Speed Control of Unmanned Ground Vehicle for Non Autonomous Operation

Khaled Sailan and Klaus-Dieter Kuhnert
Real time System Institute, Siegen University
Hölderlinstr. 3, D-57076 Siegen, Germany
Email: khaled.sailan@student.uni-siegen.de, kuhnert@fb12.uni-siegen.de

***Abstract*—This paper describes the development of speed control for non autonomous robotic vehicle for driving under a difficult conditions surveillance. The DORIS project developed at Siegen University's Institute for Real Time Learning Systems. The primary aim of the DORIS project is to develop novel mobile and unmanned ground Vehicle platforms that will extend the sphere of awareness and mobility of military units and working in difficult condition on the land and on the water. The research is focused to build the platform a, design and install the power train system, control systems, electronic systems that make the vehicle in future full automated. In this paper, the hardware system, control architecture, sensor suite, current capabilities, future research, and applications for the robotic ATV (DORIS) are described.**

***Index Terms*—hydrostatic transmission, non-autonomous vehicle, speed control**

I. Introduction

Popularity of the research on wheeled mobile robots has been recently increasing, due to their possible use in different outdoor environments. Planetary explorations, search and rescue missions in hazardous areas [1], surveillance, humanitarian demining [2], The need for large-scale robotic vehicles arises in the exploration of hazardous sites as well as in the exploring on the land and on the water. Both applications require a vehicle that can operate continuously for several hours, cover large distances at speeds of up to 25 meter per second, carry a payload of several hundred kilograms, and drive at precisely controlled speeds. To meet these needs, institute of real time learning system in Siegen University has procured an all-terrain vehicles DORIS Robot Fig. 1 with the intention of converting them to driverless operation for use as autonomous robotic vehicles. In addition to meeting the basic criteria stated above, DORIS Robot was selected for its payload flexibility, its stability on a variety of terrain, its ability to perform point turns, and the estimated ease of automating all onboard functions. The purpose of this thesis was to develop the speed control that will enable the vehicle, once it has been converted to driverless operation, to function as a robotic vehicle [3]. A speed control system, including the actuators used to achieve non autonomous operation, feedback sensors, was developed and implemented on the vehicle. The result of this research shows the control architecture for this vehicle and implements it on real-time computing hardware on the converted vehicle.

II. Vehicle Description

Figure 1. DORIS robot

The DORIS Robot shown in Fig. 1 is an 8-wheeled, skid-steering, amphibious all-terrain vehicle powered by a 29 KW gasoline engine. It is capable of operating for up to 5 hours on one fueling and has a top speed of about 25 miles per hour. Speed as low as a few inches per second can also be sustained indefinitely. Payload capacity is about 600 kg, and a variety of implements can be installed in its cargo bed. The drive train is hydraulic as shown in Fig. 2, consisting of two variable-displacement pumps driven in tandem by the engine output shaft and two fixed-displacement hydrostatic motors driving the left and right rear axles, respectively Fig. 3 shows the hydraulic power train circuit. The four wheels on each side of the vehicle are linked together by drive chains. Each pump-motor combination drives one side of the vehicle, resulting in independent control of the speed on the left and right sets of wheels. The vehicle is operated by squeezing the throttle lever for engine power and moving the Two DC Motor forward for forward motion and back to stop or reverse motion through two Pedals one for forward and the other for backward driving mode. Steering is accomplished by rotating the DC Motors in a deferent positions according to fuzzy rules this will cause

Manuscript received January 11, 2014; revised June 5, 2014.

doi: 10.12720/ijmse.3.1.44-48

different motor speed and will skid the vehicle left or right [4]. The DC Motors positions correspond to wheel speed, so care must be taken to avoid moving the control levers too quickly and stalling the engine. The levers have a dead zone at the neutral position of less than 1 cm width (1° angular width), and must be locked in this position for parking and starting.

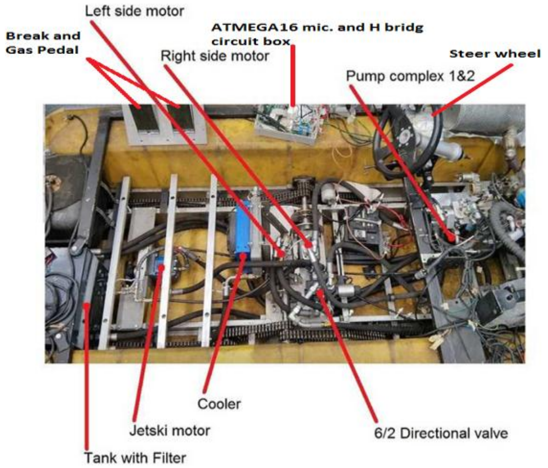

Figure 2. Hydraulic power train

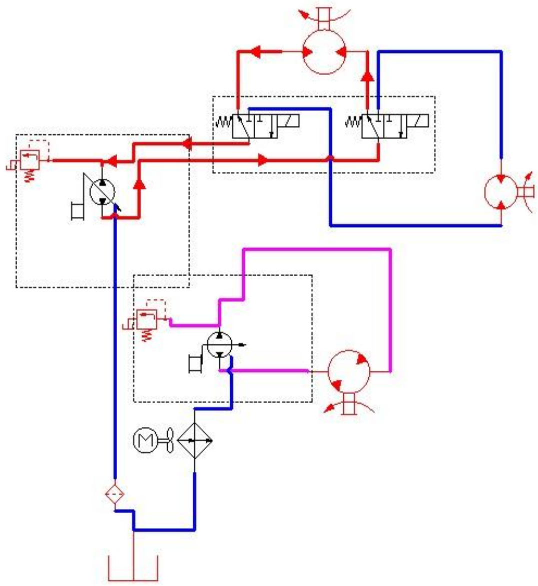

Figure 3. Hydraulic circuit

The variable displacement pumps behave like a continuously variable transmission (CVT), allowing the vehicle to be driven at any ratio of wheel speed to engine speed. This reduction ratio is set by the position of each pumps' swash plate control lever, which is connected to a DC Motors with coupling. The left and right wheels may also be driven at continuously differing speeds, allowing turns of any radius. The engine is designed to operate continuously at a speed that

Depends on the load and on the required maximum speed, engine loading under rapid acceleration is naturally large. In addition, sharp turns and maneuvers on rough pavement or in deep mud place high power demands on the engine due to the skid-steering nature of the vehicle. Novice operators invariably stall the vehicle when accelerating from a stop and when turning on pavement until they learn to control the throttle efficiently and make more gradual maneuvers.

The hydraulic CVT drive eliminates the need for clutch, gearshift, and brake actuators, which enormously simplifies remote operation.

III. Low Level Control and Vehicle Automation

The first step in converting the vehicle into a mobile robot is automating all onboard functions and placing them under closed-loop control. The task is simplified for the vehicle considered here since all drive functions (accelerating, braking and turning) are controlled through the two DC Motors connected to the hydraulic pumps, and the speed is controlled by controlling the swash pump position which connected to the DC Motors as shown in Fig. 4 and by adjusting the engine throttle valve through the servo motor as shown in Fig. 7.

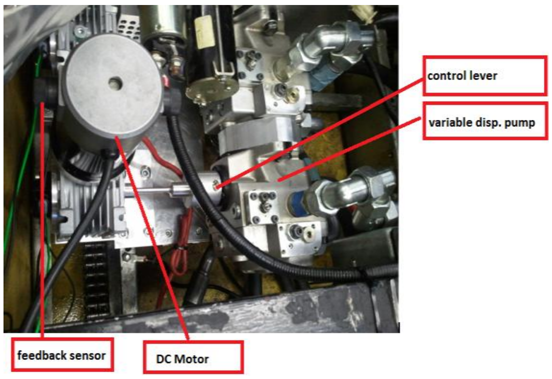

Figure 4. The pump actuators

Thus, complete automation of the vehicle is accomplished with the addition of just two feedback loops, two of which are identical, and their required sensors and actuators. As shown in Fig. 4 and one open loop for control the engine speed.

The low-level controls shown in Fig. 5 consist of two feedback loops and one open loop around the three components of the drive system: an engine speed controller, and left and right wheel speed controllers.

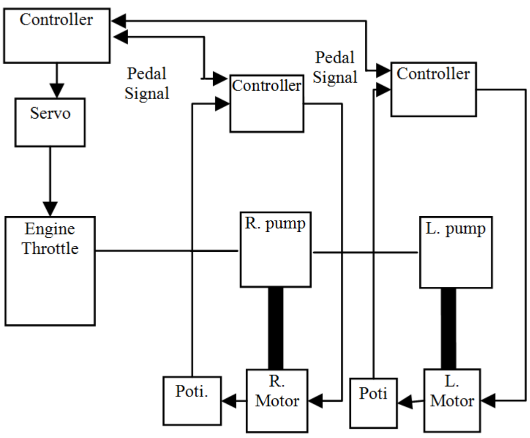

Figure 5. The Automated drive train

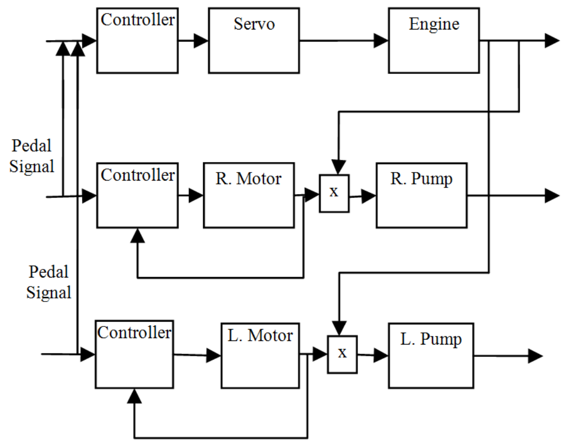

Figure 6. Uncoupled control system

The automated drive train is shown schematically in Fig. 6 It consists of the engine with a open loop speed controller and two sets of hydraulic pump-motor systems each with a closed-loop wheel speed controller. The hydraulic pumps act as a load disturbance on the engine since they must overcome inertia and drag on the vehicle. The engine acts as a speed disturbance to both pumps, since the wheel speed is directly proportional to engine speed. Fortunately, only a slight change to the low-level control architecture is required to decouple the three systems. Relying on the drive controllers exclusively to govern the speed of the wheels results in incorrect responses to terrain variation disturbances. This problem provides another compelling reason for decoupling the low-level control loops in the manner described above. When the Vehicle encounters a hill, the added load reduces the vehicle's speed. Wheel speed drive controllers would respond by moving the swash levers toward higher displacement, since this should result in higher wheel speed and compensate for the disturbance. Actually, this is analogous to shifting an automobile into a higher gear for driving up a steep

Hill, and is not the correct response. First-time operators of the Vehicle invariably stall the vehicle on the first slope they encounter, because the operation of the drive controls is somewhat counterintuitive. Moving the controls forward results in less drive force rather than more, since it increases the wheel speed to engine speed. The correct response is to hold the drive controls (DC Motors) steady and apply more engine throttle. On a very steep hill, the drive controls must sometimes even moved forwards for the vehicle to move faster uphill.

IV. Implement the Low-Level Control System

It is beyond the scope of this paper to describe in detail the design and implement of the two feedback control loops and servo open loop shown in Fig. 5.the servo motor throttle engine actuator connected to the engine leaver and driven by sliding potentiometer as an open loop for controlling the engine speed as shown in Fig 7, the two closed loop control position DC Motors controls the position of the variable displacement swash pump as in Fig. 8 which should be between -20 to +20 degree. The driven signal comes from the tow Pedals one for driving the Vehicle forward and the other to drive the Vehicle backward and Two feed-back sensors attached to the Motors sends the actual position to the microcontroller shown in Fig. 9 which process the error between the input signal and the output signal [5], the servo motor control signal gets some disturbance from the two DC Motors due to the electromagnetic interference (EMI) which is not desired signal. There are numerous EMI filters that could be considered for noise reduction but the most popularly used are the LC inductor filter and the π filter [6] for that a low pass filter used to eliminate the EMI as in Fig. 10, and because the servo motor has independent power supply the Ground line of the servo motor should connect to the Ground of the microcontroller to prevent the servo noise.

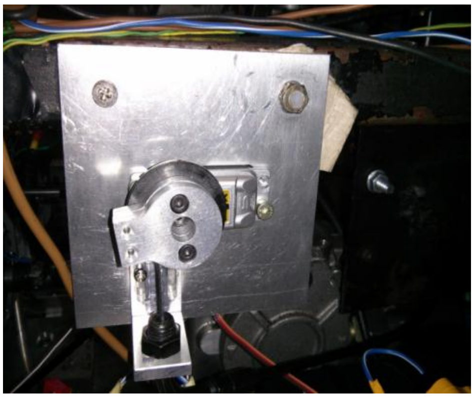

Figure 7. Throttle servo motor

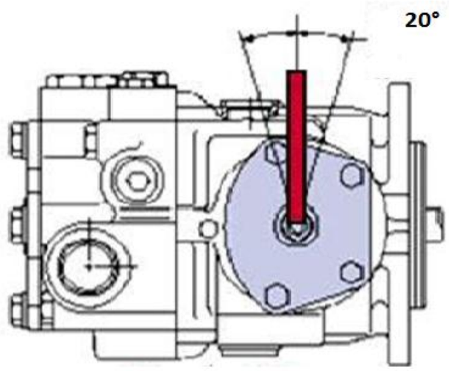

Figure 8. Hydraulic displacement pump

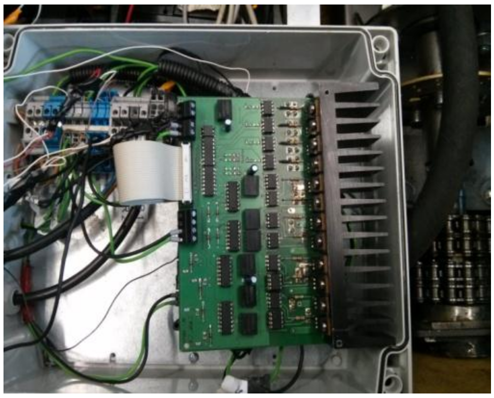

Figure 9. H bridge and microcontroller unit

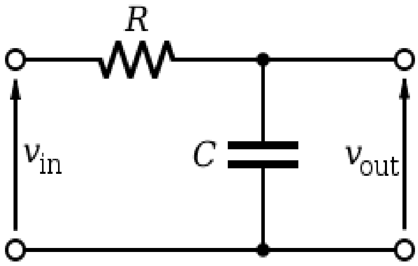

Figure 10. 10 R/C low pass filter

V. Experimental Results

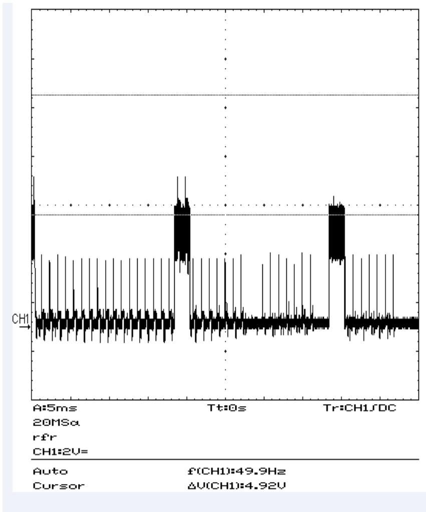

Figure 11. Servo motor noisy control signal

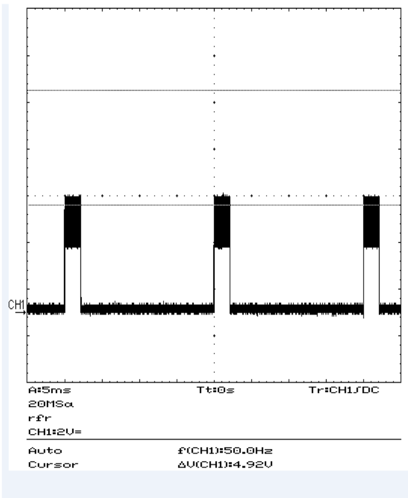

Figure 12. Servo motor control signal for big throttle angle

In this section the experimental result on the DORIS Robot are presented Fig. 11 shows the effect of DC Motors electromagnetic interference (EMI) on the servo motor control signal this problem solved by adding R/C low pass filter between the servo motor signal line and ground line Fig. 12 shows the control signal after filtering and eliminate the effect of EMI this figure is for a big throttle angle while Fig. 13 shows the servo signal in small throttle angle position. Fig. 14 shows the DC Motors positions which control the variable displacement pump swash plat to control the hydraulic motor speed and then the wheel speed ,DC Motor_1 is in position of full closed and DC Motor_2 in in full open position this will make the Vehicle to skid to the left side and Fig. 15 shows the DC Motors positions where DC Motor_1 is in full open and DC Motor_2in full closed to achieved right skid steer Fig. 16 shows the Motors in the same position where the vehicle moved straight Fig. 17 shows a different motor positions for different wheel speeds.

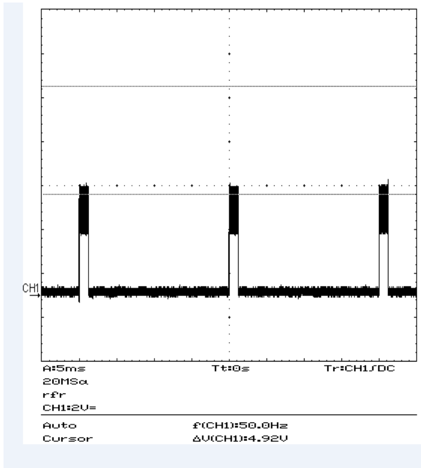

Figure 13. Servo motor control signal for small throttle angle

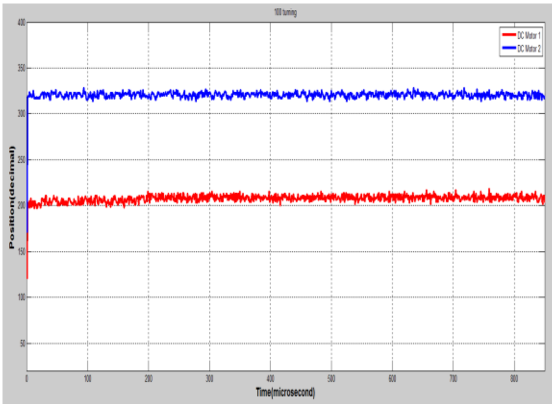

Figure 14. DC motors positions for left turning

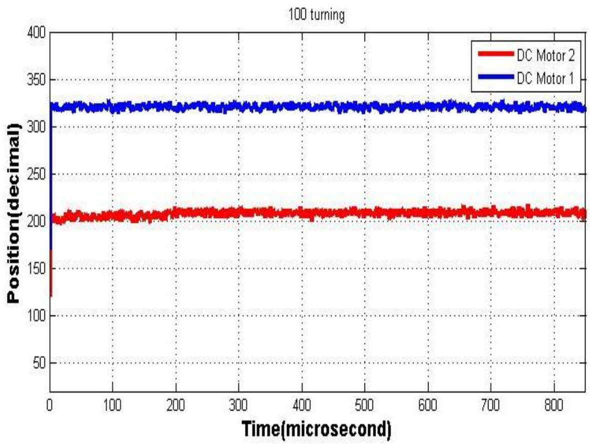

Figure 15. DC motors positions for right turning

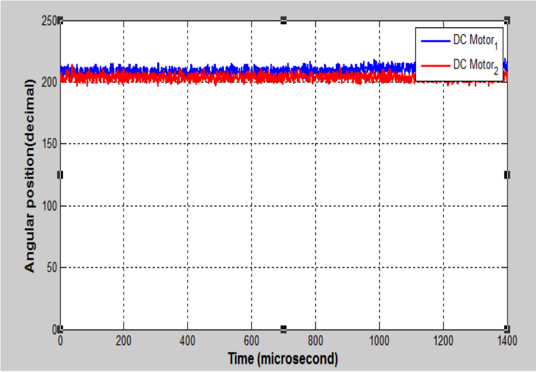

Figure 16. DC motors positions for forward driving

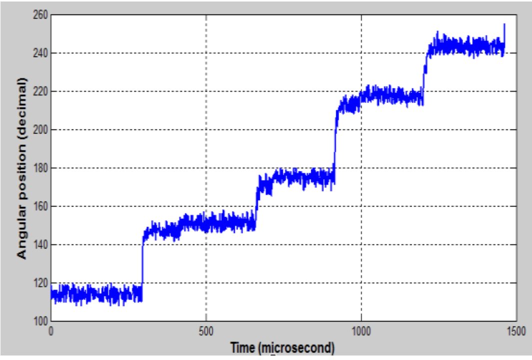

Figure 17. DC motor in different positions

VI. Conclusion

In this paper controlling speed of a manned ground vehicle is achieved by using hydrostatic transmission system, where control the variable displacement pump swash plat cause to control the flow rate and control the hydraulic motor speed that connected to the vehicle wheels. This system is coupled with servo motor to control the throttle engine and engine speed .the next task will be add the servo motor in closed loop with the dc motor closed loop control system and convert the vehicle to autonomous vehicle.

References

[1] A. Trebi-Ollennu and J. M. Dolan, "Autonomous ground vehicle for distributed surveillance: CyberScout," *Tech. Report ICES-04-09-99*, Carnegie Mellon University, 1999.

[2] L. Bascetta, G. Magnani, P. Rocco, M. Rossi, and A. M. Zanchettin, "Teleoperated and autonomous all terrain mobile robot (TA-ATMR)."

[3] J. S. Jacob, "Conversion and control of an all terrain vehicle for use as an autonomous mobile robot," M.S. thesis, 1998.

[4] K. Sailan, K. D. Kuhnert, and H. Karelia, "Modeling, design and implement of steering fuzzy PID control system for DORIS," *International Journal of Computer and Communication Engineering*, vol. 3, no. 1, pp. 57-62, January 2014.

[5] K. Sailan and K. D. Kuhnert, "DC motor angular position control using PID controller for the porpuse of controlling the hydraulic pump," in *Proc. International Conference on Control, Engineering & Information Technology Engineering & Technology*, vol. 1, 2013, pp. 22-26.

[6] P. V. Y. Jayasree, J. C. Priya, G. R. Poojita, and G. Kameshwari, "EMI filter design for reducing common-mode and differential mode noise in conducted interference," *International Journal of Electronics and Communication Engineering*, vol. 5, no. 3, pp. 319-329, 2012.

Sailan Khaled was born in Sana ́a Yemen, in 1978.He received the B.S. degree from Sana ́a University in 2001 and M.S.c. degree in Mechatronics from Siegen University of in Germany in 2010. Since 20012, he is a PhD student in Siege university institute of Real Time Systems

Prof. Klaus-Dieter Kuhnert Received his Dipl.-Ing. in Computer the Technical University of Aachen (Germany), in 1981, and a Ph.D. Degree in Computer Science from the UniBw München (Germany) in 1988. After working as leading scientist with MAZDA-Motor Yokohama he is now full professor and head of the Institute of Real-Time Learning-Systems at the University of Siegen (Germany). He received several international awards: Nakamura Price for best paper of IROS 1989, Most influential paper of the decade award from IAPR/WMVA 1998, first price ELROB 2007 for autonomous driving in urban and non-urban terrain, innovation award of ELROB 2010. He has published over 90 refereed papers and chaired numerous conferences and sessions. Referee for IEEE journals and program committees he also served for several research foundations. He is European Editor of the International Journal of Intelligent Systems Technologies and Applications (IJISTA). Beside others he is member of the graduate school MOSES, member of the center of sensor-systems NRW and founding member of the IEEE TC robotics learning. His research interests include: autonomous mobile robotics, driver assistance systems, 3D Environment Sensing, 3D modeling and visual object recognition.

