Institute of Internet and Intelligent Technologies
Vilnius Gediminas Technical University
Saulėtekio al. 11, 10223 Vilnius, Lithuania
http://www.isarc2008.vgtu.lt/

The 25th International Symposium on Automation and Robotics in Construction

June 26–29, 2008

ISARC-2008

USE OF LASER RANGEFINDER TO DETECTING IN SURROUNDINGS OF MOBILE ROBOT THE OBSTACLES

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ABSTRACT

Detecting obstacles and creating a map of surroundings are essential problems for navigation system of unmanned vehicles. Perception systems for autonomous navigation of unmanned ground vehicles (UGVs) must detect all manner of potential navigation hazards. Until quite recently, UGV perception research had focused largely on perception of 3-D terrain geometry with range sensors, perception of roads, and to a lesser degree on perceiving other traffic. Research effort is now growing on recognizing vegetation to improve the efficiency of off-road navigation.
This paper describes both Laser Rangefinder (LR) used for monitoring the environment and mapping system for representing general obstacles (positive, negative and concealment). In addition to using information provided by LR sensor, we use information supplied by Global Positioning System (GPS) and Internal Navigation System.

KEYWORDS

laser rangefinder, surroundings recognition, perception system

1. INTRODUCTION

The basic assumption in industrial robots‘ operation is accomplishing the route of an element, put in motion as a result of combination of the movements of the robots kinematics segments in a collision-free operating area. As for Unmanned Ground Vehicles, the basic issue is to recognize the environment it is in, localize terrain obstacles and moving along a track optimally close to the one assumed according to the criteria given.

It implies the following requirements and limitations referring to the steering system structure and the surrounding recognition system [2]:

– elimination of direct impulse feedbacks between the vehicle and the operator forces expansion of information generating and transmitting systems for the operator as well as supporting the process of generating signals steering the energetic track of the vehicle;

– developing emergency procedures for the steering system operation in case of interferences occurring in transmission and providing the autonomy of the vehicle's operation within such conditions;

– generating stimuli for the operator, which nature and range of information given are close to the ones to received in the operator's cabin.

– development of the measuring-diagnostic block which will broadcast control signals to the operator's stand, working autonomic ally

The above mentioned requirements and limitations were the basis for developing – throughout the research studies till now – a scheme of a functional system of remote control of UGV (Fig. 1) [1], [5].

However, there still has been very little work on detecting bodies of water that could be navigation hazards or on estimating the depth of potential water hazards. This paper presents first results on this problem, using a variety of sensors including colour imagery, ladar, short-wave infrared imagery, and thermal imagery.

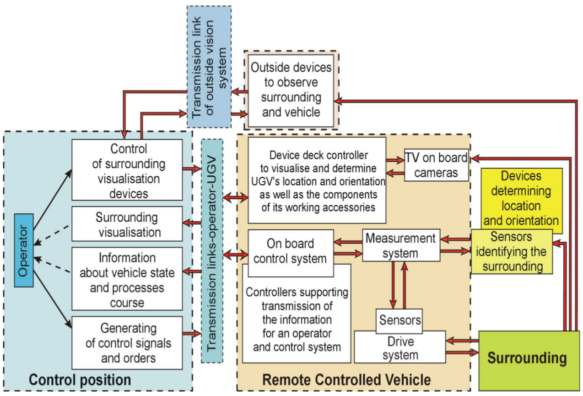

Figure 1. Functional scheme of the remote control system of unmanned ground vehicle

The key issue in realizing the project is to develop en effective system of recognizing the vehicle's surrounding – capable of detecting and localizing obstacles and other objects of possible hazard to it or being uncross able.

There are numerous methods of creating a map of the surrounding of a mobile vehicle and stating its localization. The task of creating a map and stating translocation „on-line" however, has not found satisfactory solution so far. It mainly results from the fact that in order to create a map, precise location must be known beforehand. As for stating translocation basing on sensors indications, it requires knowledge about a map or location of artificial and natural markers, i.e. knowledge about the surrounding.

In methods being developed recently no assumptions about the environment are made – the vehicle finds characteristic surrounding features and determines its location itself on the basis of camera data and determines its translocation towards chosen markers. The chosen object should possess features that do not depend on the robot's location. The vehicle's choice is strictly related to the kind of sensors it is equipped with. In case of a robot observing the surrounding with a camera, it should be an object of unique colour or shape and in case of active sensors the markers may also be walls, corners or doors. Processing camera view and building surrounding's map upon it is most often time consuming and requires significant calculation powers.

Therefore, a significant problem is to develop the most advantageous configuration of a visual system in consideration of signals‘ processing speed and the information quality required.

That is why it is planned to couple a visual system with a system of laser telemeters. The methods of creating „surrounding view" will be an evolution of classical algorithms of creating raster and topological maps. Considering the fact that the information about the obstacles‘ and vehicle‘s location will be coming from a number of sources, methods of information aggregation will be used. Use of diffusible algorithms enriched with reflexive systems‘ elements is assumed for planning the vehicle's path [5].

2. SYSTEM FOR SOURROUNDINGS RECOGNITION

A Sick LMS 200 is mounted on our remote controlled vehicle called "Lewiatan" vehicle such that the LRF looks diagonally downward and forward (at a pitch angle of -11°). While the vehicle is in motion, the fanning laser beam sweeps the terrain ahead of the vehicle and produce continuous range measurements of the terrain. For the experiments described in this paper we set our LRF to an angular resolution of 0,5° and a serial communication speed of 500 Kbaud. Under these conditions the LRF produces 361 range readings (for its 180° field of view) every 27 ms.

The SICK LMS 221 is a laser scanner based on the measurement of time of flight (TOF). As depicted in Fig. 2, a pulsed infrared laser beam is emitted and reflected from the object surface. The time between the transmission and the reception of the laser beam is used to measure the distance between the scanner and the object. The laser beam is deflected by a rotating mirror turning at 75 rps, which results in fan-shaped scan pattern.

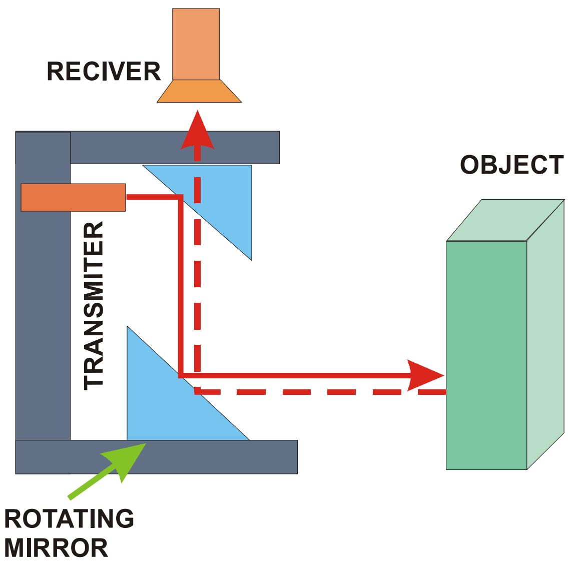

Figure 2. Principle operating on laser scanner SICK LMS 221

Ideally, a terrain map built according to the above-described algorithm should be sufficient for navigating a mobile robot. However, some range data from the Sick LMS 221 are erroneous and will cause mapping errors. The phenomenon of mixed pixels, missing data, artifacts and noise are the main sources of erroneous measurements:

1. Mixed pixels occur when a laser beam hits the very edge of an object so that part of the beam is reflected from that edge of the object and part of the beam is reflected from the background behind the object (Fig. 3). The resulting range measurement lies somewhere between the distance to the object and the distance to the background [6]. In researching the mixed pixels phenomenon we found that if the distance AD between the edge of the foreground object and the background is close to the laser pulse width, AL (AL » 1 m for the Sick LRF), then a substantial number of mixed pixels is generated. However, if AD > AL, then the number of mixed pixels drops significantly. This is because the Sick LRF is designed to accept as valid readings only reflections stemming from the same pulse[1]. This smart design feature is very effective in rejecting most ambient noise, although it does not eliminate all.

2. Missing data occur when the measured range is invalid [5]. For instance, a reflected signal may be to weak for detection due to a large incidence angle and/or due to low diffuse reflectivity of the reflecting object (Fig. 2). This may cause "SNR too low" error. Data may also be missing if a laser beam is trapped and thus not reflected back to the LRF. This condition results in an "operational overflow" error in the Sick LRF. Direct exposure to the sunlight or similar light source may lead to dazzling and cause invalid readings at certain angles.

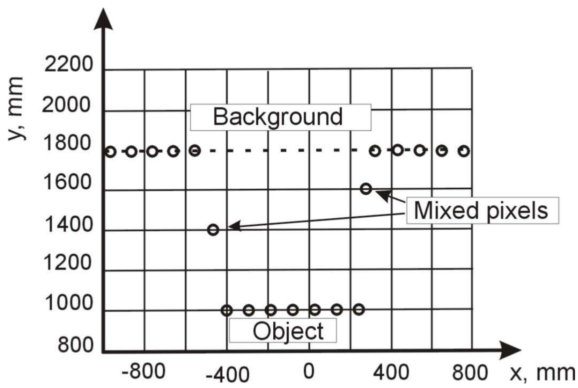

Figure 3. Mixed pixels

3. Environmental interferences, such as strong ambient light, and shock during motion [4] may potentially create noisy range measurements and hence result in noise in the elevation map.

3. A TERRAIN MAPPING METHOD FOR OBSTACLE NEGOTIATION

Our terrain mapping method assumes that 6-degrre-of-freedom pose information is available from SICK mounted on the mobile vehicle. The range data can be transformed into world coordinates and registered into a terrain map. The terrain map consists of an elevation map and a certainty map [3]. Both are 2-D grid-type maps. Each cell in the elevation map holds a value that represents the height of cell, while each cell in the certainty map holds a value that expresses our certainty in the accuracy of the corresponding cell in the elevation map (Fig. 4). The forward kinematics transformation is given by:

$$\vec{l}_g = T_l^g \vec{l}_l \qquad (1)$$

where: $\vec{l}_g = (x_g, y_g, z_g)^T$ – range measurements in the global coordinate system;

$\vec{l}_l = (x_l, y_l, z_l)^T$ – range measurements in the LRF coordinate system;

T_l^g – is the forward kinematics transformation matrix, which transforms the coordinate value of a laser range measurement in the LRF coordinate system to the coordinate value in the global coordinate.

The experimental setup are depicted in Fig. 6. The global coordinate system is denoted x_g, y_g, z_g. The coordinate system attached to the rotary table is denoted x_v, y_v, z_v with the x_v coordinate being aligned with the pitch rotation axis. Axes y_v, and z_v are parallel to y_g, and z_g respectively when the pitch angle is zero. Another coordinate system, denoted x_s, y_s, z_s is attached to the rotary table so that y_s is aligned with the roll axis and x_s and z_s; are parallel to x_v, and z_v, when the roll angle is zero. The Laser coordinate system is denoted x_l, l_l, z_l with z_l aligned with z_s and x_l, and y_l in parallel with x_s, and y_s respectively. In view of the 0.5 -degree scan resolution and the 180-degree field of view of the LRF, the LRF can be thought of as having 361 discrete laser beams in x_l, 0_l, y_l, with beam nr 1 aligned with coordinate x_l beam nr 181 aimed with y_l and beam nr 361 aligned with $-x_l$.

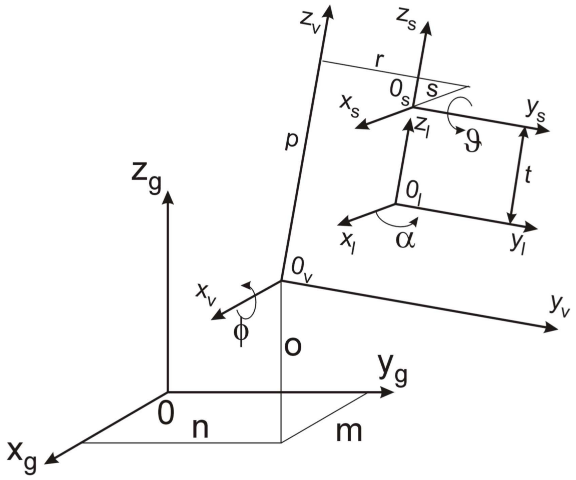

Figure 4. Coordinate systems for the experiment

4. EXPERIMENTAL RESULTS

At the initial stage of the research, LRF system was assumed. A laser telemeter delivers a series of measurements of {φ_i, d_i} nature, where d_i – is the distance to the obstacle given by the sensor at scanning angle φ_i. In case of laser telemeter manufactured by sick the resolution of scanning angle equals 0.5°, and scanning range is 180^0. The telemeter conducts 20 full measurements within a second, with 1cm accuracy. The maximum range of the device is 100 m. The coordinates of the obstacle may be calculated with the telemeters indications with the equation (1) (Fig. 4).

As a research ground a drive into garage with adjoining terrain near the building was selected (Fig. 7). These experiments were carried out into two categories:

1. Measurements with stationary lrf system placed in point a (Fig. 7) were performed. Lrf was mounted 2500 mm above ground. During measurements elevation angle β was changed from 0^0 to – 15^0 and recording results every $0{,}5^0$.

2. Measurements with moving lrf system from a (Fig. 5) into garage were performed. During this experiment lrf was mounted no the vehicle also 2500 mm above ground, but elevation angle β was constants and amounted -15^0. Vehicle was moving

from point a 40 m away into garage. Experiment's data were recorded every 1 m.

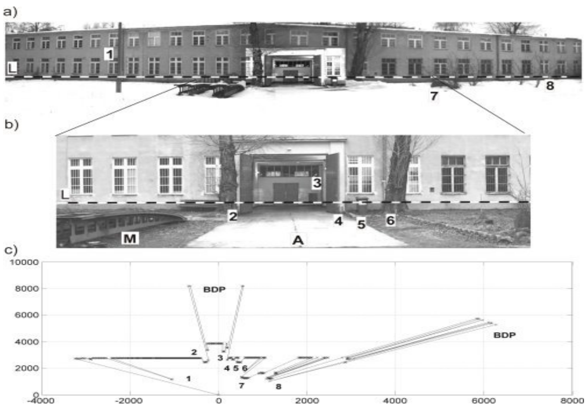

Figure 5. A view over the drive into garage: a, b) garage; c) laser scanner data from one measurement; A- position LRF during research with first method

Graphic presentation data received during one terrain laser scanning shows Fig. 5c. Measurements were carried out in when telemeter have been put in point A and elevation angle $\beta = 0^0$. Fig. 6 shows a terrain image obtained by scanning the terrain using a stationary laser telemeter by changing it's angle of inclination.

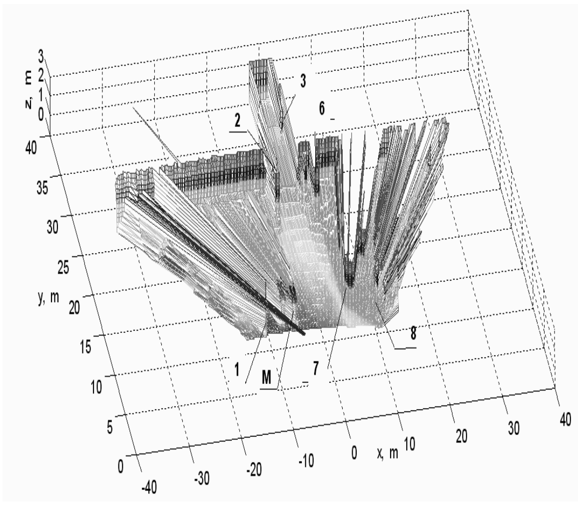

Figure 6. Terrain image obtained on the basis of conversion of points from a fixed-location telemeter with a changing angle of inclination

Where as Fig. 7 shows a terrain image obtained by scanning the space using a fixed-angle telemeter mounted on a moving surface. The analysis of those images shows that the resolution of an image is decreasing with distance from the LRF while using a stationary telemeter. It also shows that the image does not contain objects which are invisible from the telemeters' fixed location. Images obtained from a moving telemeter contain more data without any loss of resolution. Presented images were obtained as a result of conversion of points acquired using subjections (1). Using those maps, one can pinpoint the location of objects in terrain, determine their height and trace "mobile-corridors" for planning paths for machines and vehicles.

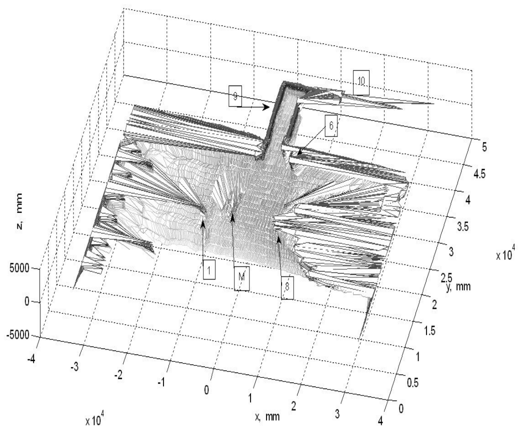

Figure 7. Terrain image obtained on the basis of conversion of points from a telemeter mounted on moving vehicle with a fixed angle of inclination.

5. CONCLUSIONS

Specific conditions of work of remote controlled vehicles prevents from coping the existing solutions used in mobile robots. Analysis presented in this paper show that an individual approach to the subject of remote controlled system in such vehicles is needed. This approach depends on technological tasks which the vehicle will have to carry out.

As a unmanned platform, LEWIATAN could play a pivotal chain role. The platform is specially predisposed to rummage contaminated areas. It can move through difficult terrain, and it's low pressure exerted on the ground allows it to drive safely on snow, ice and swampy terrain. Furthermore it possesses an important ability is to cross water obstacles without having to change it's configuration

This paper shows that the major problem with realizing the control system of tele-autonomous controlled vehicles is obstacles negotiation subsystem. Its main task is to generate information about object's location and calculate safety path for moving vehicle.

Our project built on the basis of a laser telemeter may be used for localization of terrain obstacles, as a machine vision and surroundings visualization system.

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