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# The disabled set sail

*Sailing is not an activity that can easily be done with a handicap. Sailors typically need mobility to steer a boat. An Arduino-compatible CAN architecture for sailing applications is set to change that.*

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“ We aim to give sailors with a disability access to mobile activities.

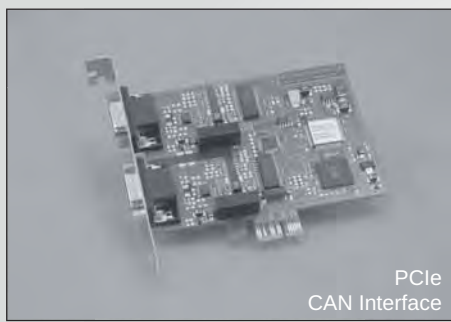
Robotics in the sailing field is now a reality as was demonstrated in 2008 at the World Robotic Sailing Championship and the associated conference [3]. Able to replace humans during competition or to realize autonomous measurements, its field of action has become larger than before. Our approach is not to remove human action, but to assist it during information acquisition, decision process and execution. Sailing globally has remained a field inaccessible for people with a disability, because of the extreme mobility the sailor needs to acquire information and to manipulate commands of a boat. Sailing requires significant efforts that not all disabled can put forth. We aim to give sailors with a disability access to those kinds of activ-

ities. The assistance system was initially composed of an electronic board and a joystick, which allow a person to steer a boat manually as helmsman, forming part of a crew. When needing free hands, the helmsman can activate compass guided steering.

An Android based HMI was developed to complete the system with a visual navigational aid for disabled people [2]. To provide a more complete view of the environment for the skipper and to counterbalance the lack of mobility, sensors were added to the system. Linked to an Arduino board, information was sent to a tablet in charge of the information display via Bluetooth. Interfacing and cabling became complex and interfaces to connect extensions became a

rare resource. Users then asked for joystick-steering on smaller single-handed boats, which requires more actuators and sensors. It was time to think about a different system architecture, with fewer connections and better reliability.

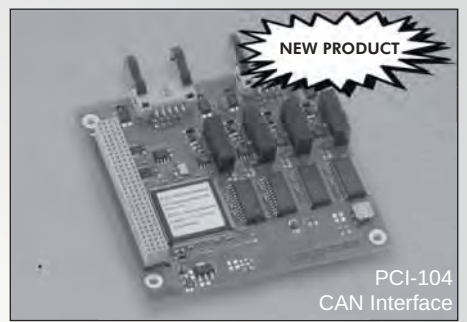
The present part of the project therefore aims to develop a CAN interface board and the necessary software to allow communication using a more modular and flexible network system. This system needed to be easily adaptable to all sorts of situations and disabilities: developers should be able to plug in their own sensors and show data directly on the tablet. On the software side, an Arduino bootloader compatible with CAN allows the programming of nodes directly through the network. The final objective ▶



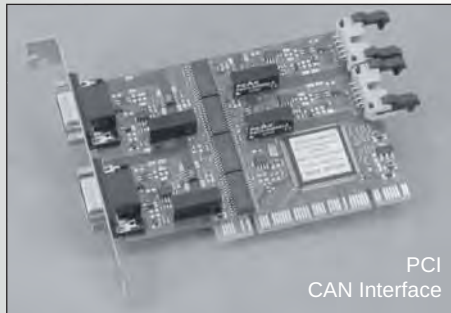
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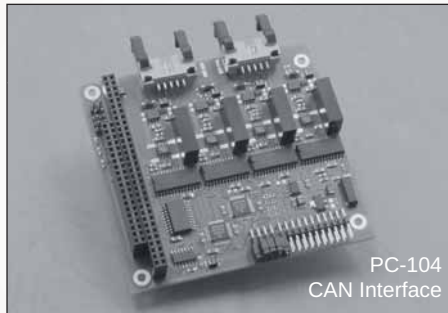
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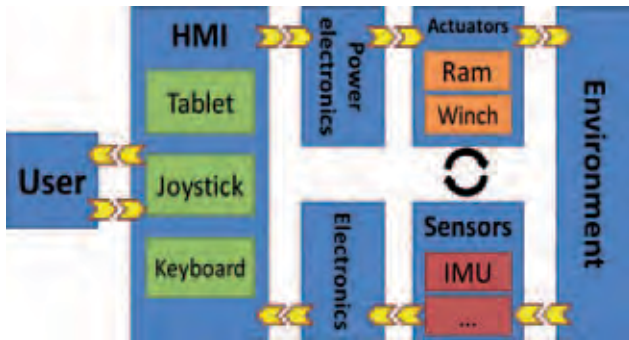


Figure 1: The system is based on a closed loop, where the user can be removed for autonomous behavior

is to provide sailors with a navigational assistance system able to perform automated tasks like heeling limitation, autopilot, etc. The system has to integrate the needed adaptability into the development process and to offer a solution for various kinds of disabilities. For example steering with a joystick compensates the lack of strength in an arm and the HMI centralizes sensor information to compensate a lack of mobility and sensitivity to wind and speed. Furthermore, due to its open-source nature, the software system is modifiable and developers can add functionality or change the HMI according to specific needs. Finally, the system should be adaptable to every kind of boat.

Displays and autopilots installed on today's sailing yachts mostly use multi-drop serial networks with vendor specific proprietary protocols. On some recent boats, the CAN-based NMEA2000 [1] network has replaced the proprietary protocols. For higher bandwidth requirements such as radar or echo sounder images, these networks are sometimes completed by Ethernet cabling (Furuno

Navnet, Raymarine Seatalk-HS). Note that the Ethernet approach is power-hungry, costly and difficult to adapt to simple 8-bit microcontrollers, but NMEA2000 offers a good solution. The problem is that NMEA2000, and the J1939 protocol it is based on, are proprietary protocols. CAN looks promising, but the missing piece is an adapted open source protocol that would allow the design and integration of new hardware for different handicaps.

The number of connections in existing sailing assistance systems has reached a limit, where the system becomes impractical and expensive in an environment where every connector has to be waterproof and saltwater-resistant. Joystick box connections need up to 9 wires; adding sensors to individual actuators would complicate the cabling even more. Since bus systems are already employed in user-interfaces, we think that they should be extended to the entire system, including actuators and associated sensors. This would simplify installation, allow more advanced interactions, better user experiences, and make

the systems more modular, flexible, and adaptable.

### System description

The system is composed of two main parts, the Programmable Servo Controller (PSC) and the HMI, which displays sensor information and allows the skipper to activate the joystick or to use the autopilot. The communication between the bus and the HMI tablet happens via Bluetooth, whereas internal communication uses the CAN protocol. As shown in Figure 1, it can be modified to work as a closed-loop system: information that comes from the environment, just

and control keyboard, and electric winches will be integrated directly into the main circuit board via the CAN interface. This PSC is based on open-source technology in order to allow the easy integration of new functions or to modify current ones. The microcontroller is compatible to Arduino boards and can be programmed with Arduino's IDE software, which gives access to the programming interface, existing libraries and various on-line examples. Wired to this box, multiple sensors such as an Inertial Measurement Unit (IMU) and a wind sensor or loch-speedo are linked into a CAN architecture. When

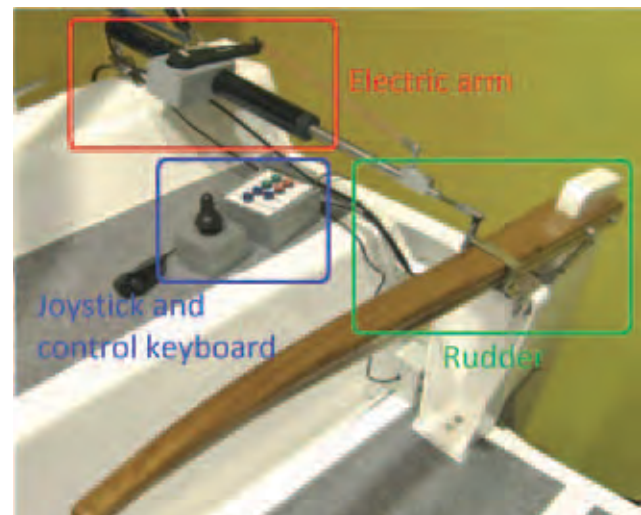


Figure 3: System composed of an electric ram (in red), a joystick and a control keyboard (in blue) and the rudder (in green)

like any human input, influences the actuators, which means the system will be able to perform automated tasks.

The programmable servo controller PSC (Figure 2) is a key component and can do the work of an autopilot course computer, which can steer to wind or compass when associated to the corresponding sensors. The PSC board (6 inch x 7,5 inch) contains a microcontroller, power electronics for an electric motor, an electric clutch and the power supply including filter circuits (Figure 3). Various interfaces for rudder angle sensor, joystick

using more than one actuator, each one uses its own dedicated PSC, with power electronics, local sensors, and a CAN interface. The whole system, including mechanical parts, is transportable and can be adapted to different boats.

The HMI, programmed for Android by using the Android Software Development Kit tool for Eclipse, contains different areas (Figure 4): in addition to textual information, some data, such as wind orientation and speed, compass and rudder angle, is also displayed in graphic form to allow a better understanding of the environment. A last area ▶



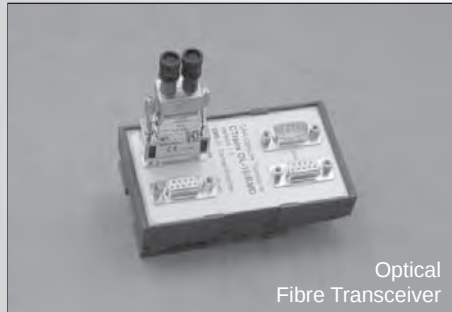
Figure 2: PSC of the Splashelec system in a waterproof case



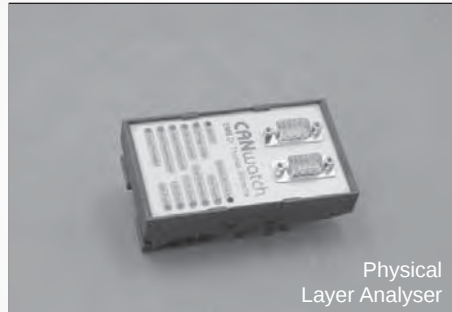
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acts as a virtual keyboard to switch between autopilot and joystick mode and the user can modify the course. The graphical layout of the HMI is realized in XML language and could easily be modified to fit the needs of specific users. This results in a system (joystick, tablet display, extra keyboard, etc.), compatible with different disabilities, while still being usable by sailors without any disabilities.

### CAN protocol

The choice of the CAN protocol for our architecture arose from the need of a broadcast communication mechanism, that had to be easy to use, able to work with multiple nodes, and which provides a reliable communication protocol to exchange information from sensors and actuators. Indeed CAN is able to detect errors with no less than three mechanisms: Cyclic Redundancy Check (CRC) to verify message integrity, Frame Check to verify that data is sent in the correct shape, and acknowledgments to guarantee reception. Besides, adding nodes to an existing CAN network can be done easily, which meets our needs for a modular architecture.

Adding nodes to the network is straightforward: adding a sensor with interfaces like for example NMEA183 (National Marine Electronics Association) or I2C (Inter Integrated Circuit) implies reading the data by the connecting nodes microcontroller and to put the data in a CAN frame. Arduino allows doing this in very few lines of code, using libraries for CAN and a plethora of choices for sensor interfaces.

### Higher-layer protocol

At this point the need for a higher level CAN protocol to organize data in the CAN frames appears. Various higher-layer CAN protocols



Figure 4: The human machine interface displays sensor information and contains a virtual keyboard (in yellow) to replace the physical one

already exist, such as J1939 used in NMEA2000, CAN Kingdom, or CANopen, but it appears that non of these fits our need for a simple CAN protocol. Too complex or not adapted for 8-bit microcontrollers, CAN protocols are not widespread and their code is not always open-source. We decided to develop our own protocol, based on our needs, called SimpleCAN, into an Arduino library containing the essential functions to support our architecture. The protocol permits adding new features.

### System architecture

Our architecture is based on Arduino compatibility and uses a CAN interface called the CANinterfacer, compatible to an Arduino with a CAN shield on top. This board [5] uses an AT-MEGA32U4 microcontroller as do the Arduino Leonar-

do and Micro. It is small in dimension (slightly smaller than 5 cm x 5 cm) and can be programmed via USB using the Leonardo bootloader and the Arduino IDE. It can be powered through CAN by an on-board switching power supply accepting from 7 V to 32 V. Most of the I/O pins are available for local connections.

In the system, a group of elements (actuators, sensors, HMI elements, etc.), wired to a CANinterfacer, becomes a CAN node (Figure 5): each CANinterfacer uses Arduino libraries to convert input from various sources, for example analog inputs, NMEA183 or I<sup>2</sup>C connected sensors, into CAN messages. Putting a CANinterfacer between the new hardware and the bus to integrate it as standard node increases the flexibility. In the same way, the PSC contains a CANinterfacer and functions as a

native node in our bus system. This allows integrating servo-controlled actuators such as rams and winches with their associated sensors.

### CAN bootloader

The CAN protocol implementation opens the way to simplified programming of every node through the bus with only one connection. To obtain that, an Arduino bootloader that accepts CAN programming commands for our CANinterfacer is needed. The Robotics Club of Aachen [4] has already worked on the subject with very similar hardware and built its own CAN bootloader that allows updating firmware and local code from CAN messages. Small modifications have been made in order to suit connections of our CANinterfacer [5]. The programming operation is initiated by a Python script that initiates the communication process between the PC connected programming node and the node which needs to be re-configured. In practice, the programming node acts as an In-System Programming (ISP) interface: it receives the new program by USB or serial port and sends it encapsulated in CAN messages to reprogram the specified node. The whole process is detailed in Weber's The CANinterfacer [5].

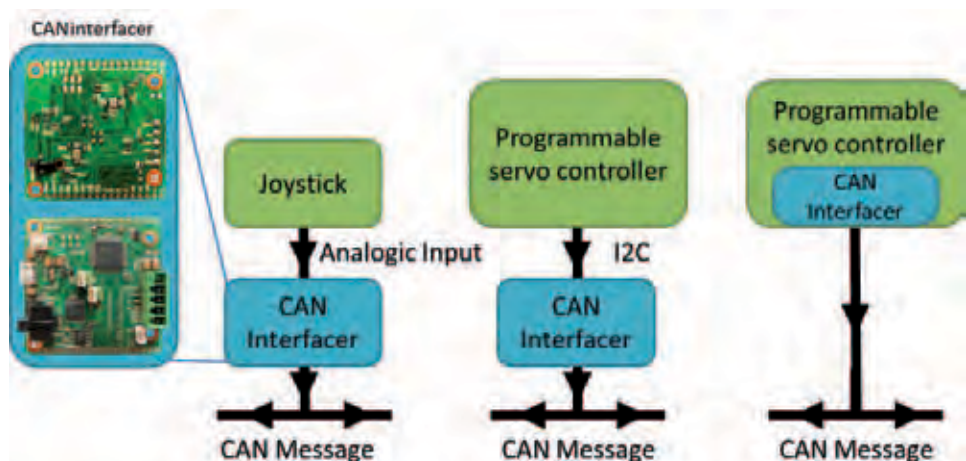


Figure 5: Examples of a CAN node: The joystick and the Programmable Servo Controller (PSC) in its first version; the next version will have a CANinterfacer integrated into the board

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## Demonstrator

The WRSC 2013 demonstrator [3] proves the flexibility of such an architecture. The choice of boat fell on a Miniji from "Handivoile Brest", based on a small scale of a historic America's Cup hull. It is an inexpensive single-handed sailing boat, ordinarily steered by foot pedals or with a steering wheel. It offers vivid sensations to the sailor seated in a comfortable position in a bucket seat.

Furthermore, instructors working with disabled sailors demand an increase in autonomy and safety. To achieve this, a boat will be equipped with electric winches and a rudder system, all interconnected via CAN. Adding sensors to the bus, this boat will be able to perform automated tasks as a sailing robot. Indeed, to increase security, we can limit the heeling or restrict the navigational area. Instructors will also be able to take control of the boat for safety reasons or even activate the autopilot.

A system based on a CAN architecture allows developers to connect new

sensors or actuators, and to reprogram the system using Arduino technology. Such a system assists the sailor during navigation and can automate complex tasks. It helps disabled people by easing the access to sailing activities and gives navigational assistance to anyone. Based on the open-source approach, electronics and software can be modified according to specific requirements. Numerous possibilities for development exist. The final aim is to obtain products with new features derived from robotic sailing, encouraging people to develop their own system modifications ◀

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