FACTA UNIVERSITATIS
Series: **Physical Education and Sport** Vol. 6, N° 1, 2008, pp. 75 - 84

Scientific Paper

AN ANALYSIS OF BASKETBALL PLAYERS' MOVEMENTS IN THE SLOVENIAN BASKETBALL LEAGUE PLAY-OFFS USING THE SAGIT TRACKING SYSTEM

UDC 796.323 (497.12)

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Abstract. *The main aim of the paper was to present the SAGIT measuring system and to establish the covered distance and the average velocity of basketball players' movements by using the aforementioned system. The SAGIT system is a relatively new technology which is based on computer-vision methods and enables an automated acquisition of data from the video recordings of games. The system was used to track the movements of 23 basketball players from two teams during three games of the play-offs of the Slovenian National Championship for men. It was established that during the 40 minutes of the active phase of the game the players covered a distance of 4,404 m on average and that during the passive phase, they covered an additional 1,831 meters. The players' average velocity of movement during the active phase of the game was 1.86 m/s. Although the players from one of the teams moved slightly faster and covered a greater distance, the differences between the teams in terms of the average velocity and covered distance were not statistically significant.*

Key words: *basketball player tracking, computer vision*

INTRODUCTION

It is interesting and useful for sport science and professional disciplines to investigate the movements imposed on players in sport games. Data on the distances covered by players, the velocity of their movement and position in two-dimensional space during a game provide an important basis for the appropriate planning and distribution of load in training sessions, thus indirectly affecting the effectiveness of training (Vučković, Perš, & Dežman, 2006).

Received April 7, 2007

Due to the complexity and unpredictability of sport games (particularly in team sports), this type of research can be very demanding and time-consuming without any appropriate video and information technology ('IT'). The development of technology that speeds up the acquisition of reliable and accurate data has thus become a priority and a challenge for many scientists and experts all over the world. The appearance of the first technologies of this type coincided with the development of computer science in the 1980s (Ali & Farrally, 1991). However, it took another two decades of development to introduce the partially automated computer-aided processing of the video recordings of players' movements during games. Research in this field was still demanding and time-consuming. Some difficulties arose due to the broad array of technologies and data-collection methodology, which led to the great variability of results concerning athletes' motions in the same sport (Bon, 2001).

A quantum leap in the field of reliable methodology for acquiring and analyzing data on players' movements in some sports came about due to the application of computer-vision methods. For the first time, computer vision offered a means of capturing at least some data from the recordings automatically, with minimum participation on the part of the operator (Vučković, Perš & Dežman, 2006).

The desire to bring objectivity and improve research on athletes' loads in individual sports prompted researchers from complementary sciences to start cooperating. The result of such cooperation is the computer-vision-based SAGIT system. The first generation of SAGIT was developed at the Faculty of Electrical Engineering at the University of Ljubljana (Perš & Kovačič, 2000; Perš et al., 2002) in co-operation with the Faculty of Sport from the same university.

Computer-vision technology involves methods and algorithms for the automatic extraction of useful information from digital images and recordings by means of a computer. The advantages of this technology lie in its high data processing capacity along with the reliability, speed and accuracy of the acquired data (Vučković, Perš, & Dežman, 2006). In addition, since it is based entirely on video technology, its use is completely non-intrusive and causes no disturbance to the game or players. Measurement and/or data acquisition procedures represent no additional burden or disturbance for athletes since they do not require the use of any sensors or transmitters. This brings an exceptional advantage over other technologies and is of great importance for both researchers and athletes.

The first to apply the SAGIT tracking system to investigate the load of handball players was Bon (2001). In the following years it was also applied to squash (Vučković, 2002), basketball (Vučković & Dežman, 2001) and tennis (Filipčič, Perš, & Klevišar, 2006).

In the context of tracking players' movements in sport games the SAGIT tracking system is essentially a measurement system and it has been tested to estimate its errors of measurement (Perš et al., 2002). The system, now in its second generation, is basically designed for indoor sports and consists of calibration, tracking, annotation and presentation modules. An additional automatic analysis module is still being developed (http://vision.fe.uni-lj.si/research/SportA/application.html.)

Calibration module

The calibration module is used to calibrate each video to the same court coordinate system. During the calibration process, the starting and ending points of the game in the video and the type of the game are manually specified and then a small number of key points are placed along the court boundaries following the computer's instructions. In this way, the computer can determine the correspondence between the image and court coordinates.

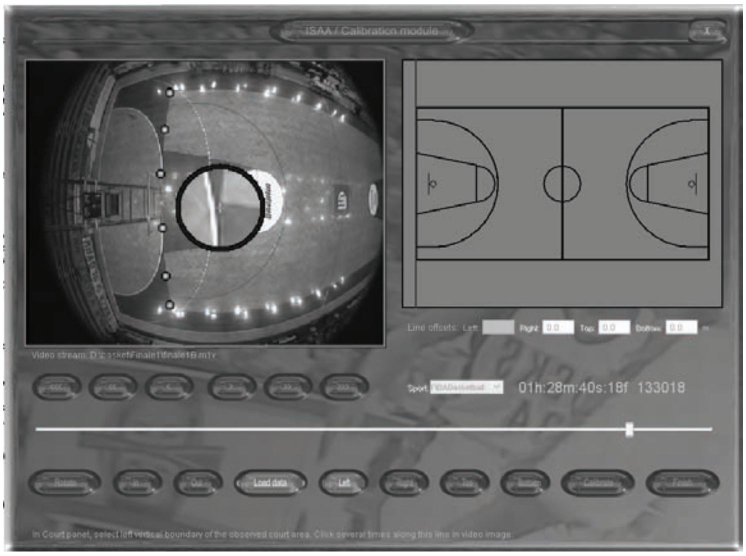

Fig. 1. Calibration module

Tracking module

The tracking module is used to obtain reasonably accurate data about a player's movements around the court. The maximum RMS error of the obtained data varies from 0.3 m under the camera to 0.5 m along the court boundaries (Perš et al., 2002). Players are initialized manually by clicks of the mouse, and then the automatic processing of the video starts.

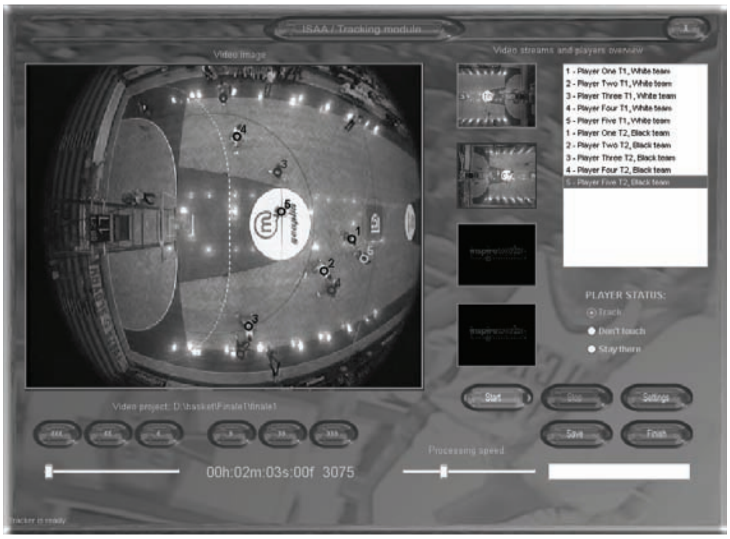

Fig. 2. Tracking module

Annotation module

The annotation module is used to enter manual expert annotations about the events observed on the court. These annotations can then be used to produce high-level game statistics about the number and positions of different elements of the game such as passes, shoots, screens etc. They are perfectly aligned since they are recorded in the same framework as the player motion data.

Fig. 3. Annotation module

Presentation module

The presentation module is used to view, export and print the results obtained with the help of the tracking and annotation modules. It can be used to produce appealing visual presentations of the obtained data.

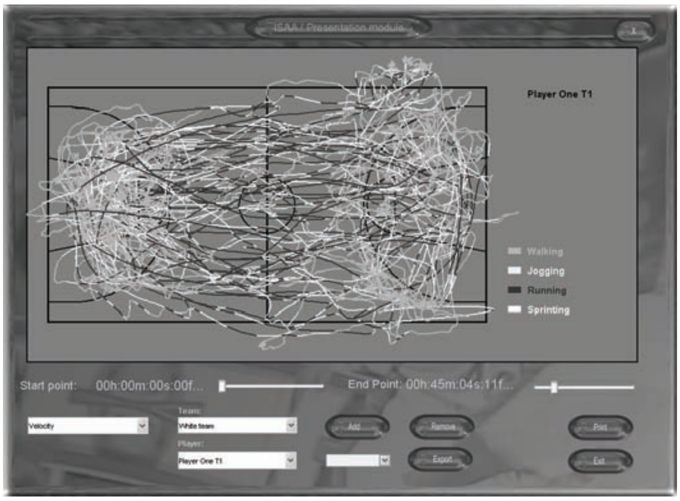

Fig. 4. Presentation module

System setup

Two video cameras are fixed to the ceiling of a hall (for larger indoor spaces the system offers the use of up to four video cameras) to record a training session or a game at 25 video frames per second, thus obtaining 25 positions for each individual player for every second of the game. The recording is done directly onto a DVD recorder and stored for later analysis. The new generation of the system provides a method for the fast and simple transfer of digital data directly from a DVD disc to a computer's hard drive.

Over the past few years a great number of changes were made to the tracking algorithm (Perše et al., 2005; Kristan et al., 2005; Kristan et al., 2006) resulting in the simplified and faster tracking of players. In the first generation of the software that was developed in 1999, 14 to 30 days were required to process and/or acquire the data from a single handball game, whereas today one basketball game can already be processed within three to four days (Vučković, Perš, & Dežman, 2006).

The system also provides the possibility to export properly aligned motion and annotation data to other applications. Well-tested data-processing methods using SQL queries can thereby be applied to motion and annotation data (Perš, Vučković, & Kovačič, 2005). Using SQL, the user can acquire a large number of statistical parameters in a relatively automated way using any commercial or free SQL database package such as Microsoft Access or MySQL.

The system is undergoing further development. At this time, the activities are focusing on data-processing algorithms, namely on the automatic identification of activities, automatic searches for known activities, automatic marking and the segmentation of games (Perše et al., 2006; Perše et al., 2007).

Little research has been carried out on the load on basketball players expressed in physical units in professional and scientific literature, even though basketball is a very popular and widespread sport. The few studies dealing with this subject (Mahorič, 1994; McInnes et al., 1995) either use relatively simple and less reliable technology or discuss the subject only partially (e.g. they fail to analyze the movements of all of the players, they analyze only one part of a game or only one game etc.). In basketball, the SAGIT system has so far mainly been used to track referees (Vučković & Dežman, 2001; Lončar, 2005; Erčulj & Lončar, 2006) and not to analyze players' movements.

We therefore decided to put the new generation of the SAGIT system to use to establish the covered distance and average velocity of the players during three games played by two elite teams in the Slovenian Men's National Championship. Given that there are several types of players in basketball who take on different roles in the game and differ considerably in terms of their playing characteristics and motor and functional abilities (Erčulj, 1998), we wanted to establish whether there are any differences between them in terms of the said physical parameters.

METHODS

The system was used to establish the covered distance and the average velocity of movement of the basketball players during three games of the play-offs of the Slovenian Men's National Championship, namely between the teams of Union Olimpija and Geoplin Slovan in the 2004/2005 season. The above parameters were established for a total of 23 basketball players who played for at least five minutes (300 seconds) in a game. As the playing time varied from player to player, an extrapolation was applied to calculate the covered distance as if each player had played for a full 40 minutes or the entire game (S40act = (2400/Tact) x Sact). The differences between the two teams in terms of the selected physical parameters were established using an Independent-Samples T-test.

RESULTS AND DISCUSSION

The initial phase of the research involved identifying the average velocity of the movement and covered distance for all of the players of both teams, irrespective of their playing position.

Table 1. Parameters of descriptive statistics for the average velocity, covered distance and playing time. Note: Std. Dev. denotes the deviation among the means of the different players.

	N	Minimum	Maximum	Sum	Mean	Std. Dev.
Vact_av	53	1.59	2.31	98.58	1.8600	.16286
Vpas_av	53	.66	1.85	46.76	.8823	.16336
Sact	53	723	4537	131253	2476.47	1058.498
Spas	53	272	2035	54567	1029.57	448.918
S40act	53	3661	5294	233449	4404.70	354.609
Tact	53	359	2400	71510	1349.25	578.268
Tpas	53	296	2271	64660	1220.00	526.731

Vact_av – the average velocity of the players' movements during the active phase of a game (while the game clock was ticking)
Vpas_av – the average velocity of the players' movements during the passive phase of a game (while the game clock was not ticking; excluding breaks between quarters of the game)
Sact – the distance covered by players during the active phase of the game
Spas – the distance covered by players during the passive phase of the game
S40act – the distance covered in the active phase of the game as if the players had played for all 40 minutes or an entire game
Tact – playing time during the active phase of the game
Tpas – playing time during the passive phase of the game

It can be established that during the active phase of a game (playing time) the players moved at a velocity of 1.86 (± .16) m/s and covered a distance of 2,476 (± 1,058) m. The last figures do not reveal much as the players do not generally play for an entire game. Therefore, an extrapolation was applied to calculate the distance covered during the active phase as if the players had played for all 40 minutes or the entire game (S40act). In this case, the players would have covered a distance of 4,404 m (± 354 m) on average. By adding the distance covered by the players in the passive phase of the game, i.e. when the game clock was not ticking,[1] the total distance is 6,235 m per game[2]. Mahorič (1994) established that the total distance covered during a game was 6,462 m, which is slightly

[1] The movement is generally slow, i.e. at walking pace.
[2] The calculation of the distance covered in the passive phase of the game was based on the assumption that a player plays the entire match (40 minutes).

more than our result. It should be noted that in the meantime the rules of the game have changed and the time of an offence has been reduced from 30 to 24 seconds. Consequently, the game has become faster, resulting in a higher number of offences and defenses and/or transitions from one phase of the game to another. After the 24-second rule was introduced, the number of offences grew by over 10% (Dežman, 2003), which probably caused an increase in the total distance covered by the players, although this does not directly follow from the results in Table 1[3]. The very same distance is covered during a game played by football players (Dominc, 2001), while the respective value in handball is slightly lower (Bon, 2001).

The established average velocity of the players' movements corresponds to slow running (according to the velocity classes suggested by Bon, 2001). It is clear that the velocity of basketball players changes considerably during a game – from slow walking to a sprint. The relevant literature revealed no information on the average velocity of basketball players' movement; however, we found some information about the average velocity of the movement of handball players. Bon (2001) reported a velocity ranging from 1.3 m/s to 1.5 m/s, yet it must be stressed that these figures apply to both passive and active phases of the game.

We were also interested in differences in terms of the average velocity of movement and distance covered in the active phase of the game. The results are shown in Table 2.

Table 2. Parameters of descriptive statistics for both teams and the Independent Samples T-test

	Team	N	Mean	Std. Dev.	Std. Error Mean	F	Sig.
Vact_av	1	27	1.8978	.1853	.0356	3.149	.082
	2	26	1.8208	.1276	.0250		
S40act	1	27	4455.44	404.57	77.86	2.368	.130
	2	26	4352.00	292.67	57.39		

The data presented in Table 2 led us to conclude that the Team 1 players moved slightly faster and covered a longer distance in the active phase of the game; however, the differences between the teams were not statistically significant. Given that the teams were relatively equal (this is also substantiated by the very results of all three games) with similar strategies of playing, large differences in terms of the intensity and volume of movement were not expected. Large differences could be expected if one of the teams mainly applied a zone defense (which is usually more static and the volume and intensity of movement are slightly lower than with a man-to-man defense) or a press defense (which is usually more dynamic and the volume and intensity of movement are larger than with the positional M-M and zone defenses). A more reliable answer to this question requires a much larger sample of games.

[3] We must emphasise that Mahorič (1994) established the total distance covered during a match on the basis of an example of only one player (guard).

CONCLUSION

For the most part, the research results confirmed our expectations of the covered distance and average velocity of the movement of basketball players. Perhaps we expected the average velocity of movement to be higher. Given that in basketball the time of an offence is limited to 24 seconds, the offence team can only find an opportunity for a clean shot and/or scoring a goal through a dynamic game and intensive movement. The same intensity of movement must also be produced by the defense team if they wish to block or at least hinder a shot and, consequently, a point. During a game, a team executes about 90 offences on average (Dežman, 2003) and most of them consist of a sub-phase consisting of a fast transition from defense to offence and often also a quick counter-attack. The transition from offence to defense must be very quick to prevent the opposing team from scoring easily from a counter-attack. The increase in intensity (velocity) and covered distance could largely be due to the so-called press defenses, which have become quite common in modern, increasingly faster and dynamic basketball. In spite of this, it should be noted that this study was based on games in the play-offs of the national championship which are quite specific in tactical terms. Fast and aggressive play is generally riskier, which is why coaches do not frequently resort to it in matches that are so important and so tight.

The findings in regards to the intensity (velocity) and distance covered by basketball players during games can substantially affect basketball theory and practice. In our opinion, the practical value of this and other similar studies is mainly seen in the planning and organization of basketball players' training, particularly during conditioning, technical-tactical and playing preparation.

With the new generation of the SAGIT system enabling almost complete automation and thus a much faster tracking of players, it will be possible to analyze larger quantities of recordings and movements of a greater number of players. A bigger sample of players and teams would improve the validity of the obtained data and hence enable more detailed findings concerning an individual sport game which would, in turn, benefit sport science and sport practice.

Acknowledgements *This work was supported by a grant from the Faculty of Sport at the University of Ljubljana and particularly the research group program named 'Kinesiology of the monostructure, polystructure and conventional sports'. We acknowledge the assistance of the program group leader, Dr. Milan Čoh*.

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ANALIZA POKRETA KOŠARKAŠA U PLEJ OFU SLOVENAČKE KOŠARKAŠKE LIGE KORIŠĆENJEM SAGIT SISTEMA PRAĆENJA

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Glavni cilj ovog rada je da predstavi SAGIT sistem za merenje i da utvrdi pređenu razdaljinu i posečnu brzinu pokreta košarkaša korišćenjem gore pomenutog sistema. SAGIT sistem je relativno nova tehnologija koja se bazira na metodama kompjuterskog pogleda i omogućuje automatsko prikupljanje podataka korišćenjem video zapisa igara. Ovaj sistem je korišćen da prati pokrete 23 košarkaša iz dva tima tokom tri utakmice plejofa Slovenačkog Nacionalnog Prvenstva za muškarce. Utvrđeno je da su tokom 40 minuta aktivne faze igre igrači u proseku prešli razdaljinu od 4,404 metara, i da su tokom pasivne faze prešli dodatnih 1,831 metara. Prosečna brzina pokreta igrača tokom aktivne faze igre bila je 1.86m/s. Iako su se igrači jednog od timova kretali brže i prešli veću razdaljinu, razlika između timova u smislu prosečne brzine i razdaljine koja je pređena nije statistički značajna.

Ključne reči*: praćenje košarkaša, kompjuterski pogled*