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LIDAR Sensing Technology Using in Transport Systems for Tram Motion Control

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Introduction

Transportation of the passengers in large cities is of great importance for the urban and economic development of those. But the public transport is not the only type of it running in the cities, people use also private transport that causes traffic congestions increasing in their turn the consumption of fuel and electric energy.

In the given work various kinds of motion control systems sensors are examined. The work subject is quite modern because nowadays such an analysis of sensors appliance can decrease effect of human factor to traffic control.

The idea is to install distance measuring sensor into trams. The LIDAR systems can be used for such purpose. The control algorithm developed in scope of this work calculates tram braking path taking as input the LIDAR provided signal.

Transport routes and vehicles should be convenient, safe and simple to use.

About LIDAR

LIDAR (Light Identification, Detection and Ranging) – technology of reception and processing of the information on remote objects by means of the active optical systems using the phenomenon of reflexion of light and its dispersion in transparent and translucent environments.

LIDAR as the device represents, at least, an active range finder of an optical range. Scanning LIDARs in systems of machine sight forms a two–dimensional or three–dimensional picture of surrounding space. "Atmospheric" LIDARs are capable not only to define distances to the opaque reflecting purposes, but also to analyze properties of the transparent environment scattering light.

Settled transfer LIDAR as «a laser radar» is not quite correct, as in systems of near radius of action (for example, intended for work in premises), the main properties of the laser: the high density and instant capacity of radiation – are not claimed, as light radiators usual light–emitting diodes can serve in such systems. However, in the basic spheres of application of the technology (atmosphere research, a geodesy and cartography) with radiuses of action from hundreds meters to hundreds kilometers, application of lasers is inevitably.

LIDARs working principles

The working principle of LIDAR has no big differences from a radar: the directed beam of a source of radiation is reflected from the purposes, comes back to a source and is caught by the high–sensitivity receiver (in a case of LIDAR – the photosensitive semi–conductor device); response time in direct ratio to distance to the purpose.

Unlike the radio–waves effectively reflected only from enough large metal purposes, light waves are subject to dispersion in any environments, including in air, therefore probably not only to define distance to opaque (reflecting light) the discrete purposes but also to fix intensity of dispersion of light in transparent environments. The coming back reflected signal passes through the same disseminating environment, as a beam from a source, is exposed to secondary dispersion, therefore restoration of the valid parameters of the distributed optical environment – is enough the challenge solved both analytical, and heuristic methods.

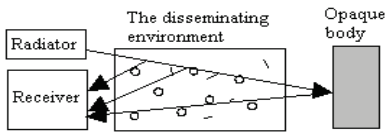

Fig. 1. LIDARs working principle

The laser forming short impulses of light of high instant capacity serves in overwhelming majority of constructions as a radiator. Periodicity of impulses or modulating frequency corresponds to the mode that the pause between two consecutive impulses was not less, than time of the response from found bodies (which can be physically further, than settlement radius of action of the device). The choice of length of a wave depends on function of the laser and requirements to safety and reserve of the device; Nd:YAG–lasers and lengths of waves (in nanometers) are most often applied:

*1550 nanometers – the infra–red radiation invisible neither for a human's eye, nor for typical devices of night vision. The eye is not capable to focus these waves on retina surfaces, therefore a traumatic threshold for a wave 1550 essentially above, than for shorter waves. However the risk of damage of eyes in practice above, than at radiators of visible light – as an eye does not react on infra–red radiation does not work also a natural protective reflex of the person;

*1064 nanometers – near infra–red radiation, invisible to an eye, but "visible" for devices of night vision;

*532 nanometers – green radiation, effectively "punching" weights of water;

* 355 nanometers – near ultra–violet radiation.

In the devices of near radius of action instead of short impulses continuous peak modulation of radiation by an alternating voltage with frequency in units of megahertz can be used.

The elementary atmospheric LIDAR systems have no means of prompting and are directed vertically to zenith.

Simple scanning heads are applied to horizon scanning in one plane. In them motionless radiator and the receiver also are directed to zenith; at an angle 45 ° to horizon and a radiation line the mirror rotating round an axis of radiation is established. In aviation installations where it is necessary to scan a strip, perpendicular to a direction of flight of the plane–carrier, the radiation axis – is horizontal. For synchronization of the motor rotating a mirror, and means of processing of an accepted signal exact gauges of position of a rotor, and also motionless markers put on a transparent casing of the scanning head are used.

Scanning in two planes adds the mechanism turning a mirror on the fixed corner with each turn of a head to this scheme – in such a way a cylindrical development of world around is formed. In the presence of sufficient computing capacity it is possible to use rigidly fixed mirror and a bunch of dispersing beams – in such design one "shot" is formed for one turn of a head.

Scope of LIDAR

Scope of LIDAR is very wide:

–Measurement of speed and direction of air streams;
–Measurement of temperature of atmosphere;
–The early notification about forest fires;
–Researches of the Earth;
–Space geodesy;
–Aviation geodesy;
–Building and mining;
–Sea technologies;
–Definition of speed of vehicles;
–Systems of active safety, etc.

For example, in Australia the elementary LIDARs are used for definition of speed of cars – the same as also a police radar. Optical "radar" essentially is more compact traditional, however it is less reliable in definition of speed of modern cars: reflexions from inclined planes of the difficult form "confuse" LIDAR.

In 1987–1995 during project EUREKA Prometheus, costing to the European Union more than 1 billion dollars, the first practical workings out of pilotless cars have been developed. The most known prototype, VaMP (the developer – Bundeswehr University in Munich) did not use LIDARS because of a lack of computing capacity of processors of that time. Their newest development MuCAR–3 (2006) uses unique LIDAR of the circular review, lifted highly over a car roof, on a level with the directed multifocal chamber of the review forward and inertial navigating system. [1]. Lidar MuCAR–3 are used by a subsystem of a choice of an optimum trajectory on a cross–country terrain, it gives the angular permission in 0,01 ° at a dynamic range of the optical receiver 1:106 that gives effective radius of the review of 120 m. For achievement of comprehensible speed of scanning the bunch from 64 dispersing laser beams is used, therefore one full "shot" demands a unique turn of a rotating mirror [1].

Since 2003 the government of the USA through agency of advanced military workings out DARPA finances working out and competition of cars–robots. Races DARPA Grand Challenge are annually spent; race of 2005 was won by the car from Stanford, at the heart of which system of sight – five LIDARS the directed review.

Example of possible use of LIDAR on a tram

To develop algorithm of regulating of tram, using technologies LIDAR, it is necessary to know some technical parameters. In this case it is necessary to know how fast a tram can brake from the moment of signal reception about necessity of braking, and calculate how long the braking way will be.

Let's assume that the weight of a tram is equal to 40 tons (m=40t) and in the conditions of intensive city traffic the tram moves with a speed (V1=30km/h). On sites of road with less heavy traffic, under the conditions of traffic regulation, the tram can accelerate momentum (V2=50km/h). In the following example it is made a calculation of braking time (t) and obtained long braking way (S). The laws of kinematics were applied to the task in view decision from corresponding section of physics.

$$S = \frac{V(t)^2 - V_0(t)^2}{2a}, \quad (1)$$

$$V(t) = V_0(t) + at. \quad (2)$$

First of all, the example is solved for speed V1=30km/h.

In this case $V_0 = V_1$ and $V = 0$. Then $S = \frac{-V_1^2}{-2a} = \frac{V_1^2}{2a}$ and $0 = V_1 - at \rightarrow t = \frac{V_1}{a}$.

Acceleration is not known but it can be found in the next way

$$F = ma \rightarrow a = \frac{F}{m}, \qquad (3)$$

here F – force of a friction $F = k_{fr} F = k_{fr} mg$.

From this the following is obtained

$$a = \frac{k_{fr} mg}{m} = k_{fr} g. \qquad (4)$$

Let's assume that the factor k=0,2 and a tram brakes half of the full weight: *m=20*. So $a = k_{fr} g = 0{,}2 \times 9{,}8 = 1{,}96 \frac{m}{s^2}$ and $V_1 = 30 \frac{km}{h} = 8{,}34 \frac{m}{s}$. It is possible to calculate values S and t for speed V_1 = 30 km/h:

$$S = \frac{V_1^2}{2a} = \frac{8{,}34^2}{2 \times 1{,}96} = \frac{69{,}56}{3{,}92} = 17{,}75\, m,$$

$$t = \frac{V_1}{a} = \frac{8{,}34}{1{,}96} = 4{,}26\, s.$$

Further also for V_2 = 50km/h: $V_2 = 50 \frac{km}{h} = 13{,}89 \frac{m}{s}$

$$S = \frac{V_2^2}{2a} = \frac{13{,}89^2}{2 \times 1{,}96} = \frac{192{,}93}{3{,}92} = 49{,}22\, m,$$

$$t = \frac{V_2}{a} = \frac{13{,}89}{1{,}96} = 7{,}09\, s.$$

After the calculation it is possible to draw a conclusion that if the tram goes with a speed 30km/h the braking way is about 18 meters, and time – approximately 4 seconds. And in the case of movement with a speed 50km/h they are correspondently 50 meters and 7 seconds.

From the calculation it is obvious that time of braking of a tram is very long in comparison in due course receptions by tram of the reflected beam for reception of the information on presence or absence of an obstacle. Therefore time of a parcel and reception of the reflected beam in this case at calculations can be considered.

Apparently from the data resulted in table 1 – time of reflexion of beam of LIDAR from an obstacle, is really insignificant, in comparison with time of braking of a tram.

Table 1. Time of reflexion of beam of LIDAR from an obstacle depending on distance

Distance to an obstacle	1 m	10 m	100 m	1 km	10 km	100 km
Return time	6.7 ns	67 ns	0.67 µs	6.7 µs	67 µs	0.67 ms

Considering this data it is possible to suggest to use LIDAR in a single–level control system of tram.

In this case it is offered to use LIDAR so that the received signal was analyzed by the special block of management and, depending on speed of a tram and distance to object, the management signal – or the prevention to the driver about necessity of braking, or if the distance to object is minimum would stand out or the driver does not react to the prevention and the tram does not brake – the system gives a signal of emergency braking of a tram. In a simple case, without going into detail of such algorithm it is possible to represent as the following block diagram (Fig. 2.).

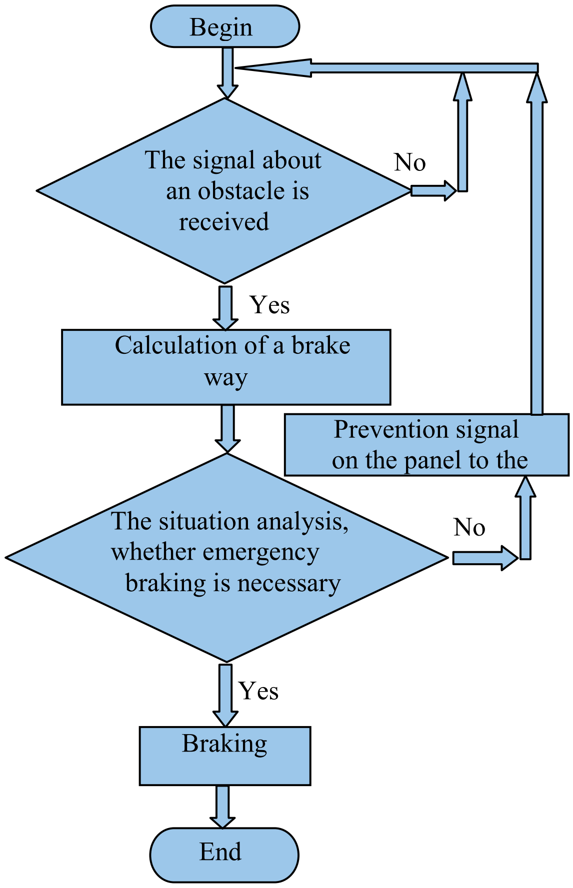

Fig. 2. The block diagram of simple trams braking systems managing algorithm

Installation

For a LIDAR sensor usually from 3 to 5 beams are available. Each beam, on the distance of 100 meters from a radiator has length and width 1 meter. (Fig.3.). The successful location of a sensor control can be on the right, about a headlight.

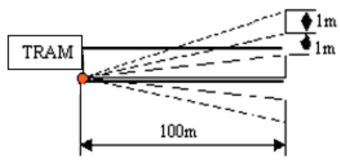

Fig. 3. LIDARs beam geometry

Conclusions

Speaking about appeal of use of technologies LIDAR by trams in the city of Riga – it is possible to draw a conclusion that this theme is at present very little investigated. As a result of a writing of this article it became clear that prospects of development of the given theme are obvious also researches can be in the field continued further to make more convenient and safe a control system of a trams of a city of Riga. The operation principles and areas of application of the LIDAR systems are summarized and analyzed within this paper and compared with other similar systems. An example presents the calculation of a tram's breaking time and way. The calculations are used in the algorithm of sensors operation that could be used for further application in the development of such system.

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The system of passenger transport is an integral part of each city. Well developed infrastructure and the reliable control system of a municipal transportation create favourable preconditions for municipal economy development as a whole. In this research motion control systems LIDAR sensors are examined. The work subject is quite modern because nowadays such an analysis of sensors appliance can decrease effect of human factor to traffic control. The main idea of this research is to install distance measuring sensor to trams. The LIDAR systems can be used for such purpose. The control algorithm developed in scope of this work calculates tram braking path taking as input the LIDAR provided signal. Ill. 3, bibl. 7, tabl. 1 (in English; abstracts in English, Russian and Lithuanian).

А. Патлин, Н. Куницина, А. Жиравецкая, С. Шукаева. Использование технологий LIDAR в транспортных системах для осуществления контроля движения трамвая // Электроника и электротехника. – Каунас: Технология, 2010. – № 5(101). – С. 13–16.

Система пассажирского транспорта является важной частью каждого города. Хорошо развитая инфраструктура и надёжная система управления пассажирскими перевозками создают благоприятные предпосылки для развития и улучшения экономической ситуации в регионе в целом. В данном исследовании рассмотрена возможность использования технологий LIDAR в транспортных системах для осуществления контроля движения трамвая. Тема исследования достаточно актуальна, т.к. в наши дни важным является уменьшение значения влияния человеческого фактора на управление не только производственными процессами предприятий, но и на управление транспортной системой, в том числе и системой городского пассажирского транспорта. Алгоритм управления системой торможения в трамвае, предложенный в данной работе, рассчитывает предполагаемый тормозной путь и время торможения до полной остановки, используя входные данные, полученные при помощи сигналов от LIDAR. Ил. 3, библ. 7, табл. 1 (на английском языке; рефераты на английском, русском и литовском яз.).

A. Patlins, N. Kunicina, A. Zhiravecka, S. Shukaeva. LIDAR technologijų taikymas tramvajų judesio kontrolės sistemose // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 5(101). – P. 13–16.

Aprašoma nauja LIDAR technologija, taikoma Rygos tramvajų judesio sistemų kontrolei. Gauti nauji duomenys, įvertinant žmogiškąjį faktorių bei kuriant įmonių gamybinių procesų valdymo sistemas. Tyrimų rezultatai įdiegti Rygos keleivinio transporto sistemose. Pasiūlyti sistemos valdymo algoritmai, leidžiantys optimaliai apskaičiuoti tramvajų stabdymo laiką, kelią bei stabdymo įvairiose stotelėse trukmę. Šis procesas puikiai valdomas LIDAR technologijos informaciniais signalais. Il. 3, bibl. 7, lent. 1 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).