A Methodology for a Low-Cost, Portable, On-Bicycle Data Collection System

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ABSTRACT

Lane sharing interactions between bicycles and overtaking vehicles continues to be a safety issue with limited supporting data. This research looked at methods for the easy collection of bicycle/overtaking vehicle data in rural areas. The available literature contained no references to an on-bicycle system for data collection that did not also require the addition of substantial weight or equipment to the bicycle. Other available methods (typically for urban areas) required the setup of stationary equipment with the hopes of an interaction occurring in that location. The results of this research provide a methodology that practitioners and researchers can use as a base system to begin on-bicycle data collection for a relatively low cost while not encumbering a bicycle with bulky (or obvious) equipment. Following this methodology, other researchers should be able to conduct similar data collection, and make additional improvements or adjustments based on their specific data collection needs. This methodology allows for the easy collection of bicycle/overtaking vehicle interaction data, in video format (with views of both approaching and departing vehicles) and via an ultrasonic distance sensor (providing the lateral clearance of overtaking vehicles). GPS technology is also incorporated to track bicycle location and speed. Initial results have shown numerous lane and other safety violations routinely made by drivers that threaten both vehicles and cyclists alike. By finally gathering this type of exposure data, practitioners and researchers will now be able to examine countermeasures to reduce and/or prevent such risky maneuvers.

KEYWORDS

Bicycle, exposure data, data collection, overtaking vehicle, on-bike sensor, video logging, rural roads, safety countermeasures

INTRODUCTION

The collection of bicycle-vehicle interaction data has always been difficult, at best. The available literature indicates that collection methods are either: cost-prohibitive, unwieldy, or just likely unworkable for a given project. These collection methods have either been on-bike, but required a substantial amount of equipment, racks, and bags attached to the bike, thereby making it stand out (and alerts drivers to their presence), or involved placing stationary equipment and recording for long periods of time in the hopes of recording a bicycle being overtaken by a car in the collection zone. Either way, drivers are alerted to something out-of-the-ordinary, and may alter their driving behavior, thereby producing results that are less than ideal. This paper presents a new methodology, partially based on prior methods, for outfitting and configuring a road-type bicycle for both video and sensor-based data collection on exurban and rural roads. The types of data collected include lateral clearance between bicycle and overtaking vehicle, bicycle speed and position, and forward and rear view video. The collection of these types of exposure data enables researchers and practitioners to better understand what is actually happening on the road, and no longer just relying on witness statements or second-hand survey responses. Lateral clearance data, in combination with the video data, shows how overtaking drivers actually deviate their vehicle path, often conducting unsafe (or illegal maneuvers), such as crossing double-yellow centerlines. Knowing bicycle speed, in combination with the lateral sensor data, can be used to calculate not only the speed differential between the bicycle and the overtaking vehicle, but also the actual speed of the overtaking vehicle, which can then be compared to the posted speed limit of a particular roadway. Knowing the bicycle position at the time of the overtaking maneuver is also critical to identify the geometrics of the roadway at that specific instant.

DEVELOPMENT PROCESS

The literature regarding on-bicycle data collection methods on rural roads is virtually non-existent, so methods used to collect data in urban and suburban areas were also examined. This was also sparse, but provided some ideas to help improve the base framework that had already been developed.

Carter and Council's work on factors contributing to pedestrian and bicycle crashes on rural highways provided the primary impetus to the development of a low-cost, portable, on-bicycle data collection system *(1)*. While their work mainly focused on the main types of motorist/bicycle conflicts and resultant crashes that occur on rural roads, they also identified several areas for future research. One of these areas was the development of a method to collect rural bicycle exposure data. They identified that without a method to collect exposure data directly (or a means to develop a valid surrogate), "changes in *risk reduction* due to a specific countermeasure" could not be accurately identified.

Effective on-bicycle data collection systems should be as unobtrusive and lightweight as possible. Nearly all bicycles traveling on the two-lane rural roads in the Madison, Wisconsin area are road or triathlon-specific bikes, meaning that most operate at between 15 and 25 mph (exceptions are on uphill and downhill segments of roadways, where speeds can fall to below 10 mph, or exceed 35 mph), and at most will have a small rack attached to the back. Given the desire to utilize a road-specific bicycle, components were sought to maximize data collection while minimizing the likelihood that an overtaking driver would be alerted to their presence. Components also would need to be designed for attaching directly to a bicycle or at least easily adaptable for that purpose.

The first iteration of the on-bicycle data collection system tested the feasibility of using video data to analyze interactions between bicycles and motorized vehicles in a rural environment. The initial setup used two Oregon Scientific ATC2K mountable video cameras attached to the handlebar of a triathlon-specific bicycle. The ATC2K cameras were selected for several reasons. First, the cameras can be mounted almost anywhere, from flat surfaces to pipes, and still be angled to provide a level, right-side up view of the road. Second, the cameras are very lightweight, using only two 'AA' type batteries, while still providing over 3 hours of continuous recording time on a single 2GB SD flash memory card at a frame size of 320x240 and rate of 20 frames per second. The cameras were approximately $100 each (now $80 each). While both cameras were mounted to the front handlebar, one recorded facing rearward, and the other recorded facing forward. In addition to the cameras, a wrist-mounted Garmin Forerunner 201 GPS unit was also used to recording bicycle location and speed throughout each ride.

To ensure that collected data (video and GPS) were closely synchronized, all three devices were activated within a second or two of each other at the start of each data collection ride. Analysis of the video and GPS data showed this setup successfully collected road conditions, signing, and pavement markings (where present), road shoulder conditions (where present), bicycle speed, geographical position, and lane positioning, overtaking vehicle type and lane positioning, and weather conditions. Initial findings indicated that the collection method was effective *(2)*.

Work done by Walker looked at driver behavior as they overtook bicyclists on urban roads within the cities of Salisbury and Bristol, in England *(3)*. Walker's work focused primarily on the effects of riding position, helmet use, and apparent gender (as seen by the overtaking drivers). This study used a Trek "hybrid-style" bicycle, which, compared to a road or triathlon-specific bicycle features a more upright seated rider position, and results in a much slower overall speed. Walker attempted to maintain 17-20 kph (10.5 to 12.5 mph). Walker's setup included an ultrasonic distance sensor (Massa M-5000/95), laptop computer, and camera all disguised in saddlebags attached to a rear rack. Walker also dressed the part of a typical commuter/utility bicyclist, specifically trying to avoid looking like a "racy 'professional' rider" or a "young 'stunt cyclist'". Review of Walker's research led to the inclusion of an ultrasonic distance sensor and collection device.

For this research, the Massa Products Corporation was contacted regarding the M-5000/95 sensor, and after reviewing the size, price (over $200 retail), and connection requirements, other ultrasonic distance sensors were evaluated. Ultimately it was decided to build a device using the Maxbotix LV-EZ1 ultrasonic range finder (retail price of $25). This required constructing a case, and wiring connections for batteries and computer interface. The case was constructed using 1-1/2 inch PVC pipe fittings available at any home improvement store (less than $5 retail). A $2 battery case (4-'AA' cell type) and wiring (from Radio Shack) provided power, and a $6 RS232 (9-pin serial) extension cable provided the computer interface. The LV-EZ1 is configured to take readings at 50 Hz (20 readings per second) with a range of 6 to 255 inches

(0.15 to 6.48 meters), which is sufficient to take multiple distance readings for each overtaking vehicle, thereby allowing for approximate speed computations as well. An external power switch was added for convenience in turning the sensor on and off.

Unfortunately no sensor was available that provided for self-contained data logging, so a laptop computer was necessary. Several Netbook computers were considered, and ultimately an HP Mini model 2140 was selected for weight (2.6 lbs) and battery life (almost 4 hours at maximum power saving settings). Since no available Netbook-type computers came equipped with a 9-pin serial port, a serial-to-USB converter was also required. These additions (computer and sensor) required the inclusion of a rear, seat-post mounted storage rack. A different bicycle was also selected which could support a rear rack. A Bontrager Seatpost Rack ($40 retail), capable of carrying up to 25 lbs (11.3 kg), was selected, which would be more than adequate for the HP Mini, sensor, and cables.

A rectangular storage container ($6 retail) was cable-tied to the rear rack for storing the HP Mini during travel, with various holes cut through the sides to allow cables to enter/exit as necessary. In front of the storage container, the sensor was also cable-tied to the rack. The rearward-facing camera was mounted below the rack on the main support beam. The forward-facing camera remained mounted to the front handlebars in this configuration, and the GPS unit was also retained.

The final cost for the current video and sensor configuration, including the HP Mini, is approximately $650. (The bicycle and GPS unit used were already owned by the corresponding author, and are not part of the total cost). The following figures provide various views of the data collection bicycle, with close-up images of various components.

FIGURE 1: Overall View

Figure 1 is a side view of the data collection bicycle, with the research components circled. On the left side (on the handlebars) is the forward facing camera (also shown in Figure 2), and on the right side is the seat post rack with the sensor, storage container, and rearward facing camera (also shown in Figure 3).

FIGURE 2: Front View

Figure 2 shows the front view of the data collection bicycle, with a circle around the forward facing camera.

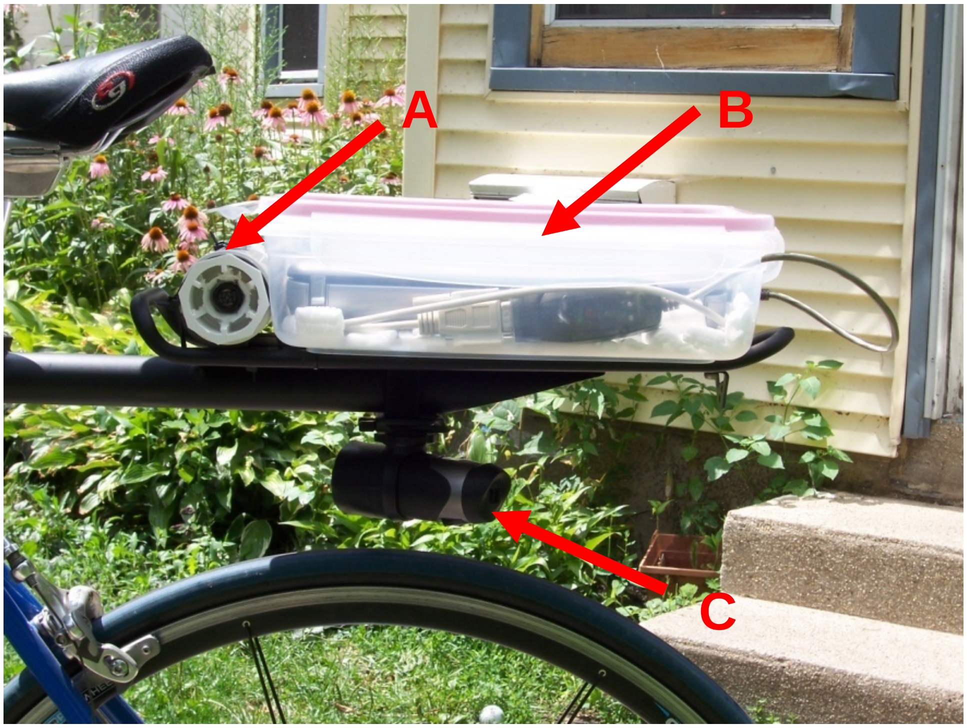

FIGURE 3: Seat Post Rack Detail View

Figure 3 shows the seat post rack with attached equipment. To the left is the ultrasonic lateral distance sensor (A). To the right is the storage container holding the Netbook computer and the serial-to-USB adapter (B). Below the storage container is the rearward facing camera (C).

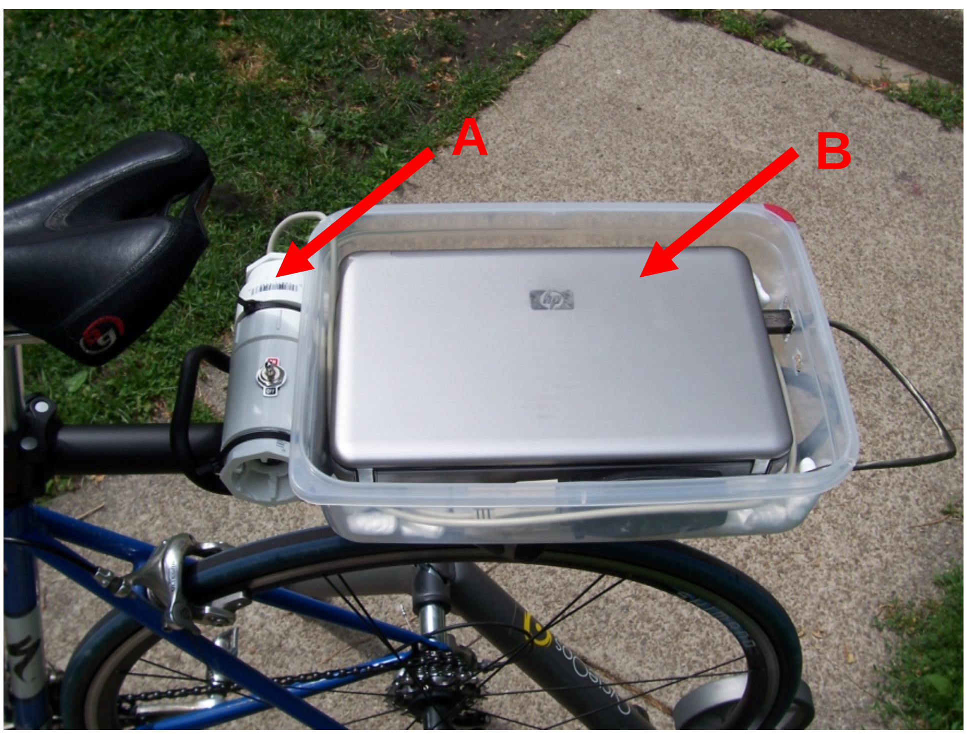

FIGURE 4: Seat Post Rack Top View

Figure 4 also shows the seat post rack with attached equipment. To the left is the ultrasonic lateral distance sensor (A) (also shown in close-up detail in Figure 5). To the right is the storage container holding the Netbook computer and the serial-to-USB adapter (B).

FIGURE 5: Ultrasonic Lateral Distance Sensor Detail View

Figure 5 is a close-up view of the ultrasonic lateral distance sensor. The on-off switch on the top enables a rider to easily activate or disable the device without having to dismount the bicycle or typically even slow down.

SAMPLE OUTPUTS

Two different overtaking vehicle interactions from a data collection ride are shown in the following figures. As an example, Figure 6 shows a large, white Ford F-150 pickup truck overtaking the collection bicycle. In Figures 6 and 7, the pickup can be seen crossing a double-yellow centerline on an uphill roadway segment, with two oncoming bicycles immediately in front, and an approaching car just cresting the hill. Such an illegal passing maneuver is quite common.

FIGURE 6: White pickup immediately prior to overtaking bicycle

FIGURE 7: White pickup immediately after overtaking bicycle (note bicyclist visible immediately in front of the truck, and headlights of oncoming car)

The pickup truck, did, however, maintain at least the minimum 3 ft clearance required by Wisconsin state law for vehicles overtaking bicycles. The ultrasonic lateral distance sensor recorded the clearance as 8.1 ft (2.47 m). While the truck probably would have been able to maintain sufficient clearance without crossing the centerline, drivers commonly do so when there is no paved shoulder available for bicycle use.

The sensor log for the time period of this interaction (converted into Microsoft Excel format) is shown in Table 1. The maximum range for the sensor is 255 inches (6.32 m), which is the default reporting value.

Ride Time (s)	Ride Time (m)	Lateral Clearance (in)	Lateral Clearance (ft)	Lateral Clearance (m)
676.10	11.2683	255	21.25	6.48
676.15	11.2692	255	21.25	6.48
676.20	11.2700	255	21.25	6.48

676.25	11.2708	255	21.25	6.48
676.30	11.2717	106	8.83	2.69
676.35	11.2725	110	9.17	2.79
676.40	11.2733	106	8.83	2.69
676.45	11.2742	97	8.08	2.46
676.50	11.2750	98	8.17	2.49
676.55	11.2758	97	8.08	2.46
676.60	11.2767	97	8.08	2.46
676.65	11.2775	97	8.08	2.46
676.70	11.2783	97	8.08	2.46
676.75	11.2792	98	8.17	2.49
676.80	11.2800	98	8.17	2.49
676.85	11.2808	98	8.17	2.49
676.90	11.2817	98	8.17	2.49
676.95	11.2825	99	8.25	2.51
677.00	11.2833	99	8.25	2.51
677.05	11.2842	100	8.33	2.54
677.10	11.2850	100	8.33	2.54
677.15	11.2858	109	9.08	2.77
677.20	11.2867	112	9.33	2.84
677.25	11.2875	255	21.25	6.48
677.30	11.2883	255	21.25	6.48
677.35	11.2892	255	21.25	6.48
677.40	11.2900	255	21.25	6.48

TABLE 1: Lateral Offset of Overtaking White Pickup Truck

The second shows a blue Chevrolet sedan overtaking the data collection bicycle. In Figures 8 through 11, the car can be seen with its driver's side wheels on or just inside a solid yellow centerline on a slight uphill grade. An oncoming car is also visible. The difference between this road segment and the previous one is the presence of a paved shoulder.

FIGURE 8: Car beginning overtaking maneuver

FIGURE 9: Car continuing overtaking maneuver

FIGURE 10: Car just past data collection bicycle

FIGURE 11: Car completing overtaking maneuver

The car also was able to maintain the minimum 3 ft clearance mentioned earlier. The ultrasonic lateral distance sensor recorded the clearance as 5.17 ft (1.57 m). The car was able to maintain sufficient clearance without crossing the centerline.

The sensor log for the time period of this interaction (converted into Microsoft Excel format) is shown in Table 2.

Ride Time (s)	Ride Time (m)	Lateral Clearance (in)	Lateral Clearance (ft)	Lateral Clearance (m)
1715.60	28.5933	255	21.25	6.48
1715.65	28.5942	255	21.25	6.48
1715.70	28.5950	255	21.25	6.48
1715.75	28.5958	255	21.25	6.48
1715.80	28.5967	255	21.25	6.48
1715.85	28.5975	255	21.25	6.48
1715.90	28.5983	65	5.42	1.65
1715.95	28.5992	62	5.17	1.57
1716.00	28.6000	62	5.17	1.57
1716.05	28.6008	62	5.17	1.57
1716.10	28.6017	63	5.25	1.60
1716.15	28.6025	67	5.58	1.70
1716.20	28.6033	255	21.25	6.48
1716.25	28.6042	255	21.25	6.48
1716.30	28.6050	255	21.25	6.48
1716.35	28.6058	255	21.25	6.48
1716.40	28.6067	255	21.25	6.48
1716.45	28.6075	255	21.25	6.48

TABLE 2: Lateral Offset of Overtaking Blue Sedan

CONCLUSIONS

The development of this data collection methodology was partially a means to an end. Bicycle exposure data on rural roads is a virtual unknown, despite the tens of thousands of riders out there. Numerous fatalities occur each year, but the exact causes are often unknown, with just witness statements, skid marks, and bicycle wreckage to examine after the fact. Collecting exposure data allows researchers and practitioners first-hand experience with what these riders face daily. In-depth examination of the collected data reveals safety violations by overtaking drivers that are far too numerous to ignore. While nearly all drivers manage to maintain the proper clearance while overtaking bicyclists, many do so by crossing double-yellow centerlines on uphill road segments without a paved shoulder, thus endangering both their lives and the lives of any oncoming drivers obscured behind the hill. The combination of video and sensor data also reveals that most drivers manage to provide the minimum lateral clearance while staying in their lane when a paved shoulder is present. The rural road environment can be made much safer once practitioners have the data available to start designing proper countermeasures. This collection methodology can provide that data through a low cost, portable, easy-to-deploy system.

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