Characterizing Reliability of Manual Intersection Turning Movement Counts Using Modern Data Collection Technology

by

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ABSTRACT

Collecting intersection turning movement counts at intersections is an essential data collection task for many types of traffic engineering studies. On a daily basis, consulting firms and agencies collect turning movement counts that are used for preparing traffic impact studies, determining design hours for road improvements, and the retiming of traffic signals. Although there is a substantial body of literature on the stochastic nature of traffic volumes and how they vary by time, day of week, and season, the literature is quite sparse on how accurately turning movement counts can be collected at signalized intersections. The objective of this paper is to characterize the reliability of manual intersection turning movement counts performed with modern data collection technology.

Live intersection turning movement counts were performed on three days for three hours to characterize the range and reliability of percent errors. Every user, regardless of interface or device, improved from the first day to the second day, and all but one improved again between the second and third day. There was no clear superior data collection technology, but with the emerging ubiquitous of smart phones and tablets, the cost –benefit of these devices has the potential to change the manual counting techniques of the future. Traffic counter software running on smart phones or consumer electronic devices has the benefit of being affordable and perhaps more convenient as an electronic counting device (ECD).

INTRODUCTION

The Strategic Highway Research Program has over 30 active or completed projects in the area of reliability [1]. These projects span a diverse portfolio of topics ranging from capacity, travel time, operations, and planning. A large number of these efforts rely on intersection turning movement counts. Although there is a substantial body of literature on the stochastic nature of traffic volumes and how they vary by time, day of week, and season, the literature is quite sparse on how accurately turning movement counts at signalized intersections can be collected.

Collecting intersection turning movement counts at intersections is an essential data collection task for many types of traffic engineering studies [2]. On a daily basis, consulting firms and agencies collect turning movement counts that are used for preparing traffic impact studies, determining design hours for road improvements, and the retiming of traffic signals. An ASTM committee has also established standards for collecting intersection turning movement traffic data [3]. The majority of turning movement counts are currently collected with electronic manual count boards using contact closure buttons. However, new popular consumer products consisting of multimedia players, smartphones, and tablet computers are available and have the potential to provide transportation professionals with an alternative way to collect traffic data. These devices are rapidly finding their way into the work environment not only by employer or agency purchase, but also via employees' reluctance to maintain multiple cell phones [4]. The objective of this paper is to characterize the reliability of manual intersection turning movement counts performed with modern data collection technology.

CURRENT TURNING MOVEMENT COUNT METHODS

Intersection turning movement counts are predominantly collected by paper and pencil, counting boards (mechanical wheel or electronic), inductive loops, or video monitoring [5,6,7]. Each one of these methods has advantages and disadvantages. The paper and pencil method was the first method implemented to collect turning movement count data and continues to be used by many individuals and agencies throughout the world. Today, this method is often limited to counting bicyclists, pedestrians, or implemented by groups conducting only limited studies. The most significant drawback with the paper and pencil method is the difficulty that one encounters when intersections with multiple lanes are quite busy. Under these conditions, the observer has difficulty recording counts and vehicle classifications or flipping intervals every 15 minutes. Multiple data collectors are often required for this method.

To overcome these challenges, manual count boards were created. Mechanical wheel count boards first entered the market with electronic count boards following later [6]. The basic electronic counting board is the most common method used today to collect turning movement counts because of its low initial costs, ease of use, and the need for the data collector to observe events that may affect the data collection effort, Figure 1a. However, much like the paper and pencil method, users typically find data collecting more challenging as traffic volumes increase, especially with respect to vehicle classification. The ability to continuously watch traffic while occasionally glancing down at the count board to determine which button or buttons to push can be challenging.

In contrast to the manual methods noted above, inductive loop detectors at traffic signals and video monitoring methods are available that use virtual detectors or pixel tracking technology to observe traffic [7]. The loop detector approach is limited to locations that have traffic signals and dedicated turn lanes on each approach. The video monitoring method either requires video based virtual detectors strategically placed at the intersection or a video camera where the video footage is later processed manually with some type of count board device or processed electronically with a computerized tracking algorithm. Video methods require higher upfront costs than traditional count board equipment and may require ongoing processing costs as part of data collection efforts. While the loop and video procedures can provide accurate data when properly set up, both of these methods are not always practical given the limited number of turning movement counts needed for a project and limited financial resources. It is anticipated that video based tracking technology will continue to evolve and improve, and that individuals needing large quantities of turning movement counts will be able to adopt data collection processes based on this technology as further development ensues. However, manual turning movement counts will continue to be used in the foreseeable future [8, 9].

EMERGING TURNING MOVEMENT COUNT METHODS

A variety of consumer electronic devices now have quite powerful computing capabilities coupled with capacitive touch screens on top of a liquid crystal display. These interfaces are becoming ubiquitous for providing a dynamic input to multimedia players, smartphones, and tablet computers. Capacitive touch screens operate when the screen detects an object that has conductive properties such as a finger. Newer, mobile computer operating systems are using the touch screens with a glass face as the primary user input method. Technology related to these screens has evolved greatly in recent years and is anticipated to evolve even further over the next couple of years.

Using finger gestures on top of a liquid crystal display that can display different views opens up new opportunities for manual traffic data collection. Software can now be written to have the screen resemble actual field conditions and change dynamically during the data collection activity. For example, intersections can now be displayed as 3-way configurations where only a 4-way static configuration was previously available. Street names and north arrows can be shown directly on the screen, and input methods can be added or eliminated depending on the data collection requirements. Figure 2b and 2c shows examples of these features on a LCD display for 3-way and 4-way intersections. This ability to graphically change input locations has the potential to improve data collection accuracy by eliminating possible sources of error.

STUDY OBJECTIVE

Research on this subject has previously been devoted to assessing the accuracy of machine counts in a variety of applications [10, 11, 12]. Current literature and ASTM Standards are silent on both the accuracy of manual turn count data collection and whether the counts vary from user to user or from device to device. With the need for accurate turning movement counts, the data and its variability and reliability must be understood. This study attempts to characterize the accuracy of turning movement counts performed by four different people over a three day period using a variety of modern turning movement counting technology.

DATA COLLECTION PROCEDURE

In this study two types of LCD interfaces were compared to the current electronic counting device. The two types are a screen tap interface, or the classic interface (Figure 2a), and the swipe interface (Figure 2b), or the hyper interface. The classic interface was designed to mimic the traditional traffic count board by implementing virtual buttons. The hyper interface is a newly designed feature that uses finger gestures to mimic the movement of traffic. The software of the hyper interface tracks the starting point for the finger swipe and registers the turning movement based on the relative position of the finger when it is lifted from the screen. The allowed variability of a finger swipe should allow the data collector to focus more on visually observing the traffic conditions with less time spent looking down at the screen.

The intersection chosen for this study was Northwestern and Stadium Avenue on the campus of Purdue University. The relative position of the counters at this intersection can be seen as callout ‘a’ in Figure 3. This intersection had an entering peak hour volume of approximately 5130 vehicles on 12 lanes during the study. This intersection was equipped with a camera focused at each approach to validate the counts of the users/devices. An example of the video screen used to validate the counts can be seen in Figure 4. Five devices and four users were used to count the traffic conditions on three days from 1100-1400 hours on June 21-22 and July

13, 2011. Figure 1 displays the five devices used to make the turning count data collection. Each day the users varied which device was used and which interface (hyper or classic) was used. Table 1 displays the device configuration used by each user for each day. The devices were all time synced and the 3 hour counting period was automatically divided into the more useful 15-minute counting periods.

DATA ANALYSIS

Using the collected data, potential trends or mistakes in counting could be determined and the reliability of each device could be established. Figure 5 shows an example of a cumulative count of two movements on Day 1 by all users. Figure 5a shows the westbound left movement, while Figure 5b shows the westbound thru movement. The dashed lines marked with callout i and ii represent User 2's count using the classic interface on an iPod Touch. It appears as though the user may have potentially confused the two buttons throughout the three hour counting period. This error could easily be replicated on the traditional electronic counting device (ECDs) and the likelihood of errors like these in manual turn counts needs to be understood.

On Day 3, the four devices used were two iPods, an iPad, and a standard ECD; the data are displayed in Figure 6. Each movement is divided between the twelve 15- minute segments and plotted in a stock plot format to establish the difference between the counts. Figure 6a and b present the higher volume Northwestern Ave. traffic counts, while Figure 6c and d show the counts for the lower volume Stadium Ave. The horizontal black line in each of these figures represents the ground truthed video count data. It is difficult to establish any noticeable trend between the device used and the offset from the actual count, which is assumed to be the video truthing. The northbound and southbound thru movements appear to have the most raw variation based on the figure, which was expected as those were the movements with the heaviest volume, and they occurred at the same time making truly accurate counts difficult.

Figure 7 shows a clearer image of the raw difference between each count and the ground truthed video count. Similar to Figure 6, Figure 7 is divided into the four turning movements; however, instead of showing the number of vehicles in each 15 minute period, the offset from the video truthed data is shown for each movement and device. Figure 7a shows the southbound movements difference; An interesting note is that a majority of the devices were low on counting both the thru and the right turning movements. This can be explained in that it is easier to miss counting vehicles than to over count vehicles that don't exist. Also, the southbound right turning movement could have been more difficult to count due to channelization and the proximity of the location to the counters on the southeast corner of the intersection, Figure 3.

In order to further understand the differences between the devices, it was important to eliminate the possibility of any variation due to when the counter counted a vehicle as a new 15 minute interval began. Similar to the example shown in Figure 5, Figure 8 displays the cumulative count of each of the users over the 3 hour counting period. This figure is perhaps the most convincing evidence that the equipment used to count will have a very minimal difference in the data collected, and perhaps ease of use and cost effectiveness should be considered when performing turning count movements. The only substantial variation shown in cumulative counts was in the right turning movements, Figure 8e, f, k, and l. As mentioned previously, the northern and southern movements were very difficult to count due to the raw magnitude of vehicles and the southbound right could have been skewed because of the close proximity to the counters. The geometry of the intersection also could have had some effect on the westbound right turns, as vehicles that turned right often appeared as if they were going to complete a thru movement instead. The proximity of the remainder of the cumulative counts, however, cannot be denied as accurate.

RESULTS

The data were compared using the percent error between the counted vehicles and the ground truthed video counts. The data were broken up into 144 segments, or twelve traffic movements for each of the twelve 15-minute periods that were counted. Figure 9 presents the percent error of each of the 144 segments in histogram form and cumulative frequency diagram form. The 0 percent error bar in Figure 9a, c, e, and g represent the number of 15-minute intervals where the counted data was within one percent error of the video truthing. User 1 using the classic interface on the iPod in Figure 9a to be the most accurate traffic counter with a very tight range of percent errors. In Figure 9b, the difference between the 25th and 75th percentile is recognized as the reliability of the counter and User 1 shows a near perfect reliability for that time period. Users 2, 3, and 4 display very similar error distributions suggesting that there is negligible difference between the ECD and the LCD touch screen application.

As previously mentioned, it is crucial to eliminate any possible errors between the 15 minute intervals, or when a new interval starts, and which vehicles get counted where. In order to analyze this change in time, the percent errors were once again determined, but the time intervals were extended from 15 minutes to one and three hour bins. Figure 10 shows the CFDs for each user based on these new one hour and three hour bins. User 1 still appears to have the tightest distribution, suggesting that they are the most reliable of the counters. Users 3 and 4 appear to have similar percent error CFDs when comparing Figure 10e and f with Figure 10g and h. User 2 appears to severely undercount or miss cars during turning movements as seen in Figure 10c and d because the cumulative frequency line is shifted to the left of the 0% line.

To assess which factors had the biggest effect on turn counting reliability the frequency of 15 minute intervals within one and five percent were compared. Figure 11a and b shows the number of 15 minute counts that are within one percent of the ground truthed data over three days of counting and four users. Figure 11a shows that there is a significant learning curve for each user throughout the three days. Figure 11b provides substantial evidence that User 1 outperforms the other three users each day regardless of the device and interface. Another interesting note is that the ECD does not differentiate itself in either a positive or negative manner when considering reliability. Figure 11c and d show the frequency that a 15 minute period falls within five percent of the ground truthed data. These figures clearly show that User 1 was a far superior counter than Users 2, 3, and 4 regardless of technology. Figure 11c and d also show that there was a learning curve from day 1 to day 2 to day 3; however, there was no noticeable difference in technologies used for manual counting.

CONCLUSIONS

Manual counts are a necessary element in transportation engineering. The current literature has compared numerous automated count techniques; however, it remains silent on the reliability of different methods of performing manual counts. A current electronic counting device, ECD, was compared with a more cost effective iPod/iPad/Smartphone application built for counting traffic movements. Four different motivated and educated users used five different devices over three days to count the movements at a single busy intersection in West Lafayette, Indiana. The counts were then compared with confirmed video count data from the intersection to establish the percent error of each of the interfaces, devices, and users.

Using 3 three-hour test periods in a live field count, the range and reliability of percent errors were determined. Figure 11 summarizes the percentage of count intervals that fell within 1 percent or five percent of the ground truthed video counts. Looking at the general pattern over the three days a learning curve can easily be identified. Every user, regardless of interface or device, improved from the first day to the second day. This information should be taken into account when engineers are choosing which individuals will be sent out into the field to measure movements. It was also shown that User 1 was substantially more accurate than the other three users. As all four of the users were educated and motivated it is important to understand that there is a skill set involved in counting movements. Even with a highly motivated group, there is substantial variation. This snapshot on reliability is a very good approximation of an upper bound on data quality one can expect without resorting to video-taping and manual data reduction techniques.

There was no clear superior data collection technology, but clearly with the emerging ubiquitous of smart phones and tablets, the cost –benefit of these devices has the potential to change the manual counting techniques of the future. LCD traffic counters have the benefit of being affordable and perhaps more comfortable then purpose built ECD’s targeted at the relative small traffic engineering study market. Furthermore, it easy to imagine further innovation in this market segment where a variety of custom user interfaces could be developed for applications such as headway studies, queuing delay studies, assessing the quality of progression (percent of vehicles arriving during a green interval), floating car studies, as well as applications in other modes such as transit.

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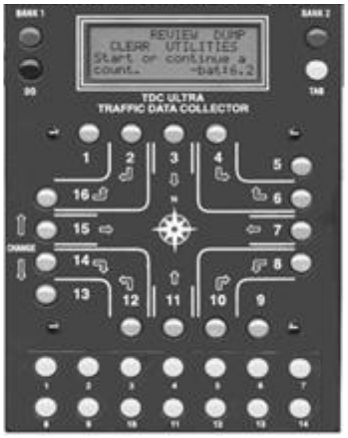


a) Electronic Counting Device (ECD)

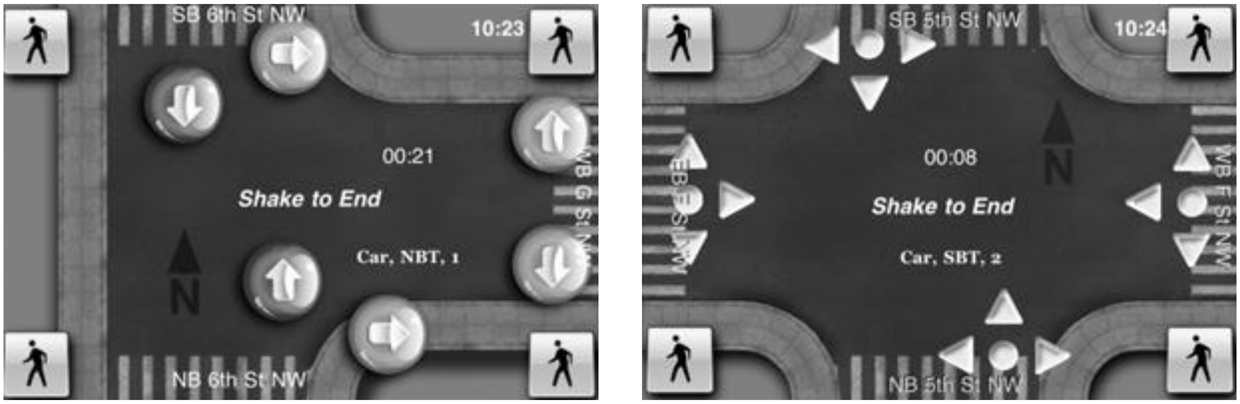
b) iPad – Hyper Interface

c) iPad –Classic Interface

d) iPod – Hyper Interface

e) iPod – Classic Interface

Figure 1. Devices used for turning count data collection.



a) 3 –way intersection with Classic interface

b) 4 – way intersection with Hyper interface

Figure 2. Alternative LCD Counting Interface

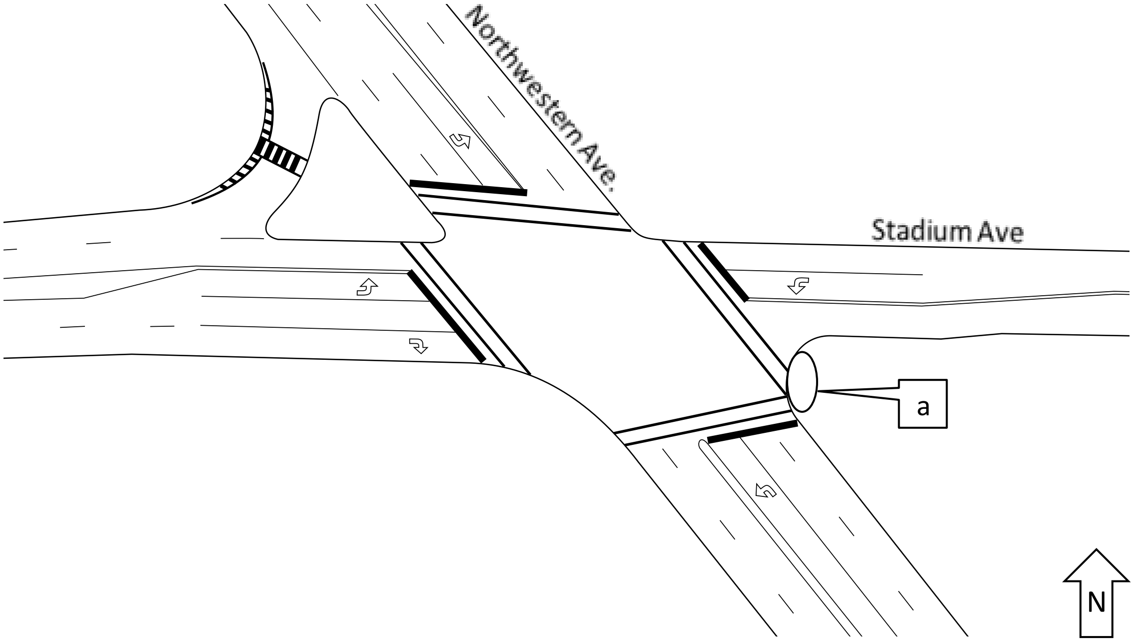


Figure 3. Northwestern and Stadium Ave. Intersection Geometry

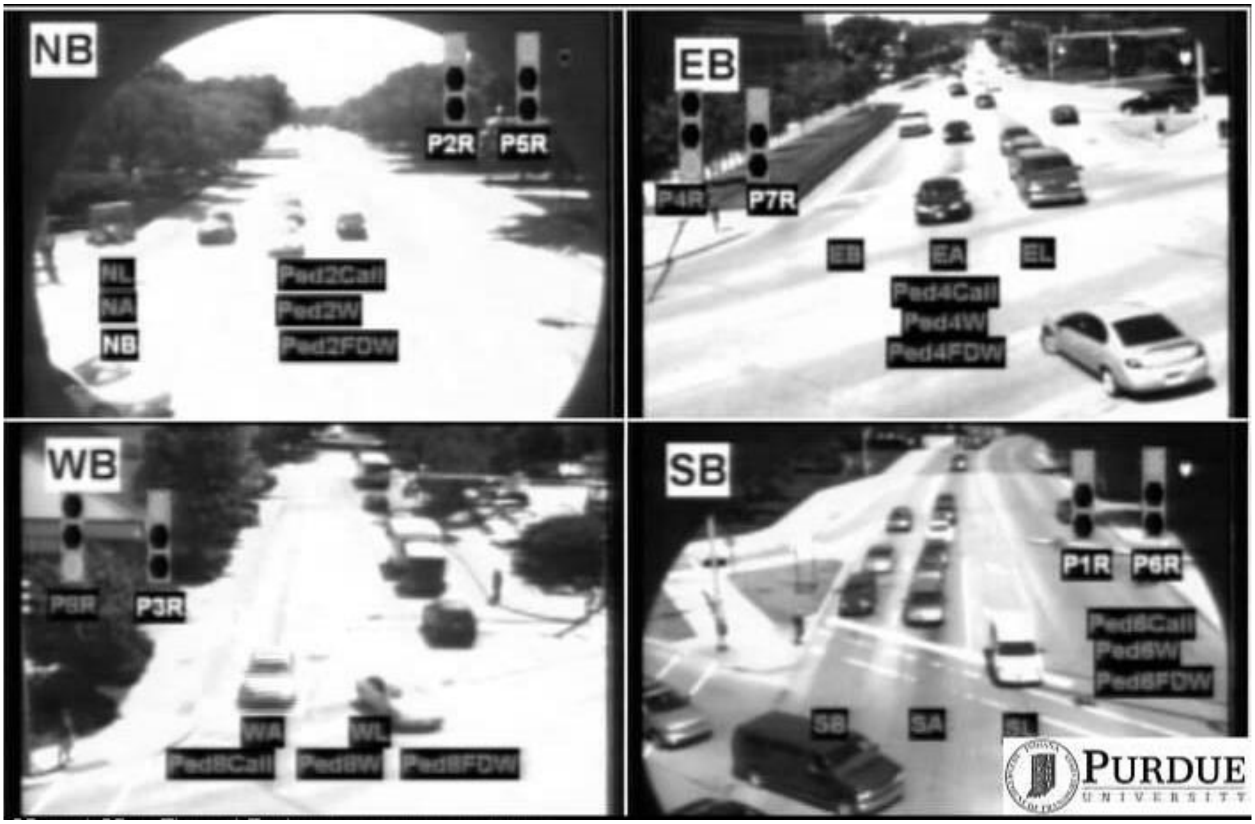
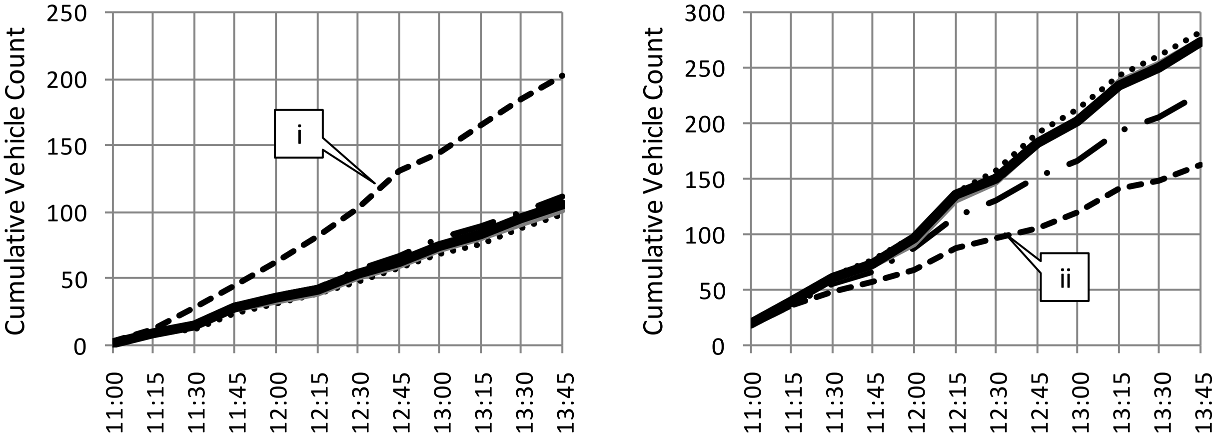


Figure 4. Video used to visually ground truth turning counts

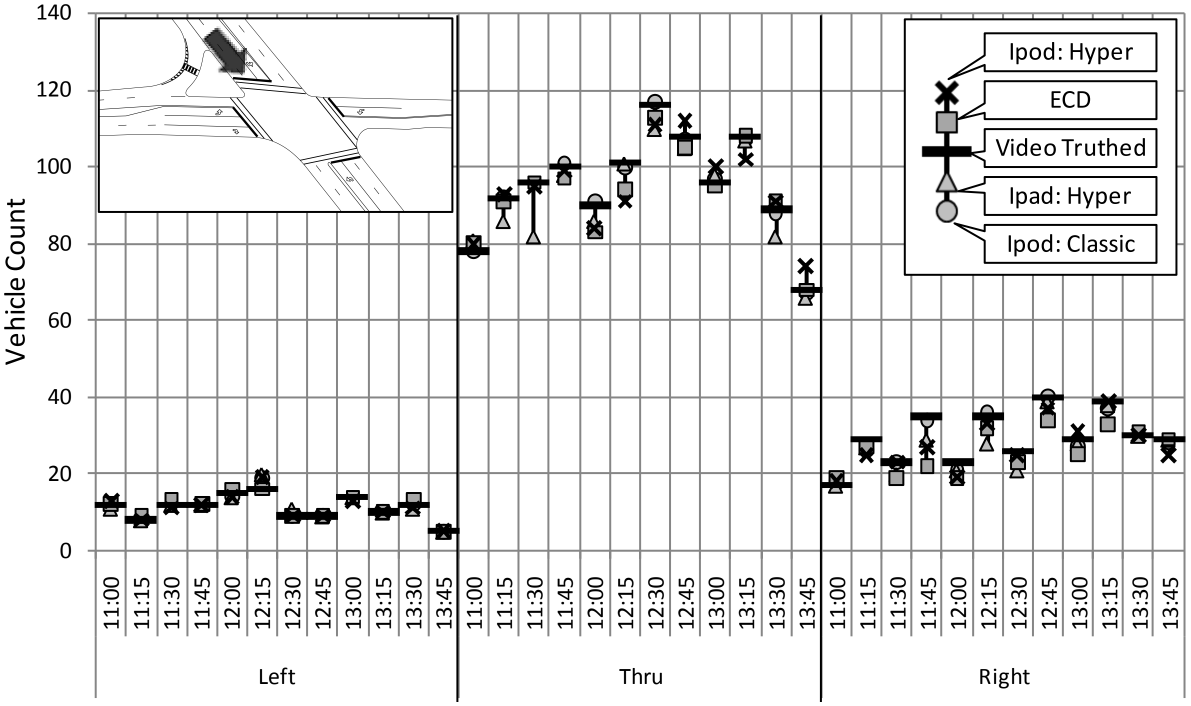
Table 1. Data Collection Procedure

Day	User	Device	Interface
1	1	iPod	Classic
	2	iPod	Classic
	3	iPod	Hyper
	4	iPad	Hyper
2	1	iPod	Hyper
	2	iPod	Hyper
	3	iPod	Classic
	4	iPod	Classic
3	1	iPod	Classic
	2	iPad	Hyper
	3	ECD	Standard
	4	iPod	Hyper

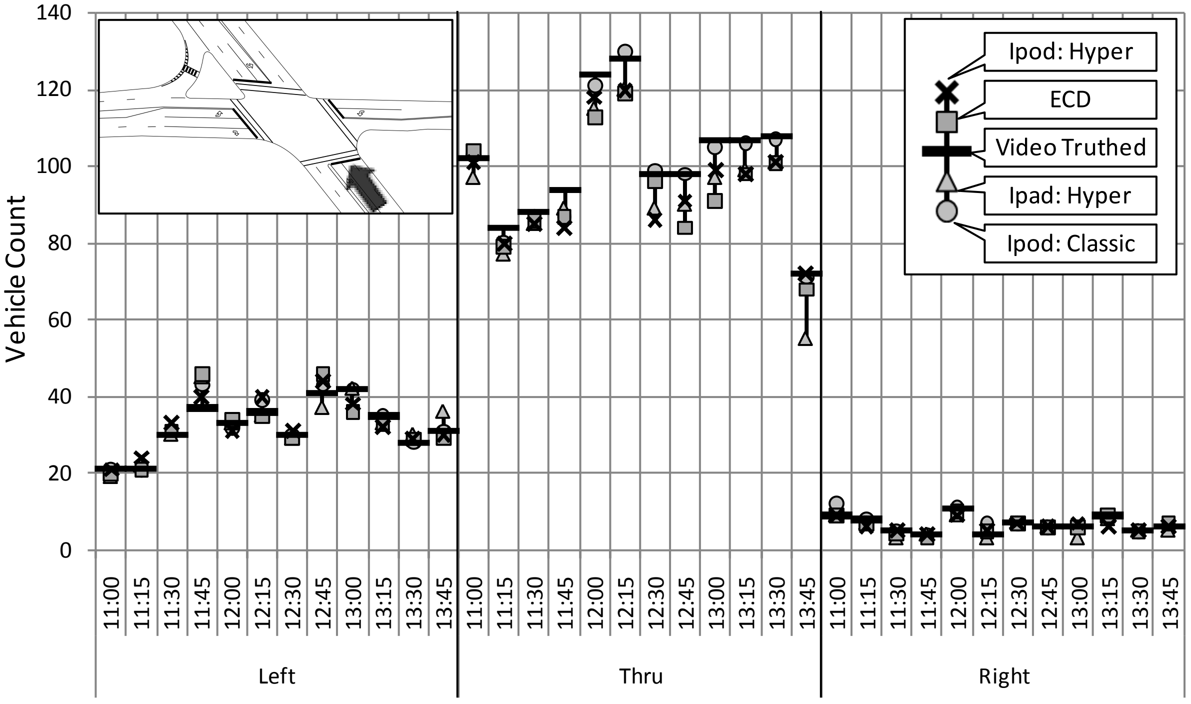


a) Westbound Left Turn b) Westbound Thru

Figure 5. Example of systematic Day 1 Data Collection Error

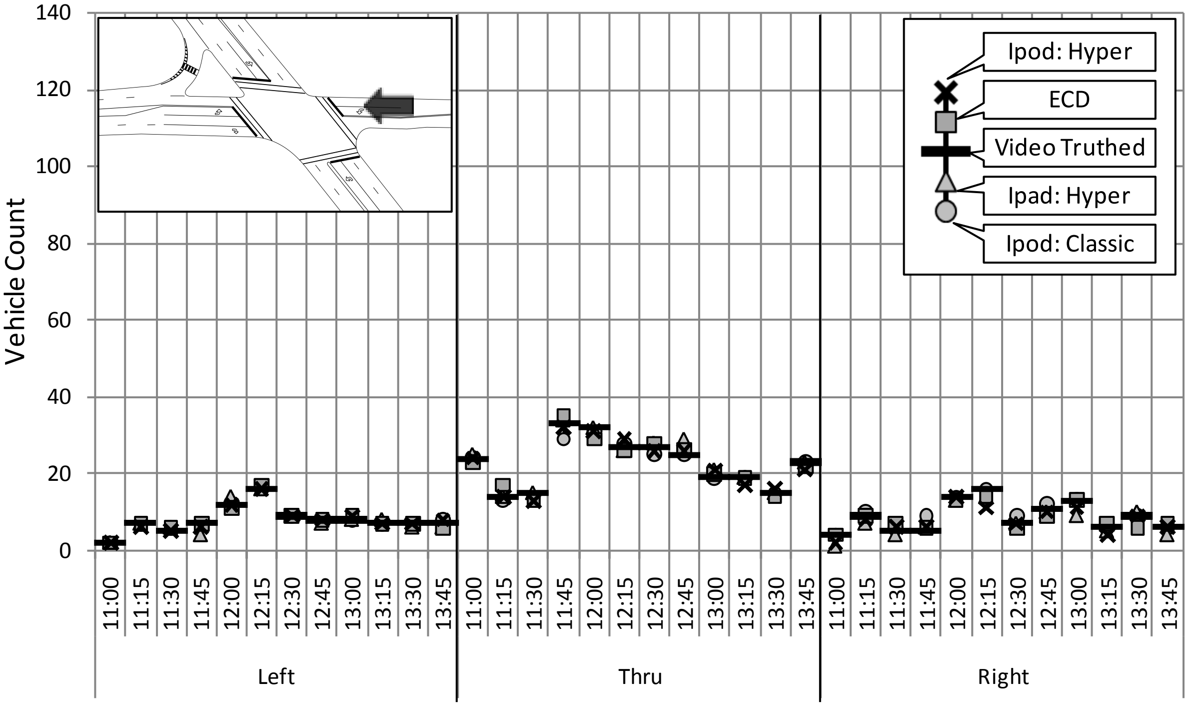


a) Southbound turn count

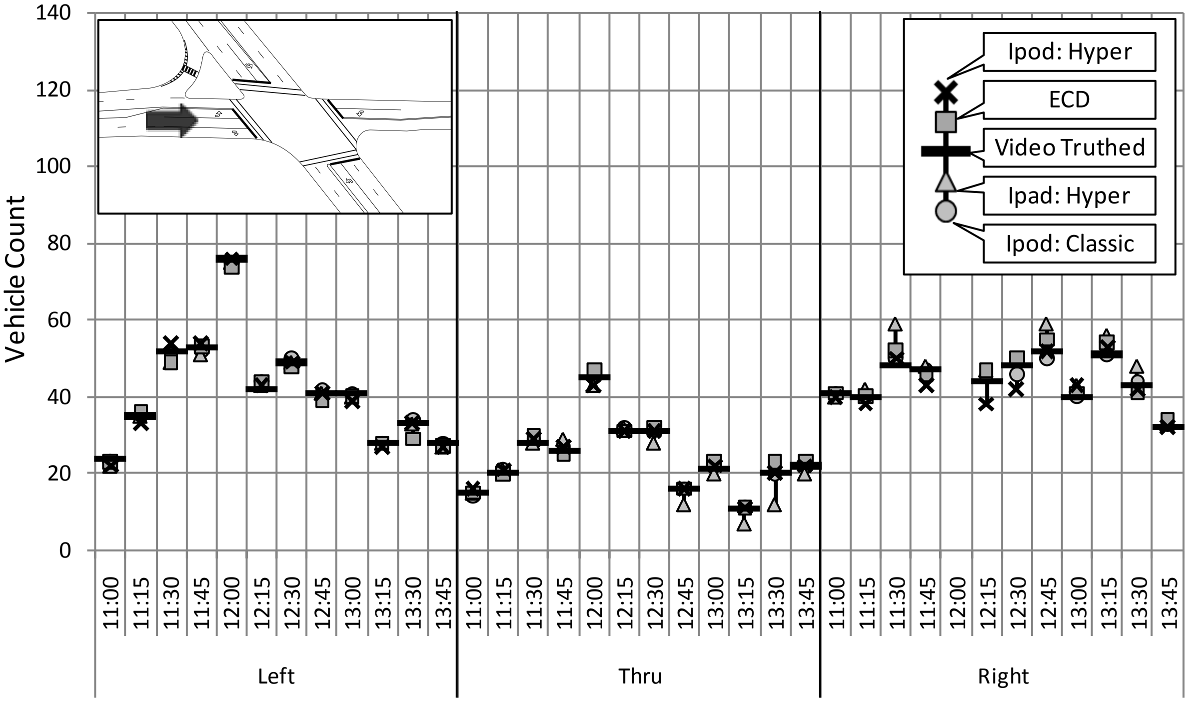


b) Northbound turn count

Figure 6. Day 3: Traffic counts over 15 minute intervals with four different counting devices.

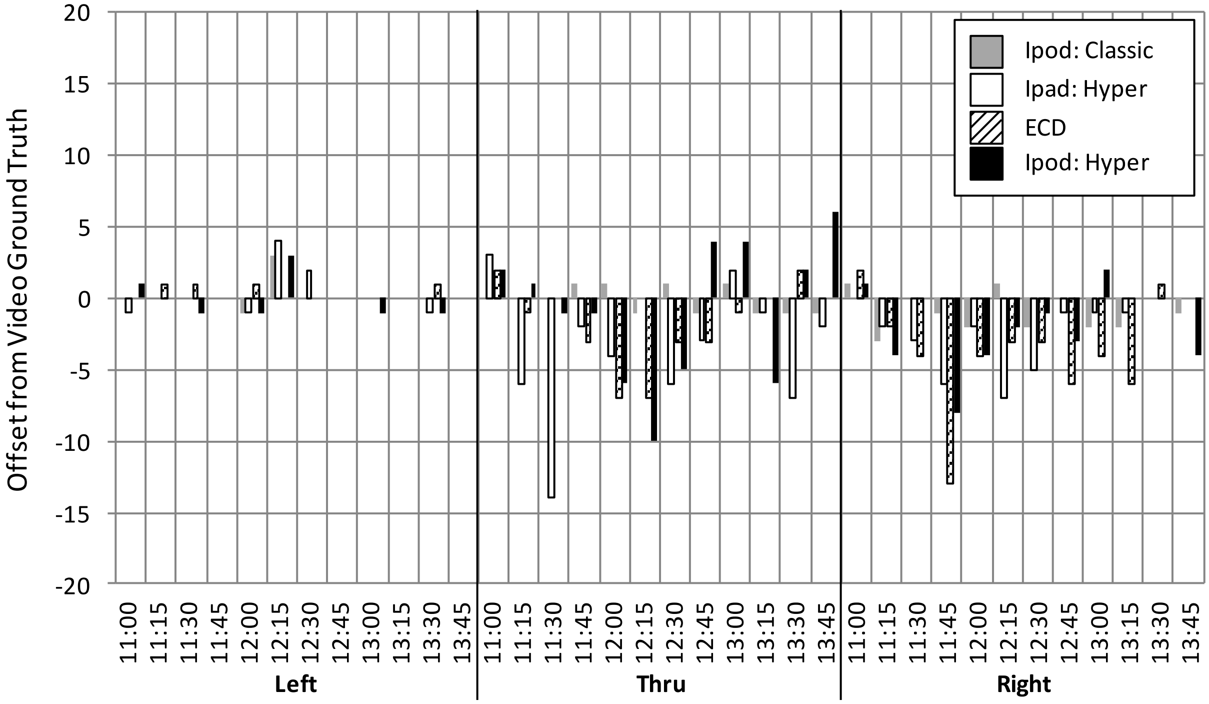


c) Westbound turn count

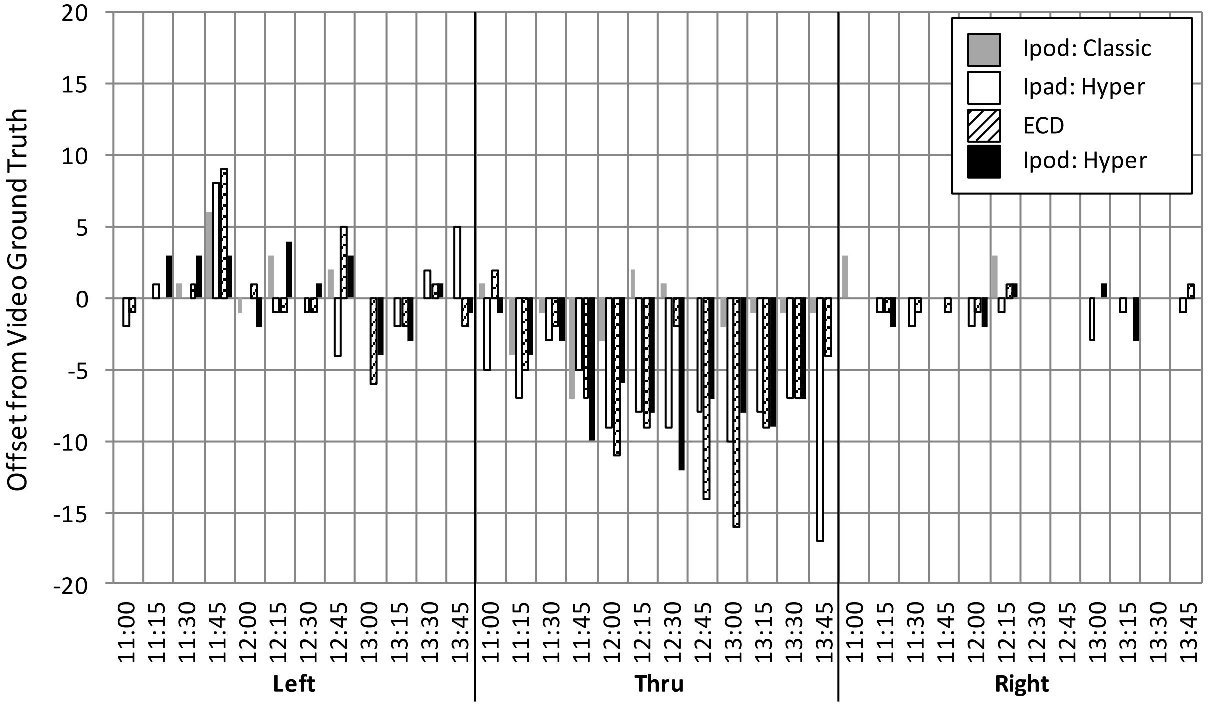


d) Eastbound turn count

Figure 6 (cont.). Day 3: Traffic counts over 15 minute intervals with four different counting devices.

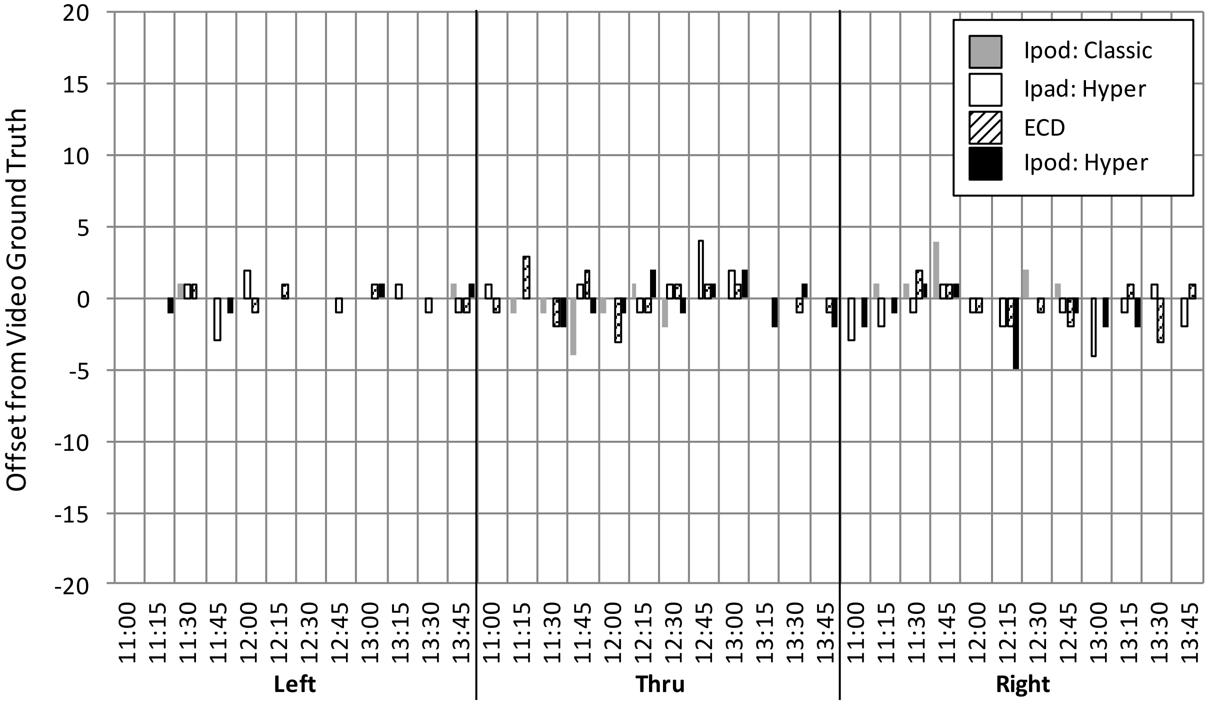


a) Southbound turn count error

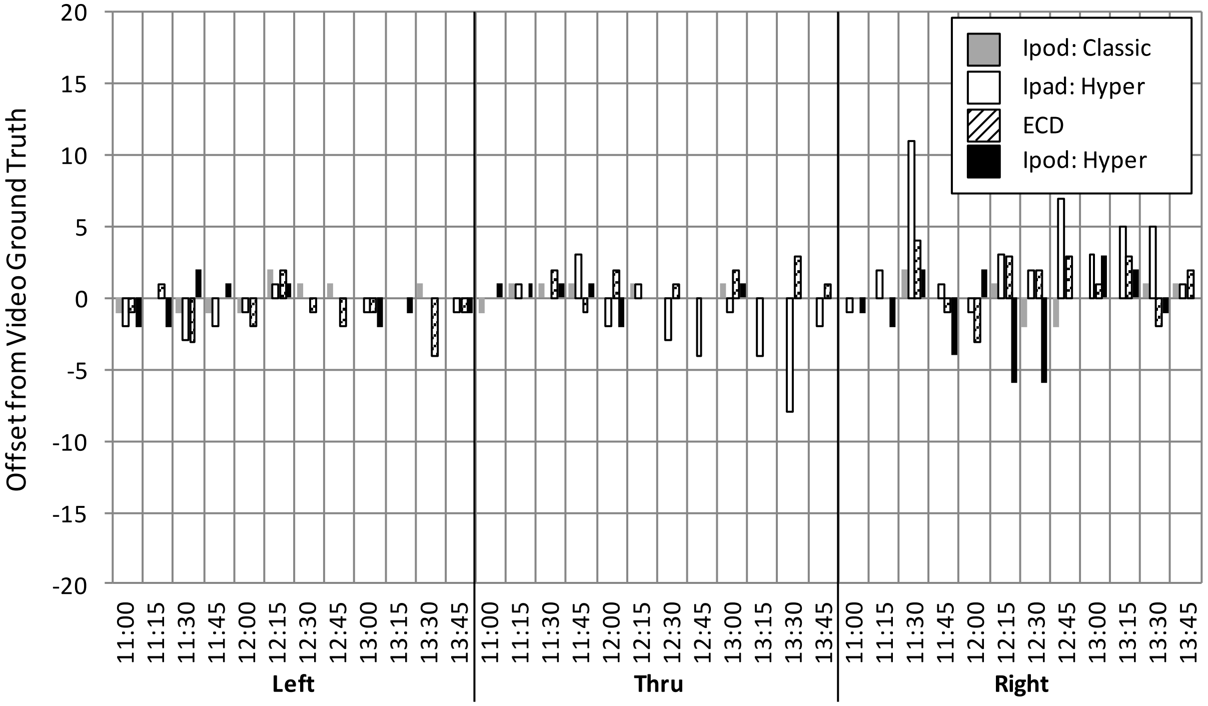


b) Northbound turn count error

Figure 7. Day 3: Turning count difference for each device compared to ground truthed video

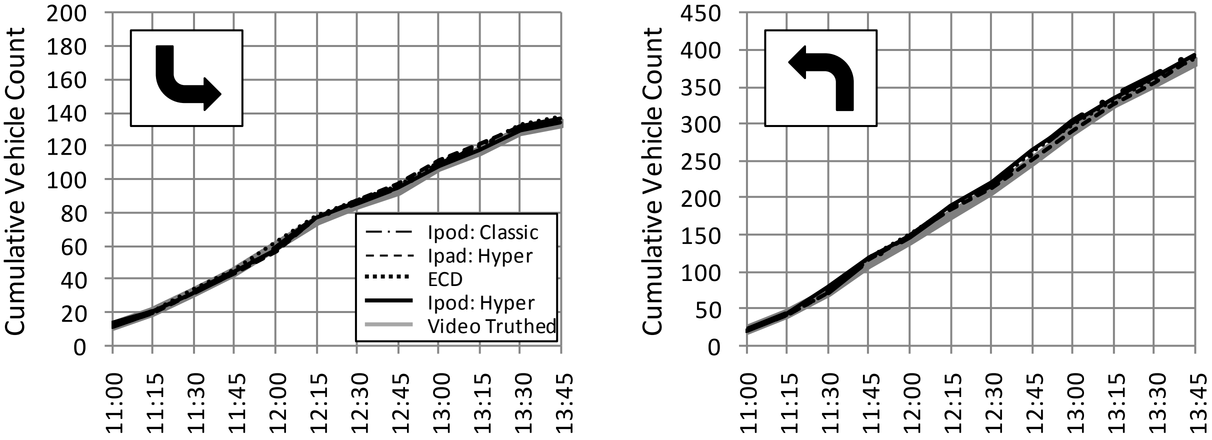


c) Westbound turn count error

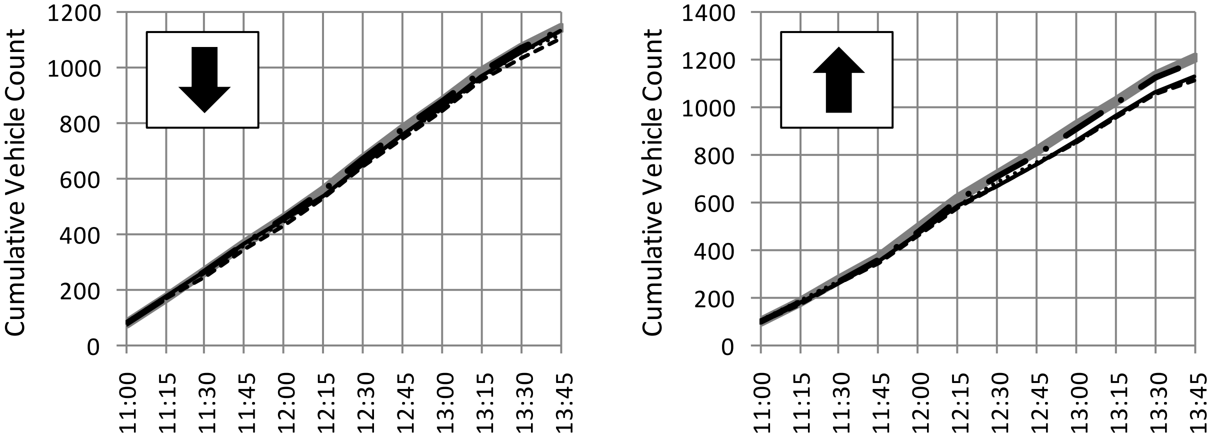


d) Eastbound turn count error

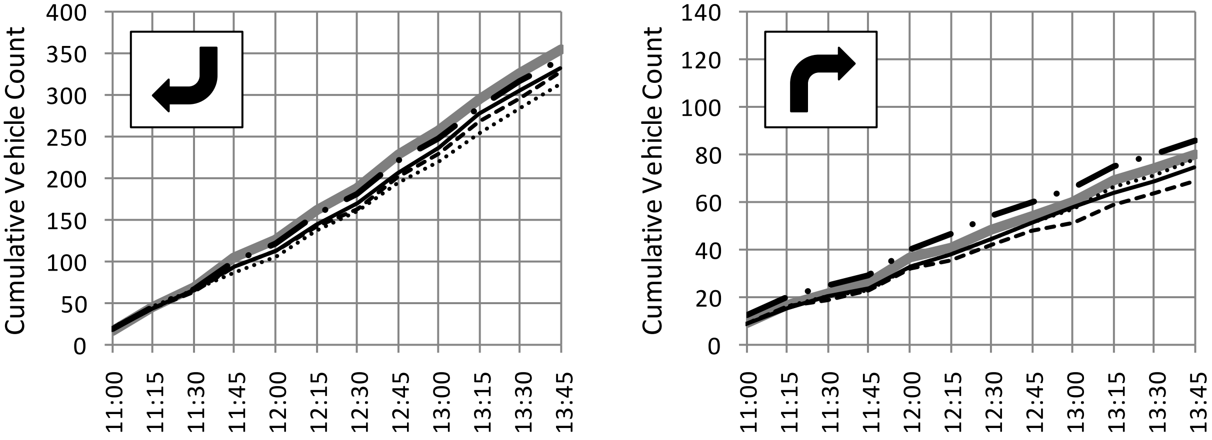
Figure 7 (cont.). Day 3: Turning count difference for each device compared to ground truthed video



a) Southbound Left Turn b) Northbound Left Turn

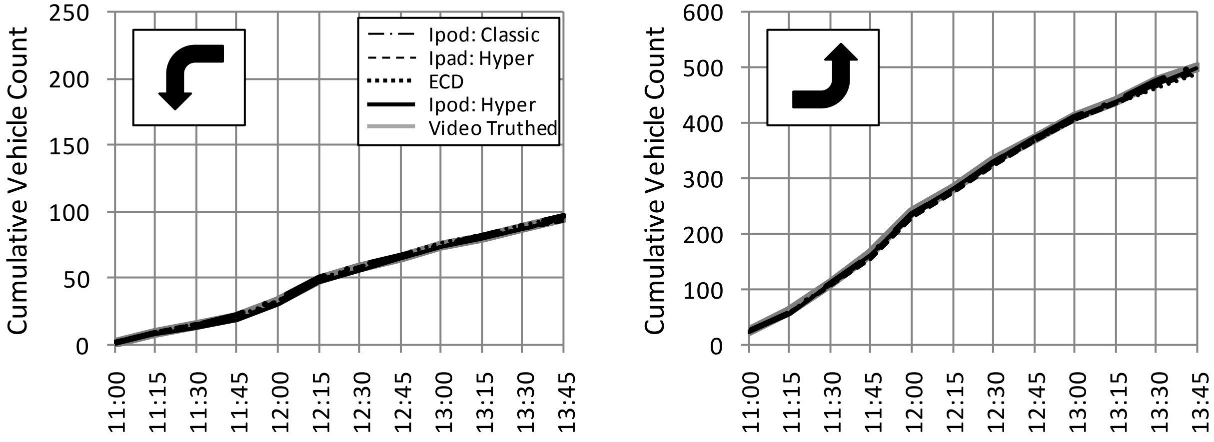


c) Southbound Thru Movement d) Northbound Thru Movement



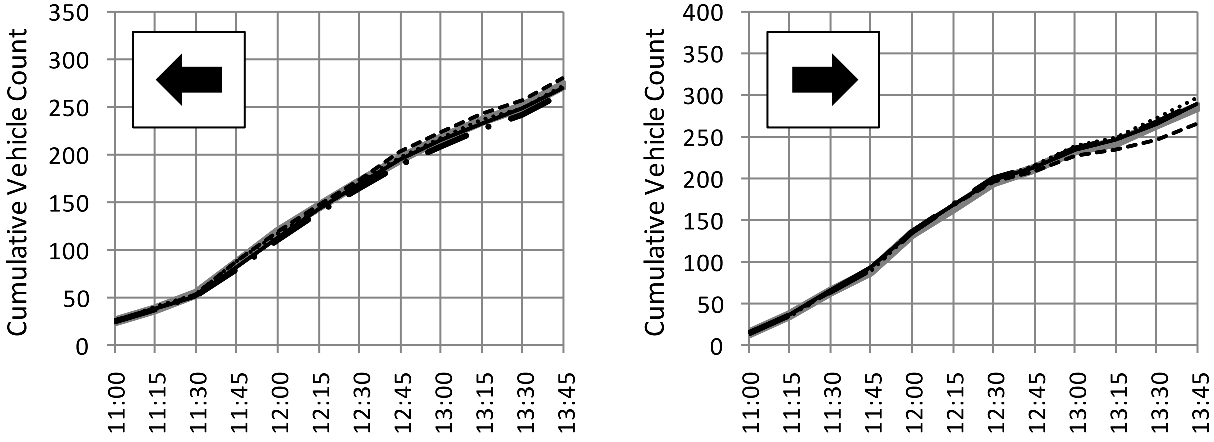
e) Southbound Right Turn f) Northbound Right Turn

Figure 8. Day 3: Cumulative traffic counts per movement by device over a 3 hour period.



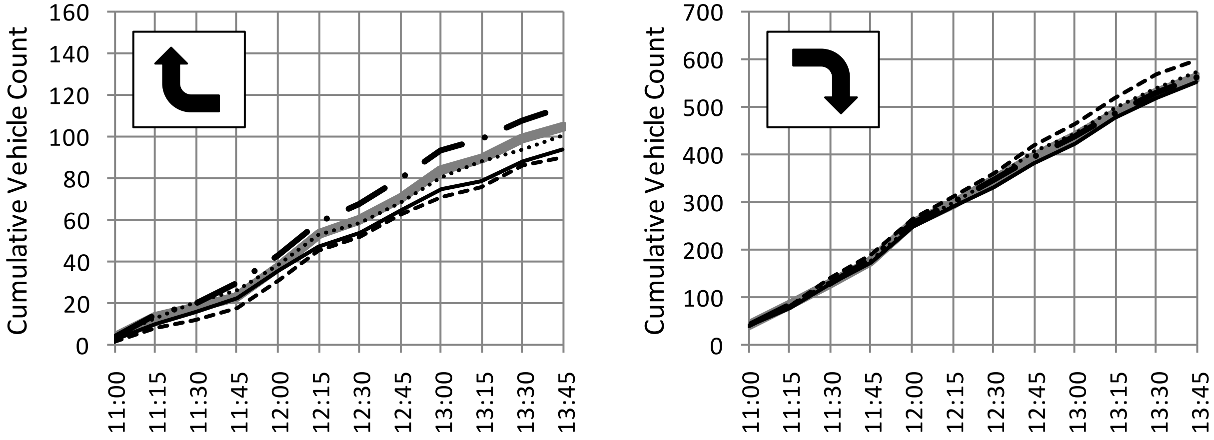
g) Westbound Left Turn

h) Eastbound Left Turn



i) Westbound Thru Movement

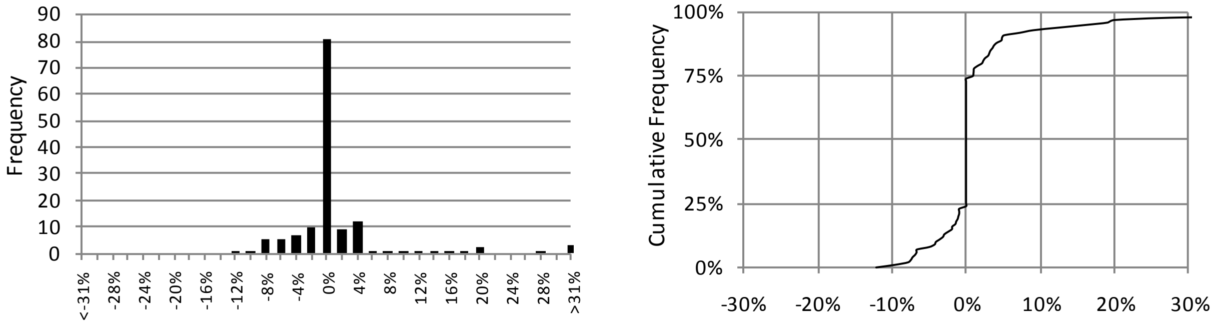
j) Eastbound Thru Movement



k) Westbound Right Movement

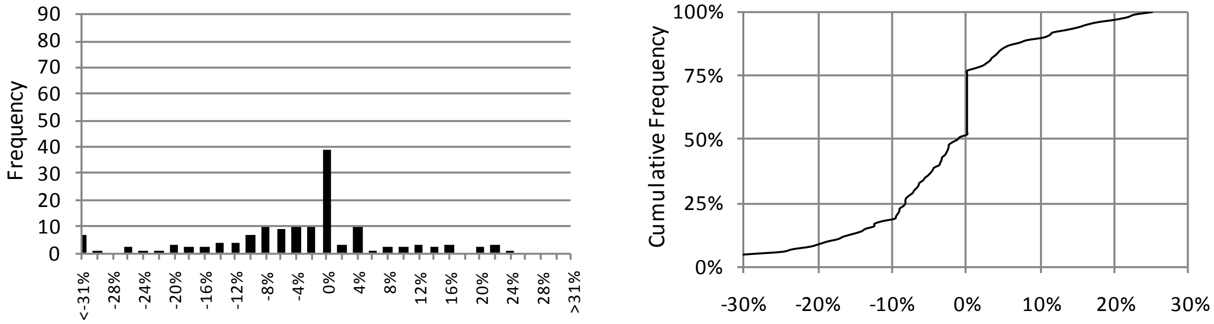
l) Eastbound Right Movement

Figure 8 (cont.). Day 3: Cumulative traffic counts per movement by device over a 3 hour period.



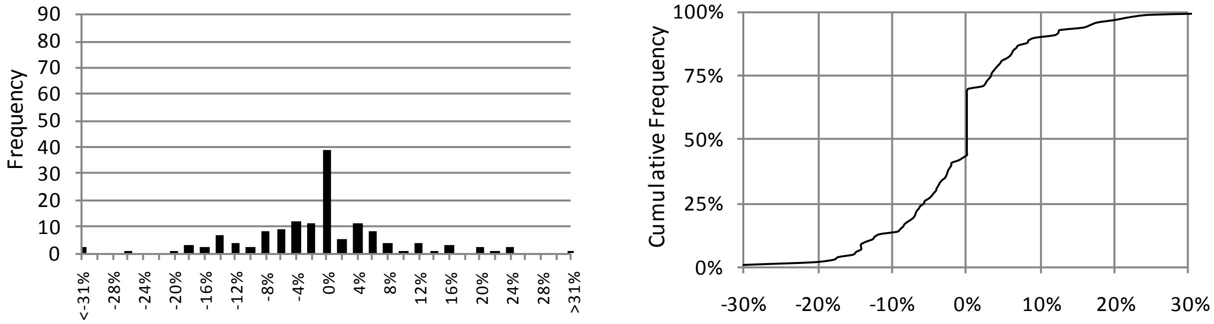
a) iPod: Classic – User 1 Histogram

b) iPod: Classic – User 1 CFD



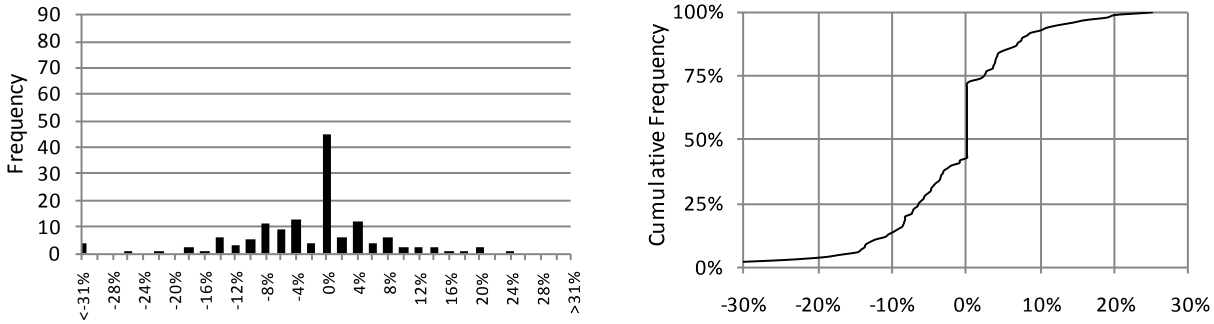
c) iPad: Hyper – User 2 Histogram

d) iPad: Hyper – User 2 CFD



e) ECD – User 3 Histogram

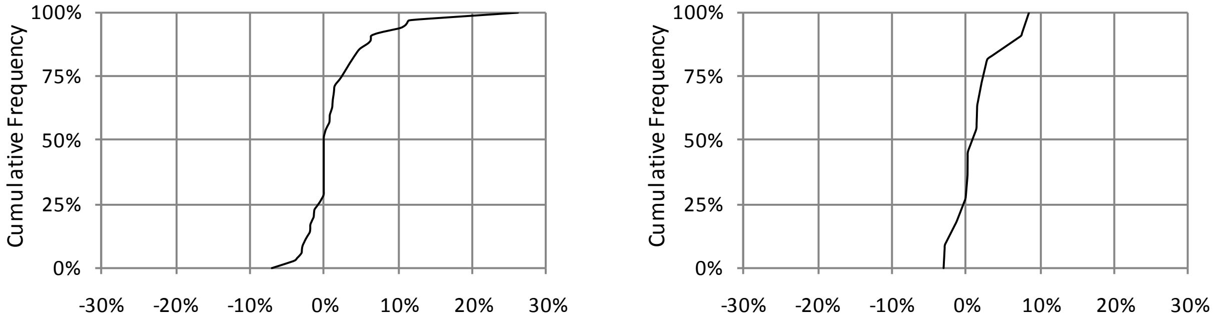
f) ECD – User 3 CFD



g) iPod: Hyper – User 4 Histogram

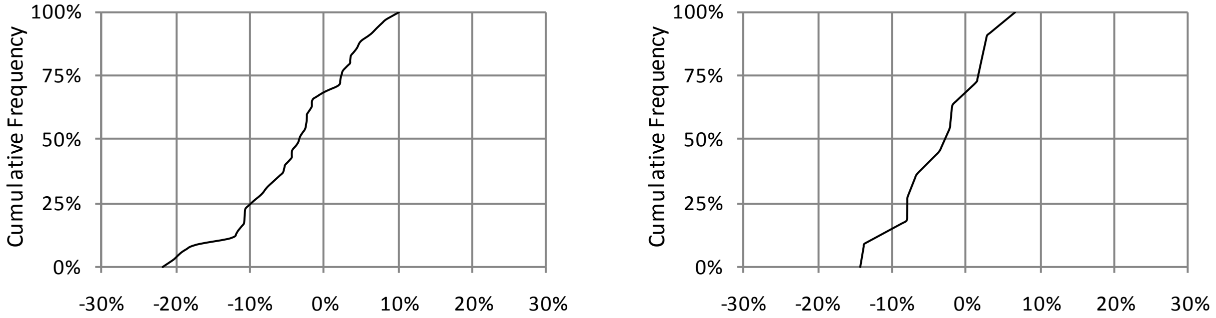
h) iPod: Hyper – User 4 CFD

Figure 9. Day 3: Percent Error for each approach and each 15 minute interval (144 per device)



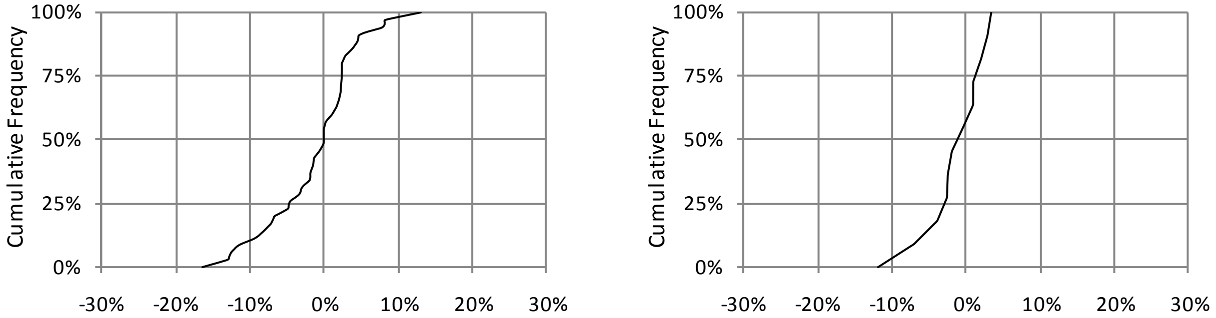
a) iPod: Classic – User 1 CFD (1 hr bins)

b) iPod: Classic – User 1 CFD (3 hr bins)



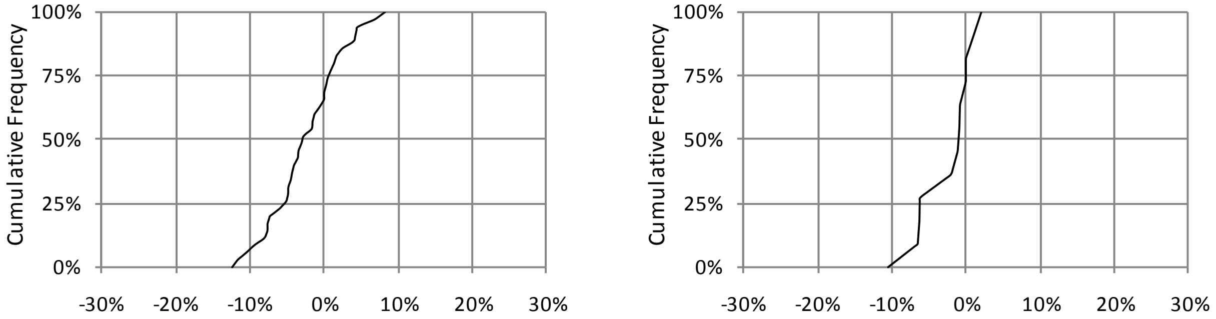
c) iPad: Hyper – User 2 CFD (1 hr bins)

d) iPad: Hyper – User 2 CFD (3 hr bins)



e) ECD – User 3 CFD (1 hr bins)

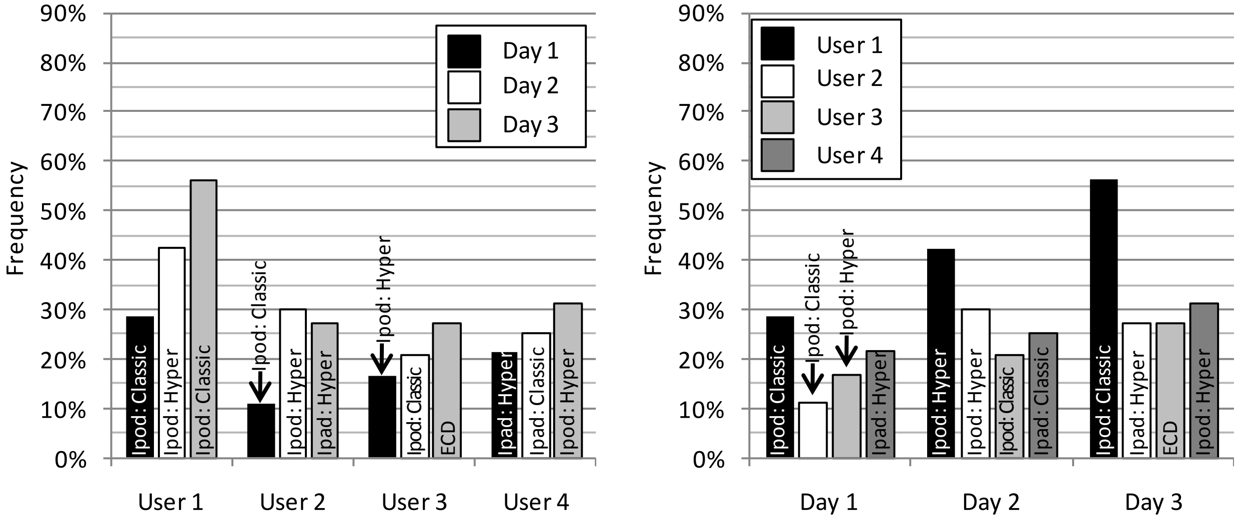
f) ECD – User 3 CFD (3 hr bins)



g) iPod: Hyper – User 4 CFD (1 hr bins)

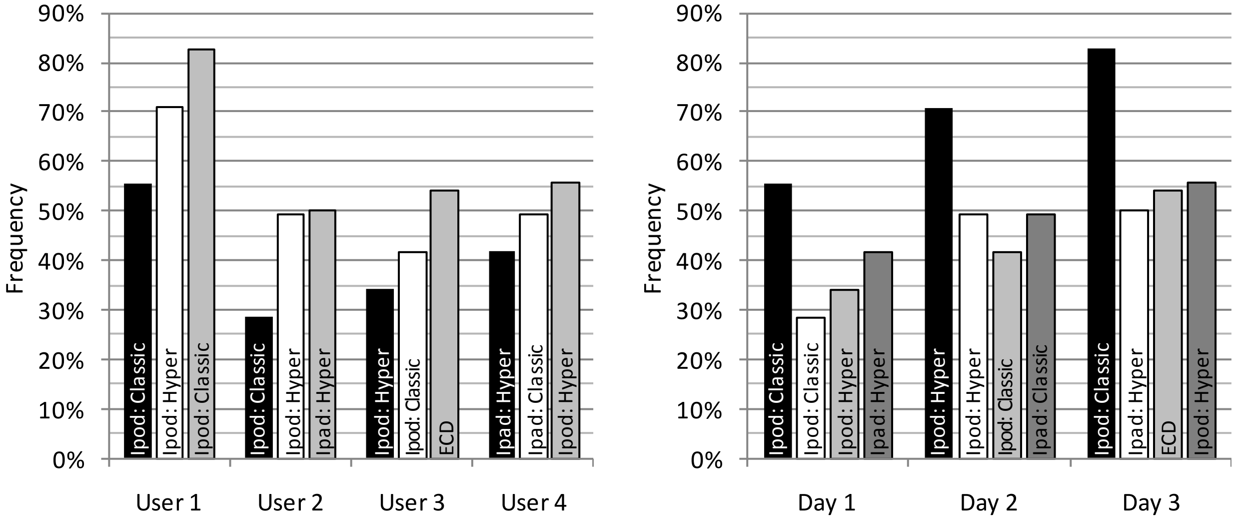
h) iPod: Hyper – User 4 CFD (3 hr bins)

Figure 10. Day 3: Percent Error for each approach and each interval with different bin sizes



a) Daily Differences (<1%)

b) User Differences (<1%)



c) Daily Differences (<5%)

d) User Differences (<5%)

Figure 11. Frequency of being within specified error of the video truthed data in a 15 minute movement.