control the display of datasets according to scale of study is one which should be developed further in subsequent versions of PUDSI.

2.3.5 Kumasi View: User Defined Rectangle and User Defined Point options on the ZOOM TO Menu

Purpose:
These options enable the user to either zoom to a rectangle or a point whose latitude/longitude co-ordinates are already known.

Technical Details:

If users are interested in a rectangular study area then they are prompted to enter the x and y co-ordinates (in decimal degrees) of the bottom left and top right corners of this rectangle. This area is then shown on the screen. If the user decides to zoom to this area then the new scale is calculated and, according to the topographic data scale thresholds, either DCW or the 1:50,000 data layers are drawn. The script used to do this is *UserDefinedRectangle*.

When users choose the User Defined Point menu option they are first prompted for the display scale (the default value is 1:100,000) then the x and y co-ordinates (in decimal degrees) of the point they wish to zoom to. The default latitude, longitude point corresponds to Kumasi city. The display then zooms to this point at the desired scale, again taking into consideration the topographic scale thresholds during redraw. The script used to do this is *ZoomToXY*.

Comments:
During an interim presentation of PUDSI at NRI it was suggested that users are unlikely to know the exact latitude/longitude co-ordinates of the area they are interested in. A more detailed user requirements survey will reveal whether this function is useful or realistic for the average user of the system.

2.3.6 Kumasi View: Querying the Database Button [Q]

Purpose:
This button queries the Access database for vector datasets which are relevant to the Kumasi study site. This list of datasets is then presented to the users for them to select those they are interested in viewing.

Technical Details:
The script which queries the Access database, *QueryVectorData*, sends an SQL statement to Access to select all the data records from Datasets (and the related table Vectors) which apply to Kumasi. It then adds these records to a table document called Vector Data Table. By default, this table is simplified by showing only the following fields: dataset name, scale/resolution, and feature class type.

The Vector Data Table GUI (Graphical User Interface) is designed to enable the user to select one or more data records (or datasets) for adding to the Kumasi View. Datasets are selected either by clicking on the row with the mouse (this highlights the data record) or by using one of the standard ArcView methods:

- using the Find button to find and select the row in the table using any text string entered;
- using the Query Builder to select records using a logical expression.

There are also a number of buttons to enable users to: select all the records in the table, unselect all the records, toggle the selected and unselected records in the table, sort rows in ascending or descending order (on the active field), and promote selected rows to the top of the table. Users can also access the table properties to alter the visibility status and aliases of the fields in Vector Data Table.

Having selected the datasets to be examined in more detail, the user presses button [A] which adds them to the Kumasi View. The function of this button is described in more detail below.

Comments:
So far we have added a button to Kumasi View which queries the Access tables to retrieve vector datasets. Future versions of PUDSI will need to add additional buttons to retrieve raster/image datasets.

2.3.7 Vector Data Table: Adding the Datasets to Kumasi View Button [A]

Purpose:
This button adds the datasets which have been selected from Vector Data Table to the Kumasi View.

Technical Details:
The script which adds the selected datasets to Kumasi View, *AddVectorToView*, performs the following functions for each dataset:

- it retrieves all the metadata information from Vector Data Table and stores it in a parameter list for that theme;

- it examines this parameter list and determines whether any lookup tables are to be joined to the feature attribute table of the new theme. It then performs the join operation based on a field which is common to both tables;

- it examines the parameter list to determine whether there is a default legend to be loaded when the new theme is added to the TOC. If so, it loads this legend and sets it to invisible. It also determines whether the title of the new theme is to be qualified by the field which is used in the classification *e.g.* Disticts by Popden84;

- it examines the parameter list to determine whether any scale thresholds have been set. Is so, they are set up and used to control the minimum and maximum display scales;

- it examines the parameter list to determine whether there are any hotlinked files attached to the features of the new theme. If there are, then the hotlink information is retrieved for that theme and the hotlink tool on the Kumasi View GUI is enabled whenever that theme is made active

These operations take place automatically for each selected dataset in Vector Data Table as long as the required metadata have been entered into the Access tables, Datasets and Vectors. Appendix A describes in more detail how these metadata are used whenever a dataset is selected from Vector Data Table and a new theme is added to Kumasi View.

2.3.8 Kumasi View: Data Description and Data Processing History Button [M]

Purpose:
This button displays two text files for the active theme: a data description text file and a processing history text file. The latter file is used to record any processing history for the dataset which may ultimately affect interpretation and further manipulation and analysis. The text files are displayed in scrolling popup text windows.

Technical Details:
The naming convention of these files is as follows: data description files are **.des* while the processing history text files are **.pro*. Both are stored in *PUDSHOME\supfiles\descfile* (PUDSHOME is an environment variable which is set to the directory location where all data and system files required to run PUDSI are stored).

The script which displays these text files is called *ViewMetaData*. Except for the topographic datasets, the names of the text files are retrieved from the Parameter List for the active theme. The text files are then displayed in popup scrolling windows.

Comments:
GDS has not actually created many of these text files due to time limitations on the project and also due to lack of detailed knowledge on the sources and operations performed on the datasets. The text files which do exist are minimal, created only to demonstrate functionality.

2.3.9 Kumasi View: Text File (No GeoReferencing) option of the IMPORT Menu

Purpose:
This menu option enables the user to import a text-delimited file with no locational information (i.e. no x,y co-ordinates) in the form of a table document. This table may then be joined to the attribute table of an existing theme.

Example:
An example file has been added to *PUDSHOME\textdata\nogeoref* called villages.txt. When this file is imported to the system it creates a table document. Once the data are stored in a table document, the user may perform any of the standard ArcView table functions and, additionally, create charts to present and compare the attribute data.

Technical Details:
The users are first asked to select the .txt file they wish to import from the *PUDSHOME\textdata\nogeoref* directory. A table document is created from this text file with field names extracted from the first row of the text file and each data record in the table corresponding to a row of data in the file. The table document is given the same name as the text file.

The users are then asked if they wish to JOIN this file to a feature theme This facility is very useful if there is some field in the text file which relates to a field in an existing feature theme. For example, the file *villages.txt* has a field called "village name" which relates to the village names which are stored in the DCW village point theme. It is the responsibility of the user to ensure that the names of the villages are indeed similar.. Any difference in spelling would result in the failure of that record being joined to the point theme.

If the users do wish to join the table document to an existing feature theme attribute table, they first select the name of the theme it will be joined to then the name of the field in this theme which will be used in the join operation. This requires some familiarity with the fields in the feature theme, in particular their content if the name is not self-explanatory. They then select the name of the field in the table document which will be used in the join. The join operation is performed and the attribute table of the feature theme is opened and made active. In the example above, the DCW villages now have additional demographic attribute data for selected villages. Since these demographic data now have a spatial reference they can be analysed in a spatial context by creating side-by-side bar symbols (section 2.3.11).

Comments.
If a join operation is being performed then the user must be familiar with all the field names in the two attribute tables. The names are often not self-explanatory. This is clearly a limitation and one which would not be acceptable for a non-technical user of the system. Several solutions are possible:

- setting up field name aliases so that obscure field names become self-explanatory;
- if user requirements were very clearly defined and likely join operations documented then joins could be performed "behind the scenes" with no input required from the user.

This is clearly one area which must be modified and/or simplified according to user requirements and level of knowledge of the data and of concepts of spatial data management.

2.3.10 Kumasi View: Text File (GeoReferenced) option of the IMPORT Menu

Purpose:
This menu option is selected to create a spatially referenced dataset (i.e. point theme) from a text-delimited file, where each record corresponds to a point and has associated attribute data. Each record in the text file has an x and y coordinate value in units of decimal degrees.

Example:
An example file has been added to *PUDSHOME\textdata\georef* called polldata.txt (see section 5.3.1 below). This text file contains hypothetical pollution data for a number of sample sites along the DCW river network. Using this option, the user can

create a theme to examine the spatial distribution of these points and, furthermore, generate histograms to compare the attribute data (section 2.3.11).

Technical Details:

When this option is chosen the user is first asked to select the .txt file to be imported from the *PUDSHOME\textdata\georef* directory. A table document is created with field names extracted from the first row of the text file and each data record in the table corresponding to a row of data in the file. The table document is given the same name as the text file.

The standard ArcView *Add Event Theme* dialogue box is then presented to the user. This is used to create a point theme from the latitude/longitude co-ordinates in the table document. The user first selects the table name which will be used to create the point theme then the system automatically searches for the fields to provide the x and y coordinate information. Having provided this information, the system then creates the point theme, assigns it the same name as the text file, adds it to the TOC of Kumasi View, makes it active and switches it on for drawing.

Comments:

This is a very powerful and potentially valuable tool as text files containing georeferencing information and attribute data can be transformed into meaningful spatial datasets then compared and integrated with other datasets in either a qualitative or quantitative manner.

2.3.11 Kumasi View: Bar Symbols Tool

Purpose:

This tool enables the user to present and compare attribute data for selected features. This is done by creating side-by-side bar symbols adjacent to the selected point, line or polygon features on Kumasi View. The bar height reflects the data value for the user specified field.

Example:

This tool may be used to compare the source of water pollution for each of the sample points taken along the river network. Adjacent to each sample point on the View would be a bar chart showing the percentage of water pollution derived from the following sources: domestic, industrial and agricultural.

Technical Details:

The script which performs this function, *MakeBarChartSpotSymbols*, is in fact derived from the Avenue script library and the user should refer to this documentation for further information.

The users are first asked to select a bar size (small, medium, large or x-large) which is relative to the size of the display area. They then select first the field name from the feature attribute table (the field must be numeric in order to be mapped) then the colour which will be assigned to that bar when it is displayed.

They repeat this procedure for each field they wish to display on the bar chart for the selected features. When selecting fields, the data should be in the same units so that they may be sensibly compared and analysed. The bar symbols are then displayed adjacent to the selected features with the maximum data value drawn as the largest bar and all other bars scaled accordingly.

The bar charts and associated legend may be deleted from the View using the Delete Graphics button.

Comments:
Once georeferenced text files have been imported into the View as point themes then this facility enables their attribute data to be displayed and presented to the user in an easily interpretable form. Similarly, ungeoreferenced text files which are joined to existing feature themes may also have their attribute data presented in this manner.

2.3.12 Kumasi View: Pie-Charts Tool

Purpose:
This tool enables the user to present and compare attribute data for selected polygon features. This is done by creating pie-style spot symbols at the centre of each polygon feature.

Technical Details:

The script, *MakePieChartSpotSymbols*, is in fact derived from the Avenue script library and the user should refer to this documentation for further information.

The script allows users to interactively select the numeric fields from the feature attribute table for which they want to generate pie symbols. Each pie slice corresponds to a field and indicates what percentage of the total for the record the field represents. The size of the pie reflects the total amount of all fields for a given record.

The pie charts and associated legend may be deleted from the View using the Delete Graphics button

Comments:
This function can only be used to represent attribute data for polygon features.

2.3.13 Kumasi View: Delete Graphics Button

Purpose:
This button deletes all the graphics which have been added to Kumasi View. By graphics we include all bar chart and spot symbols, text elements, and other graphic elements which have been added using standard ArcView functions.

2.3.14 Kumasi View: SPATIAL ANALYSIS Menu

Purpose:
This routine enables the user to examine the spatial relationships between point features of one theme relative to another e.g. select all points (towns) which fall within 10km buffer distance of main roads.

Example:
A user selects all the WCMC (World Conservation Monitoring Centre) Protected Areas (defined as points) which lie within the 1000-3000ft elevation level then adds these as a new theme to Kumasi View. The attribute data for this new point theme is then exported as a text-delimited file for further manipulation and analysis within a spreadsheet.

Technical Details

The SPATIAL ANALYSIS menu which we have added to the Kumasi View GUI contains a set of three routines which should in fact be performed one after the other in order to achieve the desired result. The three routines are as follows:

- select POINTS relative to another theme;
- convert to ShapeFile/Add to View, and
- export tabular data.

The example shown above is now considered. The first stage is to select the features of WCMC Protected Areas which fall within the 1000-3000ft elevation zone. This is achieved by running the first routine, *Select POINTS relative to another theme*.

On selecting this option, users are first asked if they have selected the features from the theme they wish to relate the points to *i.e.* have they selected the 1000-3000ft polygons from the DCW elevation level theme? This is done by using any of the standard ArcView selection functions such as the Query Builder button or the Select tool. Once these elevation polygons have been selected (they are highlighted in yellow on selection) users should make the point theme they are interested in (*i.e.* Protected Areas) active.

The standard ArcView Select by Theme dialogue box is then presented. Users should first select the theme they are relating the points to (*i.e.* DCW Elevation Levels) from a scrolling list of themes which are present in the TOC. According to the type of theme selected here (*i.e.* point, line or polygon) the user is then asked to select the point-to-theme relationship type *e.g.*

Select features of active theme that:
Intersect
Are Completely Within
Completely Contain
Have their Centre in

Contain the Centre of
Are Within Distance of

the selected features of
DCW Elevation Levels

If users select the *Are Within Distance of* relationship then they must input the distance value in the units which are presented *i.e* km. Section 2.3.3 discusses the concept of distance units for Kumasi View.

Once users have selected all the required options the spatial analysis is performed. The end result is that all the Protected Areas points which fall within the 1000-3000ft elevation zone are selected in the View. If users now wish to create a new shapefile containing only these points then they should choose the next routine, *Convert to ShapeFile/Add To View.*

A shapefile (*.shp) is created in a user-specified directory location (default location is *c:\temp*). Users may specify the name of this shapefile otherwise it is given an arbitrary name such as theme1.shp. The shapefile is then added to the Kumasi View, made active and switched on for drawing. Users may also add comments to this shapefile. This is useful if, for example, they wish to record how this dataset was derived *e.g.* "Protected Areas within DCW elevation level 1000-3000ft". These comments are easily retrieved by using the Retrieve Comments item of the THEME menu.

Users may then wish to export the tabular data for this new shapefile using the final routine, *Export Tabular Data*. The first question they are asked is whether they wish to export the x and y co-ordinate data for each point. Since the x, y co-ordinates are not specifically stored as fields in the point attribute table (*i.e.* they are implied in the point shape which is stored for each record) then special code has been written to generate these co-ordinate values for output. New fields, Xcoord and Ycoord, are added to the end of the attribute table.

Users choose the export format from the following options: dBASE, INFO and Delimited Text. The name of the output table and where it is located in the directory structure are then specified. A message such as "All records written to table1.txt" then appears in the PUDSI message box area at the bottom of the screen. The entire spatial analysis routine is now complete.

Comments:
The PUDSI interface has not attempted to provide users with numerous spatial analysis functions. Although there are many possibilities for integrating and analysing different datasets, we have provided only one example (*i.e.* the SPATIAL ANALYSIS menu) and hope that this will generate further ideas and discussions on what the end users may ultimately want to do with and derive from the datasets they have at hand in the system. Not only is it important to have clear guidelines on user requirements but the appropriate datasets must be made available in a suitable format for input to PUDSI.

This analysis routine has effectively been presented to users as three separate routines. The reason for doing this was to enable a certain amount of flexibility. For example, users may try numerous point selections before deciding that the end results merit conversion to a separate shapefile and added to the View. Similarly, the third routine may in fact not be desirable. Other reasons for presenting them as separate routines include:

- users may already have made a point selection using standard ArcView functions. In this case, they may wish to use the second and third routines without having used the first; and

- users may wish to export the tabular data of a point theme or shapefile which already exists in the TOC and which was not created using the SPATIAL ANALYSIS menu.

2.3.15 Kumasi View: Bath High Resolution Data Option of the ZOOM TO Menu

Purpose:

This menu option opens another window which is used specifically for displaying and analysing the Bath College high resolution image data. These are infra-red images flown on 6.12.95 and having a resolution of 10cm..

Technical Details:

On the Kumasi View GUI, the ZOOM TO menu has an option called Bath High Resolution Data. When the user selects this option a new View is opened which displays the location of the high resolution images overlain on the 1:50,000 urban areas, roads and railways. The script which does this is called *ZoomToBathData*.

The image boundaries are arranged in a N-S transect in the SE of Kumasi city. This boundary file was obtained from Bath College in MIF (MapInfo Interchange Format) format and imported to ArcView as a shapefile. It is called kid01.shp and is located in *PUDSHOME\data\bathdata*. Fields in this shapefile include: shape, id, filename, waveband, date, centroid_x, centroid_y, resolution, area and other.

The field called Filename is used to store the name of the TIFF file displayed when the hotlink tool is placed over that particular image. These hotlinks are set up in the script *ZoomToBathData*.

Another table (kis01.dbf, again derived from the Bath College MapInfo system) is then joined to the feature attribute table of this new shapefile. Filename is used as the join item. As a result of this join operation, the image boundary shapefile now has the following additional attributes: id, image_area, veg_area, veg_percen, bldg_area, bldg_percen, no_of_bldg, and other. The use of the id value is explained in section 2.3.16 while section 2.3.17 illustrates how a comparison of the composition of different land uses (veg_percen, bldg_percen) may be graphically depicted using side-by-side bar symbols.

2.3.16 Bath Aerial Video Images View: Label Image Sites option of the THEME Menu

Purpose:
This option enables the user to label the images with any of the fields in the attribute table.

Example:
It is useful to label the image boundaries with their id value so that they may be referenced to any chart document which may be created (section 2.3.18 below).

Technical details:

The user is first asked to select the name of the field with which to label the image(s) from a scrolling list of choices. The labels are then positioned in the centre of the image boundaries. If the text appears cluttered and difficult to read then it is possible to first zoom in before labelling. Label points are added to the View as graphic objects so they may be deleted using the Delete Graphics button.

The position of the labels relative to the image polygon feature may be changed by using the Properties option of the THEME menu. Choose the Text Label icon from the left hand side of the dialogue box then select the appropriate text position.

Individual text labels may be selected using the Select Graphics tool then moved to a new position or resized. If users click twice on the label name then the Text Properties dialogue box appears. This may be used to change the actual wording of the text label or to change the horizontal alignment, vertical spacing or rotation angle.

2.3.17 Bath Aerial Video Images View: Displaying Side-by-Side Bar Symbols Tool 

Purpose
This enables the user to compare numeric attribute data both within and between image sites using side-by-side bar charts.

Example:
The user may wish to create bar symbols for all the image sites showing the % composition of the different land uses. Adjacent to each image would be two bar charts, one showing the % of land occupied by vegetation, the other showing the % of land occupied by buildings.

Technical Details:

As this is the same tool as described in section 2.3.11 above, please refer to this section for additional information.

Bar charts are only created for selected features so the View GUI has retained all the ArcView buttons and tools required for feature selection. The bar symbols and associated legend may be deleted from the View using the Delete Graphics button.

2.3.18 Bath Aerial Video Images View: Creating Charts for Selected Images

Purpose:

This enables the user to create a separate chart (i.e. bar chart, pie chart, etc.) to display and compare the attributes of the high resolution images. This is a standard ArcView function.

Example:

For a more detailed example, see the PUDSI Demonstration in Part Three of this report.

Technical Details:

A *chart* is a dynamic, visual representation of data which is stored in a table. ArcView allows users to create charts in several different formats (*e.g.* bars, lines, pies) and to change the chart properties. A few of the chart properties which can be controlled include switching the chart axes, showing a grid or tic marks, and charting multiple fields side by side in the same chart or different ones.

We have not provided any additional functions relating to charts so users should consult the ArcView user manual for information on how to create and edit charts.

To create a chart for the image data, users first make the Bath Images theme attribute table active then select the Chart option from the TABLE menu. This opens the Chart Properties dialogue box. They then select the fields they wish to chart and the field for labelling the chart elements. If they select the ID field for labelling then it is easy to relate the chart to an image point displayed on the View- as long as they have already labelled the image points with the ID.

When users press OK on the Chart Properties dialogue box a bar chart is created for the selected feature(s). They may now use the chart GUI to customise the chart according to their requirements.

Comments:

If a user requirements study reveals more specific needs for creating charts then these can easily be incorporated into the system at a later stage.

2.3.19 Bath Aerial Video Images View: Add High Resolution Buildings Theme Button

Purpose:

This button adds the Bath College image interpretation file for buildings to the View. It depicts different building types within each image: commercial, homestead, outhouse, unfinished, unknown.

Technical Details:

When this option is chosen, a shapefile called knv01.shp is loaded into the TOC of the View. This shapefile was created using ArcView's Import MIF function to convert it from the MapInfo file format it was received in. A default legend is added showing the different building types which have been interpreted from the images by on-screen digitising.

2.3.20 Bath Aerial Video Images View: Add High Resolution Linear Features Theme Button

Purpose:

This button adds the Bath College image interpretation file for linear features to the View. It depicts different linear feature types within each image: footpaths, minor roads, tracks and rivers.

2.3.21 Bath Aerial Video Images View: Add High Resolution Vegetation Features Theme Button

Purpose:

This button adds the Bath College image interpretation file for vegetation features to the View. It depicts different vegetation feature types within each image: grassland, imm. oil palm, mixed, mixed river, oil palm, plantain, row crops.

2.3.22 Bath Aerial Video Images View: Zoom Back to Extent of Bath Images Study Area Button

Purpose:

This button enables users to zoom back to the extent of the Bath Images study area if they have been progressively zooming in and wish to return to their original start point.

2.3.23 Bath Aerial Video Images View: Using The Hotlink Tool To Display A TIFF Image For A Selected Image

Purpose:

This enables the user to place the cursor anywhere within an image boundary to display the associated infra-red image in a separate window.

Technical Details

All necessary hotlink information is set up in the script *ZoomToBathData* when the Bath images shapefile is added to the View. This means that the hotlink tool is enabled whenever that theme is made active.

Whenever the hotlink tool is placed within the boundary of an image, the system script *View.Hotlink* retrieves the name of the TIFF file from the hotlink field (Filename) for the selected feature. This TIFF file is then passed to the script *Link.ImageView* which creates a new View and displays the TIFF file. The View is assigned the same name as the TIFF file.

The hotlink tool may be used many times to simultaneously display the TIFF files for a number of image points. Section 2.3.24 describes the GUI of these special Views.

2.3.24 Bath TIFF Images View: Digitize Features Menu

Purpose:

Once users have displayed a high resolution image for a selected image (using the hotlink tool as described in section 2.3.23 above) they may then use this menu option to enable on-screen digitising and create a new interpretation file with associated attribute data.

Example:

Users may wish to create a new file showing the location of buildings on the image by digitising these features with the mouse. They may then add attribute data to this new file to store information such as building type or number of people living in the building.

Technical Details:

Those Views which display the Bath image TIFF files have a special GUI to enable on-screen digitising and creation of new shapefiles. We have added a menu called DIGITIZE FEATURES which is comprised of three separate options: Create New Theme, Add Fields and Add Data to New Fields. Users choose this function if, for example, they want to digitise the boundaries of all buildings which are visible from the image and code them according to whether they are residential or otherwise. The operation of each of the menu options is discussed below:

Create New Theme

Users are first asked whether they wish to digitise a point, line or polygon feature. A new shapefile is created and by default placed in *c:\temp*. Users may change the name and output location of this shapefile. It is also added to the TOC of the TIFF View, made active and set to visible. Notice that there is a dashed line around the tick box which signifies that the theme is editable.

Users should now activate the tool icon which creates a shape on the display. According to the feature theme chosen, that icon appears at the top of the drop down selection. For example, if a user chose to digitise point features then the tool which creates a point on the display will already be shown. The user then proceeds to digitise the features from the screen.

Add Fields

Having digitised the features users may then wish to add fields to the attribute table of the new shapefile. So far, the only field in this table is the *shape* field. Users are first asked how many fields they would like to add then, for each field, they are asked for the definition *i.e.* name, type, width and number of decimal places These new fields are then added to the attribute table of the new shapefile. If they wish to add records to these fields they then choose the next menu option, Add Data to New Fields

Add Data to New Fields

Before selecting this option, users select the feature for which they wish to add data to. They may use any of the standard ArcView selection methods although the selection tool is probably most appropriate in this case After they have selected the feature it is highlighted on the View and the corresponding data record highlighted in the attribute table.

They then select the Add Data to Fields option and choose the field they wish to add data to from the scrolling list of newly-added fields. This field then becomes active in the feature attribute table. In order to give users lots of flexibility in adding values to the fields we have used the standard ArcView Field Calculator. This enables users to not only type in a value for the chosen field but also to enter expressions using the values already present in the other fields. For example, they may add the numeric value x for NewField1 but then wish to calculate the values in NewField2 by an expression such as, (NewField1*100)/240.

Once they have added data for the selected feature(s), they then select another feature and repeat the procedure *i.e.* use the Add Data to Fields option for every feature.

Comments:

Since the TIFF files which are displayed and used as the basis for on-screen digitising are not georeferenced then the shapefiles created from this routine are also ungeoreferenced

3. Conclusions and Recommendations for Future Development

We have developed the PUDSI interface as a prototype demonstration system for peri-urban analysis but the following main limitations are obvious.

- there is no clearly defined end user(s) with well specified needs and requirements;
- there is a shortage of datasets relevant to peri-urban analysis;
- the interface (*i.e.* selection of menus, buttons and tools) may still appear too complex. This has been necessary in order to retain as many of the standard ArcView functions as may be required for further development.
- we have been unable to perform sophisticated quantitative analysis (such as land use change measurements) as specified in the Terms of Reference (section 1); and
- the design of the Access database for handling metadata relating to raster/image datasets is incomplete.

Data Needs and User Requirements

There are clearly some outstanding issues which need to be addressed if PUDSI is to develop further from this current version. These include:

- who will have access to the demonstrator system ?
- what research activities will they be engaged in ?
- what functions will they require from the system in order to support their research activities ?
- who will be responsible for adding to and maintaining the database and developing the interface functionality ?

It is suggested that these and other issues are reviewed in detail after the Kumasi baseline study is complete and, in particular, once the capabilities and information needs of local researchers have been identified. It is also important to review the system after other research teams have completed their studies considering methodological issues of spatial data integration and the preparation of videographic data.

Clearly, if at a later stage it is thought desirable for natural resource managers and policy makers to have permanent access to such a system (*i.e.* not just for research purposes) then detailed specification of such a system and its institutional context would be a pre-requisite.

Interface Complexity Versus Ease of Use

There is clearly a trade-off between *complexity* and *ease of use* of the PUDSI interface. At the current stage of its development we have not been able to tailor-make the interface due to lack of guidelines regarding user requirements. Its ease-of-use has therefore been compromised by the need to retain as many ArcView menus, buttons and tools as may be required for further development. The interface therefore appears more complex than may eventually be required.

This trade-off between complexity and ease of use can be seen in the SPATIAL ANALYSIS routine which we added to the Kumasi View. One button could have been added to the View to achieve all the separate spatial analysis routines in one simple operation with minimum interaction required with the user. However, this implementation (which may be preferable for some users) would have sacrificed the flexibility which we have introduced by dividing the operation into three distinct and separate routines (see section 2.3.14).

A user requirements study may reveal that there are two main classes of user: those who are familiar with spatial data and GIS techniques and therefore require a more complex set of functions, and those who are totally unfamiliar with computers but have a clearly defined set of operations they require from the interface. In this case, two versions of PUDSI would be required. In the latter case, the interface would be simplified as much as possible with only a few buttons or tools which, when activated, would carry out a complete function or operation with very little user input or interaction

Sophisticated Quantitative Analysis

Since ArcView is not a fully functional GIS with sophisticated vector and raster analytical capabilities, the number of spatial analysis routines which can be performed is limited. In any case, raster overlay and manipulation is certainly not possible using the current version of ArcView (Rev.2.1) although future versions promise to be more raster-friendly. For this reason, it has not been possible to carry out any land use change analysis, as specified in the Terms of Reference (section 1).

Design of the Access Database for Raster/Image Datasets

Since we were not able to acquire any georeferenced raster datasets before the end of the project we have not designed the Access tables for storing the metadata required for displaying these datasets. However, the database design is sufficiently flexible to enable additional raster-specific tables to be easily created and related to the main Datasets table. This exercise can only be properly carried out once the full range of possible raster/image data types has been identified. This will be achieved through a comprehensive data search and user requirements study.

Conclusion

As we see it, the main purpose of this prototype system is to demonstrate possibilities for data integration and analysis in the Kumasi peri-urban environment and to stimulate further ideas for functionality which would be useful to aid the decision making and planning processes. We envisage that the current version of PUDSI will be demonstrated to a wide spectrum of likely users in Kumasi and that subsequent phases will begin to identify these users and build up a clearer understanding of their requirements.

Part Two

System Requirements and Data Organisation

4. System Requirements

Due to the short time available to develop this prototype user interface, a comprehensive evaluation and comparison of available low-cost GIS systems was not possible. A joint decision was made by NRI and GDS to use ArcView2, one of the most popular and advanced GIS interface systems presently on the market The version of ArcView used to develop PUDSI was Rev.2.1.

Avenue is the object-orientated programming language used to customise ArcView2's Graphical User Interface (GUI) to meet specific user requirements. The current cost of ArcView, including Avenue, is £1,095 (as of April 1996). The ArcView/Avenue package offers a number of advantages as a development tool for a user interface such as PUDSI:

- it already has an easy-to-use and intuitive user interface;
- it is easily customised for individual applications;
- it provides good integration of multiple data types, including image and vector data integration;
- it includes a fully integrated and powerful hotlinking environment;
- it has integrated charting/graphics capabilities;
- it provides spatial analysis tools;
- it provides good tools for high quality map output; and
- it allows for full integration with advanced databases (*e.g.* Oracle, Dbase, Access) through full SQL connectivity.

PUDSI also requires the use of Microsoft Access for storing all the metadata associated with the datasets The version of Access used to develop PUDSI was Rev.2.0. Access was chosen as the tabular database for several reasons:

- it is part of the Microsoft Office suite of programs so it is likely to be already installed on many PCs;
- it is an interactive, easy-to-use relational database system (RDBMS) with powerful querying and analysis capabilities;
- there are facilities to create special data input forms so that users can easily update the metadata tables required for PUDSI; and
- ArcView2 interfaces easily to Access tables through the use of SQL queries

Due to the high memory requirements of ArcView and Access we recommend that the PC used to run PUDSI has <u>at least</u> 16Mb of RAM. The PUDSI directory currently requires about 45 Mb of hard disk but of course this requirement will change as new datasets are added and other developments take place.

5. Datasets

The datasets currently being used by PUDSI fall into three main categories:

- spatial datasets;
- hotlinked files e.g. text or TIFF files which are linked to a spatially-referenced feature; and
- text-delimited files.

These are now discussed in turn.

5.1 Spatial Datasets

All spatial datasets used by PUDSI are stored in specific directory locations beneath the level of PUDSHOME\data (section 7).

Vector

The vector datasets displayed in PUDSI must be either ARC/INFO coverages or ArcView shapefiles. Any other vector file format (e.g. ERDAS DIG files) must first be converted into one of these ArcView compatible formats.

The vector datasets are categorised according to whether they are topographic or thematic datasets.

The topographic datasets so far included in PUDSI are:

- ArcWorld 1:25M country boundaries. These generalized country boundaries are used in both the World and Africa Views;

- Digital Chart of the World (DCW) data for an area of 50km radius surrounding Kumasi city. DCW data have been digitised from the 1:1 million scale Operational Navigation Charts (ONCs) and the component layers may be purchased on CD-ROM for several world regions. NRI already possessed this data and simply extracted the relevant layers for the 50km area surrounding Kumasi city. Layers (with coverage feature type in parentheses) used in PUDSI include: contours (line), elevation levels (polygon), villages (point), urban areas (polygon), railways (line), roads (line), rivers (line) and water bodies (polygon).

- 1:50,000 topographic data for an area defined by lower left (-2, 6.5) and upper right (-1.25, 7). These datasets were digitised by NRI (March 1996) from paper maps dated 1972. Layers digitised (with coverage feature type in parentheses) include: rivers (line), roads (line), railways (line), villages (points) and larger settlements/urban areas (polygon). Although the digitised rivers were built as polygons (in order to define inland water areas) there has been a problem importing this coverage into ArcView. This matter will need to be resolved.

Metadata for the topographic datasets are not stored in Access tables as these datasets are automatically loaded whenever the user selects the Kumasi study area. Both the

DCW and 1:50,000 layers have in-built scale dependencies for display. This controls whether they are displayed at a given scale and is useful to prevent the user switching on the 1:50,000 layers (some of which are very complex e.g. river network) at a scale which is not appropriate for display i.e. 1:1 million. This concept is discussed in more detail in section 2.3.4.

The thematic datasets currently used by PUDSI include:

- World Conservation Monitoring Centre (WCMC) Protected Areas (points).
  This dataset was assembled on behalf of the UK Overseas Development Administration as part of the Tropical Managed Areas Assessment (TMAA) Project. GDS used this dataset in PUDSI to demonstrate some of the spatial analysis functionality..

- Soils
  NRI digitised soils polygons from a paper map source at scale 1:250,000.

- Disticts with associated demographic data.

The thematic datasets, unlike the topographic ones described above, have metadata stored in the appropriate Access tables, Datasets and Vectors (sections 6.1 and 6.2 respectively).

Raster/Image
The integration of useful and relevant raster datasets into PUDSI has been limited by the relatively short time period available to collate, evaluate and, if necessary, process remotely-sensed data such as aerial photography, airborne and satellite imagery. Since we have not been able to acquire any georeferenced raster or image data we have not designed the Access database to take account of raster metadata. However, the database design is sufficiently flexible to enable additional tables to be added at a later stage.

We did in fact receive a sample of georeferenced high resolution images from Bath College after the installation of PUDSI at NRI. We shall provide NRI with these data on submission of the final report.

5.2 Hotlinked Files

Using ArcView's hotlink facility users can access virtually any other data source simply by clicking on a feature in a theme. For example, click on a point representing the ground location where a field surveyor has collected several types of data, and this may initiate the following actions in ArcView: display of a text file (describing the field conditions) in a scrollable popup text window, display of a scanned photograph, display of a high resolution image, and display of a pie-chart showing the composition of land uses in a 1km square area.

All hotlinked files used in PUDSI are stored in a special directory location (see section 7 below). These files are linked to point, line or polygon features associated with a theme. This means that although they are linked to a feature which has known x, y co-ordinates they themselves do not have a spatial reference system. However, a hotlinked file such as an image may be georeferenced (e.g. a TIFF file which has been geometrically corrected) thus enabling the user to locate x, y co-ordinates when moving around the image and also enabling him to overlay other datasets such as topographic layers.

There are two metadata fields in the Vectors table, vec_fc_hotfield and vec_fc_hotscript, which contain information necessary for setting up hotlinks in PUDSI. Hotlinks are described in more detail in Appendix A.

The only vector dataset held in the Datasets and Vectors tables which has metadata relating to hotlinks is the 1:250,000 soils map of Kumasi. When the user selects a soil polygon using the hotlink tool a text file is displayed in a popup window. This text file gives a detailed legend description of that particular soil type.

5.3 Text-Delimited Files

There are two types of text-delimited files:

- those which are associated with a latitude/longitude point, and are thus georeferenced;
- those which have no georeferencing.

5.3.1 GeoReferenced Text Files

These are ASCII files which have either been created using a text editor, exported from a database system (such as an Access or DBase table) or a spreadsheet (e.g. Excel), or possibly output from a GPS system. An example of such a file (using hypothetical data), containing pollution data for a sample of four points along a river, is included in PUDSI:

polldata.txt

```
ID,XCoord,YCoord,Pollution_Level,%Domestic,%Industrial,%Agricultural
1,-1.69,6.86,7,10,43,47
2,-1.56,6.92,9,22,35,43
3,-1.4,6.79,3,25,20,55
4,-1.61,6.56,8,29,10,61
```

Note that the first line contains headings for each of the data fields. When this file is input to ArcView, these headings are used in the table document which is created. Each subsequent line corresponds to a data record. Since each record contains an x and y co-ordinate value, this file can be converted into a point theme and displayed in ArcView in the same way as any other spatial dataset. The x and y co-ordinate values must be stored in units of decimal degrees in order to be successfully imported into ArcView.

5.3.2 Text Files with no GeoReferencing

These text files are similar to those described above but with one important difference: they have no data fields for storing x and y co-ordinate values. Since they have no georeferencing they cannot be used to create point themes. An example of such a file, containing hypothetical demographic data for four villages in the Kumasi area, is as follows:

villages.txt

VillageName,%water,num_households,%school,age0-5,age5-15,age15-25,age25-40,age40-60,age>60
Ofinso,75,103,82,15,10,28,25,20,2
Ntonso,60,205,79,11,15,30,28,15,1
Kubeasi,80,91,86,15,6,36,35,8,0
Bekwai,73,141,91,10,14,37,29,10,0

Such a file may be imported into ArcView in one of two ways

- as a table document, and subsequently used for creating charts, etc., or
- joined to the attribute table of an existing feature theme using a common field

As an example of the latter method, the above file, villages.txt, may be joined to the DCW villages theme using Village Name as the common field. This is a very powerful function as it enables such data to be displayed spatially (rather than just in a tabular format) and offers numerous possibilities for representing the data in histograms or pie-charts.

6. Tabular Database Design using ACCESS

Microsoft Access was chosen as the relational database system to store all the *metadata* associated with the PUDSI datasets. These metadata, essential for efficient retrieval and display of datasets in ArcView, include: filename, data location (*i.e.* pathname), data type (coverage, shapefile, image), minimum and maximum scales for display, *etc.* Although the PUDSI data manager has knowledge of the structure of the Access tables and how they are related to each other for optimal retrieval, the end user of the system is completely unaware of the communication between ArcView and Access.

The Access database, *sites.mdb*, is held in *PUDSHOME\admin\database*. There are a number of tables in this database.

Sites	This table holds the latitude, longitude co-ordinates of all the possible study sites in the world. The Kumasi study site is the only operational example at this stage of the project.
Datasets	This table is used to store the metadata for all spatial datasets which are accessible from PUDSI.
Vectors	This table is used to store additional metadata specifically for the retrieval and display of vector datasets (*i.e.* coverages and shapefiles). There is a one-to-many relationship between a record in the datasets table and records in the vectors table.

6.1 Datasets Table

The Datasets table is used to store relevant metadata for all spatial datasets, vector and raster. Field definitions and descriptions are as follows:

FIELD NAME	*DATA TYPE*	*DESCRIPTION*
dat_id	Number	Unique ID of record
dat_filename	Text	Filename, coverage name, *etc.*
dat_longname	Text	Longer title for dataset
dat_studyarea	Text	Study area *e.g.* Kumasi
dat_loc	Text	Path to location of dataset after PUDSHOME
dat_proj	Text	Projection
dat_type	Text	Dataset type (coverage,image,shapefile, *etc.*)
dat_scale_res	Text	Scale or resolution of dataset
dat_ll_x	Number	Lat/long co-ordinates of lower left x
dat_ll_y	Number	Lat/long co-ordinates of lower left y
dat_ur_x	Number	Lat/long co-ordinates of upper right x
dat_ur_y	Number	Lat/long co-ordinates of upper right y
dat_desc	Text	Name of dataset description file
dat_proc	Text	Name of dataset processing history file
dat_minscale	Number	Minimum scale for display
dat_maxscale	Number	Maximum scale for display
dat_labelfield	Text	Field used for labelling features

The primary key in this table is dat_id. This is linked to the vec_datof field in the Vectors table in a one-to-many relationship.

6.2 Vectors Table

Field definitions and descriptions of this table are as follows:

FIELD NAME	DATA TYPE	DESCRIPTION
vec_id	Number	Unique ID
vec_datof	Number	Relates to dat_id in the Datasets table
vec_fctype	Text	Feature class type: poly. line, point
vec_fc_defleg	Text	Default legend (*.avl)
vec_fc_deflegfld	Text	Default legend field
vec_fc_hotfield	Text	Hotlink field
vec_fc_hotscript	Text	Hotlink script
vec_fc_joinfile	Text	Join file
vec_fc_jointofld	Text	Join field in feature attribute table
vec_fc_joinfromfld	Text	Join field in lookup table
vec_fc_legsuffix	Text	Whether the title of the default legend is qualified by the field it is categorised on.

It was considered necessary to have an additional Vectors table in order to store all the metadata which are unique to vector datasets. The one-to-many relationship between Datasets and Vectors is explained as follows: each ARC/INFO coverage (stored as *one* record in Datasets) is comprised of *one or more* feature class types, hence necessitating the use of one or more records in Vectors. For example, a drainage coverage may be comprised of both line and polygon features. Each feature class type is loaded into ArcView as a separate theme and has its own metadata relating to legends, hotlinks and join files.

6.3 Sites Table

Field definitions and descriptions of this table are as follows:

FIELD NAME	DATA TYPE	DESCRIPTION
ID	Number	Unique ID of site
Name	Text	Name of study site
XCoord	Number	X co-ordinate of point location
YCoord	Number	Y co-ordinate of point location
Region	Text	Region that study site is in
ViewHotlink	Text	Name of View which will be opened

Apart from the data record for Kumasi, all others in this table are hypothetical and have only been added to illustrate that other study sites may also be accessed through the same interface.

7. Directory Organisation

All the datasets, database tables, ArcView project files and scripts, and other PUDSI-related files are stored in special sub-directories beneath the level of PUDSHOME.

The user is recommended to set the following environment variables in his *autoexec.bat* file:

SET HOME = C:\TEMP
SET PUDSHOME = C:\JANE\PUDSI

The sub-directories beneath the level of PUDSHOME are as follows:

DIRECTORY NAME	DESCRIPTION
data	All spatial datasets are stored under *PUDSHOME\data*. These include topographic (*i.e.* ArcWorld, DCW, 1:50,000), and thematic vector datasets.
textdata	Text-delimited files (georeferenced or un-georeferenced)
admin	ArcView project file (*.apr), associated scripts, and the final report document.
database	Access database files used to store metadata relating to the PUDSI datasets.
supfiles	Includes a number of sub-directories to store the following files: legends, dataset description files, hotlinked features, and join files.

Data
Sub-directories used to store the different spatial datasets include: *arcw3*, *dcw*, *topo*, *bathdata*, *othervec* and *otherras*. There are currently no raster or image datasets stored in *PUDSHOME\data\otherras*.

Textdata
Sub-directories used to store the text files include *georef* (for georeferenced files) and *nogeoref* for the un-georeferenced files.

Admin
There are three separate sub-directories:

project Used to store the ArcView project file (*.apr). The PUDSI manager should always store a copy of this file in another directory location and on floppy disk in the event of the project file becoming corrupt.

scripts These *.ave files are copies of all the project scripts which are normally held internally within the .apr file.

report This is used to store the Word documents associated with the PUDSI final report.

Database
The name of the Access database containing the relevant tables for successful operation of PUDSI is *sites.mdb*. This database may be opened independently of PUDSI for further data design, creation of user input forms, or simply for data input and updating.

In order to do this, however, the user must not be running PUDSI at the same time as this introduces a conflict of access to the database.

The tables in this sites.mdb database include: Datasets, Vectors and Sites. These are described in more detail in section 6.

Supfiles
The sub-directories used to store the support files necessary for hotlinking, joining of attribute tables, display of data description files and display of legends include *hotlinks*, *joinfile*, *descfile* and *legends* respectively

Part Three

PUDSI Demonstration

8. PUDSI Demonstration

8.1 Introduction

This demonstration has been put together to enable someone with little or no ArcView experience to demonstrate the current capabilities of the PUDSI interface. However, the demonstrator is advised to first became familiar with ArcView by following the exercises shown in the ArcView Quick Start Guide.

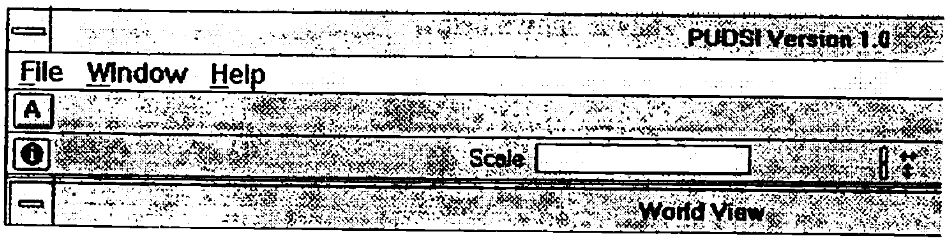
Note:
Any reference to PUDSHOME assumes the directory where the PUDSI data and system files are held *i.e.* c:\jane\pudsi.

8.2 World View

To start PUDSI, first click on the ArcView 2.1 icon in the ArcView program group. Select the "Open Project" option from the FILE menu and navigate to the directory where the Kumasi project file is stored. The project file, KUM1.APR, is held in *PUDSHOME\admin\project*.

This opens the World View. This shows generalised country boundaries overlain with the point locations of all the study sites which have been entered into the Access database. Kumasi is the only one which is relevant to this study.

The World View user interface is shown below:

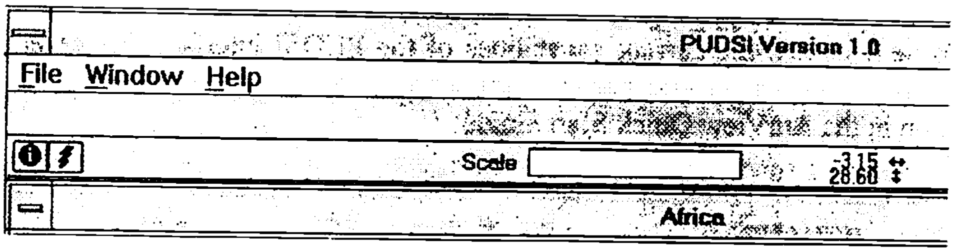


ArcView Identify tool which displays the attributes of a feature you click on with the mouse.
Make sure Study Sites theme is active and the Identify tool is enabled. Place the cursor over the Kumasi study site point and click the mouse. The attributes of this point are displayed in a window.

Press this button to zoom to the extent of the African continent.
Other buttons may be added here to zoom to other continents or regions.

8.3 Africa View

This View displays the generalised country boundaries overlain with the study sites, this time named individually in the legend. The user interface of this View is shown below:



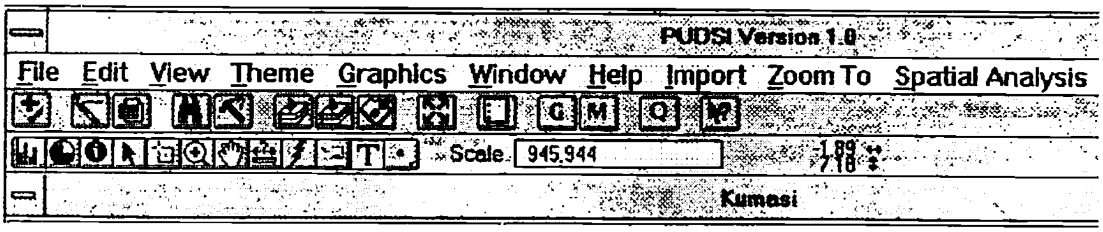
This is the hotlink tool which opens a View relating to the study site selected.

Make sure the Study Sites theme is active and the hotlink tool is enabled. Place the tip of the hotlink cursor over the centre of the Kumasi study site and click the mouse. This automatically opens the Kumasi View.

8.4 Kumasi View

When this View is opened the Digital Chart of the World (DCW) and 1:50,000 topographic data layers are automatically added as themes to the Table of Contents (TOC). The extent of the display is a circular area of radius 50km extending from the centre of Kumasi city.

The user interface for this Kumasi View is shown below:



Note:

- scale thresholds have been set for these topographic themes so, when Kumasi View is first opened, only the DCW layers are drawn;
- the scale of display is shown in a box to the right of the tool controls;
- as the cursor is moved around the display, the latitude and longitude co-ordinates (in decimal degrees) are displayed to the right of the scale box;
- default legends have already been loaded for the topographic themes but they are only made visible if the scale of display allows the theme to be drawn.

Zooming In and Out

This is the standard ArcView Zoom In tool. With the Zoom In tool enabled, click the mouse at one corner of the area you want to zoom to, then drag the cursor to the opposite corner, and release the mouse button. If you define a point you will be given a warning.

This button enables you to zoom back to the extent of the Kumasi district.

Zoom To
User Defined Rectangle

This menu item enables you to zoom to a rectangle whose lower left and top right co-ordinates are known in units of decimal degrees.

Zoom To
User Defined Point

This menu item enables you to zoom to a known location (again in units of decimal degrees) at a user-defined scale. The default location is Kumasi city (-1.62,6.69) at a scale of 1:100,000.

Demonstration

1. Starting at the extent of Kumasi district (*i.e.* when Kumasi View is first opened), select "User-Defined Rectangle" from the ZOOM TO menu.

Enter the following co-ordinates:

Enter Minimum x (decimal degrees): -1.75
Enter Minimum y (decimal degrees): 6.64
Enter Maximum x (decimal degrees): -1.49
Enter Maximum y (decimal degrees): 6.8

Confirm BL (bottom left) and TR (top right) co-ordinates.
You will then see the extent of your zoom area shaded on the View (you may have to move the message box in order to see it). Confirm zoom to this area.

The View zooms to this area, displays the new scale and automatically switches off the DCW layers (they have a minimum scale threshold set at 1:510,000) and switches on the 1:50,000 topographic layers. Notice that the legends of the DCW layers are now no longer visible while those of the 1:50,000 themes are.

2. To zoom back to the original extent of Kumasi, press the button denoted by: 

3. You may wish to zoom to a point location, say (-1.86,6.81) at a scale of 1:50,000. Select the "User Defined Point" item choice of the ZOOM TO menu.

Enter Scale: 50000

Xcoordinate: -1.86
Ycoordinate: 6.81

The point you have defined is displayed in red. Confirm whether you want to zoom to this point. The display zooms to this point at the desired scale, again taking into account scale dependencies.

Enabling/Disenabling Scale Thresholds
You have already seen that zooming in and out of the Kumasi View switches the topographic datasets on or off according to the scale thresholds which have been set. It is possible to disenable these thresholds so that the theme may be drawn *at any scale*.

Demonstration
1. Zoom back to the extent of Kumasi View.

2. Suppose you want to zoom to Kumasi city at scale 1:100,000 and display the DCW Elevation Levels theme (this would normally not be displayed at this scale).

Firstly, make the DCW Elevation Levels theme active.

Secondly, select the "Remove Thresholds" item choice from the THEME menu. Although nothing appears to happen the scale thresholds for this theme have been removed.

3. Using the "User Defined Point" option from the ZOOM TO menu, select all the default options.

You will notice that the DCW Elevation Levels theme has been drawn as well as the 1:50,000 topographic layers.

4. If you now wish to reset the scale thresholds for this theme, select the "Set Thresholds" item choice from the THEME menu. Note that this item choice changes according to whether the active theme has scale thresholds set or not.

You are then asked:
"Do you want to set a maximum scale threshold ?"
This is because no maximum scale threshold was previously set for this theme and so you are given the option of whether you wish to set one. Respond with N.

"Do you want to reset the minimum scale threshold to 510000 ?"
This time, because a minimum scale threshold had previously been set, you are given the option of whether you wish to reset it. Respond with Y.

You will notice that the View is redrawn without the DCW Elevation Levels theme being shown.

5. Another method of setting minimum and maximum scale thresholds is to use the standard ArcView "Properties" item choice from the THEME menu. Choose the Display icon on the left hand side and enter the appropriate thresholds.

Querying the Access Database for Vector Datasets Relevant to the Kumasi Study Site

So far only topographic themes have been added to Kumasi View. In order to load other vector or raster datasets it is necessary to first query the relevant tables in the associated Access database.

This button queries the Access database and retrieves the records of all the vector datasets which are relevant to Kumasi.

Demonstration

1. At the full extent of Kumasi View, press button 

This queries the Access tables and places all the relevant data records into a table document called "Vector Data Table". Note that if the database has already been queried during the current session then this table exists and is simply re-opened.

You are then asked to select datasets from this table which you want to add to Kumasi View. There are several standard ArcView methods for selecting data records (*i.e.* datasets) from this table.

2. *Selection Methods*

You may select individual data records with the mouse by simply clicking anywhere within that row. The data record is then highlighted in yellow. To select more than one data record, hold down the SHIFT key at the same time you click on that record with the mouse.

This button unselects all records in the table.

This selects all records in the table.

This toggles between the selected and unselected records in the table.

This finds the row in the table using a text string you enter.
This function will become very useful once the number of datasets retrieved from Access is larger and it is not possible to view them all at once in the table. For example, enter the text "soils" to select the Soils dataset for Kumasi. Note that this text search is not case sensitive.

This is the Query Builder which enables you to select data records using a logical expression.
For example, use this to select all datasets with feature class = "polygon".

This promotes selected rows to the top of the table.
It will become more useful once the number of data records retrieved from Access increases.

This button sorts rows in ascending order (A-Z), (0-9). The field to be used for sorting must first be made active by clicking on the name heading.

This button sorts rows in descending order.

3. If you need to access more fields for the data records then select the "Properties" item from the TABLE menu. You will notice that only three fields are currently set to visible: dat_longname (alias Dataset), dat_scale_res (alias Scale/Resolution), and vec_fctype (alias Feature Class Type).

Perhaps you need to know the data type. Click on the Visible field for dat_type then press OK. You will see that the records in Vector Data Table now have an additional field shown called Data Type.

4. Select the following datasets from Vector Data Table by simply clicking with the mouse while holding down the SHIFT key:

Soils
Kumasi Districts
Protected Areas in Kumasi Area

Once you have selected the datasets you are interested in, press button 
This adds the datasets as themes to Kumasi View.

Note:
- as themes are added to Kumasi View, they are automatically switched off and their legends set to invisible;
- they are placed in the TOC in the drawing order according to their feature type *i.e.* point themes are placed at the top of the TOC while polygon themes and images are placed at the bottom. This ensures that no point or line themes are obscured by polygon or images themes.

Importing Text Files with no GeoReferencing

If you have a text file which stores the attributes of features on a row by row basis, in text-delimited format, then you can import this file into a table document and optionally join it to the feature attribute table of an existing theme.

Demonstration

1. Select the "Text file (no georeferencing)" option choice from the IMPORT menu on the Kumasi View.

2. In the Add Table dialogue box, choose the text file called *villages.txt*. This is a text file with hypothetical demographic data for six villages. This creates and opens a table document called villages.txt.

3. When asked if you wish to join this file to a feature theme, respond Y. You are then asked a series of questions designed to gather all the necessary information required for the join operation to take place.

Select theme to join file to:
Select "DCW Villages" from the scrolling list of themes which are present in the TOC.

Select field to join file to:
Select "Ppptname" from the scrolling list of fields which exist in the DCW Villages theme.

Select field in text file to be used for the join:
Select "Village name" from the scrolling list of fields which exist in the villages.txt table document.

The join then takes place *i.e.* the villages.txt table is added to the feature attribute table of the DCW Villages theme using the village name as the join item. The table "Attributes of DCW Villages" is then opened.

4. Examine this table and notice that those records corresponding to the villages which were represented in *villages.txt* now have additional fields, starting at %water. These additional fields are the attributes which were present in the text-delimited file *villages.txt*.

5. Close this table document.

Importing Text Files with GeoReferencing

This option allows you create a point theme from a text-delimited file where records are stored on a row-by-row basis and two of the fields correspond to x and y co-ordinate information.

Demonstration

1. Select the "Text file (georeferenced)" option choice from the IMPORT menu on the Kumasi View.

2. In the Add Table dialogue box, choose the text file called *polldata.txt*. This file contains hypothetical water quality data for five sample locations along the DCW river network. A table document called polldata.txt is created and opened.

3. The Add Event Theme dialogue box appears.
Select the table polldata.txt from the scrolling list of table documents.
The X field and Y field fields are then automatically filled in, using Xcoord and Ycoord respectively. Click on OK.

You are then asked:
Do you wish to add comments to this new theme ?
Respond Yes, and add a line of comments to the input box, *e.g.* water quality data from polldata.txt.

A point theme called polldata.txt is then added to Kumasi View. It is switched on for drawing and the legend is set to visible.

Displaying a Dataset in Kumasi View which is not stored in the Access Database
The user may wish to display a dataset whose metadata have not yet been entered into the Access database. The standard ArcView Add Theme button enables the user to navigate to any directory location and select a dataset, either a feature data source (ARC/INFO coverage or shapefile) or an image data source (raster/image), for inserting into the View.

This button adds a theme to the View.

Retrieving Theme Comments
Comments for a theme may be retrieved by first, making that theme active, then selecting the "Get Comments" choice from the THEME menu. The theme comments are displayed in a message box. You will be informed if no comments exist for the theme.

Demonstration
1. Make the point theme, polldata.txt, active. This is the theme we created by importing the water quality data.

2. Choose the "Get Comments" choice from the THEME menu. Notice that the comments which you added to this theme while it was being created are displayed in a message box.

Note:
- comments may be added to any theme using the "Properties" item choice from the THEME menu. If they are added in this way then they will be retrieved using "Get Comments". However, the comments are only set for the lifetime of the current ArcView session.

Displaying Data Description and Data Processing History Text Files for a Theme

Once you have made a theme active, select the button denoted by M

This opens two text files relating to that theme: one is a Data Description text file while the other is a Data Processing History text file. These files are displayed in scrolling text windows.

Demonstration

1. Make the 1:50,000 Settlements (pts) theme active. Press button [M]

Notice that only the Data Processing History file is displayed. Although a name for the Data Description file (topo50.des) has been entered into the relevant field in the Access database, no such file has yet been created.

Hotlink Tool

Hotlinks may be set up for certain feature themes when they are added to Kumasi View. If hotlinks have been set up for a theme then the hotlink tool is enabled whenever that theme is made active.

Demonstration

1. Make the Soils theme active and notice that the hotlink tool is enabled.

2. Click the Soils theme on for drawing- note that nothing happens! This is because scale thresholds have already been set for this theme. These must first be removed using the "Remove Thresholds" item choice from the THEME menu. The Soils theme is then drawn on the View and the legend is set to visible. You may switch off some of the other themes if the display appears too cluttered.

3. Notice that the Soils legend is not very informative. What we have done is to set up hotlinks for each soil class so that when the user clicks on a soil class polygon with the hotlink tool, a text file describing the soil type in more detail is displayed in a popup window.

Make the hotlink tool active and place it anywhere over the soil class "Akumadan-Bekwai/Oda complex" on the View. A text file describing various different soil complexes is displayed in a popup window- this describes the Akumadan-Bekwai/Oda complex in more detail.

Displaying Side-by-Side Bar Symbols for Selected Features

This is a tool which has been taken from the Avenue Script Library. We will use it here to show the source of water pollution for the five sample sites which we imported as a text file (polldata.txt) and used to create a point theme.

Demonstration

1. First, switch off the DCW Villages theme to minimise the detail shown on the View.

2. Make the polldata.txt theme active then select the Bar Symbol tool.

Choose the following options:
Bar size: medium
Draw gridlines on the bars? Yes
Select the following fields and corresponding colours:
%domestic gold
%industrial gray

%agricultural green
Then press "Cancel".

Five bar charts are displayed, one for each sample site. These bar charts are positioned directly above the point corresponding to each sample site. They show the % composition of each type of water pollution. Note that these data are purely hypothetical.

Deleting Graphics from the View [G]

All graphics added to a View may be deleted using the button denoted by [G]
For example, to delete the bar symbols which were added to the View in the previous exercise press this button.

Spatial Analysis

We have added a menu called SPATIAL ANALYSIS to the Kumasi View which enables you to spatially relate point features to the selected features of another theme. You may then create a shapefile from these selected point features and add this to the View. Finally, you may export the tabular data of this new theme to a file or database.

Demonstration

Example: Select all the DCW villages which fall within the 1000-3000ft elevation level and add these as a new theme to the TOC of Kumasi View. Export the data in the point attribute table to a text-delimited file.

1. *First, select the 1000-3000ft elevation level polygons from the DCW Elevation Levels theme.*
Make the DCW Elevation Levels theme active.

Use the Query Builder button and enter a logical expression which selects all polygons which fall within the 1000-3000ft level. The logical expression you enter should be as follows: ([Hypytype] = 3). Then select the New Set button. This automatically highlights (in yellow) all the polygons of the elevation theme which satisfy the criteria you have just entered. Close the Query Builder dialogue box.

2. Make the theme active whose points you wish to spatially relate to the selected polygons of the elevation theme. In this case, make the DCW Villages theme active.

3. Select the "Select POINTS relative to another theme" choice from the SPATIAL ANALYSIS menu. You are first asked if you have selected those features from the theme you wish to relate the points to. In this case you have, so respond Yes.

The "Select by Theme" dialogue box then appears. Choose the following options from the scrolling lists.

Select features of active themes that
Are Completely Within
the selected features of

DCW Elevation Levels

Remember to select the theme (*i.e.* DCW Elevation Levels) first as, depending on what type of theme it is (*i.e.* point, line, polygon) the options for the spatial relate change. For example, if you select a line theme such as DCW Railways then the option "Are Within Distance of" is made available and another input box appears for the user to add a buffer distance.

Press the New Set option. This selects all the DCW villages which fall within the 1000-3000ft elevation level. It may be difficult to see these as the elevation polygons are still highlighted in yellow. Unselect all the selected elevation polygons by first, making the DWC Elevation Levels theme active then pressing the unselect button . You can now see the selected DCW villages highlighted in yellow.

4. You now want to convert the selected DCW villages to a shapefile and add them as a theme to the TOC of the View.

Ensure that the DCW Villages theme is active and select the "Convert to ShapeFile/Add to View" option from the SPATIAL ANALYSIS menu.

You are first asked the name of the output shapefile, the default being theme(x).shp. It is automatically placed in the user's temp directory. You may change the name to something more relevant such as highvill.shp. The name you enter here will appear as the new theme's title in the TOC.

You are then asked if you wish to add comments to this new theme. Respond with Yes and add: *DCW villages which fall within the 1000-3000ft elevation level.* These comments will be retrieved when the user selects the "Get Comments" option from the THEME menu.

The new shapefile is then added to the TOC of Kumasi View. It is made active and switched on for drawing.

5. You now wish to export the tabular data for this new point theme, perhaps to input to a spreadsheet for further analysis. Select the "Export Tabular Data" item from the SPATIAL ANALYSIS menu.

The feature attribute table of the new shapefile, "Attributes of Highvill.shp" is opened. You are then asked if you wish to store the x and y co-ordinates of the points in the table for exporting. Respond with Y. As the x, y co-ordinates of the point features (*i.e.* the latitude, longitude co-ordinates of the villages) are not explicitly stored in the table they must first be generated from the shape object for each record.

You are then asked to select an Export Format for the output file. Choose Delimited Text.

The export file is automatically placed in the user's temp directory with a default name which may be easily changed. This delimited text file contains all the attributes from the new point shapefile, including the x and y co-ordinate data.

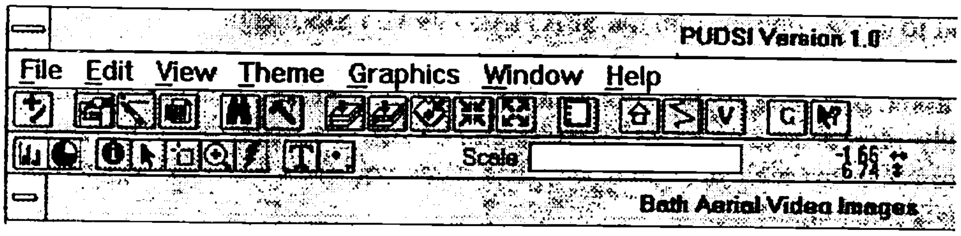
6. The operation is now complete. Close the attribute table.

8.5 Bath Aerial Video Images View

This View is accessed by selecting the "Bath High Resolution Data" option from the ZOOM TO menu of Kumasi View. This basically zooms to an area immediately surrounding Kumasi city and displays the following themes:

- 1:50,000 Roads, coded according to road type;
- 1:50,000 Railways;
- 1:50,000 Urban Areas (polygons); and
- the location of the Bath High Resolution Images, shown as image outlines.

The user interface for the Bath Aerial Video Images View is shown below:



Examining the Bath Image Attributes

The Bath images represent a N-S transect to the SE of Kumasi city. The Bath High Resolution Images theme is in fact a polygon theme with only the outlines of the images displayed. There are several attributes associated with each image and these can be accessed by opening the feature attribute table for this theme.

Demonstration

1. Make the Bath High Resolution Images theme active then select the Open Table button. This opens the feature attribute table and displays the attributes for each image.

Labelling the Bath Images

It may be beneficial to label the Bath image polygons using a field from the feature attribute table. This may be done using the "Label Image Sites" option of the THEME menu.

Demonstration

1. Use the Zoom In tool to zoom into the top six image sites (*i.e.* those closest to Kumasi city).

2. Select the "Label Image Sites" option of the THEME menu. You are then asked to select the field from a scrolling list. Choose the field called Filename. Press OK. This then adds the value for Filename to the centre of each of the image polygons. These

file names relate to the name of the associated TIFF file which would be displayed if the hotlink tool was activated for that particular image.

3. As these text labels are added to the View as individual graphics they may be selected and modified by the user. More information on manipulating graphics may be found in the ArcView user manual.

For example, if you wanted to select and move one of the labels, say LIRB31.TIF, then you would first activate the Select Shapes or Graphics tool. Click on the text label and you will notice the selection handles at each corner of the graphic. You can either move or resize the graphic or, using the "Properties" item of the GRAPHICS menu, change the text properties.

Try selecting all the text labels, grouping them together as one graphic element, then moving them so that all labels are positioned to the right of the images. This is done using "Select All Graphics" from the EDIT menu, then "Group" from the GRAPHICS menu. You can now use the Select tool to select this one graphic element and move it to the right.

Displaying the Hotlinked TIFF Files associated with the Bath Images

While you are still zoomed in to the top six images and the name of the associated TIFF file is shown as a text label to the right of each image, activate the hotlink tool and use it to display a few TIFF files.

Demonstration

1. Activate the hotlink tool and place it over the centre of one of the image polygons, say LIRB31.TIF. The TIFF file is displayed as an image theme in a separate View.

2. You can continue doing this for as many images as you wish. For the purpose of this demonstration, activate only one more, LIRB26.TIF. You will need to move and resize these TIFF windows around the display in order to view them both at the same time.

Adding the Image Interpretation Layers to the View

Bath College has digitised features from these high resolution images using the MapInfo GIS package. Three separate layers of interpretation exist: Buildings, Vegetation and Linear Features (roads, railways, rivers). These layers exist as shapefiles and may be imported to the View using a series of buttons.

This button imports the Buildings layer as a polygon shapefile. A legend has already been set up for display although you may change this at any time.

S *This button imports the Linear Features layer as a line shapefile.*

V *This button imports the Vegetation layer as a polygon shapefile.*

Demonstration

1. Use the appropriate buttons to import all the digitised layers as described above. Switch on the following themes: HR Sites: Vegetation and HR Sites: Buildings. You will notice that the interpretations are shown inside the image boxes.

2. Zoom into LIRB29.TIF and LIRB30.TIF using the Zoom In tool. You will notice that the image labels added previously are now too large for the display. Delete these using the Delete Graphics button then add the labels again. Select only the labels for the two image sites you are interested in (using the Select Graphics tool) and group them together. Now move this one graphic object so that the labels appear to the right of the images again. This time the labels are more appropriately sized.

3. Switch on the HR Sites: Linear Features theme.

4. Display the TIFF image for LIRB30 by activating the hotlink tool. Move the TIFF window until you can see the image and interpretations at the same time.

Creating a Chart for LIRB30.TIF and LIRB29.TIF

We are now going to create two pie charts, one for each image, showing the % of land occupied by buildings and vegetation.

Demonstration

1. With the Bath High Resolution Images theme active, open the attribute table using the Open Table button .

2. Select the two data records corresponding to images LIRB29.TIF and LIRB30.TIF. These are now highlighted in yellow.

3. Select the "Chart" option from the TABLE menu. The Chart Properties dialogue box appears.
Select the following fields from the scrolling list on the left: Veg_area and Bldg_area. After each selection, press the Add button to add the field to the list on the right hand side.

Label Series Using: FileName

Press OK. This creates a default histogram chart comparing vegetation area and buildings area for each site. You can change the chart properties in a number of different ways.

4. *Editing the Chart*

In order to show the building and vegetation areas in the form of a pie chart, one for each image, perform the following operations:

- select the pie-chart button ; and
- select the Toggle Series from Records/Series from Fields button .

You may then change the chart elements *e.g.* legend, title, *etc.* by using the Change Chart Element Properties tool. If the default colours used in the pie-chart are not satisfactory, change them using the Change Chart Element Color tool.

Please refer to the ArcView manual and on-line help for more information on creating and editing charts.

Other Controls on the Interface

Use this button to add any other datasets to the View.

Zooms back to the original extent of the Bath Aerial Video Images View.

Zooms in to the centre of the display.

Zooms out from the centre of the display. This is useful if you do not want to zoom right out to the full extent of the View.

Deletes all graphics from the View.

Creates side-by-side bar symbols for selected features.

Creates pie-style spot symbols for selected polygon features.

Creating Pie-Style Spot Symbols for Selected Polygon Features

This script has been taken from the Avenue Script Library. Here we will use it to show the areas of vegetation and buildings but this time only for two sites.

Demonstration

1. First, zoom back to the extent of the Bath Aerial Images View. Use the Zoom In tool to zoom in on the 7th and 8th images from the top of the series.

2. Use the Select Features tool to select these two sites by enclosing them with a box.

3. Activate the Pie-Chart tool.

You are first asked to enter two circles representing the minimum and maximum spot sizes. Do this on the screen.

Then select the field and corresponding colour:

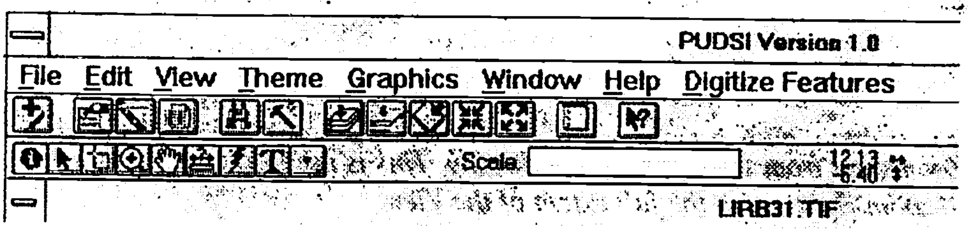
Veg_area green
Bldg_area gray

A legend and two pie charts are displayed, one in the centre of each of the selected images. Again, you can select and manipulate the individual graphic elements to create a more pleasing display.

8.6 TIFF Views

These are activated by selecting the hotlink tool on the Bath Aerial Video Images View and pointing to one of the 18 image polygons. The TIFF file of the corresponding high resolution image is then displayed as an image theme in a View. Unfortunately, the TIFF files are not yet geo-referenced so it is currently not possible to insert other themes into the View for overlaying and comparison.

The user interface for these TIFF Views is shown below:



Digitising Features from the Image

We have added a menu called DIGITIZE FEATURES which enables you to interpret point, line or polygon features from the image. These features are converted to a shapefile. You may then add more fields to the attribute table of this new shapefile and add data to these fields.

Demonstration

1. Create a new shapefile using the "Create New Theme" option from the DIGITIZE FEATURES menu.

Select the feature type, in this case POLYGON.

A new shapefile is created in the user's temp directory. It is given a default name but this and the directory location may be changed by the user. The new polygon shapefile is added to the TOC of the View. Notice how its tick box is surrounded by a dotted line- this means that the shapefile is editable.

2. Select the polygon shape tool and begin to digitise around the boundaries of a few buildings. Click the mouse on each polygon vertex and on the last vertex double-click to close the polygon. There is no need to return to the start point of the polygon.

3. When you have finished digitising the features you are ready to add new fields to the attribute table. Select the "Add Fields" option from the DIGITIZE FEATURES menu. The attribute table of the new shapefile is opened- notice that there is only one field called Shape.

You are first asked how many fields you wish to add. Respond with 2.