Web-based visualization of real-time LADAR data with support for collaboration

Technical report [DRAFT]

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Abstract

In this report, we present a web-based visualization system developed for visualizing real-time point cloud data obtained from LADAR (or other) sensors. The system allows direct visualization of captured data, visualization of data from database or visualization of preprocessed data (e.g. labeled or. classified data). The system allows the concurrent visualization from same or different data-sources on multiple clients in the web browser. Due to the use of modern web technologies the client can be also used on mobile devices. The system is developed using Bootstrap, Angular, NodeJS and PostgreSQL. The system allows connection with existing LADAR sensor grabber application developed in C++ through use of UDP sockets. Both server- and client-side parts of the system are modular and allow the integration of newly developed modules and designing the specific workflow scenarios for end-users. The system allows the interactive visualization of datasets with millions of points as well as streaming visualization with high throughput speeds.

This technical report presents a research and development work performed between July 8th and October 8th 2017 – during the research exchange visit of Ciril Bohak at Optomechatronics and Multi-Scale Robotics Laboratory at School of Engineering, College of IT Engineering, Kyungpook National University, Daegu, The Republic of Korea.

1 Introduction

There are many different ways of storing and presenting the data describing the world around us. One of more popular ways in the recent years is use of point cloud representation — a set of points in space which store different parameters and information regarding the specific spatial location. Such representation is mostly used for representing the shapes of the objects and surrounding world, but can also be used for storing other information (e.g. meteorological data, physical measurements, simulation data etc.). In our case the point cloud data is describing the surrounding world and objects in it.

Point cloud data for shape representation can be acquired using several different sensors (e.g. depth camera [1], LiDAR [2] or LADAR [8]) or can be even extracted from image data [5]. In our case the LiDAR and/or LADAR sensors were used to acquire the point cloud data representing the shape of the world (terrain, vegetation, buildings, etc.). While the LiDAR data is acquired from the planes (see Figure 1a) the LADAR data is acquired from stationary ground position using gimbal system (see Figure 1b).

Real-time visualization of large point cloud data sets with up to tens or hundreds of millions of points poses a challenge even with today's GPU hardware. This is even more true if we want to display real-time streaming data with lots of newly added points per time frame (e.g. hundreds of thousands of points per second). To achieve such performance even on consumer accessible hardware (or even on mobile devices) several limitations have to be defined.

A very important aspect for fast real-time visualization of large point cloud data sets is also the ability to provide such large amount of data fast enough to the visualization system. For streamed data this

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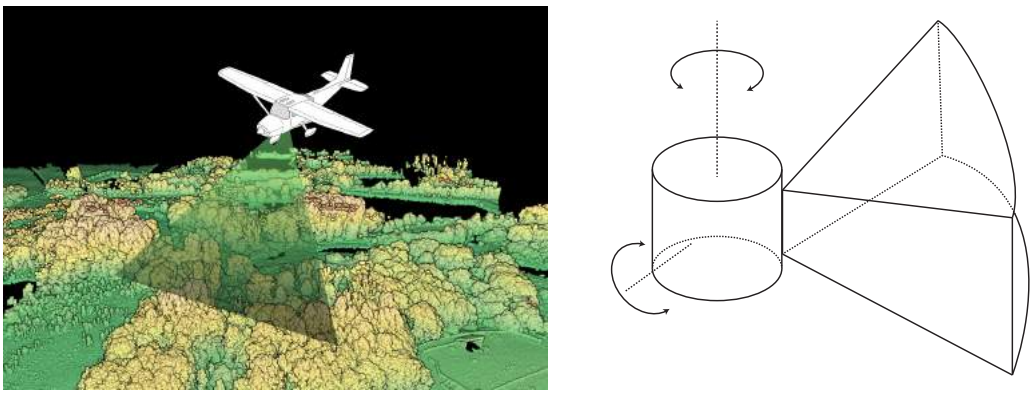


(a) (b)

Figure 1: Figure shows the acquisition process for LiDAR terrain data by plane (a) and an example of LADAR sensor structure (b)

speed is defined by speed of input sensors, but providing the already stored data at high speed is also important [7].

While the data visualization for as single user is the main goal it is often appreciated if the same data visualization can bee seen by multiple users at the same time or even if those users have an option of mutual interaction with the data. Such collaborative approach is well known in online productivity tools (e.g. Google Docs) and even in some specialized scientific tools. Such example for collaborative annotation of medical data with use of modern web technologies [3] does not only allow the collaboration between user at a distance but also allows replacement of specialized software and hardware with a modern web browser. A similar concept is exploited in the presented system.

In the following section we present the developed system for real-time visualization of 3D point cloud data with support for real-time data streaming, collaborative viewing and labeling of the data. In the final Section 3 we present the conclusions and give the pointers for possible future work.

2 Developed System

The main goal of the research was to determine whether it is possible to develop a real-time massive point cloud visualization system with support for visualization or real-time streamed data with support for multi-user viewing and labeling of the visualized data. Figure 2 shows the basic structure of the system: (1) Data Sender[1] is a standalone application for reading raw sensor data and sending it to desired application, (2) Data Preparation Module is a server based application for acquiring the data, packaging the data into desired form and sending the data to (3) Data Storage module or (4) Data Visualization Module – a web application with support for WebGL for real-time visualization of point cloud data. The developed modules (2-4) are presented in more detail in the following subsections.

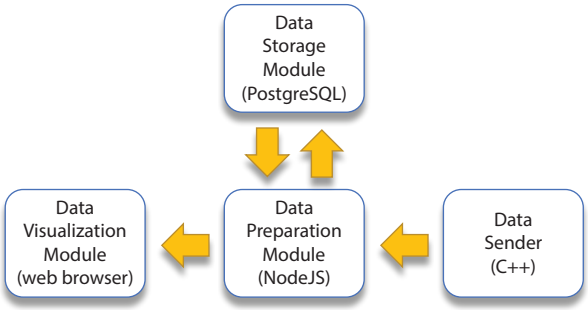


Figure 2: The basic system structure.

[1]The application is developed in C++ and does was not developed as part of the presented work

2.1 Data Preparation Module

The Data Preparation Module is a NodeJS[2] based server side application developed for linking the Data Visualization Module with data resources. Data resources can be either real-time data provider such as Data Sender or offline providers such as Data Storage Module. While data from Data Sender is acquired from sensors and directly sent to Data Visualization Module, it is up to the Data Preparation Module to request the data from Data Storage Module.

The application supports multiple connections and can simultaneously handle multiple data streams (live streams and data storage requests) and pipe them to multiple users. This allows multiple users to request data from diverse data sources. The module will prepare the data and send it to the users who requested it. Currently the system does not support user management, but distinguishes between clients using uniquely generated tokens. The layer of security was ignored at this stage of development due to specific use-cases where such security will not be needed (completely independent computer network or single computer deployment).

The Data Preparation Module also allows to simultaneously send the data obtained from Data Sender to data storage module, where the data is stored, and to multiple data visualization modules where the data is displayed in real-time. The communication between Data Preparation Module and Data Visualization Module is implemented using Socket.IO[3] – a library for fast and reliable continues communication. The communication with Data Sender is implemented using standard UTP sockets.

The data from Data Sender is received in form of binary blocks, where each block contains information from 200 points. Each point is represented with x, y and z position values with 32-bit float precision. Each package is directly submitted to all the clients (Data Visualization Modules) who are subscribed to live data streaming.

For preparation of stored data, module allows customization of query commands sent to the Data Storage Module. Some parameters of for query commands can also be defined by users through settings in Data Visualization Module. The data obtained from the Data Storage Module is packed and sent in JSON form to the client which requested it, but can also be packed into binary form for faster transmission.

While the basic functionality of module is to obtain, prepare and send the point cloud data, it can be easily extended for use with data from other domains as well. Such example might be the use of ortho-photo data or other GIS data for purposes of better final visualization.

2.2 Data Storage Module

Data Storage Module consists of a NodeJS based server side application for interfacing with PostgreSQL[4] relational database with Pointcloud extension[5]. The extension deals with the variability of point dimensionality by using custom database schema which describes the content of individual point in the database. This takes care of number of point dimensions and their data types and possible scaling and/or offsets between the actual values and values stored in database.

The above presented storage is not the fastest possible option for storing large amounts of point cloud data, but offers a good trade-off between complexity of use, speed and price [7].

2.3 Data Visualization Module

The Data Visualization Module was developed as web application using Angular[6] and Bootstrap[7] for implementing interactive responsive GUI, and ThreeJS[8] and Potree [6] for implementing fast and reliable 3D visualization using WebGL technology.

The module's GUI consists of two parts as can be seen in Figure 3: (1) preferences panel on the left, where users can select the data source and set the parameters of the visualization and (2) visualization panel on the right, where users can see and interact with displayed data.

In preference panel users can select data source from one of the existing databases or they can turn on the live data receiving option. User can set next database point loading parameters:

Number of concurrent loading patches: points in database are stored in patches containing several number of neighboring points according to their spatial position. This allows faster retrieval of neighboring points. We can choose how many patches of points we want to load in one call and thus speeding up the database response time.

[2] https://nodejs.org/
[3] http://socket.io/
[4] https://www.postgresql.org/
[5] https://github.com/pgpointcloud/pointcloud
[6] https://angular.io/
[7] http://getbootstrap.com/
[8] https://threejs.org

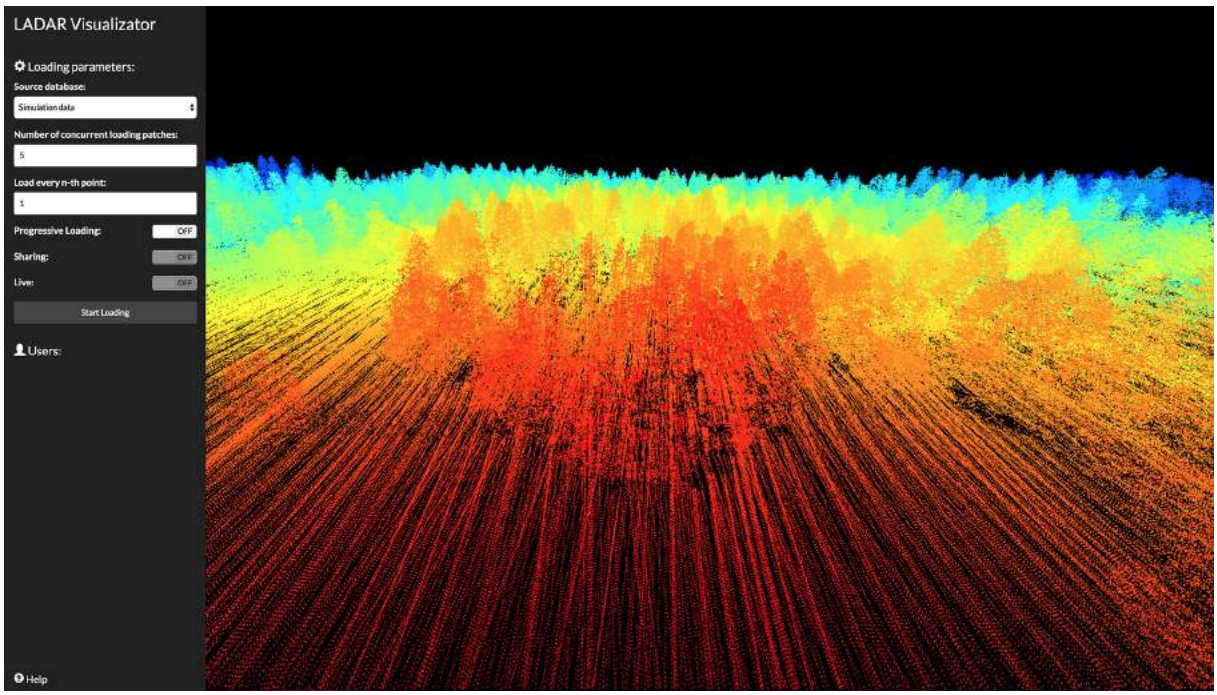
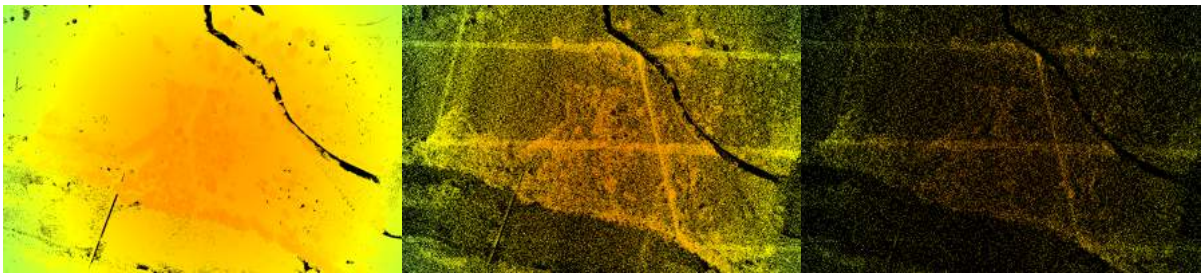


Figure 3: The Data Visualization Module GUI.

Load every n-th point: in dense point clouds it is not necessary to load all the points to get the idea of the shape they are representing. For this reason users can choose the density of points they want to display selecting only every n-th point in the database according to the geolocation sorting. This also means that client will draw less points which will result in higher frame rate. An example of visualization of same data with different setting can be seen in Figure 4.

Progressive loading: when the option of loading every n-th point has value higher than 1 this switch will define whether after every n-th point is loaded the loading will continue with incremented offset or not.



(a) Every point is loaded. **(b)** Every 10-th point is loaded. **(c)** Every 50-th point is loaded.

Figure 4: The comparison of the same data visualization with different setting for loading every n-th point.

Users can navigate in the visualization scene with use of mouse and keyboard. Mouse is used for simple view rotation and zooming. The keyboard is used for moving the camera view through the scene, speed of navigation can be adjusted by changing the velocity multiplier.

When switch for Live data visualization is active the visualization module is waiting for the data to be piped from Data Sender through Data Preparation Module in real-time. If no Data Sender is connected to Data Preparation Module or no data is sent, the Data Visualization Module will wait and no data will be rendered.

Colors of visualization display the distance from camera to individual point. A jet colormap is used to represent distances (red being closest and dark blue being the farthest away). Colormap is scaled for individual data set and can be adjusted easily. To make distance even more apparent the size of rendered points decreases with distance.

The visualization module also supports selection of desired points in the point cloud. Because the interaction with individual point would require too much overhead only selection of point groups is

supported in the current version. The size of groups can be defined as parameter. In our case the size of few thousands points per group in data set with millions of points proved to be best option for good performance. To allow faster selection of groups of points we allow two-level point selection: (1) single group under mouse cursor is selected and (2) all the groups with points under mouse cursor are selected. The focused points are rendered with pink color while selected points are rendered in white (both colors are not in jet colormap and are thus easily distinguishable from the rest). An example of focused and selected point groups can be seen in Figure 5.

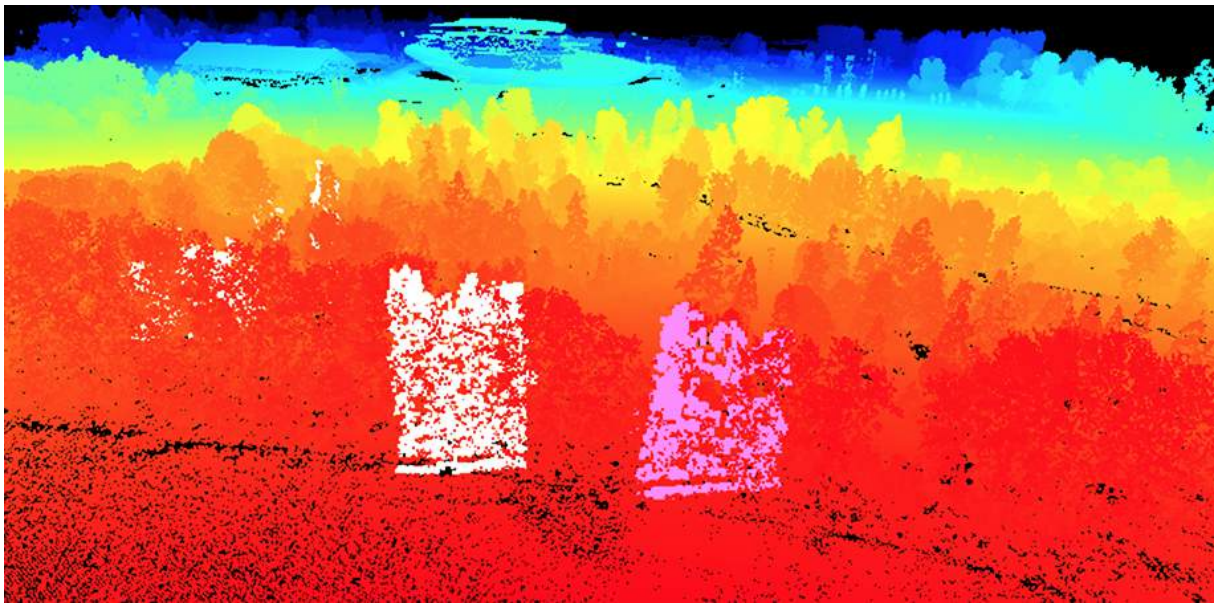


Figure 5: The example of focused points (pink) and selected points (white).

To get even better visualization experience, complete Potree visualization pipeline could be integrated, adding point shadowing and other more advanced visualization features.

2.4 Collaboration

Collaboration allows users to share their view on data with other users in real time similar to [4]. The user initiates sharing with activating share switch in preferences panel. Once activated other users can see such users in list of users (as shown in Figure 6a) and connect to a selected user by clicking on button with his/her name (see Figure 6b). Users that want to join the shared session must do so before the host user initiates data loading. After the loading is initiated by host other users can not connect anymore. The initiation of the loading starts loading the data from same database for all the connected users. The data loading is independent for each user due to the different speeds of the network connections and request handling speed of individual client.

(a) List of users who are sharing their view. **(b)** Connected to a selected user.

Figure 6: The sharing options.

The synchronization is implemented as presented in the Figure 7. Currently only the following types of sharing is supported by the system: (1) camera view parameters, (2) loading initiation cancellation and (3) data selection. While view and loading initialization are only shared in one direction (from host

to connected users) the data selection is supported in both directions and the selection state is kept on the server. The framework supports simple implementation for sharing other data or parameters as well.

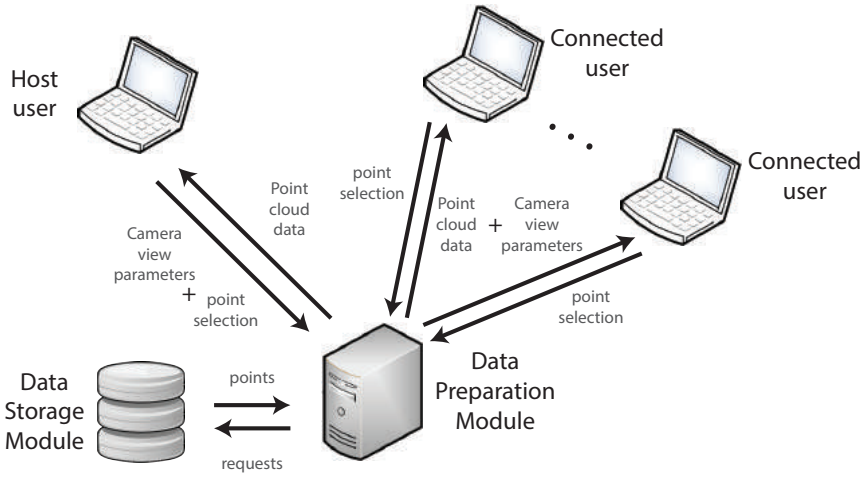


Figure 7: The diagram is showing how the shared data is distributed.

3 Conclusion

The presented system is still under development and some features are still to be implemented. Still, it presents a novel approach to collaborative view on large point cloud visualization on consumer-level hardware.

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