Ref: C0627

Versatile low-cost datalogger based on standardized CAN buses for the monitoring of mobile equipment within the farm

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Abstract

Since ten years the research station "*des Cormiers*" located in Brittany is involved in the project "Ecofuel". This project aims to better understand the conditions of use of tractors and agricultural machinery, and in particular the distribution of fuel consumption between the different works in the farm. For this study all the tractors of about ten farms have been equipped with some additional sensors and with a data logger (about 30 tractors are involved in the project).

The arrival on the market of tractors fitted with CAN buses was an opportunity to review the project in both its content and its scope, and to reduce cost of data recording. Thanks to these CAN networks it becomes possible to avoid adding sensors on new tractors and being able to record other parameters which until now have not been recorded and/or to simplify and secure other recordings.

The J1939 CAN bus provides access to data relating to the operation of the tractor while the bus ISO 11783 (Isobus) allows to access data on both tractor and implement. But while the J1939 CAN bus is now widely used on various models of tractors, the Isobus is still relatively uncommon. Additionally, many old tractors are still used by farmers, and these tractors are not fitted with CAN bus.

The aim of the project "Ecofuel2" is to record operating data for a large number of tractors and implements in a more systematic way (more parameters) and this regardless of the level of sophistication of electronic devices on-board.

Our study was therefore to develop a low cost data logger – less than 200 € - capable to record a large amount of data, with a high frequency. This datalogger can be adapted to all the types of tractors: as well for the tractors which are not equipped with bus CAN, that for completely equipped tractors (Isobus 3NF).

Keywords: Isobus, Energy, Data acquisition, Monitoring, Farm Machinery

1 Introduction

1.1 Ecofuel project : monitoring of farm machinery in real conditions of use

The station "des Cormiers" is involved in the collection of references on the use of tractors and farm machinery. These references are essential in order to give insightful advice to farmers in the choice and use of tractors and implements.

Thus the work done under the Ecofuel project has allowed to highlight the important role of road transport in the fuel consumption of tractors, to quantify the impact of the shape and size of parcels on time lost in maneuvers, on the real power level actually used (compared to the actual power of tractors),...

To acquire these references, the experiment station "des Cormiers", located in Britany, has signed a partnership agreement with ten farmers representing the diversity of Breton agriculture. This partnership is concluded for several years, with the goal to have continuous recordings of data over a long period (1-5 years).

All tractors from each farm, i.e. both the new tractor as well as the former used as tractor parts, have been equipped with various sensors and a data logger. The main elements of data concerning the location of the tractor (GPS receiver), the fuel consumption, the engine torque, the temperature of the exhaust gas, speed, hitch position,....

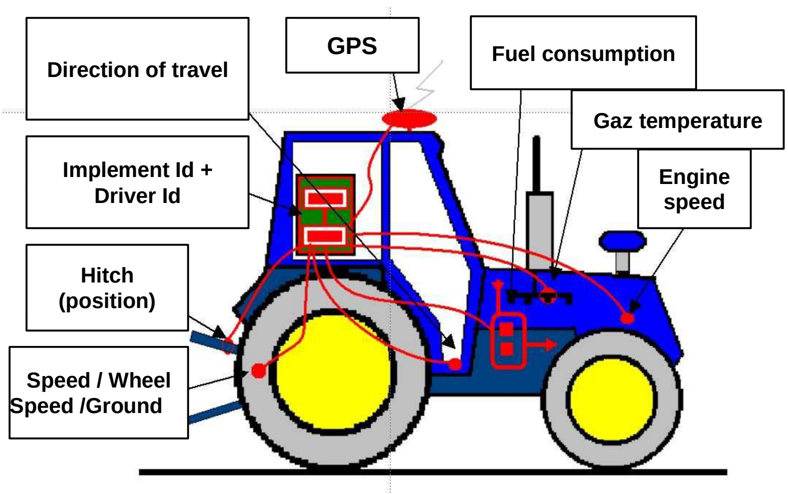

Figure 1a : schematic diagram of the system *1b : Data logger mounted on a tractor JD*

The driver is responsible for identification of driver, implement used and function performed (e.g. a tool like a trailer can be used for various functions that must be known). This identification is based on a potentiometric encoder without any feedback to the driver other than the position of the rotary encoder.

Data is sent by GPRS connection once a week, and a daily SMS can give information about the operating state of the system. The potential malfunctions are very often detected, and they cannot last more than a week.

The system has been in place since 2009, and has already provided many very interesting references. But despite this, the system suffers from various defects which do not allow to go further in the knowledge of the use of farm machinery:

-) The price of sensors and, most importantly, the price of data logger onboard on each tractor is too high (over € 4,000), which prevents fitting of such a system on many others tractors and so for increasing the number of farms involved in project,

-) The addition of sensors can be complicated, and create insurmountable problems (possible loss of warranty due to adding a temperature sensor in the exhaust system,…),

-) The reliability of some data is not assured (the driver may forget to change the identity of the driver and/or the code of the tool used, the potentiometric encoder has a drift over time,…).

-) data from existing sensors onboard the tractor are not available for recording by our system due to a lack of compatibility (proprietary connector systems,…).

1.2 Ecofuel 2: extension of monitoring of farm machinery

The arrival on the market of tractors equipped with CAN buses (J1939 and Isobus) was an opportunity to review the project in both its content and its scope. Thanks to these CAN networks now onboard, it should become possible to avoid adding sensors and being able to record other parameters which until now were not recorded (slip, rear draft force,...). The J1939 CAN bus provides access to data relating to the operation of the tractor, while the bus ISO 11783 allows to access data on both tractor and implement.

The aim of Ecofuel project version 2 is to record operating data for a large number of tractors and implements, in a more systematic way (more parameters) and to create maps of in-field variability for some of these parameters (fuel consumption, torque, rear and/or front draft force,...).

These maps are new layers of data that can be crossed with other maps of in-field variability (yield, soil properties,…), and will allow us to obtain a better understanding of agronomic phenomena.

In this paper we will present objectives, design and technical realization of the new data recording system, and first results gained with.

2 Materials and methods

Our project for designing a new data logger was split into 3 steps: state of the art, definition of functionalities and technical realization of the device.

2.1 State of the art

In order to be able to implement a data logger on a large scale, it was mandatory to have a good overview of what it is available on the market. We have made a large survey on new and recent tractors (more than 100 tractors) in order to know the percentage of use of both CAN buses J1939 and Isobus.

We have found that the J1939 CAN bus is now widely used on various models of tractors coming from all manufacturers, and we did not found any other bus used as "proprietary" tractor bus.

On the other hand, we have found that Isobus is still relatively uncommon, especially for tractors in medium range of power and/or for use in livestock farming. And the situation was very different from a manufacturer to another. Some tractors manufacturers such as Fendt, John Deere, Massey Ferguson,… have appeared as "pioneers" while other ones seemed to be "trolling".

On the occasion of this study, we noted the widespread of the diagnostic socket provided in the ISOBUS standard (ISO 11783 part 12). This diagnostic socket allows for power supplying to a data logger and a simultaneous access to the two CAN buses, without intrusion into these systems and without changing cabling.

We found this diagnostic connector on all the tractors which come from manufacturers "pioneers" on Isobus implementation, and we found that it is not yet totally widespread for the tractors from "trolling" manufacturers.

2.2 Definition of functionalities

As Isobus not yet widely adopted today, our new data recording system should not be based solely on the use of CAN buses J1939 and Isobus. Our system should work with any type of tractor, both with the most sophisticated tractor as well as with the most basic tractor.

On a farm, all types of tractors could be found and the choice of farms involved in the project should not be based on the fact that all tractors within the farm are fitted with Isobus. Otherwise we could certainly put a bias in our references.

Therefore we have defined the following functionalities and characteristics for our device:

-) the data logger must be cheap, if possible the price must be around 200€,

-) The data must be recorded with a high frequency (1 to several times per second, the frequency could be adjustable in function of the data element to be recorded),

-) the data must be stored on Sdcard and could be transferred daily or weekly via a GPRS connection to our data server,

-) At least 2 CAN bus inputs must be available (reserved for standardized CAN buses J 1939 and Isobus), additional CAN buses inputs could be an advantage for future developments

-) At least 5 binary inputs and 5 analog inputs must be available for additional sensors that could be mounted on the tractor,

-) the process for identification of the driver and/or the implement should be so simple and easy. A feedback information to the driver must be generated,

-) the device must be – as far as it is possible – plug and play and working in a transparent way for the driver.

2.3 Technical realization

Our data logger was designed on the basis of a MC9S12DP512 microcontroller unit from Motorola. This MCU is a 16-bit device composed of standard on-chip peripherals including a 16-bit central processing unit, 512K bytes of Flash EEPROM, 14Kbytes of RAM, 4K bytes of EEPROM, two asynchronous serial communications interfaces, three serial peripheral interfaces, an 8-channel IC/OC enhanced capture timer, two 8-channel, 10-bit analog-to-digital converters, an 8-channel pulse-width modulator (PWM), a digital Byte Data Link Controller, 29 discrete digital I/O channels, 20 discrete digital I/O lines with interrupt and wake up capability, five CAN 2.0 A, B software compatible modules, and an Inter-IC Bus

The capabilities of this MCU are widely upper than that we expected, in particular in terms of inputs:

-) five CAN bus inputs,

-) 60 Analog and digital inputs, with a great versatility in the choice of what could be the number of digital and/or analog inputs

This MCU is easy to connect to external peripherals (memory, GPRS), and there is a sufficient number of communications interfaces for connecting at least 5 modules. In order to follow the technical specification, we have connected this MCU to:

-) a LCD screen and a Key-pad. With these modules, it became possible to have a simple way for coding implement and/or driver Ids, in place of using a potentiometric encoder. Feedback of information to the driver is done by the LCD screen,

-) a SD-Card memory module for data storage (one month of data records),

-) and a GPRS communication module in order to generate file transfer and status message as in the previous version of the data recording system.

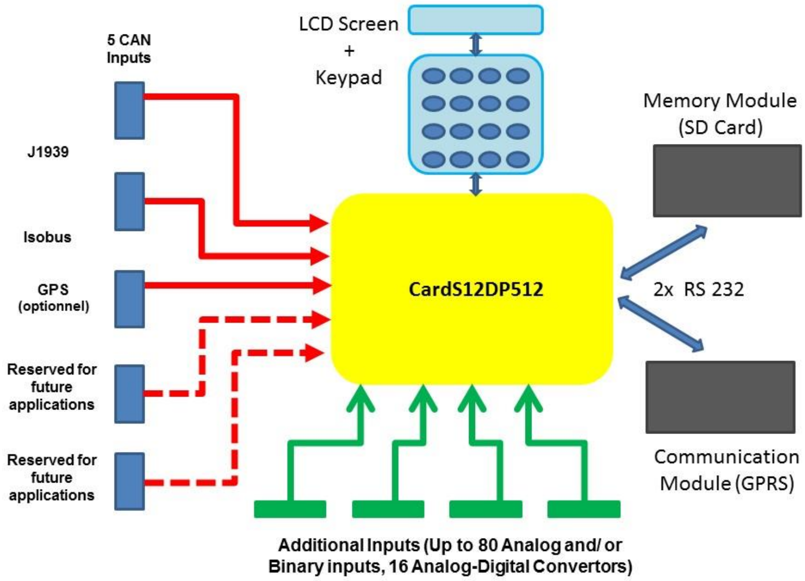

Figure 2a : schematic diagram of the data logger

Figure 2b : Driver and implement Id

The data logger is designed for being plugged in the diagnostic socket. When the starting key is turn-on, the data logger automatically is woken up and starts to record data (recording starts from power-on and stops when the net-work turns off). In the case of tractor “full Isobus”, there is nothing else to do. If there is no diagnostic socket, we must plug the data logger on a 12V socket (i.e.: cigarette lighter socket).

The recording of data elements is different according to the level of sophistication of the tractor: the data elements which are available on buse(s) can be recorded automatically. So, data elements which are part of a standard (J1939 or Isobus) are decoded according to the definition found in the standard, and raw data are stored in the SD-Card.

For this purpose, a set of PGN (Parameter Group Number) and corresponding SPN (Suspect Parameter Number) are stored in a file on the SD-Card. The software embedded in the data logger use this file in order to select the data elements to record and others to ignore.

Table 1: Some examples of PGN and SPN recorded for the project Ecofuel2

Standard	n° PGN	Name of PGN	Name of most interesting SPN
J1939	61443	Electronic Transmission Controller 2	Percent Load At Current Speed
J1939	61444	Electronic Transmission Controller 1	Engine Speed Actual Engine - Percent Torque
Isobus	65093	Primary or Rear Hitch Status	Rear hitch position Rear draft Rear nominal lower link force
Isobus	65096	Wheel-based Speed and Distance	Wheel-based machine speed Wheel-based machine distance
Isobus	65097	Ground-based Speed and Distance	Ground-based machine speed Ground-based machine distance
J1939	65266	Fuel Economy (Liquid)	Fuel Rate Instantaneous Fuel Economy Average Fuel Economy

If Isobus is missing, and / or if the sensors must be added to the tractor, we must make initial settings. For each input we have pre-defined what could be the sensor to use and the corresponding data element to record. By using this strategy, the initial setting of the data logger could be done easily always and in the same way: if the data element is not available on the bus (J1939 or Isobus), a sensor must be connected to the corresponding input, in order to record this data element.

3 Results/ dicussion

This data logger is fully compatible with any model of tractor aged of less than 10 years. This device is versatile and can run on a large range of tractors, from the tractors with only one CAN bus (J1939) to the fully equipped tractors (Isobus 3NF) that is to say with the most complete ISOBUS network.

The main advantage of this device is that it could run with any model of tractor coming from various manufacturers. It is adapted to the real situation in many farms: all tractors used for crops and livestock operations are not coming from only one manufacturer. The reasons for such situation are numerous: change in choices by the farmer, help for work done by others farmers, use of tractors from a cooperative (CUMA = cooperative for using farm machinery), work done by a contractor,..

The first tests were used to collect data and make maps of in-field variability of fuel consumption, slip and draft force.

These tests should be extended this year to more tractors and to more parameters can be mapped.

Figure 3a: travels loaded/unloaded

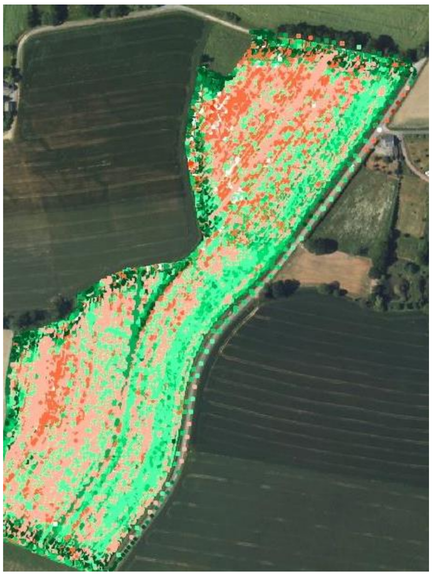

Figure 3b : in-field variability of fuel consumption

For yet a long period, the use of only data circulating on CAN buses will be not sufficient, and will not permit for transforming the tractor as a data logger.

We will continue to add some sensors on board, as the sensors are not available on the tractor or as the tractor is not fitted with the appropriate version of CAN buses (especially Isobus).

Our data logger is not expensive (less than 200 €), easy to use because it starts recording process and stops without driver intervention. There is no skill to have on it to the driver, and it has nothing to do except to correctly identify both driver and implement used each time there is a change.

This device could be also use for farm management as it is a way for gathering data independently of solutions from tractors manufacturers.

4 Acknowledgements

We warmly thank all the farmers who participate in this project for the time they spend there and for their efforts, despite the problems we have may have caused.

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