Technical Letter

Development of Open-Source GIS Educational Tools for Urban Planning

Migration to the GRASS-GIS Package in the GIS Educational Environment

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Abstract

This paper investigates the possibility of substituting open-source GIS software for commercial GIS software through the comparison of functional differences between them. In this case, we attempted adapting coursework for undergraduate urban planning education to the GRASS-GIS from materials originally developed using commercial software. We compared the features of the commercial and open-source packages, such as their respective spatial analysis functions, operational performance and user-interface. The adaptation to GRASS-GIS from Commercial GIS environment was successful. Herewith, we can expect the benefits of cost reductions with open-source GIS. In addition, the open-source environment provides the additional benefit of permitting users and developers to allocate some of their future software maintenance budgets to customization of the open-source code and training materials. This can result in better suitability in our applications, and better software and training materials for all other users of the thus-enhanced open-source software environment.

1. Introduction

Sustainability is one of the most important issues in the field of planning education, as well as in various other fields. To solve complex problems, GIS has become an indispensable tool. GIS manages large quantities of urban spatial information efficiently, and is used not only in urban planning, but also in various other research fields as a tool for visualization and analysis. Moreover, mobile communication devices, such as a mobile phones and Personal Digital Assistants, have also spread widely in Japan, and GIS is used in geographic information services (ex. search service of a restaurant or a nearest station, car navigation systems, and others.) On the other hand, there is a serious shortage of GIS specialists in our country (Okunuki, 2003). The shortage extends to software and technique developers, as well as to user-end

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specialists. In response to this shortage, the importance of GIS education is being discussed in various areas. In addition, the perceived high purchase and maintenance cost, and limited influence over enhancement, of proprietary GIS software are being questioned in some quarters.

2. Purpose of this Study

In this study, we challenge the development of GIS educational tools in the field of urban planning for undergraduate students in the university using the open-source software that can generally be used by anyone. This paper is regarded as the introductory part towards the purpose achievement. First, we compare the functions of open-source GIS software and commercial GIS software, and then verify the substitutability by using open-source GIS software. In response to the result, we aim at clarifying validity, such as the improvement possibility of the cost reduction.

3. GIS Environment and in the Educational Institute

About the use of GRASS in the educational institutions in our country, there are several applied research examples in geography, agriculture, and other fields. However, there is no positive research example using GRASS-GIS in the urban planning field that is our specialty. It is thought that the urban planning field which refers to spatial and tabular environmental information is one of the suitable research fields for introduction of open-source GIS software in many cases. This is especially true from GRASS' original objective of scientific analysis for environmental assessment, planning and management of landscapes.

3.1 About GIS Environmental Maintenance

The Department of Architecture and Environmental Systems, Shibaura Institute of Technology has two GIS training programs for undergraduate students using *ArcGIS 8.2 (ESRI Japan Corporation)* and *MicroStation/Geographics (Bentley Systems, Inc.)*. Their initial introduction cost is approximately 40,000 USD, and we need about 33,000 USD/year for annual maintenance management costs (the number of licenses of ArcGIS is 100, *MicroStation* is 200). When these GIS applications are replaced with open-source software, we could save much of those costs and use them to buy spatial data, educational facilities and other purposes in the university, as well as to customize the software and applications for the benefit of all future users of such software.

3.2 Case Study of GIS Training Course

Figure 1 shows the situation of a computer terminal room. In this room, 96 sets of terminals are installed and are always available to the students except for class hours. As shown in Figure 2 at the time of an exercise, the instructor's computer screen is reflected in the monitor which is installed in the center of each work station for students to refer to.

Figure 1: Practice Room

Figure 2: Work Environment

1) Program1 : Practice of Regional Environment Data Processing (For 3rd year)

This training course aims at utilizing GIS for various types of local environment information, and learning the fundamental skill of processing, management and visualization technology of data.

The main contents of the training module are listed below.

- Attribute data (Kobe earthquake disaster data) processing and analysis using spread sheet.
- The method of construction and management of an attribute information database. Retrieval of attribute using SQL. Training of the attachment procedure that figure data and attribute data using *MicroStation Geographics.*
- Grasp of the disaster situation that combined two or more indices and creation of the urban area diagnostic chart.

2) Program2: Information Processing for Geo-Spatial Analysis (For 3rd year)

This training course aims at acquiring an understanding of the programming technology and applied operation of GIS that is needed for the analysis and display of spatial information. This program is positioned as an application of the example mentioned above.

The main contents of training are listed below.

- Information Processing for Geo-Spatial Analysis using *ArcGIS* processing of basic attribute data, readout of analysis results, and acquisition techniques of statistics analysis.
- Acquisition of techniques for automated drawing programming of digital maps (Vector Format). Recording and reproduction of processes using macros.
- Information Processing for Geo-Spatial Analysis with DBMS.

4. Reproduction of the Same Contents by GRASS-GIS

We introduce an example that reproduced under the GRASS environment the contents developed with commercial GIS software. In this paper, we used the GRASS package *(Orkney, Inc)* with integrated Japanese language capabilities.

4.1 Vector and Raster Map Data Overlay

Figure 3 shows the screenshot of map overlay training using two different format data formats (Vector map and Raster map) using *MicroStation GeoGraphics*. As shown in Figure 4, it was demonstrated that it was possible to reproduce the same work satisfactorily under the GRASS environment. GRASS' features include high compatibility between various formats and resolutions of data in the same database. Moreover, it has well developed import and export functions.

We converted to the ASCII format the digital data in the proprietary software, such as a digital map and land use mesh map. We then developed approaches to facilitate the conversion of those ASCII data into GRASS binary formats with a customized import command macro.

4.2 Construction and Management of Attribute Data and Data Analysis

Next, Figure 5 shows the screenshot of data search and classification training using attribute databases. Attribute data derived from an investigation of the 1995 Kobe earthquake in Japan were originally stored in DBMS *(Microsoft Access2003)*. As shown in Figure 6, it checked that it was possible to reproduce the same work satisfactorily under the GRASS environment.

GRASS managed various kinds of files by the tree structure called "GRASS database'". In this management structure, figure data connect with attribute data by unique IDs. Herewith, it is possible to extract the data classified regardless of the map file format such as vector or raster. Moreover, it is also possible to stock attribute data in an external full-featured DBMS *(PostgreSQL 7.3.4)* and to perform powerful analyses therein.

4.3 Geo-Spatial Analysis using Buffering Function

Next, Figure 7 shows a screenshot of data analysis training such as calculation of buffering centering on a station point data. Figure 8 confirms that it was possible to reproduce the same work satisfactorily under the GRASS environment. GRASS is equipped with substantial geographical analysis functionality. It is possible to easily execute buffering on the raster data treated here, and also of combination and display of multiple output layers of raster and vector data.

4.4 Substitutability by GRASS-GIS

As explained using the previous examples, we confirmed that GRASS is equipped with sufficient functionality to reproduce the processes and results of work in the training exercises noted here. The GRASS-GIS's functionality and operational characteristics are summarized in Table 1 through comparison with the general commercial GIS software's functionality and operational features. In comparing the functionality of the commercial GIS and GRASS-GIS, we can safely say that there is no effective difference with respect to the tested procedures. In the case of university GIS education/training, it is considered practical to replace all such materials with open-source GIS software.

Next, we assessed the operationality that was based on the user-interface or general accessibleness. GRASS, like Arc/INFO and most other GISs developed before the past decade, was originally designed for command-line operation on the console screen under the UNIX CUI environment. Therefore, as compared with commercial GIS currently working under the *MS-Windows* GUI environment, a beginning student may feel the difficulty of getting used of the operationality and interface. Moreover, the presentation functionality to add the legend, orientation and scale, etc to the analysis results such as raster map data or graph data may be stronger in some commercial GISs. It may be difficult to cover all the same function only under the GRASS environment. Nevertheless, the Windows environment also often involves sequences of menuing and mousing operations that are not immediately intuitive. Thus, the student who is new to GIS will in any case be asked to learn new procedures and "tricks" with whatever software is used. It is not difficult to program, or script, many map composing features with existing GRASS functionality or design, and then complete the presentation in a specialty graphics program (like Ulead Photo Impact, Adobe Photoshop or an open-source alternative) to polish the final presentation to a level beyond the abilities of most, if not all, stand-alone GISs.

5. Conclusion

In this paper, we have verified the substitutability of laboratory exercise materials at our university from commercial GISs to open-source software, on the basis of a functional comparison between commercial GIS and GRASS-GIS. Judging from the results so far obtained, it is thought that the substitutability by GRASS-GIS is very high. There is almost no functional difference between both software environments. However, software operation such as the command level operation and GUI environment by the *Tcl/Tk* takes some learning by beginners.

It is thought that the operation and the description about usage of software and the ABC's of GIS using expansion tools by the Web-based cooperation can be overcome some these current challenges. Now, e-Learning System on Web combine with *Mapserver* as shown in a below Figures 9 and 10 are currently under development. Some of these initial challenges could also be overcome by our developing additional tools, by re-allocating some resources currently spent on commercial software purchase and maintenance contracts, to enhance

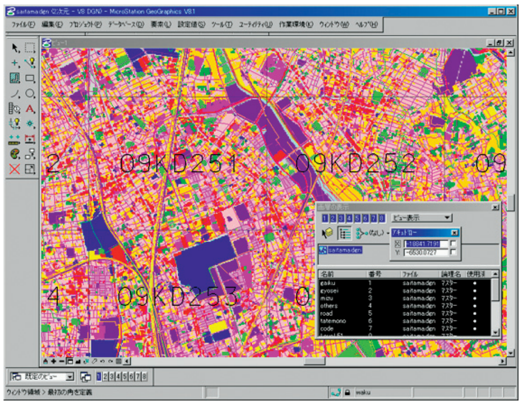

Figure 3: MicroStation GeoGraphics

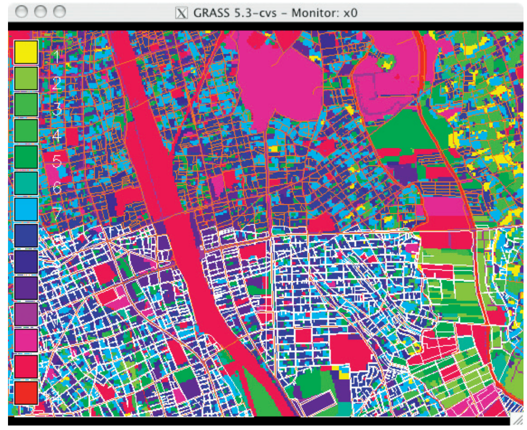

Figure 4: GRASS-GIS

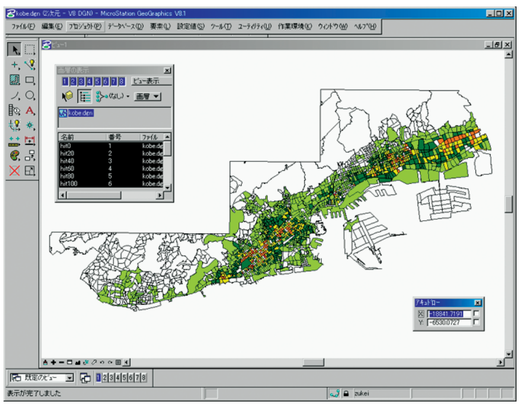

Figure 5: MicroStation GeoGraphics

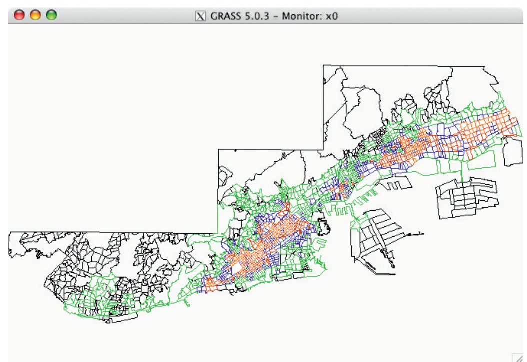

Figure 6: GRASS-GIS

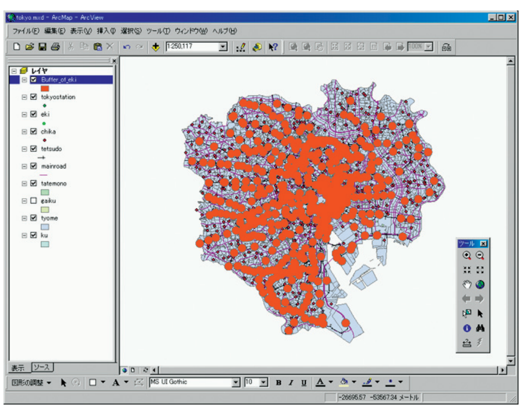

Figure 7: ArcGIS

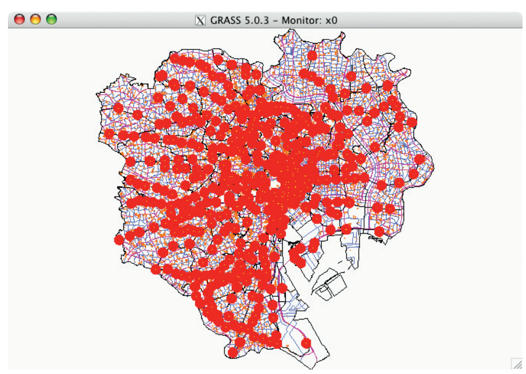

Figure 8: GRASS-GIS

Table 1: Comparison of Functionality and Operationality

Function and Operate in Commercial GIS Software	Replacement by GRASS-GIS
Various Data Input / Output, Data Convert	+++
Display of Legend Symbol, Create Histogram	++
Vector Map Data Handling	++
Raster Map Data Handling and Calculation	+++
Linkages between Figure and Attribute Data	+++
Spatial Analysis Functions	+++
User Interface, Operationality	+
Presentation use	+

+++ :Sufficient, ++ :Possible, + :Bit difficult

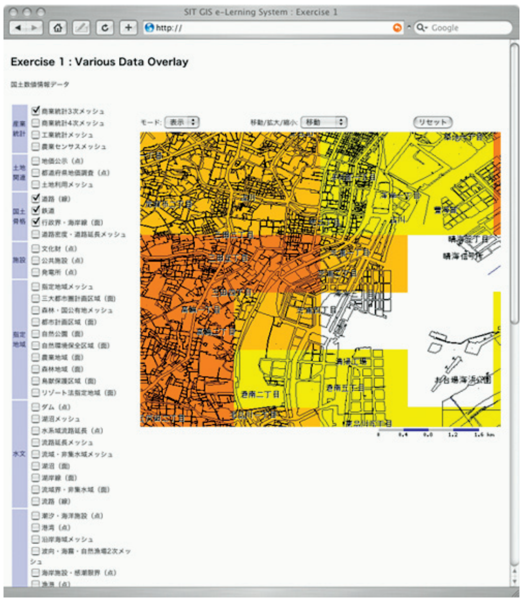

Figure 9: GIS e-Learning System (Ex.1 Various Data Overlay)

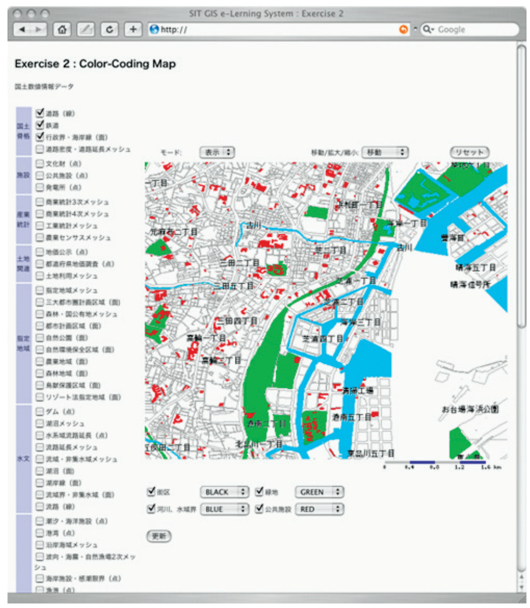

Figure 10: GIS e-Learning System (Ex2. Color-coding Map)

the open-source GRASS package in exactly the way we desire. Such enhancements could then be shared by the global GRASS user community, under the shared development culture of open-source software. Other challenges can be over-come by integrating the GIS with other software suites, including powerful specialty presenta-tion graphics software. (This can be done at the file level, as GRASS and UNIX or Linux can be scripted to produce, for example, 8-bit or 24-bit .raw file formats for direct import to Photoshop.)

In this system, the various geo-spatial data distributed by public organizations of our country are used as attribute data in GIS. By using this system, students can study the basis of GIS such as various data overlay, color-coding on map, etc easily on the Web and in the classroom.

As mentioned above, it is thought that the substitutability with the existing commercial GIS environment by the open-source GIS is generally very high. Continuing with this approach, we plan to continue the development of teaching materials and educational tools for urban planning studies using the GRASS-GIS.

Reference

Markus Netteler and Helena Mitasova, 2002, *OPEN-SOURCE GIS: A GRASS GIS Approach,* (KAP).

Okunuki, K., et al., 2003, Current issues in the use of GIS in Japanese K-12 schools, *Papers and Proceedings of the Geographic Information Systems Association GISA,* 271-274.