Engineering a Table Tennis Smart Racket

For Game Analysis and Coaching
Table Tennis

The game of table tennis was created in England in the 1800s when lawn tennis was adapted to be played indoors (The history of table tennis, 2016). Since then, the game has grown into an Olympic sport watched by millions around the world and played in more than 100 countries (2015 world table tennis, 2015). The International Table Tennis Federation (ITTF) estimates that more than 40 million professionals play table tennis while many others play for fun (Table tennis started, 2016).

![A depiction of early table tennis](Table tennis started, 2016).

**Figure 1** | A depiction of early table tennis (Table tennis started, 2016).

Gameplay

Table tennis consists of opposing players using rubber rackets to hit a small plastic ball over a net from one side of a table to the other. A player can score a point if the ball bounces twice on the opposing player’s side or if the ball bounces once and the opposing player fails to return the ball back over the net. The players take turns serving twice each rotation and points are awarded by rally scoring. The first player to reach 11 points will win the game. When a majority of three to seven games are won, a player wins the match (The rules of table tennis, 2016).
Official Table Tennis Rules

The sport of table tennis has some lengthy restrictions on the materials that can be used in gameplay. One example of these restrictions pertains to the ball; the governing body of the sport (ITTF) mandated that all balls used for gameplay be “made of celluloid or similar plastic material and shall be white or orange, and matte and weigh 2.7 g.” Also, “The table used in gameplay may be of any material but must yield a uniform bounce of about 23 cm when a standard ball is dropped on it from a height of 30 cm.” The playing surface must be uniformly dark colored and matte, but with a 2 cm wide white side line. As shown in Figure 2, the white line must traverse each 2.74 m edge and each 1.525 m edge. Restrictions in regards to the paddle used by players are also very lengthy. The ITTF rulebook states, “At least 85% of the blade by thickness shall be of natural wood; an adhesive layer within the blade may be reinforced with fibrous material such as carbon fiber, glass fiber or compressed paper, but shall not be thicker than 7.5% of the total thickness or 0.35 mm, whichever is the smaller.” Additionally, the type of rubber siding on a paddle, pimpled rubber, sandwiched rubber and hard rubber, is also regulated. The rubber must be of normal adhesiveness and be no more than 4.0 mm thick (ITTF, 2016). The materials play a huge role in the sport and have an impact on gameplay and how players train.
Technical Aspects

The technical aspects of the game can vary from player to player based on their personal preferences. One example of this variation comes from the different types of racket grips used by players. The traditional and most popular grip used in table tennis is called “shake-hand” or “shake-hands.” This name originates in the way the player holds the racket because it looks like they are shaking hands with someone as shown in Figure 3 (Shakehand Grip, 2016). Backhand and forehand shots are used when a player employs this particular grip (Shakehand Grip, 2016). Another popular grip is “pen-hold.” This grip is not as common as shake-hand but is still used frequently. The grip is also named for its visual resemblance to how the player is holding the racket as shown in Figure 3 (Penhold Grip, 2016). In this case, it is like a pen (Penhold Grip, 2016). When this grip is utilized, sometimes the player will only use the forehand side of the paddle.

Figure 2 | A depiction of the dimensions used in the sport of table tennis (Table Tennis Rules, 2016).
The different grips affect the way that the ball is hit and can influence the amount of spin put on the ball by a given hit. These types of spin include topspin, backspin, sidespin, and cork-spin as seen in Figure 4.
Importance of Training

To compete on a high level, professional table tennis players must have rigorous physical and mental training. Throughout the duration of a match, a table tennis player must be able to analyze the actions of his or her opponent and react quickly. Table tennis athletes only have 0.2 to 0.4 seconds to react to an approaching ball (Kondrič, Zagatto, & Sekulić, 2013), and after a long match, players can begin to tire. To perform at a high level, table tennis players must train and condition their bodies for the physiological demands of the game (Kondrič, Zagatto, & Sekulić, 2013). Table tennis players must keep their bodies in shape to execute at a high level, and endurance is a major part of this execution. Muscular endurance, or the ability to perform the same strokes at the same speed and spin throughout a match, is the first aspect of endurance that table tennis athletes must train for.

As in many other sports, basic fitness and oxygen intake regulation are important for professional table tennis athletes. The energy required during a game of professional table tennis could easily tire any individual out. Therefore, cardiorespiratory endurance, or the ability of a player to maintain the high level exercise that he or she is involved in, is extremely important for a player to have. According to the study conducted by Miran Kondric in 2013, the average heart rate of a table tennis player can reach peaks of 162-172 beats per minute during competition. Additionally, during training, the heart rates of players were observed to be 142 beats per minute on average (Kondric, 2013). Increased heart rate often indicates that an individual is in a state of intense exercise and these readings are significantly higher than the average human heart rate which is around 50-70 beats per minute (Robinson, 2016). Table tennis need to train to be able to handle the strain of such increased heart rates.
The second part of training for table tennis players is mental. All athletes must have a good mindset in order to compete at a high level. Positive reinforcement, focus, and goal setting are all important methods that table tennis players use to mentally prepare for the game (Fullen, 2016).

Another factor in table tennis that players must train for is consistency. Drills and hours of practice are required for any athlete to become consistently good at a sport. The commonly accepted view that 10,000 hours of practice are needed to become an expert (Gladwell, 2008) definitely applies to table tennis. Table tennis players must be able to execute on a high level throughout a match, in all aspects of the game. Table tennis players may be able to utilize high-level shots, but if they cannot consistently execute basic shots, they may lose to players who are less technically developed, but more consistent (Hodges, 2013). A variety of drills and techniques are incorporated into table tennis players’ training so they can master many different shots and aspects of the game (Table tennis tips, 2016). For example, “The X-Drill” is used to improve footwork and ball placement. As players gradually master their control, the pace of the drill can be elevated (Table tennis tips, 2016). Additionally, the multi-ball drill is a short drill where many balls are hit over the net to a player to help them improve overall speed and control of the ball. The drill can also be adapted to focus on power and placement (Table tennis tips, 2016).

**Sports Sensors**

With technology evolving every day, new innovative devices are being adapted to many different sports. Basic fitness watches are now commercially available like the FitBit, a fitness tracker that allows users of all athletic levels, to monitor their exercise and health on a mobile app (FitBit, 2016). Similarly, the company Nike has created a running sensor that can track a user’s workouts and displays them on a mobile app (Nike+ run club app, 2016). Adidas has developed a
“smart ball” for soccer that can track the speed and spin of a shot when kicked (Adidas MiCoach smart ball, 2016). In addition, Zepp, a sports company, has developed a wide array of sensors for sports from baseball to golf (Zepp, 2016).

**Tennis Sensors**

Tennis, which is very similar to table tennis, has many sensors developed for user improvement. The company Zepp has developed a small cube sensor that can be attached to the bottom of the handle of a tennis racket. The sensor is very versatile as it can be attached to any racket. The sensor connects to the Zepp app that allows the user to track how many of each type of hit they used in a session, the speed of each hit, power of each hit, and impact location of the hit on the racket. The app displays the data collected from the sensor in easy-to-read graphs and charts. Maximums, and averages for all aspects of play are recorded. The app also tracks data over time and compares it to previous sessions. This feature allows the user to see if he or she is improving in a chosen aspect of the game. The sensor is very helpful to the user, but it currently costs around $100. (Zepp, 2016)

Sony has developed a similar sensor that screws into the bottom of any tennis racket. This sensor relays data to an app much like the Zepp Tennis App. However, the Sony Tennis Sensor incorporates video recording into the session data. While a user is playing, a coach may record the player serving and the sensor data will sync with the video to show the user specific points in the video where a sensor reading occurred. Sony’s sensor costs about $200. (Sony, 2016)

Additionally, the sports company Babolat has produced a smart racket device and a wrist wearable that can be used to track tennis data like speed and power. The sensors are integrated directly into the handle of the racket and send data to the Babolat Play App. Babolat Pop, the
company’s other product, incorporates sensors in a wristband that also relays statistical tennis data. Both sensors can accurately give feedback to a user but, the Babolat Pop costs $100 and the latest model of the Play Smart Racket costs upwards of $300 (Babolat, 2015).

All of the sensors record similar data that can be utilized to effectively improve the performance of a player. Rafael Nadal, a prominent tennis player, uses a Babolat smart racket that allows his coach to make any necessary tweaks to his training plans. In the basic fitness aspect of Nadal’s training, the Babolat app allows him to see the “volume and intensity of his game.” This data that allows Nadal’s trainer to monitor his exhaustion level and plan his cardio workouts accordingly. The main feature of the apps, including Nadal’s Babolat app, is a shot classifier. The shot classifier counts the number of different shots that Nadal uses during a session. The number of each shot can help his coach determine when Nadal is getting tired, if he is relying on one shot too much, and how powerful his shots are throughout the session. The impact locator shows exactly where on the racket the ball hits most frequently. From this data, Nadal’s coach can see where he needs to place the ball, and make other adjustments (Tracy, 2016). Nadal and his coach are effectively able to utilize this data and improve the pro tennis player’s performance.

This technology is very useful to professionals and novice tennis players. However, there is currently no app-based feedback system available for the sport of table tennis (Tracy 2016).
**Engineering Plan**

**Problem Statement**
Consistency is a major factor in the performance of table tennis players. Minor changes or mistakes in technique can impede a player's progress. There is currently no immediate data feedback technology that has been adapted to table tennis.

**Engineering Goal**
The goal of this project was to engineer a system of sensors that would fit in the handle of a table tennis racket and reliably transmit data to a mobile app for the purpose of coaching analysis and immediate feedback.

**Procedure**

**Overview**
The product was built by connecting a piezoelectric array and MPU 6050 accelerometer/gyroscope to a PunchThrough Light Blue Bean (Bluetooth microcontroller). The data collected on impact location, impact force, acceleration, and paddle orientation will be run through a Java-based classification algorithm. The output of this algorithm will be relayed to the user’s app and notify them as to what hit was used. The user may also start a session in the app that will record each hit and data for speed, power, and impact location over time. This data can then be used by the user or a coach to identify patterns and make necessary changes in the training plan of the user.

**Criteria**
The criteria used to determine the most effective product were:

- Low Cost
- Accuracy/Improvement Tracking
- Easy Usability
- Little Weight/Size difference (compared to average paddle)
- Maximum Battery Life
- Maximum App Memory
- Device Compatibility (# of Platforms Supported)
- Sensors/How many types of different information are relayed to the user

**Testing**

The gyroscope/acceleration data collected will be tested by changing the orientation of the paddle. If the sensor’s output corresponds with the orientation recorded (based on positive and negative values) then the sensor will have worked. The piezoelectric array will be tested by dropping a table tennis ball from a uniform height onto different sections of the paddle. If the output displays the same location that the ball was dropped onto, and an impact force is displayed, then the array will have worked. Lastly, human subjects will test various hits with the paddle and if the classification algorithm classifies the hits correctly 90% of the time, then the algorithm will have worked well enough to classify the prototype as successful.

References


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