LiteTurn: Automated, Gesture-Controlled Bicycle Turn Lights Using Cheap and Efficient Consumer Devices

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***Abstract*—**This paper presents LiteTurn, a new gesture-controlled turn-signaling system for cyclists that uses cheap consumer devices and energy-efficient Bluetooth 4.0 (BLE) to provide cyclists and motorists with better road awareness when sharing the road with other cyclists. This midpoint paper specifically covers the LiteTurn product that was designed and developed over 24 hours at HackTX 2014, a large hackathon in which LiteTurn placed 3rd overall.

I Introduction

In a large number of major cities across the U.S., bicycling has seen a rise in popularity and use. Accompanying this rise in popularity has been an increased focus on bicycle safety and infrastructure, with government agencies frequently treading the line in order to satisfy both cyclists and motorists and accommodate both methods of transportation on the road safely and conveniently. Today, cyclists are still seen as secondary occupants on the road, and there has been a severe lack of adequate, readily-available accessories for cyclists that keeps them, and others sharing the road, aware of the conditions at hand, which can rapidly change in response to unpredictable or erratic behavior by cyclists and motorists alike. In particular, there have not been any cheap, readily-available turn signal products that are easy to use and are clearly visible to pedestrians, motorists, and cyclists traveling in a variety of different angles and directions.

Although consumer products have been developed to sell embedded lights sewn into clothing such as gloves, jackets, and helmets, these products have a high price point, require accessory clothing to be worn by the user, and require the user to make use of additional controls embedded in the clothing or attached to the handlebars to be effective. Some of these products also fail to improve visibility by a large amount; for example, the new Zackees turn-signal gloves requires users to hold a button on their glove to light up LEDs embedded in the gloves themselves, which are then deactivated as the rider holds the handlebars to start and complete the turn safely.

LiteTurn aims to solve all of these problems using cheap hardware, readily-available consumer devices with on-board accelerometer and gyroscopic sensors, and energy-efficient BLE wireless communication to provide cyclists with gesture-controlled turn signal lights that provide additional services beyond turn signaling. In addition to being able to signal a turn, the LiteTurn system will be able to provide custom lighting animations in neutral states and display slowing and stopping information in the form of acceleration-sensitive lighting.

By utilizing the official, recognized bicycle hand signals for turning and stopping, cyclists will not have to adapt to the new system -- the only requirement for cyclists is to download a mobile app on their smartphone and accompanying smartwatch, which will communicate with the cheap LiteTurn hardware mounted on their bicycle. In addition, this system is potentially compatible using any combination of smartphone and smart wearable device that provides orientation and GPS location sensor information, reducing the costs of the system significantly by using commonplace devices that many people already own and wear on a daily basis. The LiteTurn system can also replace the head and taillights commonly used on bicycles in low-lighting conditions, augmenting them with automated signaling and aesthetic capabilities at a fractional increase in price.

Figure 1: Illustrations of the four main cyclist hand signals for turning. From left: left, right, right, and left turn signals.

II Design

The focus for the first stage of LiteTurn was on accurate detection of turn signal gestures and end-of-turns, and the hardware used to display highly-visible lighting. In a general system, turn signal gestures are detected using accelerometer and gyroscope sensory data interpreted into quaternions, which can be represented as yaw, pitch, and roll rotations around a center of mass. Detection of a turn occurs when the sensors are oriented at a 90-degree yaw from the rider with the correct roll (wrist rotation) orientation. Above a certain threshold, a larger pitch rotation indicates an inward turn, rather than an outward turn.

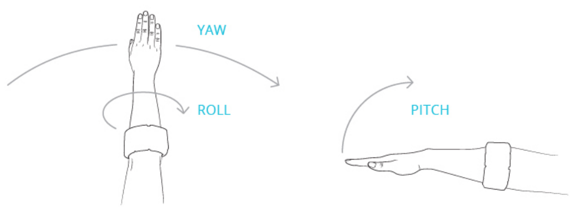


Figure 2: Illustrations of yaw, pitch, and roll rotation axes around the center of mass using accelerometer and gyroscope sensors attached to the cyclist's wrist.

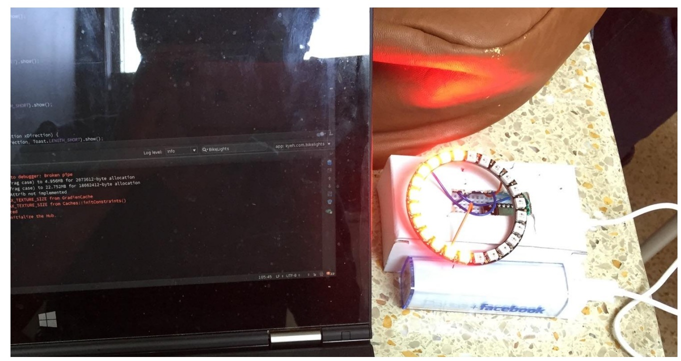
However, variations and inaccuracies in the sensors can produce noise within the readings, and this is often amplified when riding a fragile, physical piece of transport such as a bicycle. This is especially notable in the yaw rotation reading discrepancies that appear when transitioning from the outward turn signal to the inward, bent turn signal. Readings should therefore be transformed using a noise-reduction filter and sub-divided into discrete segments along the dimensional plane. This sub-division makes it easy to define regions in 3-dimensional space where gestures can be identified.

Ending turns can be broadly detected using GPS location bearings, which provides degrees along a cardinal directional system. Since most turns are roughly right turns or u-turns, detecting 90-degree and 180-degree changes within a small threshold of error will accurate provide evidence of an ended turn. Bearing readings should be taken once per some distance window, which should be large enough to avoid false positives, but short enough to be responsive to the user's activities.

III Initial Implementation and Experiments

At HackTX 2014, a prototype consumer LiteTurn product was developed using a Myo gesture-recognition armband, a Spark Core micro-controller, and a 24-Neopixel LED ring. The product used Myo gesture and orientation sensors to detect turn signal gestures, Android GPS bearing information to detect end of turns, and a wireless core hooked up to the Neopixel ring, which acted as turn signal lights. These three major components combined to become the fully-functional product that was demoed and, ultimately, placed 3rd overall in the hackathon.

(a) A Myo gesture-recognition armband



(b) A 24-Neopixel RGB LED ring and 2200mAh LiPo battery wired to a contained Spark Core micro-processor with embedded WiFi chip.

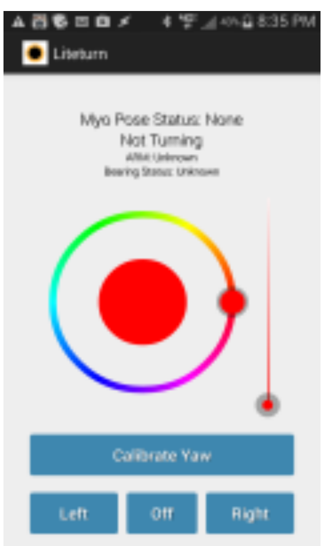
Figure 3: The hardware for LiteTurn version 1. (a) The Myo armband contains an accelerometer, gyroscope, and EMG muscle activity sensors to detect activities such as fingers spread, closed fist, and directional hand waving. (b) The LiPo battery powers the core with 5V, which sends data to a digitally-addressable ring of current-controlled LEDs.

The first component involved grabbing gesture and orientation data from the Myo's accelerometer, gyroscope, and EMG muscle activity sensors to detect when the cyclist signals for a turn (Figure 3a). Although Myo gestures (FIST, FINGERS SPREAD) worked as a precautionary filter to prevent false positives from coming through, it required extra knowledge and adaptation by the cyclist to understand the required pose to activate the lights.

Through experimentation, we found that the orientation data itself was a satisfactory indicator of the user's intentions, and that noisy data could be filtered naively by delaying the signal until the position was held for a short time. As a result, this step could be done at a much lower cost by using any sort of existing consumer smart watch or armband that the user already wears with less overall bulk. By doing so, the required calibration of the Myo is also avoided entirely. A rider who wishes to use the LiteTurn system but does not own an appropriate wearable can, in theory, strap the phone to their wrist and achieve the same effect, although this is unwieldy and should generally be regarded as less safe.

The second component involved hooking a Spark Core up to a Neopixel 24-LED RGB ring (Figure 3b) and providing a simple web API to send commands. A simple LiPo battery provided power to the micro-controller. Since the Spark Core requires a WiFi connection, cost and battery drain can easily be reduced by replacing the core with a simple micro-controller and bluetooth chip to pair directly with the user's phone. To work around this limitation at HackTX, we connected the smartphone to a 4G network and set up a wireless hotspot for the core to connect to.

The final component was the companion Android app, which brought both pieces together and added additional aesthetic features. Using GPS location bearings, we were able to determine when the user makes a turn or u-turn. Instead of combining accelerometer and magnetometer sensors, which is used in the Google Maps application to provide very precise measurements, we used GPS location changes to detect bearings. This doesn't work over short distances, but the large distances traveled on bicycles makes it a perfect fit, with the added benefit that small, sudden turn changes won't affect the turn readings. For example, if the user rides around the car in front of them, the combination of GPS location bearings and a 10 meter minimum distance for detection will prevent a false positive.



With a Bluetooth 4.0 connection opened to the Myo, a 4G connection serving a WiFi hotspot for the core, and GPS readings being taken for bearing information, this app became a huge battery drain. However, as previously mentioned, components can be swapped out to make this much more feasible and readily-available to all consumers.

Fig 4: User-facing companion Android application to display sensor readings, control light status, and change light colors.

IV Future Work

Several challenges arose regarding the LiteTurn product made for HackTX, and a number of these challenges are similar to those brought up in the RisQ paper for smoking gesture dectection[1].

1. Signal variation due to orientation changes:

Each rotational definition -- yaw, pitch, and roll -- were sub-divided into 18 definitional sections, and the yaw is particularly important and difficult to threshold, as this translates to the orientation of the user's body with respect to the cardinal directions. The yaw must be thresholded to prevent arm positions out to the rider's side (indicating turn signal gestures) from being confused with arm positions out in front of them (indicating the common handlebar pose). However, as the user maneuvers through different roads, their bearings will change and, accordingly, their yaw orientation. This can be easily prevented by adjusting the signals based on the user's location bearings.

2. Concurrent activities and confounding gestures:

More work should be done in filtering noise from the various sensors. In particular, the orientation readings should undergo a low-pass filter and an averaging of the most recent window of values to smoothen the overall readings with little increase in latency. Thresholds for the roll orientation can reduce false positives due to less common poses while riding, such as one-handed riding, waving, or high-fiving.

3. Detecting the end of turns:

By using GPS location bearings, the LiteTurn product is able to determine when a turn has ended by checking the degrees between the current bearing and previous bearings in recent memory. However, not all turns are within some small threshold of 90 or 180 degrees; in particular, forked roads and lane-change signals will go undetected as small or even unchanged bearing readings. More precise sensors, such as accelerometers, or more robust detection, such as an adaptive timeout based on the change in bearings from one time step to the next, may be required to accommodate these distinct, minute activities.

4. Better coverage of motorist and cyclist activities:

The smartphone accelerometer should be used to reflect changes in speed using the turn signal lights, as is done with common motor vehicle lights. In addition, the braking hand signal, though uncommonly used by cyclists, is an officially recognized gesture and should be detected by the LiteTurn system.

5. Consumer Aesthetics:

The LiteTurn system in its neutral state has the potential to provide customized lighting aesthetics and animations due to the 24 individually-addressable RGB LED Neopixel lights installed. Although this is unnecessary for the general LiteTurn system, a more expensive consumer line could sell these Neopixel lights for cyclists who wish to have more aesthetically pleasing hardware.

6. Cheaper Components with Full Bluetooth 4.0 Wireless

As is, the LiteTurn system takes advantage of a limited-use $150 Myo product and a $40 robust Spark Core micro-controller with an embedded WiFi chip. These components can be easily replaced by any of the increasingly popular smartwatches or wristband products and a combination of a cheap, sub-dollar micro-controller and bluetooth low energy chip to provide lower energy usage, lower costs, and more accessibility.

V References

[1] A. Parate, M. Chiu, C. Chadowitz, D. Ganesan, E. Kalogerakis. 'RisQ: Recognizing Smoking Gestures with Inertial Sensors on a Wristband.' Proc. 12th Annual Int. Conf. Mobile Systems, Applications, and Services, New York, NY, USA, June 2014.