

# **Guidebook to Applying Zenniz Game-Tracking Technology in Tennis Coaching**

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<b>Teacher(s) or supervisor(s)</b> Markus Arvaja <p>The purpose of this thesis was to create a product-based guidebook for tennis coaches in order to encourage and simplify the usage of Zenniz game-tracking technology in tennis coaching.</p> <p>The need for creating the guidebook emerged from the fast development in the field of sport technology and lack of material on applying accessible technological tools such as on-court data tracking systems in tennis coaching.</p> <p>The guidebook is limited to Zenniz game-tracking system as a tool, as it is the most used and available system in the target area, Finland.</p> <p>The report part of the thesis consists of recap on technologies present in the field of tennis, as well as analysis on performance indicators tracked by Zenniz system. The second part of the paper is Zenniz coaching guidebook itself.</p>	
<b>Keywords</b> Tennis, Coaching, Technology, Performance, Development	

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# 1 Introduction

Within the recent years, a number of innovative technologies have emerged in tennis, and it is expected that the trend will evolve stronger in the future. Hence, it is important to understand how these technologies are being used by coaches and players, and what kind of role do they play in training and coaching process.

Over the past several decades technology has had a sensible impact on the way tennis is played by the athletes and is consumed by the audience. The overall technological evolution has led to development of a number of tennis specific technologies, such as equipment technology, court technology, ball-tracking technology, media technology and other. But among the rest, performance-tracking innovations slowly but steadily retain the front row place in modern tennis.

In recent years, main governing bodies of professional men's and women's tennis have partnered with leading global companies in field of technology and analytics, to transform the experience of tennis fans and players. However, it is significant to highlight that compared to other sports like basketball, football or hockey, the field of data tracking and analytics in tennis is the most undermined. In fact, a recent study on top 30 most analytical sports has placed tennis on second last place (MIT Sloan Sports Analytics Conference, 2014).

Despite an overall rapid pace of technological development and increased discussion on the role of data in professional sports, a limited amount of innovative technology is either accessible or used as tools in coaching process. For instance, such innovative systems as Hawk-eye are not publicly available; the price of on-court PlaySight system is far beyond the budget of most tennis clubs; and the IBM data from professional tournaments is provided to fans in limited amounts and mainly for entertaining purposes. That leads to a significantly little amount of studies or practical application guidelines for coaches on using on-court systems and data in player development and coaching. At the time, Zenniz stepped up with a comprehensive game-tracking system easily accessible to coaches and players of all levels. Due to affordability and ease of

use, Zenniz technology has quickly spread across Finland and neighbor countries, and is now present in major local tennis clubs.

The main objective of this work is to explore performance indicators tracked by Zenniz on-court system to create a link between data and player development, and provide an effective tool for training and monitoring certain strategic aspects of performance by using Zenniz system as a tool.

The main task is to back the suggested drills and tools by as much statistical evidence and information available at the moment in the field of tennis technology and analytics, as well as minimize subjective interpretation on the topic. The secondary tasks include:

- Define the role of game-tracking technologies in tennis coaching;
- Research what are performance indicators in tennis and their role in coaching;
- Provide information on which performance indicators can be tracked by Zenniz game-tracking system;
- Identify the trends in modern tennis based on the actual and average values of performance indicators;
- Create an effective and easy to use coaching tool for players of different levels;
- Indicate how Zenniz tracking data can be used to monitor player development.

The content of this paper is limited to practical application guidelines for Zenniz on-court system, as it is the most used and available system in the target area, Finland. The theoretical part of this work focuses on analysis of innovative technologies, in particular related to player performance tracking in tennis and the emerging importance of data analysis provided by such technologies. Therefore, this guidebook excludes any data or analysis on such areas as court, equipment or any other tennis technologies as irrelevant to the scope of this work.

The practical guidelines in this thesis are based on analysis of performance indicators in tennis tracked by Zenniz on-court system and latest statistical data related to them. This guidebook does not relate to player or stroke properties. Due to technical specifi-

cations, Zenniz game-tracking system is limited to identify and record data related to tactical and technical skills where the player needs to improve, and does not perform biomechanical analysis to investigate problems with technique during application of those skills. Therefore practical application guidelines exclude the biomechanical aspect of tennis stroke technique. It is important to bear in mind, that tennis is individual sport and therefore this work should be viewed and considered with respect to holistic approach in player development, and applied for the needs of the player respectively. Theoretical and practical parts of this work are oriented towards singles game coaching.

The performance level of the players does not limit the usage of the system in coaching or player profiling process. Also, there are no age limitations to using the system. However, the choice of the drill appropriate for player's skill level increases the effectiveness of the practice

## 2 Emerging technologies in tennis coaching

From the very beginning, the course of evolution of tennis as a sport has been heavily affected by human inventiveness. Through the giant leap from wooden racquets to automated line calls, technological advances have reshaped and defined the modern game of tennis. Technological innovations hasn't only influenced the way tennis is played and perceived, but also affected the training process of the players.

Modern era, as well as modern sports, is dominated by developments in computing power, motion analysis software and electronics. The decrease in their costs has facilitated the development of systems that make it possible to collect highly detailed information about player performance. These products make it possible to gather a large amount of information in real time that would previously have taken days or even weeks, or was simply unavailable. In fact, a standard tennis match between two players creates an average of 60-70,000 records (SAP, 2015).

With information being instantly available to coaches and players, the proper analysis of the performance-related data can affect decision-making, enhance playing experience and improve the quality of coaching process.

In 2014 the International Tennis Federation (ITF) has changed The Rules of Tennis to allow the use of 'smart' equipment during competition, and to permit access to the information generated by that equipment at times when coaching is allowed. Same year the Women's Tennis Association WTA in collaboration with software corporation SAP SE has announced a technology innovation to allow coaches to bring a WTA-authorized mobile device onto the court during a coaching break and use real-time data insights to analyze player performance in a match. The former CEO and chairman of the WTA, describes the role of technology in women's tennis as follows:

We believe that technology will play a major role in modernizing our sport, delivering more to our fans without altering the integrity of the game. Tennis is a data-driven sport and information is power. Many of our matches usually come down to just a few key points and any advantage

that players and coaches can gain by analyzing trends and data could deliver an edge in the match. (Stacey Allaster, 2014)

On-court coaching was originally introduced by the WTA in 2008 as a broadcasting initiative, offering fans an inside look at the strategy between players and coaches.

The changes in rules and regulations by ITF approve the usage of new generation equipment such as tennis racquets with built-in sensors and data-tracking wearable devices. A recent worldwide survey revealed that the top fitness trend in 2016, according to the American College of Sports Medicine, is wearable technology (Thompson, 2015). The trend was predicted by a market report on smart wearable devices issued in 2013, which also suggests that by 2017 fitness and sports wearable devices will dominate the market (Juniper Research, 2013). In addition, the global tennis racquet market is reported to grow with a yearly rate of 2.32% by 2020 (Technavio, 2016). The above information suggests the tendency to increase in popularity and usage of technological innovations in tennis coaching, and sport in general. Since advanced product innovations are rapidly developing and impacting tennis, it is important to understand how these systems operate and what data they provide. The ITF refers to such products as 'Player Analysis Technology' (PAT) regulates their use in professional and junior tennis circuits. PAT includes any equipment that collects, stores, transmits, analyses or communicates information on player performance, and may be a stand-alone device or incorporated within existing equipment (ITF, 2014).

The PAT products typically use sensors such as accelerometers, gyroscopes, cameras and electrodes, which measure force, movement and physiological information. These variables may be related to the player, technique or ball properties. Player analysis technologies can be generally divided into three categories of tennis specific equipment: integrated, remote and auxiliary.

As classified by ITF (2014), integrated equipment is carried or worn by players on court. This includes clothing – commonly referred to as wearable (items that would otherwise be classed as clothing); tennis-specific equipment (e.g. rackets); and non-tennis-specific equipment (e.g. heart rate monitors, activity monitors) (ITF, 2014). Sensors are the latest trend in collecting data on court in tennis, and are usually worn by a



player, attached to or built into the racket itself. They mainly record data related to player and stroke properties, and are often oriented towards improvement of player's technique. Currently, the trending integrated equipment brands on the tennis market are QLIPP, Zepp Labs, Sony, Polar, Pivot and Babolat. The range of their products provides statistical data on shot type, swing, speed, spin, and ball impact. Today, their accuracy is questionable but they are likely to improve quickly. Most of the products are compatible with mobile devices and work with applications for data management. The main disadvantage of this type of equipment is reduced capacity of rechargeable battery, and therefore usage time is limited to hours. Also, there are restrictions within internal memory of the devices, allowing limited amount of shot analysis data to be stored.

Any device that is not carried or worn by the player is referred to as remote equipment and is usually in form of an on-court system (ITF, 2014). Typically, such systems are camera and sensor-based. Upon installation, the system automates scoring, line calling and provides real-time and post-game statistics. Statistical data provided is largely ball related, but within some camera-based systems can also address the technical aspect. The on-court systems are diligently tested, enhanced, and updated, but for most the main limitations are affordability and accessibility. Since its' introduction as Challenge system in 2006, Hawk-Eye has been a dominant review system in tennis. The system is a computerized network of six cameras that follow trajectory of the ball, and based on that data use an algorithm to calculate the bounce of the ball within the 5 mm margin. But due to an estimated cost of \$100,000 per court, Hawk-Eye is only accessible by professionals and the world's top tournaments. Recently, the company has launched a tennis coaching system named Hawk-Eye Smart Coach. The system combines data visualization and video that enable athletes and coaches to biomechanically analyze technique and investigate on-court performance through ball tracking data. So far, only Kim Clijsters tennis academy has been reported to use the system. A less accurate PlaySight smart court technology is a full-court camera-and-kiosk system that uses six HD cameras and sensors to provide real-time and post-match statistics. The system uses image processing and analytical algorithms to capture and log stroke type, ball trajectory, speed and spin, in-depth shot data and player movement. Every playing ses-

sion is automatically uploaded to the PlaySight network cloud. The technology comes at a price of \$10,000 in addition to license fee, and is currently present in a number of European tennis clubs, including such facilities as Stefan Edberg's academy in Sweden and the French Tennis Federation at Roland Garros.

Compared to other PAT systems mentioned above, Zenniz game-tracking solution displays visible advantages. The on-court system is easy and rapid to install, and does not require third party involvement. Zenniz system uses 30 cable sensors installed around the court, and a connected screen display attached on the side of the court to stream real-time game data. To operate the system requires electricity and an Internet connection. After calibrating procedure, Zenniz instantly starts providing automated line calls and comprehensive game data. A low fee and a registered account are required to use the system - a significantly smaller investment compared to similar on-court systems. Currently, Zenniz game-tracking machines are present in major local clubs in Finland, and a number of European countries, including Sweden, United Kingdom and Belgium. The system is currently undergoing the process of ITF certification as PAT.

The final classified category of player analysis technology is auxiliary equipment, which does not record player performance information, but may perform any of the other functions of PAT, such as tablets, mobile telephones and software operating on those devices (ITF, 2014). Currently, the most trending and used forms of auxiliary equipment in sports training, along with smartphones and tablets, is software applications. With the global smart device market rapidly expanding, the role of mobile applications becomes central. Easy accessibility to software application markets and simplicity of use attract a vast amount of users among coaches and players in tennis community. Such applications as Coach's Eye, Hudl Technique or Dartfish allow instant video recording and enable a number of performance analysis tools such as slow motion video replay, ability to make notes and store data for further player development tracking. The nature of collected data is oriented mainly towards movement and technical development and positively impacts player's awareness of own abilities; however, the fo-

cus on video analysis increases the risk of subjective data interpretation by coaches and players.

### 3 Zenniz performance indicators

As portrayed earlier in this work, it is evident that game data analyzing solutions dominate the field of innovation emerging in sports, and tennis in specific. Increasing accessibility of smart coaching systems, such as Zenniz, provides coaches with access to loads of critical information on player's performance. The use of performance indicators is essential within performance analysis to allow the vast amount of tracking data to be reduced to a more concise manageable representation. Hughes and Bartlett (2002) have identified serving, shot selection, execution and distribution, winners, errors and rally length as some of the common factors related to racquet sports. Hence, it is important to analyze and interpret the data variables correctly, because they offer a clear insight on important aspects of the game. Tactical evaluation can provide valuable information regarding patterns and styles of play to help optimize player's performance against specific opponents on different playing surfaces, whereas technical evaluation can identify areas of a player's game that require attention during training.

The main purpose of tracking data analysis within the modern tennis-coaching context is to provide feedback to players and accelerate their development. The ability to provide evidence that cannot be disputed undoubtedly speeds up the learning curve of the player and increases self-awareness.

The leading analyst for Association of Tennis Professionals (ATP), Craig O'Shannessy, suggests that based on deep data analysis of six different levels of play ranging from under 12 years old to professional, there is a massive disparity between the way tennis players practice and the way competitive matches are played. Therefore, it is essential for tennis players and coaches to take advantage of the vast amount of data provided by Zenniz and use the numbers to decide which choices are more productive.

Zenniz is an acoustic solution that tracks the shots and bounces by the sound of the ball at a rate of several million calculations per second. The on-court system uses sound sensors and advanced algorithms to identify and record game related variables. These are referred to as Zenniz performance indicators (ZPI). Tracking data includes the player's serve direction and placement on the court, contact point for returning a serve, and placement of shots during the rally. The system operates in four interactive modes: rally session, stroke and serve practice, and match play. Automated line calling is a constant for all playing modes. Each mode enables specific type of practice or play with corresponding real-time or post-play statistical feedback. All recorded data is saved in database and can be viewed and replayed at any time.

This chapter reviews Zenniz performance indicators in correlation with latest statistical data from tennis circuits and available scientific research, in order to provide best practical application tools with respect to current trends in modern sport. The performance indicators analyzed in this chapter are tracked and recorded by the Zenniz game-tracking system in four playing modes.

### 3.1 Average rally length

The average rally length (ARL) indicates the average number of shots in a rally for both players combined. The type of court surface was found to have significant influence on the average length of the rally (Schonborn, 1999). The average rallies on clay court are reported to be the longest, whereas average grass court rallies the shortest among all court surfaces in tennis (See Figure 1).

The ability to consistently maintain the ball in the rally is defined as shot tolerance. However, the usefulness of this quality in terms of performance relatedness can be challenged by recent statistics, suggesting that there are 3 specific rally types occurring in tennis, and the percentage breakdown of total points is as follows:

- Short (0-4 shots) - 70%
- Medium (5-8 shots) - 20%
- Extended (9+ shots) - 10%.

The data is provided for the following six levels of play: under 12, 14, 16, 18 year old, college and professional tennis (Craig O'Shannessy, 2016). The finding suggests the most common average rally length in modern tennis of all levels is below 4 shots.

In fact, during all four Grand Slam tournaments for both men and women, rallies of 27-30 shots occur less than 1% of all the points played. The longest rallies for both genders typically vary within 30-40 shot range (Craig O'Shannessy, 2016).

The latest statistics for 2015 and 2016 Australian Open reveals the average rally length for men to be 3.8 and 3.7 shots respectively, and for women 3.8 and 4.1 shots (Craig O'Shannessy, 2016). The above statistic pinpoints that currently the average rally regardless of sex of the player to be less than 4 shots. Furthermore, the most common rally type of 1 shot occurs in tennis 30% of the time for both men and women (Craig O'Shannessy, 2016).

The current trend in modern tennis dictates the rally-practicing routines with the focus on first shots, such as serve and return, and the one shot following afterwards.

Zenniz tracking system stores data on every session's average rally length as well as all-time ARL.

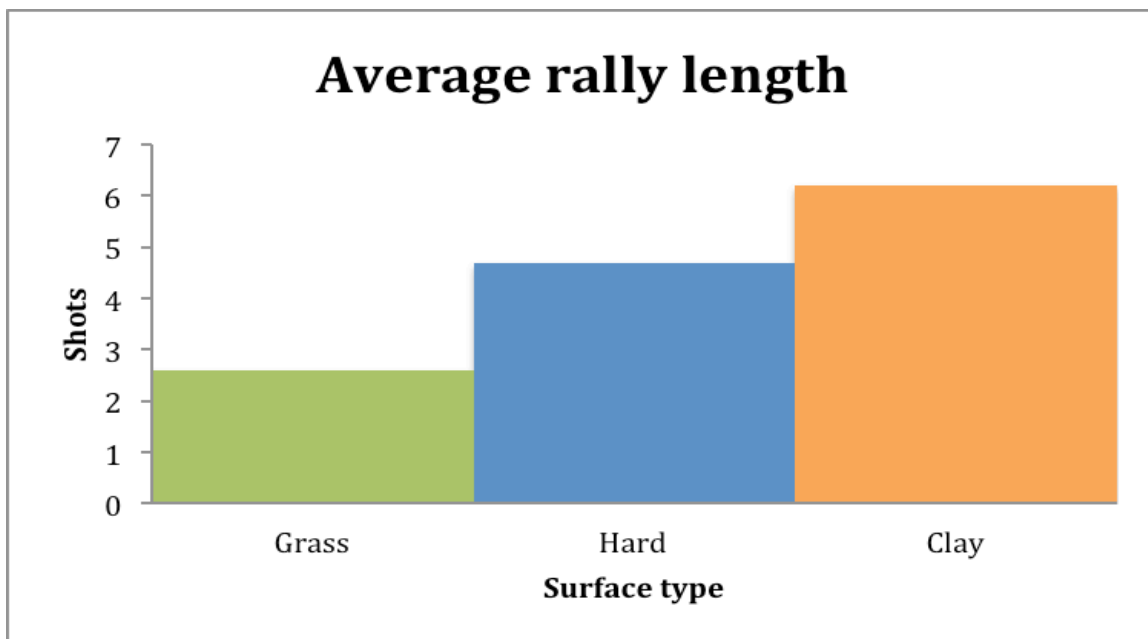


Figure 1. Average length of rallies (measured in shots per minute) per surface type published by Schonborn (1999).

### 3.2 Shot count

Shot count indicates total amount of shots hit by the player during specific playing mode (practice or match play). The significance of this variable is supported by deliberate practice concept introduced by K. A. Ericsson in 1993. The theory suggests that it takes 10,000 repetitive hours of deliberate practice to achieve expertise in a certain field of performance (Ericsson, 1993). In tennis, the theory is often converted to 10,000 stroke repetitions per element of technique. The Ericsson's model has been backed by the studies on myelin and its role on achieving sports expertise. Myelin is the tissue that insulates the nerve fibers in the brain to ensure clear transmission across synapses. The thicker the myelin gets, the faster and more accurately signals that control movement travel. With each repetition athletes thicken their myelin sheath for an activity, building more precision, skill and speed (Coyle, 2007; Fields, 2005).

The importance of deliberate repetition in sports highlights the need of monitoring the amount of shots performed by the player during practice session. The Zenniz smart court system stores the shot count data in session database, allowing the coach to monitor the progress at any stage of player's development.



### 3.3 Average rally tempo

Average rally tempo (ART) indicates the amount of shots per minute produced by the players. Tennis is an intermittent type of sport; therefore the level of intensity can vary greatly within the rally length. The average rally tempo represents the combined index of intensity in a point (Smekal, Duvillard, Rihacek, Pokan, Hofmann, Baron, Tschan & Bachl, 2001). The increase of the ART is proportional to increase of the speed in the game and players' physical activity. A notational analysis of elite tennis strategy by O'Donoghue & Ingram (2001) concluded the gender of the player and type of court surface among the factors affecting the intensity of the match play. The study also estimated average rally lengths for all four Grand Slam tournaments (See Figure 2). Grass courts enforce the highest shot rate tempo among all four Grand Slam surfaces. The results point out the necessity in adjustment of ART during practice drills to match performance demands on a certain court surface. Therefore, the average rally tempo can be concluded important variable in strategic preparation.

Another study on physiological demands of tennis match play examined 10 matches of 20 Austrian national league players (Smekal, 2001). The average rally tempo value of 270 elite male tennis games resulted in 42.6 shots per minute. The above data can be adapted and monitored in practice using Zenniz system.

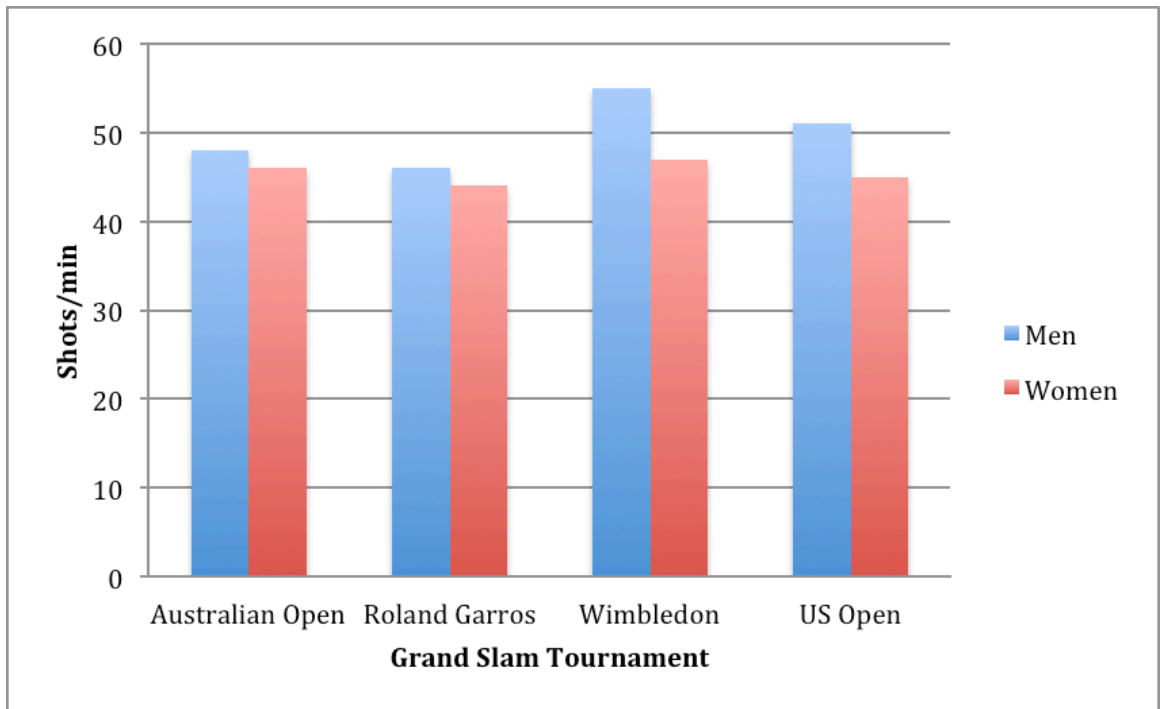


Figure 2. Average shot rate per minute of rally time for men and women published by O'Donoghue & Ingram (2001).

### 3.4 Speed

Speed indicates how fast the ball travels between the moments of impact with the racket and bounce. Speed plays a crucial role in modern tennis of all levels. The sport is seeing increase in speed of the game due to several factors. Rackets, courtesy of continued technological advancement, are becoming increasingly efficient. More research in field of sports science has contributed to improved levels of athlete's physical and technical preparation, leading to more powerful strokes. As recorded officially, professional tennis players are able to hit serves as fast as 263 km/h, 201 km/h fast forehands and 185 km/h backhands (IBM, 2014). The average first serve speed for elite male players is 184.1 km/h and 158.5 km/h for female. The average second serve speed is 150.4 km/h and 133.4 km/h respectively (Cross, 2014).

The Zenniz game-tracking solution records instant, fastest and average speeds for all types of shots occurring in the play. The average speed index accurately characterizes the state of player's physical condition, and also levels of fatigue. The study concludes that technical and biomechanical properties of the stroke significantly affect the speed of the stroke (Elliot, 2006). For instance, there is an inverse relationship between speeds of serve and spin rate (Kovacs & Ellenbecker, 2011). Flat type of serve results in the highest speed outcome, whereas kick serve displays the highest loss of speed (See Figure 3). Thus, instant feedback on speed of the shot can effectively impact the quality of technical development and increase player's interest towards the practice.

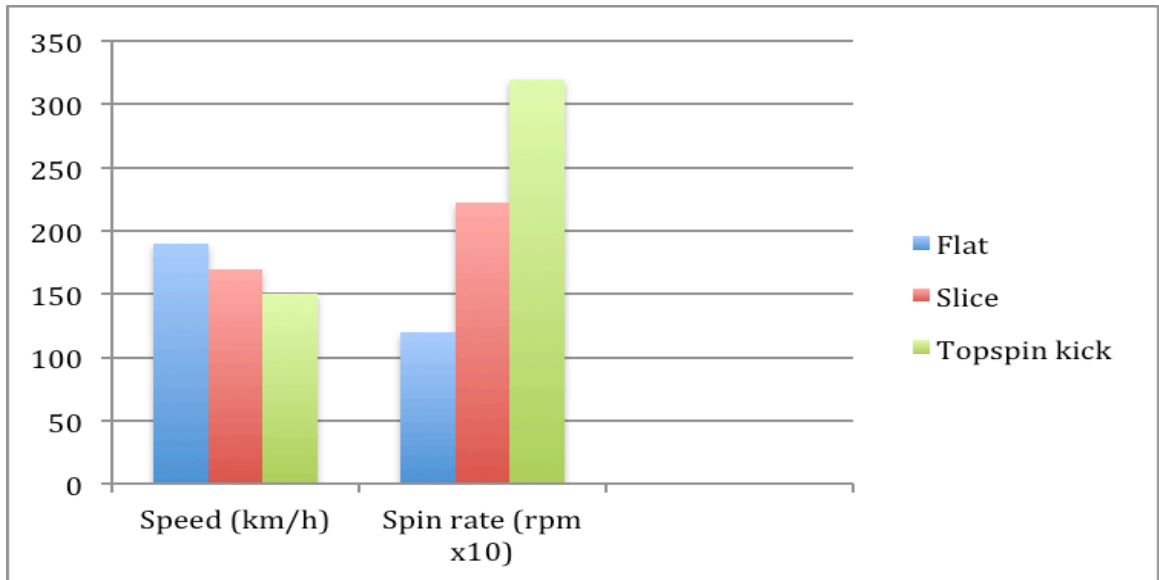


Figure 3. Speed versus spin comparisons among flat, slice, and topspin kick serves published by Kovacs & Ellenbecker (2011).

### 3.5 Hitting point

Hitting point indicates a place on the court where the ball impacts the racquet. Zenniz transforms the data on player's hitting points into interactive shot map. This variable gives an insight on the player's positioning, and is critical to identifying playing style. Using shot map in analyzing and understanding events happening in the game is a rising trend in sports analytics.

Hitting point is directly related to the level of offensiveness or defensiveness of the player. According to that, contact positioning can be divided into offensive and defensive. In tennis about 80% of all strokes are played within 2.5 m of the player's ready position. About 10% of strokes are made with 2.5–4.5 m of movement, and fewer than 5% of strokes are made with more than 4.5 m of movement (Fernandez, Mendez-Villanueva & Plum, 2006). A deviation from the average hitting point can increase or decrease the above levels. For instance, a player desired to use more aggressive style of play would benefit from taking the shots earlier and inside the baseline in order to increase the rally tempo. This would result in forcing the opponent further behind the service line and furthermore dominating the game. A valid example of such tactical solution is Roger Federer's 6-0 6-3 6-4 win against Marcus Willis during Wimbledon 2016 (See Figure 4).

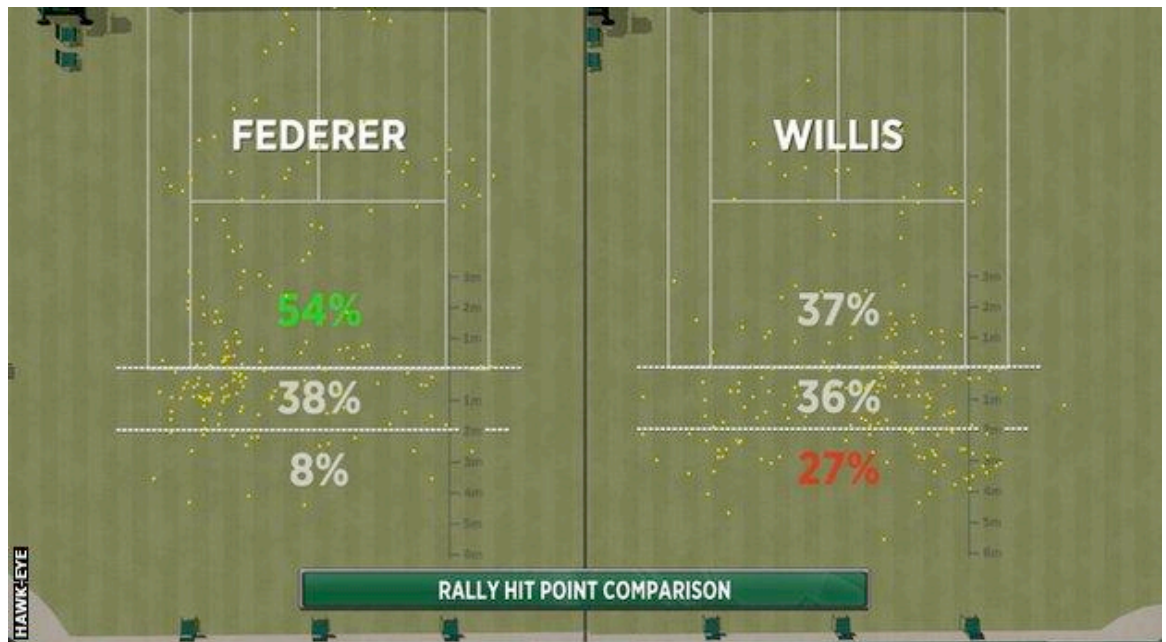


Figure 4. A comparison of contact point percentages in a rally. Data source: Hawk-Eye, 2016. Image source: <http://www.bbc.com/sport/tennis/36666910>

This also relates to contact positioning on return of the serve, with players stepping early into return being more aggressive. However, hitting point during return is also largely affected by the speed of the serve. Players usually position themselves further for first and closer to the baseline for second serve return (See Figure 5). This is due to an average difference of 34 km/h and 25 km/h between the first and second serves for men and women respectively (Cross, 2014).

Zenniz tracking system records and stores contact point maps, to be visualized at any time for further review or comparison. Tracking and comparing hit point maps over the time help to monitor important changes in player's tactical development and playing style. A small deviation in a certain data variable, as a result of effective training, can cause a great difference in the final outcome (See Figure 6).

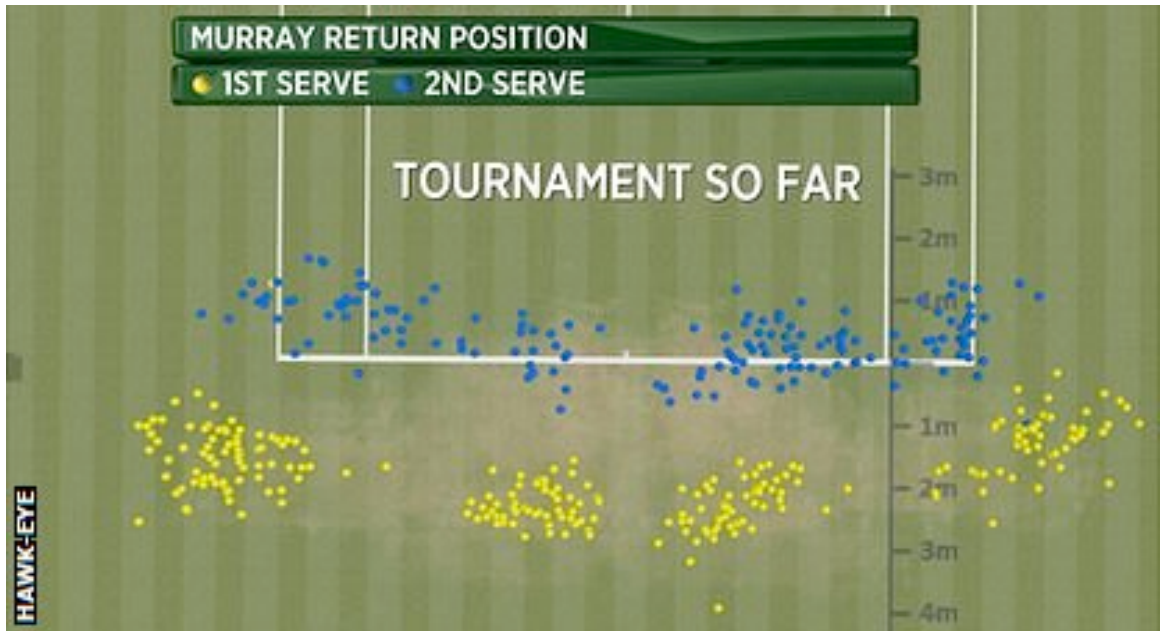


Figure 5. Andy Murray's return hitting point map. Data source: Hawk-Eye. Image source: [https://ausapproach.files.wordpress.com/2015/07/68557372\\_murrayreturnposition-thistournament.jpg](https://ausapproach.files.wordpress.com/2015/07/68557372_murrayreturnposition-thistournament.jpg)

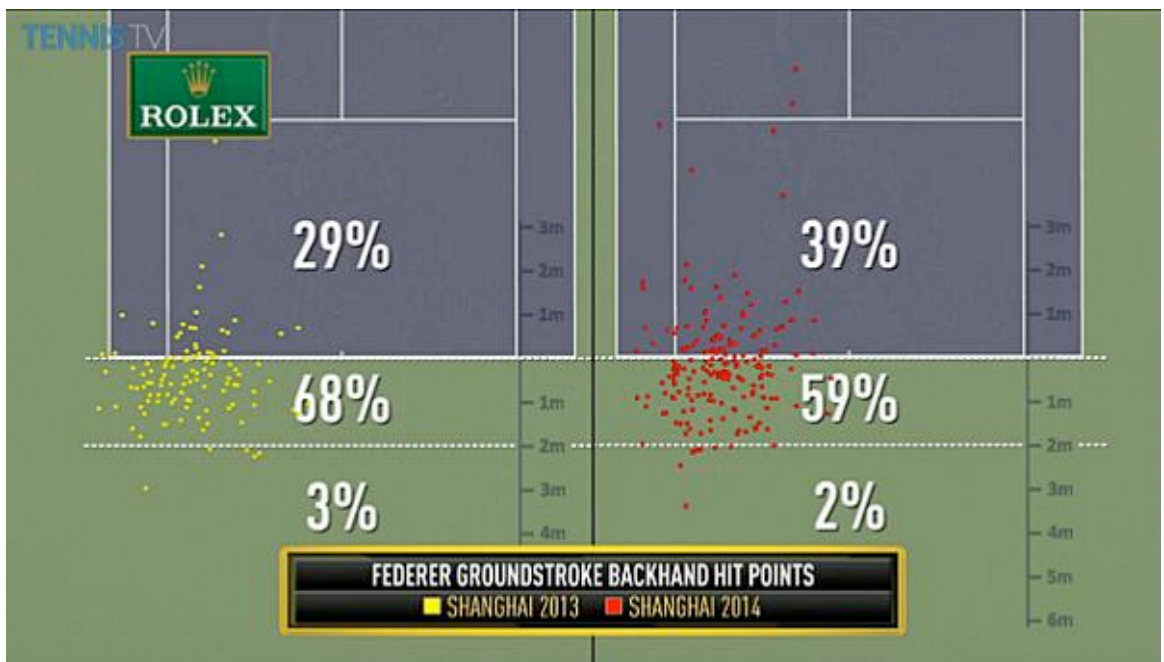


Figure 6. A comparison of Roger Federer's backhand hit point maps during 2013 and 2014 Shanghai Rolex Masters. Data source: Hawk-Eye. Image source: <https://twitter.com/braingametennis/status/520589179978547200>

### 3.6 Bounce

Bounce pinpoints the spot on the court where the ball landed. Such spots can be also referred to as shot placement. Zenniz uses data on overall shot positioning to create a comprehensive shot map. In professional tennis for instance, IBM, SAP and Hawk-Eye often provide shot maps for some Grand Slam and tour matches, using data generated by Hawk-Eye. Bounce maps can provide critical information on players' tactical abilities and level of accuracy. The latter directly reflects technical skills of the player. Shot placement monitors two crucial accuracy components: direction and depth. Direction involves three major areas: cross-court, middle and straight, and refers to both serve and strokes (See Figure 7 and Figure 8). Analysing shot distribution by direction can reflect tactical choices made by player during the match. In addition, tracking shot placement during direction-training drills increases practical effectiveness.

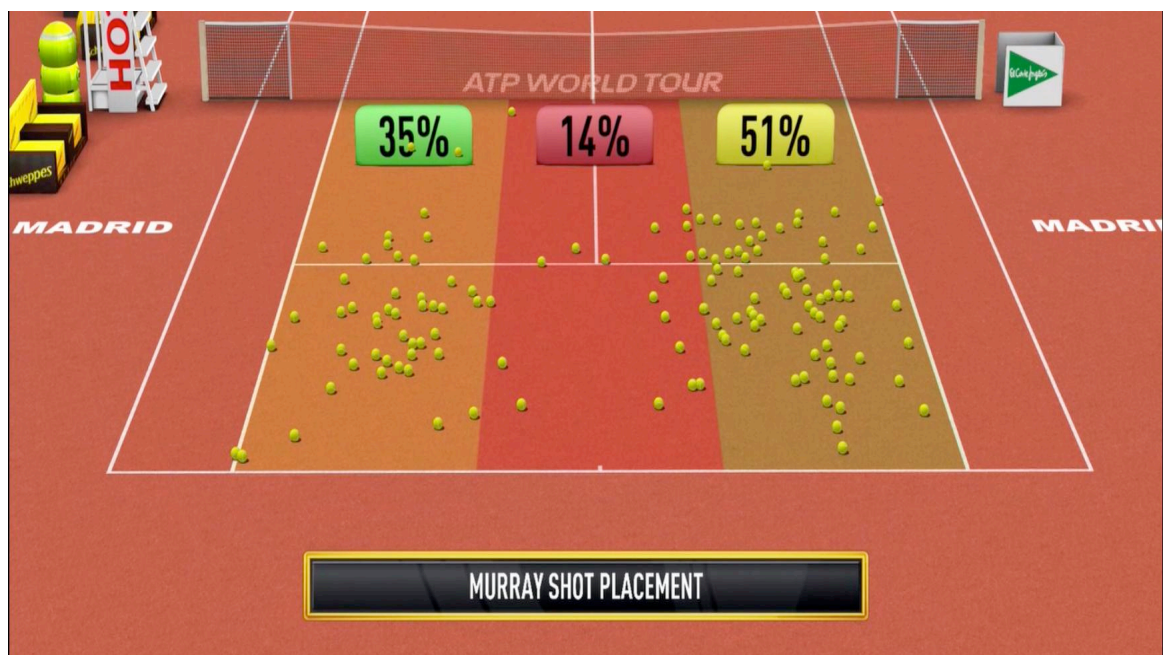


Figure 7. Andy Murray shot placement by direction during 2016 semi-final match in Madrid. Data source: Hawk-Eye, 2016. Image source: [https://www.reddit.com/r/tennis/comments/4i9c7m/match\\_thread\\_murray\\_vs\\_nadal\\_semifinal\\_2016\\_mutua/?st=ivsb6pd0&sh=5f6f3f32](https://www.reddit.com/r/tennis/comments/4i9c7m/match_thread_murray_vs_nadal_semifinal_2016_mutua/?st=ivsb6pd0&sh=5f6f3f32)



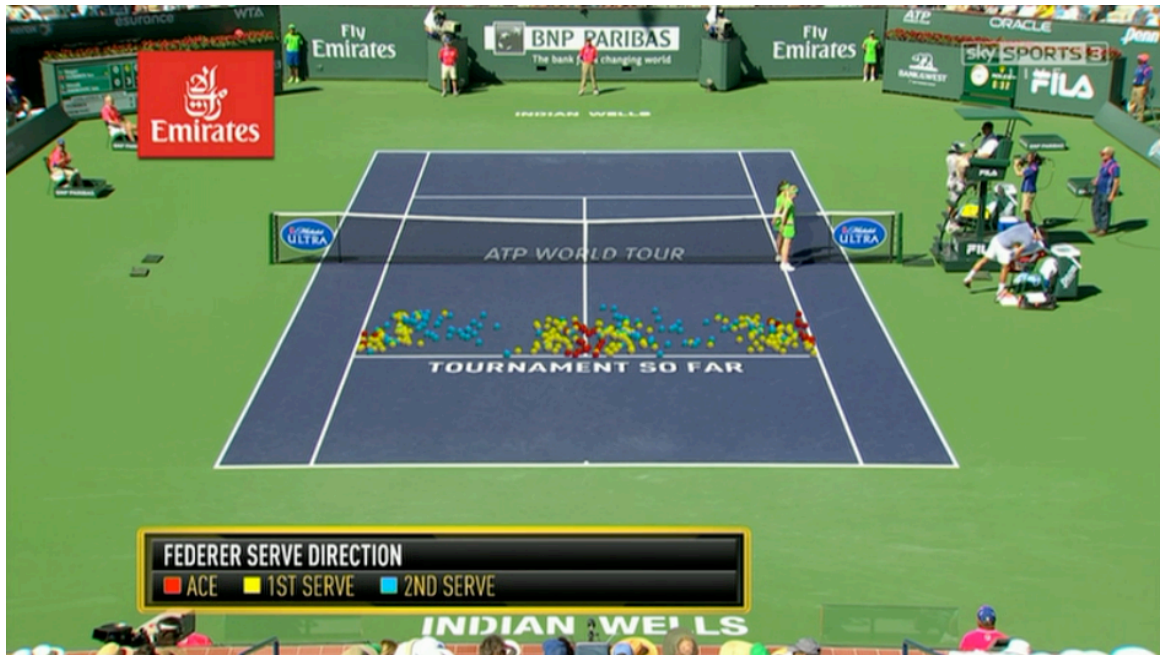


Figure 8. Roger Federer serve distribution by direction at BNP Paribas Open 2014.

Data source: Hawk-Eye, 2014. Image source:

[https://www.reddit.com/r/tennis/comments/20kpog/match\\_thread\\_roger\\_federer\\_vs\\_novak\\_djokovic\\_mens/?st=iw3f473e&sh=2fa76b22](https://www.reddit.com/r/tennis/comments/20kpog/match_thread_roger_federer_vs_novak_djokovic_mens/?st=iw3f473e&sh=2fa76b22)

Depth includes both hitting deep (closer to the baseline) and short, and is reported as the factor forcing the most errors in the match. Figure 9 illustrates a comparison of percentage breakdown of shot placement by depth for Novak Djokovic and Rafael Nadal during 2013 China Open match, which ended in favour of Djokovic. Also, varying the depth of the shots by mixing short and deep bounces causes a disruption in opponents playing rhythm and contributes to a greater winning percentage.

Monitoring shot placement during practice and match play helps to increase player's awareness of own accuracy, making it a powerful tool in player development process. Zenniz enables unique target area practice mode to increase effectiveness of accuracy-practicing drills. The system offers a number of optional target patterns, as well as ability to customize desired target areas.



Figure 9. A comparison of percentages of shot distribution by depth. Data source: Hawk-Eye, 2013. Image source: <https://twitter.com/tennistv/status/386778729688481792>

### 3.7 Game patterns

Contacts and bounces connected form a sequence of events known as game patterns. Rally is a combination of patterns executed by players. Zenniz records every rally that takes place on the tennis court and saves it in the session's database. All rallies are available for animated 3D review at any time. The function allows coaches to monitor not only direction and depth of the shots, but also trajectory of the ball.

Collectively, game patterns are an accurate indicator of competitive intelligence and creativity. Creativity reflects player's decision-making, but is highly dependable on technical skills. The ability to utilize diverse types of strokes to construct strategically effective patterns leads to a higher winning chances in the game. Tactically, game patterns can be classified into primary - used 70-80% of the playing time, and secondary - 20-30% (O'Shannessy, 2016). Primary game patterns are a direct reflection of player's strategy or playing style. Generally, playing styles can be classified into three categories: baseliner, serve-and-volley and all-court player. Each category is dominated by certain game patterns. The success of a certain playing style varies among men and women's professional tours. An interesting data on point winning percentages by players employing a particular strategy has revealed that approach winners (66%) dominate the women's tour, whereas serve-and-volley players win most points (68%) on professional men's tour (O'Shannessy, 2016).

According to statistics, the most common type of point in tennis is a 0-4 shot rally (O'Shannessy, 2016). It occurs 66% of points in women's tennis and 70% in men's. The data highlights the dominance of one and two-shot patterns, such as serve, return, serve plus one shot and return plus one shot. Former world number one Rafael Nadal uses serve plus forehand pattern on average 78% of the points with an average winning percent of 64.3%. Less than 11% of the points in tennis are extended rallies of more than 10 shots (O'Shannessy, 2016). Figure 10 illustrates patterns used by Kei Nishikori against opponents like Federer, Djokovic, Murray and Wawrinka. The data presents 2,443 baseline shots that were played over a period of 6 month in 2014-2015.

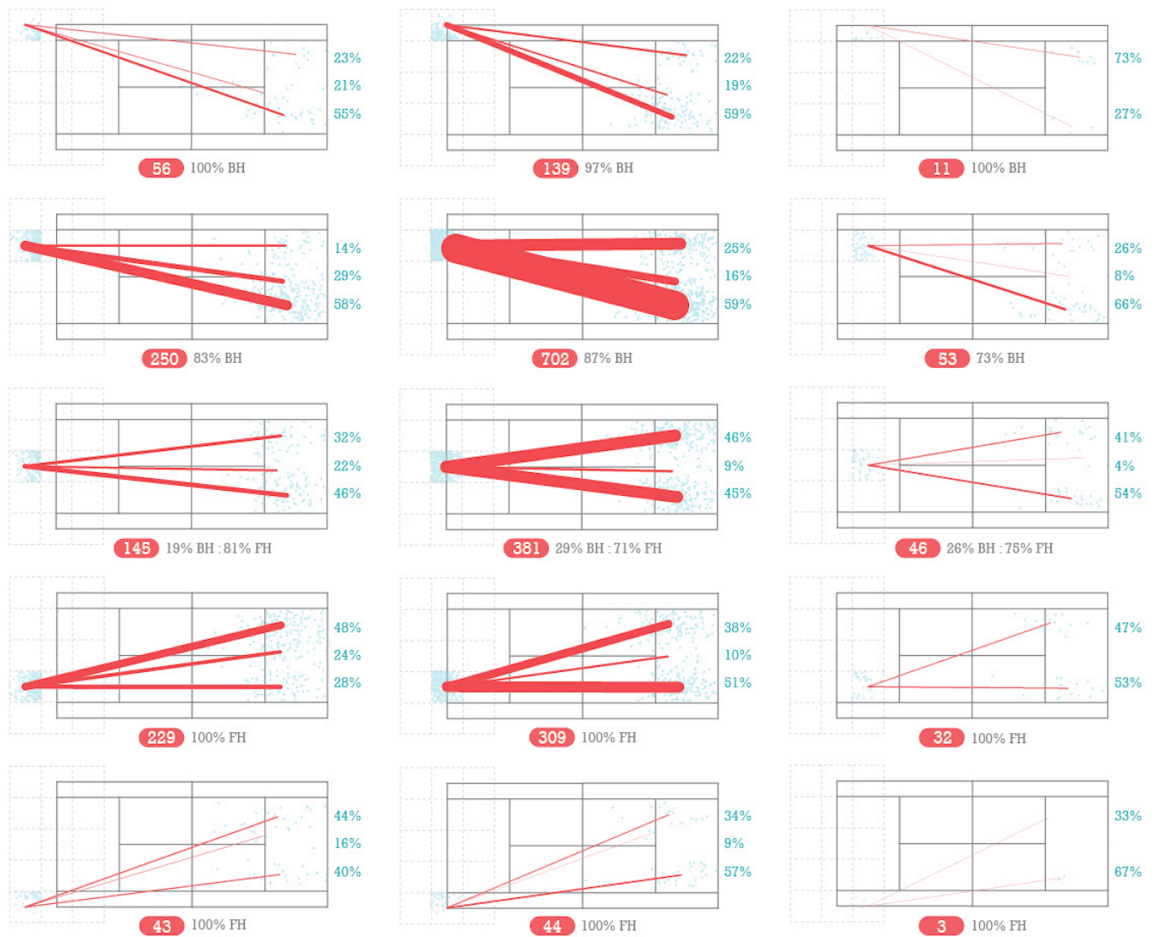


Figure 10. Baseline patterns used by Kei Nishikori. Data source: Hawk-Eye 2014-2015.  
 Image source: <http://gamesetmap.com/?p=1261>

### 3.8 Duration

Zenniz game-tracking system records duration of every training session performed using one of four playing modes. Duration refers to both rally and match duration. Time factors in tennis match play have long been among most researched topics in terms of performance analysis. O'Donoghue & Ingram (2001) found direct relation between player's gender and rally times (See Figure 11). Rallies on clay are significantly longer than on any other surface, which suggests the relevance of extended rally times during preparation phases for clay court matches. Although the average rallies on grass are the shortest, it takes 30 more points in a match than on clay courts (Kovalchik, 2013). The average length of a WTA singles match is about 97 minutes, with a range from 40 minutes up to 225 minutes (Jeff Sackman, 2016). In 2012, matches on the ATP tour were an average of 110 minutes (Kovalchik, 2013). The average value trends can be adapted training process to assure the player is prepared for performance demands of modern match play in tennis.

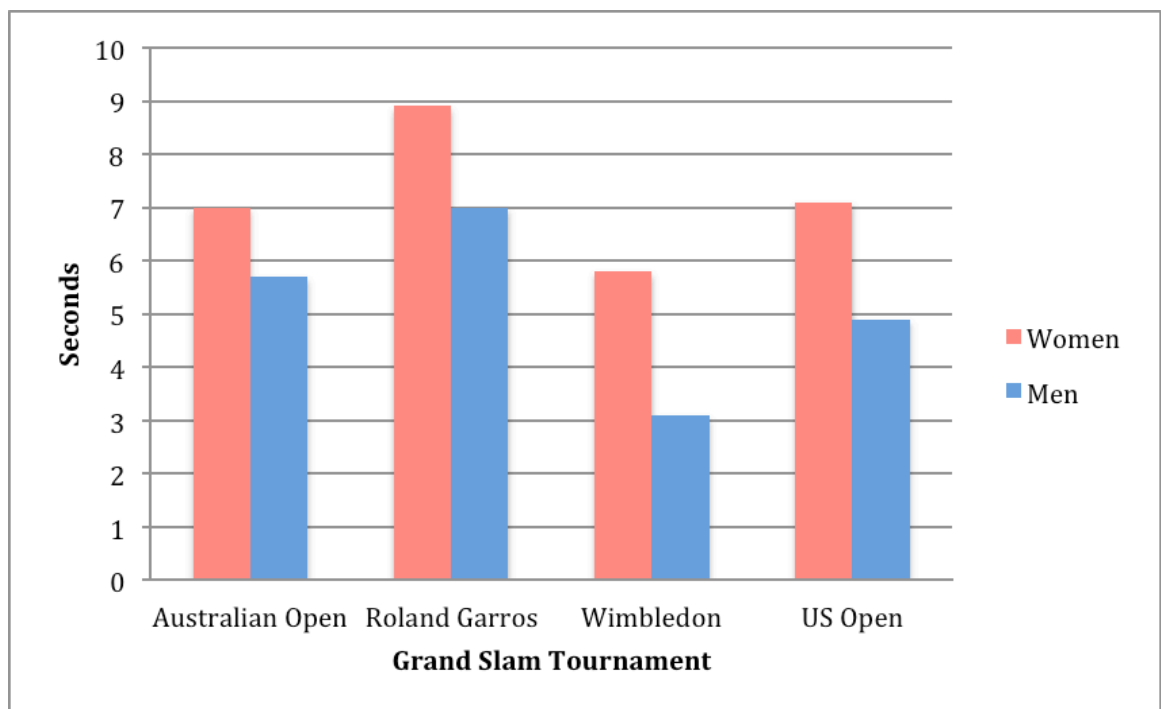


Figure 11. The average rally length in seconds for men and women published by O'Donoghue & Ingram (2001).

### 3.9 Match statistics

Analytical review of statistical data from professional circuits provides a critical insight on the level of performance in modern tennis. Furthermore, there are found significant correlations between player's ranking and statistical variables (Reid, McMurtrie & Crespo, 2010). Zennis game-tracking system calculates values for such crucial performance indicators as serve and return percentages (See Figure 12).

In modern tennis, serves and returns remain the strokes that most influence the match results. In fact, several studies (Schonborn, 1999; Kleinoder, 2001) considered serve and return as the most important shots in tennis; furthermore, winning percentages of the first shots are proven a valuable predictor of top 100 ATP ranking (Reid, McMurtrie & Crespo, 2010).

The values of serve and return winning percentages are interconnected to the type of court surface (Hughes and Clarke, 1992). A recent statistical comparison has indicated Wimbledon to have the highest 1<sup>st</sup> serve winning percentage of 71.1% among all four 2016 Grand Slam events (IBM, 2016).

On average, ATP players win more points on their first serves than second serves, while they are more likely to win points when receiving second delivery. More specifically, where the average top 100 player wins 51% of their second serve points, the game's top players appear to win approximately 10% more points when they miss their firsts serves (e.g. Novak Djokovic 56.6% - the highest in ATP top 100). Similarly, the average top 100 ATP player wins 49% of second serve return points, yet top 10 players like Novak Djokovic are more effective (58.1% - the highest in top 100) (Reid, McMurtrie & Crespo, 2010).

According to ATP statistics leader board (ATP, 2016), the highest career 1<sup>st</sup> serve returning percentage on all surfaces against all players is 36%. Interestingly, the highest career 2<sup>nd</sup> serve returning percentage on all surfaces is 56.3%, with Andre Agassi coming second with just 0.5% less (ATP, 2016). The highest average percentage of 1<sup>st</sup> serves in on professional men's tour is 70.4% and belongs to Rafael Nadal (ATP, 2016).



The total points winning percentage indicates the overall effectiveness of all performance indicators combined. In 2015, Novak Djokovic raised his overall percentage of points won by just 1%, from 55 to 56%, and posted a record-breaking 82-6 win-loss record (O’Shannessy, 2016). At the same time Bernard Tomic, a top 20 player, has won only 50% of the points he played over the last three years (O’Shannessy, 2016).

The average and individual statistical values can be used as landmarks in long-term player development. The actual player’s tracking data recorded during the match can be used in player profiling in terms of long-term development. Comparison of previous and current player’s match statistics after a training period can give an accurate feedback about the effectiveness of the approach and training methods used by the coach in practice. Therefore, statistical data is an accurate marker of player development.



Figure 12. Zenniz match statistics. Data and image source: Zenniz, 2016.

## 4 Practical application

### 4.1 Objective

The idea to create a guidebook for coaches emerged on behalf of Zenniz Company. The main objective was to arise the interest towards Zenniz game-tracking system among tennis coaches, and therefore increase the use and popularity of the system.

The guidebook to using Zenniz game-tracking system combines the review on player performance tracking technologies and statistical data tracked by Zenniz on-court system, and merges it with practical guidelines on using the system in coaching. The topic is strongly correlated to data analytics in tennis.

The main goal was to identify best possible training drills and routines based on performance indicators that are tracked by Zenniz game-tracking technology. In terms of strategy, practical application of this work is mainly oriented towards singles game coaching.



## 4.2 Methods

The guidebook was divided in two main parts: theoretical and practical.

Theoretical part includes definition on main Zenniz performance indicators and their average values according to the latest analytics in modern tennis. The practical part contains application guidelines on using Zenniz system as a coaching tool and practice examples. The application guidelines are presented in form of solution tables. Solution tables are divided into three categories: stroke, serve and intensity. Each solution table suggests practice methods according to playing level of the player and objective of the practice (problematic area). The main playing levels defined are: beginner, intermediate, advanced and professional. The definition of each playing level as follows:

1. Beginner - players with no playing experience, or training for a short period of time in progress of learning basic technical and movement skills, usually with limited or no competitive experience;
2. Intermediate - players displaying basic technical and movement skill level, with moderate performance level and limited competitive experience on national level (Finnish national ranking system class D);
3. Advanced – players of above average technical and movement skill level, with consistent performance level and rich competitive experience on national level (Finnish national ranking system class B-C);
4. Professional players with high performance and overall skill level, competing within the highest national division, or any level of international junior or professional circuits, ranked within highest national ranking level (Finnish national ranking system class A), or present in ITF, WTA or ATP tour rankings.

The coaches are encouraged to find the solution from three tables according to player's level and practice objective, and merge it into ready-to-use practice drill using Zenniz game-tracking system. The practice implementation step-by-step process for coaches was introduced. For the purpose of simplifying the understanding of the process, actual practice examples are provided. The examples are presented in the following four areas: stroke, serve and rally practice, and additional section on player profiling. The

sections were defined according to the playing mode used during the execution of the practice. Each practice example includes practical drill designed to improve a certain technical or tactical aspect of the stroke. The player profiling section includes guidelines on monitoring player's development in relevance to long-term term player development aspect.

Each practical example focuses on a certain type of practice according to the playing level of the athlete. The structure of examples consists of preparation, implementation and evaluation sections. Each section includes descriptive and practical information on executing the drill. Preparation section defines such practice properties as:

- Type of the stroke: groundstroke, volley, special shot (slice, drop shot or smash) or all strokes combined;
- Practice objective, such as accuracy (direction or depth), shot tolerance, creativity or level of offensiveness/defensiveness;
- Skill level of the player;
- Player's position on the court during execution (baseline, approach or net);
- Target size;
- Gender of the player;
- Type of practice execution: coach to player, player to player or player on his own;
- Shot count referring to the amount of shots needed to complete the drill;
- Suggested average rally tempo and length;
- Practice court surface type: hard, clay or grass;
- Shot distribution: restricted or random;

Preparation section for player profiling also includes general information about the player, such as name, gender, year of birth, level and strategy. The figures for preparation section of the practice examples were adapted from the theoretical part of this work. Therefore, all practical guidelines correlate with research information and analytical data available on the topic.

Implementation section includes instructions on using Zenniz system's playing modes during execution of a certain practice drill.

Evaluation section highlights performance indicators important to monitor according to the practice type using Zenniz system feedback features. It also indicated such executed practice properties as average groundstroke speed, shot count (referring to the total amount of shots completed by each player during execution), strokes-in percentage, average rally length and tempo. The tracking data from the actual training sessions was used in evaluation section of the practice examples in the guidebook.

The emergence of player profiling section was relevant to system's valuable feature to store tracking data on player's performance in session database. This allows monitoring player's development on long-term basis. The player profiling section includes example on creating a comprehensive player profile based on performance indicators tracked by Zenniz on-court system. The profile reflects real data variables tracked by Zenniz system and collected during the validation period of the guidelines.

### 4.3 Implementation

The validation of the practical examples from all four sections of stroke, serve, rally practice and player profiling took place during the period of time between December 2015 and November 2016 in Vierumäki tennis center, Finland. The participants were female and male Finnish tennis players. The level of play varied from beginner to professional (Finnish national A1 class). The age of the players varied from 14 to 39. There were no age or skill level limitations for practical application of this work. The execution times of the practice drills varied from 4 to 34 minutes. The execution times of assessment drills for player profiling section varied from 2 to 12 minutes.

The practical drills were executed in three ways: player to player, coach to player (coach feeding the ball) or player on his own under coach's supervision. The maximum amount of players participating in practice sessions was limited to two with the goal of maximizing the accuracy of received data. Due to technical specifications of the system, the rallies can be performed with single ball only; therefore tracking data can be effectively defined for maximum two players on the court. However, practical application of Zenniz game-tracking solution in practice is not limited by amount of players and can be successfully performed with larger groups of players.

The implementation of the guidebook started immediately upon finalizing of this thesis. The users of Zenniz game-tracking system were notified via email about delivery of the coaching tool, accessible to all players and coaches. The guidebook was made available online to all registered and potential users. The Google online sheet has been created, for users to be able to generate the practice guidelines according to the playing level and practice objectives. The sheet also included development-monitoring option in form of the progress chart.

## 5 Discussion

There is little doubt that technologies for data tracking will play more of a role in tennis coaching in the future, but for now the main challenges in terms of accessibility. The review on innovative technologies in modern tennis has shown limited access to comprehensive data tracking technologies such as on-court systems due to their costly prices and operational complicity. In fact, the accessibility to modern data tracking technology is limited in form of hierarchy; the most advanced innovations display such high costs, that only big budget clubs and highest-level tennis tournaments are privileged to use them. Average tennis enthusiasts and local clubs in their turn are limited in access to moderately priced innovations, such as racquet sensors and software technologies. In these conditions, Zenniz solution presents a balanced combination of accessibility and innovative advantage.

However, there are still challenges in terms of acceptance by local coaches, supported by little to no practical information on possible advantages of applying game-tracking systems, such as Zenniz, in coaching. While analytics has not and will not replace talented players and good coaching as recipes for success, they have certainly become established as important augmentation for those basic success factors. The evident possibilities of deploying Zenniz data-tracking system and analytics in several different areas are:

1. Support for individual approach to player development;
2. Insights on player performance to provide specific tactical and technical training;
3. Modeling customized types of drills with the ultimate goal of strategic development, such as competitive intelligence and tactical options;
4. Sharing of performance analysis with players to reinforce messages and empower them to take ownership of their performance improvement.

The latter indicates that practical application of Zenniz game-tracking system correlates with fundamental principles of athlete-centred coaching approach, meaning players take ownership of their learning, thus increasing their opportunities and strengthening their abilities to retain important skills. Using Zenniz system as coaching tool facilitates this kind of learning, which develops player's ability to make informed decisions during competition, an important element in successful performance at any level.

Furthermore, some important performance indicators are impossible to coach or monitor without data-tracking system. Such crucial time-related performance indicators as average rally tempo have long been researched by scholars, but with no further application in coaching. Likewise, there are a number of studies on elite player's strategies, but the only way for coaches to monitor indicators related to them, such as tactical solutions and game patterns, was by means of observation. Such approach significantly increased the chances of subjective interpretation and difficulties in terms of application.

The increase in application of Zenniz performance-tracking system in coaching can positively influence the effectiveness of training session and coaching quality, and possibly reinforce the level of tactical and technical preparation of national level players. Therefore, it is important to provide local coaches with as much possible practical tools on using Zenniz systems across the country in their daily coaching. This leads to a possible need for creation of an online Zenniz drill database, which could be accessed by coaches and players at any time. The database could provide valuable coaching material to support national tennis coach education. It could be also beneficial for Finnish Tennis Federation to create national player database, based on player profiling done by the local coaches using Zenniz. For instance, this could give an important insight on current level of national junior player's across the country and assist in developing effective national long-term development program (LTDP). The Finnish Tennis Federation could also monitor the execution of the LTDP in local clubs and individual player development by performing assessments using Zenniz game-tracking system.

The Zenniz solution owns all functional properties of similar on-court systems allowed by International Tennis Federation for use during official tournaments. Therefore, it

has potential to be certified by ITF as official player analysis technology, and could be used as data tracking and coaching tool during ITF circuit tournaments.

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