PHOTOGRAMMETRIC SYSTEM FOR MOVEMENT ANALYSIS IN TEAM SPORTS

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This work develops a system based on photogrammetric methodologies; such system enables us to analyse the movements of the player in team sports such us soccer, indoor soccer, handball, basketball, etc. It can also be used in individual sports such us tennis with the same aim of quantifying player's movements. This system, called "RUNNER", can quantify player movements, by obtaining several kinematic parameters useful for deducing the physical loads on the players in real conditions. In this work we present some results obtained from soccer and indoor soccer studies.

KEY WORDS: photogrammetry, team sports, methodology, kinematics, work load.

INTRODUCTION: This work develops a system based on photogrammetric methodologies; it enables us to analyse the movements of the player in team sports such us soccer, indoor soccer, handball, basketball, etc. It can also be used in individual sports such us tennis with the same aim of quantifying player's movements. The work area of sport biomechanics researchers has traditionally been focused on those sport events in which kinematic parameters are specially relevant for performance and the prevention of risk factors which may cause injuries. As a result, other research lines focused on team sports are not usual, particularly since collective interaction is considered more important that kinematic factors in team sports. The difficulty in the biomechanical analysis of team sports is the traditional photogrammetric methodologies of sport biomechanics because are commonly used in reduced spaces, due to the problem of developing big reference systems and other problems associated to the usual algorithms of three-dimensional reconstruction. Another difficulty is the long time intervals that have to be analysed in these sports, making the usual frame by frame methodology in the digitising process, virtually impossible in these cases. In this sense, traditional photogrammetric methodologies cannot be used for analysing the movement of players in team sports over long intervals of time, and other methodologies are not commonly available at present. Similar methodologies have been made in other works (Riera & Aguado,1989; Winkler, 1991; Hernández, 1991; Ohashi *et al*, 1993). The accurate quantification of a player´s movement in field conditions enables us to obtain knowledge relevant for deducing the physical loads to which the player is subject. This knowledge is particularly relevant to specialists involved in the training work area, since with this information they can programme training loads more precisely, using analysis of the player's movements and velocity. The main aim of this work is the development of a photogrammetric system that allows us to analyse team sport movements in real conditions. This system, called "RUNNER", can quantify the player´s movements, obtaining several kinematic parameters useful for deducing the physical loads on the players in real conditions. Individual sports such us tennis can also be analysed with this system.

METHODS: For the development of this work we have adapted the traditional 2D photogrammetric methodology, creating a software called "RUNNER" (version 1.0). It has been used to analyse some different team sports such us soccer and indoor soccer. The methodology is based on a sequential process in which different phases are applied, starting with the filming. We used video recording in S-VHS format (PANASONIC MS-5 cameras), locating one or two cameras from above the pitch, in positions as elevated as possible, to try to minimize the perspective deformation that would later be eliminated in the computerizing process. The filming area contained the field area that the researcher wanted to analyse. The reference system is defined from the dimensions of the playing area. For big spatial areas 2 cameras are recommended, each of them focused on different playing areas. After filming, the computerizing process in pc-platform running Microsoft Windows operating system begins, using different modules included in "RUNNER" software. Each player is digitised in real time using an specific module that works using the cursor of a digitising table (a mouse can also be used, but the digitising table is more accurate). The geometric centre of the support base (mid-point between both feet) is used to follow the player's movements. The user of digitising module must be intensely trained to be able to achieve the necessary precision in digitising. Periodically, the possibility of estimation errors in the digitising process must be tested because of the difficulty of real time digitising; that is why we developed a methodology to estimate errors in which the user must digitise a well-known indoor soccer player movement of 1000 meters of displacement during an interval of 10 minutes. We can validate the data comparing the real motion with the estimation obtained with the software (differences lower than 2% should be enough accurate). The researcher can choose different intervals of recording frequency with the cursor (between 50 Hz and 1 Hz). From our pilot studies, we recommended 4 Hz for soccer and indoor soccer, since that provides enough accuracy in the kinematic analysis of the player's movements and greater frequencies do not give more precision in those sports. Afterwards, the position of the player throughout the match is smoothed using digital filters (Figure 1), reconstructed using trigonometrical algorithms for removing perspective deformation, and in that cases we used two simultaneous cameras, temporal synchronization being applied for the different views recorded by each camera. The perspective error is removed using trigonometrical and vectorial algorithms based on the detection of the four angles of each corner of the playing area.

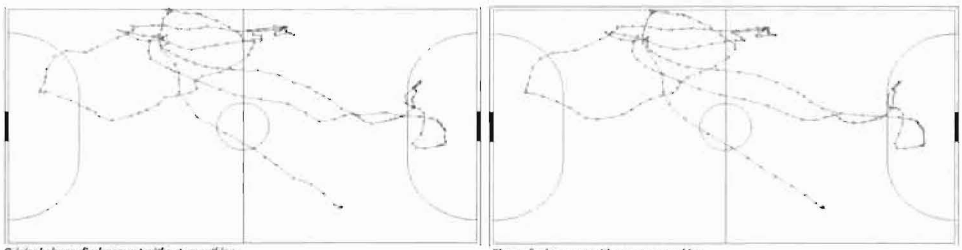


Figure 1. Smoothing process using RUNNER v.1.0 analysing indoor soccer.

At the end of the computerizing process, different numerical (kinematic parameters) and graphic results are obtained. "RUNNER" software calculates and evaluates in depth the movements of the players using different possibilities as shown in detail in the results section. Basically, these results are based on different temporal analyses, calculation of distances, instantaneous velocity and acceleration in each position, work loads deduced from the time acceleration curve, analysis of spatial areas most used during the game, trajectories, etc. At the present time, in our laboratory, different projects using this methodology are being developed, one in soccer and the other in indoor soccer. The latter develops the analysis of players in professional teams of the Spanish league at different moments of the competitive season (3 matches, analysing all the players). The soccer project is focused on semi-professional players in the Spanish league, analysing some specific positions. In both cases players are filmed in real conditions during official matches, with the main aim of deducing the real kinematic behaviour of players during competition. For better understanding of the movements, the curve of the velocity during the time is analysed, deducing from it different types of behaviour (figure 2):

" Rest: interval of time without movement (player on the bench, or in static position).
" Walking: interval of time or effort where peak of velocity is less than 1 m/s.
" Slow running: interval of time or effort where peak of velocity is less than 3 m/s.
" Medium running: interval of time or effort where peak of velocity is less than 5 m/s.
" Fast running: interval of time or effort where peak of velocity is less than 7 m/s.
" Sprinting: interval of time or effort where peak of velocity is higher than 7 m/s.

Using this classification we developed all the statistic processes for analysing movements.

RESULTS: in order to validate our results we applied the methodology (previously exposed in Method chapter), at the beginning and ending of digitising the estimation errors were of

1.89% and 1.92%. In the following figures some of the kinematical and graphic results obtained using our methodology in the two projects (soccer and indoor soccer) are set out. In both cases the analysis obtained in one half of the match is given. More detailed analysis can be obtained by contacting the author using e-mail.

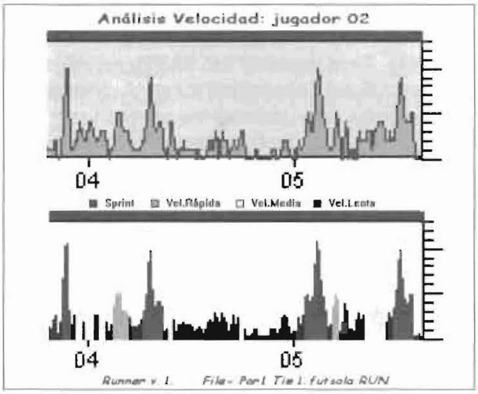


Figure 2. Analysis of the velocity of indoor soccer player during two minutes. In black: static-walking-slow running, yellow: medium running, pink: fast running, red: sprinting. Horizontal axis represents time (minutes). Vertical axis represents velocity (m/s).

Figures 3, 4, 5, 6 and 7 show some calculations made during one half of a match in indoor soccer. Figure 3 gives the interval of time used by each player. The analysis of the velocity of one player throughout the time is set out in figure 4, different kind of efforts made by the player in different colours are exposed. Figure 5 and 6 present the descriptive statistics of the temporal and spatial analysis of all the players. Figure 7 summarises the efforts made by the players, describing the work loads in training terms. Figure 8 draws areas most frequently used by all the players during the match, and by one individual player.

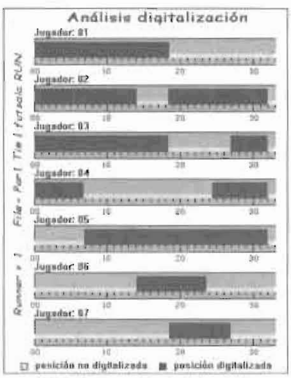


Figure 3. Temporal analysis of 7 players in one indoor soccer match (half).

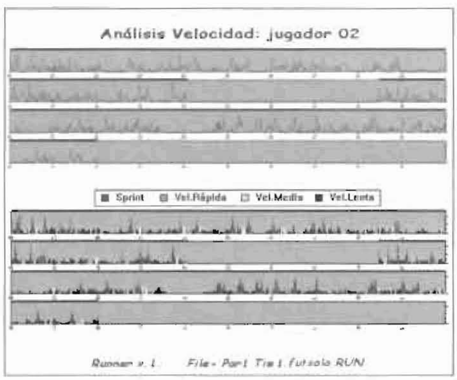
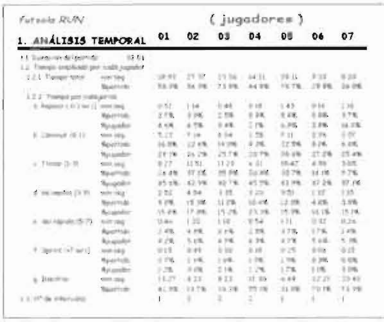
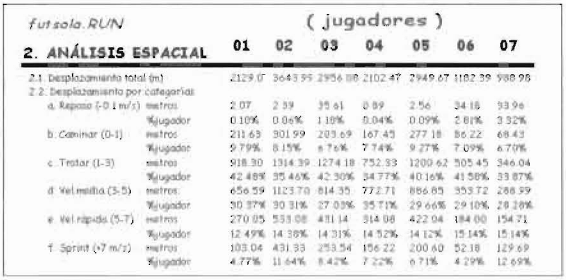


Figure 4. Analysis of the velocity of one indoor soccer player during a half match.

DISCUSSION: The methodology proposed in this work, using RUNNER v.1.0, enables the movements of team sport players in real playing conditions to be quantified and described, using non-invasive indirect techniques, without affecting the normal behaviour of players during competition. For an accurate estimation of the calculations, the process of digitising must be developed by experts with enough training in this skill, using accurate methodologies for controlling the possible errors introduced in this phase of the process. We consider this system very useful in any kind of team sport and individual sport.





futsala.RUN — 2. ANÁLISIS ESPACIAL		01	02	03	04	05	06	07
2.1. Desplazamiento total (m)		2129.07	3643.95	2956.08	2102.47	2949.67	1182.39	988.98
2.2. Desplazamiento por categorías								
a. Reposo (-0.1 m/s)	metros	2.07	2.39	35.61	0.89	2.56	34.18	93.96
	%jugador	0.10%	0.06%	1.10%	0.04%	0.09%	2.81%	3.32%
b. Caminar (0-1)	metros	211.63	301.99	205.69	167.45	277.18	86.22	68.43
	%jugador	9.79%	8.15%	6.76%	7.74%	9.27%	7.09%	6.70%
c. Trotar (1-3)	metros	918.30	1314.39	1274.18	752.33	1200.62	505.45	346.04
	%jugador	42.48%	35.46%	42.30%	34.77%	40.16%	41.58%	33.87%
d. Vel.media (3-5)	metros	656.59	1123.70	814.35	772.71	886.85	353.72	288.99
	%jugador	30.37%	30.31%	27.03%	35.71%	29.66%	29.10%	28.28%
e. Vel.rápida (5-7)	metros	270.05	533.08	481.14	314.08	422.04	184.00	154.71
	%jugador	12.49%	14.38%	14.31%	14.52%	14.12%	15.14%	15.14%
f. Sprint (+7 m/s)	metros	103.04	431.33	253.54	156.22	200.60	52.18	129.69
	%jugador	4.77%	11.64%	8.42%	7.22%	6.71%	4.29%	12.69%

Figure 5. Temporal and spatial analysis: descriptive statistics of seven indoor soccer players.

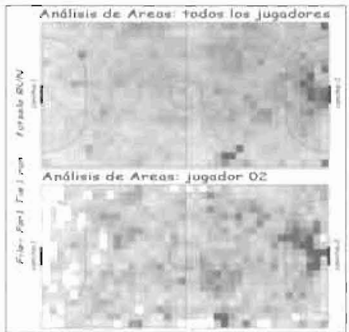


Figure 6. Efforts made by seven indoor soccer players, describing work loads in training terms.

Figure 7. Areas most frequently used, by all the players during the match, and by one player.

In order to improve the possibilities of this system and make it more useful it would be interesting to synchronise this methodology with other parameters such us heart frequency (using cardiometers). In future work lines for improving the system, real time digitisation technologies that can substitute the manual process, should be developed. At this present moment some technological developments exist, but they are expensive or useful only in laboratory. Algorithms of artificial recognition will help more than the use of sensors in the player's body.

REFERENCES:

Hernández,J. (1991). Análisis de la acción de juego en baloncesto y fútbol sala. *IV Congreso Panamericano de Medicina del Deporte*. La Habana, Cuba.

Ohashi,J.; Togari,H.; Isowaka,M. & Suzuky,S. (1988). Measuring movement speeds and distances covered during soccer match-play. In Reilly,T; Lees,A.; Davis,K. & Murphy,W.J. (Eds). *Science and Football*. 329-333. London, E.& F.N.Spon.

Riera,J. & Aguado,X. (1989). Sistema informático para medir los desplazamientos en competición. *Apunts: Educació física i esports*. **15**, 61-64.

Winkler,W. (1991). Match analysis and improvement of performance in soccer with the aid of computer controlled dual video systems. *Science & Soccer*. **4**, 6-10.