A Complex Non–Contact Bio–Instrumental System

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INTRODUCTION

One of the major challenges that the human computer interface (HCI) faces nowadays is that of identifying a subject's state, in a real world environment, characterized mainly by its being: open-recorded, event-elicited, and internal *emotional state*-driven (Picard, Vyzas, & Healey , 2001). The main requirement for such system regards the noninvasive character of their working principle.

Subsequently, in order to improve communication in HCI systems or to asses the human state, the analysis of the *body language* could be a solution. Thus, a "sensitive computer" could use the body movements and the positions of the body in order to assess the state of a person (e.g., confusion, illness, nervousness, lack of attention, motor fatigue, agitation, etc.).

In the rehabilitation process, the measurements of the motion impairments are very important because they can quantify the patient's recovering between two consecutive medical sessions. Nowadays, this type of motion analysis is achieved by physicians through visual observation of the patient during some standard tests. As a result, the physician subjectivism is introduced and, much more, when different physicians evaluate the same patient, the reproducibility of the measurements becomes a difficult task.

To respond to the previously presented requirements in different application fields, a noncontact laser system was introduced by the authors (Cracan, Teodoru, & Dobrea, 2005; Dobrea, 2002; Dobrea, Cracan & Teodoru, 2005; Dobrea & Serban, 2005). Here, we present the implementation of an independent system constructed as a self-contained unit that can be further integrated in much more complex and intelligent structures, together with new possible applications.

This article proposes a new real-time, noncontact system able to:

- Acquire and interpret the subject's *body language*,
- Recognize static *hand signs*, and
- Provide physicians with a quantitative tool to monitor the evolution of the *Parkinson Disease.*

BACKGROUND

The proposed bio-instrumental system (BIS) was designed to be used in the medical field, in applications such as: rehabilitation, functional movement analysis, evaluation of the cognitive deficits, or motion and support offered to the vocally impaired subjects.

Nowadays, in order to evaluate and assess the severity of *Parkinson's Disease*, physicians use different rating scales. The method used to assess *Parkinson's Disease* is based on a questionnaire : Unified Parkinson's Disease Rating Scale, (MDSTF, 2003). The most important disadvantage of the rating scales is the lack of results reproducibility. Different physicians obtain different results on the same patient due to different medical experience and the possibility to observe, at one moment, only one cross-section of the patient. The BIS presented in this article will be used in the quantitative analysis of the head tremor movements. Even if, for this application, other methods exist to acquire the movement, based on accelerometer sensors (Keijsers, Horstink, & Gielen, 2003), optical data flow, and gyroscope (Mayagoitia, Nene, & Veltink, 2002), no method has imposed yet as a standard.

Recognition of the *hand signs* is a challenging task for the nowadays systems and it is very important for the vocally impaired people. Even if the research in this field fade in time, the first large recognized device for identifying the *hand signs* was developed by Dr. G. Grimes (1983) at AT&T Bell Labs. This device was created for "alpha-numeric" characters communication

by examining hand positions like an alternative tool to keyboards; it was also proved to be effective as a tool for allowing nonvocal users to "finger-spell" words and phrases. In order to understand the *hand signs* language the hand gesture must be acquired. Mainly, the *hand signs* are acquired using video cameras (Cui & Wenig, 1999; Ho, Yamada, & Umetani, 2005) or some devices that directly determine the position of the hand parts (such as gloves) (Hernandez-Rebollar, Kyriakopoulos, & Lindeman, 2004).

There are strong relations between psychological states and the body movements, confirmed by the theories of Kestenberg-Amighi, Loman, Lewis, and Sossin (1999) and Hunt (1968) or by the analyses realized in the field of the *body language* investigation (Pease, 1992). Moreover, these relationships make the subject of the somatic theory. The health care efficiency in the activity related to the human-computer interaction is directly dependent on both the subject's state and the capability of the health care systems to recognize the specific needs of the user in order to change their response accordingly. Unfortunately, acquiring and interpreting this kind of information is very difficult and, as a consequence, all the actual systems have only a limited ability of communication. Current strategies for user's *emotional state* acquisition are either obtrusive (Picard et al., 2001) or the data captured by the systems consist in low level useful information.

A NEW TYPE OF NONCONTACT BIO-INSTRUMENTAL SYSTEM

The new proposed BIS was designed to determine, in a fast way and without any physical contact with the subject, the movements, the position, and the distance to an observation point. Using this information, the physiological and *emotional states* of the subject are estimated.

System's Architecture. Working Principle

The BIS is composed of a laser scanner, an interface unit, a video camera, and a software program, running on a DSP platform that controls the scanner, acquires the images, and extracts the distance/position information, as in section a of Figure 1. The BIS schematics and the system data flow are presented in section b of Figure 1.

The working principle of the whole system is based on a laser scanner that generates a laser plane at a constant angle from the horizontal plane. When the laser plane hits a target in the imaged area, a line of laser light appears on the body of the subject. See Figure 2 – Img_{t+1} image. The video camera acquires two images: first, with the laser diode off, Img_t, and second, with the laser diode on, with a line of laser light that appears on the target, Img_{t+1}. Subtracting the two images we get only the laser line projected on the people's torso, *OutImg* – Figure 2. In the ideal situation, all pixels for which $Img_{t+1}(x, y) \neq Img_t(x, y)$ describe the laser line which appears on the user's body torso. In real cases, the images are corrupted by noise. This problem was solved using an experimentally obtained noise model, σ. The criterion to extract the line of the laser light becomes now: $Img_{t+1}(x, y)–Img_t(x, y)>\sigma$. Other problems, such as shadows, slight body subject movements, light sources, video camera saturation, and background changes do not affect the reliability of the laser line feature extraction. This is happening because the time interval between the two images acquisition is less than 40 ms and the noise model presented above have been proven to be adequate. Based on this operating principle, the extraction of the laser line becomes a very fast task—a major advantage of this system.

If the object is far away, the extracted laser line will be farther from the bottom of the image, h_1. In the opposite situation, it will be closer to the bottom part of the resulting image, h_2. At this point, one knows the angle between the laser scanner and the horizontal plane, the position in space of the video camera and the extracted shape of the laser line on the subject body. The depth information of each point on the extracted laser line is calculated using some basic geometric formulae. Further on, having all these values, we exactly determine the real 3D subject body position with respect to the camera.

The hardware system has two components: the electro-mechanical scanner and the DSP system. The scanner has a low-power laser diode and a mechanical system with mirrors, section a of Figure 1 (Dobrea, 2002). The plate with mirrors is attached to an engine shaft. The DSP system interfaces with the engine control system only through a single digital line that can start/stop the engine.

Since this application deals with images and all these type of applications are considered data and computing-intensive, the TMS320C6416 DSP was chosen due

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