Control Algorithm for Adaptive Front Light Systems

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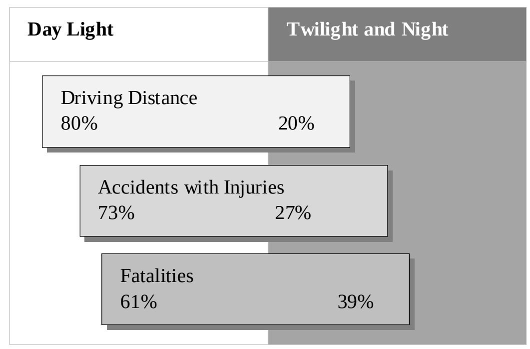
ABSTRACT: *During the night driving, the reaction time of a human driver go into a compromise due to inadequate peripheral vision or lack of color and depth perception. The conventional headlamps of any automotive vehicle are insufficient to provide an effective illumination in the road while the vehicle is negotiating a curve. The Adaptive Front Light System assists to improve the visibility of the road during the night time driving, which in turn improves safety by reducing the probability of accidents. The Adaptive Front Light System controls the aiming direction and pattern distribution of the low beam according to the amount of steering wheel angle, the vehicle speed and the direction of cornering. This feature is known as low beam "Swiveling". Additionally, the Adaptive Front Light System is featured with a functionality called low beam "Leveling" which makes the head lamp capable of positioning the low beam exactly in to the intended position irrespective of the weight distribution between the front and rear side of the vehicle. Static weight distribution might happen if the vehicle is loaded with additional passengers or extra luggage in the boot space. Dynamic weight distribution might happen during the acceleration or braking, which introduces a pitching motion to the vehicle over the lateral horizontal axis. Furthermore, the Adaptive Front Light System features the High beam length adjustment in country roads according to the speed of the vehicle which in turn improves the visibility of the road while the vehicle is cruising with a high speed.*

Keywords *–Adaptive Front Light System, AFLS, Swiveling, Leveling, Road Safety, Active Safety Systems, Controller Area Network, Local Interconnect Network.*

I. INTRODUCTION

Driving at night or twilight partake a major cause of automotive accidents. Even though the average distance driven during the nighttime is 75% as lesser as compared to the average distance driven during the daytime, the amount of road accidents with fatalities or injuries in the sun down are 300% more than as compared with the day time. Again, the statistical studies from the National safety council disclose the fact that 55% of all road accidents in night or twilight are occurring in the curved roads due to insufficient illumination and poor judgment of curves. A 50 year old driver needs 3 times the illumination needed for a driver of 20 year old.



Source: Official German Accident Statistics 2006

Fig. 1. Accident Statistics comparing Day light and Night.

II. CONVENTIONAL HEADLAMPS

Generally, any conventional headlamp systems shall produce a low beam and a high/full/main beam. A low beam of the headlamp is equipped to provide illumination to the road, mainly in an adequate distance to the forward direction and for the lateral illumination. This beam is intended and advised to use when there are oncoming vehicles in the road. The International regulations strictly prevent the low beams to be directed towards the eyes of the other road users. The shape of the low beam is laterally asymmetric, being wider and downward in the right side in the left traffic countries and vice versa in the right traffic countries.

The high beams are bright and centre weighted symmetrical light beams of an automobile headlamp, which is directed either parallel or slightly below the horizontal plane. The high beams are not advised to be used in an already illuminated road or when there is oncoming traffic since they can blind the eyes of other drivers.

III. DISADVANTAGE OF CONVENTIONAL HEADLAMPS

The major inconvenience due to the conventional automobile headlamp occurs in the curved roads. Since they are always shining straight ahead of the vehicle, they illuminate the side of the road more than the road while the vehicle negotiates a curve. The area of irradiation by the front beam is improper which in turn conduce to low visibility of the road and may lead to accident.

Also, the braking distance required to stop any vehicle is directly proportional to the square times the velocity of the vehicle. This is not only the part which determines the braking distance but also the reaction time needed by the driver for responding to any panic.

The reaction time of the driver plays a key factor during the night time driving as even an experienced driver become helpless to react to any situation which is invisible to his eyes.

Similarly, when a vehicle equipped with conventional headlamps is climbing uphill, the light beam may be temporarily aimed towards the skies or to the eyes of the oncoming drivers.

IV. ADAPTIVE FRONT LIGHT SYSTEM

The Adaptive Front Lighting System (AFLS) is designed to give the driver improved visibility under varying driving conditions. AFLS is an intelligent system that optimizes the illumination in the curve roads during the night, on the basis of signals representing several quantities such as speed, acceleration, steering wheel angle, etc.

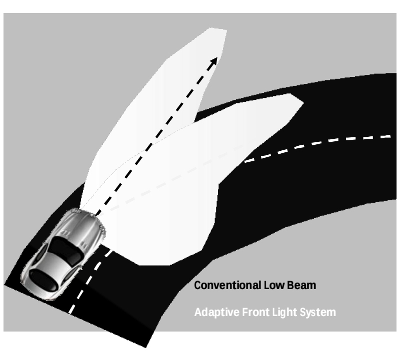


Fig. 2. Conventional Headlamps v/s AFLS

V. REACTION TIME AND GAZE POINT

The stopping distance of an automotive vehicle depends mainly upon the following factors:

- Speed of the vehicle.
- Reaction time of the driver to detect the panic situation and complete suppression of the brake pedal.
- Efficiency of the brake system.

Here, assuming the efficiency of the brake system as a static factor over various velocities, the stopping distance can be derived as,

$$S_{stop} = S_r + S_f \qquad (1)$$

Here,

S_{stop} is stopping distance.

S_r is the distance travelled during the driver reaction time.

S_f is the Braking distance.

Consider the average thinking time before reacting for any human driver is typically, ~500ms.

Here,

For a vehicle which runs at 36kph, after the detection of a panic situation by the driver, the vehicle continues to move for an additional distance of 5m without the brake being applied.

And this distance is directly proportional to the vehicle velocity (V m/s).

$$S_r = 500ms * V \qquad (2)$$

$$S_r = 0.5s * V \qquad (3)$$

Assuming full brake force being applied on the vehicle which is sufficient enough in order to keep the vehicle without being slipped, the stopping distance is proportional to the square of the vehicle velocity (V m/s).

$$S_f = V^2 / (2* (k_f)) \qquad (4)$$

Where,

k_f is the efficiency of braking which is inversely associated with the Stopping distance.

For a passenger vehicle on a normal asphalt road, the k_f is in the range of 0.8g ($0.8 * 9.8 m/s^2 \approx 8 m/s^2$).

Hence,
For a vehicle which is travelling at 36kph, the braking distance upon a full application of brake is 5m.

Therefore, from *(1)*

$$S_{stop} = 0.5 * V + 0.125 V^2 \qquad (5)$$

Following table describe about the braking distance and the relationship with respect to vehicle velocity.

Velocity	S_r	S_f	S_{stop}
18 kph	2.5m	3.1m	5.6m
36 kph	5m	6.2m	11.2m
54 kph	7.5m	12.4m	19.9m
72 kph	10m	24.8m	34.8m
108 kph	12.5m	49.6m	62.1m
144kph	15m	99.2m	104.2m

Fig. 3. Stopping distance v/s Vehicle velocity.

The term gazing point of the gazing distance is a safe distance which shall be visible for the driver at any amount of vehicle velocity. Since the effective usage of the automotive brake into its complete efficiency cannot be applicable in all the scenarios, the gazing distance can be derived as 150% of the stopping distance.

$$S_g = S_{stop} * 1.5 \qquad (6)$$

Therefore, from *(5)*

$$S_g = 1.5 (0.5 * V + 0.125 V^2) \qquad (7)$$

$$S_g = 0.75 V + 0.1875 V^2 \qquad (8)$$

VI. CONTROL ALGORITHM: SWIVELING

Let the steering wheel angle of the rotation be

$Ø_t$ (Degree)

The vehicle turn angle due to the steering rotation is determined by the steering gear ratio k_t,

$k_t = 0.1$ (typical values)

Then the amount of total vehicle steering angle is

$$Ø_{v(rad)} = (Ø_t * k_t)/\pi \qquad (9)$$

Assuming that the steering turn is applied only to the front axle and the length between the front and rear axle is L_x(m)

Then, the radius of vehicle turn is R_t(m).

Here,

$$R_t * Ø_{v(rad)} = L_x \qquad (10)$$

$$R_t = L_x / Ø_{v(rad)} \qquad (11)$$

$$R_t = L_x / (Ø_t * k_t)/\pi \qquad (12)$$

$$R_t = \pi L_x / (Ø_t * k_t) = 10 \pi L_x / Ø_t \qquad (13)$$

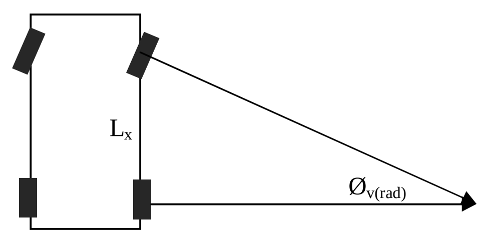


Fig. 4. Radius of Turning Calculation.

During a curve the gazing point shall be on road for safe driving, which will not happen with a conventional low beam.

In figure 5, the G_c shows the conventional gaze point. G_t shows the Gaze point with respect to the angle of vehicle turn, but it is not getting placed on the curve via which the vehicle undergoes the maneuver.

The swiveling control algorithm shall define the swiveling angle, $Ø_{sw}$. The centre of turning curve of the vehicle is at Z. The length between the point Z and the estimated Gaze point G_s is R_t.

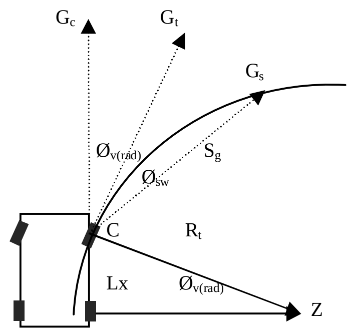


Fig. 5. Gaze point Calculation in a curve.

The distance between the vehicle and the point G_s will be the Gaze distance S_g.

From *(8),*

$S_g = 0.75\ V + 0.1875\ V^2$

From the arc CG_s , by considering the Z as the centre of arc, we calculate.

$S_g = R_t * (2* Ø_{sw})$ *(14)*

Thus,

$Ø_{sw} = S_g /(2* R_t)$

$Ø_{sw} = (0.75V +0.1875\ V^2) * Ø_t /20\pi\ L_x$ *(15)*

Total swiveling angle

$Ø_{sw\_tot} = Ø_{sw} + Ø_{v(rad)}$

$Ø_{sw\_tot}$ == $(0.75V +0.1875\ V^2) * Ø_t /20\ \pi\ L_x + (Ø_t/10\pi)$ *(16)*

VII. Control Algorithm: Leveling

During the driving of any vehicle, the vehicle undergoes a pitching motion due to mainly two reasons. Static weight distribution between front and rear side of the vehicle happens due to the extra passengers or extra luggage in the boot space. Dynamic weight distribution between the front and rear happens during the acceleration or braking of the vehicle which introduces a pitching motion over the horizontal lateral axis.

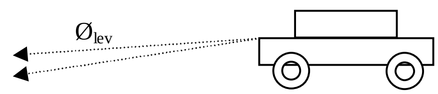


Fig. 6. Leveling Algorithm.

Suppose the difference between the front and the rear heights are denoted as

$h_{delta} = h_f - h_r$

$Ø_{lev} = (h_{delta})/ L_x$ *(17)*

where, L_x is the length of the vehicle between front and rear axis. The Adaptive Front Light System shall able to correct the $Ø_{lev}$ by counteracting towards the pitching direction of the vehicle.

VIII. Control Algorithm: High Beam Length Adjustment

During the high speed motor ways it is acceptable to switch to the high beam and the Adaptive Front Light System shall be capable of adjusting the aiming length of the High beam according to the speed of the vehicle. In general, the gaze point analysis is applicable in this situation too.

Hence, Adaptive Front Light System uses the equation *(8)* to calculate the Gaze point distance.

$S_g = 0.75\ V + 0.1875\ V^2$

The Adaptive Front Light System uses various methods to adjust the length of the High Beam. Most commonly used method is to adjust the shield actuation method, which adjusts the focal points of the lens cluster associated with the High beam

IX. Control Algorithm: Failure Mode of AFLS

The AFLS shall check the validity of the input messages and take a decision only when all the input signals are plausible (valid) in both hardware/electrical and software manner. Otherwise the vehicle driver shall not be disturbed via false operation of the system.

X. CONCLUSION

Adaptive Front Light System is an active safety mechanism which reduces the probability of accidents via intelligently aiming the head lamp where it is really expected to be. A class and B class sedans and SUVs are already started adapting the various versions of this technology.

REFERENCES

Journal Papers:

[1] M Yali Guo, Electr. Eng. Inst., Guizhou Univ., Guiyang, China ,Qinmu Wu; Honglei Wang, "Design and implementation of intelligent headlamps control system based on CAN bus ", Systems and Informatics (ICSAI) , 2012 International Conference on 19-20 May 2012

[2] Ms. Monal Giradkar, Dr. Milind Khanapurkar "Design & Implementation of Adaptive Front Light System of Vehicle Using FPGA Based LIN Controller" Fourth International Conference on Emerging Trends in Engineering & Technology

[3] Shaji Alakkat, Santosh Patel B.J., A.C.Meti, "Design and Implementation of Control Algorithm for Adaptive Front Light System of a Vehicle", SASTECH, Vol 7 April 2008