

Design and Implementation of Soil Spatial Variation Analysis System

GAO LINGLING, ZHANG RONGQUN*, ZHAO MING, YUAN HUI, CAI SIMIN

Department of Geographic information engineering, College of information and Electrical Engineering

College of Information and Electrical Engineering

China Agricultural University

Tsinghua East Road No. 17, Beijing, 100083, China

pretty-gao@foxmail.com *Corresponding Author: zhangrq@cau.edu.cn

Abstract: - The advantages of traditional integrated GIS(Geographic Information System) are integrate each component of GIS and form independent complete system, for example ArcGIS and MapGIS, but the system is complex, huge, difficult to install, leads to high cost and difficulty in integrate with other applications or system and so on. Component GIS that meet various professional needs not only can carry on reorganization freely and nimbly between each module, but also has a visualization interface and easy-to-use standard interfaces. Spatial variation research mainly has traditional statistics analysis and geostatistics. The advantage of geostatistics is not only consider the value of the sample size, but also pay attention to sample space position and its distance, that make up for the defect of traditional statistics analysis that ignore spatial position. Geostatistics has not been integrated with GIS is a severe flaw of GIS. So, we develop a light-duty Soil Spatial Variation Analysis System use VS 2005 in the support of ArcGIS Engine combined present needs. The article introduces the system's design ideas, the major function modules, the development and implementing; and use HeBei province Handan County soil data to do system test. The result shows that the system has a good operation efficiency and accuracy to meet the general soil spatial variation analysis need.

Key-Words: - Spatial gridding methods; Geostatistics; Soil Spatial variation analysis; Components development; ArcGIS Engine

1 Introduction

Soil spatial variation research mainly has traditional statistics analysis and geostatistics. Many of the soil characteristics is not independent in space and not belongs to pure random variables, but exist spatial correlation a certain range. This attribute is due to the continuity of soil forming process, the gradation of climatic and so on. The found of correlation of soil characteristics questions the applicable scope of traditional Fisher statistical principle. Scientists must explore new method to quantitative analysis soil spatial variation characteristics. Since the 1960's, especially after the 1980's, people pay more attention to the study of soil spatial variation characteristics. Gradually mature geostatistics can quantitative analysis the soil spatial variation characteristics and make soil variation evaluation become formulate soil sampling solutions and indicates the not sampling points a new approach or basic step. Study soil spatial variation characteristics base the geostatistics can provide effective approach for determined sampling dimension rationally and the soil sample number, the prediction or simulation of soil process closer to the actual situation of agricultural soil changes.

Geostatistics is a new branch of statistics also known as geological statistics, the French

well-known statistician G. Matheron proposes it first through substantial theoretical research. Geostatistics could not integrate with GIS analysis model well long time. New version of the current commercial GIS include statistical analysis module, because of the high cost, complex installation, too large memory space and other factors, its application is limited. ArcGIS Engine (referred to as AE) is the bridge between Geostatistics and GIS, making the complex geostatistics to achieve well. Therefore, we use C # develop the system to meet the need of the soil spatial variation job.

2 System Development Environment and Development Model

2.1 AE Technology

The basic thought of Com GIS is divide each big function module of GIS into some controls, each control complete different function of GIS, between every GIS control, and between GIS control and other controls, can integrate conveniently by the visual software development tools, and then forms the ultimate GIS application. The controls as a heap of various blocks, them realize different function of GIS (include GIS function and others), assemble them according to the needs, and then form the application system. It is based on technologies which

contain COM (Component object model) and ActiveX.

Major international commercial component GIS software are ArcObjects (referred to as AO), MapObjects, ArcGIS Engine that all of them are developed by ESRI. Compared with the AO, MapObjects has fewer interfaces but provides common GIS functions, even the dynamic characteristics of GPS, and its structure is rational, and easy to understand, but it is only meet the user who need result inquiry, searching, graphical display and easy Edit functions only. AO is a heavyweight platform, owns more than 1800 components, is the most powerful, most components, has the most complex structure. AE is a independent components package based on AO, its function are basically the same with AO, through reintegration and expansion, it do not bundled with ArcGIS Desktop, provides running version and development version, suitable for advanced development. The programmer can install development AE kits on their computers, works in their familiar programming languages and development environments. AE embedded GIS function in the application through add controls, tools, menu bar and objects to the development environment.

2.2 Visual .NET Integrated Development Environment

Visual C # .NET is created based on the powerful C ++ tradition language. C # is a powerful, intuitionist, object-oriented programming language, which not only allows C ++ and Java developers familiar with it right away, but also provides important improvements, includes a unified type system, to maximize the developer-controlled "non - security " code as well as most developers easier to understand powerful new language structure. Visual.NET provides a convenient, fast, friendly, powerful toolbox; improve the efficiency of system development greatly.

2.3 Development Method

Common GIS basically development patterns are independent development, simple second development, integration secondary development. The independent development does not rely on any tool software, from the spatial data gathering, editing to data processing and analysis and results showing, all algorithms are designed independent by developers, then choose a programming language, such as using VB, c ++, Delphi, etc, implement on certain operating system platform. The advantage of this approach is it does not dependent on any commercial GIS tool software, reduce the cost, But for most developers, ability, time, and financial

aspects limit it, the function of its product is weak than commercialization GIS software, and not so such developers rack brains in the development process as saves money on purchase tool GIS tool software.

Simple second development refers to use development language which GIS tool software provides to complete application system development. Most GIS software tools provide users the secondary development macro language. For examples, ArcView of ESRI provides Avenue language; MapInfo Professional of MapInfo provides MapBasic language etc. Users can use these macros language to develop their own application object according to different applications base the GIS tool software development platform .This pattern is convenient, but the function of the macro language is weak as a programming language used to develop applications.

Integrated secondary development realize the basic function of GIS using the professional GIS tool software, such as ArcView, MapInfo, etc, and then integrate them based on software development tools, especially the visualization development tools. There are two methods, one is OLE/DDE, and the other is COMGIS. OLE/DDE develop the front executable program using software development tools, start up GIS tools run in daemon base on OLE automation or DDE, using callbacks technique gain the return information dynamically, then realize the GIS application, but it is difficult to realize.

Independent development is much more difficult, simple secondary development is limited by the programming language that GIS tools supplied, and the effect is not good enough, so, integrated secondary development that combine GIS and today's visual programming language become the mainstream approach of the GIS applications development. It can take full advantage of management and analysis spatial data of GIS tools, but also can make use of highly efficient and convenient programming advantages of other visual language, not only can improve the development efficiency of application system greatly, and has a better appearance, more powerful database functionality, reliability, easy to transplant, easy to maintain. This study uses the second method of integrated secondary development. Inset GIS function into C# applications directly base AE, then complete all of the function of the system.

3 System Design and Implementation

3.1 System Design

Overall goal is to build an all-purpose spatial variation analysis system, its design follow following principles: user-friendly, prototype model, advanced and practicality, openness and scalability. System design method is from the next and the next modular and structured.

3.2 System Function

Fig1 is the System function and achieve procedure, the drawing is optional, classification color the gray level showing results, enhance the visual effect, make it more clearly and easy to analysis

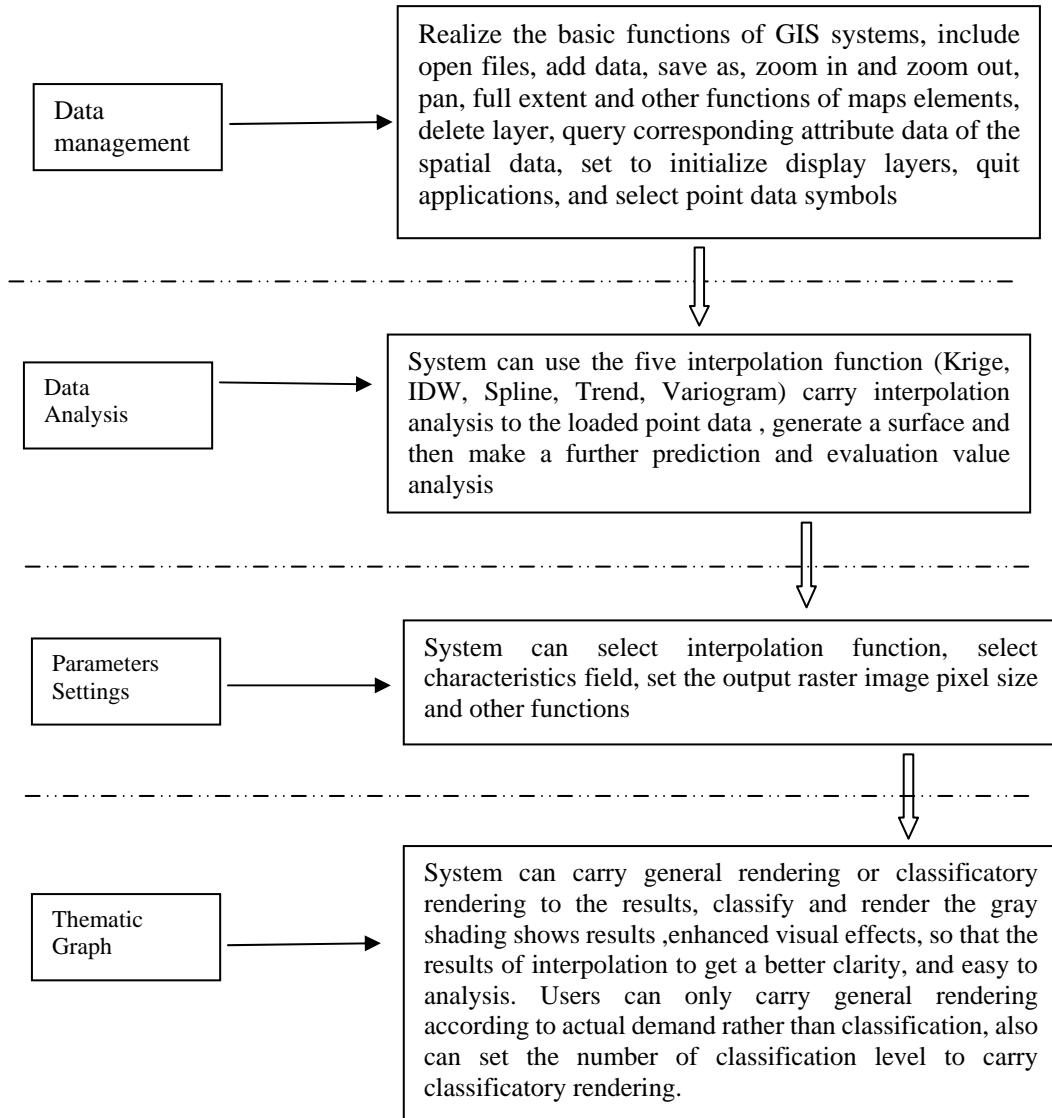


Fig1. System Function and Achieve Procedure

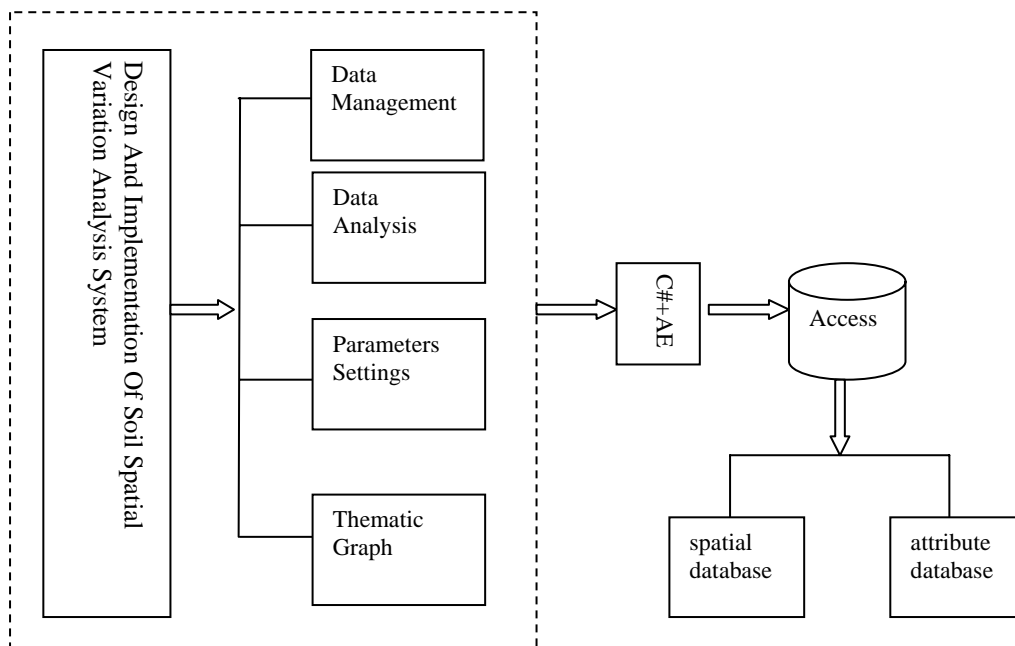


Fig2.System Structure

3.3 System implementation

3.3.1 Implementation Method

First, load ArcGIS controls and other AE component libraries in the Visual.net operating environment. In the Project "menu, select six function include 'Add Reference', then select 'ESRI.ArcGIS.Carto', 'ESRI.ArcGIS.Display', 'ESRI.ArcGIS.Geometry', 'ESRI.ArcGIS.System', 'ESRI.ArcGIS.SystemUI', 'ESRI.ArcGIS.Utility' in the verification dialog tabs, click on the 'OK' then complete the loading of AE component libraries.

Define a new kit named 'AE ', then choose controls according to user need in custom toolbox, and then the controls will be displayed on the control toolbox. The default page of Visual.net environment is page design, can select the control from toolbox directly, and the system will generates code automatically. The interaction between traditional GIS software and users or second developers is usually realized through the menu or toolbar buttons. The interaction between ComGIS and clients or users is usually realized through properties, methods and events.

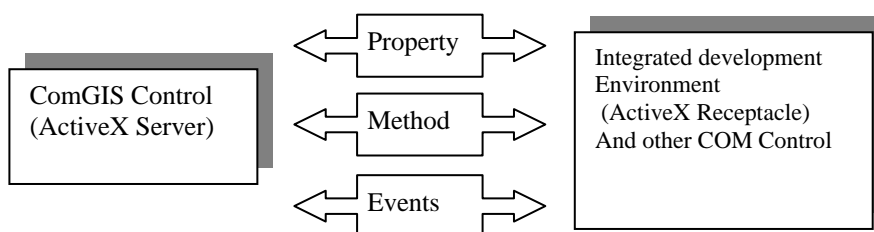


Fig3. Relationship between ComGIS, Integrated Development Environment and Other Eomponents

Property is the data which describe the characteristic of control or object, such as background is the back color of map; GPSIcon is the icon for GPS dynamic target tracking display, etc. Designate the property values can change the attributes of control and object. Property usually corresponds to a variable in the internal control.

Method is the action of object, such as show, AddLayer, open, close and so on. Control can execute these actions by call these methods. Method usually corresponds to a function in the internal control.

Events are the response of object. When object execute some actions may trigger an event, it is can be before execute actions, also can be in the process

of action or after the completion of the action, then it is easy to make client response to the events. For example: Control execute selected events(ItemPicked) when use the mouse to click the map and choose a map elements, then inform client program that some elements map are selected, and return parameters of the information which describe the number of selected objects and its map.

Properties, methods and events are the general standard interface of the control, and it is can be language development of any ActiveX container, its commonality is strong.

3.3.2 Specific Implementation

Visual ActiveX Control of AE provides data management capabilities. First of all add ToolBarControl, through the Item attribute to add the basic required functions of the system, such as load geographic layers, zoom in, zoom out, pan, full extent and so on. Add TocControl, MapControl control, and set the buddy attribute of ToolBarControl and TocControl, that it bundled with MapControl, user clicks on the view or drag the map can change the display scope of the map. Through setting the Anchor attribute of MapControl, makes the running size is always match window.

Key codes:

```
private void Form1_Load(object sender, EventArgs e)
{
    comboBox2.Items.AddRange(new object[]
    {1, 5, 10, 30, 50, 100, 200, 500});
    comboBox5.Items.AddRange(new object[] { 3, 5, 7, 9, 10, 12, 15, 20, 50, 100 });
    comboBox6.Items.AddRange(new object[]
    { "IDW", "Kriging", "Spline", "Trend", "Variogram" });
    m_tocControl =
    (ESRI.ArcGIS.Controls.ITOCControl2)axTOCControl1.Object;
    m_mapControl =
    (IMapControl3)axMapControl1.Object;
    m_tocControl.SetBuddyControl(m_mapControl);
    axToolBarControl1.SetBuddyControl(m_mapControl);
    //Add pre-defined control commands to the
    ToolbarControl
    axToolBarControl1.AddItem("esriControls.Controls.SelectFeatures
    Tool", -1, 0, false, 0,
```

```
esriCommandStyles.esriCommandStyleIconOnly);
axToolBarControl1.AddToolBarDef
("esriControls.Controls.MapNavigationToolbar", 0, false, 0,
esriCommandStyles.esriCommandStyleIconOnly);
```

```
axToolBarControl1.AddItem("esriControls.Controls.OpenDocCommand", -1, 0, false, 0,
esriCommandStyles.esriCommandStyleIconOnly);
```

```
m_menuLayer = new
ESRI.ArcGIS.Controls.ToolbarMenuClass();
m_menuLayer.AddItem(new
RemoveLayer(), -1, 0, false,
esriCommandStyles.esriCommandStyleTextOnly);
m_menuLayer.AddItem(new
DisplayAttribute(), -1, 1, false,
esriCommandStyles.esriCommandStyleTextOnly);
m_menuLayer.SetHook(m_mapControl); }
```

System runs connect spatial database when load data, we develop three classes include connect attribute data of the corresponding spatial data, delete the current layer and symbols selector, user can achieve the operation through the main program invoke the corresponding class.

The core of the system is data analysis module, that is IRasterAnalysisEnvironment interface definitional five methods (Kriging, IDW, Spline, Trend, Variogram), the user can run the drop-down box to select the appropriate method in accordance with actual situation. Every method has its parameter. The five methods share the first parameter, its meaning is put IFeatureClassDescriptor type definitional variable that pfdc forced into Geodatabase type, it provide the characteristics field of the current activity layer; the second parameter is different optional meanings of each method.

Key codes:

```
private void
button3_Click(object sender,
EventArgs e)
{
    IFeatureLayer pPlayer
    =
    (IFeatureLayer)axMapControl1.get
    Layer(0);
    IFeatureClass
    pFclass = pPlayer.FeatureClass;
```

```

IFeatureClassDescriptor pfdc =
new
FeatureClassDescriptorClass();
    IQueryFilter
pQueryFilter = new
QueryFilterClass();
    pfdc.Create(pFclass,
null, comboBox1.Text);
    IInterpolationOp
pinterp = new
RasterInterpolationOpClass();
IRasterAnalysisEnvironment penv
=
(IRasterAnalysisEnvironment)pin
terp;
    object dcellsize =
Convert.ToInt32(comboBox2.Text);
penv.SetCellSize(esriRasterEnvS
ettingEnum.esriRasterEnvValue,
ref dcellsize);
    IRasterRadius
pradius = new
RasterRadiusClass();
    object maxDistance = 0;
pradius.SetVariable(6, ref
maxDistance);
    object Missing =
Type.Missing;
    switch
(comboBox6.Text)
    {
        .....
        case "Krigé":
            IRaster poutraster2 =
(IRaster)pinterp.Krige((ESRI.Ar
cGIS.Geodatabase.IGeoDataset)pfc,
esriGeoAnalysisSemiVariogramEnu
m.esriGeoAnalysisCircularSemiVa
riogram, pradius, false, ref
Missing);
            IRasterLayer poutraslayer2;
poutraslayer2 = new
RasterLayerClass();
poutraslayer2.CreateFromRaster(
poutraster2);
axMapControll1.AddLayer(poutrasl
ayer2);
axMapControll1.Update();
axMapControll1.Refresh();
break; .....
        default: break;    }    }

```

The productions of thematic maps provide general color rendering and classificatory rendering function,

so that the analysis results are clearer. General rendering achieves by IRasterLayer, IRasterStretchColorRampRenderer, IRasterRenderer, IAlgorithmicColorRamp interfaces.

Key codes:

```

private void
button1_Click(object sender,
EventArgs e)
    {
        .....
        IRaster pRaster =
(IRaster)pRlayer.Raster;
IRasterStretchColorRampRenderer
pStretchRen = new
RasterStretchColorRampRenderer(
);
        IRasterRenderer pRasRen
= (IRasterRenderer)pStretchRen;
        pRasRen.Raster = pRaster;
        pRasRen.Update();
        IColor pFromColor =
new RgbColorClass();
pFromColor.RGB=Color.AntiqueWhi
te.ToArgb();
        IColor pToColor = new
RgbColorClass();
        pToColor.RGB =
Color.Blue.ToArgb();
IAlgorithmicColorRamp pRamp = new
AlgorithmicColorRampClass();
        pRamp.Size = 255;
        pRamp.FromColor = pFromColor;
        pRamp.ToColor = pToColor;
        bool myBool;
pRamp.CreateRamp(out myBool);
pStretchRen.BandIndex = 0;
pStretchRen.ColorRamp = pRamp;
        pRasRen.Update();
        pRlayer.Renderer =
(IRasterRenderer)pStretchRen;
        .....    }

```

Classification rendering achieves by IRasterLayer, IRasterClassifyColorRampRenderer, IAlgorithmicColorRamp, IRasterRenderer, IFillSymbol interfaces, and user can select the classification number through the drop-down box. Method's core is setting the colorRamp attribute of IRasterStretchColorRampRenderer or IRasterClassifyColorRampRenderer then assigned it to the renderer attribute of current layer (IRasterLayer) to achieve rendering.

Key codes:

```

private void
button2_Click(object sender,
EventArgs e)

```

```

        { IRasterLayer pRLayer
=
    (IRasterLayer)axMapControl1.get
    _Layer(0);
        IRaster pRaster =
    (IRaster)pRLayer.Raster;
    IRasterClassifyColorRampRendere
    r pClassRen = new
    RasterClassifyColorRampRendere
    rClass();
        IRasterRenderer
    pRasRen =
    (IRasterRenderer)pClassRen;
        pRasRen.Raster =
    pRaster;
    pClassRen.ClassCount =
    Convert.ToInt32(comboBox5.Text)
    ; ;
        pRasRen.Update();
    IAlgorithmicColorRamp pRamp = new
    AlgorithmicColorRampClass();
        pRamp.Size =
    Convert.ToInt32(comboBox5.Text)
    ; ;
        bool myBool = true;
    pRamp.CreateRamp(out myBool);
        IFillSymbol pFSymbol
    = new SimpleFillSymbolClass();
        int i;
        for (i = 0; i <
    pClassRen.ClassCount; i++)
        { pFSymbol.Color =
    pRamp.get_Color(i);
    pClassRen.set_Symbol(i,
    (ISymbol)pFSymbol);
    pClassRen.set_Label(i, "class" +
    " " + i.ToString()); }
        pRasRen.Update();
        pRLayer.Renderer =
    (IRasterRenderer)pClassRen;
        ..... }
    
```

4 System Application

4.1 Application Introduction

System integrates five methods used for spatial variation analysis, covers the classical theory algorithms of geostatistics, the software is easy to operation, user-friendly, results intuitive, has good usability.

The core of geostatistics is choosing appropriate spatial interpolation method to create surface according to analysis the sampling data and study the geographical features of sampling area. This system

provides five interpolation methods include Krige, IDW, Spline, Trend, Variogram. Krige and Variogram belong to geostatistics, the others belong to traditional statistics.

1) IDW is a linear interpolation method that determine the weight according to the distance of sample points to the interpolation points. The formula is:

$$Z = \frac{\sum_{i=1}^n \frac{Z_i}{d_i^2}}{\sum_{i=1}^n \frac{1}{d_i^2}}$$

N is the number of samples, z_i is the value of sample point i , d_i is the distance of sample point i to interpolation point; z is the value that wait to be estimated. The weight is 1 when the sample point is the same with the interpolation point, if not it is 0. When estimate the weight consider the distance of the sample points to the unknown point only. And its the interpolation point is the same with the point, belong to precision interpolation.

2) Krige is similar to IDW; they both gain the value of unknown point by the weight of sample point. Which is different is that, when Krige estimate the weight consider not only the distance but also the spatial distribution of the sample point and the space location relation with unknown sample points through variation functions and structure analysis. Krige belong to non precision interpolation.

3) Spline is an interpolation method which developed from engineering practice, cubic B-spline interpolation is used widely for its high precision. It use piecewise low quadric polynomial function to approach the surface, usually use polynomial function that low than cubic polynomial, and ensure the second derivative of the interpolation function of sample point is continuous at the same time, then give corresponding spline function according to the different boundary conditions. Surface through the sample points strictly and it is suitable for smooth surface interpolation.

4) Trend analysis just fitting from the trend, it is a smooth function strictly speak. Trend surface does not through the original data points generally. Another important characteristic is that it can reveal the biggest parts different from the whole trend. It is so important that there are many man-made factors and inhuman factors in the processing of sampling in practice, so we can find the antipathetic information from the whole information through the trend analysis, then eliminate it according to certain standards, and then gain the best result through analyses.

5) Variogram and Krige both use Kriging method to realize spatial interpolation, the difference is half variance function of Krige use the default parameters, but that of Variogram can be set.

4.2 Examples of Application

We analyze the soil nutrient data of Hebei Handan use Trend interpolation analysis (Fig7 , 8), characterized field is Total_K. We can see the entire Handan total soil K content from the chart, the

maximum value is 31.0628, the minimum value is 11.1926, and extreme difference is 19.8702. The center region has the highest K content, the lowest is in the Northeast, and the general trend is reducing from west to east. Compare to the integrated GIS spatial variation analysis module, the results of the analysis show that the system redundancy small, fast, reaching the same results, and simple operation, easy to understand and installation.

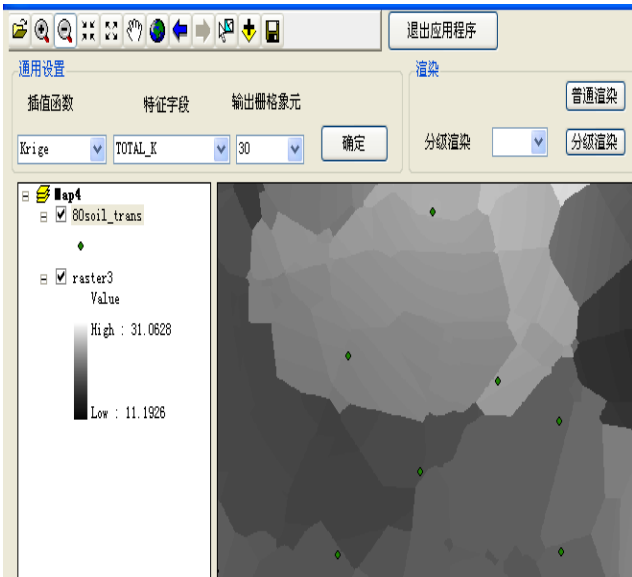


Fig4. Krige Interpolation

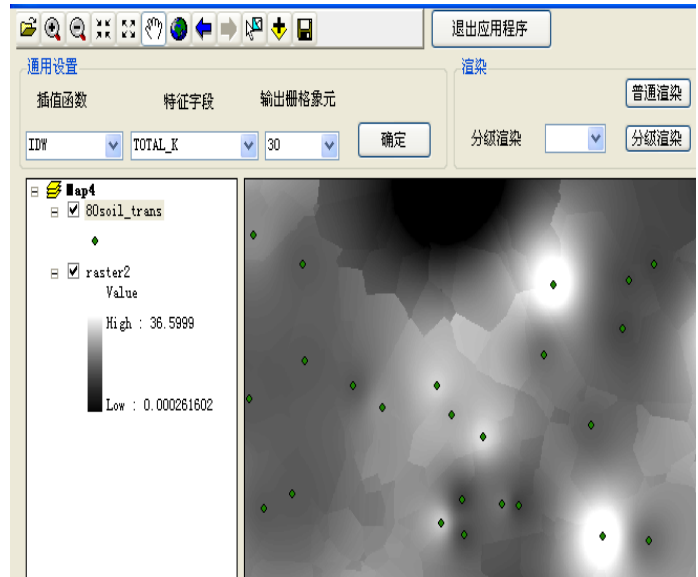


Fig5. IDW interpolation

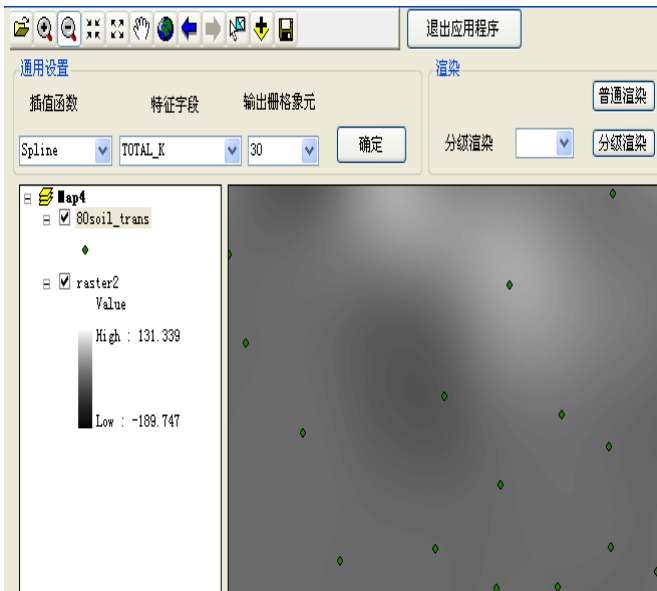


Fig6. Spline Interpolation

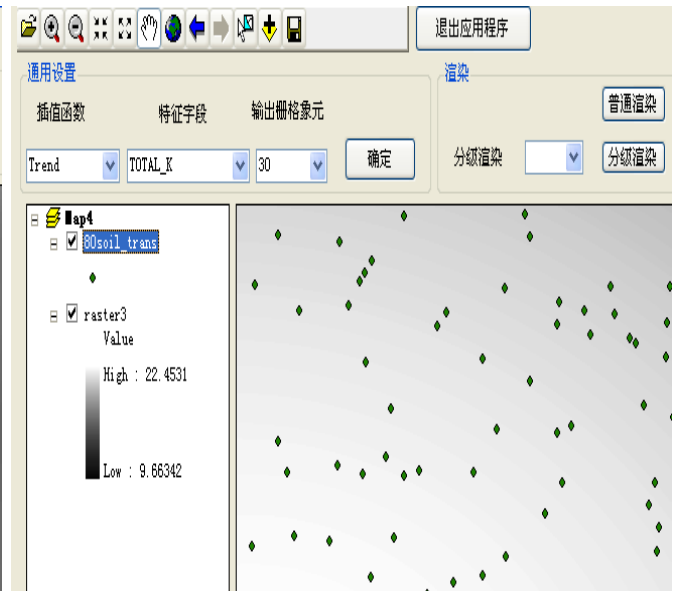


Fig7. Trend Interpolation

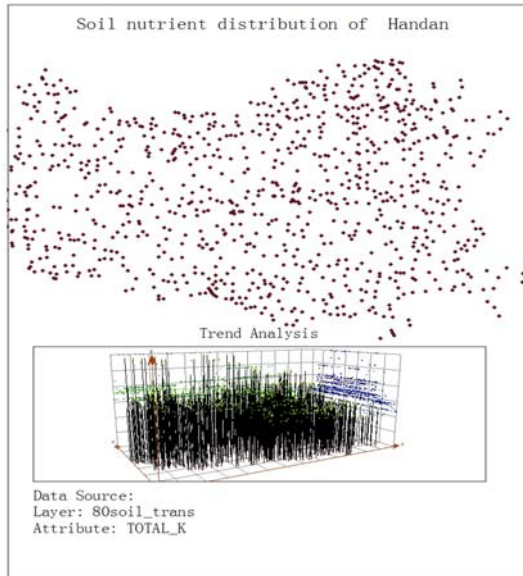


Fig8. Trend Analysis

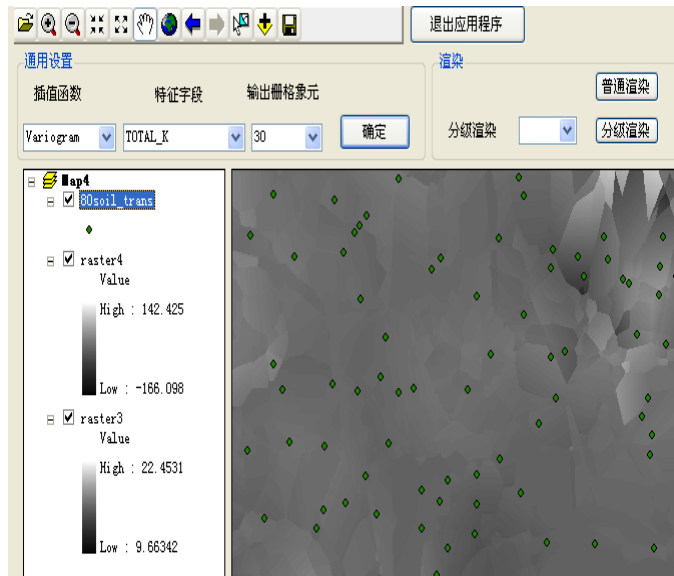


Fig9. Variogram Interpolation

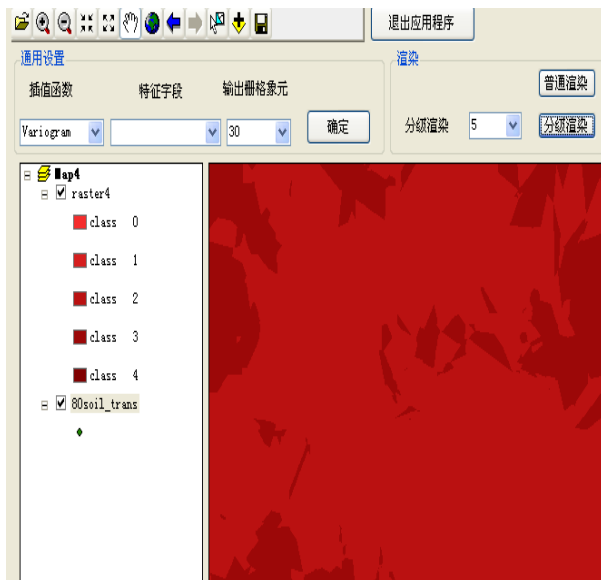


Fig10. Classification Rendering

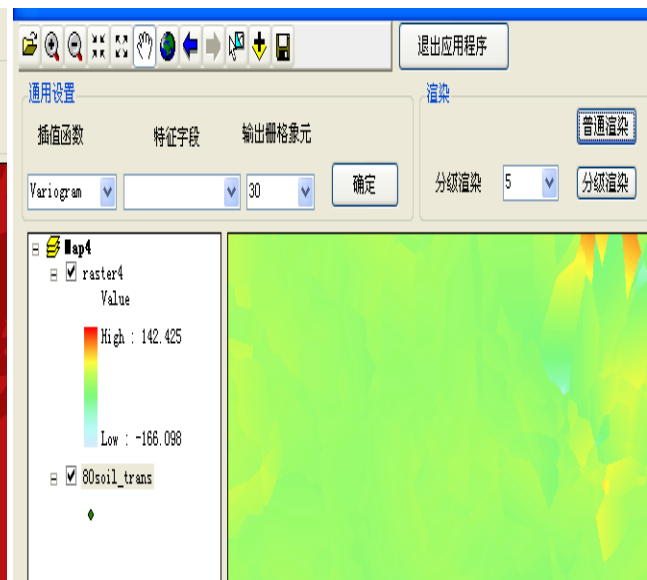


Fig11. General Rendering

5 Conclusion

Spatial variation analysis system considers the user's needs, uses GIS, computer technology, programming design, can analyze the spatial variation characteristic of regional variables quickly, conveniently and accurately, can meet the need of current research and analysis of spatial variation , can be used in soil science, meteorology, ecology, geology, hydrology and environmental resources all field that exist "Spatial Variation ",and provides help management ,fertilizer ,and so on for agricultural production. Future development work is to increase graphics output and other functions.

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