TrimBot2020 Deliverable D1.1

Platform 1: Sensor Data Collection including Ground Truth

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Abstract: This document gives an overview of the first data collection session including the recorded ground truth data. During this data collection session several scenarios with a prototype vehicle and with a handheld camera setup were performed. In addition to these data sets also a ground truth point cloud model of the entire garden was recorded with a Leica laser scanner. An overview of the vehicle, the sensors used for the ground truth data recording and the handheld camera setup is given in this document. A selection of the recorded scenarios and the reference point cloud are also shown.

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1   Vehicle Platform 1

The platform 1 is a modified Indego lawn mower. It is equipped with 6 monochrome and two colour cameras from ETHZ. The cameras are placed on a tower in the centre of the vehicle and are arranged in an octagonal setup. The colour cameras are mounted to the front and front right position. In addition to the cameras several sensors for ground truth data recording are integrated into the vehicle. A Velodyne VLP16 lidar sensor is mounted above the cameras to record a reference point cloud from the same point of view. An IMU sensor and an external position tracking system are used to estimate the 6-DOF ground truth position of the vehicle. The external position tracking system requires a prism reflector on the vehicle. Figure 1 shows the platform 1 as used for the ground truth data recording session. A more detailed description of platform 1 is given in deliverable D6.1 (First Integrated Platform).

Figure 1: First integrated platform at the data recording session in Wageningen.

2   Handheld Camera Setup

To support the trimming task with close range images from the trimming object, further cameras will be mounted to the arm of the final demonstrator. These cameras are used for the visual feedback during the trimming action. To be able to record camera data as expected from the arm cameras, a handheld aluminum frame with 4 stereo camera pairs was created during the first data recording session in Wageningen. The base lines of the camera pairs are approximately 25 mm, 35 mm, 45 mm and 55 mm. Figure 2 shows this handheld setup. A reflecting prism is

Figure 2: Handheld setup with four stereo camera pairs.

mounted on top of the handheld frame to track the position with the external position tracking system. The data from all eight cameras together with the tracked position was recorded during the data recording sessions in Wageningen.

3 Ground Truth Data

During the first data recording session in Wageningen several ground truth data sets were recorded. First, a Leica ScanStation P15[1] was used to record a ground truth point cloud from the entire test garden. A more detailed description of this ground truth point cloud data set and the sensor accuracy is given in Section 3.1. A second reference point cloud from the ego perspective was recorded during every recording run with the Velodyne VLP16[2] lidar sensor. An example for such a point cloud is shown in Section 3.2. In addition to these point clouds, the tracked position of the vehicle and measurements from an integrated IMU sensor are recorded. Therefore, a STIM300[3] IMU sensor and the Topcon Total Station[4] position tracking position system are used. According to the datasheet of the Topcon Total Station, the distance measurement accuracy when using a prism which is standing still is 1.5 mm + 2 ppm. When the prism is moving and is tracked by the robotic Total Station, we assume an accuracy of ~ 1 cm. Based on the tracked vehicle position and the recorded IMU measurements a 6-DOF ground truth position of the vehicle is calculated in a post processing step. The calculation of this

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[1]Leica ScanStation P15 data sheet.

[2]Velodyne VLP16 data sheet

[3]STIM300 data sheet

[4]Topcon PS Series Robotic Total Station data sheet

ground truth vehicle position is presented in more detail in Section 3.3.

The position of the vehicle and respectively all video and point cloud data is recorded w.r.t a global coordinate system. For each test garden this global coordinate system is defined before the first data recording session starts. After the initial definition of this global frame it is used for all the data recording runs over all sessions. The global reference frame is defined by several reflecting markers which are placed on fixed positions in the garden. Figure 3 shows two of these markers placed on fence posts. With these markers the Topcon Total Station's position and respectively the vehicle's position can by localised w.r.t the initially defined global frame. The markers are also used to align the reference point cloud from the Leica ScanStation with the global frame.

Details on data structure, reference frames, semantic annotations and additional parameters will be described in D7.4 (Ground-Truth Data Definitions and Acquisition).

Figure 3: Markers used for relocalisation to the global reference frame.

3.1   Garden Reference Point Cloud

The Leica ScanStation P15 is used to record a high quality 3D point cloud from the entire test garden. This ScanStation combines distance measurements from a laser scanner and with the corresponding RGB values from a colour camera. The maximum measurements distance for the laser scanner is 40 m with an accuracy of 3 mm at 40 m. However, the range and the RGB measurements are performed sequentially thus the measurements are not synchronised in time. For moving objects this can lead to wrong RGB values: for example if a leaf of a tree moves between the distance and the colour measurement it gets the blue colour from the sky because the camera see the blue sky at that point where the leaf was before. This effect can be seen on the trees of the point cloud from the Wageningen test garden.

The point cloud from the test garden in Wagningen is shown in Figure 4. This point cloud consist of 280 million points and has a size of about 12 GB as text file. Due to the measurement range of the Leica scan station also object outside the test garden are included in this point cloud. To reduce the amount of data a second point cloud which is cropped to an area close to the test garden is also provided. This point cloud is further called garden_only point cloud. It is shown in Figure 5. However, this cropped point cloud has still 235 million points and a size of 10 GB as text file. To further reduce the amount of data, the point clouds were downsampled and compressed to a binary file format. Either the Leica Software or the 3D voxel grid filter

from the Point Cloud Library (PCL) were used for the downsampling step. For better data compression the binary point cloud format from the PCL was used.

Figure 4: Detailed 3D reference point cloud with included colour data from the test garden in Wageningen. The point cloud is recorded with a Leica ScanStation P15 during the first ground truth data collection session.
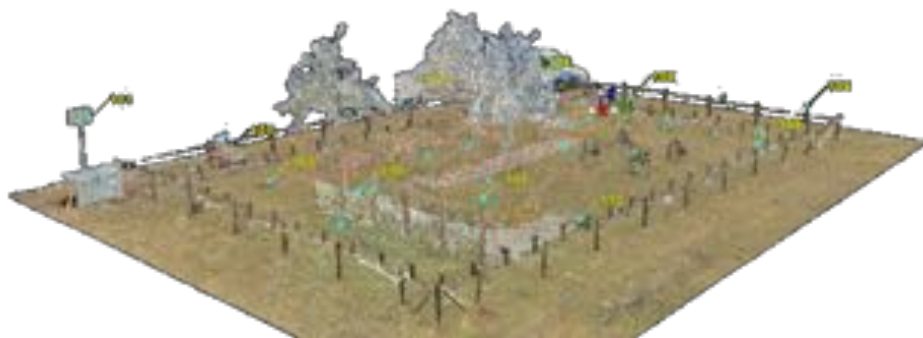

Figure 5: Cropped version of the Wageningen test garden point cloud (garden_only point cloud).

The filter from the Leica software reduces the points to achieve a minimal distance between two points of 10 mm. This filter reduces the full point cloud from 280 million points to 125 million points and the garden_only point cloud from 234 million points to 83 million points. However, the file size of this reduced point clouds is still 5.3 GB respectively 3.5 GB using the PCL binary file format. The 3D voxel grid filter from the PCL uses a 3D filtering object and approximates all the included points by their centroid. Thus, the size of the downsampled point cloud depends on the size of the filter object. For the Wageningen test garden a filter object of 0.01 m and 0.02 m is used. Downsampling the garden_only point cloud with a 0.01 m filter object leads to a point cloud with 16 million points and a file size of 254 Mb for the binary

PCL format. A detailed list of all point cloud files from the Wageningen test garden is shown in Appendix A.

Due to the message size limit of 1 GB, only the downsampled point clouds can be used in ROS. Example images from the Rviz visualisation of the downsampled garden_only point cloud are shown in Figure 6.
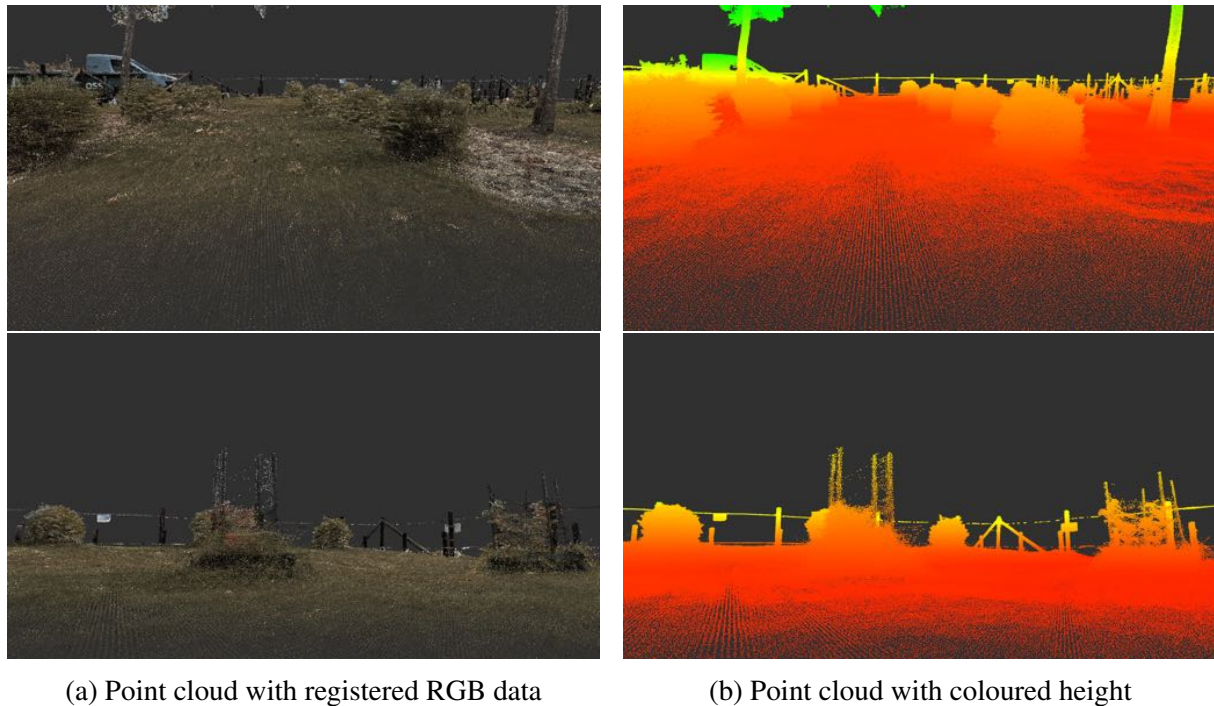

(a) Point cloud with registered RGB data   (b) Point cloud with coloured height

Figure 6: Detailed Rviz views from the downsampled garden_only point cloud. The upper two images show an example for the boxwood row and the lower two images show one of the roses.

3.2 Onboard Reference Point Cloud

A Velodyne VLP16 lidar sensor is mounted on top of the camera frame to record a reference point cloud from the ego perspective. This lidar sensor has a 360° horizontal field of view with an angle resolution from $0.1° - 0.4°$ depending on the rotation rate from 5 Hz - 20 Hz. For the ground truth data recording an angle resolution of $0.2°$ and a rotation rate of 10 Hz is used. The VLP16 has 16 horizontal rays. These rays span a vertical field of view of $\pm 15°(30°)$. The scanning range is up to 100 m with an accuracy of ± 3 cm. An example for a Rviz visualization of a VLP16 measurement in the Wageningen test garden is shown in Figure 7. In this example the vehicle is placed between two box row. Thus four box woods on the left and four on the right can be seen in the lidar data. The circles around the vehicle are the ground measurements from the downward looking rays.

3.3 Vehicle Position

The 6-DOF ground truth position of the vehicle is calculated based on the measurements from the external Topcon TotalStation tracking system and the Stim300 IMU sensor. The Topcon
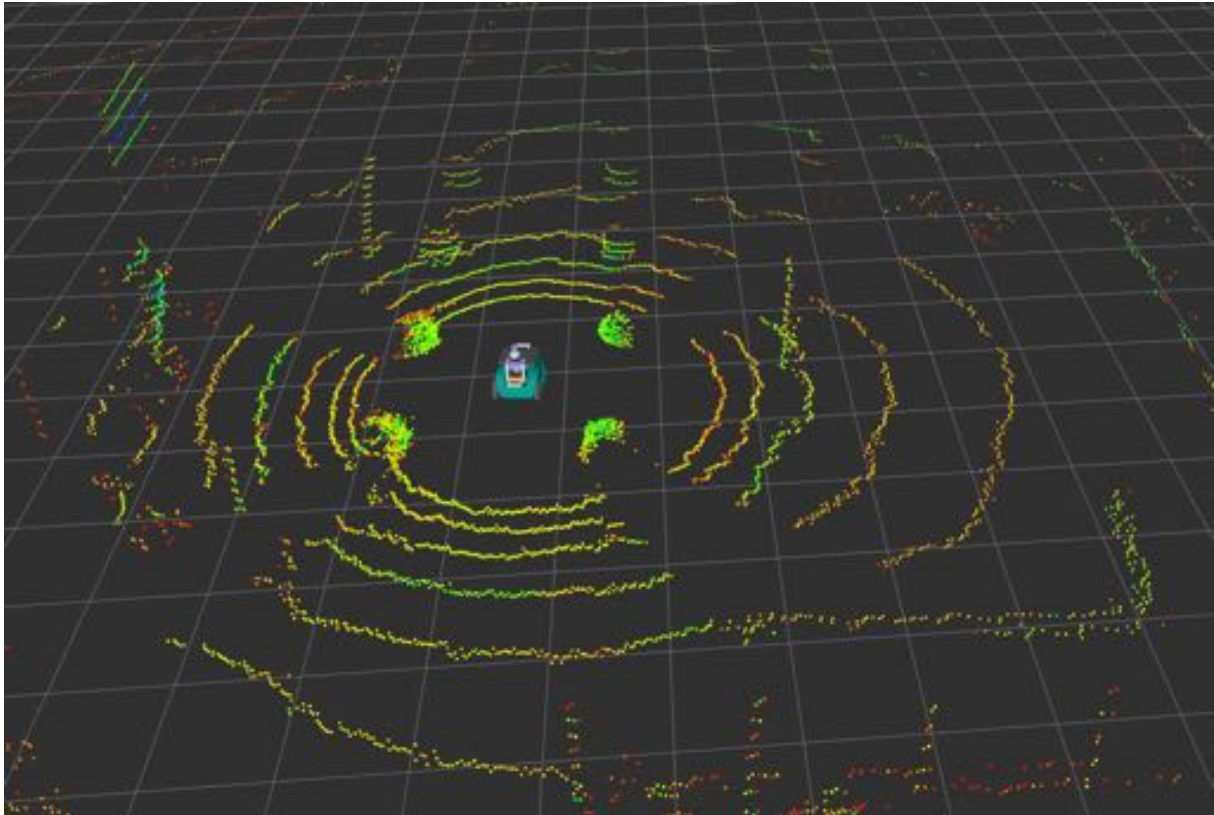
Figure 7: Example of a VLP point cloud recorded in the middle of the boxwood row.

Total Station is placed on a tripod and relocalised in the global reference frame for each data recording run. During the runs it tracks the position (x, y, z) of the prism on top of the vehicle w.r.t the global reference frame. To estimate the corresponding orientation (roll, pitch, yaw) the acceleration and rotation rate measurements from the IMU sensor are also recorded. Based on these measurements the orientation of the vehicle is calculated in an offline post-processing step using a strapdown filter implementation. The resulting orientation is then merged with the tracked position to achieve a 6-DOF ground truth pose of the vehicle.

4   First Data Recording Session Wageningen

The first data recording session took place from 30. August 2016 to 1. September 2016 in the Wageningen. During this data recording session, several scenarios with the platform 1, the handheld cameras and the Leica reference point cloud were recorded. The vehicle scenarios are presented in Section 4.1 and the handheld scenarios in Section 4.2.

The ROS recording method with bag files is used for all vehicle and handheld scenarios. A ROS bag is a file containing recorded ROS messages. These files are named bag files because of their .bag extension. A variety of tools have been written to allow recording, storing, processing, analyses, and visualization of them. For more information about ROS bags see the ROS wiki[5] [6].

## 4.1   Scenarios with Vehicle Cameras

The vehicle scenarios are grouped in three classes depending on their motion pattern:

1. Approach a plant or an obstacle

2. Drive around a single plant, a group of plants or the entire garden

3. Drive along a boxwood row or along a hedge

For all these scenarios, camera data, Velodyne point clouds and ground truth position of the vehicle were recorded. Several ground truth position plots for the approaching scenarios are shown in Figure 8. The blue lines in the images show the driven path. Examples for the drive around scenarios are shown in Figure 9 and examples for drive along scenarios are shown in Figure 10. Lists of all vehicle scenarios recorded during the data collection session in Wageningen are shown in the Appendix Table 2, Table 3 and Table 4.
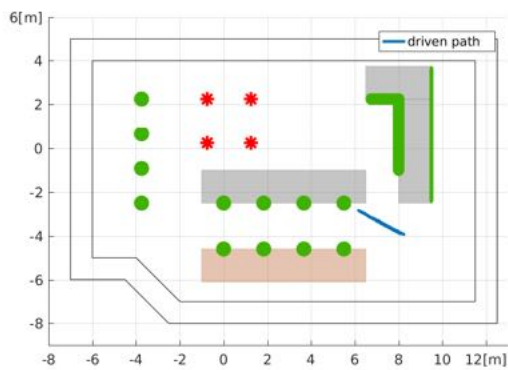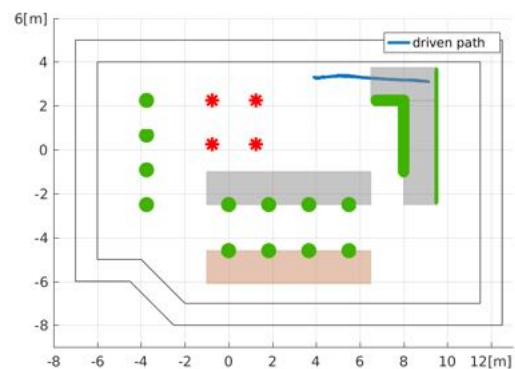

(a) Approaching a single boxwood
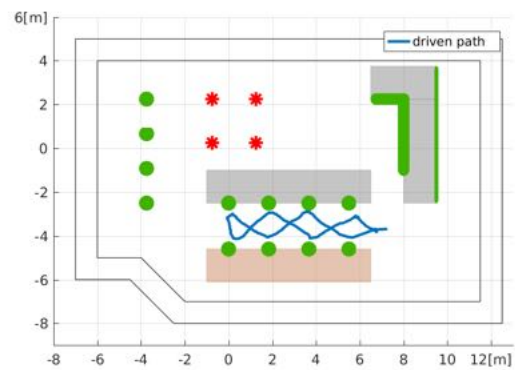
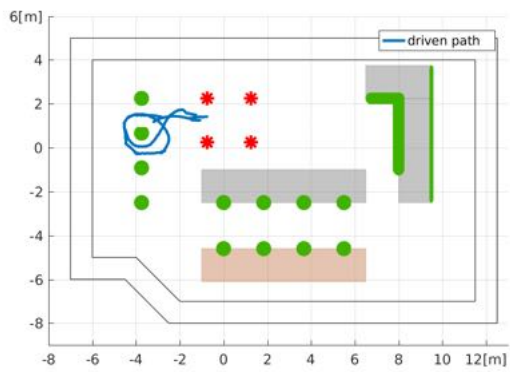(b) Approaching all boxwoods in the row
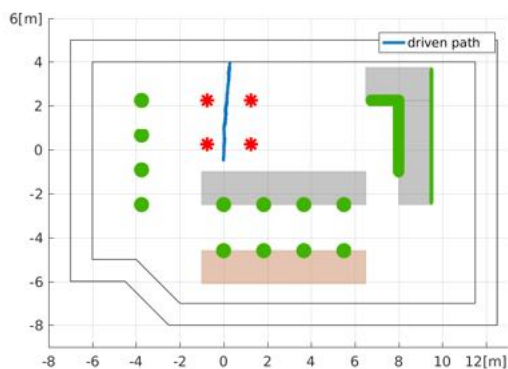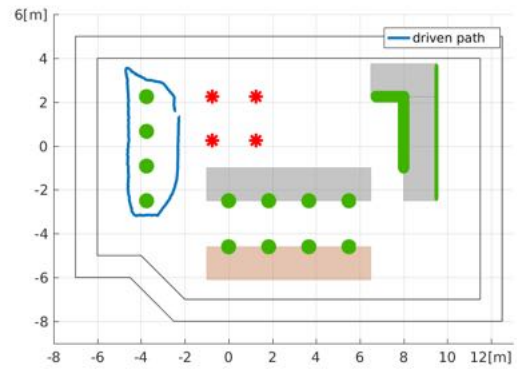

(c) Approaching the gravel

(d) Approaching the ivy hedge

Figure 8: Examples for approaching data sets. The blue line shows the driven path, the green circles the boxwoods and the red asterixs the roses.

(a) Around a single boxwood

(b) Around all boxwoods on the slope

(c) Around a single rose

(d) Around all roses

(e) Around the hedge
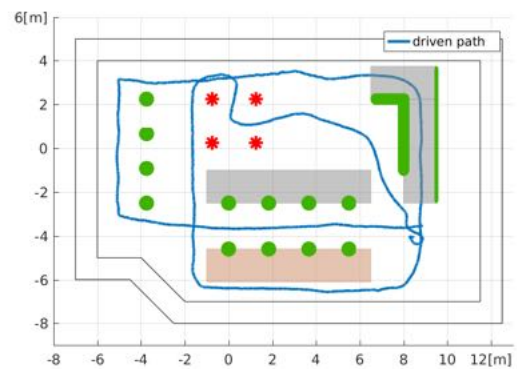
(f) Around the entire garden

Figure 9: Example for driving around data sets. The blue line shows the driven path, the green circles the boxwoods and the red asterixs the roses.
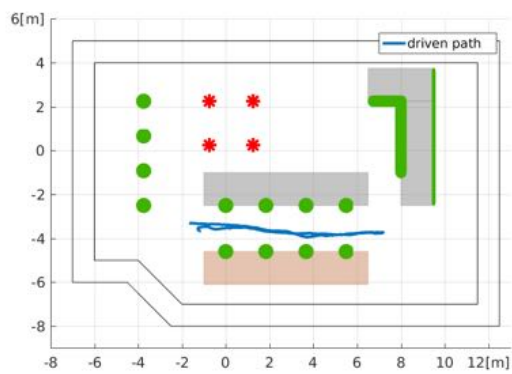
(a) Drive along the boxwood row   (b) Drive along the ivy hedge

Figure 10: Examples for drive along data sets. The blue line shows the driven path, the green circles the boxwoods and the red asterixs the roses.
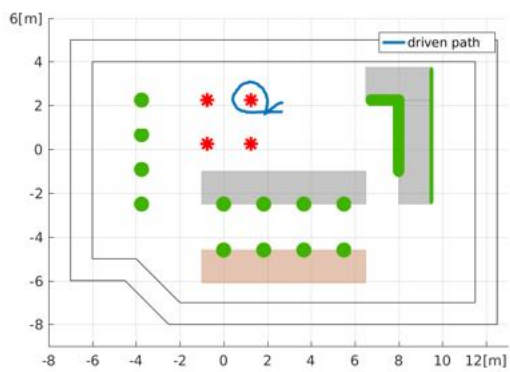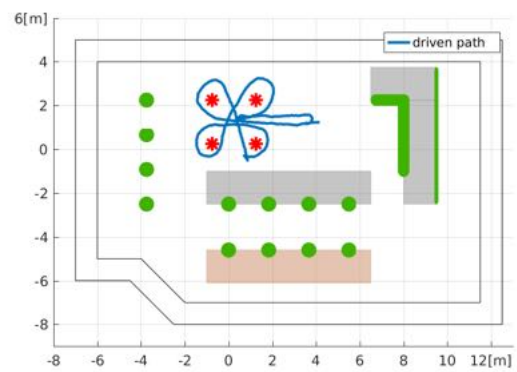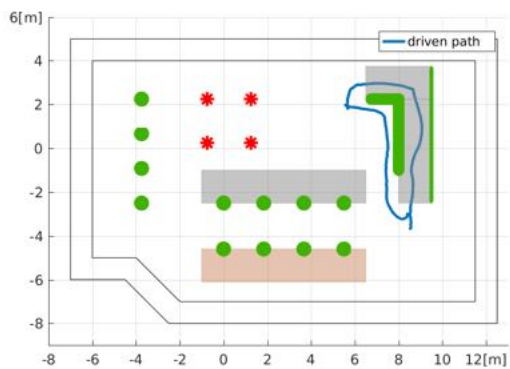
4.2   Scenarios with Handheld Cameras

The scenarios with the handheld device were recorded to have video data sets which are close to the video data expected from the arm cameras. During the first data recording session in Wageningen, scenarios were recorded for approaching a bush, move around a bush and move along a hedge. For move around a bush and move along a hedge scenarios with several distances to the ob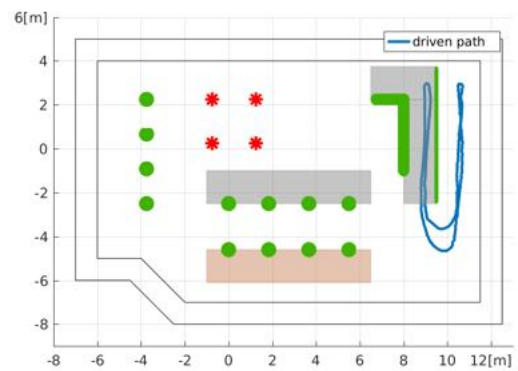jects are recorded. Four examples of handheld scenarios are shown in Figure11. A detailed list with all recorded scenarios is included in Appendix C. The handheld device used for the Wageningen data collection session is shown in Figure 2.

(a) Approaching a single boxwood

(b) Moving along the hedge

(c) Moving around a boxwood in close distance

(d) Moving around a boxwood in wide distance
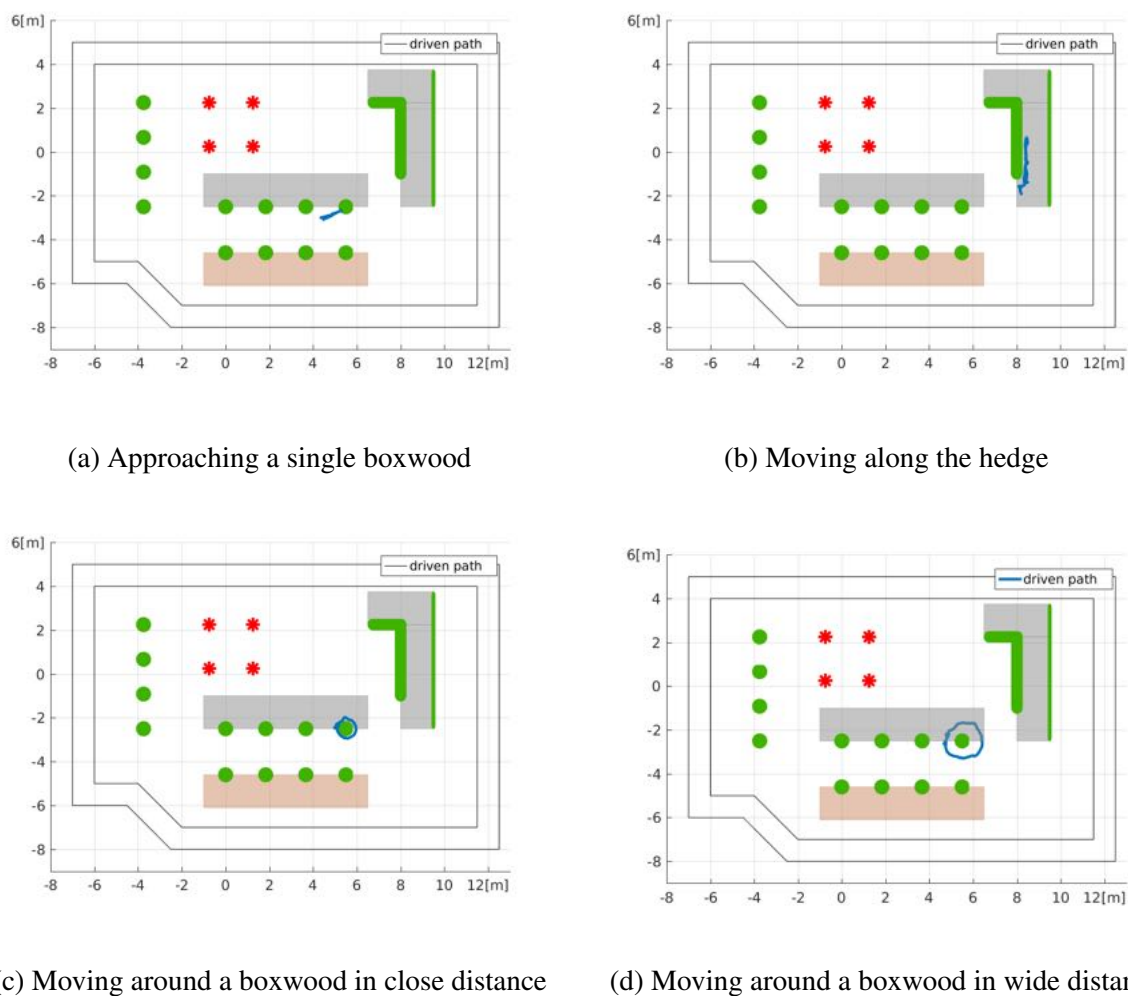
Figure 11: Examples for the handheld data sets. The blue line shows path of the handheld device, the green circles the boxwoods and the red asterixs the roses.

4.3   Data Availability

The datasets are currently available from internal project repository to consortium members. After semantic annotation and additional processing, selected parts of the dataset will be released publicly as presented in D8.2 (Data Management Plan and Framework).

5   Future Considerations

The data collection Platform 1 will be used further in the project at least until Platform 2 becomes operational. During its lifetime we expect modifications and events to occur, some of them listed below.

5.1   Camera Setup

The camera setup undergoes redesign to feature $360°$ coverage of both colour video streams and stereo disparity. Lenses with wider FOV will be used to get sufficient overlap between cameras.

5.2   Renningen Garden Data Collection

Data collection in the second garden at Bosch campus in Renningen is scheduled for Spring 2017. Initial test recording in the garden was performed in December 2016.

5.3   High Resolution Imagery

In addition to the standard resolution WVGA video streams (from the vehicle camera rig) there is the option to add an additional HD camera. It could be mounted on top of the vehicle and be used for a detailed 3D reconstruction and evaluation.

Appendix A　Leica Point Clouds from Wageningen 2016

There are two versions of the point cloud from the Wageningen test garden. The first includes the complete area and the second is cropped to the test garden area (garden_only). Figure 12 shows these two point clouds. A list of all point cloud versions is shown in Table 1. The downsampled point clouds are indicated by a corresponding postfixes, _downsampled_01 for a the 0.01 m voxel grid filter, _downsampled_02 for the 0.02 m voxel grid filter and _10mm for the Leica filter.

(a) 160920_Wageningen.pts　　　　　　　　　(b) 160920_Wageningen_garden_only.pts

Figure 12: Leica 3D reference point cloud from Wageningen test garden.

Leica ASCII files	Number of Points	Size (byte)
160920_Wageningen.pts	280.440.708	12,5 G
160920_Wageningen_10mm.pts	125.032.500	5,6 G
160920_Wageningen_garden_only.pts	234.928.018	10,4 G
160920_Wageningen_garden_only_10mm.pts	83.242.524	3,4 G

PCL ASCII files	Number of Points	Size (byte)
160920_Wageningen.pcd	280.440.708	11,8 G
160920_Wageningen_downsampled_01.pcd	41.575.997	1,9 G
160920_Wageningen_downsampled_02.pcd	15.511.282	700,5 M
160920_Wageningen_garden_only.pcd	234.928.018	9,9 G
160920_Wageningen_garden_only_downsampled_01.pcd	16.493.662	720,0 M

PCL binary files	Number of Points	Size (byte)
160920_Wageningen_binary.pcd	-	-
160920_Wageningen_downsampled_01_binary.pcd	41.575.997	604,1 M
160920_Wageningen_downsampled_02_binary.pcd	15.511.282	231,5 M
160920_Wageningen_garden_only_binary.pcd	234.928.018	3,6 G
160920_Wageningen_garden_only_downsampled_01_binary.pcd	16.493.662	254,2 M

Table 1: Overview of size and points from the Wageningen Leica point cloud.

Appendix B   Vehicle Scenarios Recorded in Wageningen 2016

The following tables list all the recorded vehicle scenarios from the first data collection session in Wageningen 2016. Table 2 lists the approaching scenarios, Table 3 lists the drive around scenarios and Table 4 lists the drive along scenarios.

Vehicle Scenarios	Data	Time	Duration	
approach a single boxwood	2016-09-21	16:23	1:00	(60)
	2016-09-21	16:26	0:49	(49)
	2016-09-21	16:29	1:47	(107)
approach the boxwood row	2016-09-21	16:09	1:44	(104)
approach the fence	2016-09-21	16:36	0:56	(56)
approach the ivy	2016-09-21	16:38	1:03	(63)
	2016-09-21	16:48	1:22	(82)
approach the hedge	2016-09-21	16:58	0:49	(49)
approach a person	2016-09-21	17:00	1:02	(62)
approach a crossing person	2016-09-22	12:01	1:06	(66)
approach a tree	2016-09-21	16:34	0:50	(50)
approach the gravel	2016-09-21	16:32	0:57	(57)

Table 2: Approaching scenarios

Vehicle Scenario	Data	Time	Duration	
drive around the garden	2016-09-21	16:17	3:41	(221)
	2016-09-22	11:23	3:53	(233)
	2016-09-22	17:34	3:39	(219)
drive around the hedge	2016-09-21	15:26	2:13	(133)
	2016-09-21	15:38	2:03	(123)
	2016-09-21	16:43	2:06	(126)
	2016-09-22	11:16	1:41	(101)
	2016-09-22	17:15	1:23	(83)
	2016-09-22	17:17	1:40	(100)
drive around a single boxwood	2016-09-21	15:50	1:38	(98)
	2016-09-21	15:53	2:15	(135)
drive around all boxwoods on the slope	2016-09-21	15:56	1:15	(75)
drive slalom around the boxwoods on slope	2016-09-21	15:59	2:09	(129)
drive around a single rose	2016-09-21	15:42	1:06	(66)
	2016-09-21	15:43	1:16	(76)
drive around all roses	2016-09-21	15:46	2:13	(133)
	2016-09-22	11:19	1:28	(88)

Table 3: Drive around scenarios

Vehicle Scenario	Data	Time	Duration	
along the boxwood row	2016-09-21	16:05	1:30	(90)
	2016-09-22	17:20	1:32	(92)
along the ivy hedge	2016-09-21	16:13	2:13	(133)

Table 4: Drive along scenarios

Appendix C   Handheld Scenarios recorded in Wageningen 2016

The following Table 5 lists all the recorded handheld scenarios from the first data collection session in Wageningen 2016.

Handheld Scenarios	Data	Time	Duration	
around a boxwood	2016-09-22	15:26	2:23	(143)
approach a boxwood	2016-09-22	15:29	0:35	(35)
around a boxwood close distance	2016-09-22	15:30	0:42	(42)
around a boxwood different heights	2016-09-22	15:32	1:04	(64)
over a boxwood	2016-09-22	15:36	0:28	(28)
along a hedge	2016-09-22	15:51	1:24	(84)
along a hedge	2016-09-22	15:53	0:59	(59)
around a boxwood far distance	2016-09-22	16:08	0:46	(46)
around a boxwood close distance	2016-09-22	16:09	0:40	(40)
along a hedge with different distances	2016-09-22	16:14	1:04	(64)

Table 5: Data sets recorded with the handheld device.