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A LOW COST AUTOMATED TABLE TENNIS LAUNCHER

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ABSTRACT

The purpose of this project is to innovate a low-cost table tennis robot with unique control system. Currently, the available table tennis robots are very expensive, and almost all of them are with wired controller where the player himself cannot control the machine when training sessions. A new design and concept are developed in order to solve these problems. This innovation called automated table tennis launcher, a self-table tennis training kit prototype which is integrated with a microcontroller better known as Arduino. This machine is controlled by the use of Android smart phones to enhance the user-friendliness and the use of wooden support and PVC pipes to fabricate greatly reduces the manufacturing cost. A 3D virtual prototype is developed by using SolidWorks software before the fabrication process and tested for function ability. This fabricated prototype can shoot the ball in three different directions and with adjustable spinning direction, which helps the user to practice almost all types of strokes in this sport. The machine is being tested and analyzed in terms of ball speed, ball shooting coverage, feeding rate and shooting distance. The results show reliable data where this machine could develop a player's ability to return the ball with proper strokes as well as improve the player's reaction. Furthermore, this machine is considerably very cheap for its function compared to the currently marketed products. As a conclusion, this automated table tennis launcher able to function as expected and can perform better when fabricated into the real products by using the customized size for every part.

Keywords: low cost table tennis machine; ping pong; table tennis robot; training kit; sports engineering.

INTRODUCTION

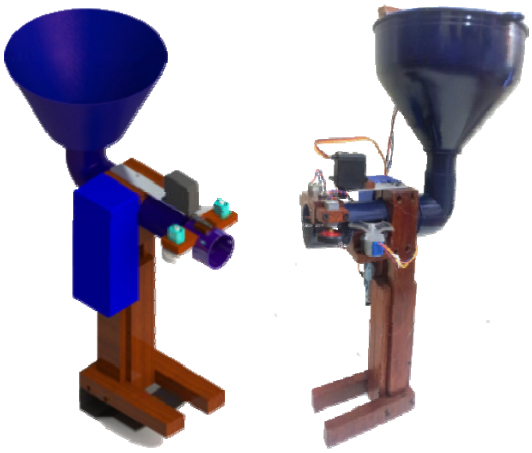
Table Tennis can be classified as a major sport worldwide, with millions of participants, major tournaments and many other things that make a sport truly a class of its own. The sport of table tennis played in Olympic since 1988 ("Table Tennis", 2011) and since then many advancement in terms of self training machines occurred. Table tennis launcher is recently manufactured for self-training purpose which provides automatic shooting of ping pong ball for professionals to improve their skills.

Table tennis sports having multiple types of strokes to be mastered such as push, block, kill and counter drive (Ivan, Roberto, and Franco, 2010) where each of this strokes means a lot when returning the ball to the opponent. The strokes anyhow can be defined in terms of winning, transitional and losing (Ivan, Rocco and Franco, 2011). In February 2000, the ball size becomes another factor that came into consideration to improve the rally game by reducing the ball speed (Takeuchi, Kobayashi, Hiruta and Yuza, n.d.). 40mm diameter ball is then adopted to be the official ball in all table tennis sport worldwide. The ball experiences projectile motion when being hit or launched. During projectile motion, the ball is considered to have both vertical and horizontal component of velocity ("Projectile motion", n.d.) which explains the distance and height the ball covers.

In the upcoming trend, table tennis ball launcher brings together an expensive price tag. Other than that, currently available table tennis machines in market also having less shooting modes. Training with multi-ball concept with the aid of table tennis machine can be very effective (Dinesh and Rajath, 2013). Besides, manually operated table tennis machines does not reflects current trend of technology that makes currently available machines dull. Nevertheless, certain cheap table tennis machines provide poor stability and lack of functionabilities.

METHODOLOGY

A 3D virtual prototype was designed and then fabricated in order to put into real life testing. Both virtual and fabricated prototype is shown in the Figures 1 and 2. The servomotor (M. F. Işik, 2010), stepper motor and DC motor were attached in order to activate the mechanism. The mechanism was mainly controlled by a programmable microcontroller, Arduino with the aid of electronics such as motor driver, resistor and switch. The motor driver functions to control the flow of electric current and also the polarity which enables the DC motor spins in 2 different directions and in few modes. Other than that, the microcontroller is programmed is such way that it takes input signals from Android smartphones. A Bluetooth module is attached which act as a bridge between the Android smartphone and the Arduino microcontroller that enables the user to control the machine by using Android smartphones. An Android application also developed which act as interface for the user to control the machine. The application interface is shown in the Figure-3. The machine is powered by 5V DC power adapter or 5V battery supply. The machine able to shoot the ball in 3 different directions and in 2 different spins which concluded as 7 modes in the interface. These 7 modes cover for almost all types of strokes that a player should acquire.



(a) (b)

Figure-1. (a) 3D modelling and (b) Fabricated prototype.

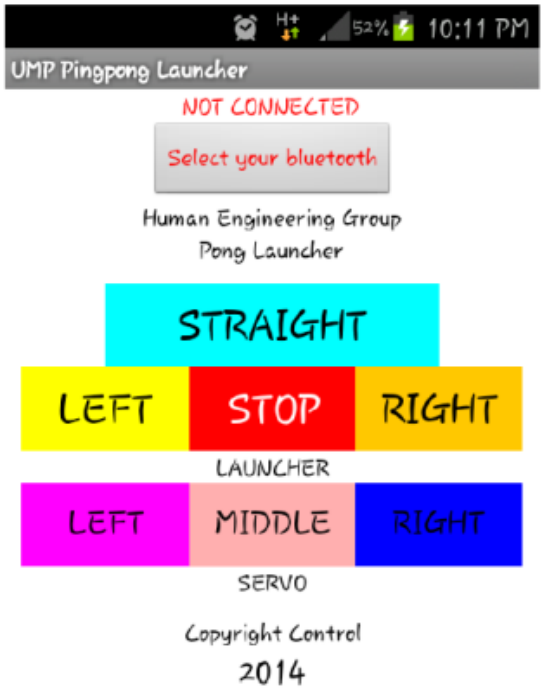


Figure-2. The android application (interface)

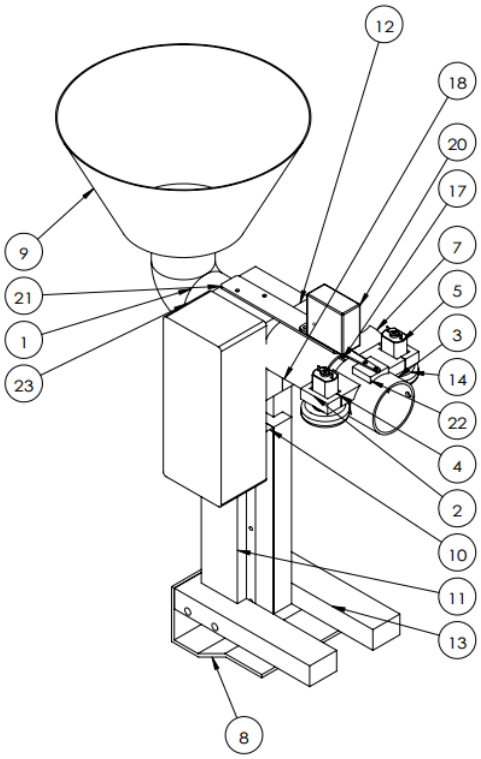


Figure-3. Labelled components.

Table-1. Components function.

No.	Component Name	Function
1	Connector	To connect between the tube (6) and connecting shaft (18). Allow table tennis ball to pass through tube (6) and channelled to the connecting shaft (18).
2	Motor holder	Work together with shooting motor holder (4) to clamp the motor in place and minimised the vibration of the motors during operation. Ensure the motors securely locked at one position.
3	Shooting barrel	Act as guide to launch the table tennis ball during operation. Can turn left and right with the help of servomotor to create variation of shooting direction. Consist of the assembly of: motors, shooting wheels (14), motor holders (2) and shooting motor holders (4).
4	Shooting motor holder	Work together with motor holder (2) to clamp motor in place. Minimised motor vibration. • Securely locked the motors in place.
5	Motor	Provide rotation to rotate and shoot out the table tennis ball from the shooting barrel. Attached with shooting wheel (14) to push out the table tennis ball. DC operated motor. Linked with motor driver to control the on and off of the motors.
6	Tube	Channel the table tennis ball from the basket (9) to the connector (1).
7	Feeder disc	Contain two concave parts to contain and push table tennis balls. Attached to steeper motor (9) to control the feeding rate which will determine the frequency of ball launched.
8	Holder	Used to clamp the table tennis launcher to the table tennis table. Work together with support (13).
9	Basket	Contain and hold table tennis balls. Contain the assembly of stirrer which consist of steeper motor to stir and unclog the table tennis balls.
10	Cover 1	Contain 2 piece attached together and work with casing 1 (11) and casing 2 (12). Contain holes to adjust launcher height. Function as the stand for launcher.
11	Casing 1	Assembled with cover 1 (10).
12	Casing 2	Assembled with cover 1 (10).
13	Support	Act as the base for the launcher to stand. Work with holder (8) to clamp the launcher to table tennis table.
14	Shooting wheel	Outer part made of rubber to enhance the gripping between the wheel and table tennis balls. Rotated by motor to produce centrifugal force thus forcing the table tennis ball out from the shooting barrel (3).
17	Steeper holder	To hold steeper motor in place.
18	Connecting shaft	Connect the table tennis ball from connector (1) to the shooting barrel (3).
19	Steeper motor	Rotate the feeder disc (7). Rotation speed controlled by arduino Uno.
20	Servomotor	Attached to the servo holder (21). Rotate shooting barrel (3) left and right. Angle of rotation and speed of rotation was controlled by using arduino Uno.
21	Servo holder	Attached with servomotor (20). Hold servomotor in place. Attached to the connecting shaft.
22	Servo guide	Attached with servomotor (20). Attached to the shooting barrel.
23	Cover 2	Cover the electronic components of the launcher.

RESULTS AND DISCUSSIONS

The data are obtained by using camera and measuring tape. Camera is used to capture ball shooting video to calculate the shooting speed and ball feed rate. On the other hand, measuring tape is used to measure the shooting distance and shooting coverage. To obtain the true data value, the launcher need to be run for about 1 minute before shooting in order to stabilize the motor speed. The analysis is based on 40mm Table tennis ball and a standard table tennis table size of 137cm X 152.5cm.

Ball shooting coverage (left and right shooting mode)

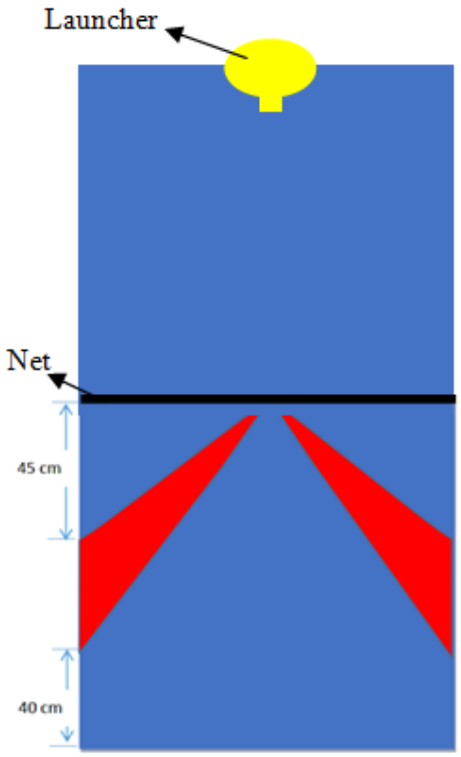


Figure-4. Ball shooting coverage.

The red coloured region is the coverage that this prototype table tennis launcher achieved during the testing. The region covered is 45cm from the table joint to 40cm from the end of the table. In short, it cover approximately 52cm (side distance) of the table.

Ball shooting distance (all modes)

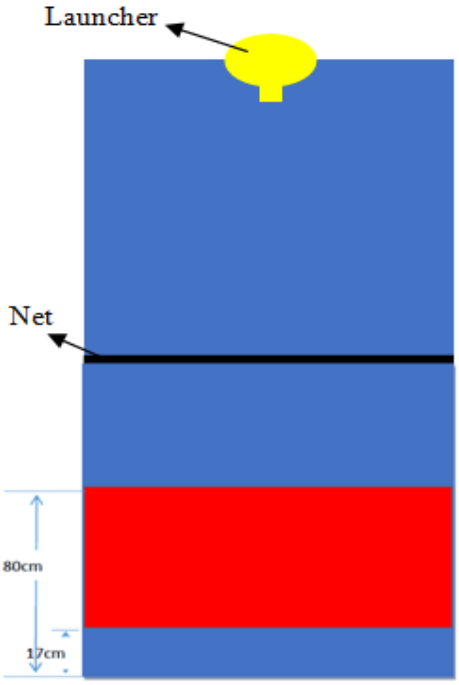


Figure-5. Ball shooting distance.

The maximum distance the ball can be shot is 17cm from the table end and the minimum distance is 80cm from the table end as illustrated in Figure-5.

The ball shooting coverage and distance does not cover some of the region due to the angle of the shooting barrel. The current settings are 10˚ from middle for both left and right shooting mode. The shooting coverage area can be widened by creating a variable shooting angle which will require more complex Arduino coding. However, for the training purpose, the current coverage able to cover most of the real match situation.

Theoretical ball speed

Table-2 shows the motor model FK-130SH-17102 specification at maximum efficiency as provided by the supplier.

Table-2. FK-130SH-17102 speed and torque.

Model No.	Speed (r/min)	Torque (mN.m)
FK-130SH-17102	11452	2.303

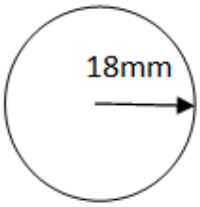


Figure-6. Shooting wheel radius.

$$T = Fr$$

From the torque formula above, by applying the radius of the shooting wheel as shown in Figure-6, the force exerted by the wheel to the table tennis ball is:

$$2.808 = F \times 18$$
$$F = 0.1279N$$

The power supplied by a single dc motor is:

$$P = T\omega$$
$$P = 2.808 \times 10^{-3} \times \left(\frac{11452}{60}\right)$$
$$P = 2.762W$$

The power supplied by a single motor is 2.762W and it is assumed that the power if fully supplied to the table tennis ball without any losses. At the same time, the motor exerted 0.1279N of force to the table tennis ball. Thus, the velocity of the table tennis ball is:

$$P = Fv$$
$$2.762 = 0.1279 \times v$$
$$v = 21.593m/s$$

The Table tennis ball velocity obtained above is the velocity generated by a single motor. Thus, the final velocity generated from two motor are:

$$v_t = 2v\#$$
$$v_t = 43.29m/s$$

Experimented ball speed

Table-3. The tabulation of ball speed data.

Attempt	Distance (cm)	Time (s)	Velocity (m/s)
1	207	0.13	15.923
2	197	0.11	17.909
3	194	0.08	24.250
4	210	0.13	16.154
5	250	0.17	14.796

Ball speed plays a vital role in determining the difficulty level for each shot (Kamijima, Ushiyama, Yu, Fei, Izuka, 2010). Thus, the ball speed was measured and tabulated in Table-3. The average speed of the table tennis ball is: 17.806m/s. The current maximum ball speed is approximately 33.528 m/s which is smash speed. Thus, with the current ball speed, it is suitable to be used for stroke training. Besides, comparing with the theoretical value, the average tested velocity is 17.806m/s while the theoretical value is 43.29m/s which is 25.484m/s lesser. This is due to the loss contact between shooting wheel and the table tennis ball. However, if the barrel dimension (PVC pipe) is customized to 41 to 42 mm inner diameter instead of 44 mm (market dimension), the ball speed will be significantly higher than the current testing result as the table tennis ball will enter the barrel and been launched by the shooting wheel in a perfect contact point. In term of software and coding, all perform as been planned whereby all the function needed able to execute as designed.

Ball feed rate

The ball shooting rate is 7 to 8 balls per minute which mean 2 balls will be launched for every 15 seconds. The feed rate is fixed for training purpose, since the user needs time to recover after each stroke. The feed rate can be programmed to shoot more frequent if the user already acquire enough skills to return the ball faster.

Summarized results

Table-4. Summary of the analysis of automated table tennis launcher.

Tested parameter	Results
Ball shooting coverage	40-92 cm from the table end.
Ball shooting distance	17-80 cm from the table end
Ball feed rate	7-8 balls per minute
Ball speed	17.806 m/s

Linear regression and correlation

Table-5. Regression Statistics summary.

Regression Statistics	
Multiple R	**0.99**
R Square	0.99
Adjusted R Square	0.99
Standard Error	0.07
Observations	5.00

Table-6. Coefficient from regression statistics summary.

	Coefficients
Intercept	16.109
Distances (cm)	0.068
Time (s)	-109.036

From Table-5, there is strong positive linear correlation between independent and dependent variables. 99% of the variation in dependent (ball speed) is predictable from independent variables (distances and time).

CONCLUSIONS AND RECOMMENDATIONS

From the testing result, we can conclude that our table tennis launcher able to meet the requirement for table tennis athlete normal practice. The shooting distances of the ball not very stable due to the inner diameter of the barrel (44 mm) which can be consider as large for a 40 mm table tennis ball. This can be improved by customizes the barrel inner diameter during real product manufacturing. As a conclusion, the design of the table tennis launcher able to function as expected and can perform better when fabricated into real product by using the customized size for every part. This machine which cost about 50 USD is considerably cheap and can be marketed.

As for the recommendations:

- Use motor with higher and stable speed for faster ball speed.
- Use stepper motor with higher speed to obtain higher ball feed rate thus increasing the shooting frequency.

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