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Optical mouse acting as biospeckle sensor

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ABSTRACT

In this work we propose some experiments with the use of optical computer mouse, associated to low cost lasers that can be used to perform several measurements with applications in industry and in human health monitoring. The mouse was used to grab the movements produced by speckle pattern changes and to get information through the adaptation of its structure. We measured displacements in wood samples under strain, variations of the diameter of an artery due to heart beat and, through a hardware simulation, the movement of an eye, an experiment that could be of low cost help for communication to severely handicapped motor patients. Those measurements were done in spite of the fact that the CCD sensor of the mice is monolithically included into an integrated circuit so that the raw image cannot be accessed. If, as was the case with primitive optical mouse, that signal could be accessed, the quality and usefulness of the measurements could be significantly increased. As it was not possible, a webcam sensor was used for measuring the drying of paint, a standard phenomenon for testing biospeckle techniques, in order to prove the usefulness of the mouse design. The results showed that the use of the mouse associated to a laser pointer could be the way to get metrological information from many phenomena involving the whole field spatial displacement, as well as the use of the mouse as in its prime version allowed to get images of the speckle patterns and to analyze them.

1. Introduction

The optical computer mouse has been used in several applications beyond its traditional use in computers [1]. The first mouses had in their internal structure two main integrated circuits, such as the Complementary Metal Oxide Semiconductor (CMOS), which was used for image acquisition, and the Digital Signal Processor (DSP), which was responsible for the image processing and to generate the signal related to the mouse movement to the computer [2]. The new generation of mouses has the two devices compacted into one single integrated circuit, thus restricting the possibility to access the images before their processing, which was possible when the components were split. In this way, the alternative applications of the mouses have been concerned with the cursor position, related to the movement of particles [3] and objects, as well as in roughness analysis [4], in monitoring deformation [5], and in monitoring oscillations and vibrations [6,7]. The use of the optical mouse in its original design presents some limitations such as the distance between the device and the mouse pad or table, which is about 1.25 mm [7]. This limitation, however, can be circumvented if, for example, the LED inside the mouse is disabled and an external source of light adopted, in particular a laser, which can enlarge the distance to 300 mm [1]. Despite the barrier offered by the new configuration of the mouse, its anatomic design and as the accessible low price are some reasons to the search for alternatives to still use the mouse as an instrument of image acquiring. The optical mouse, or mice, as called by some researchers, inspired the construction of prototypes to monitor surfaces, and in particular to get images from them in order to evaluate their roughness [8]. One limitation observed in the prime optical mouse was related to its use on reflective surfaces, which was solved by the changing of the light source in the mouse. An infrared laser was therefore adopted in commercial mouses, and the image analyzed by the DSP was the speckle pattern generated upon the surface and its changes [9]. The changes in the interference speckle pattern [10] can be linked to many phenomena, and therefore the dynamic speckle presented as a reliable way to measure the activity in biological and non-biological samples [11]; the use of the mouse associated with the laser light became then an alternative instrument. In addition it was proved that the reduction of the data does not compromise the dynamic speckle analysis [12], which unfolds the use of alternative apparatus. This work aims to analyze the feasibility to use the optical mouse associated with a laser light source as an instrument to monitor biological and non-biological phenomena

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through the movement observation and by the fitting of an external camera or an external source of light.

2. Materials and methods

2.1. Measure of displacement

We adopted an optical mouse with a CMOS of 800 DPI, with a USB connection, and with the internal LED disabled; the external laser set was a solid state of 635 nm and 5 mW. The Cartesians coordinates of the cursor position on the screen were detected and stored at a rate of 100 coordinates per second by specifically designed software. We conducted three experiments of displacements to analyze the feasibility of using the mouse as a sensor. One experiment was the measurement of the local displacement of a wood bar under deformation due to a strain process, monitoring the displacement in a plane, the second experiment was related to the movement of the skin due to the change of the diameter of an arm radial artery caused by heart beating, in a movement perpendicular to the plane of observation, producing a change of the speckle pattern, and the last was the monitoring of the off centered rotation of a sphere simulating an artificial eye.

2.2. Wood movement

Fig. 1 presents the experimental configuration related to the measurement of the local displacement of a wood bar supported in the ends caused by an increasing controlled load in its center. The aim was to monitor the translational movement of a point in the center of the wood bar where the load was applied till rupture. The distance between the mouse and the wood sample was of 100 mm.

2.3. Skin displacement

The monitoring of the change in the diameter of a radial artery, due to heart beating, by means of the displacement of the skin, was conducted in accordance with the set up shown in Fig. 2. The light beam from the laser was directed to the skin over the radial artery of the arm at rest over an antivibration surface. A (minimally intrusive) small paper sticker slightly glued to the skin produced the speckle pattern and simultaneously prevented the interference of the biospeckle due to blood flow. The distance between the paper diffuser and the mouse was 70 mm. The displacement of the skin moving as a rigid body during the expansion and contraction of the artery was responsible for the displacement as a whole of the speckle pattern in the sensor.

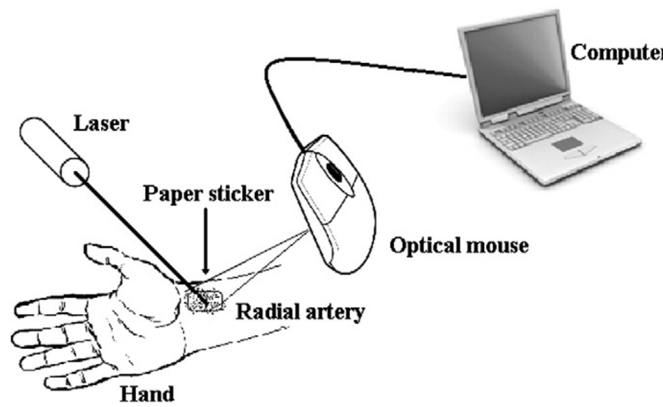

Fig. 2. Experimental configuration related to the skin displacement caused by heart beating.

2.4. Movement of an artificial eye

An artificial eye was simulated using a steel sphere of 40 mm of radius positioned slightly off the center of a goniometer. The mouse was positioned at a distance of 90 mm of the central point of the sphere, as presented in Fig. 3, and the laser illuminated the surface through a ground glass diffuser. The goniometer was rotated at 6° from the right to the left side, passing by the center, and back, covering an angle of 6° in the goniometer.

2.5. Image acquiring using an adapted webcam

For the following experiment we used a commercial webcam in place of the CCD array of the mouse and fitted it into its housing. A solid state laser (8 mW with 635 nm) and a CCD of a webcam (Robot Cam K-Mex AW-R2035, Color CMOS Image with 350 K pixel, JPG/BMP image format, AVI video, resolution of 640×480 pixels, and communication of USB 1.1) were located in the place of the LED and the CMOS respectively (Fig. 4). The time rate of the frames acquisition was of 10 fps. The image measurement was carried out over a well known experiment concerned with the paint drying process under biospeckle analysis [13]. We made 9 observations in an interval of 15 min between each observation after 10 min of initiation of the drying of the painting process on a coin. During all the process the

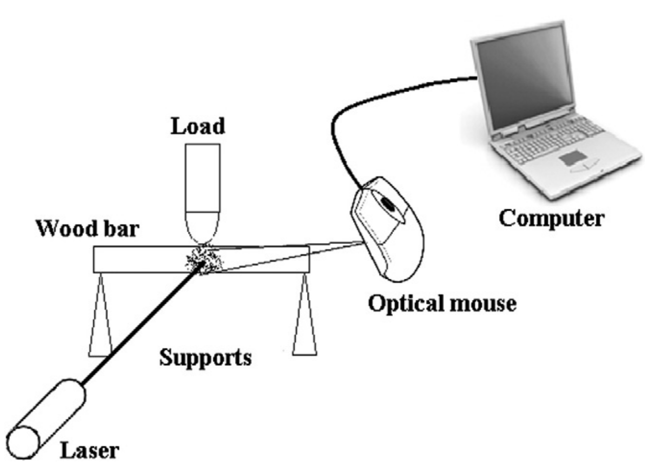

Fig. 1. Experimental configuration related to the displacement of a wood bar caused by a controlled load.

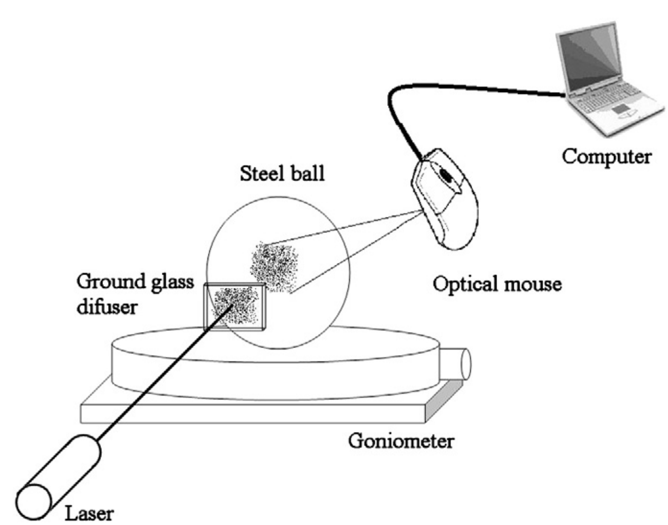

Fig. 3. Experimental configuration related to the artificial eye movement caused by horizontal rotation of a goniometer.

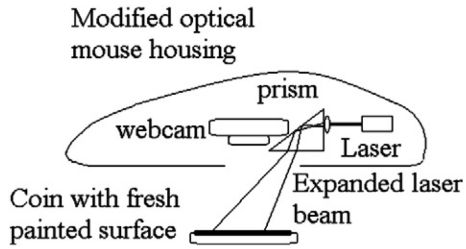

Fig. 4. Experimental configuration related to the mouse adaptation to acquire images from a laser.

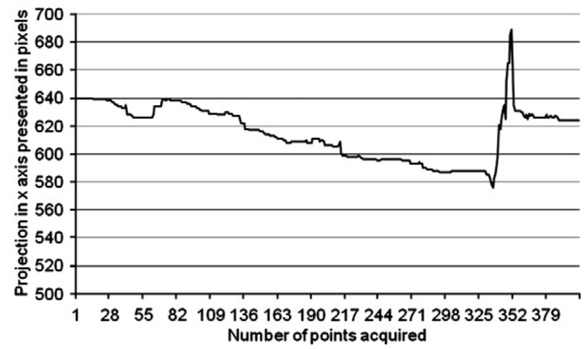

Fig. 6. Projection of the mouse's cursor path during the wood deformation in the *x* axis.

coin was placed over a plate of a laboratory scale with precision of 0.01 g. The images (128 in each observation) were processed by the Inertia Moment technique [14].

3. Results and discussions

3.1. Displacement in wood deformation

The controlled deformation of a wood bar was monitored by a mouse. The cursor path can be seen in Fig. 5. The path itself does not present any useful information, in turn the projections of the path in the coordinates *x* and *y* are shown in Figs. 6 and 7, respectively. The projection in Fig. 6 is related to the *x* coordinate and should not represent any information, since the main displacement was conducted in the *y* coordinate. The projection in the *x* coordinate was mainly a straight line as expected, however the non-desired results are attributed to the mechanical displacements out of the observation plane. In Fig. 7, the projection in *y* coordinate presents the information about the continuous deformation applied to the wood in the vertical direction which varied from 0 to 17 mm. The abrupt change in the end of the deformation is related to the crack of the wood. This well controlled experiment was considered as a preliminary procedure to adjust the system, mouse and external laser, and to validate it to the application in more complex approaches.

3.2. Variation of diameter in the radial artery

The measurement of the diameter variation in the radial artery showed much more than the ability to monitor the pulse rhythm, it was possible to recognize in the signal the characteristic profiles that are important features in medicine. As sustained by Rourke [15] 'arterial pulse is the most fundamental sign in clinical medicine'. This reference contains an important review of many reasons to show its relevance. It is traditionally measured through applanation tonometry, an intrusive practical technique requiring pressure to be applied to the artery against the bone that only detects the extremes of the pulse. The diameter variation of the radial artery (ADV) has been proposed as a measure of several significant parameters of the arterial pulse [16] and a capacitive instrument proposed for its measurement. Hypertension, arteriosclerosis (no to be confounded with atherosclerosis), heart failure, effects of drugs, artery stiffening and degeneration with ageing are between several non symptomatic precursors, leading to high mortality rates in occidental hemisphere that are highly correlated to the artery parameters [16]. Their praecox detection is then of the most importance for clinical treatment. So, a cheap instrument that could screen the conditions of the arterial system and induce further clinical diagnosis if required could be of interest in medicine. In Fig. 8 it is possible to observe the path of the mouse cursor on the screen during one monitoring of the speckle changes following the skin movement. In Fig. 9 it is possible to see its projection in the *y* coordinate where it is possible to observe 16 periods, which means 1.14 Hz per period since the acquiring process was working in the 100 Hz. The transformation of the 1.14 Hz in beats per minute (the common way to measure the heart beating) resulted in 69 beats per minute, which is expected to a human being [17], and close to the obtained in another experiment using the biospeckle laser

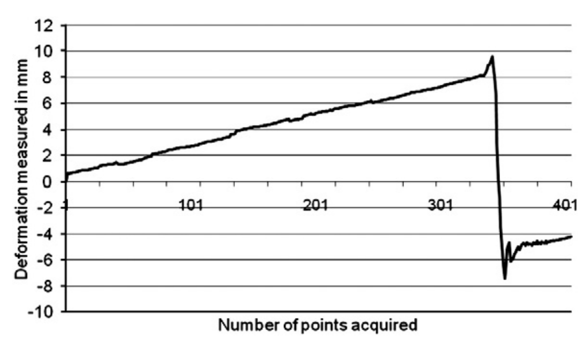

Fig. 7. Projection of the mouse's cursor path during the wood deformation in the *y* axis.

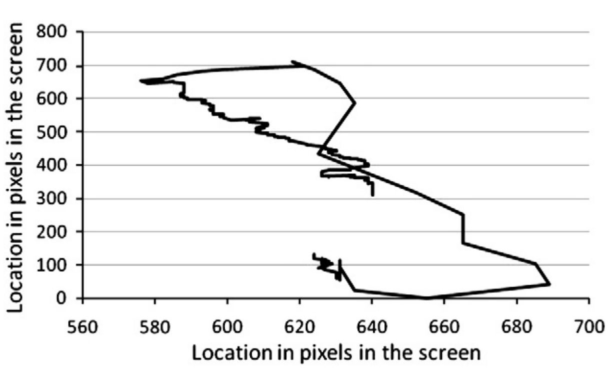

Fig. 5. Path of the mouse cursor during the wood deformation.

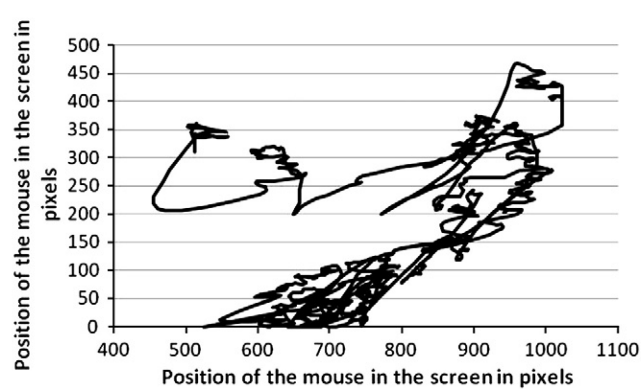

Fig. 8. Path of the mouse cursor during the skin movement.

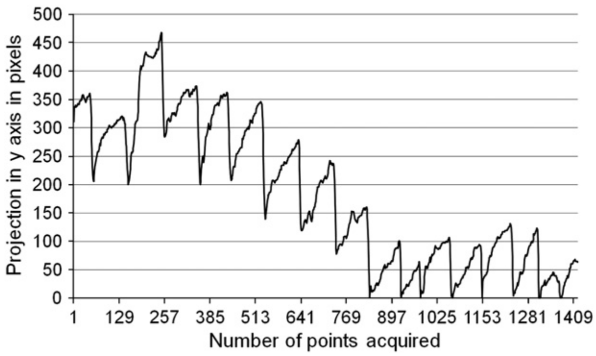

Fig. 9. Projection of the mouse's cursor path during the skin movement in the *y* axis.

[18]. It is possible to see in Fig. 10 that some repetitive patterns are present [15,18], and notice that they were selected in Fig. 11a, where the pulse shape can be recognized. A number (8) of the profiles were averaged, as is the case with the traditional measuring techniques [15]. Averaging helped to improve the quality of the profile and diminish the kinking effect of random involuntary movements. All the profiles were processed in the same way and their maxima were made to coincide by adjusting the abscissas. The pulse, with the highest standard deviation, was discarded and the average calculated again without it. The resulting averaged profile, presented in Fig. 11b, is very similar to the diameter variations shown in the literature in Fig. 11c [16]. The main features that are to be expected in the averaged profile, are the systolic wave, the reflected systolic wave and the diastolic wave which can be easily identified. It could be expected that if access to the non-processed signal of the mouse detector, faster and much more precise measurements could be done by using the correlation techniques [19]. In addition, it can be observed that the small paper sticker used here was, comparatively, minimally intrusive or invasive, and should not affect or damp the signal.

3.3. Movement of an artificial eye

In Fig. 12 it is possible to observe the projection of the *y* coordinate of the cursor related to the movement of the artificial eye from one side to another, rotating about 6°, 3° from the right to 3° to the left side, passing by the frontal observation. It can be shown that an angular movement of a slightly off centered sphere introduces an additional optical path to the scattered light corresponding to a linear phase delay in the observation plane. Its effect is to displace the far field speckle on the mouse detector by a sensitive rotation providing an excursion covering quite the whole screen. That amplification allows to the user a small effort to change the position of the cursor. Despite the noise expected considering the illumination of the actual eye caused by the biospeckle in the tears, microcirculation and micro-tremors [20], it was possible to see that the artificial eye can move the cursor while the eye moves in the horizontal way, which can be expected if there is motion of the eye in any direction. Even the use holding it in a hand produces some distortion in the path and the position of the mouse. The hazard to the eye related to the direct illumination of a beam can also be avoided also with the use of a non-collimated laser, creating to the eye the same effect as would the natural light. The maximum permissible exposure MPE related to laser illumination is restricted to collimated beams. In turn, with the diffuser, between the laser and the illuminated object, the risk of damage to the eye would be diminished, which should be carefully evaluated before intending an experiment with a person.

3.4. Paint drying

The monitoring of the paint drying process was conducted by the collection of the dynamic speckle images in the illuminated coin with a layer of paint. The speckle patterns was analyzed by the Inertia Moment methodology and compared with the gravimetric results. The monitoring was stopped after 130 min when the variation of the weight was less than 0.05%. In Fig. 13 we can see the evolution of the weight loss and the values of the normalized Inertia Moment.

The ability of the mouse with the adapted webcam and laser pointer to follow the paint drying shows that it is possible to use that instrumental approach to analyze the biospeckle in some applications. If there were any possibility to bypass the configuration of the hardware of the mouse, or if it were possible to offer to the users the accessibility in the integrated circuit to the signal before its processing by the DSP, the OCM would be considered a rather fast, cheap, small and handy tool to analyze the biospeckle phenomenon.

4. Conclusions

The use of the computer mouse associated to a laser pointer presented here showed to be a way to get robust and reliable information from several phenomena related to whole field spatial displacement, with a low cost, in a similar way as the use of the mouse as in its prime design allowed to get images of the speckle patterns during activity monitoring and to analyze them still with enough sensitivity.

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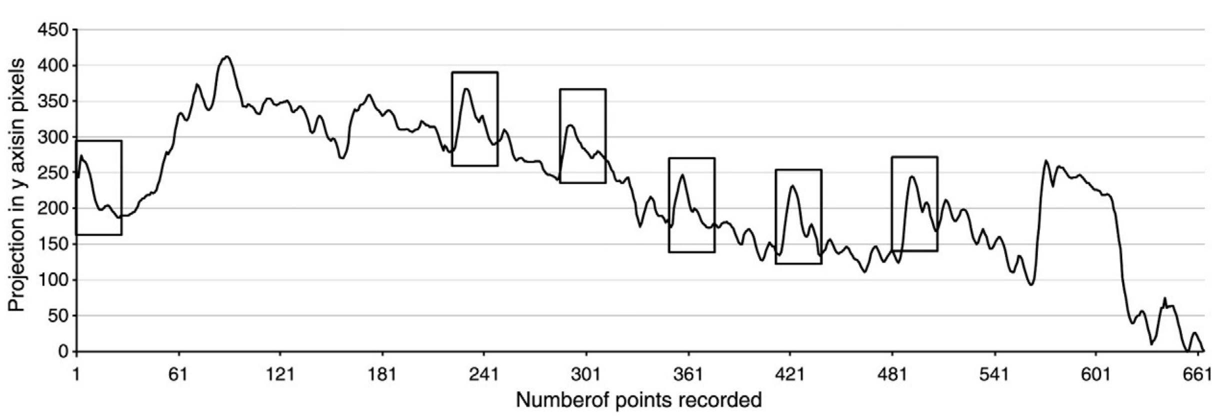

Fig. 10. Profile from the projection of the mouse's cursor path during the skin movement in the *y* axis with some highlighted standard profiles.

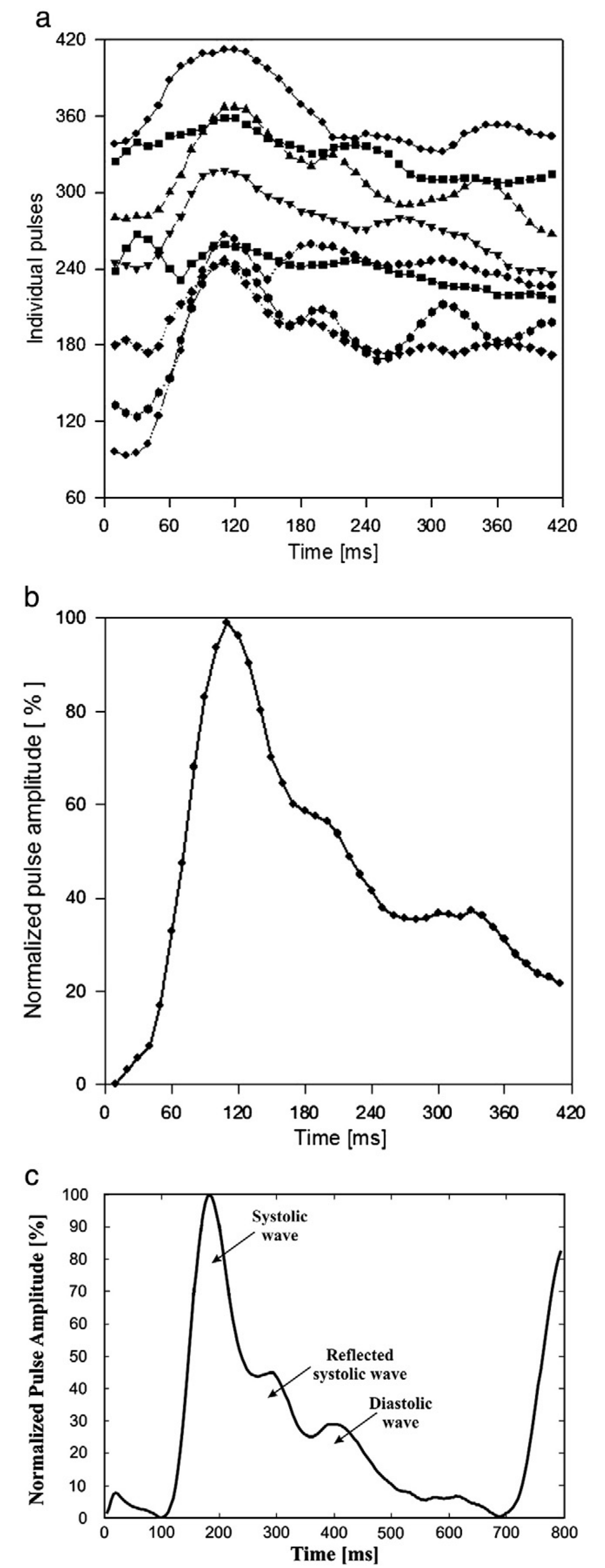

Fig. 11. Collection of (a) some profiles from a *y* projection of the mouse's cursor path during the skin movement, (b) their average curve and (c) diameter variations (Permission to reproduce by L.I. Passoni, G. Meschino, A. Scandurra, F. Clara, A. Introzzi. Optimization of arterial age prediction models based in pulse wave, 2007, Journal of Physics).

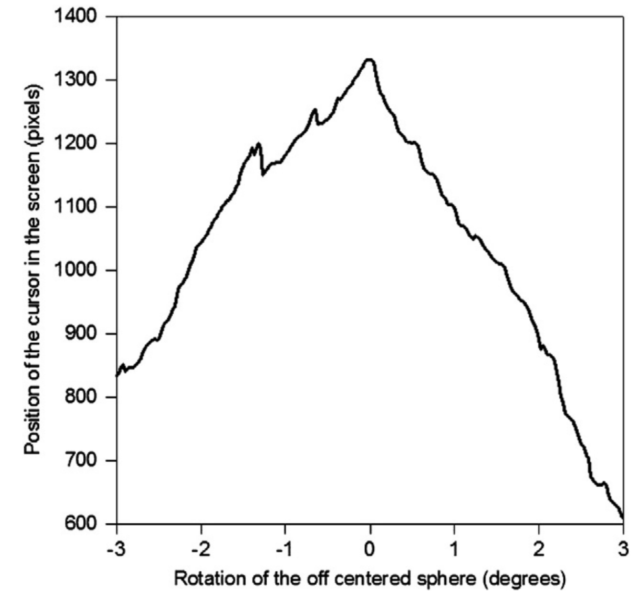

Fig. 12. Projection of the mouse's cursor path during the artificial eye motion in the *y* axis.

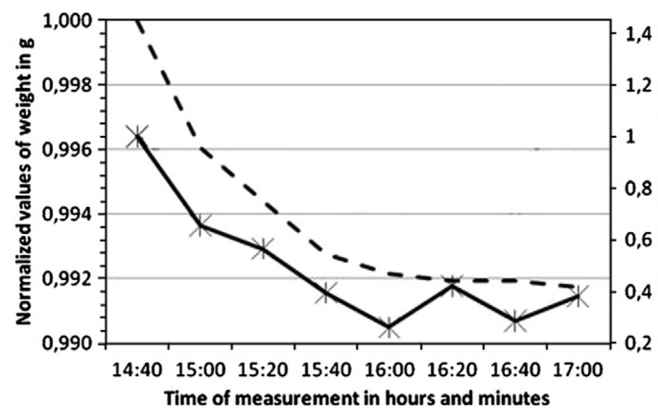

Fig. 13. Evolution of the paint drying monitored by a scale, in dashed line, and the IM values.

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