GeoS4S Module GIS for ITS: A Knowledge Bridge from GIS to ITS

Lin, L., Zhongliang, C., Qingyun, D., You, W. and Haihong, Z.
School of Resource and Environmental Sciences, Wuhan University, China
E-mail: lilin@whu.edu.cn

Abstract
As an important and smart applicable area, Intelligent Transportation Systems (ITS) representing a major transition in transportation on many dimensions has attracted the substantial attention from GIS communities. Addressing how GIS and related technology are adapted for ITS at improving the traffic safety and the effectiveness of surface transportation systems, this teaching module focuses on data organization of road network and integration with traffic data, as well as models for improving transportation efficiency. Its primary goal is to extend the students' ability from fulfilling GIS projects to integrating GIS-related technologies for supporting ITS projects. The current paper summarizes the learning objectives, lesson content, learning activities and evaluation scheme for this module.

Key Words: GIS, ITS, Geo-spatial Data Organization, Traffic Modeling, Transportation

1. Introduction

GIS has been expanding into many application domains and has shown its merits in improving transportation systems. As an emerging advanced technology, Intelligent Transportation Systems (ITS) has adopted a lot of GIS technology and shown its increasing scale in industry. However, current graduate education in geo-information science provides little knowledge about transportation or ITS, and ITS related disciplines focuses on electronics, communication, information and management. In order to bridge the knowledge gap from GIS to ITS, this module is designed to provide an overview of ITS architecture in the perspective of GIS and applicable GIS technology in spatial data organization, integration with traffic data, building traffic models with GIS functions in terms of its roles in ITS, which expands GIS students' working ability in the field of ITS or transportation.

1.1 Module Description

Most GIS courses and textbooks usually present very general knowledge about geo-spatial information study and technology, focusing on technical topics: data acquisition, geospatial data representations, algorithms, models, visualization and so on. As an important and smart applicable area, ITS representing a major transition in transportation on many dimensions has attracted the substantial attention from GIS communities. To exploit the inherent advances of GIS technology, it is necessary for GIS practitioners to understand a general architecture of ITS, the roles of geo-spatial data in ITS and functionality of GIS supporting traffic control and modelling.

This module introduces the development of ITS, technical features of ITS in terms of information processing linking with geo-spatial information technology, geo-spatial data organization especially road network organization, and modeling capacity of GIS for traffic systems. The course caters for those with GIS-related background and offers a knowledge bridge, standing on the GIS discipline, to cross GIS general technology to the profound application of GIS in ITS. The goal of applying those knowledge is to achieve a more efficient operation of transportation and public transportation coordination, safer traffics and less congestions, and to demand satisfaction for mobility and access, and pedestrian protection etc..

Although there are some textbooks for GIS for transportation or ITS related, those books are used to introduce GIS to ITS and cater for those with ITS or transportation background. There are rich materials and references available for either GIS or ITS. The bulk of information are adopted to build the module 'GIS for ITS', including presently published papers in academic journals. With going through the materials in this module in the period of studying course, students will have a basic understanding of the emerging field of ITS and acquire applicable knowledge and skill of adopting GIS technology for dealing with technical problems in ITS.

1.2Learning Outcomes

By learning this module, the students will acquire the following outcomes:

- Establish an overview of ITS architecture and recognize the interactions of people, vehicle, infrastructure and institution on ITS by learning the components of ITS and emerging of ITS;
- Understand the role of GIS technology in supporting ITS through geo-spatial information integration, management and analyses, embodying a solution of information technology to complex issues;
- Build the ability to link geo-spatial data with ITS and to complete simple tasks in GIS-related issues for ITS such as organization of road data, integration of traffic data with road segments and etc.;
- Use some common GIS tools to fulfill data integration, data processing, data organization, geo-visualization of traffic data and development of traffic models;
- Have a starting capacity for working in the ITS fields related with information technology by knowing general processes or methodologies for ITS issues.

2. Module Structure

2.1 Module Overview

This module consists of 13 lessons with about 30 slides and accompanying notes in each, plus required and optional reading assignments, practice exercises, hands-on interactive and individual assignments, and self-assessment quizzes. The overall student effort is estimated at 150 to 170 hours, and the module is intended to provide credit equivalent to 6 ECTS. The module materials are designed to be used flexibly, in either a traditional classroom setting or for on-line self-study. The first three lessons are numbered in the syllabus in an order to present an easy way to capture an overview of ITS. The other lessons are organized from basic knowledge about data organization to understanding data model and functionality of GIS for solutions to deeper ITS technical problems. However, those with profound GIS knowledge may use those lessons individually or in any order.

2.2 Summary of Lesson Content

This section briefly presents the content and goals of each lesson:

- *Lesson 1: What is ITS?*-This lesson provides general concept about ITS starting with the nature of transportation, emerging ITS, applications of ITS and ending with some examples of development of ITS in USA, Japan and China which may represent different contexts.
- *Lesson 2:ITS architecture*-This lesson presents a general framework of ITS, an overview of ITS architecture and components of ITS and an intuitive image of ITS roles in improving transportation with some examples. In addition, geographical features embedded in ITS are introduced. This lesson with the first lesson helps students learn of a linkage between ITS and GIS.
- *Lesson 3: GIS Technology Supporting ITS*-This lesson reviews main functionality of GIS, presents the general role of GIS in transportation in terms of engineering in planning and design, management in construction, safety as well as security. Modeling capacity of GIS useful for ITS is further described.
- *Lesson 4:Linear reference system*-This lesson presents the basic principle of LRS by describing its general characteristics and structure elements such as route, measure and events, and linear referencing methods. It also introduces the basic required functions for LRS and provides a detail view into the basic data model of LRS such as the hierarchy of data elements and relationships among them.
- *Lesson 5:Road data and network organization*-This lesson provides the understanding of road network organization for ITS by introducing road data and road network databases, and explaining architecture of road network by describing its geographical features, connectivity and attributes. Road network analyses are further presented to explain the effectiveness of such road network organization.
- *Lesson 6:Traffic data collection*- This lesson introduces the traffic data in general for ITS and its informative role in ITS. Methodology for collection of traffic data in the form of traffic flow is then presented by outlining three commonly used methods and followed by discussion of the features of those methods. This lesson tries to provide GIS students with an initial comprehension of relationship between traffic data and geo-spatial data.
- *Lesson 7:Road Network Update Technology*- This lesson presents the role of updating road network and the updated features by reviewing elements of road network, and then describes the currently adopted road updating technology-extracting roads from trajectory, as well as the general procedure for network

matching. A median-based method is also introduced to further explain the extraction technology from trajectory points.

- *Lesson 8:Introduction to Car Navigation System and GDF*- This lesson gives a brief introduction to car navigation system by outlining the three related major functions for recognition of merits of geo-spatial processing for smart navigations, and describes the architecture of GDF and detail data structure for road and ferry--the most important element in navigation systems. Learning this lesson enhances the linkage between GIS and ITS.
- *Lesson 9:Travel navigation*- This lesson further presents the importance of spatial data organization for ITS by describing organizing road data and guidance data for travel navigations in a more micro-view. This lesson introduces data content and file organization required by travel navigations, and then describes road data, background data, index data in means of file organization, being followed by simple examples of path navigations.
- *Lesson 10:Moving objects databases*-As management of moving vehicles being the critical issue in ITS, this lesson introduces the basic principle of moving objects databases by reviewing the characteristics of spatio-temporal databases, linking spatio-temporal databases with moving objects, describing the key functions of moving objects databases in terms of modeling and querying both past and current movements.
- *Lesson 11:Traffic modeling*-By explaining the role of traffic model in improving transportation, this lesson introduces a very effective and implemented quite simple modeling tool--Cellular Automata (CA) method. The principle of CA is presented and the Game of Life is used to explain the mechanism of CA capturing dynamic evolution. Then typical CA-based transportation models are provided to better exploring the CA-based models in traffic applications.
- *Lesson 12:Urban Traffic Simulation Model*- This lesson discusses a deeper modeling method for urban traffic applications and further shows the efficacy of comprehensive GIS technology in supporting ITS. In this lesson, urban traffic system and simulation model are briefly introduced, some commonly used simulation tools are outlined, and then a case study for simulation of urban subway is presented as an example for better understanding modeling procedure and modeling technology.
- Lesson 13: *Introduction to Autonomous Driving* - This lesson presents a brief description of autonomous driving(AD) technology by outlining its development and describing the architecture of AD in terms of its three core components: sensing, self-driving decision and action. High precision map designed for AD is introduced and discussed to demonstrate GIS supporting this most advanced technology in ITS.

3. Hands-on Sessions

The module provides 4 assignments and 6 exercises which includes a number of interactive and hands-on activities to supplement the lecture content, deepen students' understanding, and develop their practical skills. Hands-on activities are following:

- Linear reference system (assignment 2 in Lesson 4)
- Finding the best route using in a network (assignment 3 in Lesson 5)
- Travel navigation based on Google Maps API (assignment 4 in Lesson 9)
- Building CA models with Matlab tool (exercise 6 in Lesson 11)

This module assumes the prior knowledge of GIS and Databases, meaning having known some commonly used GIS tool such as ArcGIS and general skill in programming.

4. Teaching and Learning System

This module adopts the lecture-based teaching with student centered strategies. Orienting ITS solutions, students learn basic knowledge of ITS and geospatial information technologies in supporting ITS. Through extra readings, exercises, assignments and discussions, students understand general methods applying GIS technology in ITS issues and gain an ability of working or further studying in ITS-related fields.The module may roughly divided into 4 parts, which may adopt different learning methods.

Part 1: (lessons 1-3) introduces concepts, philosophy and values for GIS for ITS. Aside from studying the overview provided by lecture notes, students will read 3 short papers discussing the philosophy and practice of ITS and build an overview of ITS architecture and geographical features of ITS. More extending readings may provide students with deep insight into GIS technology for ITS.

Part 2: (lessons 4-7) presents a deep comperhension of road data and network and an initial view of traffic data. Two hands-on activities are designed in this part to help to understand organization of road network deeper and acquire the skill of using the common GIS tools to fulfill certain tasks. The required readings and exercises in this part will present a linkage of road data with traffic data.

Part 3: (lessons 8-9) further introduces geo-spatial data organization focusing on road data for navigation systems and shows some complexity of data organization and the important role of geo-spatial data in some aspects of ITS. Readings, exercises and an assignment (hands-on practice) are provided for enhencing the ability of applying geo-spatial data techniques to serving a certain functions in ITS and development of functional modules for certain purposes of navigations.

Part 4: (lessons 10-13) introduces profound knowledge from moving object databases to building traffic models. In addition, autonomous driving invloved in the most advanced technologies is introduced to show the trend of developping GIS technology. All readings, exercises and an assignment are designed to extend the ability of better understanding of advancing GIS technology and deep applying the GIS technology in a smart way to technical issues in ITS.

5. Evaluation System

Performance evaluation for this module involves 3 components: participation(15%), hands-on practices(40%) and two written reports (10%+35%).

1) Participation (15%): participation is counted either in students's attending class or submision of the exerxies and assignments to the instructor.
2) Four hand-on activities (40%): a technical document for each practice for completing a certain task in ITS-related issues.
    - Assignment-2: Linear referencing system, exploring the basic linear referencing processing for the practical linear referencing system in ArcGIS
    - Assignment-3: Finding the best route in a network, learning road network data organization and network analysis by finding the quickest route (shortest path) between stops with ArcGIS.
    - Assignment-4: travel navigation based on Google Maps API, learning how to use the Google Maps API to implement some common functions of travel navigation.
    - Exercise-6: Building CA models with Matlab tool, learning how to use Matlab to build CA-based models.
3) Two written reports (45% in total)
    - Assignment 1(10%). A visiting report (visiting the local traffic control centre)requires students to record the observation during their visiting and outline how the traffic control center works(about 1500 words).Or a review report on the role of GIS for ITS(if visiting the local traffic control centre is not applicable)requires students to provide a general overview on what ITS is, how ITS emerges and linkage of GIS with ITS (about 1500 words).
    - Term paper. A term paper (35%) (no less than 4500 words) should be written in a similar style to academic papers such as including abstract, introduction, relevant study, discussion and conclusion, as well as references. References are properly cited.

For the interactive, discussion-based exercies and assignments, the instructor will provide feedback and suggestions, but grading will be based on participation and apparent effort and thought. The purpose of all hand-on activities is to give students practice with specific tools and techniques, and to engage them in both analysis and synthesis.The written reports will assess the degree to which students have internalized the concepts and techniques addressed by the module and can apply them to a specific case. In addition, the module provides several self-test quizzes to help students evaluate whether they understand the basic concepts of the preceding few lessons and gain the general knowledge presented in the module.

6. Conclusions

In the era of fast development and advancement of information technology, GIS technology has been tending to expanding into various domains. Following the trend, the graduate eduction in GIS is required to provide knowledge bridges to those promising domains with an increasing scale of industries such as transportation or

ITS. This module is designed for students with GIS background to extend their ability of conprehensively applying GIS technology with other advancing technologies to supporting ITS. To improve the books related to GIS or ITS with limited bridge knowledge between the two discinplines, the new syllabus for the module 'GIS for ITS' is designed and a lot of references and material are collected and prepared to build this module consisting of 13 lessones. Those lessones with readings, exercies and assignments provide students with effective paths to lean the principles, methodology, procedures and paradigms as well as skills of applying GIS technology in solving problems in ITS. By going through all materials in this module, students will obtain the ability of working for ITS industry and related acadmic communities.

Acknowledgements

This module has been developed within GeoS4S project (http://geos4s.zgis.at) co-funded by the European Commission (EC) under Erasmus+ program and also partly supported by China research projects(41471325, 2017YFB0503701). I would like to thank the project consortium and the EC for giving me the opportunity to delve into the issues of GIS for ITS and create this module. I also appreciate the colleagues in this consortium team who have provided a lot of valuable comments on this module and opportunities the project has provided to interact with the teachers and students from several countries, being a part of this international collaboration has been an extremely valuable experience. Last but not least, special thanks would go to Dr. Xiaoyu Xing, Dr. Hui Xia, Dr. Feng Luo, Mr. Dalin Li, Mr. Hang Zhang, Mr. Yu Liu, Mr. You Li, Mr. Hui Yang, Mr. Linfeng Li, Mr. Lei Tang, Mr. Yu Zhang and so on who have provided with a lot of help in collecting documents and preparing materials for this module.

Bibliography

ISO14825-2011, Intelligent Transport Systems - Geographic Data Files (GDF5.0)..

Junping, Z., Fei-Yue, W., Kunfeng, W., Wei-Hua, L., Xin, X. and Cheng,,C., 2015. Data-Driven Intelligent Transportation Systems:A Survey. *IEEE Trans*. ITS, VOL. 12(4): 1624-1639

Lieberman, E. B., 2014, Brief History of Traffic Simulation. *Traffic and Transportation Simulation*, 2014: 17.

Nowacki, G., 2012, Development and Standardization of Intelligent Transport Systems. TransNav the *International Journal on Marine Navigation & Safety of Sea Transportation*, 6(1), 224-226.

Pelekis, N. and Theodoridis, Y., 2014, Mobility Data Management and Exploration. Springer New York.