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Validation of a Manual Position Tracking Software (TACTO) to Quantify the Football Movements

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Abstract The aim of this study was to present a validation protocol using a global positioning system with real-time differential correction (dGPS) to assess the validity and the reliability of a semi-auto tracking software (TACTO) used to quantify the movement patterns of football players. In order to obtain the 2D coordinates of the movements of a player from the virtual coordinates, the TACTO software was used twice, first for calibration (the virtual coordinates of a set of reference points at the game surface were collected, corresponding to points with known real coordinates) and then for digitalization (reconstruction of coordinates). The reconstruction of virtual coordinates of the player into real coordinates was carried out using DLT-2D, with algorithms developed in MATLAB' software routines. The coordinates obtained by this methodology were compared to the coordinates obtained by dGPS receiver. The validity and the intra-user and inter-users reliability of the methodology used were proved by all the statistical parameters used (the relative technical error of measurement (ETM), the Pearson coefficient (r), and the intra-class correlation coefficient (ICC))

Keywords TACTO, Reliability, Validity

1. Introduction

Since Reilly and Thomas [1], early study in monitoring football players, the interest and timeliness of this topic has been demonstrated by research conducted by several teams [2-12] over the last decades. Several published works have focused on circuits designed to simulate typical situations of a football game, characterized by movements at different speeds, from walking to maximum speed (sprint), frequently without ball, including quick change of direction [1, 6, 13].

The two main systems used for game analysis, in the different sports, are based on video images analysis and GPS technology [14].

The camera calibration procedures and the tri-dimensional reconstruction of the coordinates were initially proposed by Abdel-Aziz and Karara [15] and are known as Direct Linear Transformation (DLT). The position of an object on the plane, in relation to a reference, is defined with the help of two independent coordinates, such as the rectangular coordinates (x and y), in relation to the time (t). The aim of this approach is to transform the images in order to obtain two-dimensional spatial coordinates (2D-DLT), which results in a simplification of the parametric equations proposed by Abdel-Aziz and Karara [16], thus eliminating the need for camera synchronization [17].

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The difficulty in obtaining the information in real time and errors during the image digitalization is an important disadvantage of this method [3]. Small systematic errors can be introduced by the different techniques used, at the level, for example, of the eyes - hand coordination, of the visual sharpness and of the standards of concentration [3]. Furthermore, traditional methods of motion analysis require operators tracking the positions within the video, which is extremely labour intensive and a major step back in relation to existing auto-tracking systems [6].

Various commercial systems based on processing of video images exist on the market. The systems for the collection and processing of information in team sports can be relatively expensive in particular the "AMISCO Pro®" and the "ProZone®" systems [6]. The need for permanent placement of various cameras in the stadium at previously studied fixed positions, and the associated high cost are limitations to their acquisition and open new perspectives for alternative systems of significantly lower costs. The “TACTO” (“Tool for Applied and Contextual Time-series Observation”) software developed by Fernandes [18] in Visual Basic – version 7.0 for analysis of the positions is a relatively economical and simple solution. In general, these systems require the validity and reliability evaluation. Reliability and validity are very important for measuring error during digitalization and coordinates transformation [19-20]. Jennings et al. [21] and Waldron et al. [22] are examples of previous published test protocols to evaluate the validity and reliability of tracking systems. Carling et al. [6] stressed that it is important to evaluate intra-user and inter-user reliability of the video images analysis system in each kind of exercise in which displacement is measured. The study of Duthie et al. [20] is one of the few published papers dedicated exclusively to the evaluation of the reliability of the digitalization process. Dobson and Keogh [19] and Carling et al. [6] have expressed some concerns about the scientific validity of the accuracy and the reliability of different systems of obtaining coordinates by digitalization of video images.

Several studies have tested the validity of commercial GPS receivers to characterize the types of movements made by football players [14]. Coutts and Duffield [23] concluded, however, that this system can not be sufficiently accurate in situations involving high speeds or frequent changes in speed or direction. On the other hand, the GPS technology with real-time differential correction (DGPS-RTK), used especially in works of topography provides an accuracy of a few centimeters in positioning [24], being suitable for validation of other tracking systems [2]. Therefore, the main purpose of this study was to present a validation protocol using a global positioning system with real-time differential correction (dGPS) to evaluate the "TACTO-DLT-2D" methodology for obtaining kinematic parameters for monitoring the movement patterns of the football players.

2. Material and Methods

2.1. Measurements

The sampling of this study was made from several time series of coordinates, obtained by digitalization of video images (virtual coordinates) and coordinates obtained from the dGPS-RTK receiver (real coordinates).

2.2. Procedures

The aim of validation (Figure 1) is to demonstrate the validity and the reliability of the system [6]. The validity consists in comparing the system under study (TACTO) with a reference system. The accuracy of dGPS technology makes it an ideal tool for this purpose [24-25].

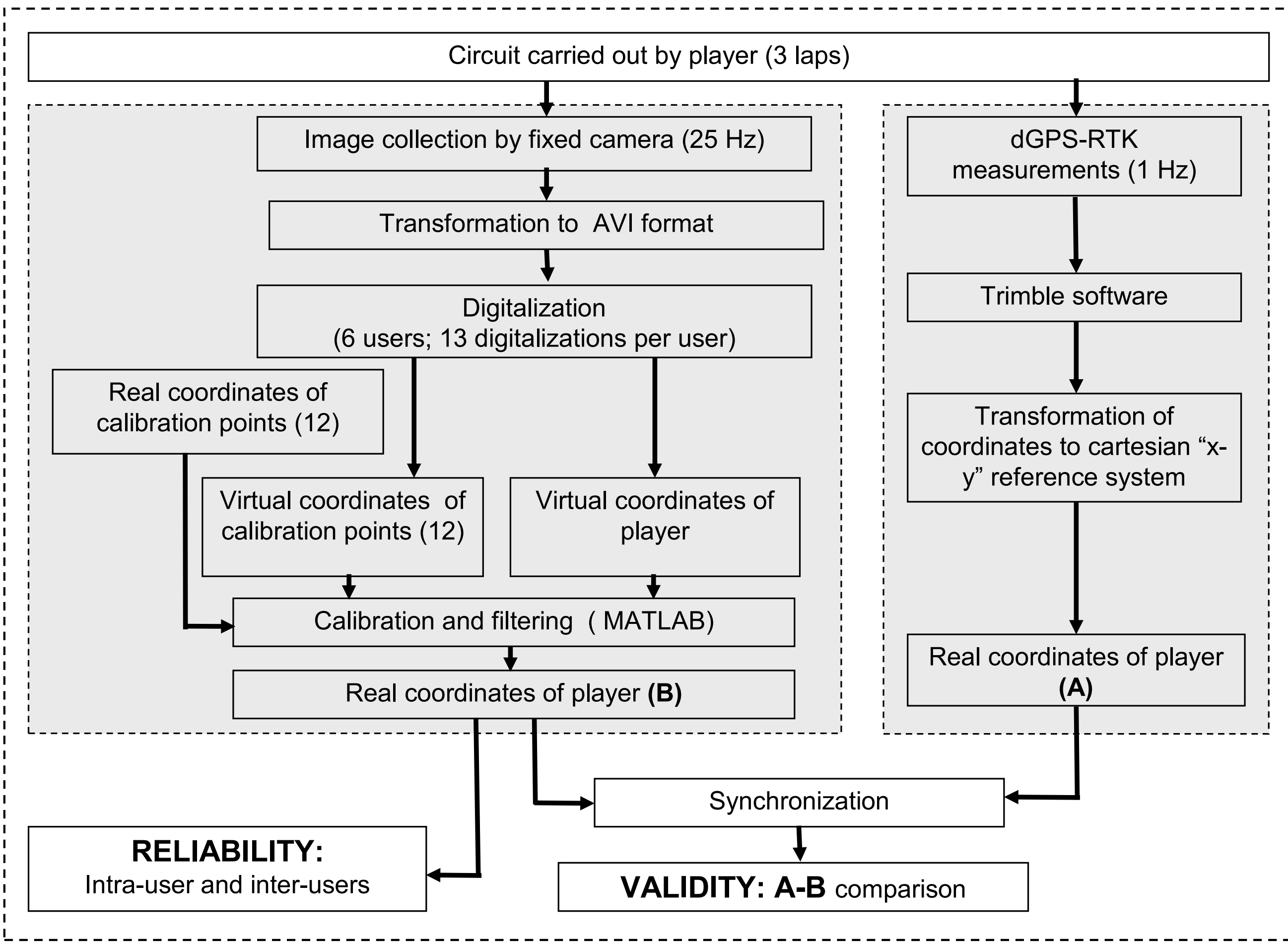

Figure 1. Validation of "TACTO-DLT-2D" methodology

This study was conduct using a circuit installed in the middle of a football field, included seven exercises (Figure 2), to reproduce standard displacements carried out by a player during a football game, based on indications of Reilly and Thomas [1], Carling et al. [6] and Reilly and Gilbourne [13]. Three of these exercises included movements with ball (driving, pass and shot) and four other exercises without ball at different speeds: slow speed (stations E3, E4 and E7) or sprint (stations E1, E2, E5 and E6). Lateral displacements and shifts still to the rear running, both with sudden changes of direction were included in each of these categories. One moderately trained male player (age 20 years) equipped with a dGPS-RTK receiver (Figure 3) completed three laps of the circuit. The dGPS-RTK receiver data (differential correction station and mobile antenna) was sampled at 1 Hz and analyzed by Trimble^{TM} software (Trimble Navigation Limited). Player's displacement coordinates (latitude, longitude and altitude, with reference to the World Geodetic System, WGS 84) and the corresponding time were quantified. These coordinates were transformed according to a Cartesian "x-y" reference system using a rotation matrix relative to the reference frame of the field.

The experiment was carried out on a clear day and with 8-10 detected satellites, thus allowing for perfect operation of the dGPS during the whole day.

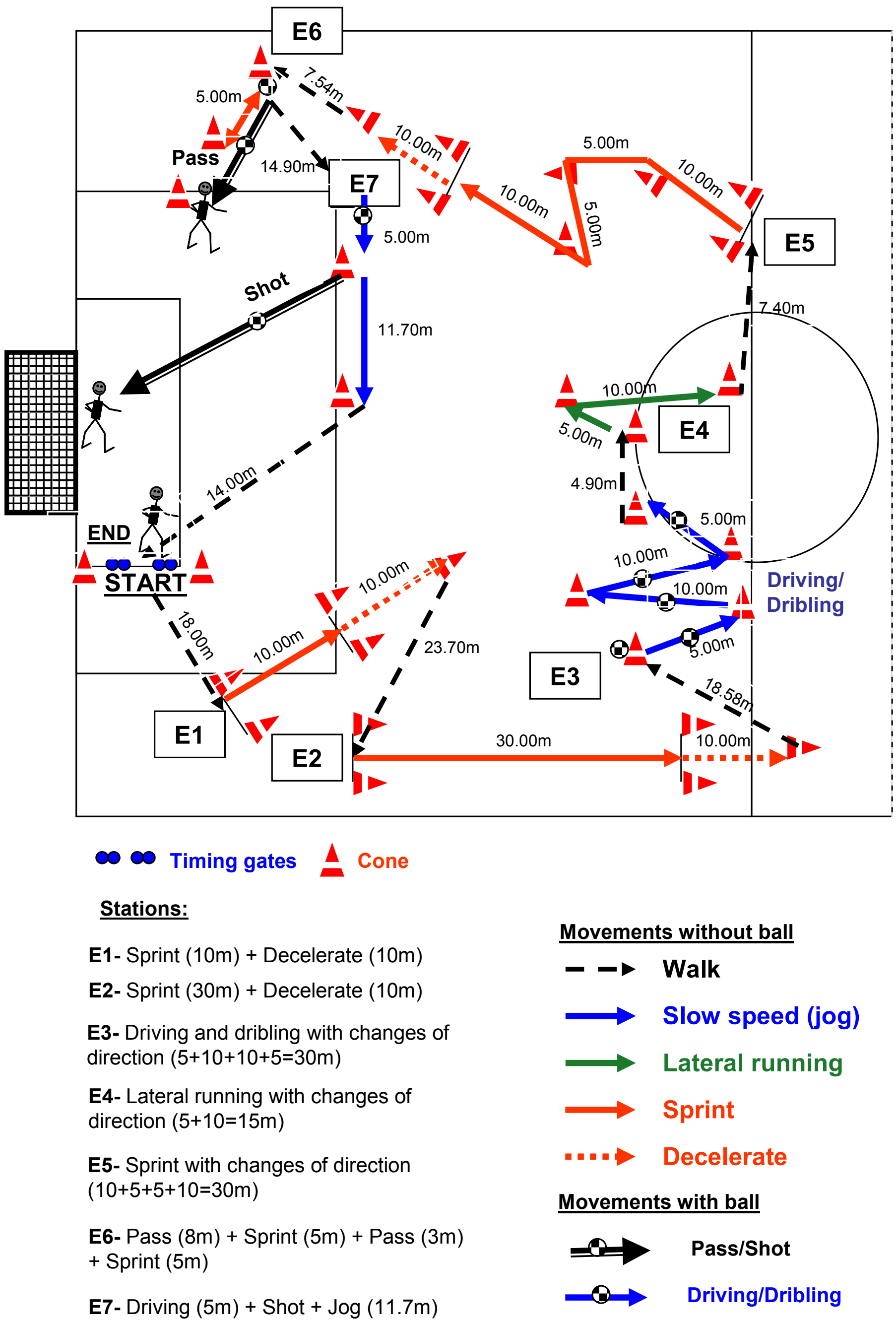

Figure 2. Circuit courses representative of the most frequent movements of football players

Figure 3. Differential correction station (dGPS) (top) and the football player equipped with mobile GPS antenna (bottom)

A fixed camera placed on one of the stadium's lighting towers collected images of the pathways of the player. The images captured by the cameras were stored digitally using the Audio Video Interleaved (AVI) format. The coordinates from the video images were obtained through digitalization using the "TACTO" software with a sampling frequency of 25 Hz.

Six students (age 20.2 ± 0.8 years) volunteered to participate in the digitalization process of this study (reliability). Each one of these students carried out thirteen digitalizations on different days (test-retest), during two weeks at different hours, using the same video images. The procedure was explained to the participants and they had a minimum break of one hour between sessions of consecutive digitalization. Each user followed the player by tracking a middle point between both feet on the ground, corresponding to the approximate location of the projection of the center of gravity on the ground. These coordinates were filtered using a digital second order Butterworth filter with a cut off frequency of 6 Hz to minimize the error inherent in the digitalization process [26]. The direct linear transformation 2D (DLT-2D) was used twice with algorithms developed in "MATLAB" software routines, first for calibration (the virtual coordinates of seven reference points at the game surface were collected, corresponding to points with known real coordinates) and then for digitalization (reconstruction of coordinates). This process transforms the virtual coordinates of the player (obtained through tracking on the monitor, in pixels) into real coordinates (in meters).

2.3. Synchronization of the Systems

Filming of the dGPS- RTK receiver screen at the end of the data collection, provided a means for establishing the temporal correspondece between the time read by the dGPS-RTK receiver and the time registered by the video camera. Thus it was possible to have the coordinates obtained by the two methods (dGPS-RTK and digitalization of video images) on the same time reference (time synchronization). Given the difference in the sampling rates (1 Hz in the case of dGPS-RTK receiver and 25 Hz in the case of the video image digitalization), a "MATLAB" routine was created that searchs and identifies the records obtained by dGPS-RTK system that correspond, in terms of sampling rates, to the coordinates obtained in the process of digitalizing of the video images in the set of three laps of the circuit completed by the football player (sampling rates synchronization).

3. Results and Discussion

3.1. Validity

Table 1 shows the values of the coefficients of determination (r^2) in linear regression analysis between the coordinates obtained by dGPS receiver and coordinates obtained by digital video images (mean of 78 digitalizations). The values were 0.998 for the x-coordinate and 0.999 for the y-coordinate. The ETM changed from 2.01 to 2.53 % for the x-coordinate and from 1.09 to 2.08 % for the y-coordinate.

Figure 4 illustrates the coordinates collected by dGPS receiver and video images digitalization after application of "TACTO-DLT-2D" methodology during one of the circuit laps made by the football player. For an applied viewpoint, the mean expected absolute difference between coordinates measured by the two systems is 0.70 ± 0.29 m.

Table 1. Linear regression analysis between the methods of obtaining coordinates (dGPS receiver and digital video images)

Coordinate	α	β	r^2	$F_{[1,343]}$	p
"x"	0.525±0.070	0.983±0.002	0.998	211376.5	0.000
"y"	-0.012±0.049	0.997±0.001	0.999	594406.2	0.000

In linear regression analysis, r^2 values very close to "1" show a good fit between the the linear model results and the observed experimental data. The slope of the line (coefficient β) around "1" and the intercept (or linear coefficient α) of around "0" validate the scan system's ability to obtain the coordinates ("x" and "y") and reproduce the actual positions covered by the player.

The ETM results in this work were less than 3% on both coordinates, which, according to Edgecomb and Norton [3] and McInnes et al. [28], demonstrate a good degree of approximation to the real path values.

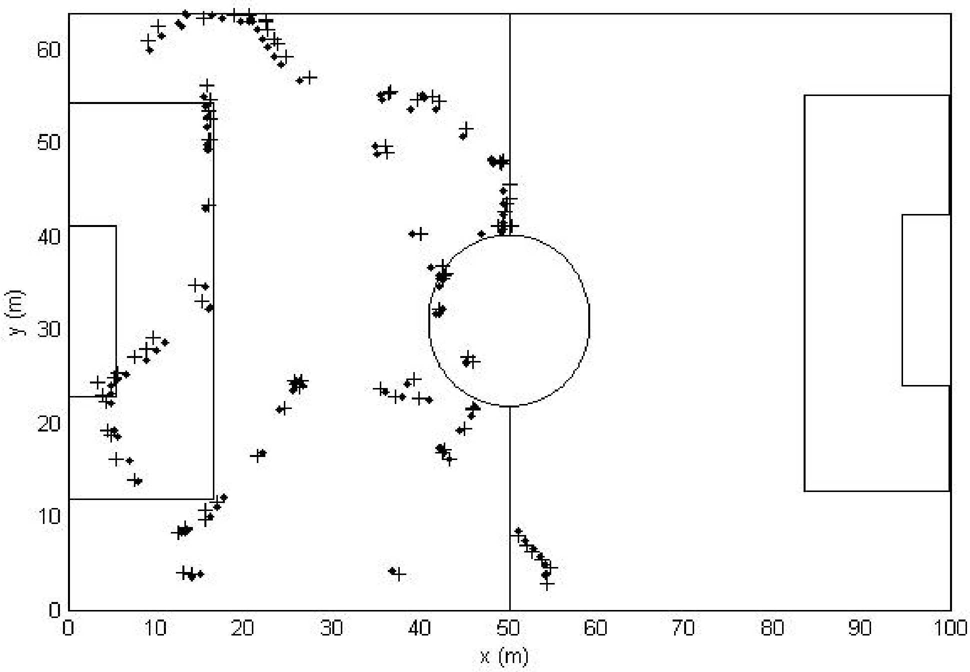

Figure 4. Coordinates collected by dGPS receiver (.) and video images digitalization (+), during one of the circuit laps made by the football player

3.2. Reliability

The correlation between thirteen digitalizations of each participant (intra-user reliability) was significant and the medium value of the correlation coefficient of Pearson (r) for intra-user and inter-users correlation changed between 0.993 ± 0.007 and 0.998 ± 0.001 for the x-coordinate and between 0.952 ± 0.064 and 0.991 ± 0.007 for the y-coordinate (Table 2).

Table 2. Mean ± standard deviation of correlation coefficients between all digitalizations of each participant

Participant	Coordinate "x"	Coordinate "y"
I	0,997 ± 0,002	0,984 ± 0,009
II	0,995 ± 0,004	0,969 ± 0,031
III	0,998 ± 0,001	0,989 ± 0,007
IV	0,993 ± 0,007	0,952 ± 0,064
V	0,995 ± 0,004	0,965 ± 0,043
VI	0,998 ± 0,001	0,991 ± 0,007

The ETM between the first and the following digitalizations (intra-user reliability) carried out by each participant changed from 0.53 to 2.74 % for the x-coordinate and from 0.32 to 2.30 % for the y-coordinate (Tables 3 and 4).

The ICC values obtained in both coordinates correspond to the classification excellent consistency [29-30]. The dimension of the ETM values (less than 2% for all operators in successive digitalizations) is clearly lower than the 5% defined by McInnes et al. [28] and used by MacLeod et al. [8] as the limit below which the results are considered to have good consistency. It is also lower than the 2.4% obtained by Edgecomb and Norton [3] in the evaluation of intra-user reliability. The high values obtained for the correlation coefficients and ICC (close to "1") associated with the ETM values demonstrate the reliability of this methodology.

Finally, the ICC values for all 78 digitalizations carried out by the six participants (inter-user reliability) were 0.980 for the x-coordinate and 0.985 for y-coordinate (Table 5).

Table 3. The relative technical error of measurement (ETM, %) of "x" coordinate: comparision between the coordinates obtained in the first digitalization and the coordinates obtained in the following digitalizations by each one of the six participants (I-VI)

Digit.	I	II	III	IV	V	VI
2	1.66	1.00	1.24	1.66	1.26	0.90
3	1.18	1.11	1.14	1.32	1.37	1.31
4	1.42	2.44	1.12	2.04	0.94	0.99
5	1.58	1.26	1.13	1.40	1.13	1.07
6	1.42	2.25	1.04	1.49	1.17	1.01
7	1.12	1.45	1.45	0.98	0.98	1.38
8	1.56	0.95	1.01	1.61	1.35	1.23
9	1.20	1.15	0.86	2.74	1.00	0.53
10	1.21	1.30	1.24	1.45	2.17	0.96
11	1.06	2.16	0.99	2.44	2.17	0.96
12	0.85	1.59	1.24	1.85	1.11	0.70
13	1.26	1.84	1.08	1.63	1.11	1.02
Mean±SD	1.29±0.24	1.54±0.51	1.13±0.15	1.72±0.49	1.31±0.42	1.00±0.24

Digit. –Digitalization; SD- Standard deviation.

Table 4. The relative technical error of measurement (ETM, %) of "y" coordinate: comparision between the coordinates obtained in the first digitalization and the coordinates obtained in the following digitalizations by each one of the six participants (I-VI)

Digit.	I	II	III	IV	V	VI
2	0.99	0.47	0.71	0.80	0.94	0.50
3	0.71	0.67	0.76	0.82	0.70	0.76
4	0.82	1.77	0.69	1.07	0.56	0.49
5	0,98	0,70	0,61	0,72	0,92	0,53
6	0,90	1,61	0,80	0,80	0,84	0,53
7	0,53	0,62	0,81	0,48	0,67	0,70
8	0,94	0,50	0,65	0,81	0,82	0,60
9	0,70	0,70	0,74	2,30	0,70	0,32
10	0,87	0,67	0,79	0,80	1,63	0,69
11	0,71	1,40	0,52	1,79	1,63	0,54
12	0,54	0,79	0.64	0.96	0.84	0.47
13	0.62	0.94	0.80	0.79	0.77	0.64
Mean±SD	0.78±0.16	0.90±0.44	0.71±0.09	1.01±0.51	0.92±0.35	0.56±0.12

Digit. –Digitalization; SD- Standard deviation.

Table 5. Intra-class correlation coefficient (ICC) for "x" and "y" coordinates, of the set of 13 digitalizations (k) carried out by the 6 users (n)

Coordinate	n	k	SMS	RMS	EMS	ICC
"x"	6	13	1402.348	12.652	0.168	0.980
"y"	6	13	870.576	4.959	0.252	0.985

SMS-average square between operators; RMS- average square betwen digitalizations; EMS- average square of error.

3.3. Study Limitations

Since in official competitions, the athletes are not allowed to carry electronic components, and the fact that the GPS antenna looks very hindering for a football player, an actual game was not considered for the collection of data, which one can be pointed out as a major limitation of this study. The randomness or unpredictability of the game allows for a diversity of typical situations in real context, which would lead to a more ecological approach.

On the other hand, the different sampling rates used by the two systems (1 Hz in the case of dGPS-RTK receiver and 25 Hz in the case of the video image digitalization), may pose greater difficulty in the synchronization process.

Finally, the "TACTO-MATLAB" methodology used in this study, based on the reconstruction of coordinates in two dimensions ("2D-DLT"), obtained from images captured by a fixed video camera located above the football field is a simplification of the "3D-DLT" methodology applied to sports where the movement occurs essentially in one plane, as is the case of football. However, this approach does not consider the movements that occur in the vertical plane, which may be especially important in a specific analysis of the movement, particularly in the evaluation and improvement of technical skills.

4. Conclusions

The linear regression analysis show a good fit between the linear model and the experimental data, which, associated with low values of dispersion indicator (ETM), demonstrate a good degree of approximation between coordinates obtained by digitalization and the real path values. The high values obtained for the intra-user and inter-users correlation coefficients and ICC between digitalization associated with the low ETM values also demonstrate the reliability of this methodology.

The validity and reliability of the low-cost "TACTO-DLT-2D" system for obtaining coordinates of football players, demonstrated by all the statistical parameters used, including regression analysis, correlation and error of determination, opens good perspectives for the generalized use of the methodology in other sports and in places such as inside of buildings (futsal, handball, basketball, etc.) where it is not possible to use GPS receivers due to inaccessibility of satellite signals inside buildings.

REFERENCES

[1] Reilly, T., and Thomas, V., 1976, A motion analysis of work-rate in different positional roles in football match-play., J. Hum. Movement Stud., 2, 87-97.

[2] Terrier, P., and Schutz, Y., 2005, How useful is satellite positioning system (GPS) to track gait parameters? A review. J. Neuro Engineering and Rehabilitation, 2, 28-38.

[3] Edgecomb, S. J., and Norton, K. I., 2006, Comparison of global positioning and computer-based tracking systems for measuring player movement distance during Australian Football. J. Sci. Med. Sport, 9(1), 25-32.

[4] Roberts, S., Trewartha, G., and Stokes, K., 2006, A comparison of time-motion analysis methods for field-based sports. J. Sports Physiol. Perform., 1, 388-399.

[5] Barros, R. M. L., Misuta, M. S., Menezes, R. P., Figueroa, P. J., Moura, F. A., Cunha, S. A., Anido, R. and Leite, N., 2007, Analysis of the distances covered by first division Brazilian soccer players obtained with an automatic tracking method. J. Sports Sci. Med., 6, 233-242.

[6] Carling, C., Bloomfield, J., Nelsen, L., and Reilly, T., 2008, The role of motion analysis in elite soccer. Contemporary performance measurement techniques and work rate data. Sports Med., 38(10), 829-862.

[7] Barbero-Alvarez, J. C., Soto, V. M., Barbero-Alvarez, V., and Granda-Vera, J., 2008, Match analysis and heart rate of futsal players during competition. J. Sports Sci., 26(1), 63-73.

[8] MacLeod, H., Morris, J., Nevill, A., and Sunderland, C., 2009, The validity of a non-differential global positioning system for assessing player movement patterns in field hockey. J. Sports Sci., 27(2), 121-128.

[9] Hill-Haas, S., Dawson, B. T., Coutts, J. A., and Rowsell, G. J., 2009, Physiological responses and time-motion

characteristics of various small-sided soccer games in youth players. J. Sports Sci., 27(1), 1-8.

[10] Brewer, C., Dawson, B., Heasman, J., Stewart, G., and Cormack, S., 2010, Movement pattern comparisons in elite (AFL) and sub-elite (WAFL) Australian football games using GPS. J. Sci. Med. Sport, 13(6), 618-623.

[11] Castellano, J., Alvarez-Pastor, D., and Bradley, P. S., 2014, Evaluation of research using computerised tracking systems (Amisco(®) and Prozone (®)) to analyse physical performance in elite soccer: a systematic review. Sports Med., 44(5), 701-712.

[12] Magel, R., and Melnykov, Y., 2014, Examining influential factors and predicting outcomes in european soccer games. Int. J. Sports Sci., 4(3), 91-96.

[13] Reilly, T., and Gilbourne, D., 2003, Science and football: a review of applied research in the football codes. J. Sports Sci., 21(9), 693-705.

[14] Randers, M., Mujika, I., Hewitt, A., Santisteban, J., Bischoff, R., Solano, R., Zubillaga, A., Peltola, E., Krustrup, P., and Mohr, M., 2010, Application of four different football match analysis systems: A comparative study. J. Sports Sci., 28(2), 171-182.

[15] Abdel-Aziz, Y. I., Karara, H. M., 1971, Direct linear transformation from comparator coordinates into object-space coordinates. Proc. ASP/UI Symp. On Close-range Photogrammetry (Urbana, 1995). American Society of Photogrammetry, Falls Church (Va/USA), pp. 1-18.

[16] Misuta, M. S., 2004, Rastreamento automático de trajetórias de jogadores de Futebol por videografia: validação do método e análise dos resultados. Tese de Mestrado, Faculdade de Educação Física, Universidade Estadual de Campinas, Campinas, Brasil.

[17] Hopkins, W. G., 2000, Measures of Reliability in Sports Medicine and Science. Sports Med., 30(1), 1-15.

[18] Fernandes, O., 2008, Tool for Applied and Contextual Time-series Observation ("TACTO"). Oral Presentation of the 2nd Internacional Congress of Complex Systems in Sport, 4-8 November, Madeira, Portugal.

[19] Dobson, B. P., Keogh, J. W. L., 2007, Methodological Issues for the Application of Time-Motion Analysis Research. Strength Cond. J., 29(2), 48-55.

[20] Duthie, G., Pyne, D., and Hooper, S., 2003, The reliability of video based time motion analysis. J. Hum. Movement Stud., 44, 259-272.

[21] Jennings, D., Cormack, S., Coutts, A. J., Boyd, L., and Aughey, R. J., 2010, The validity and reliability of GPS units for measuring distance in team sport specific running patterns. Int. J. Sports Physiol. Perform., 5(3), 328-341.

[22] Waldron, M., Worsfold, P., Twist, C., and Lamb, K., 2011, Concurrent validity and test-retest reliability of a global positioning system (GPS) and timing gates to assess sprint performance variables. J. Sports Sci., 29(15), 1613-1619.

[23] Coutts, A. J., and Duffield, R., 2010, Validity and reliability of GPS devices for measuring movement demands of team sports. J. Sci. Med. Sport, 13(1), 133-135.

[24] Morales, Y., and Tsubouchi, T., 2007, DGPS, RTK-GPS and StarFire GPS Performance Under Tree Shading Environments. In: Proceedings of the IEEE International Conference on Integration Technology, Shenzhen, China, pp. 519-524.

[25] Witte, T. H., and Wilson, A. M., 2004, Accuracy of non-differential GPS for the determination of speed over ground. J. Biomech., 37(12), 1891-1898.

[26] Winter, D., 2004, Biomechanics and Motor Control of Human Movement. Third Edition, John Wiley & Sons, Inc., pp. 40-44.

[27] Serra, G, and Bottura, C., 2007, An IV-QR Algorithm for Neuro-Fuzzy Multivariable Online Identification. IEEE T. Fuzzy Syst., 15(2), 200-210.

[28] McInnes, S., Carlson, J. S., Jones, C. J., McKenna, M. J., 1995, The physiological load imposed on basketball player during competition. J. Sports Sci., 13(5), 387-397.

[29] Collins, J. J., and De Luca, C. J., 1993, Open-loop and closed-loop control of posture: A random-walk analysis of center-of-pressure trajectories. Exp. Brain. Res., 95(2), 308-318.

[30] Chiari, L., Cappello, A., Lenzi, D., and Croce, U., 2000, An improved technique for the extraction of stochastic parameters from stabilograms. Gait Posture, 12(3), 225-234.