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CREATING OF A SURROUNDINGS MAP FOR A REMOTE CONTROLLED BIOMASS TRANSPORTATION VEHICLE

Summary

This paper presents a design concept of an environment map building system for a baled biomass collecting and transporting remote controlled vehicle. A typical remotely operated vehicle is usually equipped with cameras which may provide insufficient information about the vehicle's surrounding thus leading to the operator having difficulties in driving such a vehicle in unknown environment. This paper presents a concept of a close area map building system based on additional sensors. The concept assumes equipping the vehicle with laser range find scanners, an inclinometer and radar speed sensors. Combining information from these devices allows to build a map which helps an operator to drive the vehicle in a safer manner and more efficiently.
Keywords*: remote controlled vehicle, navigation system, 3D map building, surroundings recognition*

TWORZENIE MAPY OTOCZENIA DLA ZDALNIE STEROWANEGO POJAZDU DO TRANSPORTU BIOMASY

Streszczenie

W artykule przedstawiono koncepcję projektowania mapy otoczenia dla zdalnie sterowanego pojazdu zbierającego i transportującego bele z biomasy. Typowy zdalnie sterowany pojazd jest zwykle wyposażony w kamery, które dają niewystarczające informacje o najbliższym otoczeniu, a operator ma trudności z prowadzeniem takiego pojazdu w nieznanym środowisku. W artykule rozważany jest problem budowy mapy najbliższego otoczenia pojazdu na podstawie dodatkowych urządzeń. Pojazd wyposażony jest w lasery SICK LMS, inklinometr i radary. Łączenie informacji z urządzeń pozwala zbudować mapę, która pomaga operatorowi wydajniej sterować pojazdem.
Słowa kluczowe*: pojazd bezzałogowy, system nawigacji, budowanie map 3D, rozpoznawanie otoczenia*

1. Introduction

A necessary condition to stop the succession of vegetation on wetlands is the collection of biomass, which ensures the proper development of plant communities and the sustainability of meadow ecosystems. This is particularly important in relation to large complexes of protected wetlands. One of the challenges in the process is the transportation of harvested biomass on surfaces with difficult terrain conditions, such as meadows with variable-water levels (temporarily flooded) and wetlands [2].

The needs and restrictions presented above gave rise to the development of assumptions and the construction of a vehicle for transporting the biomass obtained. A typical scenario for using such a vehicle is reaching the required location, loading, transporting, unloading of biomass taken and reaching the next loading area (Fig. 1).

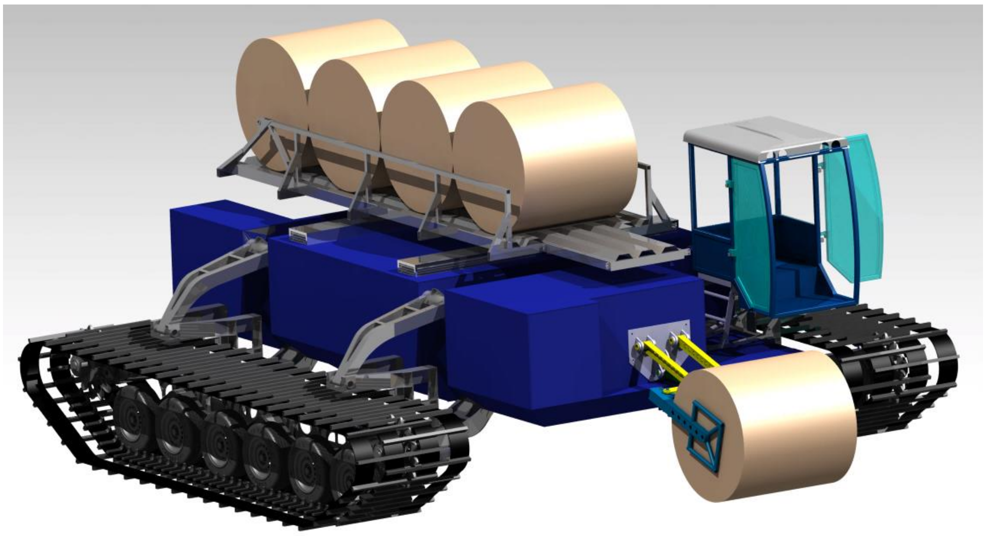

Fig. 1. Vehicle for biomass transport [2]
Rys. 1. Pojazd do transportu biomasy [2]

In addition to the obvious technological challenges regarding the construction of the base vehicle, there are several aspects of the localization and control systems that need to be addressed:
– possibility of autonomous journey to the place where the belled material is located,
– detection of the mowing vehicle, its identification and picking up the belled materials,
– possibility of autonomous travel to the unloading area and automatic unloading.

All these functionalities rely on the ability to precisely map the vehicle's environment.

2. Concept of a map creating system

There are a number of navigation trends that improve the ability to navigate in all sorts of environments. While GPS has been the driving factor behind most of these trends, it has its limitations, which become more evident over time as we are starting to be more and more dependent on this type of navigation.

The problem of integrated navigation is to combine the outputs of different types of sensors (Fig. 2). Navigation sensors, like any system have strengths and weaknesses. For examples, GPS has exceptional accuracy, but it is subject to outages due to the loss of satellite signals. Internal sensors rely only on gravity and vehicle dynamics, which cannot be jammed, but they exhibit errors that grow over time and eventually become unacceptable. There is no one set of sensors can be used for operations in all environments. This is implies that ultimate solution will be a modular system in which a suite of sensors can be selected for a give situation and a high level integration scheme will adaptively integrate those sensors in an optimal fashion. One such solution can be a Navigation Kalman filter. This design however, requires a careful error analysis and model development for each of the sensors to be integrated.

While GPS is very good in determining the position of an object in an open space and at high altitudes, the closer to the ground level and the more complex the environment and data accuracy starts to decrease. Even though recent advancements in high-precision GPS allow to acquire more and more accurate data, determining the precise position i.e. in a forest environment is still impossible.

Summarizing the navigation requirements in a manner similar to [2], it would be desirable to develop a navigation system that supports:
– an indefinite mission duration,
– real-time 3D location performance,
– localization in forest environments,
– operation in an unknown (unmapped) or sparsely known (partially mapped) environment,
– localization from the power-off condition and requires no separate starting location initialization of the user equipment.

For the reasons described above, alternative navigation techniques have been and are currently being developed to help fill this navigation gap. At least three broad categories of alternative navigation techniques exist:
1. Image/Ladar/Doppler/DR aiding of inertial.
2. Beacon-based navigation (including pseudolites).
3. Navigation using signals of opportunity.

3. Concept of a map building model

In order to help creating a map of the environment in which a biomass transporting vehicle operates, we've developed a map building model. It combines data from laser range scanners, an inclinometer and radar speed sensors. The information is being stored in on-board computer which is also responsible for creating the map. Because the range of used SICK LMS 111 laser range scanners, which is 20 m, our model creates a map which is a 40 x 40 x 12 meters cuboid with the vehicle in the center. When the vehicle moves data which is behind the cuboid is lost and new data is added to the map. Because the vehicle can operate in a rough terrain conditions we've divided the 12m height into two sections: below the robot (3 m) and above the robot (9 m). The cuboid is divided into "voxels" (3D pixels). Each voxel keeps a binary free/occupied value. Each data received from laser is transformed into Cartesian coordinate (the robot is in the center of it) and is being assigned to a certain voxel. One voxel represents a cube the size of 0.2 m. Fig. 3 presents the model of the map.

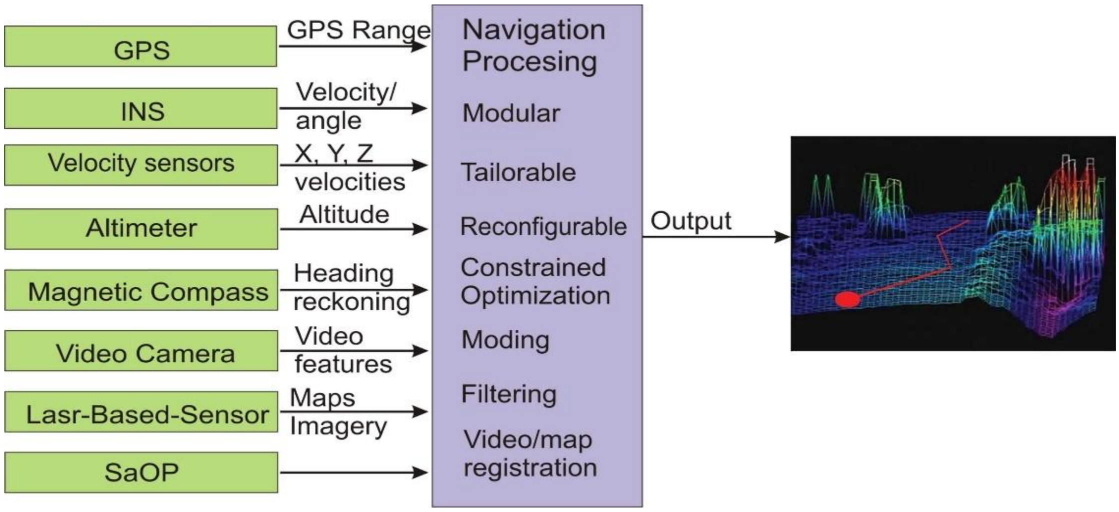

Fig. 2. Modular, adaptive, multisensory integrated system to providing robust navigation [1]
Rys. 2. Modułowy, adaptacyjny, multisensoryczny zintegrowany system zapewniający niezawodną nawigację [1]

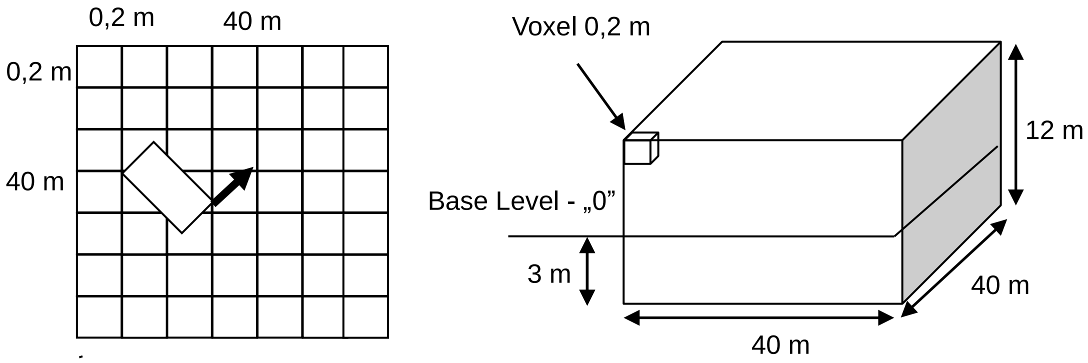

Fig. 3. The idea of map model. The vehicle is always in the centre of the map [1]
Rys. 3. Idea modelu mapy. Pojazd zawsze znajduje się na środku mapy [1]

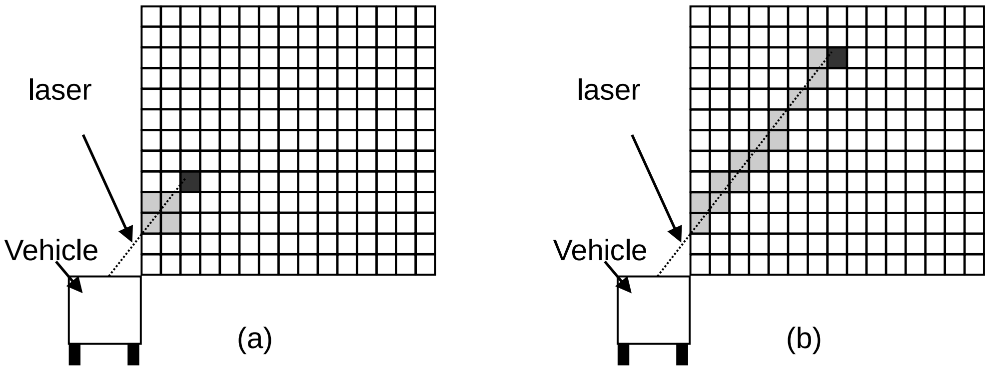

Fig. 4. Changing voxel mode: a) – obstacle in time t, b) – obstacle in time t+1. Gray voxels change their mode from *occupied* to free [1]
Rys. 4. Zmiana trybu wokseli: a) – przeszkoda w czasie t, b) – przeszkoda w czasie t+1. Szare woksele zmieniają swój tryb z zajętego na wolny [1]

One of the problems which have to be solved in this scenario is the ability to recognize dynamic objects in the environment. The assumption was that when a dynamic object is observed , it should not be treated as an obstacle. Because of this it has been assumed that if a voxel has previously been categorized as "occupied", it's possible to change its state if sensor data proves that it's not being occupied anymore. This changes the voxel's state to "free". Such assumption allows to accept dynamic objects in the environment of the vehicle. Fig. 4 shows the idea behind the method.

4. Map building system

We built our map building system and have mounted in on an unmanned vehicle dedicated to operate in unknown and wilderness terrain. Motivation behind its creation, basic assumptions and test results are described in [1]. The vehicle is remotely controlled by an operator who is located up to a kilometer away from the vehicle. The operator has a typical, paper map of the surroundings and doesn't know the environment well. Besides cameras which allow him to drive the vehicle, it is equipped with a map building system (Fig. 5).

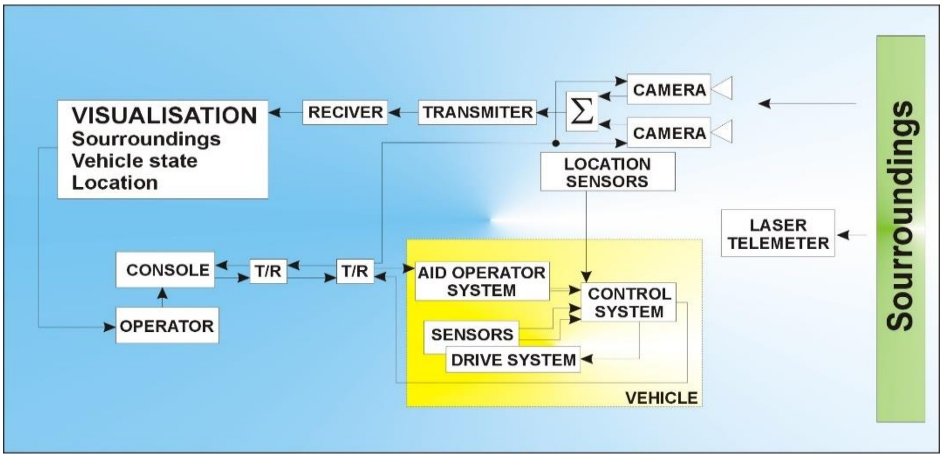

Fig. 5. Signal transmission between operator and the vehicle [1]
Rys. 5. Transmisja sygnału między operatorem a pojazdem [1]

The laser range scanner set consists of 5 SICK laser scanners, an inclinometer is being used to determine the orientation of the sensors (and thus the vehicle) and two radar speed meters are used for error correction. The heart of the system in industrial computer mounted on the vehicle. It's task is to read data from all the sensors and based on it build a list of obstacles in the nearest surrounding. The laser scanners are mounted in front of the vehicle – 3 of them are horizontally facet in the center, while the other two are vertically orientated facing on the both sides and looking outside the vehicle. Such arrangement guarantees that all possible information regarding the object and obstacles in the immediate vicinity of the vehicle will be available to the system. Figs 6 and 7 show map building system devices mounted on a vehicle and the range of observed area respectively.

The map building system has two tasks: to protect from obstacles in front of the vehicle and build a map of obstacles in the nearest area of the vehicle. The idea behind the former presents Fig. 8. When the terrain in front of the vehicle becomes unavailable, the system reports it to the operator.

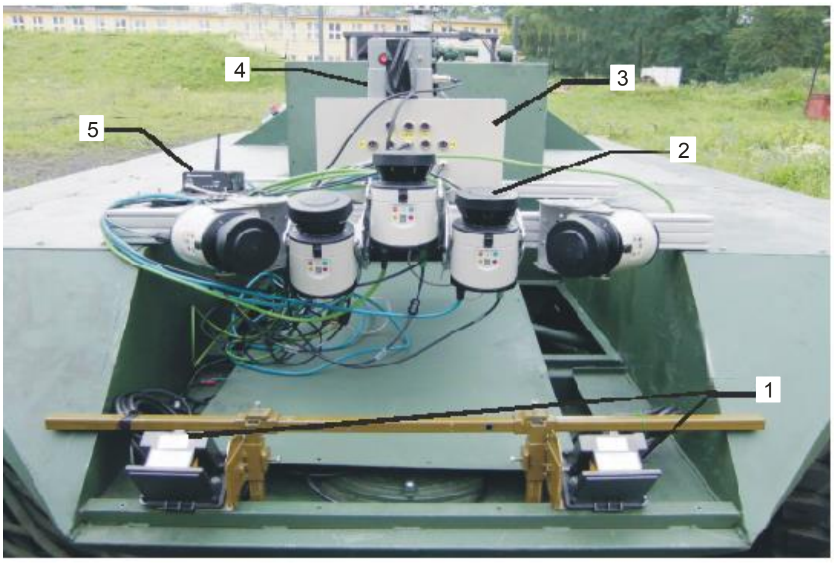

Fig. 6. Map building system mounted on an unmanned vehicle : 1 – radar speed sensors, 2 – laser range scanners, 3 – onboard computer, 4 – acceleration and rotation sensors, 5 – radio link transmitter [1]

Rys. 6. Badawczy układ budowy mapy otoczenia zainstalowany na pojeździe: 1 – radarowe czujniki prędkości, 2 – skanery laserowe, 3 – komputer pokładowy, 4 – czujniki przyspierzeń i rotacji, 5 – nadajnik łącza radiowego [1]

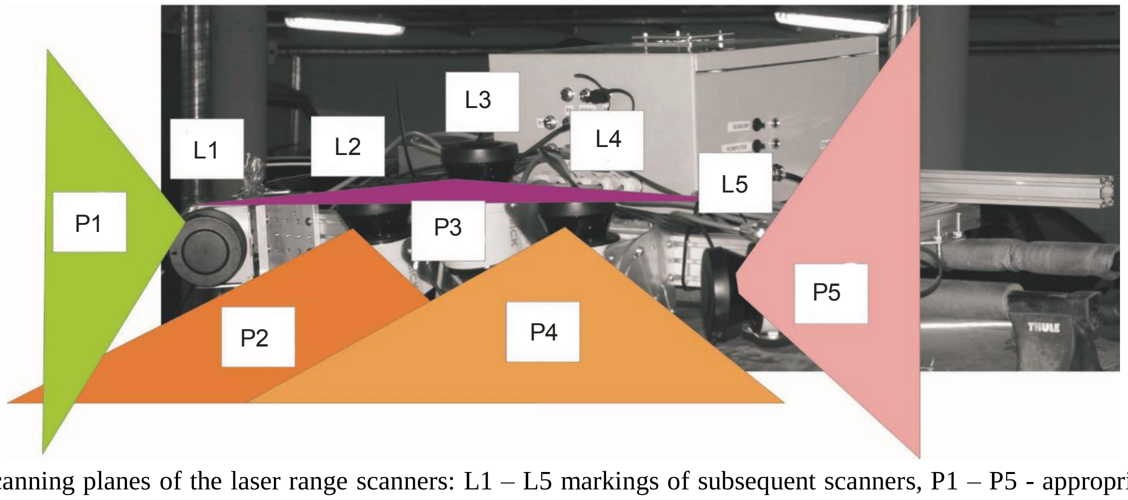

Fig. 7. Scanning planes of the laser range scanners: L1 – L5 markings of subsequent scanners, P1 – P5 - appropriate scanning planes [1]

Rys. 7. Płaszczyzny skanowania przez skanery laserowe terenu przed maszyną: L1 – L5 oznaczenia kolejnych skanerów, P1 – P5 – odpowiednie płaszczyzny skanowania [1]

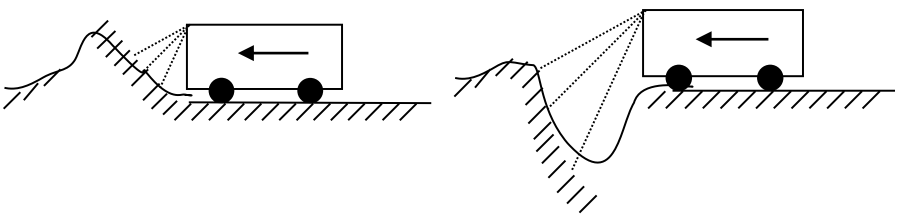

Fig. 8. The map building system’s concept of informing the operator about obstacles in front of the vehicle [1]

Rys. 8. System budowania mapy ma chronić przed przeszkodami przed pojazdem [1]

5. Conclusions

The future holds a lot of promise for the continued development of unmanned vehicles of all types. Applications and missions suitable to unmanned vehicles will continue to be identified and robotic technologies will further evolve to fill those needs allowing more complex missions to be performed using unmanned systems.

The typical system of a remotely operated unmanned vehicle is equipped with a set of cameras may provide insufficient information about the environment and an operator has difficulties to use the vehicle efficiently in unknown terrain. In the article we've sketched out a possible tool to be used in such scenarios, in the form an additional map building system which is intended to help the operator. The system we presented has the following features:

– equipped with 5 laser range scanners, an inclinometer, radar speed sensors and on-board industrial computer,

– no GPS signal used,

– transmits far less data than cameras and the data has more information,

– shows the distance to obstacles which is invaluable for operators,

– gives the information about area availability in front of the vehicle.

Resolving problems with navigation and steering of those types of vehicles will allow expansion of its applications from both civilian and military point of view in the upcoming few years, to a wide range of applications in times of crisis with direct human life threat.

6. References

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[2] Typiak A.: Rodzina pojazdów specjalistycznych do prowadzenia zabiegów renowacyjnych i ochronnych w środowisku wodno-błotnym. Raport końcowy w ramach przedsięwzięcia pilotażowego NCBR pt.: Wsparcie badań naukowych i prac rozwojowych w skali demonstracyjnej Demonstrator+ Tech/Info-Bio. Warszawa 2017.