CONTROLLER AREA NETWORK STANDARD FOR UNMANNED GROUND VEHICLES HYDRAULIC SYSTEMS IN CONSTRUCTION APPLICATIONS

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Piotr Szynkarczyk, Józef Wrona, Adam Bartnicki

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Abstract: *Unmanned vehicles occupy more and more space in the human environment. Mobile robots, being a significant part thereof, generate high technological requirements in order to meet the requirements of the end user. The main focus of the end users both in civil, and so called "defense and security" areas in the broadly defined segments of the construction industry should be on safety and efficiency of unmanned vehicles. It creates some requirements for their drive and control systems being supported among others by vision, communication and navigation systems. It is also important to mention the importance of specific design of manipulators to be used to fulfill the construction tasks. Control technologies are among the critical technologies in the efforts to achieve these requirements. This paper presents test stations for testing control systems and remote control system for work tools in the function of teleoperator using the CAN bus and vehicles which use hydrostatic drive systems based on the Controller Area Network (CAN) standard. The paper examines the potential for using a CAN bus for the control systems of modern unmanned ground vehicles that can be used in construction, and what limitations would possibly prevent their full use. It is exactly crucial for potential users of unmanned vehicles for construction industry applications to know whether their specific requirements basing on the tasks typical in construction [9] may be fulfilled or not when using the CAN bus standard.*

Keywords: *CAN bus, control systems, unmanned ground vehicles – mobile robots, hydrostatic drive systems, construction equipment*

1. Introduction

Unmanned construction systems could be used to perform emergency countermeasure work and restoration work at disaster sites but also to increase safety at ordinary construction sites. Unmanned construction was used in civil engineering work for the first time in Japan in 1969 when an underwater bulldozer was used to excavate and move deposited soil during emergency restoration work at the Toyama Bridge that have been blocked by the Joganji River disaster [9]. There were also some concepts to implement the remote controlled systems into manned platforms [6].

The executions can be categorized as emergency and restoration works [9]. It creates possibilities to define some principal types of hazardous tasks typical in construction for which unmanned vehicles could be used. There can be specified following works: rock removal work (excavation, loading, transporting), structure demolition and removal work (crushing and pulverizing concrete and cutting steel reinforcing bars, loading and transporting the products), large sandbag placing work (transporting and placing), concrete block work (removing obstructions, leveling ground, placing), temporary road work (cutting, filling and compaction), erosion and sediment control dam work (excavation, embanking, backfilling, compaction, pouring concrete), watercourse work (excavation, pouring concrete, placing foot protection blocks), tree felling work (cutting, stumping, transporting), Reinforced Cement Concrete RCC work (transporting, spreading and leveling, compaction, spraying, laitance removal), ready-mix concrete work (installing form materials, pouring and compacting concrete) and soil form work (excavation, loading, transporting, removing form materials) [9]. The specificity of the tasks performed by today's unmanned ground vehicles, the ability to use them for hazardous construction tasks creates demanding requirements for both their drive, control, communication and navigation systems. The basic requirement for drive systems being discussed in this paper is to provide high mobility and control precision in the conduct of reconnaissance and rescue missions, as well as to achieve high power and torque for actuators of work tools. The progressive development of hydraulic components (their reliability and susceptibility to control) are the reasons why hydrostatic drive systems are increasingly used in solutions for drive systems of modern unmanned land platforms which offer both very good traction parameters of a vehicle and sufficiently large forces for their work tools which is crucial in case of construction machinery. An advantage of such solutions is relatively long operating time of these platforms limited only by the capacity of their fuel tanks (supplying combustion engines), as opposed to robots driven by electric propulsion systems whose working time is limited by the capacity of battery cells. Recreating readiness for reuse is at the present stage of cell technology development significantly longer than the process of refuelling. Full utilization of the potential of these drive systems is only possible where modern control systems are introduced. Due to the principal categories of work performed the method described in [9] there are two examples of unmanned ground vehicles presented in this paper when this is a problem in the execution of construction tasks like rock removal work (loading, transporting), structure demolition, large sandbag placing work (transporting and placing), some concrete block and tree felling work.

Robert Bosch GmbH commenced its development of a Controller Area Network (CAN) in 1983. A Controller Area Network (CAN bus) is generally a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other in applications without a host computer [7]. Unlike a traditional network such as USB or Ethernet, CAN does not send large blocks of data point-to-point from node A to node B under the supervision of a central bus master [8]. In this paper the main focus is on the applications of CAN systems for controlling hydraulic drives of modern unmanned ground vehicles for use in construction.

The CAN technology officially was introduced in 1986 at the Society of Automotive Engineers (SAE) Congress in Detroit, Michigan. The first CAN commercial solution appeared on the market in 1987, produced by Intel & Philips [3]. In 1991, Bosch released version 2.0 of CAN. Bosch first developed the CAN controller technology for use in a vehicle network in 1985 [3]. The advent of new technology for the control of hydraulic components – the CAN-bus system in its mobile version opened a new, long-awaited opportunities in the field of tools and work process control in machines equipped with hydrostatic drive systems. While descriptions of applications of this technology for drives other than hydraulic are available [1,2,3], the knowledge about the applications of CAN systems for controlling hydraulic drives is limited.

That is why the control system for an unmanned land platform based on a CAN bus standard has been developed and results of analysis to answer the scientific question what are opportunities and limitations for the use of such a standard in hydrostatic drive systems for unmanned construction machinery and how this research will contribute to determining whether the use of CAN-bus systems is indeed feasible in such machinery is presented in this paper.

2. Test Station for Hydrotronic Tests of Drive Trains Operating in the CAN-bus System

For the purposes of identifying the limitations and possibilities of implementation of the CAN-bus technology in mobile robot control systems and modern engineering machinery, two test stations were built at the Institute of Robots and Machine Design, Faculty of Mechanical Engineering, Military University of Technology (Figs. 1,2) at which actuators for the hydrostatic drive system were tested, controlled with the use of hydraulic distributors equipped with electronic modules cooperating with the CAN bus.

The basic elements of the stations are five working ports hydraulic valves (1 – Fig. 1) allowing the control of all movements of the work tools, consisting of single PVG32 type sections and operating in the LS (Load Sensing) system. The movement of hydraulic valves spools is controlled via PVED-CC electronic modules which are designed to work using the CAN-bus protocol. The PVED-CC Series 4 is an electrohydraulic actuator which consists of an electronic part and a solenoid H-bridge. The PVED-CC Series 4 transforms a command signal transmitted on a CAN bus into a hydraulic action by applying pressure acting on the end of the spool [11]. The individual coils are activated using remote control panel joysticks (2 – Fig. 1) generating analogue and digital control signals or the test station for testing the remote control system for work

Fig. 1. Test stations for testing control systems using the CAN bus: 1 – hydraulic valve with electronic CAN-bus modules, 2 – remote control desktop, 3 – hydraulic power unit, 4 – work tools

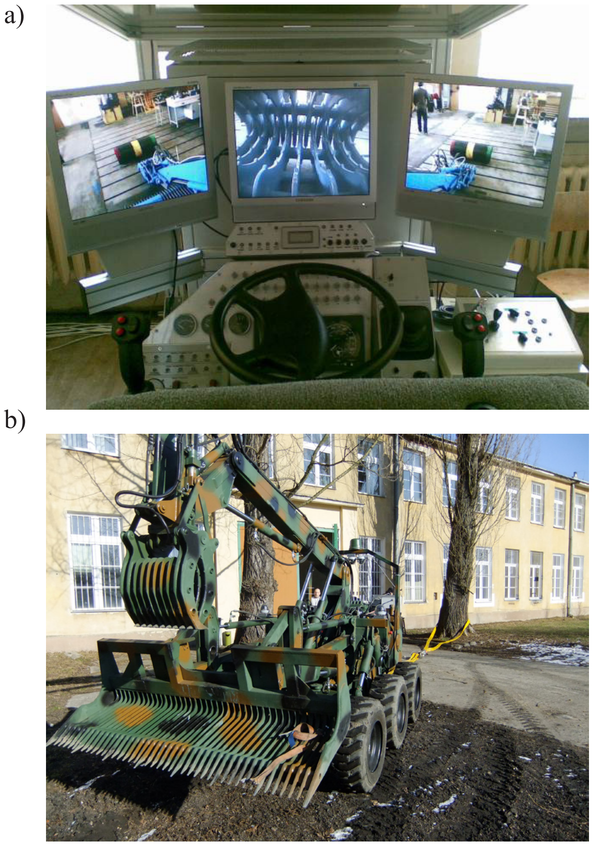

Fig. 2. Test station for testing the remote control system for work tools in the function of teleoperator (a), based on the CAN bus of Engineering support robot EOD/IED “Marek”

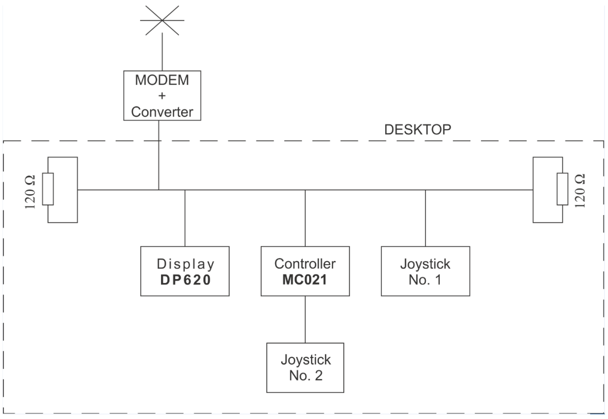

Fig. 3. Scheme of control desktop of the remote control station

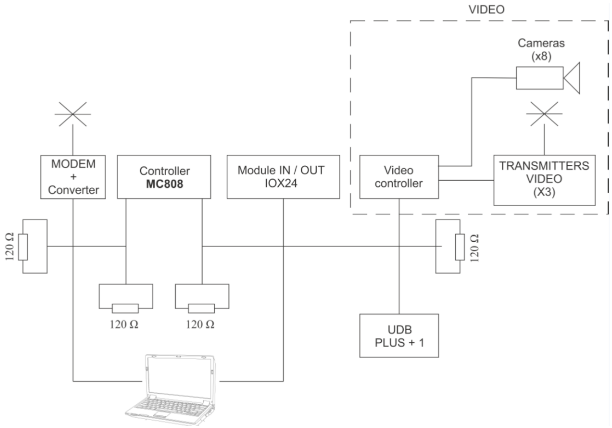

Fig. 4. Scheme of platform on-board control system

tools in the teleoperator function based on the CAN bus (Fig. 2). In this case the vision system provides a panoramic view of the surroundings, and a camera mounted in the manipulator holder (a – Fig. 2) allows for the identification and analysis of picked objects.

Below, (Fig. 3) there is presented the scheme of main control desktop as a component of the remote control station. Whereas on Fig. 4 the scheme of platform on-board control system is presented.

Beside the tests of functionality and effectiveness of manipulator operations, the measurements of its maximum load for different manipulator lift range were done at the test station (Fig. 5). The measurement system is based on force sensor CL-14d (1 – Fig. 5) equipped with amplifying system CL 71, ZEPWN (2 – Fig. 5). Additionally, the load force was measured using dynamometer 9016 APU-20-2-U2 (3 – Fig. 5). The results of tests were recorded with the use of ESAM TRAVELLER Plus data acquisition system.

Fig. 5. Test station for measurement of load force of engineering support robot manipulator (description in the content of the text above)

The value of manipulator loads were recorded both for different manipulator lift ranges and for different its configurations but the same lift range. There, on Fig. 6 the exemplary manipulator configurations for lift range of 2100 mm were presented. The achieved results of the tests are presented at the Fig. 7.

These results approved manipulator capabilities to lift the loads of 500 N for maximum lift range of 4700 mm and possibility to lift the load of 13 kN for lift range of 2100 mm and optimal manipulator configuration.

These tests allowed to define the maximum value of manipulator loads from the point of view of its kinematics and parameters of hydrostatic drive line controlled with the use of Controller Area Network Standard system.

Mutual communication between elements of the control system is carried out using microcontrollers of the PLUS+1 system. CAN-based PLUS+1 microcontrollers are the brains behind intelligent vehicle control. Swiftly programmable to its specific requirements [12].

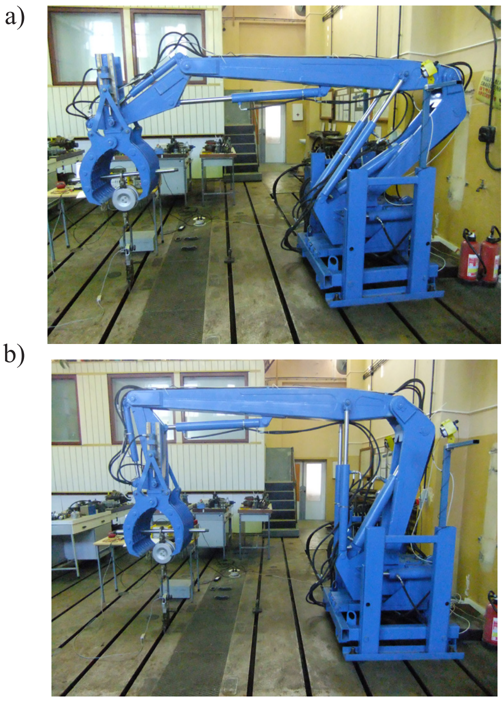

Fig. 6. Exemplary manipulator configurations for lift range of 2100 mm

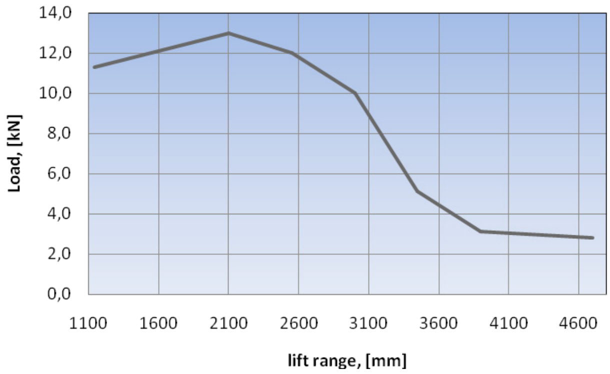

Fig. 7. The graph of engineering support robot manipulator load

3. Unmanned Land Platform Controlled Based on a CAN Bus

As part of research into the possibility of using the CAN bus to control unmanned construction vehicles a light high mobility unmanned vehicle was developed with hydraulic coupling equipped with a hydrostatic drive in which a turn is accomplished by changing the angle of the relative positions of two parts of the vehicle connected by the coupling (Fig. 8). The high mobility of the vehicle is provided by a flexible crawler track where tracks are driven independently by four gerotor motors. Control of the vehicle is realized on the basis of hydraulic valves equipped with electronic modules operating in the CAN system which allows both – changing the speed of the vehicle and its direction of movement. The main drive unit of the vehicle (a combustion engine) and the hydrostatic drive system make it possible for the vehicle to be equipped with additional work tools utilizing the hydraulic energy of the operating fluid or electricity generated by on-board sources of energy. It is therefore possible to mount all kinds of self-levelling platforms, manipulators, cutting saws, hydraulic cutters, etc. on the vehicle. All such components can also be adapted for remote control.

There will be conducted tests to reach more data for quantitative anaylysis on the base of this platform. It will be also part of Validation&Verification tests for simulation models of platform and its drive line components equipped with electronic modules operating in the CAN system.

4. CAN-Bus in Remote-Controlled Engineering Robots for the Modern Battlefield

Other two designs which use the CAN bus in drive control and work tool control systems are engineer-

Fig. 8. Unmanned land platform with control based on a CAN: 1 – hydraulic valve, 2 – electronic CAN-bus modules

Fig. 9. Engineering support robot "Boguś"

ing support robots *Boguś* and *Marek* (Figs. 9 and 10). *Boguś* is designed to perform tasks related to the supply of field work crews operating in a difficult to access areas. It can also act as a carrier of various types of reconnaissance or construction task systems like rock removal work (loading, transporting), structure demolition, large sandbag placing work (transporting and placing), some concrete block and tree felling work. The robot is built as a two-part structure, with a hydraulic coupling connecting the two parts. The power unit is a turbocharged diesel engine with a power of about 60 kW, the drive system is 10x10 (the first part – 6x6, second part – 4x4), transmission – mechanical and hydrostatic with interaxial lock. Independent hydro-pneumatic suspension with lockable front wheels and an lever-articulated turn system. The time of operation has been determined to be not less than 8–10 hours. With the use of the two-part system with a specially designed hydraulic coupling it is possible to obtain a turning radius of about 4 m. This solution makes it possible to clear ditches with a width of 1 m and hills with a slope of 45°. A hydraulic fork lift mounted on the second part is designed for self-loading and self-unloading of objects (e.g. a standard pallet sized 2.5x1 m) with a weight up to 2000 kg, from storage level and from trucks.

The main dimensions of the robot are: length 7-8 m, width approx. 2.1 m, while the basic parameters are: curb weight approx. 4000 kg, load capacity 2000 kg + 1000 kg, maximum speed 30–40 km/h.

"Marek" (Fig. 10) is a 6-wheeled vehicle with a weight of approx. 3200 kg powered by a turbo-

Fig. 10. Engineering support robot EOD/IED "Marek"

charged diesel engine with a power of approximately 60 kW. A 6x6 drive system with independent hydro-pneumatic suspension was proposed as part of this solution. Adequate traction properties have been achieved by using a hydrostatic drive system with a side lock and an interaxial lock, in which each wheel is independently driven by a gerotor motor. The side turn system makes the vehicle very manoeuvrable and allows turning with a zero turning radius, around the vertical axis of the robot. The robot is equipped with a manipulator with a special gripper and an openwork bucket loader. Work tools of the machine are also driven using the hydrostatic drive system.

The kinematics of the manipulator and its design are to provide the ability to pick from a roadside ditch or from a cavity in the ground:

- a load up to 250 kg and with a diameter of 600 mm (e.g. a barrel, aerial bombs, artillery ammunition, missiles);
- small objects with a diameter of less than 100 mm (e.g. grenades);
- prefabricated concrete elements, debris and boulders weighing up to 250 kg;
- steel and wood structural elements (rods, sections, beams, boards, timber).

Like in the case of *"Boguś"* robot, *"Marek"* is designed to perform tasks related to the supply of field work crews operating in a difficult to access areas. It can also perform construction task systems like rock removal work (loading, transporting), structure demolition, large sandbag placing work (transporting and placing), some concrete block and tree felling work.

In addition to the manipulator, the robot is equipped with a lift and loader tools with a quick coupler for linking various different tools. The main tool is an openwork bucket capable of digging loose soil (category I and II) and separating from it objects with a minimum diameter under 50 mm, and lifting/turning over bulky objects, digging out subsurface objects, anchoring – in order to increase the forces achieved by the manipulator – and as a support to increase robot stability. With the lift, it is to be capable of moving (lifting, pushing) concrete blocks, cave-ins, tree trunks, barriers, steel trusses etc. with a mass of up to 2000 kg. The proposed design solutions ensure 8-10 operating hours of the robot.

In both cases, the drive systems of the vehicles are controlled using a CAN bus based on the elements of the PLUS+1 system. Independent drivers are also used in the ride, work tool, hydraulic coupling and active hydropneumatic suspension control systems. The use of hydraulic gerotor motors designed to work on a CAN bus has made it much easier to control them in terms of obtaining the maximum values of torque on individual wheels, and the process of controlling the hydropneumatic suspension ensured continuous contact of drive wheels of the vehicle with the ground.

Another example could be the *Expert* robot [15]. A potential application of the *Expert* robot is to inspect critical infrastructure including dangerous places being results of earthquake or any other disasters. It was also used to set explosives in the building destined for demolition. *Expert* was designed for use in small spaces where the larger Inspector robot [10] would not be able to enter. Such confined spaces include small rooms in buildings.

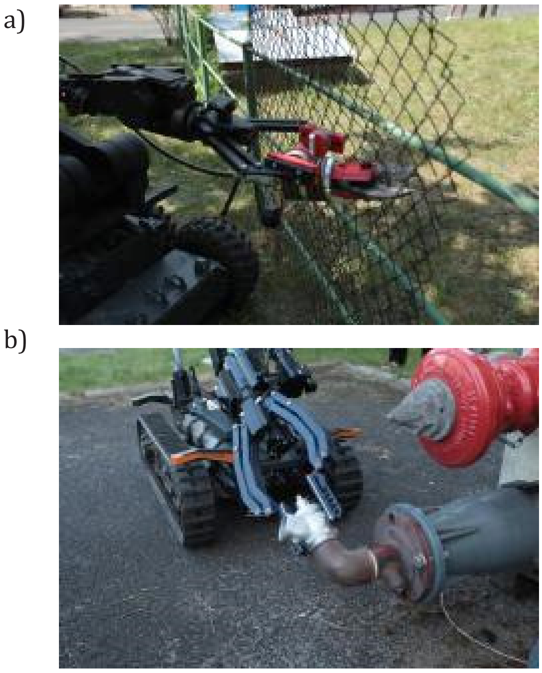

Fig. 11. Two PIAP robots performing construction tasks: a) Ibis/RMF with hydraulic cutter, b) RMI turning off the valve to demonstrate wrist infinite rotation functionality

The robot is powered from gel batteries permitting operation for 3 to 8 hours, or through a cable from 230V mains. Expert features a significant operating range of the arm, almost 3 m. The manipulator has six degrees of freedom plus the clamp of gripper jaws, each step being independent. The robot is equipped with six cameras, four of them on the mobile base of the robot. Two cameras are placed on front tracks and look in opposite directions to the sides; their location over the ground changes with the setting of the tracks.

The other examples are *Ibis/RMF* [13] and *RMI* [14] shown in Fig. 11. The first one is six-wheeled chassis robot with independent drive of each wheel that allows to operate in challenging and varied terrain. IBIS® is a fast robot (10 km/h). Special design of mobile base suspension ensures optimum wheel contact with the ground. Manipulator with extendable arm ensures a large reach (over three meters) and a high range of motion in each plane. It is possible to equip the manipulator in different tools including construction. The second one **PIAP RMI®** – Mobile Robot for Intervention is a tracked vehicle which can replace or assist humans in the most dangerous tasks. It's dimensions and drive system allow to carry out activities both indoors and in difficult field conditions performing different task including construction.

5. Testing Methodology

Testing hydraulic systems can be carried out using both the quantitative method [4] and the qualitative method [5]. At this stage, using the results obtained from tests conducted with the assumed methodology, it is possible to perform a qualitative analysis but some quantitative results are presented at Fig. 7. These will be the issue for the next step tests.

While these test methods have been developed to enable answering the research question: whether there is a possibility of using a CAN bus for the control systems of modern unmanned ground vehicles, and whether certain limitations do not prevent their full use being focused on the quantitative rather then qualitative analysis.

The test subjects were:

- two test stations (Figs. 1,2), at which actuators for the hydrostatic drive system were tested, controlled with the use of hydraulic valves equipped with electronic modules cooperating with the CAN bus;
- light high-mobility unmanned vehicle with a hydraulic coupling, equipped with a hydrostatic drive (Fig. 8);
- engineering support robots *Boguś* (Fig. 9) and *Marek* (Fig. 10).

It was assumed that the tests would focus on issues relating to the areas of both the possibilities and limitations resulting from the use of systems based on the CAN standard.

The abovementioned subjects were tested in order to obtain analytical material for such research areas as:

- requirements for systems based on the components of the CAN standard;
- operational reliability of both the actuator elements and control;
- susceptibility of unmanned land vehicles to control;
- precision of control and system diagnosis;
- creating complex, multifunctional control systems;
- creating complex, multifunctional diagnostic systems;
- implementation of CAN systems for autonomous unmanned land platforms;
- application of CAN standard components in existing mobile robot solutions;
- costs.

Based on the results of tests carried out on real objects qualitative analytical tests were carried out, the

Tab. 1. Analysis of possibilities for the use of CAN bus in control systems for mobile robots

No.	Possibility	Description of possibility
1.	Operational reliability where used for both actuators in hydrostatic drive systems and their control systems	The CAN bus is a solution with very high operational fail-safety, reliability and low interference potential. RED CAN used as a closure of the bus ensures increased, improved reliability in the case of partial failure of the bus.
2.	Susceptibility to control, including remote control	CAN actuators enable their easy configuration and interference in control characteristics.
3.	Precision of control – particularly important for tasks requiring high precision, e.g. identification, picking and neutralization of hazardous charges	Control procedures generated by CAN controllers bring a new quality – an innovative approach to control logic based on intuitive control.
4.	Creating complex, multifunctional control systems	The application of the CAN technology enables the implementation of a multi-processor, multi-controller process.
5.	Creating complex, multimetric diagnostic systems	The use of the CAN technology makes it possible to implement a multi-processor, multi-controller process supported through the use of CAN sensors capable of self-calibration (intuitive control system). It helps diagnose hydrostatic drive systems and their control systems.
6.	Implementation of CAN systems for autonomous unmanned land platforms	The complexity of the structures of autonomous systems enforces the implementation of the CAN technology. In their control systems there is an increasing number and volume of transmitted information. Given the current technological possibilities for its transmission to and from the system, the use of the CAN technology enables the follow-up of the control system and actuating system. Placing on the market intuitive programming systems for controllers generating control signals to the CAN bus also results in the emergence of friendly, intuitive user interfaces (Human-Machine Interface, HMI).
7.	Flexible design	Application of the CAN technology allows the introduction of modular design, in which even the user can make changes to the configuration (e.g. add or remove equipment of the vehicle fitted with CAN-bus nodes). There is also the susceptibility of the design to be extended by functionalities which were initially unforeseen.
8.	Cost reduction	The costs of application of professional systems of connectors and cables often add up to considerable amounts. The use of CAN significantly reduces the number of cables.

Tab. 2. Analysis of limitations to the use of CAN bus in control systems for mobile robots

No.	Limitation	Description of limitation
1.	Need to change the approach to the design and construction of systems with the use of control systems based on the CAN bus	Implementation of control systems based on the CAN bus requires unmanned vehicles to be equipped with actuators designed to be controlled by control components operating based on the concept of CAN systems. This process should take place as early as the design phase.
2.	Adapting existing unmanned land vehicles for the use of the CAN bus	The use of CAN system components gives rise to the need to redesign both the control system and the actuator system.
3.	Need to change the concept of diagnosing the status of the robot	The introduction of systems to diagnose the status of a robot based on the use of the CAN standard necessitates the need to use appropriate sensors and requires the use of specialized diagnostic equipment.
4.	Costs	A higher price of components made in the CAN standard as compared to the previously used components.

results of which have been tabulated and discussed, indicating both the possibilities and limitations of the use of systems operating in the CAN standard.

Then conclusions were formulated focusing on answering the research question posed in this paper.

6. Test Results and Analysis

Analysis of the results of analytical research was carried out based on the results of tests carried out in accordance with the developed methodology, using two testing stations and three unmanned ground vehicles indicated in the previous section, focusing on the research areas identified therein. The results of the analytical tests are given in Tables 1 and 2.

Table 1 identifies six areas of possible use of CAN bus in control systems for mobile robots.

The analysis of the results of analytical research shows that the CAN bus is a solution with very high operational fail-safety, reliability and low interference potential. The use of the Controller Area Network (CAN) protocol analyzer (RED CAN) as a closure of the bus offers increased and improved reliability in the case of partial bus failure, which is very important from the point of view of the continuity of control, particularly for remote control. In previous developments of this technology, problems with CAN were noted which were associated with the inability to obtain a response to information in real time, in particular to information with a lower priority [2]. Currently, the CAN protocol is an asynchronous serial communication protocol compliant with the ISO standard 11898 (11898-1 [3]), widely used due to its real-time operation, reliability and compatibility with other devices [1] including, as was noted in the course of the testing in question, components of hydrostatic drive systems and control systems of unmanned ground vehicles. The protocols of top level are DeviceNet protocols, open CAN, J1939 [3]. Therefore, CAN actuators currently used for these applications enable their easy configuration and interference in control characteristics.

In the case of unmanned ground vehicles, susceptibility to control and precision of control are particularly important for tasks requiring high precision, e.g. dealing with hazardous materials on project sites, inspect critical infrastructure including dangerous places being results of earthquake or any other disasters is very important. Testing vehicles with a hydraulic drive system, where the vehicle is controlled using hydraulic distributors equipped with electronic modules operating in the CAN system, they allow their easy configuration and interference in control characteristics. On the other hand, control procedures generated by CAN controllers bring a new quality allowing the use of an innovative approach to control logic which is based on intuitive control.

The ability to create multifunctional control systems, multimetric diagnostic systems is essential when using the CAN technology for autonomous unmanned land platforms. In their control systems there is an increasing number and volume of transmitted information. Given the current technological possibilities for its transmission to and from the system, the use of the CAN technology enables the follow-up of the control system and actuating system. Placing on the market intuitive programming systems for controllers generating control signals to the CAN bus also results in the emergence of friendly, intuitive user interfaces (Human-Machine Interface – HMI). It would also not be possible to develop the subsequent levels of autonomy without the ability to implement a multi-processor, multi-controller process supported through the use of CAN sensors capable of self-calibration (intuitive control system). The use of the CAN technology helps diagnose hydrostatic drive systems and their control systems.

Table 2 identifies four areas of limitations for the use of the CAN bus in control systems for mobile robots.

The results of research show that most of the limitations are due to the need to change the philosophy of designing new solutions for unmanned ground vehicles, in this case in the field of hydrostatic drive systems and their control systems with the use of control systems operating on the basis of the CAN systems concept. On the other hand, when using this technology for existing mobile robots the use of CAN system components gives rise to the need to redesign both the control system and the actuator system. In both cases, it is necessary to change the concept of diagnosing the status of the robot. This forces the need to use appropriate sensors and requires the use of specialized diagnostic equipment, but it is very important especially when achieving higher levels of autonomy of the vehicles.

The last of the analyzed areas was the cost of implementing this technology for unmanned ground vehicles. At the current stage of development and application of this technology in the field of hydrostatic drive systems and their control systems for mobile robots, the higher price of components made in the CAN standard as compared to the previously used components can give rise to some budgetary constraints.

7. Conclusion

Many areas of the possibilities and limitations of the use of the CAN technology for hydrostatic drive systems and control systems of unmanned ground vehicles overlap with other areas of application of this technology. However, unmanned ground vehicles are characterized by a specificity resulting from the range of their tasks and how they are executed.

The developed methodology has enabled carrying out analysis in order to answer the research question: whether there is a possibility of using a CAN bus for the control systems of modern unmanned ground vehicles. As a result of the carried out analytical research their possibilities and limitations have been determined. The latter do not prevent the use of this technology for hydrostatic drive systems and thereby for control systems of mobile robot with this kind of drive.

The need for precise control of the new generation of engineering machines, the possibility of interfering with their control procedures online and the need for continuous diagnostics of work processes are now becoming a global standard. Its fulfilment, however, requires the knowledge of the capabilities and limitations of the existing systems. This knowledge is currently possessed by the few companies working on new technologies in this area, and there are no scientific publications on this subject. The use of the new control technology, the CAN bus system, for the implementation of technological tasks by today's unmanned ground vehicles can significantly affect both the efficiency of their work processes and operator comfort when using remote control. Therefore, identification of these problems, learning about the possibilities and identification of limitations to the control of hydrotronic systems in the CAN-bus system of mobile robots, determination of the possibilities for the use of the CAN-bus technology for the remote control of work tools has allowed us to implement state-of-the-art drive systems for unmanned ground vehicles – guaranteeing the high quality of their performed technological tasks, as well as the safety of these tasks in hazardous areas.

This is the purpose of vehicles and machines with hydrostatic drive, controlled based on the CAN bus. The conducted research shows that it is possible to use the CAN bus to control of drive and work tools of unmanned vehicles. Its results to date in such research areas as: requirements for systems based on the components of the CAN standard, operational reliability of both the actuator elements and control, susceptibility of unmanned land vehicles to control, precision of control and system diagnosis, creating complex, multifunctional control and diagnostic systems, implementation of CAN systems for autonomous unmanned land platforms, application of CAN standard components in existing mobile robot solutions and costs have made it possible to carry out qualitative analysis of possibilities and limitations for the use of can bus in control systems for mobile robots .

Implementation of the next phase of research consisting of unmanned platforms being equipped with sensors to measure parameters resulting from defined methodology will allow performance of a quantitative analysis, which should answer the next research question: what are the quantitative differences between using classical components and control systems for vehicles with a hydrostatic drive system, and the application of components of drive system and vehicle control based on hydraulic valves equipped with electronic modules operating in the CAN system. A future approach will also involve carrying out tests of manned vehicles in which remote control systems have been implemented [6]. These tests will be also part of Validation & Verification tests of simulation models, both some platforms described in this paper and its drive line components controlled based on a can bus.

AUTHORS

Piotr Szynkarczyk – ŁUKASIEWICZ Research Network – Industrial Research Institute for Automation and Measurements PIAP, Al. Jerozolimskie 202, 02-486 Warsaw, Poland.

Józef Wrona* – Military University of Technology (WAT), ul. gen. Sylwestra Kaliskiego 2, 00-908 Warsaw, Poland, e-mail: jozef.wrona@wat.edu.pl.

Adam Bartnicki – Military University of Technology (WAT), ul. gen. Sylwestra Kaliskiego 2, 00-908 Warsaw, Poland.

*Corresponding author

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