The New College Vision and Laser Data Set

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The International Journal of Robotics Research 2009; 28; 595
DOI: 10.1177/0278364909103911

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Abstract

In this paper we present a large dataset intended for use in mobile robotics research. Gathered from a robot driving several kilometers through a park and campus, it contains a five-degree-of-freedom dead-reckoned trajectory, laser range/reflectance data and 20 Hz stereoscopic and omnidirectional imagery. All data is carefully timestamped and all data logs are in human readable form with the images in standard formats. We provide a set of tools to access the data and detailed tagging and segmentations to facilitate its use.

KEY WORDS—Data paper, laser, vision, stereoscopic, omnidirectional, navigation, mapping, mobile robotics, field robotics, New College

1. Synopsis

In this paper we provide details of and release 30 GB of data intended for use by the mobile robotics community. Our anticipated consumers are parties interested in outdoor six-degree-of-freedom (6-DOF) navigation and mapping (metric or topological) using vision and/or lasers. Gathered while traversing through a college's grounds and adjoining parks, in addition to 5-DOF odometry (x, y, yaw, roll and pitch) the dataset contains stereo pairs gathered at 20 Hz, five-view omnidirectional imagery (from a Point Grey LadyBug 2 camera) and data from two lasers scanning at 75 Hz comprising both range and reflectance data. The laser are mounted so as to scan in a vertical plane normal to the vehicle's forward motion. Figure 1 shows the campus and parkland workspace in which the data was gathered. Imagery is recorded in lossless .png and .jpg formats. Laser, Global Positioning System (GPS), inertial measurement unit (IMU) and odometry data is in compressed plain text. All data streams have synchronized timestamps to three decimal places of accuracy.

The data is available at the dataset website http://www.robots.ox.ac.uk/NewCollegeData.

The paper is structured as follows. Section 2 provides a description of the platform used including relevant sensor parameters, conventions and logging technicalities. A description of the environment and salient features of the dataset is given in Section 3. Finally, Section 4 provides a summary of data access and the parsing tools provided.

2. Data Description

Data collection was performed using the vehicle shown in Figure 2. The drive unit is that of a RMP200 base from Segway. This unit also provides the roll and pitch data recorded in the odometry data stream. The data was gathered over a 2.2 km traverse of the college grounds using the sensor configuration described in Table 4. All data was logged using the MOOS software infrastructure (Newman 2003).

2.1. Coordinate Frames

Figure 2 shows the vehicle used with sensor coordinate frames superimposed upon it. The numerical values of these transformations are given in Table 5. Where applicable we have adopted a right-handed, "RPY" Euler angle parameterization

The International Journal of Robotics Research
Vol. 28, No. 5, May 2009, pp. 595–599
DOI: 10.1177/0278364909103911

Figures 1–2 appear in color online: http://ijr.sagepub.com

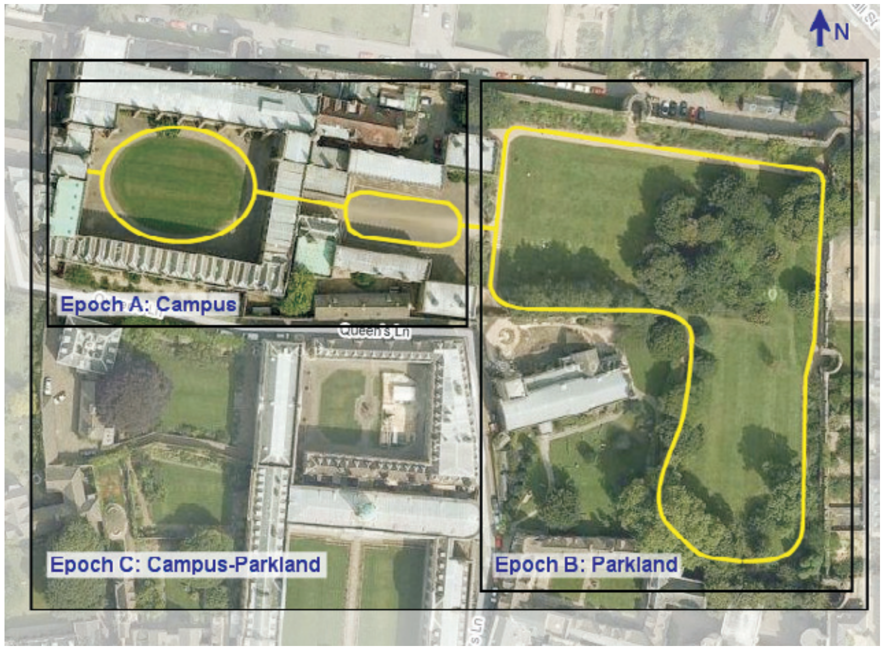

Fig. 1. An aerial view of the workspace and paths driven (multiple loops are not shown). Although the data is contiguous, it can be partitioned into three epochs with different characters: the areas in which the vehicle was operating during each of these are marked in the figure. See Tables 1, 2 and 3 for a broad description of the epochs. Substantial details are available on the dataset website.

Table 1. Summary of events in epoch A ("Campus"; Start: 0.000; End: 1026.718). Finer granularity is provided on the dataset website.

Partition	Description
Quad Loop I Start: 0.0 End: 151.446	Platform remains stationary for 35 seconds before moving. Some pitching and rolling while turning. Groups of people are frequently observed walking towards the vehicle.
Quad Loop II Start: 151.446 End: 255.960	Tarmac ground has some puddles and wet areas.Walking and standing groups of people are frequently observed.
Quad Loop III Start: 255.960 End: 425.161	Loose groups of people are observed. One group is observed both at the start and end of the loop.
Quad and Mid-section I Start: 425.161 End: 655.580	Images are dark while the platform traverses a short tunnel. People often walk past the platform in the mid-section.
Quad and Mid-section II Start: 655.580 End: 1026.718	Extended traversal through gates with some pitching while turning. Images are dark in the tunnel section and under trees. People are occasionally in view in the distance.

of $\mathcal{SO}_3$ using a fixed axis interpretation, this transformation is:

- **Roll**, rotation by α about the body y-axis; followed by
- **Pitch**, rotation by β about the *original* body x-axis; followed by
- **Yaw**, rotation by γ about the *original* body z-axis;

Table 2. Summary of events in epoch B ("Parkland"; Start: 1026.718; End: 1913.179). Finer granularity is provided on the dataset website.

Partition	Description
Park Loop I Start: 1026.718 End: 1518.990	Substantial platform pitching. Images are dark under foliage. A pair of people and a person pushing a cart overtake the platform.
Park Loop II Start: 1518.990 End: 1913.179	Platform pitches while navigating uneven terrain and slopes. People are rarely observed and are poorly illuminated.

Table 3. Summary of events in epoch C ("Campus and Parkland"; Start: 1913.179; End: 2634.139). Finer granularity is provided on the dataset website.

Partition	Description
Quad and Mid-Section III Start: 1913.179 End: 2177.979	Prolonged navigation while entering the mid-section through gates. Images are dark in the tunnel section. The platform approaches a group of stationary people.
Park Loop III Start: 2177.979 End: 2634.139	The platform halts briefly during the loop and again at the end while turning out of the park and through the park gates. Images are dark under foliage. A gardener is observed partially occluded by a bush.

$$R(\alpha) = \begin{bmatrix} \cos(\alpha) & 0 & \sin(\alpha) \\ 0 & 1 & 0 \\ -\sin(\alpha) & 0 & \cos(\alpha) \end{bmatrix},$$

$$R(\beta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\beta) & -\sin(\beta) \\ 0 & \sin(\beta) & \cos(\beta) \end{bmatrix},$$

$$R(\gamma) = \begin{bmatrix} \cos(\gamma) & -\sin(\gamma) & 0 \\ \sin(\gamma) & \cos(\gamma) & 0 \\ 0 & 0 & 1 \end{bmatrix},$$

such that the overall 3×3 RPY rotation matrix R is

$$R = R(\gamma)R(\beta)R(\alpha).$$

3. Partitioning and Salient Features

3.1. Workspace Summary

The dataset was gathered within the New College grounds in Oxford during early November 2008 in the afternoon. The "Campus" environment is typical of buildings in Oxford, being a grouping of medieval buildings with similar architecture. The "Quad" is an enclosure centered around an oval lawn. A short tunnel leads from the Quad to a more open, cambered tarmac space surrounded by old buildings. This, in turn, leads via a gate in a large wrought iron screen (railings) to parkland. The parkland can be circumnavigated via a cambered gravel path around its perimeter. Much of the path adjacent to an old city wall and a herbaceous border, occasionally passing under heavy autumnal foliage.

3.2. Partitioning and Event Tagging

We have broadly partitioned the data into the following three epochs, each with a particular character.

- **Epoch A** "Campus": three circumnavigations of the main Quad followed by two more that also incorporated passing through a tunnel to the mid-section of the dataset. The epoch ends with a prolonged period near the park gates.
- **Epoch B** "Parkland": two circumnavigations of New College gardens. To the northwest the path is predominantly flat with one large puddle. The southeastern section is partially covered with undergrowth, has some dark images and dips roughly 1 m lower than the rest of the dataset.

Table 4. Description of payload sensors and modes of operation.

Sensor	Description	Log format	Measurements
Odometry	28 Hz roll and pitch from Segway base. Yaw and displacement integrated from wheel counts	Plain text	70×10^3
Laser	Two LMS 291-S14 lasers scanning over 90° at 75 Hz with 0.5° resolution in body-vertical plane on the sides of the vehicle	Plain text range and intensity 13-bit range and 8-bit reflectivity	70×10^6 laser points
Stereo	Point Grey BumbleBee 20 Hz 512 × 384 grayscale	.png files	50×10^3 pairs
Panoramic camera	LadyBug 2, five images per frame 384 × 512 color at 3 Hz	.jpg	16×10^3 images
GPS	CSI Series 5 Hz intermittent reception due to urban setting	Plain text	12×10^3

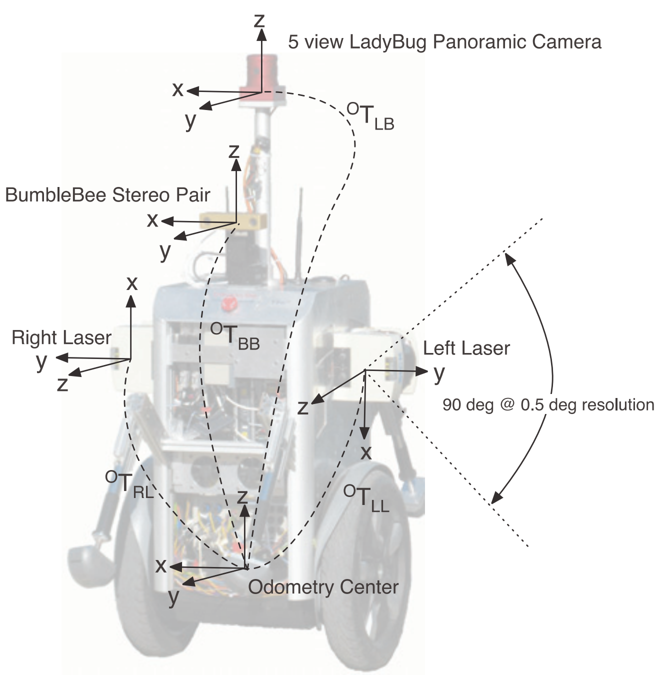

Fig. 2. Vehicle with sensor coordinate frame centres shown. Odometry data reports the robot centre position, taken to be y-forward and z-up frame anchored at the half-way point along the platform's wheel axle. The BumbleBee's coordinate centre is at the left camera's focal point and the LadyBug's centre is at the mean of the five radial camera centres. Laser scanner centres are at the point of intersection of the emitted beams.

- **Epoch C** "Campus and Parkland": one circumnavigation of both the Campus and Parkland environments. Evening was falling and so the images are darker than in earlier passes.

Figure 1 shows the epoch boundaries while Tables 1, 2 and 3 provide an overview of typical salient features/event of each of the epochs. The dataset website provides a substantially more detailed description of interesting and challenging events occurring in each epoch and provides time indexes by which they can be accessed. Events/tags are listed both chronologically and by event type.

4. Data Access Methods

The data is available for download from http://www.robots.ox.ac.uk/NewCollegeData/. This site also goes into much greater detail when describing the dataset than is appropriate for this paper. To avoid the requirement to download the full 30 GB just to evaluate the data, the data is available compressed as single events (periods of a few seconds) and chunks of the entire dataset. All non-image data is stored in plain text files with an "alog" suffix. Each line contains a single log entry which is a comma-separated list of token–value pairs. The format of all log entries is supplied in detail on the website.

4.1. Supplied Tools

Ease of use is important and while having plain text logs results in OS-independence and a degree of immediacy, it has the disadvantage that a parsing step is required to extract numerical data. We have provided some tools to help with this task and expedite data access.

- **Parsing**. To ease use of the dataset, we have supplied a dependency-free C++ source file which builds a tool to parse the plain text logs into numerical arrays. With a log file as input, it creates arrays of data in plain text or, if invoked from inside Matlab, returns a set of Matlab variables. For example, one might want to create a

Table 5. Sensor coordinate frames relative to the vehicle frame (odometry) origin with all angles in degrees and displacements in meters, $[x\ y\ z\ \alpha\ \beta\ \gamma\ ]$**.**

Transformation	Sensor	Estimate
${}^{O}T_{\mathrm{LB}}$	LadyBug	$\begin{bmatrix}0.000 & 0.000 & 1.169 & 0 & 0 & 0\end{bmatrix}^{\mathrm{T}}$
${}^{O}T_{\mathrm{BB}}$	BumbleBee (left camera)	$\begin{bmatrix}-0.062 & 0.205 & 0.837 & 0 & -13 & 0\end{bmatrix}^{\mathrm{T}}$
${}^{O}T_{\mathrm{RL}}$	Right Laser	$\begin{bmatrix}0.270 & -0.030 & 0.495 & -90 & 0 & -90\end{bmatrix}^{\mathrm{T}}$
${}^{O}T_{\mathrm{LL}}$	Left Laser	$\begin{bmatrix}-0.270 & -0.030 & 0.495 & 90 & 0 & 90\end{bmatrix}^{\mathrm{T}}$

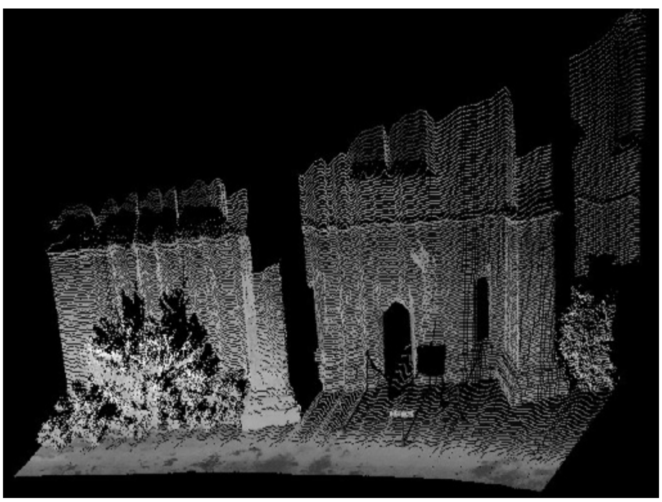

Fig. 3. A detail of the “Quad” rendered relative to an odometry-derived trajectory using laser range and reflectance data. We provide example code for extracting this data from the log files and creating VRML data files, which can be loaded into a viewer of choice and rendered as shown here. Note that by capturing reflectance data extra relief is added to the scene: foliage and the white writing on signs provide strong (bright) returns. The apparent wavy pattern on the walls is an illusion caused by the pitching of the vehicle.

matrix of vehicle poses between two times or a matrix of laser scans over the duration of a particular tagged event. We provide instructions and examples on how to use this parsing code to extract named data. We stress that there is nothing about our data that is tied to or requires the use of this parsing code. Consumers of the data are welcome to write their own parsers in a language of choice. The file parser we supply is simply a convenience (it is also quite fast). The same source file compiles into a standalone executable or a Matlab mex file. In the former case, arrays are written to a simple binary data file, while in the latter arrays are returned directly to the Matlab workspace. Note that to extract data there is no requirement to use or have Matlab or run a particular operating system.

- **Rendering**. As a further example, we provide Matlab code which invokes the text parser to extract laser and odometry streams, project laser ranges into three dimensions and display in a Matlab figure. The same code can also output the transformed laser points and reflectances to plain text and VRML for use with third-party viewers. A typical rendered point cloud is shown in Figure 3.
- **Stereo rectification**. We provide a standalone C++ source file to build an executable to rectify the stereo images using the calibration parameters specific to the stereo pair we used. Rectification removes lens distortions and allows the stereo correspondence task to be posed as a one-dimensional search along raster lines. All calibration parameters are also provided in plain text.

Acknowledgments

The work reported in this paper undertaken by the Mobile Robotics Group was funded by the Systems Engineering for Autonomous Systems (SEAS) Defence Technology Centre established by the UK Ministry of Defence, by Guidance Ltd and by the UK EPSRC (Platform Grant EP/D037077/1 Industrial Case Studentships with BAe Systems, OC Robotics and Oxford Technologies Ltd). The authors would like to thank Robbie Shade and Gabe Sibley for their contributions to the processing of stereo data, and also Alistair Harrison and Dare Cole for systems design and support.

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