A Multi-element System of Surrounding Recognition And Objects‘ Localization for Unmanned Ground Vehicles

Franciszek Kuczmarski, Barbara Siemiątkowska, Andrzej Typiak

Military University of Technology, 2 Kaliskiego Street, 00-908 Warsaw, Poland
typiak@wme.wat.edu.pl

ABSTRACT: Equipping engineering machines and trajectory vehicles with automatic and remote control systems is necessary in case there is any environmental hazard for an operator i.e. environment conditions, an impact from fire field etc. It is particularly crucial when there is no possibility for any person to be in a machine or in its close surrounding. It applies to both extreme environment conditions (high temperature, pressure or environment contamination) and the likeliness of direct man health and life hazard (i.e. removal, disposal or neutralization of hazardous materials or area demining – particularly when the enemy operates on a fire field). In all above cases of using engineering machines and trajectory vehicles there is a need to remote control without the possibility of using direct impulse feedback by operators. That is the reason why it is so necessary to work on elaboration vision system enabling determination of the machine location in geodesic system and operating accessories configuration.
This paper describes an overall characteristics of the steering unit in an unmanned ground vehicle depending on tasks to be performed, considering the drive and the steering’s system structure required. Current development of visual systems used in unmanned ground vehicles has been shown. A visual system to be used in remote controlled machines and ground vehicles has been presented. Its structure and limitations within picture depth estimation resulting from the system’s structure have been presented. Furthermore the system of defining the cameras‘ location in an external reference system has been described.

KEYWORDS: Unmanned Ground Vehicle, Surrounding Recognition Systems, Laser Scanner, Visual Unit.

1. INTRODUCTION

The intense development of industrial robots used to perform jobs of possible hazard to humans was the activator of efforts towards developing Unmanned Ground Vehicles (UGV). Many opposing technological and environmental factors, significantly reducing the possibility and social-economical efficiency of robotizing numerous processes in terms of production were not taken into consideration in comparison with range conditions – the necessity of performing constantly alternating tasks at lack of surrounding recognition, together with an interfering or even destructive environment influence [3,4].
Focusing exclusively on the problems of controlling the operation of UGV, it has to be said that the steering system structure depends highly on the kind of tasks to be performed – what is unmistakably shown in fig.1. Within UGV development for the needs of the broadly understood military sphere as well as security and technical rescue, seven main types may be distinguished (fig. 1) – differing from one another not only with the assignment but also with the way of power generation and steering.
The presented scheme clearly shows fundamental differences among various UGV resulting from the drive type and steering system structure required. In opposition to the steering system of a typical working machine or vehicle, the unit featured in the scheme shows the problems resulting from remote control. Carrying the operator away makes it necessary to add additional information channels through which the data could flow (data of the run of a working process), and above all, it forces adding data channels for broadcasting the view of the surrounding or operation field of a mobile working machine.
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

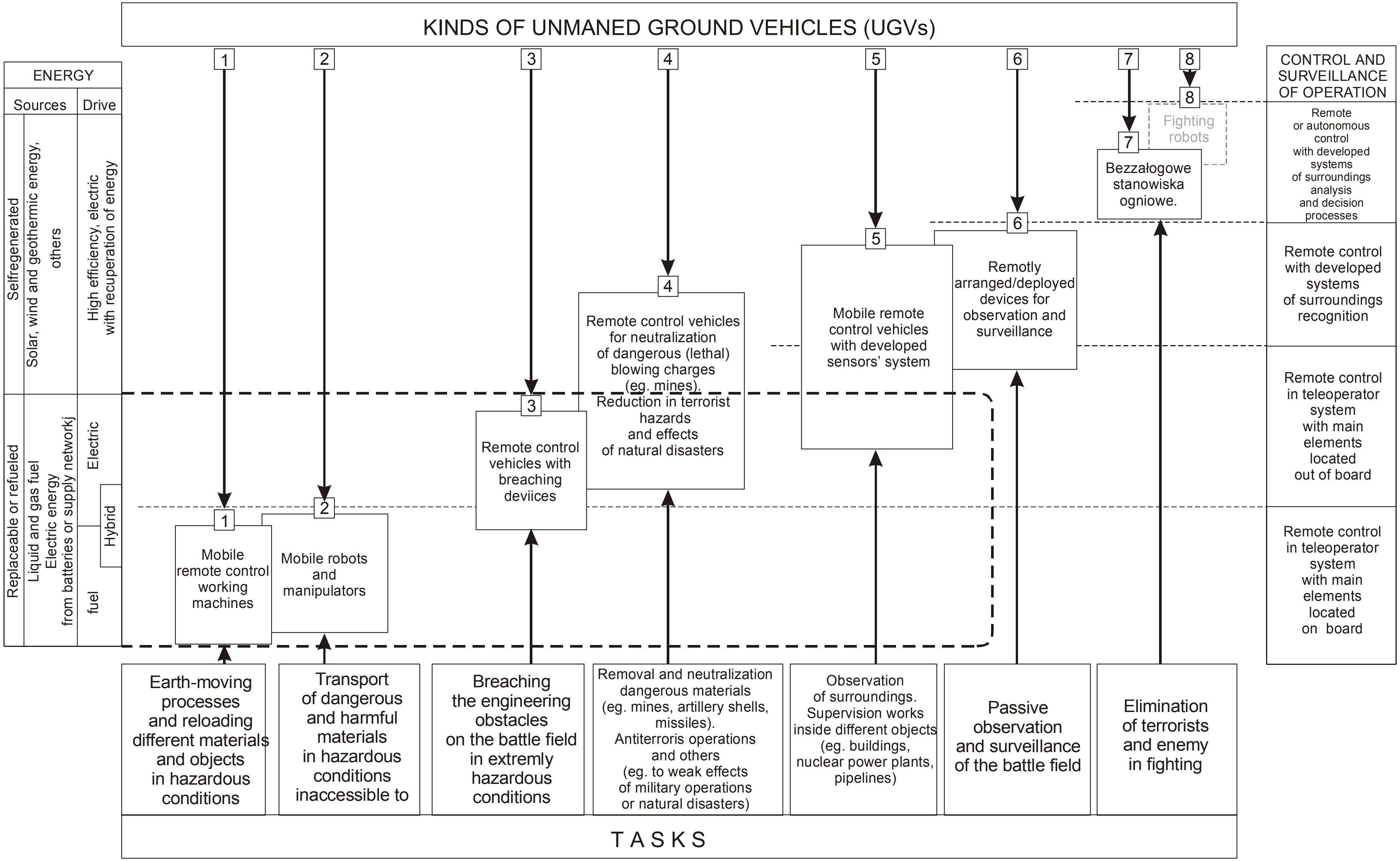

Figure 1. Basic types of unmanned ground vehicle in the aspect of their aim, energy generation and control way

operating area. As for UGVs, 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:

- 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 autonomously

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.2) [1,5]. Efforts towards developing such vehicles are undertaken in numerous countries but their broad scale implementation in armed forces, technical rescue and anti-terrorist actions is still not the fact.

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 un crossable.

Localization methods have been developed for years. They may be divided into several groups. The first one bases on detecting translocation in relation to artificial active markers (eg. light, ultrasonic) or passive ones. This approach most often uses triangulation [9]. GPS is also a similar method but its accuracy however is not sufficient enough for autonomic navigation.

An other method of localization is determining the vehicle's position in virtue of vector or raster maps [7]. In this method, the data obtained by the sensors is compared to the one stored as a map which gives the possibility to determine localization and orientation. The basic disadvantage of the methods mentioned above is the fact that an area map or the exact localization of the markers are needed in order to use these methods.

There are numerous methods of creating a map of the surrounding of a mobile vehicle and stating its localization. However the task of creating a map and stating translocation „on-line" 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.

There are separate modules for composing a vector or raster map in classical navigation systems and a topological map in the more advanced systems. There are many methods of localization but the one that is used most often is odometry due to being cost effective [2]. It enables exact determination of translocations in case the vehicle's movement time is relatively short and sudden changes of velocity and direction resulting from wheels and caterpillars slipping do not take place. The main disadvantage of odometry is that inaccuracies hard to calculate cumulate in time. It is caused by systematic errors e.g. uneven wheels, limited resolution of decoders and accidental errors e.g. differences in wheels' slip resulting from loads, uneven surface.

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.

2. SURROUNDING RECOGNITION SYSTEM FOR UGV

Standard visual systems perceive reality in a two dimensional way (because of no possibility of measuring distances to the objects and their sizes). Therefore, the main research problem in visual systems is the three dimensional perception of picture, especially depth. Data about the spatial location of objects that is not included in a single picture is included in e.g. stereoscopic picture.

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.

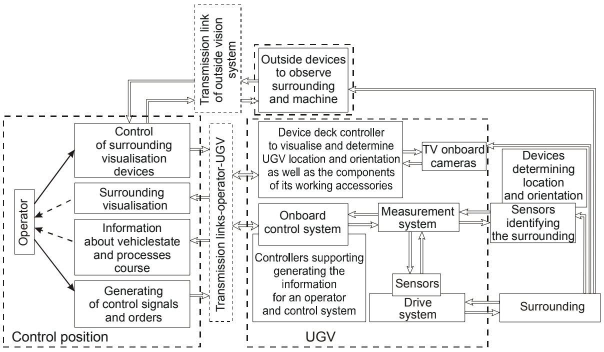

Figure 2. Functional scheme of the remote control system of unmanned ground vehicle

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 [8].

At the initial stage of the research, a standard stereo-visual system was assumed. A visual system consists of two main blocks : the operator's stand and observational system was built in the Machine Construction Institute of the Military University of Technology for that purpose (fig. 3).

The observational system consists of a steering head (1) with a carrying beam fixed onto it (2). Change of the beam's rotation degree is realized by the steering head. A GPS device put on the beam in the head's rotation axis reeds the azimuth and specifies: the unit's location in geographical coordinates, altitude above sea level and ground incline. The GPS data may be put onto a digital map – which enables to draught e.g. the vehicle's route (with a visual system installed). The observational system is also used to observe the terrain or chosen objects with CCD cameras (6), which orientation is set by the heads (5). The system's structure enables the observation of chosen objects by the two cameras simultaneously (realizing stereo-vision process) or observation of objects located in different directions (azimuths).

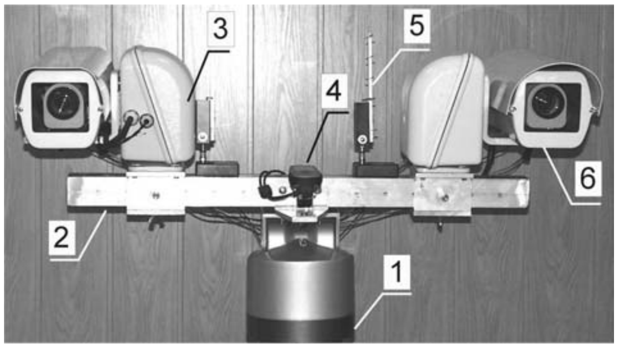

Figure 3. Research observational system (description included in the text)

The described visual system may be used as well for localizing the observed object and its surrounding observation along with detecting terrain obstacles but also for observation and visualization of the location of working equipment of engineer's machines. It may be mounted on a vehicle, or an engineer's machine as well as independently fitted outdoors and used for geodesic localizing of stationary and moving objects [6]. The further research stages are supposed to deal with using telemeters for detecting and localizing obstacles and objects.

A laser telemeter delivers a series of measurements of $\{\varphi_i, d_i\}$ 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^o , 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):

$$\begin{aligned} x_i &= x_R + d_i \cos(\varphi_i + \varphi_R) \\ y_i &= y_R + d_i \sin(\varphi_i + \varphi_R) \end{aligned} \qquad (1)$$

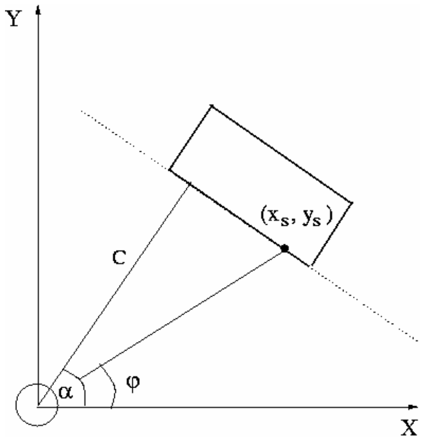

Figure 4. Parametrical presentation of a rectilinear

where d is the distance to obstacle indicated by laser and φ_I is the scanning angle, the threesome (x_R, y_R, φ_R) – specify the location and orientation of the vehicle in the reference system assumed.
The indications of a laser distance sensor may be also treated as a picture. A pixel of (x, y) coordinates has a no-zero value if in the area corresponding with (x, y) a fragment of an obstacle will be detected. As an example, laser telemeter's data for obstacles map shown in figure 5 is shown in figure 6. Spaces where obstacles have been detected were marked with black dots.

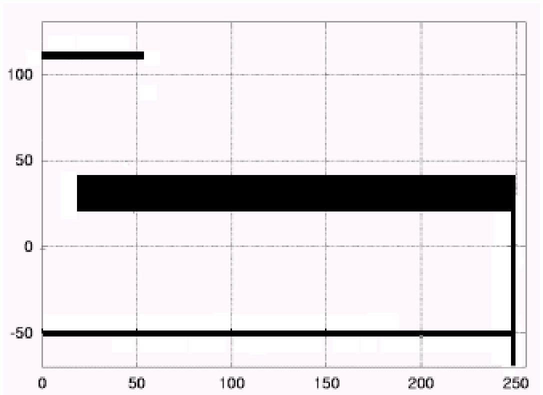

Figure 5. An exemplary map of an obstacle

The suggested system may be used to avoid collisions [1]. The method of avoiding collisions is based on an algorithm of directional histograms. In this approach the robot's surrounding is divided into identical sectors, a measure of obstacle's occurrence is calculated for each of them, then a histogram is made and its values are threshold. The direction of robot's movement is acceptable if the measure of obstacles‘ occurrence lies below the threshold given.

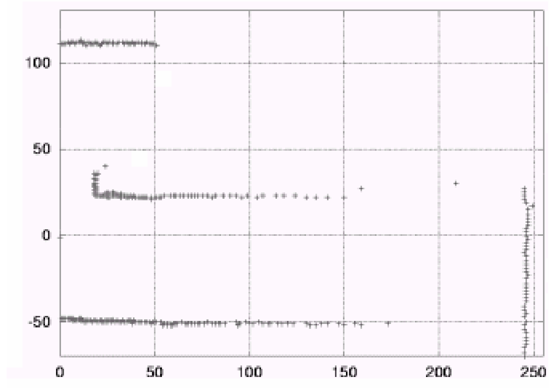

Figure 6. Laser scanner's data

The algorithm's scheme is as follows:

1. Probability of obstacles' occurrence is calculated for every reading of the laser scanner {d_i, φi}, according to the formula:

$$m_{ij} = a - bd_{ij} \qquad (2)$$

where: *a, b* – vehicle dimensions related parameters
d_{ij} – distance between vehicle's centre and the obstacle

2. The measure of obstacles‘ occurrence is calculated for each sector according to the formula:

$$h_k = \sum m_{ij} \qquad (3)$$

An acceptable translocation direction is the one for which the measure's of obstacle occurrence value dos not exceed the threshold given. Basing on data analysis (from fig. 7) the histogram featured in fig. 8 was created. The directions in which the vehicle is able to move are the ones that has the obstacles' occurrence value lower that the assumed threshold.
The sectors where the vehicle should not appear are marked grey in the figure 7.
Laser telemeter's data enables not only to specify safe directions of vehicle's movement but also to determine vehicle's translocation between the measurement points given. Hough's transformation was applied in order to determine vehicle's changes. It makes parametrical specification of obstacles‘ shape possible. Monitoring changes of these parameters we may specify orientation change and translocation of the vehicle [2,3].

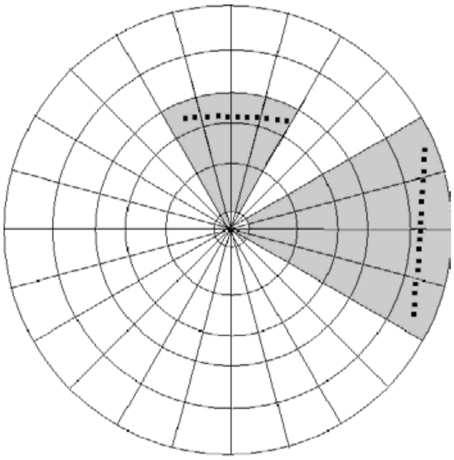

Figure 7. Laser readings and acceptable directions of vehicle's movement

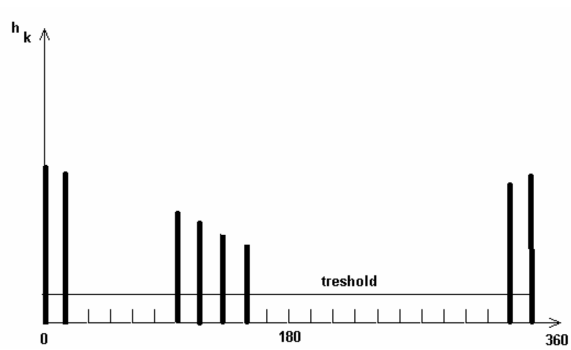

Figure 8. Form of a histogram

3. CONCLUSIONS

Specifically operating conditions of a multi-purpose astronomical vehicle make full duplication of solutions already in use in mobile robots impossible. The analysis featured suggests that individual approach to the issue of design of the steering structure of such vehicles, depending on their technological tasks is necessary. The main problem conditioning realization of the steering system shown i.e. developing a system for visualizing the vehicle's surrounding was indicated.

The system's main task is to generate information about objects' location, their translocation in case of remote control – in a hardly or unrecognised environment. The research visual system shown in the paper may be used as well for localizing the observed object along with observing its surrounding and detecting terrain obstacles.

Coupling a system of laser telemeters into it may provide an effective system of detecting and localizing mobile objects as well as obstacles in UGV's operating area.

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