3D Visualization of a Public Transportation System

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ABSTRACT
In this paper we present early results from our investigation in whether the utilization of 3D objects brings added value in public transportation visualization systems. We describe the implementation of our easily generalizable WebGL based system titled "Virtual Bus", and the results of a preliminary evaluation. The evaluation consists of a small user study where the Virtual Bus system was compared to visualization capabilities of a commercial PTS information system. The results of the evaluation imply potential in 3D visualizations.

ACM Classification Keywords
H.5.1 Multimedia Information Systems: Artificial, augmented, and virtual realities

Author Keywords
WebGL; Virtual Environments; Public Transportation

INTRODUCTION
In most modern cities, a Public Transportation System (PTS) is a vital component, improving the city ecosystem in a multitude of ways. Since information quality of a PTS plays a significant part in its utilization, [11, 8, 4], it is an attractive subject for information visualization projects. A famous example is the KickMaps project which aimed to increase subway use in New York city by improving the uncomfortably large and complex subway map of the city [18]. In this paper, we present early results from our investigation in the usefulness of utilizing 3D objects in an open data based PTS visualization. We describe the implementation of our web based PTS visualization system titled "Virtual Bus", and the results of a preliminary user evaluation. The implementation of the Virtual Bus system is in very early stage and does not contain all properties usually found in contemporary PTS information systems.

BACKGROUND
Utilizing 3D graphics in information visualizaton systems can be understood in multiple ways, for example by mapping information in three dimensions [22, 23], or representing locations utilizing 3D graphics [3]. In this study, we are interested in the latter. 3D visualizations have become easy to utilize through the capability of modern web browsers to render 3D graphics without additional plugins; GPU accelerated 3D and 2D graphics as well as physics can be incorporated through the HTML5 canvas element utilizing WebGL API [16]. In turn, various frameworks such as three.js [5] and babylon.js [6] allow a high-end interface for the WebGL API. WebGL has also brought the possibility to visualize large 3D city models in web. Examples include the 3D visualizations of Google Maps [12], visualizations such as ViziCities [17] that utilize OpenStreetMap (OSM) [9] and its Overpass API [10], Cesium [2], and many more. Berlin and Rotterdam are examples of cities that provide their own 3D city data in the popular CityGML format [20, 19, 7]. 3D cities can be procedurally generated from geospatial data sources, laser scanning data, or using photogrammetry[24]. When augmented with semantic data, the city models can be utilized for many analysis purposes [24]. Examples of hand-modeled gamelike virtual cities are presented in [1, 21].

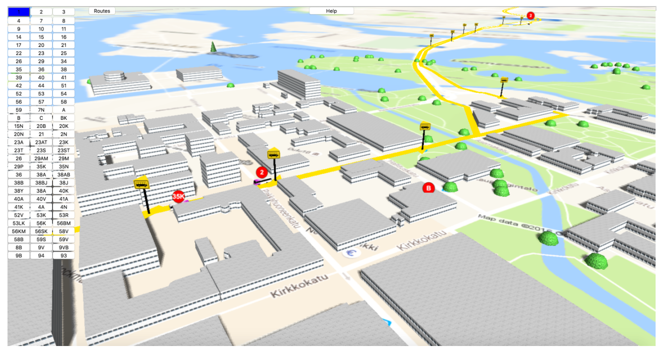

Figure 1. The Virtual Bus user interface

EXPERIMENTAL SYSTEM
The Virtual Bus system consists of client and server components that utilize open data sources; the client acts as a user interface for the system while the server contains static route information and acts as a proxy for the open data. The client runs in a browser and enables the user to explore bus routes and bus locations interactively as a 3D representation of the city, see Figure 1. The open data utilized by the Virtual Bus system comes from three sources: the municipality service provider, OSM Overpass API [10] and Google Static Maps

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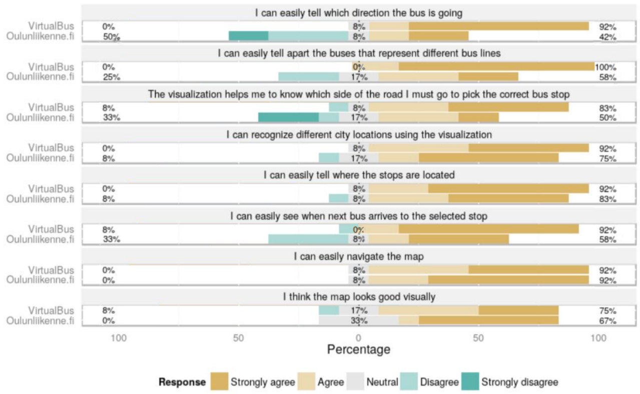

Figure 2. Questionnaire results

API [13]. The data acquired from the municipality service consists of real-time bus location information as well route and destination information as static data. The real-time bus data is provided as realtime GTFS feed [14], whereas the static data is provided as static GTFS [15]. The service provider data contains longitude and latitude of the bus at intervals ranging roughly between 1-30 seconds, as well as the next stop the bus is currently in transit to. The static data consists of route lists, geographical information of trips that follow the routes, coordinates of bus stops as well as their timetables. The data to generate 3D buildings, forests and parks is acquired through the OSM Overpass API [10] in JSON format. The available data consists of points, polygons, lines, polygon sets and metadata tags. Buildings are described with one or several polygons with building type and height (or number of levels) as metadata. Forests and parks are polygonal areas with vegetation type as metadata. The 2D image data for street map is acquired through Google Static Maps API. The image data is provided as PNG image tiles with specified size and level of detail.

Client

The client utilizes the three.js [16] framework to render a 3D visualization of the PTS system for the user. The user interface allows the user to manipulate his/her viewpoint in 3D, as well as highlight the single or multiple bus routes of the municipality by selecting them from a menu. When a bus route is highlighted, the user can also click on individual bus stops to visualize their timetables. The translation and rotation of the viewpoint takes place utilizing a mouse or touchpad. The 2D map data as well as the infrastructure data is loaded dynamically according to camera coordinates. The images for the 2D map data is fetched from Google Maps API [13]. The image tiles are chosen from three different sizes of varying detail according to the camera vertical position. The 3D scene consists of a street map that is layered among the ground plane, coupled with 3D content that is generated utilizing the OSM Overpass API [10]. The 3D objects that describe the city infrastructure consist of buildings and vegetation areas. Vegetation areas are occupied by randomly placed trees and bushes represented as textured cone or sphere primitives. The generated vegetation type depends on whether the area is specified as forest and/or park. Buildings are generated by extruding vertically from the spatial dimensions of the buildings according to the building height. The walls and rooftops of the buildings are textured with generic building images. The 3D content that describes the bus mobility, is generated from municipality open data. The bus movement is approximated using to the GPS coordinates received from the GTFS data. The route line number of the bus is visualized on the roof of the bus as well as a floating number when buses are far away.

Server

The Virtual Bus server hosts static files and also acts as a reverse proxy to transfer data from the third party data sources described above. The static GTFS data [15] (for route, destination and timetable information) is hosted in a SQLite database for efficiently joining various GTFS data upon client requests. The real-time GTFS [14] provided by the municipality service provider is also buffered in a SQLite database, and served through an interface similarly to the static GTFS.

EVALUATION

We evaluated the Virtual Bus system with a user study to inspect the potential of utilizing 3D content in web-based PTS visualizations, as well as to gather specifications for further development. The evaluation was carried out as a mixed method user test where direct comparison was made between the Virtual Bus system and the current commercial online visualization system of the same PTS. After using each system, the participants were asked to fill a small questionnaire. The order in which the systems were introduced to the participant was alternated as the tests progressed. The questionnaire contained 8 questions in which the participants answered whether they agree or disagree in Likert 5 -scale. The participants were also able to give open feedback on the system. The questionnaire as well as the participants' responses can be seen in Figure 2. A total of 12 users participated in the evaluation.

CONCLUSION AND FUTURE WORK

We have examined the potential of visualizing public transportation systems utilizing 3D graphics in a web browser. The research was carried out by evaluating the Virtual Bus prototype that visualizes bus traffic through 3D visualization and open interfaces. The future work consists of refining the Virtual Bus prototype further. The obvious flaws of the system, such as the inaccurate bus movement, are fixed during the next stage of the prototype development. Other properties are added the according to specifications provided by municipality traffic officials. Our future plans also include utilizing detailed mesh-models as well as other game-engine visuals in the Virtual Bus system. This allows us to investigate the use of real-time PTS visualization in the context of immersive multi-user virtual worlds.

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