A New Zigbee-based Device for Measuring Visual Reaction Time in Sport Activities

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Abstract— **There is a growing demand for smart tools and devices that measure visual reaction time during sports and physical activities in outdoor environments. However, one of the major problems is the need to maintain an on-time 1 pulse per second (pps) reference with a known uncertainty. The introduction of ultra-low-power wireless chipsets such as Zigbee technology open new horizons for many new use cases. This paper investigates in-depth the calibration and the reliability of a new wireless Zigbee-based device for smart modeling of sport practioners interactions and measuring remotely their reaction time. The uncertainty of the calibration is shown to be less than 100 µs.**

Keywords—; Calibration; reliability; B-percept; visual reaction time ; Zigbee.

I. INTRODUCTION

Testing methods for the human reaction time have been investigated since the 1980s [1]. Many efforts focused on standardization of stimuli presentation to provide accurate analyzes and reliable tests. One of the most preferred methods [2-4] is the computerized test, which can accurately measure the reaction time to the millisecond level [5-9]. Despite its advantages compared to traditional paper-and-pencil method [10-12], these type of methods still suffer from different operability limitations in sports and other fields of activities outside the laboratory environment. Thus, stopwatches and timers are the instruments commonly used by sports practitioners to assess reaction time [13, 14] and time intervals. A stopwatch is a counter-based instrument which measures and displays the time interval from a given starting point or signal that begins at the instant when the stopwatch is started [15]. The absolute accuracy of these devices is the maximum allowable offset from nominal.

In order to calibrate a stopwatch or any conceived device for measuring time intervals, there are three methods usually used to validate the most smaller uncertainty [16] than the International System of Units (SI) : the direct comparison method [17], the time base method [16] and the totalize method [18]. Though, recently the Hong Kong Standards and Calibration Laboratory (SCL) has developed a new totalize method for the calibration of stopwatches [19] by using a high-speed video camera to record short videos clips with 240 or 480 frames per second (fps).

In the present article we aim to detail the calibration of a new timing device that we have developed using the high-speed video recording method [19-21]. Than, we study its reliability and reproducibility for measuring visual simple reaction time.

The studied device called B-percept is conceived for modeling 1 to 8 visual flashing LEDs signals (figure1) by synchronizing standard or randomized lighting LEDs periods from 250ms up to 60000ms and preprogrammed latency periods form 500ms up to 60000ms. We are limiting the calibration process on a single B-percept device. The device measures simple visual reaction time (SVRT) and complex visual reaction time (CVRT) by using a Zigbee wireless Standard (IEEE 802.15.4-2003) [22, 23] for data transmission through low power-demanding devices (XBee S2; 3.3v) capable of supporting a Personal Area Network (PAN) [22, 24, 25]. The device aims to reproduce subjects' interactions [26] in sport fields using electronic numeric simulation modeling [27, 28]. Moreover, it intends to help facilitate comparisons between player's motor skills in sport and in physical education.

The first section of this article details the calibration of the studied timing device using the high-speed video recording method [19, 29]. The second section studies the reliability and reproducibility features of measuring simple visual reaction time (SVRT) for flashing LEDs signals.

II. MATERIALS AND METHODS

A. Apparatus and Experimental setup

Five key components are used for experiments: B-percept® [30] C-board, S-Board, P-Board and a Laptop (with Java plugin installed) and a power supply as illustrated in Figure1. The B-percept software was set-up on a Windows 7 Edition (X64), SP1 laptop with the following specifications : Intel Core i5 at 2.40 GHz, 8 Go DDR3, SSD Samsung SSD850EVO500GB SATA III. The device's timer is based on a Microchip-PIC 16f877a microcontroller incrementing time by 1Hz using an external oscillators quartz time-base that runs at a nominal frequency of 32 768 Hz to produce 1 pulse per second [31]. The microcontroller's time base can be sliced into fractions of a second such as milliseconds (10^{-3}s) or microseconds (10^{-6}s).

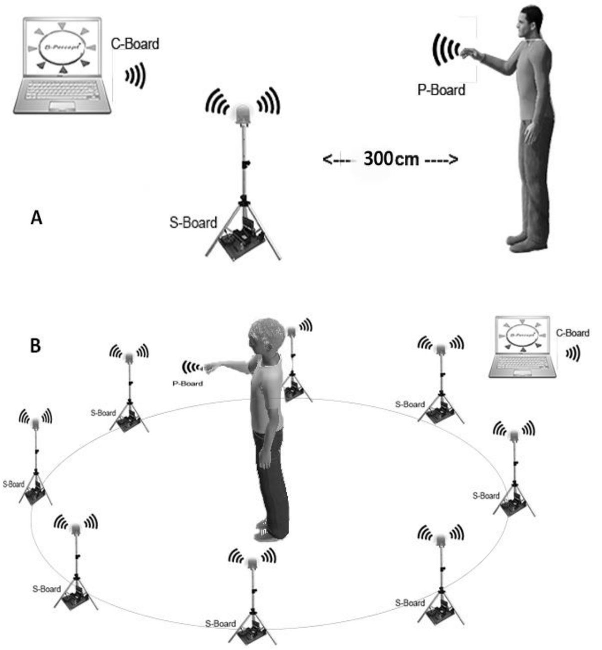

Figure 1: B-percept® testing process for measuring Visual Reaction Time. (**a**): process for measuring Reaction Time using 01 LEDs signal. (**b**) process for measuring Reaction Time using randomized 08 LEDs signals.

B. The calibration method

A generated signal of 1 kHz is set-up from the PC software to feed B-percept timer which was carried out simultaneously to start incrementing with a LED light starting [19] [32] [33]. A high speed digital camera (GoPro HERO4 Black) was used to record 100 LED blink video clip at 240 fps, which then deinterlaced to 480 fps by the open source software (VirtualDub-1.10.4 for Windows) [19, 34]. The recorded video is viewed frame-by-frame to search for the frame at which the display of the LED situation starts to change. The readings of the first lightning LED frame took place from the one immediately preceding this frame and synchronized with the time displayed by the PC software.

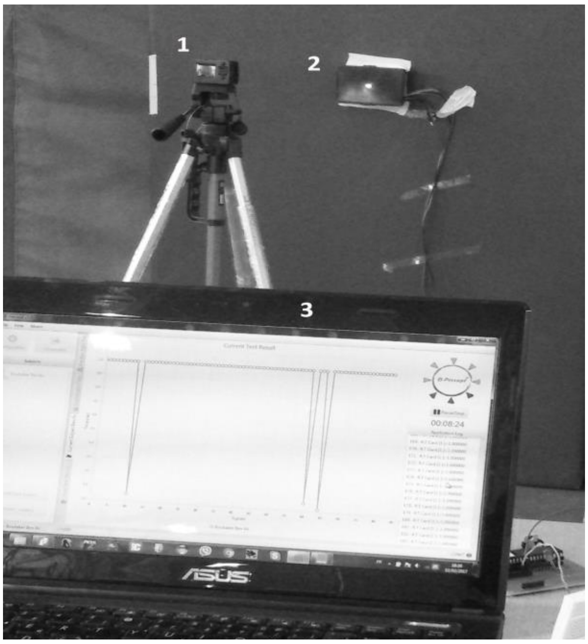

Figure 2: Equipment's needed for the experiment: (1) a high-speed video camera (2) the B-percept® timing device with visual signal LEDs. (3) a Laptop.

C. Unit Set-up of subject groups and data processing and statistics

- Participants

For our experiments we selected forty five participants (22 years old men ± 1.8) in compliance with the Helsinki convention [35, 36]. They have moderate and regular physical activity. Participants have received exhaustive information about the testing protocol, and they were familiarized with the B-percept devices. They carried out the experiments process for the "Test" and the "Retest" during three weeks.

- The testing process

The testing process was programmed every Tuesday throughout three weeks, from 2:00PM to 4:00PM in a gymnasium having an average temperature of 19 degree [37, 38]. The brightness was measured by Lux meter (ref : Voltcraft MS-1300) for average 100 lux [18].

The high-speed camera used to film the flashing LED was positioned at 3m from it and at 1 m high from the floor (Figure 2) [39]. While standing at 3m on the front of the flashing LED signal [21], participant had to stop the LEDs light as fast as possible for 100 repeated time by using the remote P-board. The signal time T_{sig} length was per 1 second and the latency time T_{lat} was per 5 seconds [12, 40,

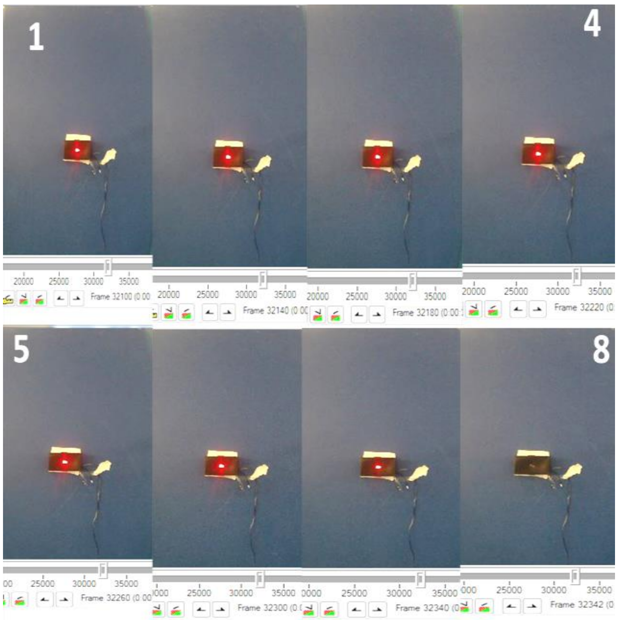

Figure 2 Video frame sequences (by 40fps interval) for 1 sec flashing LED time measurement. The advantage of this method is that many flashing LEDs can be measured simultaneously in a short time. The accuracy of this method is limited by the speed of the video recording devices; this method is recommended when measuring the time interval of LEDs that flash at a low frequency.

41]. The flashing LEDs time interval is calculated by viewing the recorded video frame-by-frame to find out the timing between the start and the shut down of the LEDs light. The measured interval intended to express the duration between perceiving the signal and the motor reaction of the tested participants. Thus, recorded video clips were analyzed frame by frame and the results of the SVRT were compared to results chronicled by B-percept.

D. The uncertainty due to the human reaction time

To minimize the effect of human reaction time each participant was asked to repeat the measurement process of 1 s flashing LEDs 100 times within 5 s of latency interval, and the resulting 100 differences between the video totalize

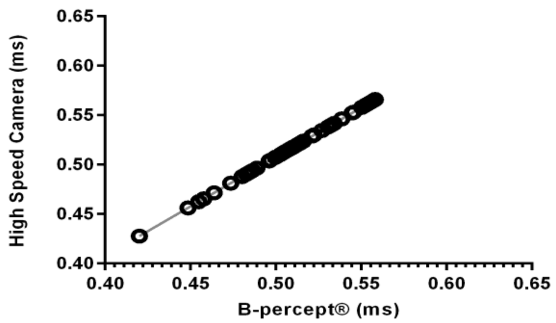

Figure 3: Bland and Altman plots illustration between timing comparisons: High speed video camera vs. B-percept®

method using a high-speed video timing and the B-percept timing were recorded and plotted (Figure 3).

E. Statistical analyses

Data was stated as mean ± standard deviation and the confidence interval was set at 95%. We used the analysis of variance (ANOVA) for a pair wised comparison tests to include differences between each pair by comparing means and standard deviation for both two test process. We used Bonferroni correction for multiple comparison adjustment.

We assessed absolute and relative reliability using the Standard Error of Mean (SEM), intra-class correlation coefficient (ICC). The smallest worthwhile change (SWC) between means was assumed as: SWC= 0.2xSD [42]. Calculation and statistical analyses were performed by using the Statistical Package for Social Science for Windows (SPSS, IBM Corp. V.21), G*Power software (V. 3.1.9.2) [43] and Microsoft Office Excel 2010.

III. RESULTS

A. Calibration of measuring 1 second time period

As shown in Figure 4 the video clips were recorded at 240 fps and the flashing time interval period from a fame to the one just before was calculated as: $F_{P2} - F_{P1}$ = (32341-32100) -1 = 240 fps. To get further accuracy, the video was deinterlaced using VirtualDub to 480 fps (Table 3), because the uncertainty [21] due to the video recording frame rate has a rectangular distribution [44, 45] with semi-range of the time interval between two successive frames of the video recording (1/480 fps = 2.1ms) and it is calculated as:

$$2.4/(2\sqrt{3}) = 0.61ms$$

The repeatability was evaluated as a “Type A” uncertainty which is determined from the scatter of data points around the average of a series of measurement runs. The flashing LED was analyzed at 480 fps through 595 seconds as: 100 flashing time of 1 sec. and 20 latency interval of 5 sec.

The measurement results summarized in Table 2a shows that the calculated flashing periods, T1, are stable, as indicated by the fact that the standard derivation is zero. The standard uncertainties of each uncertainty component and combined standard uncertainty are summarized in Table 2b.

Table 2 b : *Measurement results and estimated standard uncertainty*

B. Measurement Error	
Nominal time interval	1s
Measured time interval	1.0001s
Measured error	0.0001s
C. Uncertainty components	
T_{P2} reading of synchronous video frame at the end of a LED flashing period, $\mu(T_{P2})$	0.61×10^{-4}
T_{P1} reading of synchronous video frame at the end of a LED flashing period, $\mu(T_{P1})$	0.61×10^{-4}
Repeatability , μ (n)	0 s
Total standard uncertainty	0.1 ms

D. Reliability of measuring visual simple reaction time

As shown in the Table 3, the measurement taken by each unit, the mean, standard deviation, maximum value and minimum value were calculated for the flashing LEDs period and for all tested participants (n = 45).

The analyze of variance by repeated measurement test chows no difference between the means and the standard deviations at $P < 0.01$ (Figure 4) for the results get by the high-speed camera and B-percept. Thus, the absolute and the relative reliability of the testing process measured by the "SEM" shows that there are no significant differences between simultaneous "VSRT" measured by the video totalize method of a high-speed camera at 480 fps and the B-percept device, the uncertainty of measures is smaller than 1×10^{-5}, and the there is a very little and non-significant SWC = 0.007.

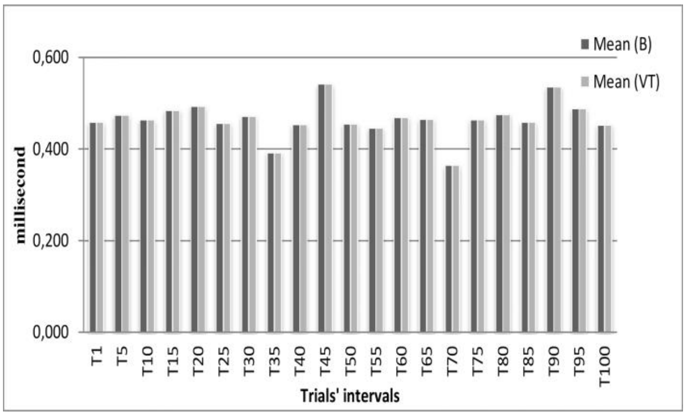

Figure 4: Comparison between results means of the high-speed camera recording and B-percept® after every five flashing LEDs

IV. CONCLUSION

The calibration process provides high accuracy of the new conceived electronic device for measuring the visual reaction time. The video totalize method is suitable for the measuring time intervals of multiple flashing LEDs with low flashing frequency.

Moreover, in dissimilarity with our expectations we were pleased while measuring the reaction time for the 45 participants, to notice no significant differences between the time measuring tools and methods. Thus, we assume that giving 5 second latency between light signals was clear-sighted to reduce uncertainty impact due to accidental or recurrent anticipating of signals by using the remote P-Board to shutdown LEDs light. Thus, the calibration and the reliability of B-percept show uncertainty to be less than 100 µs. The measuring accuracy seems to be sufficient for

TABLE 2a : *Flashing LEDs for 1 second time intervals*

Time	T_{P2}	T_{P1}	$TI = T_{P2} - T_{P1}$
Data 1	2,865	2,384	1.0001s
Data 2	17,481	17,000	1.0001s
Data 3	31,913	31,432	1.0001s
Data 4	46,353	45,872	1.0001s
Data 5	60,793	60,312	1.0001s
Data 6	75,233	74,752	1.0001s
Data 7	89,673	89,192	1.0001s
Data 8	104,105	103,624	1.0001s
Data 9	118,545	118,064	1.0001s
Data 10	135,873	135,392	1.0001s
Data 11	150,313	149,832	1.0001s
Data 12	166,353	165,872	1.0001s
Data 13	179,185	178,704	1.0001s
Data 14	193,625	193,144	1.0001s
Data 15	208,057	207,576	1.0001s
Data 16	222,497	222,016	1.0001s
Data 17	236,937	236,456	1.0001s
Data 18	251,377	250,896	1.0001s
Data 19	265,817	265,336	1.0001s
Data 20	280,257	279,776	1.0001s
Data 21	294,697	294,216	1.0001s
		Mean	**1.0001**s
		SD	**0**

remotely assessing reaction time and modeling sport and physical activities.

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