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Proceedings of DSP Application Day 2013

e-Conference & Webinars

Special edition: ***Sensor Technology, Signal Processing, and Data Fusion***

Editor: ***Mario Malcangi***

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DSP Application Day 2013

May 10, 2013

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DSP Application Day 2013

e-Conference & Webinars
10th May 2013

Special Edition:
Sensor Technology, Signal Processing, and Data Fusion

As has by now become tradition, DSP Application Day aims to inspire students, researchers, teachers, and industrial designers in fields using digital signal-processing technology or embedded systems for real-time applications. The proceedings focus on sensors, related technologies, signal-processing solutions, and data-fusion methods that lead to interesting and innovative applications.
The section “What’s to Come from the Industry?” presents some innovative silicon-level solutions, thanks to contributions from some leading companies in the field of sensors to the level of silicon integration and system-on-chip design.
The papers discuss some key methods and application issues for sensors, each highlighting the peculiarities and the potential of sensors as an enabling technology for innovation in every application domain.
In the webinars section, the first paper discusses methods for multi-sensor application to enhance signal acquisition, signal processing, and data fusion.
The second webinar paper focuses on a very interesting emerging application paradigm, the meta-instrument. It concisely discusses the meta-instrument and its sensory level, a key issues in human-to-machine interface. The paper then introduces an innovative approach to musician-to-machine interface in the field of musical instruments, applied in this case to meta-instruments: the musician-to-machine interface using gesture sensing for real-time algorithm control.
The third webinar paper focuses on applying the meta-instrument paradigm to musical instruments, drawing on experience with the metapiano and instant interpretation of musical scores.
DSP Application Day gives a wide audience the change to learn about innovations, new methods, new technologies, and new solutions.

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Sensor Technology, Signal Processing, and Data Fusion: Toward the Natural User Interface and Beyond

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Sensor Technology, Signal Processing, and Data Fusion: Toward the Natural User Interface and Beyond

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Abstract: Sensor technology is the most promising and most radical innovation in information and communication technology, both for exploring big data and building simpler user interfaces. The move from the traditional interface toward immersive interaction with the machine (e.g. haptics, gesture, speech, and bioelectric input) will be fostered by a new generation of highly integrated, intelligent sensors and new software paradigms. This innovation will also involve machine-to-machine interaction, thanks to more extensive application of digital signal-processing (DSP) technology and softcomputing methods for data fusion.

Key words: Sensors, Data fusion, DSP, Softcomputing

1. Introduction

Sensor technology is the most promising and radical innovation in information and communication technology, ICT, both in terms of exploring big data, and of devising simpler user interfaces [1][2]. The move from the traditional interface, toward immersive interaction with the machine (e.g. haptics, gesture, speech, and bioelectric input) will be fostered by a new generation of highly integrated, intelligent sensors, and new software paradigms. This innovation, will also involve machine-to-machine interaction, thanks to more extensive application of digital signal-processing (DSP) technology, and soft-computing methods for data fusion.

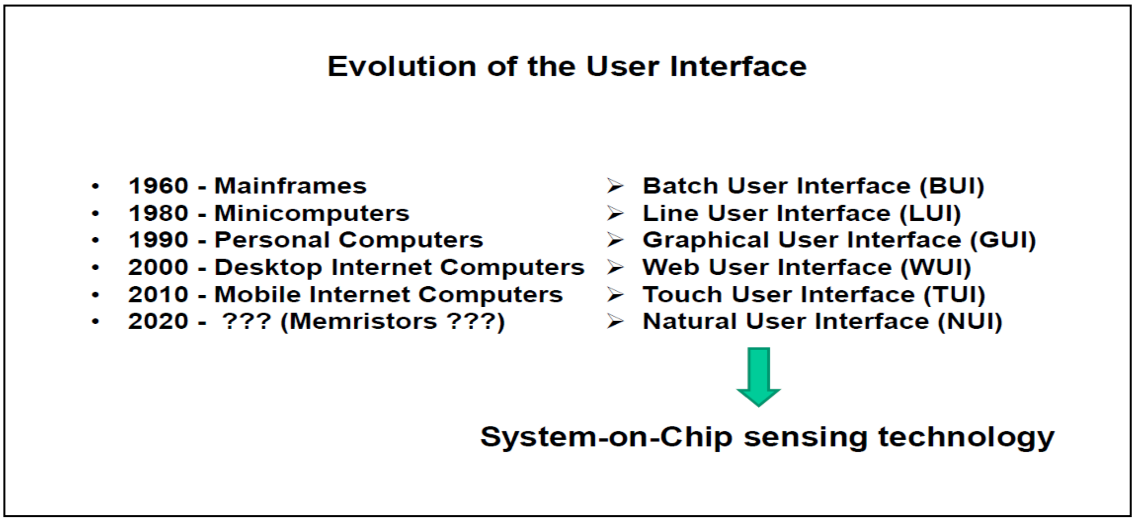

Figure 1. Evolution from the traditional interface toward immersive interaction.

2. The Evolution of the User Interface

The evolution of the user interface, has taken place in parallel to that of the computer. While the computer was increasing its computational power, the user interface increased its naturalness. From the batch user interface, to graphical user interface, the enabling technology was only to be computational. The new paradigm of natural user interface, needs an enabling technology. Such enabling technology is «sensing».

The sensor technology, is developing rapidly to meet a wide range of applications. Many of these applications, are part of what will be the natural user interface in the next generation embedded systems. Some of these applications already exist, based on current sensory state-of-the-art technology, while others are in the intentions of the developers, and are waiting for the availability of sensory enabling solutions.

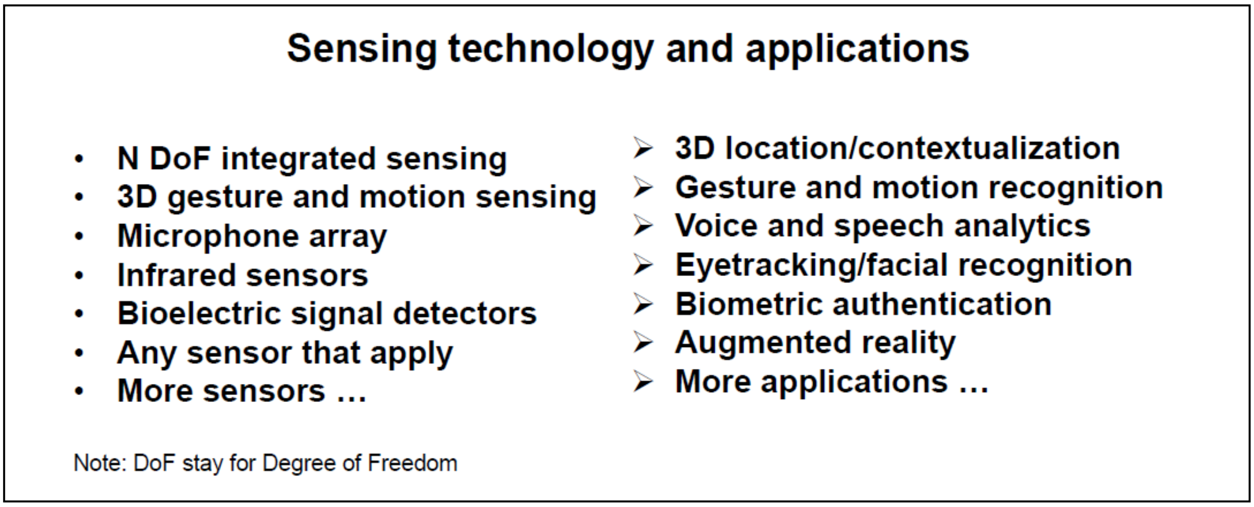

Figure 2. Sensing is the most important enabling technology for most applications.

3. Contextual Sensing

Contextual sensing is a form of embedded user interface that integrates several sensor technologies and other system technologies, to interface human-to-machine. The technology of contextual sensing, refers not only to the physical world that surrounds the user, but also its the physiological and biological state.

Context information acquisition of information about a user and his surrounding environment, is what it is needed to adapt the behavior of applications. Multiple sensors and multiple algorithms are running at the bottom level of the framework, capturing, analyzing, and featuring signal information. At higher level runs data-fusion decision algorithms and inferring engines, to integrate each other's results and retrieve more accurate and higher abstract context information.

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GestIC enables the next dimension in intuitive, gesture-based, non-contact user interfaces for a broad range of end products. The configurable MGC3130 is the world's first electrical field-based 3-D gesture controller, offering low-power, precise, fast, robust hand-position tracking with free-space gesture recognition.

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Freescale Semiconductor

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Freescale Semiconductor: Xtrinsic Intelligent Contextual Sensing

Xtrinsic is an intelligent, high-precision, motion-sensing-enabled controller that manages multiple sensor inputs and makes system-level decisions for advanced user-interface functionality targeted at mobile devices.

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What's to Come from the Industry?

Analog Devices: Wearable Sensors for Heart-rate and Activity Monitoring

Applications for measuring vital signs are on the rise, with emphasis on home healthcare and personal health management. The AD8232 single-lead ECG AFE for heart-rate monitoring and the ADXL362 MEMS accelerometer for activity monitoring are the highlights of this trend.

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What's to Come from the Industry?

Microchip Technology: BodyCom Technology for Secure Bidirectional Communications Through the Human Body

Microchip's BodyCom Technology is a short-range, low-data-rate communication solution for securely connecting to a wide range of wireless applications. Activated by capacitively coupling to the human body, the system communicates bidirectionally between a centralized controller and one or more wireless mobile units. Intra-body communication occurs utilizing the human body as the transmission medium. Compared to other existing wireless technologies BodyCom offers lower active and standby energy usage, increases security through bidirectional authentication provides a secure communication channel using the human body and allows for simpler circuit-level designs.

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Jan-Hein Broeders

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What's to Come from the Industry?

The AD8232 is Changing the Game in Cardiac Measurement

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The AD8232 is Changing the Game in Cardiac Measurement

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Abstract: In the past, vital signs have been monitored mostly on people with physical complaints or detected diseases, but today we are interested in monitoring these parameters to anticipate unexpected situations. Heart rate is often monitored to measure the condition of a person or to find our physical limits. To support these needs, Analog Devices (ADI) launched the AD8232. This AD8232 is an integrated analog front-end, able to measure ECG signals or to monitor heart rate at low power dissipation, which makes it attractive for battery-operated and portable systems.

Key words: Analog front-end, ECG, heart rate, low power dissipation, portable systems.

1. Introduction

Among bio-potential measurements, ECG and heart rate are measured the most, as these are a good indicator for our physical condition. This allows you to exercise safely, as well as providing feedback about your physical improvement and success during exercising. Heart rates taken during exercise encourage you to exert yourself enough without overexerting or overstressing. Keeping track of heart rate allows you to monitor your cardiac output to verify whether you are in a safe operating mode during the entire fitness program or not. In addition, monitoring heart rate over a longer period of time gives feedback about long-term progress. If you are able to exercise at a more intense level without increasing your heart rate, you're becoming stronger and more efficient.

There are two options for measuring heart rate; by contact or contactless measurements. The AD8232 is a new low-power integrated signal conditioning front-end, developed for ECG- and other bio-potential measurements. It uses 2- or 3-electrodes to obtain the cardiac signals from the human body.

The chip converts the small, noisy signals from the electrodes into a large, filtered signal that easily can be digitized by a standalone A/D converter or an ADC, integrated in a microcontroller.

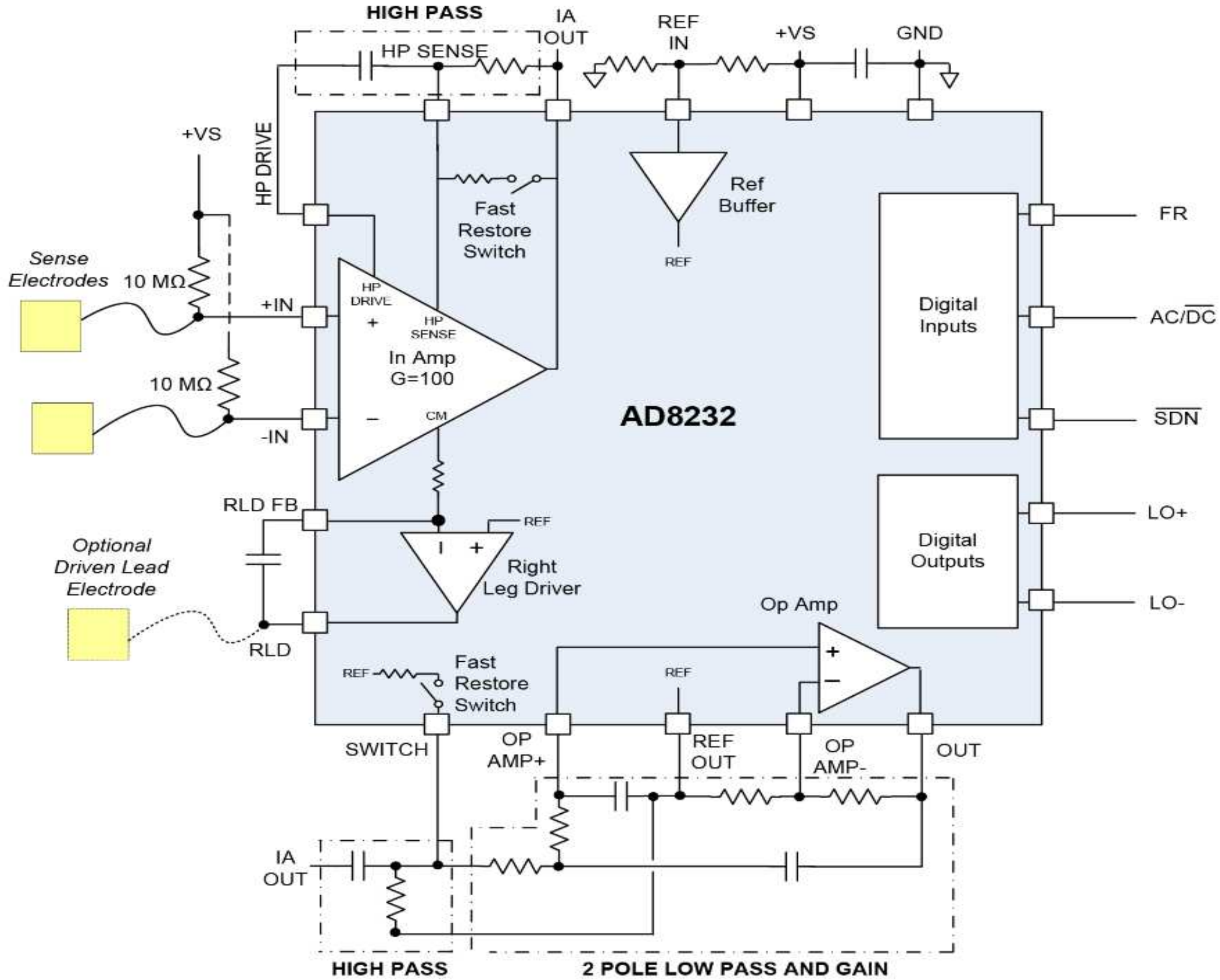

Figure 1. The AD8232, a new low-power integrated signal conditioning front-end, developed for ECG- and other bio-potential measurements.

2. Signal chain conditioning

Figure 2 shows a simplified circuit diagram of the AD8232, which in principle can be seen as four individual sub functions. The input is built around a differential amplifier stage followed by an amplifier stage that supports low pass filtering. In addition a right leg drive amplifier is integrated and an on-chip reference buffer.

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Middleware Infrastructure for Monitoring Bed Activity

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Middleware Infrastructure for Monitoring Bed Activity

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Abstract: This work describes a service-oriented middleware platform for ambient-assisted living and its use in two different bed-activity services: preventing bedsore and monitoring sleep. It includes detailed description of the middleware platform, its elements and interfaces, as well as a service that can classify typical user bed positions. The key idea behind our work is to leverage wireless sensor networks by collecting the received signal strength (RSS) measured among fixed general-purpose wireless devices, deployed in the environment, and a wearable one.

Key words: ambient assisted living (AAL), middleware, bed activity monitoring, received signal strength (RSS).

1. Introduction

The use of middleware infrastructure that can provide data from any kind of sensor installed at the assisted person’s home is essential for ambient assisted living (AAL) applications where context information can be shared among different services. The objective of this work is to provide a middleware infrastructure for the rapid prototyping of applications of ambient intelligence (AMI) for healthcare and AAL, with a certain degree of dependability. In particular, we propose a bed position detection service that is the input for other two important services, namely bedsore prevention and sleep monitoring services. These are the core services for bed activity monitoring service [1] providing inputs for further analysis by other AAL services. Wireless sensor networks (WSNs) are supposed to be widely deployed in indoor settings and on people's bodies in tomorrow's pervasive computing environments. The proposed system leverages the presence of WSNs by collecting the received signal strength (RSS) measured among fixed general purpose wireless devices, deployed in the environment, and a wearable one. The RSS measurements are used to classify a set of user's positions in the bed, monitoring the activities of the user, and thus supporting the bedsores and the sleep monitoring issues. The proposed component-based architecture lets developers use services in a modular way. Future services will be able to use the data produced by the bed position detection service without rewriting a new ad hoc component.

Bedsore prevention service: Nursing homes require caregivers that ideally observe the elderly around the clock to prevent bedsores. The caregivers have to provide a high degree of surveillance and attendance to the elderly all the time. Moreover, the knowledge and personality of caregivers affect the quality of nursing care. The most widely accepted ways of preventing bedsores is to actively turn the patients who have limited mobility on a regular basis (every 2 hours) to avoid unrelieved pressure from forming on the body. Usually the caregivers use a turning sheet to keep track of the patient's position, recording the last position, the elapsed time, and the next position (turning plan).

In this work we propose a service able to automatically assess the bedsore risk, and able to help the caregiver to decide the care program and thus control that the actual patient's position matches with the turning plan, increase the quality of nursing care. This is the scope of this service that want to support the pressure ulcer prevention i) monitoring the patient's self-movements and adapting the caregivers interventions, and ii) decreasing the burden of the caregiver to prevent the bedsore. In fact, by knowing posture of the subject, potential bedsore risks of the subject can be inferred and timely reminders can be sent to caregivers.

Sleep-monitoring service: Sleep plays an important role in quality of life and is an important factor in staying healthy. Having inadequate and irregular sleeping patterns has a serious impact on our health, and can lead to many serious diseases like cardiovascular disease, obesity, depression and diabetes [2].

The proposed sleep monitoring service is essential to recognize sleeping disorders for diagnosis and prompt treatment of disease. Moreover, it can also provide detailed sleeping profiles that depict periods of restlessness and interruptions helping to find trends that correlate to certain diseases. Finally, it enables monitoring effectiveness of treatments to sleep-related diseases.

2. Our Solution in a Nutshell

The goal of our work is to infer the elderly position in the bed, without using an ad-hoc or sophisticated hardware. In fact, we suppose that the elderly/patient wear any wireless sensor device able to transmit (hereafter also called mobile), and that the environment is equipped with fixed wireless devices (hereafter also called anchors) installed transparently at home in general purpose devices such as lights, mains power outlets or light switches. We propose a bed position detection service that leveraging the RSS measured between the mobile and the anchors infers the patient bed position. By doing so, we would be able to both support the bedsores prevention and monitoring the patient sleep. Indeed, the proposed services would be able to alert the caregivers if the position of the patient keeps fixed for a long time, and tailoring the interventions to the patient's current needs (bedsores prevention service) or to recognize sleeping disorders as early as possible for diagnosis and prompt treatment of disease (sleep monitoring service).

3. Middleware Architecture

The sensors, the services, and the components integrated in the system will use a software infrastructure, which is based on a middleware that hides heterogeneity and distribution of the computational resources in the environment. The proposed middleware solution uses a Java/OSGi platform as the reference platform for the development. However, the integration of such components is demanding, especially if we consider that the system is composed of different services written in

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Data Fusion from Sensors for Context-aware, Healthcare-management Systems

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Data Fusion from Sensors for Context-aware, Healthcare-management Systems

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Abstract: *Information and communication technology (ICT) plays an essential role in supporting daily life in today's digital society. Used everywhere, ICT is now becoming essential to delivering better and more efficient healthcare services. Data come from several separate medical devices, from sensors located near the patient that provide environmental data, from electronic medical records stored by the hospital, from hospital administrative records, and from financial and healthcare resource management. There has been growing interest in multi-disciplinary research on multi-sensor, data-fusion technology, driven by its versatility and diverse areas of application. Therefore, there seems to be a real need for context-aware development in the data-fusion domain. However, different sensors may use different physical principles, cover different information space, and generate data in different formats at different update rates. Sensor-generated information may also have different resolution, accuracy, and reliability properties. Cooperation is vital because e-health systems must be secure and interoperable in order to foster collaboration among healthcare actors (professionals, organizations, patients, etc.). National and local policy-makers and stakeholders must cooperate in order to resolve the various associated legal, organizational and policy issues. In this proposal, we extend the event-driven approach based on interoperable and secure command-query responsibility segregation (CQRS) to define and implement event data based on a general publish-subscribe model. This allows evaluation based on sensor-fusion solutions for a wide range of context-aware computing applications.*

Key words: data fusion, healthcare, CQRS, domain-driven design, SOA.

1. Introduction

Correct decision-making is a major issue in Information Systems(IS). Within IS facilities thousands of decisions are made every day, timely availability of information is a crucial factor for improving the quality of decision making. However, increased cross-border mobility of people may make it difficult to get hold of appropriate information at the time of decision, as this information may reside on servers located in another institution, region or even in a different country. From the technological point of view, a major obstacle to timely deliver of information is lack of interoperability. In theory, IS are expected to operate in a fully interoperable manner with a high level of service for all stakeholders involved thanks to international standards for information representation and sharing. Thanks to the wireless sensor network, information coming from different sources is merged regularly to create a comprehensive data set, available to all IS delivery sites. Various applications of ICT concepts exist, including wirelessly networked tablet computers and notebook allowing clinicians to access patients' data while moving unhindered around a mobile medical unit. However, the management of data in this kind of systems is becoming increasingly complex. Frequently, decision makers (physicians or other professionals, medical services…) are confronted to inaccurate, incomplete or untimely information. Many examples suggest that these information quality problems are largely due to data-fusion issues that cannot be solved by data standardization alone. Performance of data fusion needs to be predictable and information about service levels should flow smoothly and accurately to all who need it. In other words, upper bounds must be guaranteed for fusion service levels.

Achieving certified non-functional properties for data fusion across organizational and state boundaries is by no means an easy task, and a major reworking of the architecture of current platforms is needed. Indeed, IS data may come from different devices, from sensors located near the patient that provide environmental data, from electronic medical records or administrative information stored by a remote application, and from different financial and resource management systems.

We claim that a radical re-thinking of the approach to data fusion can lead to more efficient, safer, and higher-quality distributed IS. This proposal is aimed at performing such a rethinking via a sound research methodology and provide some measurable pilots of its outcome.

In traditional data-fusion architectures, available operations are usually limited to Create Read Update and Delete which is commonly known as CRUD. No other verbs are available within the domain. When however one talks with domain experts it is extremely rare that one ends these four verbs are sufficient to express the desired functionalities.

When one looks at the healthcare architecture in the context of data exchange scaling one will quickly notice that there is a large bottle neck: the data storage. When using a RDBMS as this becomes even more of a problem, as most RDBMS are not horizontally scalable and vertically scaling very quickly becomes prohibitively expensive.

1.1 *Why our Framework*

A major problem of "CRUD" architectures is that the purpose of the user in accessing remote information can be easily lost. Because the client typically interacts by posting data-centric DTOs (Data Transfer Object) back and forth to healthcare servers, the domain often becomes a glorified abstraction of the underlying data model. The reason why a specific piece of information is needed exists only in the client, or worse in the heads of the user. Full proceedings are available from Maggioli Editore

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Daniela Micucci

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A Time-driven Approach to Sensing Systems

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A Time-driven Approach to Sensing Systems

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Abstract: *The concept of time is paramount in sensing systems. Surprisingly, this concept is seldom explicitly captured by programming-language constructs or by operating-system primitives. From the programmer's viewpoint, a system's temporal behavior can hardly be defined explicitly, because it is implicitly managed by relying on priority mechanisms and the like. Moreover, temporal behavior depends on hidden policies in the kernel, which are not visible to the application programmer and subject to change in different versions of the OS platform. Ultimately, the timing of sensing activities is somehow nondeterministic, as long as the software cannot define it deterministically. A set of architectural abstractions has been identified that raises time to the level of a first-class concept. It includes a collection of hierarchically organized virtual clocks, whose speed can be tuned at the application level. Atomic actions to be performed are arranged in timelines, whose advancement is driven by the virtual clocks. Therefore, temporal behavior is explicitly defined and can be dynamically controlled by tuning the speeds of the virtual clocks.*
Furthermore, temporal behavior can be observed and tested, even in an emulation environment. A prototype version of the platform was developed and tested for certain experimental applications.

Key words: real-time, time awareness, architectural abstractions

1. Introduction

Time is a key element in real-time systems, as their correctness depends on when activities are performed [1]. Key elements in specific application domains are usually captured and modeled by means of architectural abstractions [2]. In particular, the design of real-time systems should be supported by a set of architectural abstractions that model the temporal behavior of the system with concepts including time and speed. Surprisingly, time and speed seldom emerge as basic abstractions. The lack of such abstractions leads to the development of tricky code that heavily depends on platform mechanisms, intermixes design choices and implementation details, can hardly be tested and maintained.

Many recent developments focus on the representation and on the analysis of time-related issues. MARTE [3], for example, is a UML profile that adds capabilities to UML for the design of real-time and embedded systems. AADL [4] is an analysis and design language that not only allows a representation of the software architecture to be defined, but also the syntax and semantics, so that the representation can be verified and validated [5]. Both the approaches, however, only provide modeling capabilities but no embedded tools to directly implement the system. The same holds for [6], which exploits MARTE (the logical time concept) and the CCSL language (Clock Constraint Specification Language) [7] to specify the causal and temporal characteristics of the software as well as the hardware parts of the system.

Languages like Giotto [8] and SIGNAL [9] extend existing paradigms to include time-related issues. However, such issues are managed at compile time, preventing the system temporal behavior from being adaptive. Similar to Giotto, PTIDES (Programming Temporally Integrated Distributed Embedded Systems) [10] is a programming model for distributed embedded systems based on a global, consistent notion of time. Finally, [11] proposes a modular modeling methodology to specify the timing behavior of real-time distributed component-based applications. It allows building models of resources and of software components, which are reusable and independent from the applications that use them.

The key idea behind our proposal is that time should be a full-fledged first-class concept, which directly turns into basic architectural abstractions supported by a running machine [12]. The abstractions are reified by mechanisms that an application can directly exploit to dynamically adapt its own policies by relying on time-related knowledge both about the domain and its own behavior. According to the principle of separation of concerns, the abstractions capture three well distinguished concepts: *time drivenness*, *time consciousness* and *time observability*. A time driven activity is triggered by events that are assumed to model the flow of time (for example, it periodically samples incoming data). A time conscious activity reasons about facts placed in a temporal context, no matter when the computation is realized (for example, it performs offline statistics on timestamped historical data). A time observer activity observes “what time it is” (for example, it observes the current time to timestamp the generated data). A full-fledged time-aware system is a collection of components that perform activities that are time driven, time conscious, time observer and/or a combination of these.

2. Time-related abstractions

The properties of drivenness, consciousness and observability, which characterize a *time aware* system, can be enabled by means of three well distinguished concepts (architectural abstractions): *Timer*, *Clock* and *Timeline*.

2.1 Timer

A Timer is a cyclic source of events, all of the same type: two successive events define a *duration* (see **Error! Reference source not found.**). A timer generates events by means of its *emitEvent* operation, as shown in the state diagram of **Error! Reference source not found.** (left).

A *Virtual Timer* is a timer whose event generation is constrained by the behavior of its *reference* timer: it counts (by means of the *count* operation) the number of events it receives from its reference timer and generates an event when this number equals a predefined *value*. The duration is thus specialized to a *virtual duration*. This behavior is shown in the state diagram of **Error! Reference source not found.** (right).

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Techniques for Mapping Underwater Environments with Integrated Sensors

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Techniques for Mapping Underwater Environments with Integrated Sensors

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Abstract: In the context of developing autonomous vehicles to survey extreme environments, such as ocean seabeds, the demand for computer vision to support the on-board decision system is increasing. Our work aims to improve procedures for understanding the underwater scene. We propose a new method for processing multi-sensor data to i) create large scale maps, ii) recognize geometric patterns in the scene, iii) provide textural analysis of the seabed, iv) perform a 3D reconstruction of the scenario, and iv) perform robust object recognition and classification by integrating all the available data.

Keywords: Cultural Heritage Safeguard, Autonomous Underwater Vehicles, Automatic Vision System, Side-Scan Sonar, Geometric Feature Recognition, Image Segmentation, Image Classification, Multi-Sensor Data Integration

1. Introduction

This report will focus on multi-sensor mapping techniques as a support to underwater archaeology and cultural heritage preservation. The framework in which our activity may find application (Figure 1) will be introduced and some technical issues typically related to the main topic of the report will be analyzed. Data capturing and processing at different levels will be tackled, starting from low level signal processing to high level data analysis. Finally a preliminary model concerning the formalization of a data integration method will be introduced.

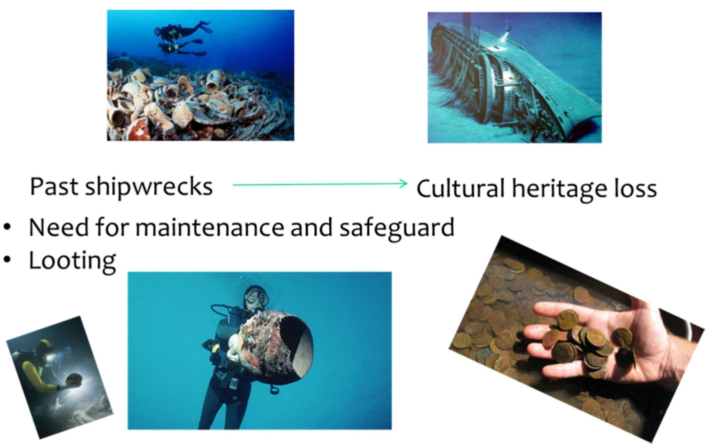

Figure 1. Activity framework overview.

1.1 Underwater Cultural Heritage

As known, seafloor areas host large amounts of cultural heritage as a consequence of past shipwrecks. Fast growth of technology represents a promising tool for rescue operations. This is true for both cultural authorities as well as for looters. That is why there is an urgent need for developing procedures of maintenance and safeguard of underwater sites.

1.2 Authorities Commitment

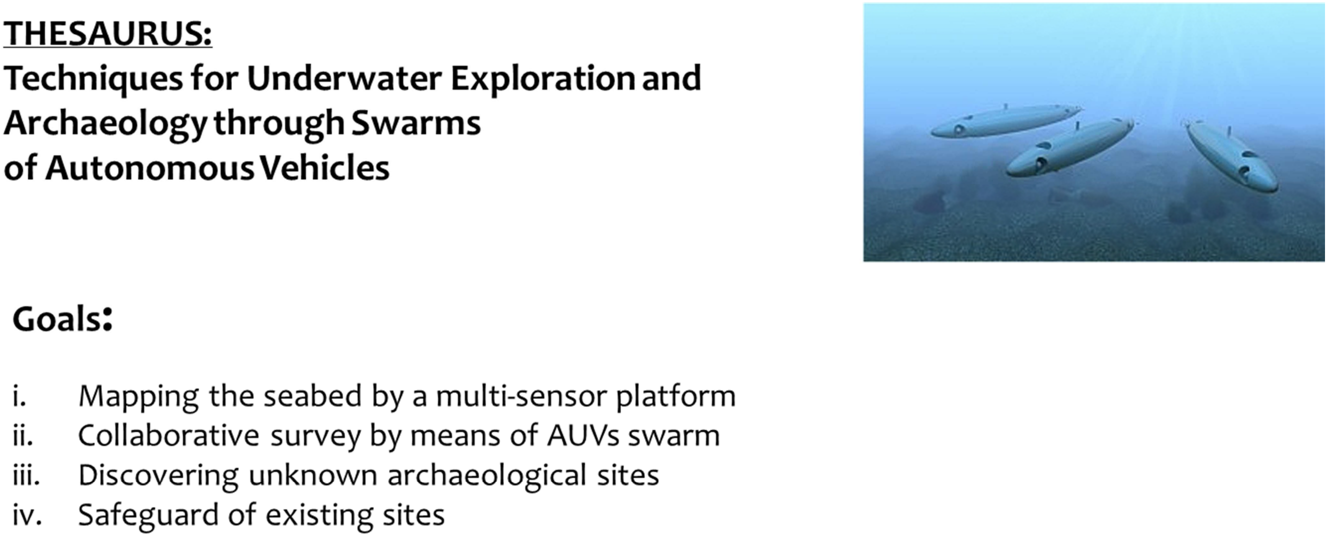

Figure 2. Thesaurus main goals

Authorities commit themselves by supporting scientific collaboration projects. For example the Signals and Images Laboratory (SI-Lab, ISTI CNR), together with other academic partners, is currently involved in a project called THESAURUS (Figure 2). Main goals of the project concern the development of appropriate multi-sensor platforms for the survey operations; these surveys will be performed by Autonomous Underwater Vehicles (AUVs) equipped with sensors. We expect that these sensors will be forced to work in non-optimal conditions due to the demanding environmental conditions, i.e. water turbidity, shallow or deep waters. Different kind of sensors will be used depending on the particular survey scenario.

Different vehicles will host different sensors and they will form together a survey troop. One of the ambitious targets of the project will be the development of algorithms that will introduce a cooperation behavior within the AUV swarm. Based on this strong sensory platform we are interested in the discovery of new underwater archaeological sites and in safeguarding them.

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Localizing and Identifying Audio or Voice Sources with a MEMS Microphone Array

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Localizing and Identifying Audio or Voice Sources with a MEMS Microphone Array

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Abstract: In the last decade, interaction between humans and electronic device by means of spoken language and audio signals has grown more and more important in everyday's life. Different capabilities have to be exploited by the device itself to achieve the best performances in this field, like audio localization, automatic speech recognition, speaker identification, and so on. In this paper we focus on both the algorithms adopted to gain these results and the hardware architecture that will enable the embedding of the whole application: the MEMS microphone array.

Key words: localization, speech recognition, identification, MEMS microphones

1. Introduction

Localizing and identifying sources are key preprocessing functions for audio and voice-signal capture and processing in noise-sensitive applications, such as automatic speech recognition, audio pattern recognition and speaker recognition and identification, among others. Audio localization with microphone arrays has received significant research attention from the scientific and industrial research and development community, especially since the availability of microphone arrays based on micro-electrical mechanical systems (MEMS) [1][2].

An embedded implementation of localization, automatic speech recognition, and automatic speaker identification is under development using a MEMS-based microphone-array subsystem. Recognizing and locating sounds is fundamental to the human to recognize who is speaking and to turn one's head so that visual information of that speaker can be obtained.

Audio-source localization is a key function to improve the performance of an automatic speech- and speaker-recognition system. Microphone array can capture sounds coming from different directions and an algorithm can steer them to amplify the sound signal captured in a direction and attenuate the signal captured in a different direction, acting like a smart single microphone.

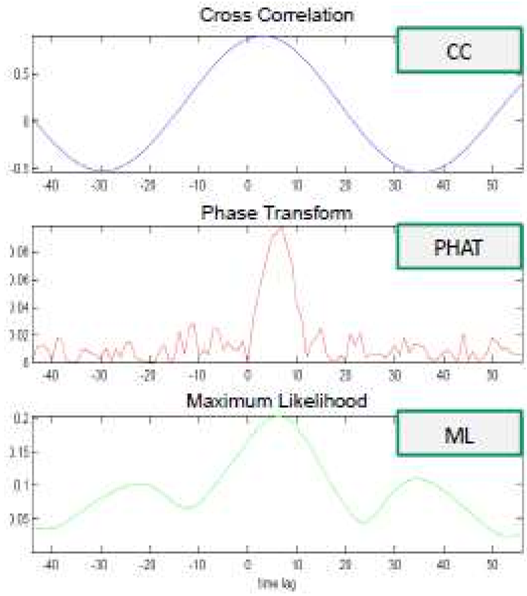

Figure 1. Audio source localization is based on a combination of cross-correlation (CC) and Phase Transform (PHAT) and Maximum Likelyhood (ML) processing of the microphone audio sources.

2. System Framework

The whole system consists of an audio source direction measurement subsystem based on the microphone array and running three different methods for direction of arrival estimation, a data fusion subsystem to infer about direction, an automatic speech recognition subsystem, and an automatic speaker identification subsystem. The direction of arrival is used by the automatic speech recognition subsystem to enhance the primary voice source and attenuate all other audio sources surrounding the primary one. Then some keywords are recognized and the related features used to match the identity of the speaker.

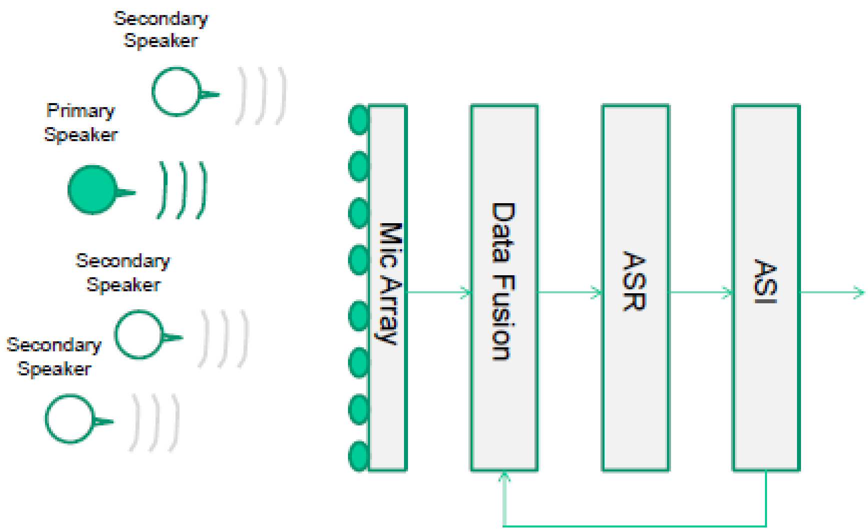

Figure 2. System framework.

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Massimo Magrini

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Multi-sensor Signal Acquisition, Processing and Data Fusion

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Multi-sensor Signal Acquisition, Processing and Data Fusion

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Abstract: *The paper describes the basic hardware of the multi-channel acquisition chains typically used in many applications, along with some strategies added to process incoming multi-sources information. Several commercially available conventional platforms are characterized by high flexibility and are mainly used as references in industrial, military fields etc. however, many other civil applications, such as consumer or research projects, may require more flexible or innovative solutions. In general, row data from the sensors require analog or digital pre-processing, for instance to correct for noise, distortion or artifacts found in the signals during acquisition. The evolution of electronic technology often allows acquisition-chain functions to be integrated in a single device. Data management and analysis depend on the specific application and can be carried out by classic, well-known techniques or other special innovative methods, such as data-fusion strategies, based on logical concepts and cognitive models, using fuzzy logic, etc. Examples of the seminar topics also include recent and ongoing projects at ISTI-CNR Labs.*

Key words: sensors, analog front-end, signal processing, data fusion.

1. Summary

It is well known that in order to optimize the study of physical events or to automate the control of almost all practical processes, suitable electronic systems must be adopted. Many hardware devices arrangement and software packets are used to implement the required operations and they are usually represented by a sequence of linked functional blocks, that is a signal acquisition-processing chain model as in Figure 1.

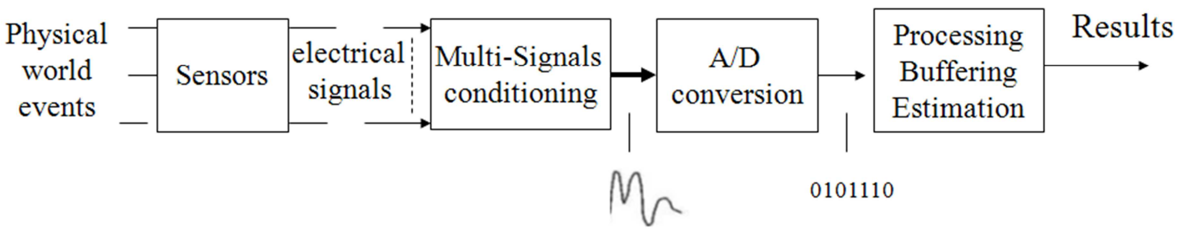

Figure 1. Typical acquisition chain block diagram.

This paper is a revised version of a webinar presentation [1] and deals with a very broad and pervasive subjects, so we are only able to describe a little more than an introduction to the main involved topics. A concise index of the presentation content is the following:

- Brief historical notes on signals processing technology
- Multi-sensors acquisition & processing chain blocks description
- Data processing and results estimation strategies
- Some example of solutions and applications

1.1 Foreword: acquisition chain technology evolution

Before the invention of digital computers, signal processing was performed by analog technology. The typical components are operational amplifiers (Op-amp) performing functions such as derivatives, integrals, adders etc. managing analog signals in the "Time Domain". Results were obtained with much difficulty, especially when many correlated signals had to be observed and studied at the same time. For example patient EEG and ECG recordings were directly plotted on paper and their evaluation depended greatly on the physician's skills.

The invention of digital computers made the automatic numerical acquisition and processing of physical variables possible from the 1960s onward. A few years later digital techniques were exploited for signal treatment obtaining better results in many applications compared to the analog modalities.

As in Figure 1, a typical acquisition chain manages electrical signals incoming from sensors and performs adequate conditioning (amplitude, frequency), usually by analog devices. Suitable analog-to-digital (A/D) converters transform analog signals into digital sequences. These digital samples can be pre-processed directly by a digital signal section in embedded solutions, usually a DSP, FPGA, etc. Other complex operations and estimations can be performed on a host computer (personal computer, supervisor station, etc.)

Digital processing of multi-sensor signals can be implemented in various solutions, so it is impossible to describe it exhaustively. We only offer a general description and some examples of industrial and civil applications, beginning with an old system developed and tested in our laboratory.

1.2 Historical notes on signal processing in our labs

The CSCE (Centro Studi Calcolatrici Elettroniche, 1955) was a research Consortium founded with the aim of designing and building an innovative scientific digital computer (CEP, Calcolatrice Elettronica Pisana,1955-1961), in operation until 1967 [2].

Transistor devices became widely available in the 1960s; thus many projects in the biomedical field were launched at CSCE, creating some analog-digital machines with "discrete" components for multichannel acquisition and pre-processing: collected data were processed afterward on the general-purpose calculators of that time, in our case the CEP itself.

Afterward the design in Italy of the first self-synchronizing pacemaker (1966, [3]) at CSCE, then called IEI-CNR (Istituto Elaborazione Informazioni) was created a bioengineering team mainly working in collaboration with the Neurology Institute of the University of Pisa. Later the bioengineering research team changed its name to the current S&ILab "Signal&Image Lab". In 2000 all 16 CNR Institutes, formerly scattered throughout Pisa, moved to a research campus, in the Pisa suburbs.

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Meta-instruments: the Musician-machine Interface and Gesture Sensing for Real-time Algorithm Control

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Meta-instruments: the Musician-machine Interface and Gesture Sensing for Real-time Algorithm Control

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Abstract: *The meta-instrument is the paradigm that will enable a new generation of musical instruments and interaction tools between the musician and the machine. New sensing technologies have been applied to implement instruments that allow us to hear gestures by driving the algorithms that produce sounds and control musical performance.*

Key words: Meta-instrument, sensing technologies, musician-to-machine interface

1. Introduction

The meta-instrument is a new paradigm that will enable a new generation of musical instruments and new interaction tools, between the musician and the machine. New sensing technologies have been applied, to implement instruments that allow us to hear gestures, by driving the algorithms that produce sounds and control musical performance [1][2][3].

A performer and a musical instrument form a multisensory (auditory, visual, tactile, physical, and physiological) feedback-based system. It is very similar to an automatic control system: the performer acts on the instrument by means of an appropriate gestures, then the instrument generates a set of sounds accordingly. Thanks to the multi-sensory feedback, the performer is able to modify the gestures, to comply with his performance needs.

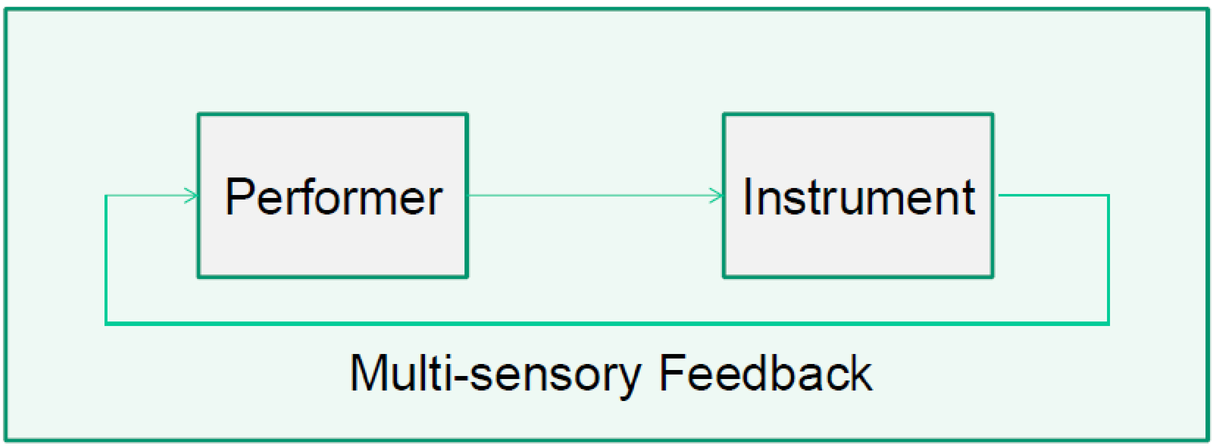

Figure 1. A performer and a musical instrument form a multisensory (auditory, visual, tactile, physical, and physiological) feedback-based system.

The meta-instrument can be considered an evolution of the traditional instrument. It allows the performer to completely control the instrument, using natural gestural interface, so that training is not required. Because the meta-instrument is computer-based, there is no limitation on interaction between the performer and the instrument. The instrument can be functionally equivalent to a traditional instrument or a new traditional-type instrument or an electronic abstract instrument.

Traditional instruments		Meta-instruments
✓ Pitch control (full)	VS	✓ Pitch control (extended)
✓ Dynamic control (full)		✓ Dynamic control (full)
✓ Timing control (not full)		✓ Timing control (full)
✓ Timbre control(Very limited)		✓ Timbre control(unlimited)
✓ Needed very intensive training		✓ Training is not mandatory

Figure 2. The Meta-instrument can be considered an evolution of the traditional instrument.

The meta-instrument, has the same feedback-base system architecture, but, the instrument, and the performer to instrument interface, are virtual. These, are model-based and computer-based simulated natural, or artificial instrument and interface, that enable a full control of the performance, and a free play of any score.

The computer is a generalized processing system (a hard-computing or a soft-computing paradigm) capable of real-time performance, so that, the traditional instruments are a subset of all the possible instruments that can be implemented.

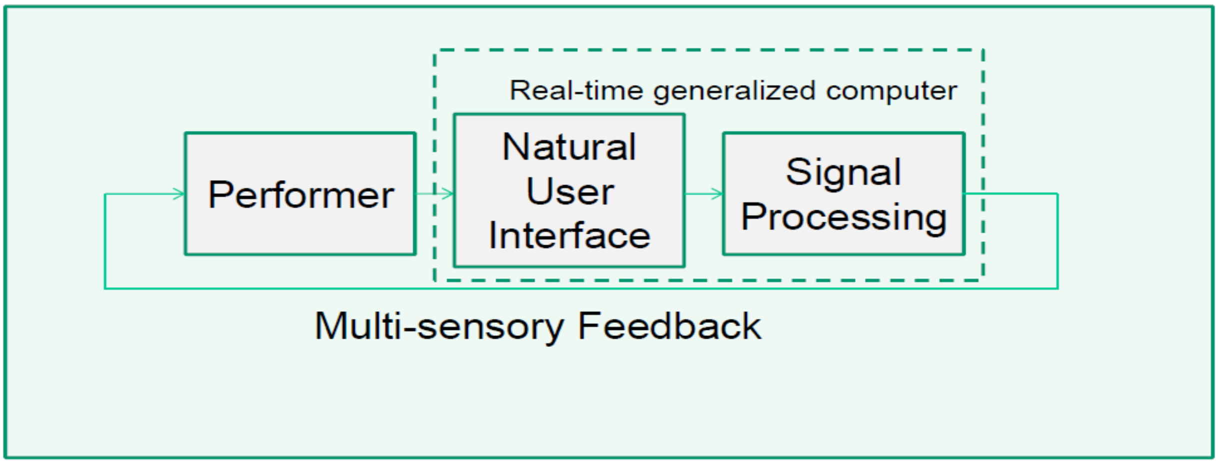

Figure 3. The computer is a generalized processing system capable of real-time performance: the traditional instruments are a subset of all the possible instruments that can be implemented.

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The Metapiano and Instant Interpretation of Musical Scores

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The Metapiano and Instant Interpretation of Musical Scores

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Abstract: The metapiano is concentrated in only nine piano keys. It can be played with a few fingers, or even with one finger. As its name underlines, the metapiano goes beyond traditional instruments, because it stores the notes that will be performed by the musician. In practice, the music is analyzed in terms of its melodic, harmonic, and contrapuntal relations. Only the pitches of the notes and their relations are codified and stored digitally, according to the rules of Pianotechnie. This musical structure can be set in music and sound by playing the restrictive number of keys of the metapiano. The musician, who knows the musical score, applies rhythms, tempo, articulations, accents, dynamics, and agogic phrasings to this structure, and interprets the music with his own style. An unusually short time takes place between the "notage", i.e., the coding of the score and its immediate interpretation on the metapiano. To interpret a musical score without going through the usual long learning phase proposes to reverse the questions of "what" and "how". This inversion leads the musician to immediately consider various possible interpretations of a given musical piece and to produce them instantly.

Key words: keyboard, key, piano, finger, interpretation, notage, coding, Metapiano, Pianotechnie.

1. Genesis of an instrument

Our research has focused on finding the performance minimal conditions to control the expression and the interpretation of a musical score. To this aim, we have explored the possibilities offered by a very common interface: the key of a piano [8]. Historically, the keyboard represents the most efficient device to reach the maximum possibilities of controls with the simplest access: the key. Compared to voices, wind or string instruments, on which sound is to be controlled continuously, the key of a keyboard has only two instants of control, the moment of depression, and the moment of release. On the piano, the possibility of varying the intensity of attack is the third actor for control. Moment of depression, moment of release, and instantaneous intensity are the only few play settings necessary to create, execute and interpret a musical piece.

This deserves to take a closer look. On a score a figure of note is printed in a single place, focusing symbolically the beginning, duration and ending of a sound. This notation positions only the beginning of the note. The duration and end of the note are not represented graphically. We know when a note starts; we have to think when it stops (Figure 1). Thus, the usual notation does not treat equally the start and the end of a note. This may explain the overwhelming attention given to the attack of a sound and the lack of attention to how this sound finishes. If many pedagogical works and piano methods focused on how to attack a note, a very few emphasize the achievement of its stop. About this we will quote a controversial formula that E. Bernard made in 1918: “It's not how you press a piano key that can affect the quality of the production... the beauty of sound depends only on how the sound continues to be heard. So it is the damper and not the hammer vested in this role [3].” Such a reversal of roles leads to further examine the play of a note on a piano.

1.1 An instant play mode

To play a note means browse through the cycle made of the three phases linking depression, sustain, and release of the key. This cycle acts on the underlying piano action [6]. During the depression, the hammer approaches the string, hits it and leaves it vibrate; during the release, the damper absorbs the vibrations of the string and the resonance of the soundboard. Two instant finger actions successively put into play two independent parts of the piano action, the hammer mechanism and the damper mechanism. Both devices covered with the same material, the felt, generate two opposing actions: the vibration and the damping of the sound.

1.2 Key stroke

The gestural intensity is transmitted to the sound; it is a specific parameter of the piano playing. The intensity can be expressed (in the artistic and technical meanings) only during the key depression, that is to say, in a moment. This is why the attention given to the attack of a note in the piano playing is leading. Anticipating, and pre-hearing what will be expressed during the key press is a necessity. After it is too late to revise: the player has successfully reached the good sound level or missed it. The intensity mastery results from a lifelong learning linking gestural energy and sound intensity. The player develops a memory of that couple gesture/intensity in close relation with the piano action on which he works, and with the intensity of sound produced. This is the touch sensitive component that is unique to each piano and pianist.

1.3 Key sustain

The note, once issued according to a desired time and intensity, can only decrease. It evolves towards extinction when the key is maintained depressed. No action is possible on the irreparable decay of the sound, other than an attentive listening to its disappearance. When the key is released, the damper accelerates the natural muting of the vibrations to silence. The moment chosen to damp a sound is not indifferent as it can occur at any levels of decay. This decrease is directly related not only to the pitch of the note but also to its intensity. Low-pitch sounds have a very long decreasing while the treble ones spontaneously decay very quickly. Similarly, for any pitch, the greater is the intensity of the attack, the longer is the decay. In playing and listening to the sustaining of a piano note we can perceive its degradation following two perspectives: how long or short it is depending on the intensity of the attack; how slow or fast it is, according to its pitch in the note range.

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