A proposal for bicycle's accident prevention system using driving condition sensing technology

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While there has been an increase in the use of the bicycle as a convenient means of transportation, the number of accidents related to bicycles has also increased. This paper proposes a system that prevents bicycle accidents. The proposed system consists of a driving situation sensing unit, control and evaluation unit, and warning unit. The system mainly focuses on preventing collision between bicycles and pedestrians. In order to avoid the collision, the system senses the traveling speed of the bicycle and warns the cyclist or pedestrians if the sensed speed is over the threshold speed. In addition, the system senses any course deviation and also issues a warning. This paper describes the system concept and implementation architecture. Experimental trials were conducted in order to define and confirm the thresholds value of dangerous cycling. From these trials, the threshold value of traveling speed and cumulating steering angle is 18 km/h and 540 deg per 10 s, respectably. This paper also proposes a three-level alarm using vibration, light, and sound.

I. Introduction

There has been a large increase in the use of bicycles of late, both because of their convenience and low environmental impact. This trend has been observed not only in traditional high bicycle use areas such as China but also in Europe or Japan. This increase has led to an increase in bicycle accidents. There are several different categories of accidents, such as bicycle-automobile accidents, bicycle-pedestrian accidents, and so on. Figure 1 shows statistics for bicycle accidents in Japan. Bicycle accidents account for about 20% of all traffic accidents. In addition, severe accidents such as fatal accidents have been increasing. As a result, the prevention of bicycle accidents has become a major concerns. In terms of preventing bicycle accidents, exclusive cycle way and bicycle traffic regulation are the most commonly employed measures. The use of an accident prevention mechanism or system on the bicycle has not been widely considered until now.

In this research, we have developed an accident prevention system that is attached to bicycle. This system can be expected to reduce the incident of bicycle accident, and it enhances the safety of bicycle. In the research, Fault Tree Analysis was used to determine the cause of bicycle accidents. From the results of the Fault Tree Analysis, we developed an accident prevention system that avoids collisions caused by over-speed cycling or meandering. This paper reports the basic concept of the system, including the cycling situation sensing and the collision warning mechanism for cyclist. Moreover, the performance of the system in actual experimental cycling is also summarized.

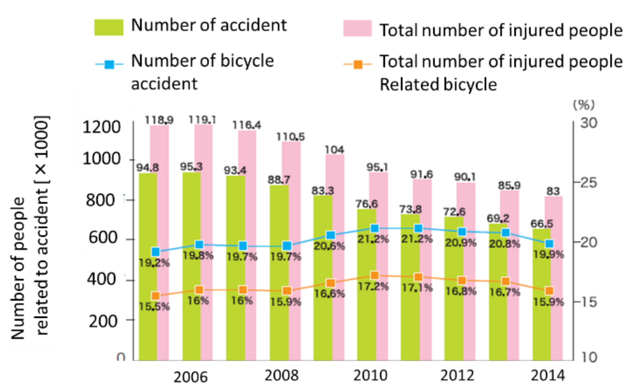

Figure.1 Statistics for bicycle accident

II. Related works

For bicycle accidents, Paul Schepers has proposed a conceptual framework for cycling safety. In his framework, crash and injury risks are modelled by the three safety pillars[1]. Especially, vehicles themselves are one of the most important pillars. Mohd Khairul has proposed a smart helmet with sensors for accident prevention[2]. In the research, motorcyclist will be alarmed when the speed limit is exceeded. A force sensing resistor is used to detect for motorcycle's speed. Aviral Vijay also developed a high-tech helmet for avoiding bike accident[3]. In his system, GPA and GSM are used to find the present location and cycling situation. Ashwarya has proposed an IoT based accident prevention and tracking system for night drivers[4]. The system provides an Eye blink monitoring system.

As shown above, in most research for bicycle accident prevention, a specific device such as a helmet or monitor is used to attach the supporting systems. However, wearing these devices can be inconvenient for the average bicycle user making a short trip to shops. Furthermore, the implementation cost of these devices is relatively high, and the cost of the unit may be higher than that of bicycle itself. The high cost of any unit will be an obstacle to its widespread use. On the other hand, there is few low-cost system with simple mechanism that are attached to the bicycle itself in order to avoid an accident.

III. Basic Idea

III.A Bicycle accident analysis

Figure 2 shows a Fault Tree of bicycle accidents. There are various types of accident from slight accident to more sever fatal accidents. Of these, collision accidents between bicycles and pedestrians tend to cause serious consequences, such as physical damage to pedestrian etc. Collisions between bicycle and humans are mainly caused by following reasons.

1. Over-speed cycling
2. Meandering cycling in congested areas
3. Cyclist's recognition delay for pedestrians

Most cyclists understand their cycling speeds and cycling situations. On the other hand, pedestrians around bicycles sometimes cannot recognize an approaching bicycle travelling at high speed or wandering. As a result, they may not get out of the way of dangerous bicycle. Moreover, nowadays some cyclists ride their bicycles while using smartphones or wearing earphones, which makes it difficult for them to recognize their cycling behavior. One of the most important factors in bicycle accident prevention is the detection of a dangerous cycling situation, enabling notification of the dangerous situation to the rider or pedestrian around the bike, and enabling evasive action. Taking these factors into consideration, the following system functions are needed to prevent a bicycle accident.

1. Sensing bicycle's speed and degree of meandering
2. Evaluating a dangerous cycling state by analyzing the sensed data
3. Then, warning cyclist and nearby people of the approaching danger.

By issuing warnings to both the cyclist and the pedestrians around bikes, accidental collision between bicycles and pedestrians can be avoided. Moreover, for the warning to be timely, the system should issue the warning 2 or 3 s before the possible collision between the bicycle and the pedestrians.

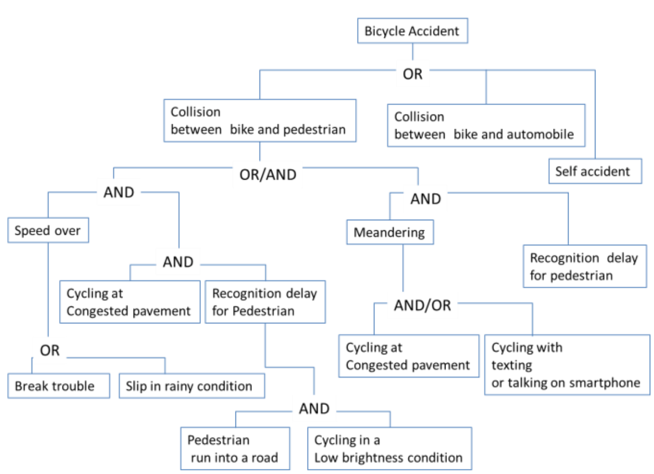

Figure.2 Fault Tree of bicycle accident

III.B Constraints

To enable the system to be attached to the bicycle, it should be developed as an embedded system combining both sensing and actuating units. However, there are a number of constraints from the cycling environment that must be considered.

1. Constraints from weather condition
   Breaking and skidding performance are heavily affected by rainy conditions. Thus, the safe cycling speed limit differs according to the weather conditions. In addition, pedestrian bicycle awareness may become difficult in rainy conditions.
2. Constraints from road conditions
   As for detecting meandering cycling, the system should be able to discriminate between simple cornering and dangerous meandering cycling. Both cycling around a simple curve and meandering cycling may result in similar steering angles. Thus, the system measures the frequency of steering over a defined period as well as the cumulating steering angles. In meandering cycling, movements with small steering angles are repeated and the frequency of steering tends to be high.
3. Constraints on attaching the system to the bicycle
   The system should be attached to the bicycle, thus the system's battery capacity should be taken into consideration. There is a trade-off between size or weight and battery capacity. If a lightweight and small size battery is chosen, the electrical capacity of the battery will be limited. The ideal system would have a high-capacity battery with a small size and weight. In addition, if a bike is ridden on an unsurfaced road, there is high physical vibration. This vibration can have major effects on system behavior, and in the worst case, the system may malfunction and fail. Thus, vibration proof features should also be considered in the system mechanism.
4. Cost constraints
   As mentioned before in related work, the cost of the system is one of the crucial factors. The cost of unit should be lower than that of bike itself. In addition, the size or weight of the unit should also be as low as possible. Taking these factors into consideration, the system should be developed as an embedded system using a microcomputer and simple sensors.

III.C System overview

III.C.1 System's main function

The proposed system measures a bicycle's traveling speed and steering angle using sensors, then compares the sensed data with thresholds of dangerous cycling and issues a warning. As road surface and weather condition are major contributors to accident, as mentioned above, the system also takes these factors into consideration. The system senses the brightness of the surface and differentiates between fine and rainy conditions and refers these data as additional criteria for dangerous cycling evaluation.

Traveling speed sensing:
A magnetic reed switch is attached to the bicycle's front wheel to measure its rotation speed. This is used to calculate the traveling speed of the bicycle.

Steering angle sensing:
A rotary potentiometer is mounted on the top of the handlebars to measure the steering angle of the bike.

Brightness sensing:
A illuminance meter on the rear deck of the bicycle measures the brightness of the road surface.

Weather sensing:
A short range reflective distance sensor on the front of the handlebars detects the presence of raindrops to evaluate the presence of fine or rainy weather.

All sensed data are processed on a microcomputer unit that is attached to the bicycle and are compared to the threshold value of dangerous cycling.

III.C.2 System architecture

Figure 3 shows the architecture of the proposed system. The system consists of four parts: the running condition sensing unit, running situation sensing unit, running status evaluation unit, and warning unit. Of these, the running condition sensing and running situation sensing units are constructed using the sensors described above. The running status evaluation unit controls the timing of each sensor, the warning timing, and the evaluation of dangerous cycling using a 16-bits microprocessor.

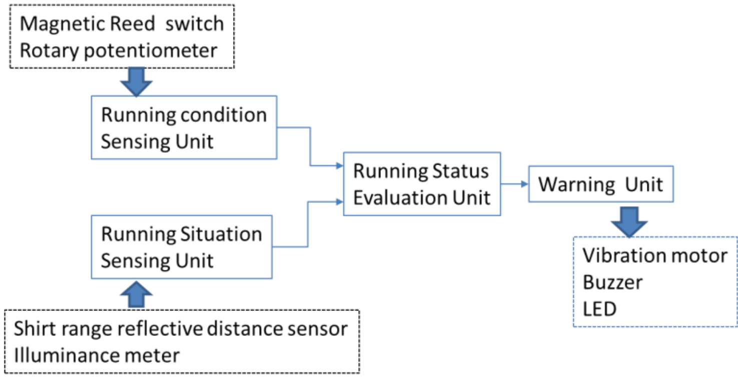

Figure.3 System architecture

III.C.3 Running situation sensing method

In bicycle accident prevention, statistics show that running condition such as rain or fine weather conditions and daytime or nighttime driving conditions are both large influential factors on accidents. Thus, the system has a running situation sensing unit that evaluates these two factors. Although a number of sensing units have already been developed that detect rainfall and daylight and have been applied in various systems, these conventional sensing units are not suitable for application to bicycles because of their size, weight or power consumption. Thus, our system uses original sensing units developed using sensors and microcomputers to aid application on a bicycle.

(A) Rain falling detection sensor

In the system, an infra-red light distance sensor is used to detect rain falling while cycling. Raindrops reflect infra-red light that radiates from the sensor. Catching the reflected light from raindrops in the sensor identifies that rain is falling. The sensing distance of the sensor is from 15 cm to 150 cm. The peak value of sensor is output at 15 cm distance from sensor to raindrops, and the output decreases as the distance increase. Figure 4 shows the output from the rainfall detection sensor. In the figure, the blue bar represents the output under rainfall conditions, while the red bar represents the output in fine weather. Both conditions are sampled three times. In the figure, the vertical axis shows the output voltage, and each trial covers a 10 s duration. From the figure, we see that in rainy weather the output exceeds 100V because the sensor detects raindrops 15 cm away. On the other hand, in fine weather, the output voltage is only 20 V because of the sensor did not detect any raindrops. Comparing these data, there is five times difference in measured voltage over 10 s between rainy and fine weather conditions. From these data, the rainfall detection technique using infra-red light sensor can be seen to be practical.

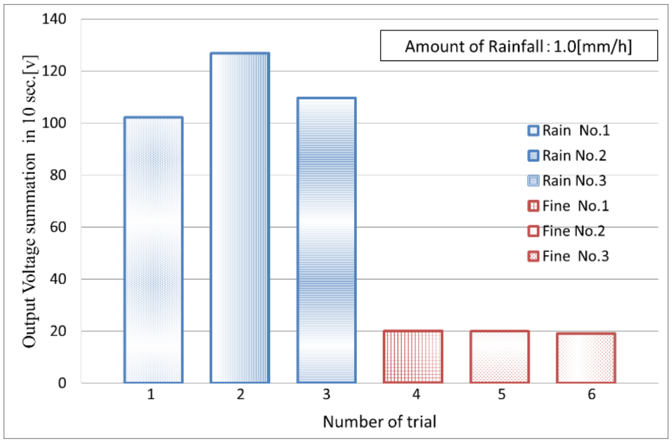

Figure.4 Rainfall sensing

(B) Daytime or night time detection unit

The unit detects the brightness of cycling road and its surroundings using a photodiode. This is a sensor that changes its output current in accordance with the brightness of the light input. The sensor detects light from 320 to 820mm, which corresponds to the visible light band, thus the sensor can detect the same levels of brightness as a human. The measured range is from 0.1 to 1000 Lux, and the sensor can operate without any reference to daytime or nighttime. Figure 5 shows an evaluation of the results from this sensor. The dotted line in violet represents the ideal data, and the actual line in blue represents the measured values. There are some differences these two lines. However, when driving at nighttime, the brightness varies between moonlight and town brightness (under street light or arcade at night) . Though riders can identify an obstacle on the road under town brightness, they cannot recognize an obstacle or pedestrians on the road. From this result, in order to discriminate daytime running and nighttime running, we determined the threshold value at 1.0 V (under 50 Lux).

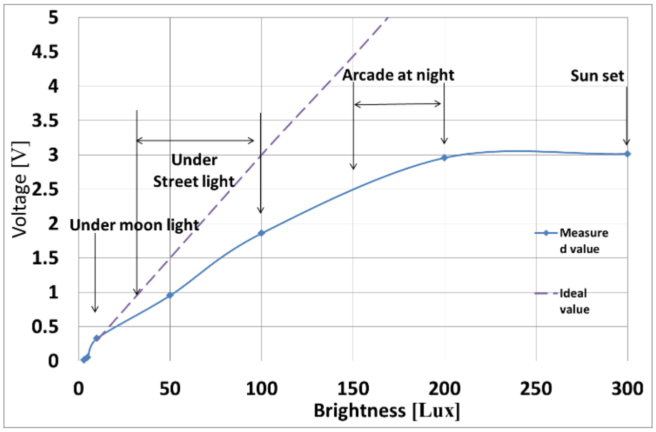

Figure.5 Daytime and night time detection

IV. Experiment

IV.A Outline

In order to develop the proposed system, an experiment was conducted. The main point of experiment was to calculate the threshold value for detecting dangerous cycling. In the experiment, the following two situations are considered:

1. Avoiding an accidental contact between a pedestrian and an overspeed bicycle
2. Avoiding an accidental contact between a pedestrian and a meandering bicycle.

The experiment was conducted on a paved road in a fine day in order to minimize environmental factors.

IV.B Avoiding an accidental contact between a pedestrian and an overspeed bicycle

Figure 6 shows changes of running speed with hard breaking. In this case, the bicycle is driven on a straight road at a constant speed. If a bicycle at high speed, say 20 km/h, breaks hard, the cyclist may fall forward and an accident may occur. Therefore, a cyclist cannot brake extremely hard. As a result, the bicycle may take some distance to stop. In accordance with Japan Industrial Standards, bicycles running at 25 km/h should stop within 7 m using only front breaking, and within 10 m using only rear breaking. A bicycle with both front and rear breaking should stop within 5.5 m. This distance indicates that a bicycle running with this condition runs about 8 m within 1 s after finding a pedestrian on a road. In this situation, we cannot avoid a collision between a pedestrian and a bicycle. Actually, from our experimental data, we could confirm that a bicycle running at 20 km/h travels about 10 m after hard breaking.

Taking this into consideration, the threshold value for overspeed cycling should be set at 18 km/h (5m/s) in order to avoid collision between a pedestrian and an overspeed bicycle. At this speed, a bicycle can stop within 5 m after detecting a pedestrian on a road. So long as the pedestrian is not running into road, the collision can be avoided.

In terms of our system development, the running speed is measured by the running condition sensing unit. In this unit, the running speed is sensed by a magnetic reed switch. The system microcomputer reads the sensed data over a fixed time interval by using an interrupting mechanism. From our experiment, about 1 s was found to be a suitable reading interval of data sensing.

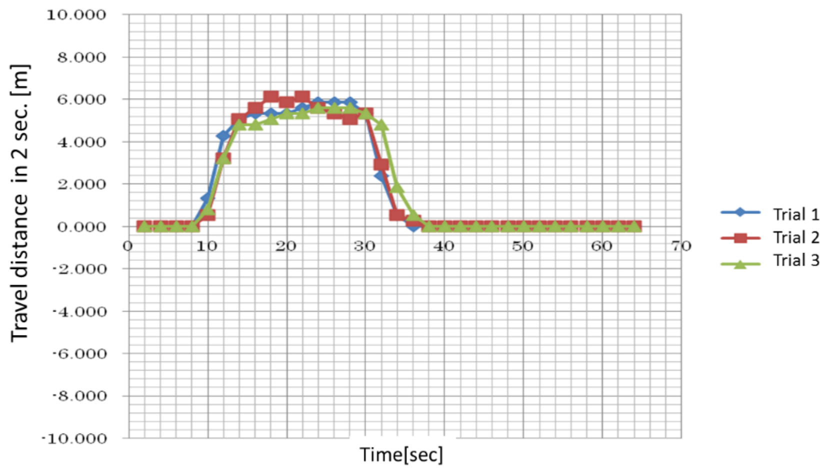

Figure.6 Running speed with hard breaking

IV.C Avoiding an accidental contact between a pedestrian and a meandering bicycle.

Figure 7 shows cumulative handlebar angle data during meandering cycling over a course made with pylons arranged at regular intervals. When a bicycle travels along a walkway, it turns right and left with quite a short period in order to avoid accidental contact with pedestrians. Thus, in the system, in order to discriminate simple curve and meandering, the cumulative angular change of the handlebar over a defined period is sensed, and this is evaluated as the meandering level.

In the experiment, the cumulative steering angle data and visual instability of cycling are compared, and cumulative steering angle data with running off the cycling course is measured. In the experiment, cycling road length is about 8 m, and the pylons are arranged as shown in Figure 8. The points of the experiment's data analysis are: how long the sensed data is accumulated and how great is the threshold value of the cumulated steering angle. Analyzing the result, the cumulative time is determined to be 10 s, and the threshold value of cumulative steering angle is 540º, the driving situation of bicycle becomes extremely unstable and it runs off the cycling course and occasionally makes accidental contact with the pylons.

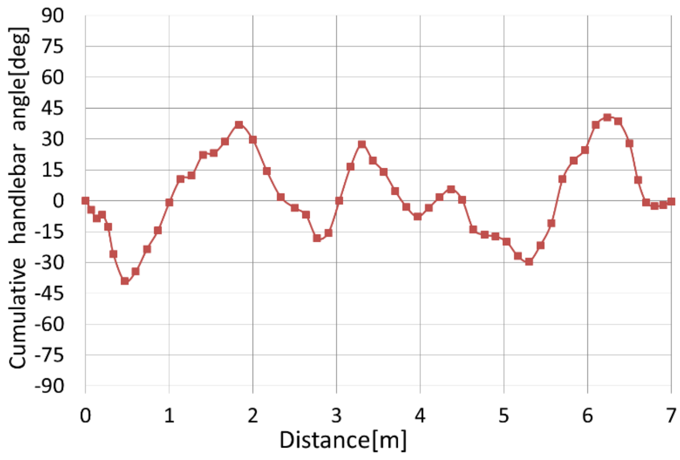

Figure.7 Handlebar angle during meandering cycling

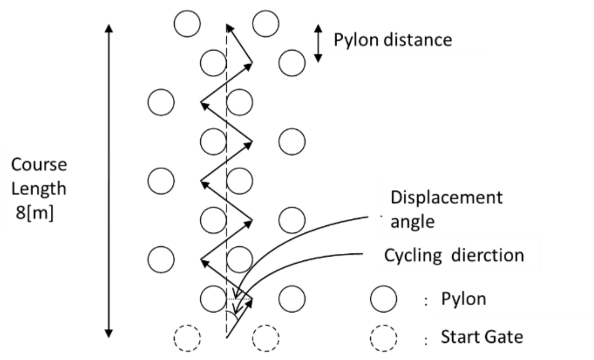

Figure.8 Cycling course of the experiment

IV.D Warnings for dangerous cycling

In terms of overspeed cycling and meandering cycling, the thresholds of dangerous driving are as follows.

Over speed cycling threshold: 18 km/h (5m/s)
Meandering cycling threshold: 540 deg per 10 s

The system issues an alert to bicycle's rider and pedestrians around the bicycle if these values exceed the thresholds. As shown in Figure 9, in the basic idea, the system first warns a bicycle's rider and if there is high possibility of accidental collision, then the bicycle issues an alert to pedestrians around it. Thus, there are three levels of warnings as shown in Table1. The first level warning mainly focuses on bicycle's rider, using vibrating devices attached to the handlebar. The second level warning focuses on both the rider and pedestrians, using a LED lighting unit on the bicycle's front panel to issue an alert. If there is high possibility of accidental collision, the third level warning is issued. The third level warning issues a sound or voice warning by applying a warning buzzer. Thresholds for each warning level are shown in Table 2.

In the experiment, the usefulness of these warnings was confirmed by interviewing the research participants. The interviews showed that the first warning using LED lightning alone was sufficient to make riders pay considerable attention to the pedestrians, enabling them to take safety action to prevent accidents. On the other hand, the LED warning was found to be influenced by ambient lighting or sunlight. Moreover, warning by voice or sound was found to be heavily influenced by undesired noise on roadways.

Table.1 Warning Level

Device	Action	Role in this system
Vibration motor	Vibration	1st Level alarm
LED	Lighting	2nd Level alarm Speed over : Blue Meandering : Red
Buzzer	Warning buzzer	3rd Level alarm

Table.2 Thresholds for warning

Cycling pattern	Alarm Level	Handlebar angle [deg](-)	Handle bar angle [deg](+)	Evaluation pediod [s]	Cumulative angle [deg]	Speed [m/s]
Meandering Cycling	1st Level Arlarm	20	20	5	460	
	2nd Level Alarm	35	35	5	500	
	3rd Level Alarm	50	50	5	540	
Speed over	1st Level Alarm					5

V. Discussion

The experiment focusing on the distance and time period from breaking to stopping the bicycle running enabled the evaluation of warning thresholds that can avoid accidents caused by over speed cycling. However, in a bicycle accident the recognition of the cause of the accident and the evasive actions following this recognition are quite important. In this respect, a warning for over speed traveling can prevent an accident after the rider recognizes the dangerous situation and reduces speed to enable safe stopping. However, this warning system cannot help if the rider does not recognize problems like pedestrians or obstacles on the cycling road. As shown in the Fault Tree of Figure 2, when riding, while texting, or talking on a smartphone, the riders did not recognize obstacles in front of the bicycle and this led to an accident. In order to avoid this situation, an active alert mechanism is required that warns a cyclist the existence of a pedestrian or obstacle in front of the bike. In automobile, front obstacle detecting techniques such as millimeter-wave radar and imaging camera are applied. However, this technique is difficult to apply to a bike because of its cost and unit's size. Therefore, in our research, by applying a simple sensor, such as a Doppler ultrasound sensor, a front dangerous detection technique has been developed.

On the other hand, in order to detect meandering driving, the system monitors the cumulative angle of the handlebar. The system starts measuring and cumulating handle's angle in 10 s when the bicycle's driving pattern changes from straight driving to meandering driving. However, when avoiding collisions between the bike and humans on the sidewalk, the handlebar's angle varies significantly according with density of pedestrians or bike's traveling speed. In the experiment, the handlebar's angel is measured with varying densities of pylons to simulate pedestrians on the sidewalk, while the traveling speed of bicycle was not considered. Therefore, further experiments, such as confirming the relationship between the handlebar angle and the bike's driving speed, and density of obstacle on the road, should be conducted.

VI. Conclusion

This paper proposes a bicycle accident prevention system and introduces an implementation example and its basic idea. The proposed system is mainly focused on avoiding collision between bicycles and pedestrians, and it detects over speed driving or meandering cycling and then issues an alert to the bicycle rider or pedestrians around the bicycle. In the paper, the experimental results also reported. From the experiment, we propose the threshold values for avoiding bicycle accidents: the speed threshold is 18 km/h and the cumulative handlebar angle is 540 deg per 10 s. This paper focuses on discussing the basic idea for the bike's accident prevention system and also discussing the threshold values for avoiding accidents. Based on the discussion in this paper, we would like to improve the system and continue experiments in order to develop more practical systems. Moreover, focusing on bicycle accident statistics, collisions between automobile and bicycles on crossings are as severe a problems as collisions between bicycles and pedestrians. Thus, we would like to develop a system that can detect automobiles on blind crossings by using simple sensors.

References

1. Paul Schepers, et.al. A conceptual framework for road safety and mobility applied to cycling safety, pp. 331-340,Journal of accident analysis & Prevention, vol.62, January 2014.
2. Mohd Khairrul, et,al. Smart Helmet with Sensors for Accident Prevention, Porc. Of 2013 International conference on electrical, electronics and system engineering, December 2013.
3. Aviral Vijay, et,al. Hi-tech Helmet and Accident Free Transportation System, International Journal of Advanced Techology and Engineering Exploration, Vol.2 Issue-6, May 2015
4. Aishwarya S.R, et,l. An IoT Based Accident Prevention & Tracking for Night Drivers., International Journal of Innovative Research in Computer and Comunication Engieering, vol.3, issue 4, April 2015