Accuracy-Power Controllable LiDAR Sensor for Autonomous Vehicles Using an Algorithm of Variable Resolution

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***Abstract*—Light detection and ranging (LiDAR) sensors are used to detect the surrounding environment and the distance in autonomous vehicles. Conventional LiDAR sensors have the demerit of consuming constant power depending on the normal operation. In this paper, we propose an algorithm that improves the inefficient power consumption during the normal operation of a conventional LiDAR sensor. The LiDAR sensor with the applied algorithm provides efficient power saving by controlling resolution through a variable transmission period of a laser diode (LD) depending on the vehicle's speed. The proposed LiDAR sensor with the variable resolution algorithm reduces power consumption of the LD by 6.96% to 32.32% depending on the vehicle's speed compared to the maximum number of the LDs.**

I. Introduction and Proposed Method

The Light detection and ranging (LiDAR) sensors measure the distance to an object, as shown in Fig. 1(a), by transmitting a laser at a laser diode (LD) and detecting the laser reflected at an avalanche photo diode (APD). The LiDAR sensor, among various sensors equipped in vehicles, is the most important sensor of autonomous driving technology for detecting the distance of objects and recognizing objects. Currently, because the conventional LiDAR sensors on the market consume constant power by operating, the conventional operation method is inefficient for autonomous vehicles equipped with multiple LiDAR sensors and battery-powered electric vehicles [**?**]. In particular, because it causes weak-points in long-distance driving, it is necessary to improve the operation method to reduce the power consumption. [**?**] As shown in Fig. 1(b), in the basic operation, the proposed LiDAR sensor transmits the laser 580 times at $0.25°$ intervals, and implements one frame at a horizontal field-of-view (HFoV) of $145°$ using a motor. Because the conventional LiDAR sensor periodically transmits the laser of the LD, it detects an object with the same accuracy and consumes a certain power, and the accuracy of the object detection and power consumption are proportional. The aim of the proposed LiDAR sensor is to reduce power consumption by controlling a transmission period of the LD and the resolution of the LiDAR sensor, according to the vehicle's speed, as shown in Fig. 1(c).

When the vehicle's speed is faster than 100 km/h, the LiDAR sensor uses the maximum accuracy to detect faraway objects at high speed. However, when the vehicle's speed is slower than 100 km/h, the number of laser transmission (T_x) is reduced to decrease power consumption. As shown in Fig. 1(d), when the speed of the car is faster than 100 km/h, the LiDAR sensor transmits th laser 580 times with $0.25°$ resolution. When the vehicle is driving at medium-high speed (80 km/h - 100 km/h), the LiDAR sensor transmits the laser 483 times with $0.3°$ resolution, so our method reduces T_x by 16.73%. T_x is decreased by 28.62% with 414 laser transmissions and $0.35°$ resolution, when the the vehicle is travelling at middle speed (60 km/h - 80 km/h). For middle-low speed (40 km/h - 60 km/h), the LD transmits the laser 362 times, which is a 37.56% reduction, and the resolution is $0.4°$. If the speed of the vehicle is slower than 40 km/h, T_x, which is 322, can be decreased by 44.48% with $0.45°$ resolution. Applying this theory, Fig. 1(e) represents the algorithm.

Fig. 1(f) shows the system configuration to verify the proposed LiDAR sensor. The verification system consists of a multichannel scanning LiDAR sensor and a power measurement device to measure power consumption. The average power 6.971 W, required for the basic operation of the LiDAR sensor, was excepted when calculating power reduction. In the basic operating condition, when T_x is 580, the average power consumption (APC) of the LD is 470 mW. When T_x is 483, the APC is 437.3 mW, and the difference in average power consumption (DAPC) is 32.7 mW, which is 6.96% less than when T_x is 580. The APC is 375.7 mW with a 94.2 mW DAPC (20.05%) when T_x is reduced to 414. When T_x is 362, the APC and DAPC are 337.2 mW and 132.8 mW, respectively, which is 28.25% less than when T_x is 580. Finally, if T_x is 322, the reduction rate is 32.32% less than the default operation at 580, with 318.1 mW of the APC and 151.9 mW DAPC. Fig. 1(g)–(K) is a graph of power consumption according to the change of T_x, and the operating power of the LD at a vehicle speed of 100 km/h and 40 km/h shows a power reduction of up to 32.32%.

II. Conclusion

This paper proposes an algorithm to improve the inefficient constant operating method of the conventional LiDAR sensor. The proposed LiDAR sensor effectively reduces power consumption by controlling the resolution, which is the transmission period (T_x) of the LD's laser, according to the vehicle's speed by applying the proposed algorithm, and it was successfully tested and verified through the verification system.

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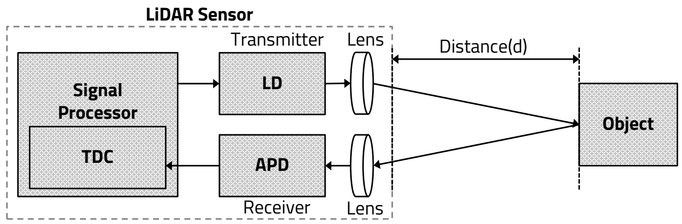
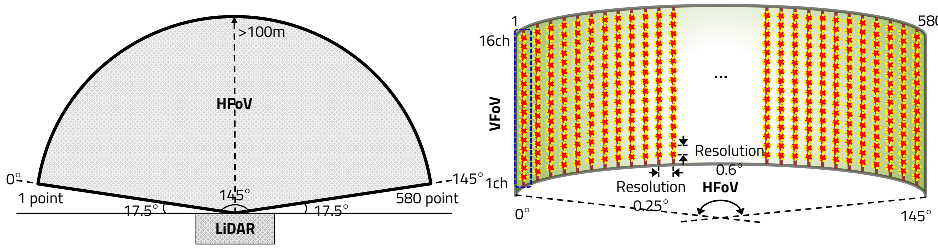


(a) LiDAR sensor block diagram

Speed(km/h)	T_x	Resolution(°)	T_x rate(%)
S ≥ 100	580	0.25	100
100 > S ≥ 80	483	0.3	83.23
80 > S ≥ 60	414	0.35	71.38
60 > S ≥ 40	362	0.4	62.41
40 > S ≥ 0	322	0.45	55.52

(d) T_x of speed



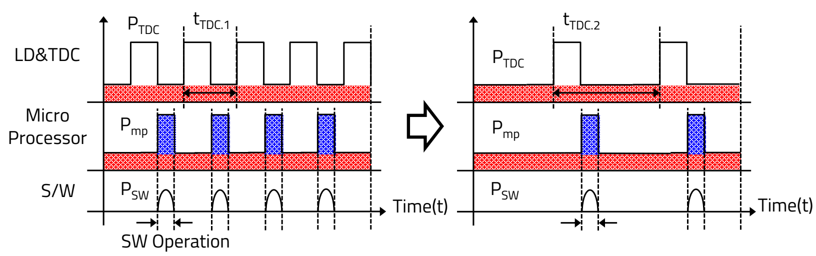
(b) HFoV and frame

Algorithm : *Accuracy control based speed*

Goal : *Determine* T_x
S : *a speed of the vehicle*
A : *accuracy of the sensor*
D : *a sensing delay*
D_0 : *a base sensing delay*
T_x : *the number of the laser's transmission*

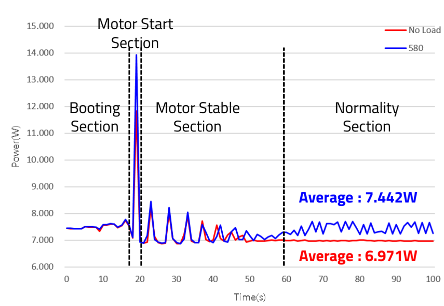
Function : *SpeedBasedControl*(S)
$D = D_0$
if $40 > S \geq 0$ ***then***
$A = 55.52\%$
elseif $60 > S \geq 40$ ***then***
$A = 62.41\%$
elseif $80 > S \geq 60$ ***then***
$A = 71.38\%$
elseif $100 > S \geq 80$ ***then***
$A = 83.23\%$
else
$A = 100\%$
$T_x = 580 \times A$

(e) Accuracy control algorithm

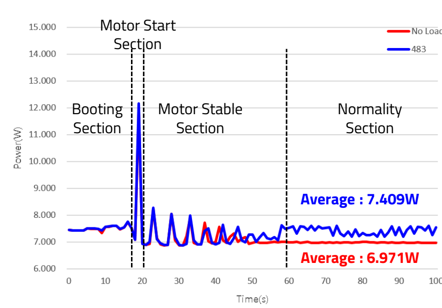


(c) Variable transmission period

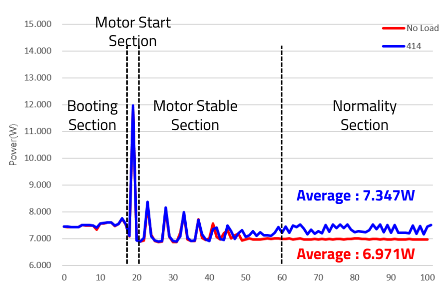
(f) Verification system



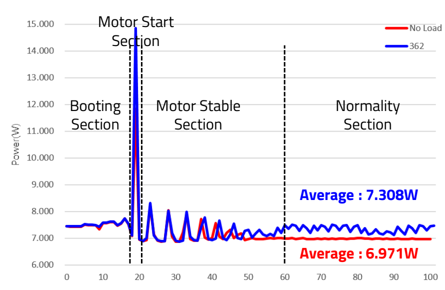
(g) Result from 580 point



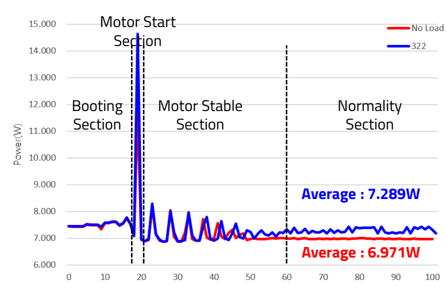
(h) Result from 483 point



(i) Result from 414



(j) Result from 362 point



(k) Result from 322 point

Fig. 1: Proposed method and result