**Title:** # Application of LonWorks Technology to Low Level Control of an Autonomous Wheelchair.

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## 1.-Introduction

This paper describes the application of LonWorks technology in the mobile robot field. The capacity of the Neuron Chip as a controller of dynamic systems has been proven, exploiting both its excellent capabilities in the transfer and exchange of messages, and its wide-ranging control possibilities through its input/output devices and objects.

The basic idea behind this work was that of decentralizing the control tasks of a mobile robot by increasing the intelligence of the peripheral systems, ie, sensors and actuators. The capacities of the system are thereby increased without increasing the computing needs of the central processor and what is more important, reducing the amount of information needed in the system local buses.

In the systems constructed with LonWorks technology, the Neuron Chip carries out both tasks of network management and control of the associated sensor or actuator system, furnishing each node with enough intelligence to control any device using the information received from the network. Furthermore all this has a very short development time because of the very nature of the devices and tools available.

## 2.-Work carried out

In the Departamento de Electrónica (Electronics Department) of the Universidad de Alcalá different systems have been implemented based on LonWorks technology. The basic idea behind all the work is that of creating a distributed control system capable of controlling different motors and sensors.

A first system [1] used the Neuron Chip simply as a communication node in the guidance by artificial vision of an industrial lift truck. The high level application communicates with the traction and steering motors of the truck through a PC with the aid of a PCLTA board. The system developed is shown in figure 1.

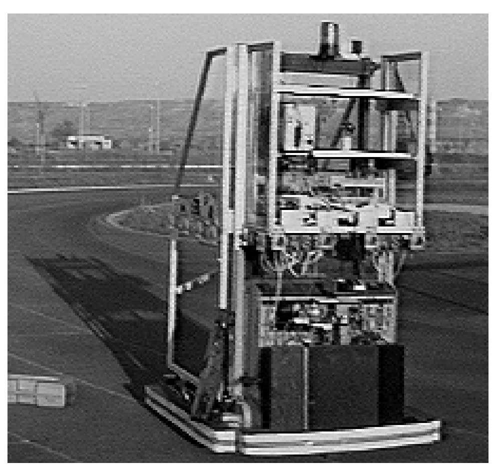

Figure 1.- Industrial Lift Truck.

The movement of the truck is controlled by means of two commands to its traction and steering motors. The Neuron Chip simply obtains these commands by collecting them from the network, from where they can arrive from the PC or from any other node (intelligent sensors). The information is then sent on to a specific motor controller, which then carries out the appropriate control loop. Figure 2 shows a block diagram of the system.

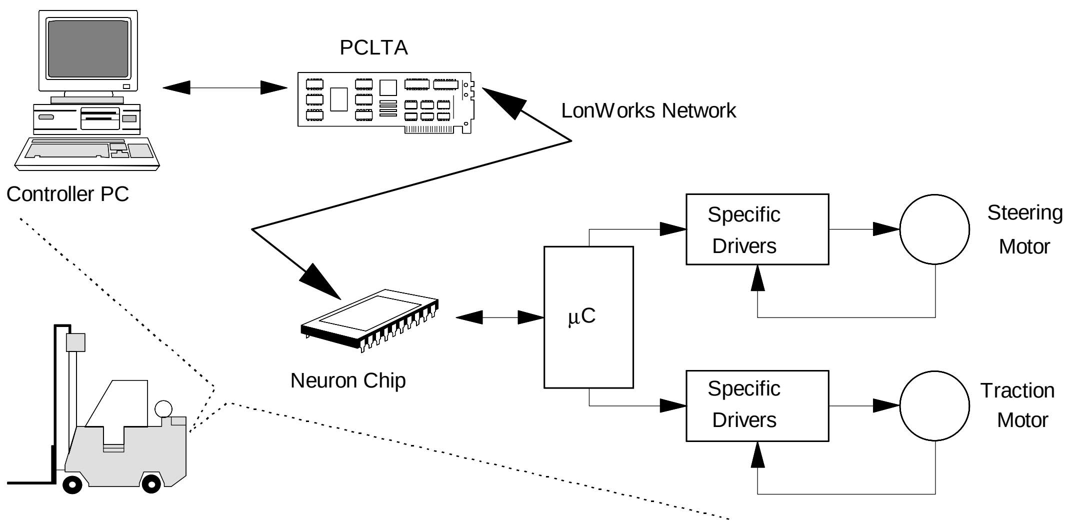


Figure 2.- Industrial Lift Truck: Block Diagram.

The second system already was experimented with the idea of the Neuron Chip itself carrying out the complete closed loop control of the motors, eliminating the need of any additional controller. Two controlling boards, one for each driving wheel, were mounted on a platform with two driving wheels and two castor wheels. The complete system includes a vision guidance device formed by a CCD camera and a laser device. This set provides through the PCLTA the speed commands that the Neuron Chip motor controllers need to establish the movement. Figure 3 shows the system described above.

In this case the variables controlled are the angle speed of each of the driving wheels to achieve the linear speed and the turning angle of the mobile robot, a similar system to that used with the industrial truck.

The Neuron Chip receives commands from the second feedback loop that constitutes the vision system, in terms of the closeness of objects that crop up in the robot's path. The total scheme of this new system is shown in figure 4.

Finally, the experience drawn from the two above applications has been applied to a new project, designed to facilitate mobility for people with a severe physical handicap: the construction of an autonomous wheelchair. It is this last application that is described in greatest detail in this paper.

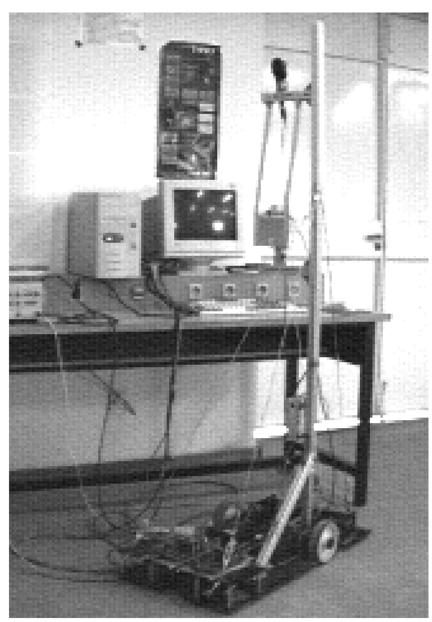

Figure 3.- Movil Robot with vision guidance.

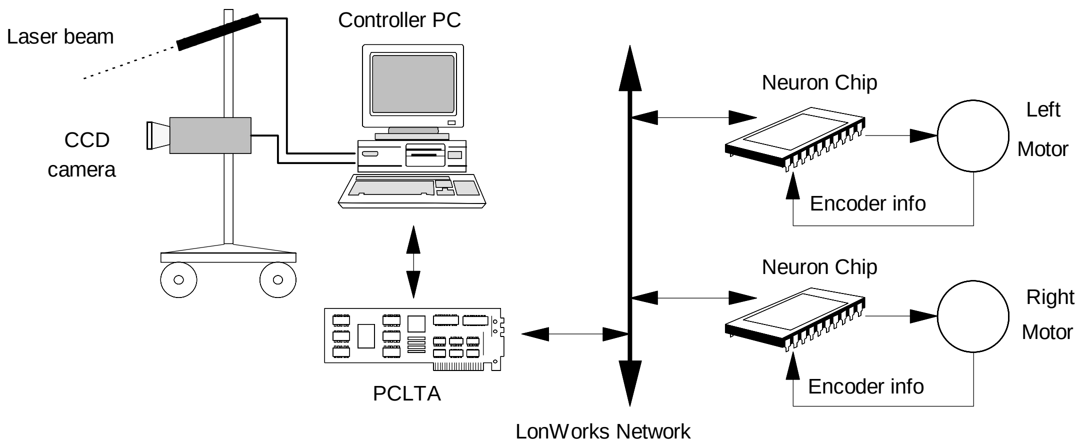


Figure 4.- Diagram of the Mobile Robot, guided by a laser range finder.

## 3.-Construction of an Autonomous Wheelchair System

The system constructed has the distribution shown in figure 5, where it can be seen that it is an open system so that new sensor modules or controllers can be simply fitted to and removed from the assembly. Furthermore, each node is capable of acting on its own initiative in response to events occurring in the module, so the tasks of the robot are thereby decentralised. All this was possible thanks to the architecture and capabilities of the Neuron Chip.

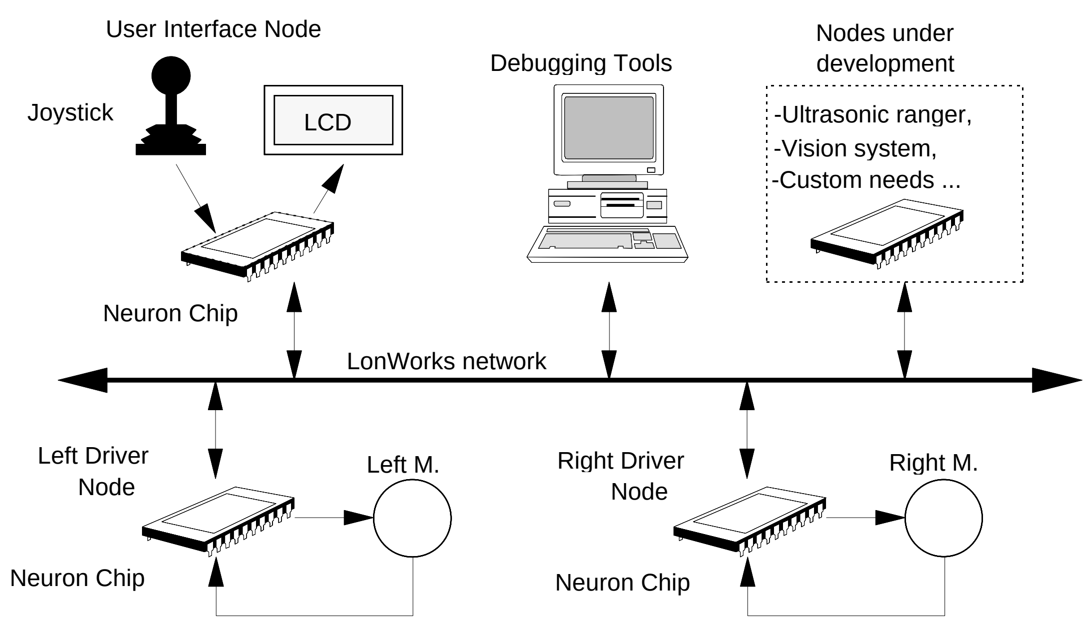


Figure 5.- Block diagram of the Wheelchair.

The wheelchair is moved by a pair of DC-motors controlled by two H-bridges. The H-bridge transistors are driven by specific drivers that receive a PWM signal, the working cycle of which indicates the motor speed [2]. A closed loop system was constructed to control the speed of the robot's wheels. This loop is closed through a system of encoders that determine the position of the motor at all times.

Experiments have proven that the Neuron Chip has all the necessary support to carry out all the control tasks developed in the node described:

1. It can generate a PWM signal by simply indicating to one of the I/O objects the desired working cycle. This signal goes directly to the driver of the transistor bridge, eliminating the need of a specific motor controller.

2. It can gauge the encoder signals to obtain the real speed of the motor, a task carried out through the specific I/O object built into the Neuron Chip firmware.

3. It executes a control algorithm, written in Neuron C and loaded in the same chip. Modifying part/all of this software is very simple, especially bearing in mind the multiple firmware functions included in the Neuron Chip. The great time constant (over 100ms) of the typical traction motors means that the algorithm can be executed without problems.

No additional circuit is therefore necessary to carry out all the low level control of the robot's wheels, since each node acts as an intelligent component of the system. It should also be noted that each node includes all communications support.

In the current architecture the user guides the robot (wheelchair) by means of a joystick that, when operated, controls in turn another node managed by a Neuron Chip. This node is higher in the control hierarchy, so the suitable speed and direction commands are sent through the network to each motor controller node. Furthermore this superior node carries out other interface tasks with the user. The tasks thereby carried out are the following:

1. Obtaining movement commands thorough the joystick. The signals of the joystick have therefore to be digitalized and converted to speed commands for each of the wheels.

2. Comparing the intended speeds with the actual speed of the wheels, received through the network, executing a second feedback loop additional to the one of the lower level, incorporated in the motor nodes themselves.

3. Lastly, this controller node also controls a display LCD and a series of buttons that complete the system communication with the user.

There are two speed control loops (as shown in figure 6) to establish the trayectory selected by the user:

1. The first level operates directly over the angular speed, $\omega x$, of the right and left wheels from the information obtained from the optical encoders placed in the axes of the motors.

2. The second level operates over linear and angular speeds (V and Ω) of the chair itself. This allows to establish simple trajectories (lines and curves), where the curve radius comes from the ratio between the two angular speeds, ωr and ωl, of the driving wheels.

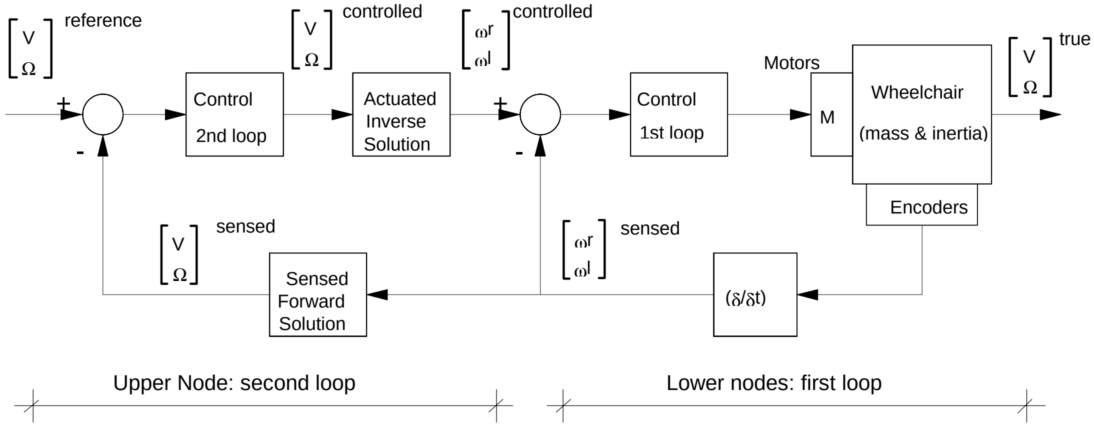


Figure 6.- Double control loop in the Wheelchair.

Upper node in the hierarchy computes transformations among the different kinds of speeds. So, network variables are only angular speeds, both sensed and controlled, coming from the right and left DC-motor nodes. Sampling rates are about 5ms in the first loop and 20ms in the second one; these rates are enough for this application.

In the wheelchair developed, therefore, there is no other controller than the Neuron Chip, distributed in three independent modules interconnected by a twisted pair network. One of this modules, the DC-motor controller, is shown in figure 7. An overview of the wheelchair can be seen in figure 8.

Sensor modules and processors of a higher level (planners, etc) will be phased into the development to give the system the desired autonomy. Some of these, such as voice guidance and ultrasonic rangers were previously tried out in another local Bus system [3, 4 and 5] (less reliable than the LonWorks system) and need only to be switched over to the new system.

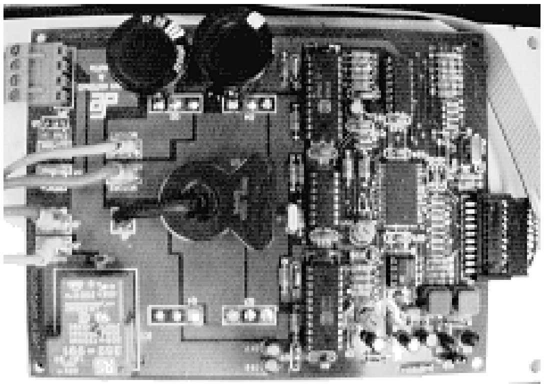

Figure 7.- DC-motor board, with the controller, drivers and H-bridge.

Figure 8.- Wheelchair with Lonworks architecture.

## 4.-Results and Conclusions

Main features of the system developed are summed up below.

The existing communication channel between the boards controlling the motors and the user board consists of a simple twisted pair and a pair of terminal resistances. No specific transceiver is necessary since the Neuron Chip itself includes it for this type of channel.

Extensive firmware included in the Neuron Chip, combined with the fact that it is programmed in a high level language like Neuron C, means that the control system can be rapidly adapted to any change in the configuration (number and type of modules incorporated).

The modules being worked on at the moment are: ultrasonic ranger, artificial vision, voice recognition, etc. These modules aim to complement the original design by adapting it to the physical peculiarities of the users, even to severely handicapped persons. The intrinsic flexibility of LonWorks technology provides for rapid modification and adaptation to each particular case, simply by using the appropriate module.

Design flexibility could likewise be incorporated to production chains. As an example, it can be made a compact DC-motor module, made up by the motor itself and its gear box, the encoder that closes the feedback loop and the controlling board, and with a single controller: the Neuron Chip.

The work carried out has managed to apply LonWorks technology to a field with as much scope as that of mobile robots, obtaining a reliable, low cost system easy to install and re-program, flexible, and user friendly.

## 7.-Acknowledgments

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## 6.-References

Listed below can be found the references made to previous works of the Mobile Robots Group of the Electronics Department (some of them, in spanish).

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