GeoS4S Module 3D City Modelling

Zhang, K., Sheng, Y. and Yang, L.
School of Geography Science, Nanjing Normal University, Nanjing, PR China
E-mail: shengyehua@njnu.edu.cn, zhangka81@126.com

Abstract
3D city model is a digital representation of the earth's surface and its related objects such as buildings, trees, roads, and other man-made features belonging to urban area. How to construct and represent 3D models of these objects are becoming vital importance in the field of smart city. This teaching module employs case studies and interactive exercises to introduce the basic concepts, technologies, methods and tools used in 3D city modelling. Its high-level goal is to prepare the student for reconstructing their own 3D city models with the existing techniques. The current paper summarizes the learning objectives, lesson content, learning activities and evaluation scheme for this module.

Key Words: 3D City Model, 3D Model Reconstruction, 3D Modelling Techniques, Smart City

1. Introduction

The needs for 3D city models are growing and expanding rapidly with the development of city informatization. 3D city models consisting of the geometry and texture of urban surfaces could aid applications such as urban planning, training, disaster simulation, and virtual-heritage conservation. As an information model, 3D city model has been recognized as the best representation of the real city. Undergraduate education in geoinformation science should cultivate students to have the ability for digitally describing, monitoring, and modelling urban environment and human activities. This module will help GIS students master basic theories of 3D city modelling and know how to create and represent 3D city models.

1.1 Module Description

3D city model is a digital representation of the earth's surface and its related objects such as buildings, trees, roads, and other man-made objects belonging to urban area. How to effectively construct 3D city models is becoming vital importance in smart city. 3D city modelling relies on quick and exact acquisition of 3D geospatial information of ground objects. The techniques used to automatically or semi-automatically create large-scale city models are emerging rapidly, such as modelling from vector map, high resolution aerial or satellite images, 3D laser scanning point clouds, etc.

This module focuses on the basic theories and techniques of 3D city modelling from a single object to a whole city scene. Following contents will be mainly discussed: the general 3D data model for expressing objects in the city; the traditional and latest technologies for acquiring 3D geospatial information of city objects; the methods for constructing 3D city models with acquired 3D geospatial information; the integration of 3D city models to express the whole city scene. After completion of this module, students will be able to construct their own 3D city models with existing 3D modelling techniques. There are no textbooks for this module. Thus, this module requires lots of extracurricular reading. Furthermore, there are some exercises for training students' practical ability in this module.

1.2 Learning Outcomes

- Understand general characteristics of CityGML, and the function of CityGML model in expressing 3D city objects.
- Outline the main technologies of acquiring 3D geospatial data (including 2D vector map, 3D laser scanning, digital photogrammetry, etc.).
- Identify and utilize the methods of constructing 3D models of single object and large-scale city scene (outdoor and indoor) with the multi-sourced 3D geospatial data.
- Be familiar with the methods of integrating individual 3D models into the whole 3D city scene.
- Construct student's own 3D city models with existing 3D modelling approaches.

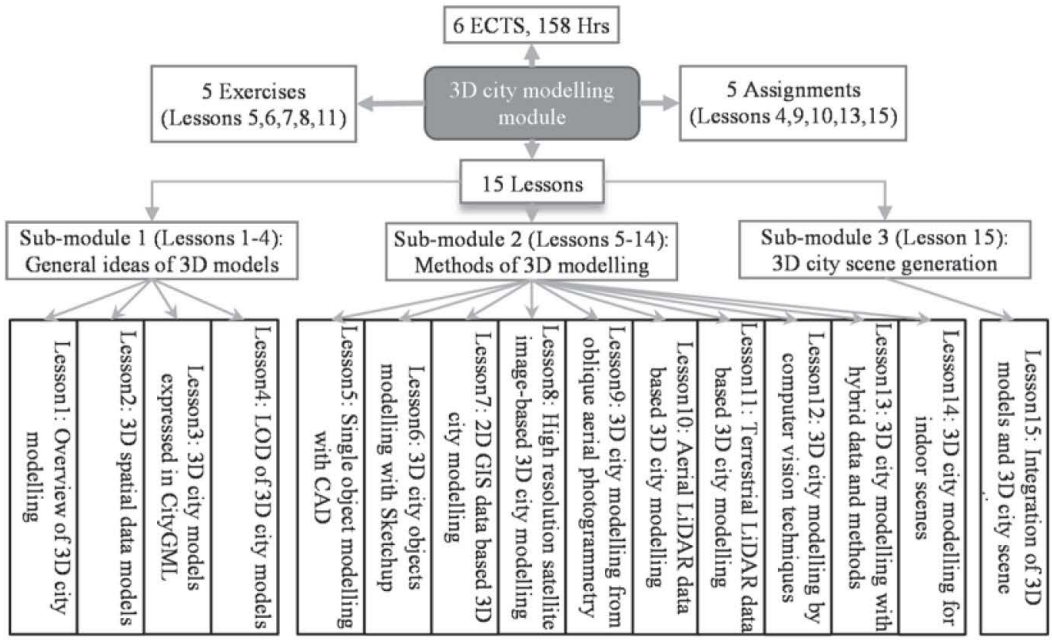

Figure 1: The Module Diagram of 3D City Modelling Course

2. Module Structure

2.1 Module Overview

This module consists of 15 lessons with slides and accompanying notes, plus required and optional reading materials, practice exercises, and individual assignments (shown in Figure 1). The overall student effort is estimated at 158 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 module is organized into three sub-modules as described in section 4.

2.2 Summary of Lesson Content

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

- *Lesson 1: Overview of 3D city modelling* - This lesson discusses basic concepts of 3D city model and 3D city modelling, and gives some application examples of 3D city models. It also gives the general picture of approaches for 3D city modelling.
- *Lesson 2: 3D spatial data models* - This lesson describes the concepts of spatial entity and spatial data model. Then it gives different expression forms of 3D spatial data models and their applications.
- *Lesson 3: 3D city models expressed in CityGML* - This lesson explains the definition and general characteristics of CityGML. It also discusses the functions of CityGML in expressing 3D city objects.
- *Lesson 4: LOD of 3D city models* - This lesson discusses the concepts of LOD models. It also introduces some methods of 3D model simplification and the process of generating the viewpoint-based LODs model.
- *Lesson 5: Single object modelling with CAD* - This lesson gives basic operations of 3D modelling for the single object with AutoCAD software and texture mapping with 3DS Max software.
- *Lesson 6: 3D city objects modelling with Sketchup* - This lesson explains how Sketchup can be used in 3D modelling, and gives implementation steps of 3D city objects modelling with Sketchup.
- *Lesson 7: 2D GIS data based 3D city modelling* - This lesson firstly explains basic concepts, types and collecting techniques of 2D GIS data. Then it gives the detailed introduction of 3D city modelling with 2D GIS data.
- *Lesson 8: High resolution satellite image-based 3D city modelling* - This lesson presents image-based methods for extracting and modelling ground objects. Some typical softwares and the workflow of image-based 3D modelling are also discussed in this lesson.

- *Lesson 9: 3D city modelling from oblique aerial photogrammetry* - This lesson explains the basic concepts and principles of aerial photogrammetry. It also discusses the technological procedure of semi-automatic 3D modelling based on multi-view UAV images.
- *Lesson 10: Aerial LiDAR data based 3D city modelling* - This lesson provides the basic principles of aerial LiDAR scanning and the characteristics of the scanned data. It explains how to use point clouds captured by aerial LiDAR to semi-automatically construct 3D models of ground objects.
- *Lesson 11: Terrestrial LiDAR data based 3D city modelling* - In this lesson, students learn about the basic principles and data processing flow of terrestrial LiDAR scanning. The lesson describes the implementation of 3D object modelling with terrestrial LiDAR data and point clouds-based 3D modelling software.
- *Lesson 12: 3D city modelling by computer vision techniques* - This lesson explains the basic principles of 3D object reconstruction with image series, and presents the technological procedure of 3D modelling by computer vision techniques.
- *Lesson 13: 3D city modelling with hybrid data and methods* - This lesson explains the differences and complementarity among multi-sourced data for 3D city modelling. It also discusses some typical hybrid methods for 3D city modelling.
- *Lesson 14: 3D modelling for indoor scenes* - This lesson describes the concepts, methods, and technological procedure of 3D indoor scene modelling.
- *Lesson 15: Integration of 3D models and 3D city scene generation* - This concluding lesson discusses how to integrate the 3D models, generate the 3D city scene, and publish the 3D city scene on the web.

3. Hands-on Sessions

The module provides some hands-on activities to supplement the lecture contents, deepen students' understanding, and develop their practical skills. These activities are also part of the module evaluation scheme.

- Modelling one building with CAD software (Lesson 5)
- Modelling a small street block with Sketchup (Lesson 6)
- 3D modelling by 2D GIS data (Lesson 7)
- Building and road extraction from high resolution satellite image (Lesson 8)
- 3D modelling of city objects from terrestrial LiDAR point clouds (Lesson 11)

This module does not assume any prior knowledge of specific software, although some of the activities will be easier if students have some exposure to programming concepts.

4. Teaching and Learning System

The learning and teaching strategies are student centred. They are encouraged a deep learning approach by using reflection and self-evaluation. A written Directed Reader will be provided on-line, which will provide the essential background, the framework for study and essential detail. It will include self-assessment exercises. Each section of this Reader will be framed with a context setting introduction, clearly identified learning outcomes and additional reading within the academic and professional literature. Students will be required to reflect on their learning as part of the self-assessment exercises and the summative assignments. Opportunities for students to discuss issues with staff and fellow students will be provided via an online bulletin board. The module is divided into three sub-modules, which use rather different learning methods.

Sub-module 1: (lessons 1-4) introduces definitions, concepts, expressions, applicationis and values for 3D spatial data models and 3D city modelling. Aside from studying the overview provided by lecture notes, students will read 8 extracurricular papers extending their knowledges. This sub-module also offers one assignment to allow students to check their understanding on different LODs of 3D city models and their functionality.

Sub-module 2: (lessons 5-14) focuses on traditional and latest techniques for acquiring 3D geospatial information and reconstructing 3D models. Learning activities will involve 10 lectures studying, extensive extracurricular reading, 5 exercises of these techniques with actual data, and 3 assignments.

Sub-module 3: (lesson 15) considers 3D models integration for generating a whole 3D city scene. Students will learn the detailed workflow of 3D model integration, the definition and publishing of a 3D city scne. After this lesson, one assignment, which is to complete one proposal for integrating 3D models in GIS platform and publishing a 3D city scene on the web, will be given to students.

5. Evaluation System

Performance evaluation for this module involves two components: five hands-on exercises (40%) and five written project assignments (60%). For the interactive exercises, the instructor will provide feedback and suggestions, but grading will be based on participation and apparent effort and experimental results. The purpose of all exercises is to give students practice with specific tools and techniques, and to engage them in both analysis and synthesis. The written assignment are in the form of essays or project designs, which are used to assess which students have internalized the concepts and techniques addressed by the module and can apply them to a specific case.

6. Additional Notes

The primary resource will be the Directed Reader supplemented by a mixture of academic journal and professional references and case studies. See the online module for more information on the primary and recommended reading material. In addition, the sub-modules in this module are somewhat independent. Students who are using the module material for self-learning rather than for credit may not complete all modules.

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