Design and Implementation of Visible Light Communication based toys

Ain Najihah binti Baharudin, Mohamed Hadi Habaebi, Farah Abdul Rahman
Department of Electrical and Computer Engineering, International Islamic University Malaysia, Malaysia

1. INTRODUCTION

The current main concerns in telecom community now is increased demand for bandwidth to facilitate exchange of data with low latency. Transmitting signals using radio waves is widespread but it lacks security, reliability and scarce bandwidth [1, 2]. It may not be safe to use radios in hospitals, nuclear plant and airplanes [3, 4], and exposure to high doses of RF power for a prolonged period of time may not be healthy [5]. Visible light communication (VLC) technology uses data signals to modulate the light intensity of light emitting diodes (LEDs) [6] and RGB laser diodes (LDs) [7]. In the receiver side, photodiodes detect the fast variations of the emitted light signals [8, 9].

Recently, laser light that is used in the toys have attract the attention of kids since kids easily get attraction to something bright and colorful. Because of that, kids easily get bored when teacher or parents were too exposing them with education books in their early learning process. It is because most of the education books are not colorful and attractive which causing them to be not interested in learning. Hence, parents were trying in finding new medium for education that are bright and colorful to attract the attention of kids in their early learning process.

Apart from that, the implementation of laser light in toys still get strong obstruction from parents since the it can cause hazard to the eyes sight which it can affect the health of their children. Moreover, there are too many new cases involved laser light toys reported in the media social. Other extreme is mostly of the parents strongly believes that new technologies nowadays will only give more harmful than benefit if it is exposed to their children at a very early age. They thought that the kids will prefer to play rather than study if they are allowed to own devices of new technologies that are trending nowadays.

Laser Communication Device was developed in [10] for a smart communicating toy system which transmit text using photo resistors and laser diodes. Array is declared as a library in this system.
After received the user input, the message is simplified into each individual character and total length of it recorded at the transmitter part. Meanwhile at the receiver part, temporary array is created when it received laser input and compared it to the library of the array. The character corresponding to it was displayed. It is implemented using Arduino UNO, 5x5 Volt 6mm diameter laser diodes, acrylic tubing and photo resistor. However, it cannot produce the 100% character accuracy because a few letters may get suck during the conversion from laser input to the array of letter.

Khalil Islam and Ibrahim Radwan [11] presented their smart toys system called Laser Fight Toys which based on the concept of a paintball game. Each of the players wore the T-Shirt that is connected to a Raspberry Pi, a light sensor and colour LEDs while the toy gun contained a laser transmitter. Each player has life points, which were marked with LEDs, and each time the player hit, the player will lost one life point by turning off one of the LEDs. If all points are lost the player was considered lost. In this system, Raspberry Pi 2 Model b, laser transmitter, light sensor im120710017, Wi-Fi dongle and mini metal speaker were implemented. With the implementation of Wi-Fi dongle, it enabled the receiver part of the system detect the signal from the laser transmitter even in a long distance between the players. However, this toys system cannot be used without the internet connection to run the program since it use Python Idle 3 that needs internet connection.

In the system proposed by Jr. D [12], Laser Gun Toy was presented by produce a “PeePeePeeuuw” sound when triggered and a red laser associated with the sounds shot during the game. Laser transmitter and laser receiver were used to send and detect the red laser while mini metal speaker was used to produce “PeePeePeeuuw” sound. However, this toy system was not equipped with Wi-Fi module. Hence, it cannot detect signal from other player within a long distance. This system also not offered any display unit to display the total number of shoots that have been made.

All the systems previously discussed do not include any display input into their systems. Display unit is important to display the data transmission that occurred between the transmitter and receiver part. Therefore, in the proposed system, a display unit will be added in order to observe and display the transmission of data between the laser modules.

2. RESEARCH METHOD
2.1. Project overview

The proposed system is a smart laser communication toys. It is a medium for educational purposes for kids. The basic idea of the device is kids can use it as a device to send a message to one another. Users will be sending message by switching on the device, which will pop up a on a TFT LCD Touchscreen. Users are free to choose whether they want to send or receive message by only pressing the button on the main screen of the TFT LCD Touchscreen. User can type the message or receive it in type of binary data which will be converted to letters before displayed it on the screen of the touchscreen. The basic design of the system is shown in Figure 1.

![Figure 1. The basic design of the proposed system [13]](image-url)

In the smart laser communicating toys, Arduino Mega ADK is the brain of the proposed system. The inputs of the system are receiver unit and input module. The receiver will receive the binary input from the transmitter while TFT LCD Touchscreen which acts as an input module enable the user to enter the input to be transmitted. The outputs of the proposed system are transmitter unit, display unit and buzzer. The transmitter send the message in a binary number. Moreover, display unit is used to display the output of the data and buzzer is used to produce the "buzz" sound each time the laser transmitter module of the sender send the data message to the laser receiver module of the receiver according to the binary code of each transmitted letter by producing the “buzz” sound each time the binary code is 1 and not produce any “buzz” sound when the binary code is 0. Figure 2 shows the block diagram of the system.
2.2. Flowchart

The proposed flow of the smart laser communicating toys system is shown in Figure 3. The receiver will sense for any light signal detected, interpret the light switching and convert it into a representative binary code and translate it to the respective ASCII code. Hence, build the alphabetical message character by character and display them on the LCD. Since the encoder and decoder uses asynchronous transmission, words are separated by spaces. Similar reverse pattern happens on the transmitter stream. The ASCII encoder uses a translation table, see figure 20, for the equivalent binary codewords received.

![Flowchart of the proposed system](image)

2.3. Mechanical design

Figure 4 through Figure 7 show the isometric, side and back views of the system respectively. To maintain the fun, a beetle shaped casing was selected to encase the LCD, keypad, Arduino board and Transceiver hardware. The wings of the flying beetle opens up to access the LCD and keypad. It opens from the back for a smooth handling by the palm and easy typing on the keypad.
2.4. Hardware development

2.4.1. Transmitter system

Laser transmitter is used to communicate where it sends signal in terms of voltage. When the voltage is high, it is considered as 1 in binary, where the signal was presented. Vice versa, when the voltage is low, it is considered as 0 in binary so that the laser considers that there is no transmission of data. Hence, this laser transmitter module is programmed to send signal by transmitting a red laser light when binary is 1, and vice versa.

2.4.2. Receiver system

Laser receiver in this proposed system receives only high and low voltage which is 5V and 0V. There is no in between of them. When the receiver receives 5V of laser, the receiver reads it as 1 in binary whereas when the receiver does not detect any 5V in the time setup, it read as 0 in binary.

Hence, it is actually programmed to receive high volts as 1, and no volts as 0 so that the laser receiver in this proposed system was received 1 when there are red light transmitted to it, and reads 0 when it cannot detects any high volts in defined time. It receive the sequence of binary bits and converted it back to ASCII letters which are understandable to the users.

2.4.3. Input and display system

2.8” TFT LCD Touchscreen module is used in this system to enable the user to enter the input data and display the input data in the sender part and display the output data for the player in receiver part. Thus, it acts as both input and display module which makes this proposed system very convenient and flexible.

2.4.4. Sound system

Small Active Buzzer Alarm 5V Sounder Speaker Arduino PIC is programmed to produce the “buzz” sound each time the laser transmitter module of the sender send the binary data 1 to the laser receiver module of the receiver and any “buzz” sound was not being produced when it send binary data 0. This “buzz” sound enabled the player became alert to receive the data message during the transmission of data.

2.5. Software development

2.5.1. Arduino IDE

Arduino IDE is used as a platform used to write programs and uploaded them to Arduino expansion board interfaced to it. The board is programmed to read inputs from the transmitter where the library of ASCII is used in the coding to give output in binary number. A letter which consists of 8 bit binary codes was converted into 0s and 1s. Some fonts, variables and the libraries that are needed for the program were also defined.
In developing the program for this proposed system, Graphical User Interface or GUI is used since 2.8” TFT LCD Touchscreen used GUI concept to make it functioned as an input module which is a keyboard and as a display module to display the output data message. The x and y coordinates is setup for each character in the keyboard so that it detect and display the right character each time the user touch the touchscreen. Figure 8 shows x and y coordinates that is used to setup each character in the keyboard on a TFT LCD Touchscreen.

\[
\begin{align*}
X &= 539 \\
Y &= 679 \\
\text{Pressure} &= 415 \\
\end{align*}
\]

\[
\begin{align*}
(112, 229)
\end{align*}
\]

Figure 8. X and Y coordinates for each pressed letter

3. RESULTS AND ANALYSIS

3.1. Distance test

The sensor and transmitter was set within a certain distance defined to see the effectiveness of the module. The module is set within 1 cm distance, and it was worked. Then, the distance is increased by 1 cm until the sensor cannot sense any light transmission anymore. At the end of the testing process of the module, the product is then defined to be effective in the range of 10 Meter during the day 15 Meter during the night. This shows that there are less interference and noise that can interrupt the transmission of the signal during the night compared to during the day. Hence, it can be concluded that the laser receiver module can detect the signal in a longer distance during the night. Figure 9 and Figure 10 show the distance test during the day and night.

3.2. Angle test

The sensor and transmitter was set within a certain distance angle defined to see the effectiveness of the laser receiver module to detect a red laser signal transmitted by the laser transmitter module. The distance is then increased by 1 cm to observe the limit of the angle between both laser modules until it cannot sense any light transmission anymore. At the end of this test, the product is defined to be effective at the angle of 180 degrees only when the distance between the modules is 1 m until 8 m and when the distance between the modules is 9 m until 11 m, it achieves the effectiveness at the angle from 177 degrees to 180 degrees only.

Meanwhile, for the distance between the modules of 12 m until 15 m, the product is then defined to be effective at the angle from 175 degrees to 180 degrees. It can be concluded that the increased of a distance between modules will increase the effective angle for laser receiver module to detect a red laser signal. Figure 11 and Table 1 show the angle test that have been done and the summary result of the angle test.

| Distance between modules (m) | Effective angle between modules (degrees) |
|-----------------------------|------------------------------------------|
| 1 m–8 m                     | 0 degrees                                 |
| 9 m–11 m                    | 0–3 degrees                               |
| 12 m–15 m                   | 0–5 degrees                               |

Table 1. Summary result of the angle test
3.3. Programme Test

The programme test was done by using Arduino compiler where the ASCII codes is converted to the binary codes. The program asked whether the device is used for sending or receiving the data message. When the mode of control is selected, the message intended is send. The message is sent in ASCII format, which is the common language used for users. The message is then converted into 0s and 1s before being transmitted to the laser receiver module of the receiver. Then, the laser receiver module of the receiver was received the data message in 0s and 1s and converted it back into ASCII format.

Thus, when user in device A is send the data message to the second device such as letter ‘A’, the program converted the letter into binary, where ‘A’ is 065 in ASCII table making it 01000001 in binary code. The laser blinked one time and then blinked once more after some time. The touchscreen of device B receives 01000001 in binary code and the equivalent character for each binary code and displayed it. The program is tested and validated. Figure 12 to Figure 19 show the result of the programme test while Figure 20 shows the conversion table chart.

Figure 12. Main screen of the proposed system
Figure 13. The Keyboard page appeared when the user choose the SEND button
Figure 14. The blank page appeared when the user choose RECEIVE button
Figure 15. The sender entered the text message to be send to another player
3.4. Analysis result of the programme test

At the beginning of the system, the users were asked to choose whether to send or receive the data. One player has to send the data while another player has to receive the data. After both players choose the transmission mode, the keyboard page appeared on the screen of the sender while the blank page appeared on the screen of the receiver ready to receive the message. The sender entered the input message which is in ASCII code. Referred to the above test, the sender send message “HI FRIEND”. During this test, the message that have been sent and the number of total bits appeared on the serial monitor of the sender. The total number of bits of message sent were 9 bits. Space in the message sent is also counted as 1 bit. For each letter, the binary code for the corresponding of each letter is appeared. The letter was sent bit by bit.
Reference to the above programme test, ‘H’ in binary code was 01001000 and ‘I’ in binary code was 01001001. Hence, the laser transmitter sent the binary code of the letter ‘H’ first followed by the letter ‘I’ and others. Each time the binary code is 1, the laser transmitter blinked to show that it was a high voltage which was 1 and vice versa. After the sender pressed the send button on the keyboard, the ASCII code is converted to the binary code and sent to the receiver. The laser receiver module of the receiver receives the binary code for each letter and converted it back to the ASCII code. Then, the output message was displayed on the screen of the receiver.

During this test, the binary code for each letter that has been read by a laser receiver module displayed on the serial monitor of the receiver. When it do not receive any letter, it read it as a 0 which was a low voltage. After the full output message is displayed on the screen of the receiver, the system is looped back to the main page for the both devices which required both players to choose the transmission mode again. Figure 21 and Figure 22 show the serial monitor for both sender and receiver part.

3.5. Final product

Figure 23 and Figure 24 illustrates the overall design of the smart laser communicating toys system. The beetle shaped casing hides all the hardware wiring and peripherals inside. We have experimented with several casings. However, the beetle had shaped casing had an attractive appeal for children. Several colours can be selected.

4. CONCLUSION

This project proposed a design of smart laser communicating toys using Arduino Mega ADK and equipped with laser modules that can send and receive the data message to and from each others. Testing of the system to verify the functionality of the system has also been conducted in addition to several system testing. With more enhancements in a future, this smart laser communicating toys can be a very useful system for kids for as a platform for the development of their brain and cognitive skills during their childhood. The future work is to integrate further features into the toy to make it commercially viable and more fun for kids including a remote control module from a smart phone.
ACKNOWLEDGEMENTS

This work was conducted at the IOT and wireless communication protocols lab and is partially supported by the the International Islamic University Malaysia (IIUM) Research Initiative Grant Scheme (RIGS) with the grant number RIGS16-087-0251.

REFERENCES

[1] Y. Zou, J. Zhu, X. Wang and L. Hanzo, "A Survey on Wireless Security: Technical Challenges, Recent Advances, and Future Trends," in Proceedings of the IEEE, vol. 104, no. 9, pp. 1727-1765, Sept. 2016.
[2] K. J. Hole, E. Dymnes and P. Thorsheim, "Securing Wi-Fi networks," in Computer, vol. 38, no. 7, pp. 28-34, July 2005.
[3] George, J.J.; Mustafa, M.H.; Ahmed, N.H.; Hamed, D.M. “A Survey on Visible Light Communication”. Int. J.Eng. Comput. Sci. 2014, 3, 3905–3908.
[4] P. H. Pathak, X. Feng, P. Hu and P. Mohapatra, "Visible Light Communication, Networking, and Sensing: A Survey, Potential and Challenges," in IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2047-2077, Fourthquarter 2015.
[5] F. Barnes and B. Greenenbaum, "Some Effects of Weak Magnetic Fields on Biological Systems: RF fields can change radical concentrations and cancer cell growth rates," in IEEE Power Electronics Magazine, vol. 3, no. 1, pp. 60-68, March 2016.
[6] M. A. Khalighi and M. Uysal, "Survey on Free Space Optical Communication: A Communication Theory Perspective," in IEEE Communications Surveys & Tutorials, vol. 16, no. 4, pp. 2231-2258, Fourthquarter 2014.
[7] Janjua, B.; Ouhei, H.; Durán, J.; Kee, T.; Ting, C.; Yung, H.; Chieh, Y.; Chung, H.; Ru, G.; Hau, J.; et al. “Going beyond 4 Gbps data rate by employing RGB laser diodes for visible light communication”. Opt. Express 2015, 23, 18746–18753.
[8] M. Figueiredo, L. N. Alves and C. Ribeiro, "Lighting the Wireless World: The Promise and Challenges of Visible Light Communication," in IEEE Consumer Electronics Magazine, vol. 6, no. 4, pp. 28-37, Oct. 2017.
[9] R. A. Martinez Ciro, F. E. Lopez Giraldo and A. F. Betancur Perez, “RGB Sensor Frequency Response for a Visible Light Communication System,” in IEEE Latin America Transactions, vol. 14, no. 12, pp. 4688-4692, Dec. 2016.
[10] D. John, “Laser Communication Device (Arduino Project),” Mechanical Attraction, 2016.
[11] Islam Khalil and Radwan Ibrahim, “Laser Fight - Hackster.io," 2015.
[12] D. Jr, “Laser Gun: 6 Steps,” 2016.
[13] A. N. Baharudin, M. H. Habaebi and F. A. Rahman, "A Laser Pointer Communicating Toy," 2018 7th International Conference on Computer and Communication Engineering (ICCCE), Kuala Lumpur, 2018, pp. 421-425.
[14] P. Krumin, “ASCII Cheat Sheet,” browserling, 2013. [Online]. Available: http://www.catonmat.net/blog/ascii-cheat-sheet/. [Accessed: 05-May-2018].
[15] T.S. Gunawan, I.R.H. Yaldi, M.Kartiwi, N. Ismail, N.F. Za’bah, H. Mansor, A.N. Nordin, “Prototype design of smart home system using internet of things,” Indonesian Journal of Electrical Engineering and Computer Science, 7 (1). pp. 107-115.

BIOGRAPHIES OF AUTHORS

Ain Najihah binti Baharudin is with the Department of Electrical and Computer Engineering, Kulliyyah of Engineering, International Islamic University Malaysia P.O. Box 10, 50728, Kuala Lumpur, Malaysia. Her research interests are in digital communications, visible light communication and IoT.

Mohamed H. Habaebi (M’99–SM’16) received his first degree from the Civil Aviation and Meteorology High Institute (CAHI), Libya (’91), his MSc in Electrical Engineering from Universiti Teknologi Malaysia (‘94), and his Ph.D. in Computer and Communication System Engineering from Universiti Putra Malaysia (‘01). He is currently an Associate Professor and the Post Graduate Academic Advisor at the Department of Electrical and Computer Engineering, International Islamic University Malaysia. He heads the research works on Internet of Things at the department. He has supervised many Ph.D. and M.Sc. students, published more 120 articles and papers and sits on editorial board of many international journals. He is actively publishing in M2M communication protocols, wireless sensor and actuator networks, cognitive radio, small antenna system & radio propagation and wireless communications & network performance evaluation. He is an active member of IEEE and an active reviewer to many international journals.
Farah Diyana Abdul Rahman obtained her PhD degree from Department of Electrical and Electronic Engineering, University of Bristol, UK in 2015. She has been appointed as an Assistant Professor in Electrical and Computer Engineering Department, Faculty of Engineering, International Islamic University Malaysia (IIUM). Her research interest includes image and video processing, video quality evaluation, multimedia transmission and wireless communication systems. She is an active member of the IEEE, a registered member of the Board of Engineers Malaysia (BEM) and Institute of Engineers Malaysia (IEM).