A Novel Biaxial Control for Motorbike Headlights by using Gravity to Realize Triaxle Regulation

Chu Tz-Nong[1], *Huang Chung-Neng* [1,*]

[1] Graduate Institute of Mechatronic System Engineering, National University of Tainan

Abstract. Taiwan is a developed country with high concentration, difficult to find a parking space in most of the cities. Motorbikes, with the advantages such as higher mobility, smaller size, easy parking, lower cost and cheaper maintenance etc. over automobiles, are selected to be the transportation tools by most of the residents. However, according to the statistics of the Ministry of Communications, there were 296,826 car accidents registered in 2017. Where, motorbikes accounted for 46% of the A1 class accidents while the private cars only 29%. It shows that the accidents caused by motorcycles are more and serious than the ones by cars. In addition, the motorbike accidents occurring in pm. 06:00 to am. 06:00 account for 53.3%. It also shows that there has room for improvement on the lighting technology for motorbikes. In this study, in order to serve above problem a biaxial control to realize the triaxle regulation for traditional headlights with faster response is proposed. Here, the gravity is used to adjust the mirror instead of the electric actuator to improve the control reliability. The effectiveness of this proposed design is confirmed through simulation studies.

1 Introduction

Motorcycles are an important means of transportation. However, the plain area covers 9489.90 square kilometers, accounting for only 22.7% of the total area, while the remaining 77.3% consists of mountains and hills in terms of the geographical environment of Taiwan [1]. The winding, hilly roads are often highly dangerous.

In response to these conditions, car manufacturers have developed adaptive headlight systems for cars, while motorcycles have rarely developed this area. According to the statistics of the Ministry of Transportation and Communications (MOTC), the number of automobile licenses is 7,948,783, while the number of motorcycle licenses is as high as 13,755,582. Nevertheless, most headlamp light sources and optical designs of motorcycles are outdated, which cannot suffice energy conservation, safety, and many more. Such a vast mobile population is risking the dark but lacks the protection of an advanced lighting system, which is the fundamental problem to be solved in this work.

On the premise of environmental protection and energy conservation, how to improve lighting brightness and reduce energy consumption is one of the subjects of this work. One the premise of driving safety, increasing light fixture power for higher brightness does not save energy. According to the performance analysis of LED headlights at present, the LED is five times as bright as conventional halogen headlights, and its energy consumption is only 10% of that of halogen lamps. LED headlights, demonstrating better service lives of light fixtures overall, have a life span of up to 100,000 hours, which is superior to xenon headlights of 2,000 hours and halogen headlights of 1,000 hours. Therefore, in an era of energy conservation and low emission, the application of LED in energy-efficient vehicles, is more appropriate.

Hamm and Schoettle's study estimated the typical power of conventional filament vehicle lighting systems and LED lighting systems. Based on driving modes in the United States, the study lists the estimated mean values of different lighting as well as signal functions and summarizes them in the table below. It also lists the total annual lighting energy use of conventional filament vehicle lighting systems and LED lighting systems.

Function	Power per vehicle (W/vehicle)			Annual energy use (kWh/year)	
	Filament source	LED source	Annual use (h/year)	Filament source	LED source
Low-beam headlamp	124	87	97	12.08	8.47
High-beam headlamp	132	64	10	1.29	0.63
Daytime running lamp	48	18	382	18.30	7.03
Position lamp	14	3	107	1.54	0.29
Front turn signal	52	14	22	1.15	0.31
Rear turn signal	52	10	22	1.15	0.22
License plate lamp	17	2	107	1.80	0.16
Reverse lamp	43	7	4	0.16	0.03
Center high-mounted stop lamp	34	4	81	2.73	0.28
Brake signal	52	11	81	4.16	0.86
Tail lamp	14	2	107	1.52	0.26
Total annual energy use (kWh/year)				**45.9**	**18.5**

Fig. 1. Estimated the typical power of conventional filament vehicle lighting systems and LED lighting systems.

It can be seen from figure 1 that a vehicle light source can save 27.4 kilowatt-hours per year by changing from conventional filament light source to the LED light source. According to the MOTC, the number of cars licensed in Taiwan is 7,948,783 a year. Full replacement with LED lighting systems of ex-factory vehicles not only reduces energy consumption considerably but also gains international recognition for Taiwan's efforts and contributions in energy conservation and carbon reduction.

LEDs are incredibly responsive, three times more efficient, and 55 times longer than older halogen lamps. Quick high-speed responses occur when the vehicle

* Corresponding author: kosono@mail.nutn.edu.tw

encounters an emergency, which is not affected by the bulb response time. Luminous efficacy enhancement may effectively reduce the electricity generating system load of vehicle engines, which conserves energy and reduces carbon. Increased longevity implies more reliable light fixture components that do not require a lot of spare parts for eco-friendly purposes, such as reducing manufacturing costs. Despite large quantities of competing LED products on the market, as shown in figure 1, the failure to adequately control light pollution is a common predicament of the after-sales modification. Modifications should not be conducted until light pollution is solved conclusively.

2 Attitude Derivation and Simulation

Three axial differences, including the yaw-axis, pitch-axis, and roll-axis, occur when the motorcycle crosses the corner, as shown in figure 2. In this study, the theoretical relationship between the steering angle and the roll angle of the motorcycle is calculated by the vehicle motion analysis method of Nakano et al. [3], as shown in figure 3 and figure 4.

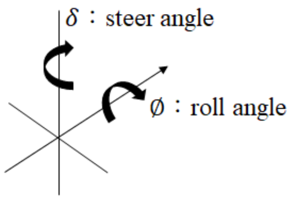

Fig. 2 Pitch-axis, and roll-axis, when the motorcycle crosses the corner

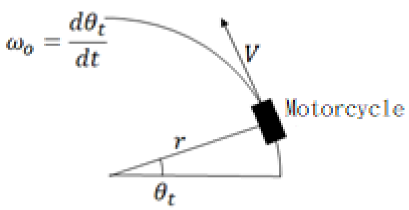

Fig. 3 Top view of motorcycle crosses the corner

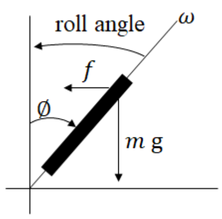

Fig. 4 Front view of motorcycle crosses the corner

the velocity is

$$V = r \cdot \omega_o \tag{1}$$

the relationship of angular velocity in turning is

$$\omega = \omega_o \cdot \cos\emptyset \tag{2}$$

the centrifugal force during turning is

$$f = m \cdot V^2/r \tag{3}$$

and the equilibrium between gravity and centrifugal force.

$$f = mg \cdot \tan\emptyset \tag{4}$$

By combining eq. 3 with eq. 4 to get eq. 5, and

$$m \cdot V^2/r = mg \cdot \tan\emptyset \tag{5}$$

By substituting eq. 2 into eq. 5 can get

$$\sin\emptyset = \frac{V^2 \cdot \omega}{r \cdot g \cdot \omega_o} \tag{6}$$

Finally, by substituting eq. 1 into eq. 6 to get the theoretical relation of the roll angle expressed as following.

$$\emptyset = \sin^{-1}(V \cdot \omega/g) \tag{7}$$

$\emptyset$ ： Roll angle (roll)
δ ： Steering angle (steer)
V ： Velocity (m/s)
r ： Steering radius (m)
ω_o： Steering angular velocity (rad/s)
ω ： Roll angular velocity (rad/s)
f ： Centrifugal force (N)
m ： Mass (Kg)
g ： Gravitational acceleration (m/s^2)
θ_t ： Angle

This deduces that the roll angle does not take into account the rider's posture and center of gravity, so the motorcycle posture cannot be accurately simulated. This study, aiming to be more consistent with actual driving dynamics, combines with the motorcycle dynamic simulation software (BikeSim), simulates and analyzes the steering and roll angle differences during the driving of motorcycles, and discusses the impact of these two angles on motorcycle headlights for further verification and analysis.

The simulation results of this study are in line with practical road usage. Hence, the general road specifications of the curvature radius provided by the construction department of the Construction and Planning Agency of Minister of the Interior (CPAMI) [4], as shown in figure 5, is adopted for modeling purposes.

	The curvature radius of the general road specifications					
Speed(km/hr)	30	40	50	60	70	80
Curvature radius(m)	80	110	140	170	200	220

Fig. 5 The curvature radius of the general road specifications

Figure 6 shows the rolling angle simulation analysis results of the motorcycle. The simulation results can be converted into a three-dimensional stereogram, as shown in figure 7, in which the triangular relationship between the rolling angle, velocity, and road curvature radius can be more intuitively understood. The following conclusions can be drawn from the observation: the higher the speed, the greater the required rolling angle; the larger the radius of curvature of the road, the greater the required rolling angle.

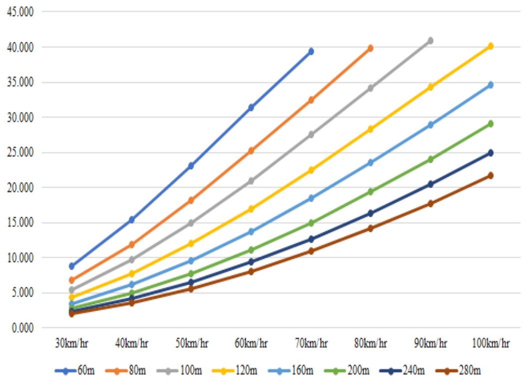

Fig. 6 Result of roll angle simulation

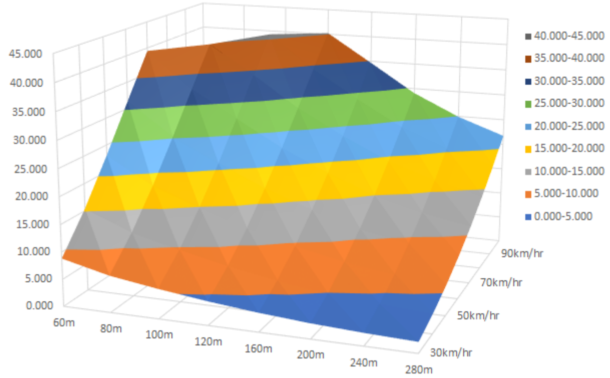

Fig. 7 The simulation results convert into 3D stereogram

3 Experimental Methods and Design

There are considerable differences between the movement of cars and motorcycles. If a car needs to make a turn, it only needs to deflect the yaw-axis; however, it works differently on motorcycles. If a motorcycle needs to make a turn, it deflects not only the yaw-axis but also the roll-axis at different angles depending on the speed [5]. Therefore, it is not a wise decision to transplant the advanced adaptive headlight system of an automobile directly to a motorcycle. Motorcycles require 3D control, including the yaw-axis, pitch-axis, and roll-axis.

This study aims to achieve three-axis control under the premise of using only two axes, as shown in figure 8, which is composed of a combination of the yaw axis and roll axis. The angle of the mixed axis is also the focus of this study. Reducing one axis means not only reducing possible failure but also reducing the cost to improve functions and maximize the safety of the people within acceptable costs.

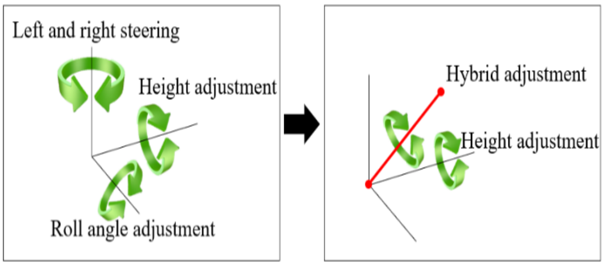

Fig. 8 Simplify the three-axis into two-axes systems.

The objectives of this study are as follows: first, the horizontal framework is complete, including overall system planning, communication between sensors and controllers, coordination of overall work schedule management, and technological promotion to the industry; second, the vertical technological research and development, optimization of mechanical design, rationalization of algorithm, and system failure strategies.

Figure 9 below shows the system structure. The sensor unit consists of a magnetometer, a gyroscope, and an electronic accelerometer. The microcontroller unit (MCU) is expected to utilize Arduino Uno R3 as the development platform, and the height adjustment system actuator is expected to adopt SG90 of Tower Pro.

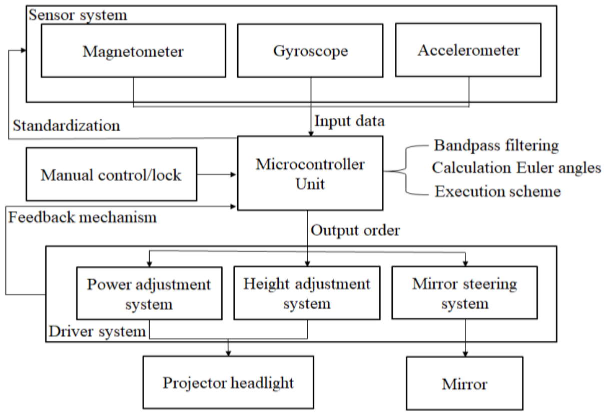

Fig. 9 System Structure

4 Conclusion and Discussion

Figure 10 is a schematic diagram of the design of this study, which clearly shows the integration of the three components, including the reflecting mirror, the projection light source, and the mechanical structure. These echo the integration of the electromechanical system, united by the three cores, including mechanical design, optical design, and electrical design.

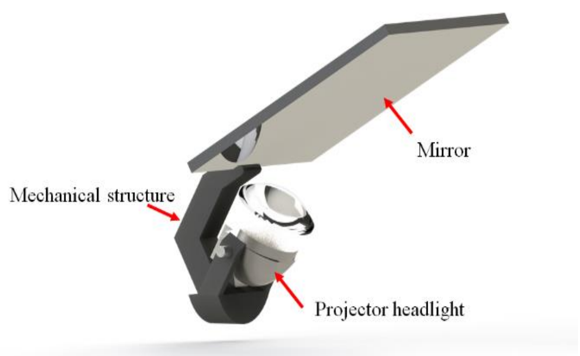

Fig. 10 The schematic diagram of the design

Figure 11 is a ray-tracing diagram of this study. This diagram is a side view, which indicates the path and direction of light rays. Light rays from the light source are refracted in the correct direction by a mirror at the focal point, and the receiver is located at 25 meters, corresponding to the ECE distance. Specular refraction does affect lighting efficiency slightly, but the light is controlled, which signifies an excellent improvement in the utilization rate.

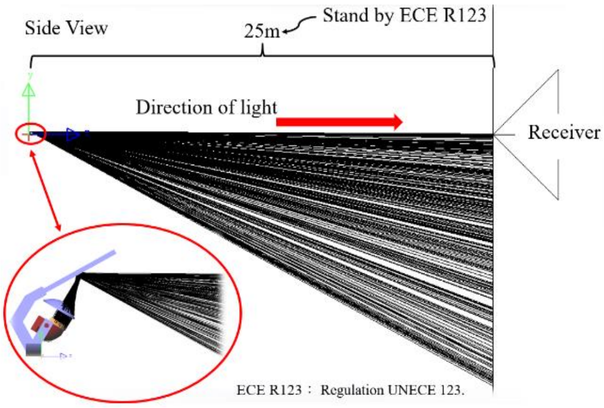

Fig. 11 The ray-tracing diagram

Figure 12 is the light scattering diagram of this study. The schematic diagram is viewed from the front, which is opposite and faces the light source through the receiver, showing the light type of the virtual wall light receiver at 25 meters. The light type designed in this study, also conforming to relevant ECE specifications, is asymmetrical with low left and high right to further avoid affecting the driver of oncoming vehicles.

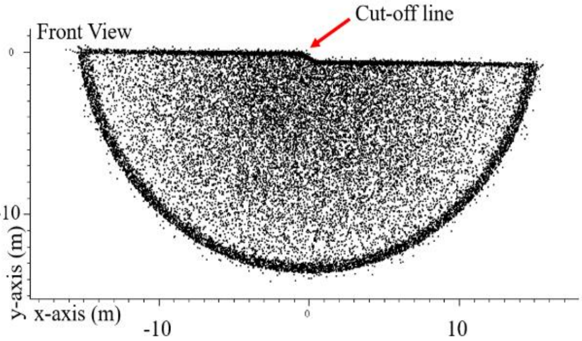

Fig. 12 The light scattering diagram

With the roll angle and velocity as input variables, the curvature radius of the road can be measured, which may be combined with the velocity to estimate the optimal irradiation center. In the limit state, according to the simulation results, the vehicle attitude roll angle reaches 40.874 degrees, and the headlight can make corresponding correction and compensation, as shown in figure 13. The light type is shifted 15m to the left at 25m, and the included angle of the center point is 30.96 degrees, with the lighting cut-off line meeting expected results. Relevant data of simulation will be associated in order to have headlights perform corresponding actions in the future.

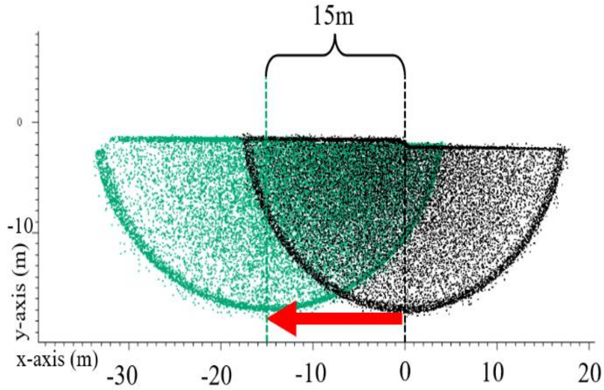

Fig. 12 The light scattering after correct

5 Conclusion

The advanced vehicles of the future will no longer be just a means of transport between two places. Continuous innovation of vehicle technology contributes to safer vehicles. Eyes are the most direct and vital interface for humans to receive external information, while headlights are the second pair of eyes of drivers at night. With significant influence on night driving safety, it is dedicated to improving the forward vision of drivers and enabling the vehicle headlights to adapt to different road conditions and lighting requirements as follows: turning, speed changes, crossroads, intersections, weather (cloud, rain, and fog changes), brightness (day, night), car reception, automatic multi-directional adjustment system, and many more.

This study also supports the same view as the related industries. Based on the safety-first principle, it is expected that the traffic conditions of Taiwan allow passersby to feel comfortable, perceiving headlights as the beginning to develop a peaceful and flourishing society.

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