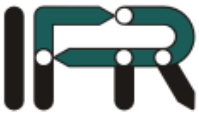
Technical University of Braunschweig
Institute of Control Engineering
Department Vehicle Electronics
Prof. Dr.-Ing. Markus Maurer



TUBS Road User Dataset

Data Format Documentation

Author: Christopher Plachetka, M. Sc.
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1 Structure

1.1 Batches and recordings

Our dataset is organized in various recordings. The TUBS batch contains recordings with automatically and manually labeled laser scans as well as corresponding images. The TUBS Point Cloud Only batch contains solely automatically labeled laser scans.

All recordings are organized with respect to the specific conditions during their creation, such as weather, daytime or domain. Both batches provide a PrelabelingConfig.xml file that contain ID or timestamp information. The configuration files are part of our labeling tool, which can be downloaded on GitHub [1]. Table 1.1 and Table 1.2 give an overview of the TUBS and Point Cloud Only batch, respectively. Recordings marked with (L) were made with our second research vehicle.

Table 1.1 Recordings in the TUBS batch

Name	Point clouds	Images	conditions
City Ring - Mid Day	12,200	36,600	– weather: sunny – traffic density: average
Inner City - Mid Day	8,400	25,200	– weather: sunny – traffic density: average
Motorway - Mid Day	11,900	36,600	– weather: sunny – traffic density: light

Table 1.2 Recordings in the TUBS Point Cloud Only batch

Name	Point clouds	Images	conditions
City Ring - Light Snow	15,000	-	– weather: snowy – traffic density: average
City Ring - Mid Day (L)	9,300	-	– weather: sunny – traffic density: average
City Ring - Mid Day (L) II	21200	-	– weather: cloudy – traffic density: average
City Ring - Mid Day (Winter)	17,000	-	– weather: cloudy – traffic density: average
City Ring - Rain (L)	15,700	-	– weather: rainy – traffic density: average
City Ring - Rush Hour	17,500	-	– weather: sunny – traffic density: high
City Ring - Rush Hour (Winter)	9,900	-	– weather: sunny – traffic density: high
Inner City - Rush Hour	8,500	-	– weather: sunny – traffic density: high

Motorway A2 - Rush Hour	6,300	-	– weather: cloudy – traffic density: high
Motorway A2, A39 - Rush Hour	16,000	-	– weather: sunny – traffic density: high

1.2 Directories

Every recording is split into several directories containing different data types. Table 1.3 explains these directories. The file structures are explained in detail in section 2. Every directory contains a number of sequences within which temporal consistency is ensured. Rare gaps between sequences may occur whenever a sample is missing in the sensor recording. Within a batch, sequence and sample IDs are unique (both 10 digits numbers).

Table 1.3 Directories

Name	Datatype	Explanation
ImageData_*ImageType*	jpg	Images of the specific image type
ImageLabels_*ImageType*	xml	Image metadata information (e.g. timestamps or size) and image labels (object lists)
PCDataMatrices	bin	Point cloud data (e.g. range and reflection) stored as data matrices
PCMovableMatrices_Edited	bin	Extension of PCDataMatrices: The matrices assign a label and an object list entry to every point. Generated by the TUBS labeling tool.
PCMovableMatrices_Prelabeled	bin	Label and object list assignments generated by the automatic labeling system
PCMetadata	xml	Point cloud metadata (e.g. timestamps or ego movement)
PCMovableLabels_Edited	xml	Point cloud object lists created by the TUBS labeling tool [1]
PCMovableLabels_Prelabeled	xml	Point cloud object lists created by the automatic labeling system

2 File formats

2.1 Image labels

Table 2.1 explains the data fields of an image label file (*SampleID*_ImageLabels_*ImageType*.xml).

Table 2.1 Data fields of an image label file

Name	Datatype	Explanation
FormatVersion	Float	Current data format version
ImageType	String	Image type (front, right, rear, left)
Height	Integer	Image height in pixels
Width	Integer	Image width in pixels
Timestamp	Integer	Timestamp of the moment the image is taken (after exposure). Currently, we reset the cameras' internal clocks periodically. In future releases, we will use the PTP protocol.
PCDeltaT_ms	Float	Time difference between the point cloud's timestamp at the Velodyne's position that triggers the image and the image timestamp. This is only a rough estimate until we timestamp the images using the PTP protocol.
Labels	List	Object vector
Object	Object	Object structure containing the label information as stated by the fields below
Class	String	Classification (car, van, license plate etc.)
ShapeType	String	3D (3D bounding box), rectangle (for license plates and faces), polygon (coarse segmentation)
VertexVector	List	List of all (x, y) tuples specifying the position in the image. Rectangle: 4 outer edge points. 3D: 8 edge points and one last vertex indicating the middle position. Polygon: All vertices.
Vertex	Object	Tuple of x and y positions
x	Float	x position of a vertex
y	Float	y position of a vertex

2.2 Point cloud data

2.2.1 Data matrices - PCDataMatrices

The sensor's reference frame is shown in Fig. 2.1. Our Velodyne HDL-64E records 64 layers and 2000 channels (discretized azimuths).

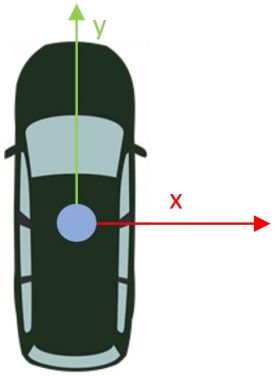

Fig 2.1 The scanner's reference frame

Point clouds are stored as binary files (*SampleID*_PCDataMatrices.bin). In order to keep the scan's structure, a file contains complete matrices with the size of 64-by-2000 (written layerwise: (layer 0, channel 0), (layer 1, channel 0), etc.). The matrices are written in the same order as in Table 2.2 (first Valid, then Range etc.). Values that are stored as 16-bit integers need to be divided by the factor 100. Table 2.2 explains the specific data matrices. Datatypes marked with an (u) are unsigned.

Table 2.2 Data matrices of a point cloud file

Name	Datatype	Explanation
Valid	8-bit integer (u)	Indicates if a point is a valid measurement
Range	16-bit integer	Range measurement
Intensity	16-bit integer	Intensity of the reflected beam
X	16-bit integer	A point's x position in the Cartesian reference frame of the sensor (calibrated)
Y	16-bit integer	A point's y position in the Cartesian reference frame of the sensor (calibrated)
Z	16-bit integer	A point's z position in the Cartesian reference frame of the sensor (calibrated)
GroundLevelZ	16-bit integer	The z position (Cartesian sensor reference frame) of the ground level at the current point's position (x, y, z) or (layer, channel), respectively. This value originates from our vehicle's ground estimation.

2.2.2 Data matrices - PCMovableMatrices

The binary files containing the label and object list indices (*SampleID*_PCMovableMatrices_-*Prelabeled/Edited*.bin) follow the same principles as described in section 2.2.1. Table 2.3 explains the data matrices.

Table 2.3 Data matrices of a point cloud file

Name	Datatype	Explanation
LabelID	8-bit integer (u)	The point's label as specified in the EditorConfig.xml file (download at [1])
ListIndex	8-bit integer (u)	Referencing a point to a specific object list entry *(SampleID*_PCMovableLabels_Edited.xml or *SampleID*_ PCMovableLabels_Prelabeled.xml). Objects within those xml files are identified by an ascending index.

2.2.3 Point cloud metadata

The data fields of a metadata file (*SampleID*_PCMetadata.xml) are described in Table 2.4.

Table 2.4 Data fields of a metadata file

Name	Datatype	Explanation
FormatVersion	Float	Current data format version
PCID	Integer	Point cloud (sample) ID. All related files (e.g. corresponding images) share the same ID.
RecordingName	String	Recording from which this sample originates
isFristOfSequence	Boolean	True if sample is the first in this sequence
isLastOfSequence	Boolean	True if sample is the last in this sequence
SegmentsAvailable	Boolean	True if segments IDs were exported (not supported in the current release)
NumberOfLayers	Integer	The scanner's number of layers
NumberOfChannels	Integer	The scanner's number of channels
EgoVx	Float	Ego velocity in x direction (m/s), sensor reference frame
EgoVy	Float	Ego velocity in y direction (m/s), sensor reference frame
EgoAx	Float	Ego acceleration in x direction (m/s^2), sensor reference frame
EgoAy	Float	Ego acceleration in y direction (m/s^2), sensor reference frame

EgoYawRate	Float	Ego yaw rate per second (°/s). Turn rate around the z-axis, sensor reference frame.
EgoVarVx	Float	Variance of ego velocity (x) (estimate)
EgoVarVy	Float	Variance of ego velocity (y) (estimate)
EgoVarAx	Float	Variance of ego acceleration (x) (estimate)
EgoVarAy	Float	Variance of ego acceleration (y) (estimate)
EgoVarYawRate	Float	Variance of ego yaw rate (estimate)
EgoLongitude	Float	Geo position (longitude) in WGS 84 coordinates (°)
EgoLatitude	Float	Geo position (latitude) in WGS 84 coordinates (°)
Timestamp_us	Integer	Timestamp in microseconds (averaging FirstTimestamp_us and LastTimestamp_us)
FirstTimestamp_us	Integer	Timestamp of first measurement in this scan
LastTimestamp_us	Integer	Timestamp of last measurement in this scan
Successor_PCID	Integer	Next point cloud ID in sequence (0 if point cloud is the first of the current sequence)
Successor_Timestamp_us	Integer	Timestamp (average) of next point cloud in sequence
Successor_FirstTimestamp_us	Integer	Timestamp of the next scan's first measurement
Successor_LastTimestamp_us	Integer	Timestamp of the next scan's last measurement
Predecessor_PCID	Integer	Previous point cloud ID in sequence (0 if point cloud is the last of the current sequence)
Predecessor_Timestamp_us	Integer	Timestamp (average) of previous point cloud in sequence
Predecessor_FirstTimestamp_us	Integer	Timestamp of the previous scan's first measurement
Predecessor_LastTimestamp_us	Integer	Timestamp of the previous scan's last measurement
ImagesAvailable_*ImageType*	Boolean	Indicator if a specific image is available

2.2.4 Point cloud labels

Both types of point cloud label files (*SampleID*_PCMovableLabels_*Prelabeled/Edited*.xml) follow the same structure as described in Table 2.5.

Table 2.5 Data fields of point cloud label files

Name	Datatype	Explanation
FormatVersion	Float	Current data format version
Object	Object	Object structure containing the label information
PositionInList	Integer	List entry as ascending number. This number is referenced by the *SampleID*_PCMovableMatrices_*Prelabeled/-Edited*.bin files in order to map a specific point to an object.
TrackID	Integer	The object's track ID. Unique only within a recording.
isActive	Boolean	Indicates if the object is an active road participant (false for parking cars, parking bicycles, sitting pedestrians etc.)
ExistenceLikelihood	Float	Existence mass of the current object as estimated by our vehicle's tracking system
Classification	String	Class of current object. We provide six classes in our prelabeling stage: Car, van truck, bicycle, motorbike and pedestrian. Our labeling tool is not restricted.
Timestamp	Integer	Last measurement or prediction timestamp in microseconds
ProbabilityVector	List	List of class objects specifying the object's probability for specific classes
Class	Object	Tuple of name and probability
Name	String	Name of class
Probability	Float	Probability of that class
BBMiddle_x	Float	Position of bounding box middle (x), sensor reference frame (m)
BBMiddle_y	Float	Position of bounding box middle (y), sensor reference frame (m)
BBMiddle_z	Float	Position of bounding box middle (z), sensor reference frame (m)
BBHeight	Float	Height of bounding box (m)
BBWidth	Float	Width of bounding box (m)
BBLength	Float	Length of bounding box (m)

BBYaw	Float	Heading of the bounding box (°). Objects facing in the sensor's x direction have a BBYaw of 0° (90° when facing in the sensor's y direction).
VxAbs	Float	Absolute velocity in x direction (m/s), sensor reference frame
VyAbs	Float	Absolute velocity in y direction (m/s), sensor reference frame
AxAbs	Float	Absolute acceleration in x direction (m/s^2), sensor reference frame
AyAbs	Float	Absolute acceleration in y direction (m/s^2), sensor reference frame
YawRatePerDist	Float	Yaw rate per distance (°/m)
VarBBMiddle_x	Float	Variance of the position estimation (x)
VarBBMiddle_y	Float	Variance of the position estimation (y)
VarVxAbs	Float	Variance of the velocity estimation (x)
VarVyAbs	Float	Variance of the velocity estimation (y)
VarAxAbs	Float	Variance of the acceleration estimation (x)
VarAyAbs	Float	Variance of the acceleration estimation (y)
VarBBYaw	Float	Variance of the yaw estimation
VarBBYawRatePerDist	Float	Variance of the yaw rate estimation

Attachments

[1] https://github.com/TUBSDataset/TUBS_LabelingTool