Web-Based Provisioning and Application of

Large-Scale Virtual 3D City Models

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Abstract

Virtual 3D city models represent and integrate a variety of spatial data and georeferenced data related to urban areas. With the help of improved remote-sensing technology, official 3D cadastral data, open data or geodata crowdsourcing, the quantity and availability of such data are constantly expanding and its quality is ever improving for many major cities and metropolitan regions. There are numerous fields of applications for such data, including city planning and development, environmental analysis and simulation, disaster and risk management, navigation systems, and interactive city maps.

The dissemination and the interactive use of virtual 3D city models represent key technical functionality required by nearly all corresponding systems, services, and applications.
The size and complexity of virtual 3D city models, their management, their handling, and especially their visualization represent challenging tasks.
For example, mobile applications can hardly cope with these models due to, e.g., their massive data volume and data heterogeneity.
Therefore, the efficient usage of all computational resources (e.g., storage, processing power, main memory, and graphics hardware, etc.) is a key requirement for software engineering in this field.
Common approaches are based on complex clients that require the 3D model data (e.g., 3D meshes and 2D textures) to be transferred to them and that render the received 3D models.
However, these applications have to implement most stages of the visualization pipeline on the client side.
Thus, as high-quality 3D rendering processes strongly depend on locally available computer graphics resources, software engineering faces the challenge of building robust cross-platform client implementations.

Web-based provisioning aims at providing a service-oriented software architecture that consists of tailored functional components for building web-based and mobile applications that manage and visualize virtual 3D city models.
This thesis presents corresponding concepts and techniques for web-based provisioning of virtual 3D city models.
In particular, it introduces services that allow us to efficiently build applications for virtual 3D city models based on a fine-grained service concept.
The thesis covers five main areas:

1. ***A Service-Based Concept for Image-Based Provisioning of Virtual 3D City Models*** It constitutes a conceptual frame for a broad range of services related to the rendering and image-based dissemination of virtual 3D city models.
2. ***3D Rendering Service for Virtual 3D City Models*** This service provides efficient, high-quality 3D rendering functionality for virtual 3D city models.
   In particular, it copes with requirements such as standardized data formats, massive model texturing, detailed 3D geometry, access to associated feature data, and non-assumed frame-to-frame coherence for parallel service requests. In addition, it supports thematic and artistic styling based on an expandable graphics effects library.
3. ***Layered Map Service for Virtual 3D City Models*** It generates a map-like representation of virtual 3D city models using an oblique view. It provides high visual quality, fast initial loading

times, simple map-based interaction and feature data access. Based on a configurable client framework, mobile and web-based applications for virtual 3D city models can be created easily.

4. ***Video-Service for Virtual 3D City Models*** It creates and synthesizes videos from virtual 3D city models. Without requiring client-side 3D rendering capabilities, users can create camera paths through a map-based user interface, configure scene contents, styling, image overlays, text overlays, and their transitions. The service significantly reduces the manual effort typically required to produce these kinds of videos. Videos can be automatically updated when the underlying data changes.
5. ***Service-Based Camera Interaction*** It supports task-based 3D camera interactions, which can seamlessly be integrated into service-based visualization applications. It is demonstrated how to build such web-based interactive applications for virtual 3D city models using this camera service.

These contributions provide a framework for the design, implementation and deployment of future web-based applications, systems, and services for virtual 3D city models.
The approach shows how to decompose typical complex monolithic functionality of today's 3D geovisualization systems into independently designed, implemented, and operated service-oriented units.
In that sense, this thesis also contributes to microservice architectures for 3D geovisualization systems---a key challenge of today's IT systems engineering to build scalable IT solutions.