Integration of Vision and Acoustic Sensors in the Ethernet Powerlink Protocol

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***Abstract*—This paper describes a new revolutionnary distributed acquisition/control platform that concretize the convergence between multimedia like sensors (vision, acoustic) and actuators with the CANopen/Powerlink industrial ethernet protocol. We first argue in this paper that the CANopen/Powerlink is the best industrial ethernet protocol for achieving the industrial multimedia convergence in networked distributed systems. We then describe the CYBERIO « Nauplius » robot that is proposed as a first relevant application of our work. We finally conclude this paper by discussing one of the most promising perspective of this work : developping new sensorimotor application for robotic systems that mimics the nervous system of many animals, especially mammals.**

***Index Terms*—Industrial ethernet, sensor network, distributing processing, sensori-motor approach.**

I. Introduction

DISTRIBUTED sensing systems through real-time fieldbus protocol is still an emerging market. It gives rise to new R&D topics like distributed acquisition and control systems. However, the industrial ethernet landscape is like a jungle where a lot proprietary/open claims to be the best solutions for everything. Existing COTS industriel ethernet IO nodes are highly limited to either control nodes (drive,...) and low speed acquisition nodes (pressure, temperature,...). In term of fast speed acquisition only systems, distributed acquisition is classically done with LXI standard or proprietary standards like LANXI from B&K. On the other hand, the audio market is also dominated by proprietary ethernet protocols : « EPL-like » Cobranet from Cirrus, « Ethercat-like » Ethersound from Digigram, ateisnet from Ateis group,..; and now ethernet AVB based higher layer protocols. Networked Industrial vision is also dominated by the GigE standard, i.e a standard that was invented only for the vision sensor kind

As far as industrial sensori-motor applications are concerned, it is high time for convergence. The CANopen/Ethernet Powerlink (PLK) protocol has been chosen as the best candidate to achieve this « convergence » concept. One of the most serious still existing divergence issue in the automation industry relies on the fact that high speed acquistion nodes line audio/video nodes can not be found as COTS products compatible with a full range of existing actuator nodes such as drives.

In this paper we show a revolutionary usage of the Ethernet Powerlink protocol consisting in :

- Defining a « vision application » CANopen profile and developping an Ethernet Powerlink camera node,
- Defining an acoustic application CANopen profile and developing an Ethernet Powerlink microphone node.
- Defining a High performance Computing profile for intensive audio/video processing an developping an ethernet Powerlink nodes based on the Playstation 3 from SONY.
- Developping a first prototype demo of a humanoid robot.

II. Target Platform

At the beginning of the project, the goal was to achieve a unique field bus protocol that aims to be convergent for both multimedia data (industrial vision and audio) and standard automation data (low speed sensor, digital I/O and actuators data). It was clear that one of the best flexible solution in term of deployment target was the DSP/micro-controler chip market. After having surveyed the existing silicom items, we finally chose the Blackfin technology from Analog Devices and developed a dedicated C-coded stack (At the time we began the project, the OpenPowerlink stack was not released). As the Blackfin chip is a unique piece of technology in term of media convergence, we originally though that it was the best candidate on the semiconductor market to support the PLK stack.

The ADSP-BF537 is the higher performance series member, with more embedded memory enabling higher throughput needed for embedded applications such as video security/surveillance and industrial-environment-based distributed control/factory automation applications. Embedded

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network connectivity of the BF537 stack is enabled by an integrated CAN and ethernet controller. It has been established in a first benchmark study that the jitter performance was exceptional [1].

III. The Cyberio Nauplius Robot

A. Basic sensori-motor architecture

A first basic sensori-motor architecture has been built in order to show the benefit of using acoustic and vision nodes in a CANopen/Powerlink network. It gives rise to a first robotic architecture that has been named Cyberio « Nauplius ».

A 3D view of the robot (Fig. 1.) as well as its parts are shown in the next figures and described now. The individual parts of the system consist in :

- 3 evaluation boards A from the Bluetechnix company [2] powered by the Blackfin BF537 core modules (B) and extended by a Camera and Microphones extension board (C). We have designed a specific four microphones extension board compatible with the Bluetechnix evaluation board.
- A Din rail is directly mounted on a Pan&Tilt system (D) powered with two servo-drives. The servo-drives are controlled by the Blackfin processor that is used also as the input video nodes.
- A computing node build with a powerful computation unit. It has been first planned to use a sony PS3. In order to cope with the development of a new ethernet driver, a first approach is to use a portable laptop with a powerfull graphic cards. This unit is powered with a linux system and the Open Powerlink stack as the Master node of the CANopen/ Powerlink network.
- The processing of the acoustic data is done on the graphic cards of the Laptop with the OpenCL framework.
- A eight port ethernet POE switch.
- A 12 V battery supply. New POE evaluation board have currently been designed for facilitating the energy supply of all the slave boards necessary for building such kind of robots.

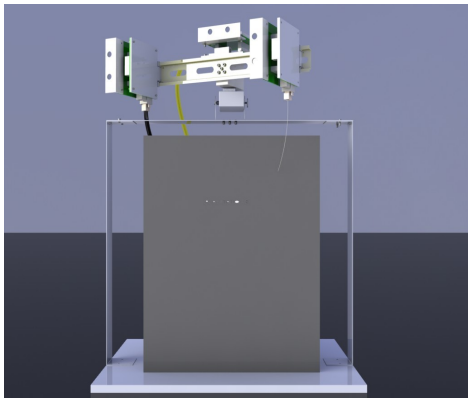
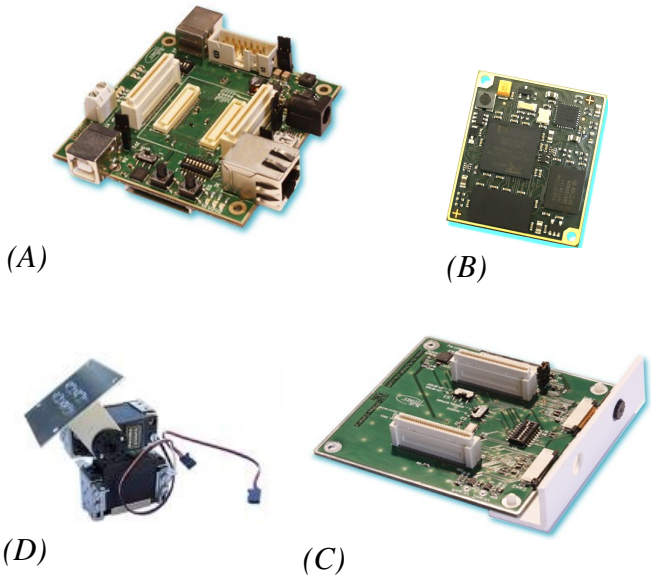


Fig. 1. 3D view of the CYBERIO Nauplius robot.



B. Signal processing and motor control

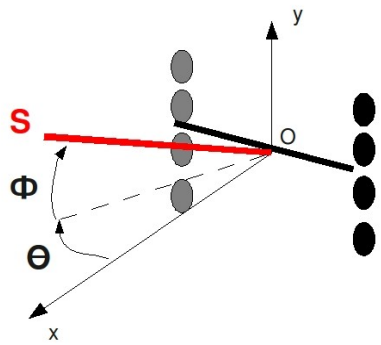


Fig. 3. The geometrical sensori-motor problem of the Cyberio Nauplius robot.

In a first approach, the following basic sensori-motor problematic has been chosen for a first demonstration prototype (refer to Fig. 3) :

- the acoustic sound field coming from a localized sound source is continuously acquired by the acoustic slave nodes. The raw signals (four hydrophones) are transmitted to the HPC Master nodes.
- The HPC master compute a basic beamforming algorithm according the following design guidelines :
  - the azimuth angle Θ of the coming sound source is continuously computed by considering at least two microphones from the two horizontally mounted « ears ». Since the ears are directly

mounted on the din rail, the distance between the ears can be adjusted.

- the elevation angle Φ is computed by considering the four vertically mounted hydrophones of each ear individualy.
- The azimuth and elevation angle are tranmitted to the vision slave that can then control the position of the two servo drives.

IV. Applications

A. Acoustic acquisition systems

1) field survey of echolocating animals

The developped acoustic CANopen/Powerlink nodes will be proposed to the market by the CYBERIO company [3] for wild life survey of marine mammals and bats. These mammals species that all exhibits fascinating acoustic echolocating behaviours are now endangered species identified in the IUCN red list[4].

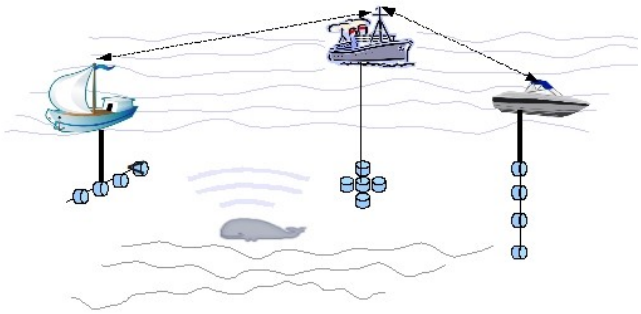


Fig. 4. Deployment of a CANopen/Powerlink acoustic acquisition underwater network.

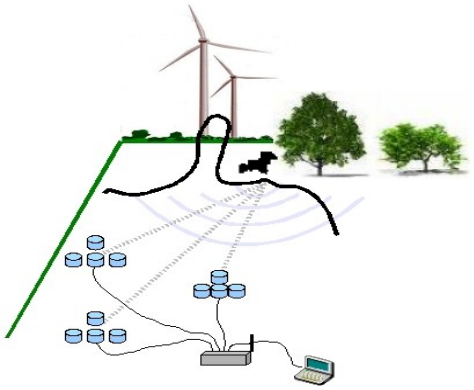


Fig. 5 Deployment of a CANopen/Powerlink atmospheric ultrasound acoustic acquisition network.

With the applications of Fig. 4 and Fig. 5 , the CANopen/Powerlink technology will be directly involved in many biodiversity actions plan all over the world. The first customers of the CYBERIO company will use the acoustic CANopen/powerlink network for achieving bat surveys on the field.

2) Predictive Maintenance

The following figure give a schematic view of how the CANopen/Powerlink proocol can be applied in a energy production plant.

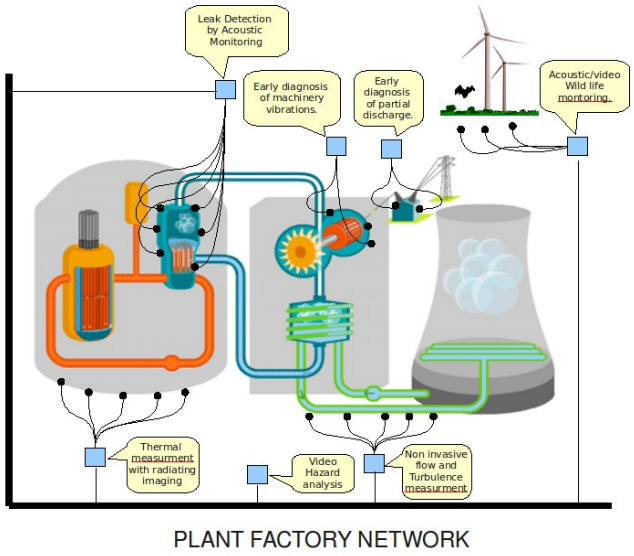


Fig. 6. Location of the energy plant factory where a multimedia Canopen/Powerlink network may be used.

As described in Fig. 6, many critical areas in a energy production power plant can benefit from acoustic/vision sensors directly pluggable on a CANopen/powerlink real time network. Note that in some cases, the Powerlink nodes can be implemented in a reduce protected segment of the overall plant factory network. In such a case, the acquired data of the can be accessed through a specific CANopen gateway.

B. Bio-inspired robotics

It is clear that a system that combine sensors like audio and video, actuators and calculators connected to the same ethernet backbone perfectly mimics the nervous system of many animals.

As the number of acoustic and vision nodes will increase, the bandwidth of the fast ethernet network will be a serious physical limit of using CANopen/Powerlink protocol. We can of course argue that the PLK protocol can be extended to gigabit ethernet but the most promosing application is to deploy bio-inspired software strategies. We can argue for

example that the CANopen/powerlink network will greatly facilitate the following bio-inspired perception concept :

- The « brain » of the system may be centralized at the HPC master node,
- Acoustic and vision data can be compressed before being transmitted to the « Brain », ie the Master HPC node.
- The compression algorithm implemented in the acoustic/vision nodes are highly dependent on the kind of information that the robot needs for its perception problem.
- The perception problem must be clearly solved as a sensori-motor problem : what kind of information does the brain needs from its environment for achieving the given actions of the robot?
- The quality and the quantity of acoustic/vision sensor nodes depends on the perception problem and the complexity of the robot environment.

V. Conclusion

As we can see, it will be now easier as never to implement bio-inspired complex sensori-motor algorithm in a industrial robot or machine. The CANopen/Powerlink protocol is an ideal technology to fullfill the need of fast transfert of information between vision/ acoustic sensor and calculators. The fact that the Powerlink protocol is especially wel disseminated in the drive industry will facilitate the market penetration of the CANopen/Powerlink sensori-motor concept that we promote in his work.

New research topics conducted at the GIPSA-LAB laboratory are :

- artificial sensory intelligence based on networked sensors,
- acoustic survey of echolocating animals (marine mammals and bats)
- synchronization of fast acquisition systems with model-based PLLs,
- integration of ultrasound/imaging sensors in control/command network,
- array signal/image processing for dynamic and transformable array of networked sensors,

They concern the following applications :

- robotics, vision and acoustic imaging,
- acoustic target recognition and localization for surveillance/localization systems,
- room and public area acoustic control for audio streaming applications,
- mixed acoustic/video target recognition and localization for quality control.

VI. Perspective

The first prototype that has been built will be exhibited according the following use case :

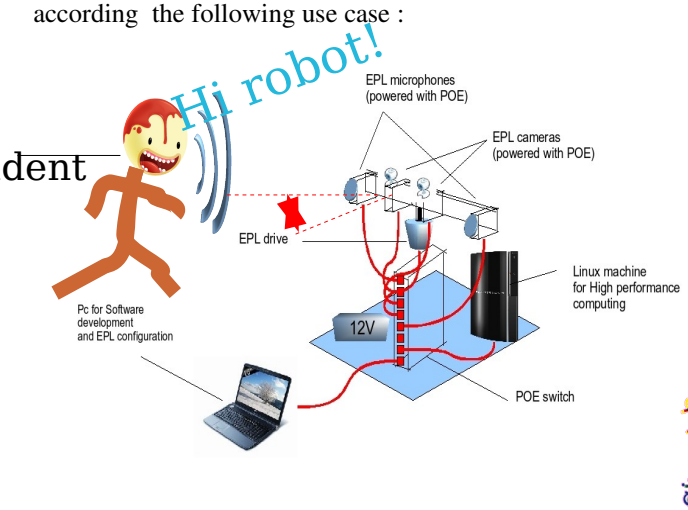


Fig 7. Sound acquisition, signal processing and head orientation of Cyberio Nauplius.

The robot, as shown in Fig 7 is able to localize the sound source coming from a given space location and to turn its head to that direction so that the camera can focus on the sound source (the student!). All the processing are done on a ps3 Sony Playstation with linux installed on it. This robot will be demonstrated at different shows [5].

Acknowledgment

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