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An Adaptive Sigmoidal Activation Function for Training Feed Forward Neural Network Equalizer

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Abstract: Feed for word neural networks (FFNN) have attracted a great attention, in digital communication area. Especially they are investigated as nonlinear equalizers at the receiver, to mitigate channel distortions and additive noise. The major drawback of the FFNN is their extensive training. We present a new approach to enhance their training efficiency by adapting the activation function. Adapting procedure for activation function extensively increases the flexibility and the nonlinear approximation capability of FFNN. Consequently, the learning process presents better performances, offers more flexibility and enhances nonlinear capability of NN structure thus the final state kept away from undesired saturation regions. The effectiveness of the proposed method is demonstrated through different challenging channel models, it performs quite well for nonlinear channels which are severe and hard to equalize. The performance is measured throughout, convergence properties, minimum bit error achieved. The proposed algorithm was found to converge rapidly, and accomplish the minimum steady state value. All simulation shows that the proposed method improves significantly the training efficiency of FFNN based equalizer compared to the standard training one.

Keywords: Non linear equalization, Feed for word neural networks (FFNN), Digital communication channels, Adaptive sigmoidal activation function

Introduction

Achieving high data transmission rate is the main objective in wireless communication systems, though they are confronted to channel impairments, which alter the digital signal and causes inter symbol interference (ISI). Equalization is an approach to mitigate channel ISI and recover the transmitted data (Proakis, 2001; Mehmet et al., 2013). Equalization structure based on linear adaptive filters, limit the performance of the system, nonlinear structures are superior to linear ones; in particular, on non-minimum phase or nonlinear channels (Zerguine et al., 2001; Baloch et al., 2012; Mehmet et al., 2013; Sunita et al., 2015). Many researches have revealed that feed for word neural network (FFNN) equalizers (FFNN) can provide better system performance than conventional ones (Amgothu & Kalaichelvi, 2015; Baloch et al., 2012; Corral et al., 2010; Lyu et al., 2015; Sunita et al., 2015; Zerdoumi et al., 2015).

Back propagation (BP) training algorithm is a supervised learning method for the (FFNN) (Haykin, S, 1999), based on steepest descent, its major drawback is the convergence rate wich still very slow. Many researches have been reported to the BP algorithm in order to improve its efficiency and convergence capabilities (Saduf, 2013; Wang et al., 2004). An overview of learning strategies in FFNN as well as numerous improvements in steepest descent through BP algorithm was provided in Schmidhuber (2015).

Among BP learning speed up algorithms, those using the adaptation of the activation function plays a decisive role (Daqi et. al., 2003; Chandra et. al., 2004). It has been recognized that training algorithms that adapt the activation function lead to faster training than those that do not (Chandra et. al.,2004; Daqi et. al., 2003; Xu & Zhang, 2001; Yu et al., 2002).

In our approach we propose an improvement to the FFNN learning algorithm by adapting the nonlinear activation function. Then, the proposed learning algorithm is derived to adjust the free parameter as well as the connection weights and bias in the FFNN structure. The proposed method adapts one free adaptive parameter mutually with weights and bias, therefore computational burden is avoided and the convergence capabilities of the algorithm are significantly improved.

Feed forward neural network-based equalizer

The equalization technique is performed at the receiver to compensate channel impairments such as ISI, noise and nonlinearities, therefore the transmitted is recovered. Conventionally equalizers are structured as adaptive digital filters. More recently nonlinear structures based on neural network are used to enhance system performance, since they can perform complex mapping between input and output spaces and are capable of forming nonlinear decision boundaries. Neural network equalizers perform well on severe environment and can deal with nonlinear ISI due to their strong capabilities. In our work we consider only feed forward neural network-based equalizer as depicted in (Figure 1).

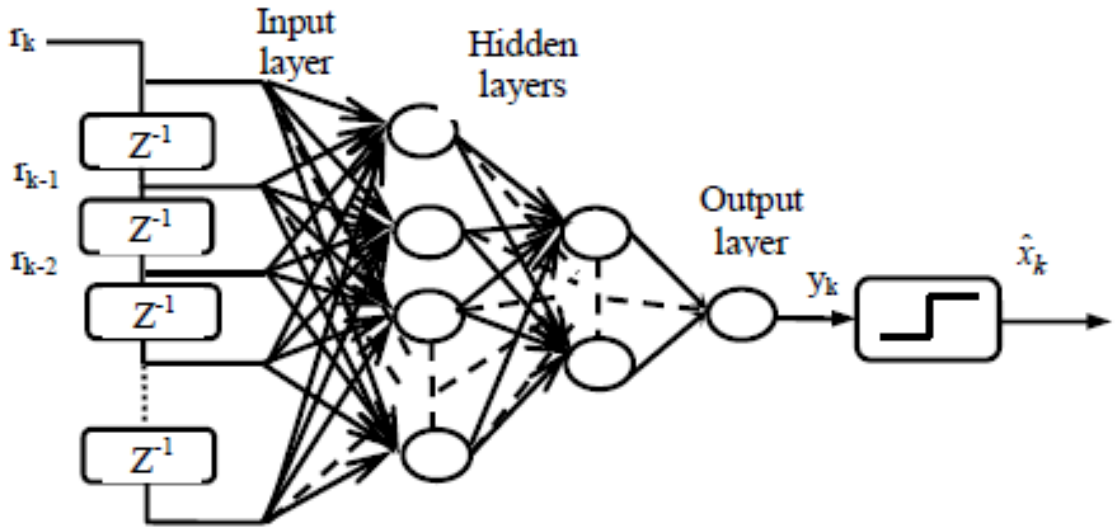

Figure 1. Feed forward neural network-based equalizer

The Feed forward neural network-based equalizer (Figure 1) is realized by connecting the received signal to a time delay line (TDL) which is connect to the input layer of the FFNN. The FFNN is composed by three layers; the input layer connected to the TDL, two hidden layers and an output layer connected to the hard decision device.

Activation functions

Activation functions play an important role in the training procedure of FFNN, they procure nonlinearity and establish the speed convergence of the learning algorithms (Daqi et. al., 2003; Sartaj et. al., 2014). It has been established that adapting the activation function lead to faster training and more flexibility in achieving the

nonlinear behavior required (Chandra et. al.,2004; Daqi et. al., 2003). Owing the ability of adapting the activation function the nonlinear capability and the flexibility of the FFNN is improved considerably; consequently, the convergence properties are enhanced. Sigmoidal activation functions are the most commonly used in the FFNN structure. We consider a parametric bipolar-sigmoid (Power, 2001) as the nonlinear activation function. Such function and its derivative are defined as below:

$$\varphi(x)=\frac{1-e^{(-\beta x)}}{1+e^{(-\beta x)}}\ ;\quad \varphi'(x)=2\beta\left(1+e^{-\beta x}\right)^{-2}e^{-\beta x}=\frac{\beta}{2}\left(1-\left(\varphi\ (x)\right)^2\right) \tag{1}$$

Where β is the slope parameter, it controls the nonlinearity of the sigmoid. The derivative of $\varphi(x)$ is given by:

Adaptive sigmoidal activation function learning algorithm

FFNN structure is composed by a set of sensorial units organized in hierarchical layers; the input layer, one or more hidden layers and the output layer. The consecutive layers are completely linked. The outputs of the neurons in one layer form the inputs to the next layer. The information is progressed from the input layer to the output layer. The hidden layers perform complex nonlinear mappings between the input and the output layer via the nonlinear activation function (Haykin, S, 1999). In our approach we propose an algorithm that enhances the nonlinear capabilities of the FFNN by adapting the sigmoidal activation function slope of the hidden layers. Thus procures more flexibility and suppleness to the FFNN structure.

Consider a FFNN with an input layer, one hidden layer and one out put layer. Let w_{ik} be the weight that links the inputs to the hidden layer and w_{ji} the weight that links the hidden layer to the output layer. Let $k=\overline{1,m}$, be the inputs index, $i=\overline{1,p}$, the hidden layer index and $j=\overline{1,n}$ the output index. In order to train the sigmoid activation function to perform the desired mapping, a cost function is defined as the sum of the squared error between the actual network output and the desired output, as expressed below:

$$J=\frac{1}{2}\sum_{j=1}^{n}\left(d_j-\mathrm{y}_j\right)^2 \tag{2}$$

We define the following entities for the output's neuron i and hidden layer neuron j respectively as follows:

$$\mathrm{net}_i=\sum_{k=1}^{m}\mathrm{w}_{ik}x_k+\theta_i \tag{3}$$

$$\mathrm{net}_j=\sum_{i=1}^{p}\mathrm{w}_{ji}y_i+\theta_j \tag{4}$$

The outputs of the neuron i of the hidden layer and the neuron j of the out put layer are given respectively by:

$$\mathrm{y_i}=f(\mathrm{net}_i)=\frac{1-e^{-\beta_i net_i}}{1+e^{-\beta_i net_i}} \tag{5}$$

$$\mathrm{y_j}=f(\mathrm{net}_j)=\frac{1-e^{-\beta_j net_j}}{1+e^{-\beta_j net_j}} \tag{6}$$

The proposed learning method baptized adaptive activation function (AAF) algorithm adjusts the FFNN common parameters in addition to the sigmoid activation function parameter using the gradient rule. Let's evaluate the gradient of the cost function regarding to the FFNN parameters explicitly weights, bias and sigmoid parameter via considering the output neuron j as flow:

$$\frac{\partial J}{\partial w_{ji}} = \frac{\partial J}{\partial y_j} \cdot \frac{\partial y_j}{\partial net_j} \frac{\partial net_j}{\partial w_{ji}} = \frac{\beta_j}{2}\left(y_j - d_j\right)\left(1 - y_j^2\right) y_i \tag{7}$$

$$\frac{\partial J}{\partial \theta_j} = \frac{\partial J}{\partial y_j} \cdot \frac{\partial y_j}{\partial \theta_j} = \frac{\beta_j}{2}\left(y_j - d_j\right)\left(1 - y_j^2\right) \tag{8}$$

$$\frac{\partial J}{\partial \beta_j} = \frac{\partial J}{\partial y_j} \cdot \frac{\partial y_j}{\partial \beta_j} = \left(y_j - d_j\right)\frac{net_j}{2}\left(1 - y_j^2\right) \tag{9}$$

In the same manner as above, we evaluate the gradient of the cost function regarding to the FFNN parameters by considering the hidden neuron i :

$$\frac{\partial J}{\partial w_{ik}} = \frac{\partial J}{\partial net_i} \cdot x_k = \frac{\beta_i}{2}\left(\sum_{j=1}^{n} \frac{\beta_j}{2}\left(y_j - d_j\right)\left(1 - y_j^2\right) w_{ji}\right)\left(1 - y_i^2\right) x_k \tag{10}$$

$$\frac{\partial J}{\partial \theta_i} = \frac{\partial J}{net_i} \cdot \frac{net_i}{\partial \theta_i} = \frac{\beta_i}{2}\left(\sum_{j=1}^{n} \frac{\beta_j}{2}\left(y_j - d_j\right)\left(1 - y_j^2\right) w_{ji}\right)\left(1 - y_i^2\right) \tag{11}$$

$$\frac{\partial J}{\partial \beta_i} = \frac{\partial J}{\partial y_i} \cdot \frac{\partial y_i}{\partial \beta_i} = \left(\sum_{j=1}^{n} \frac{\beta_j}{2}\left(y_j - d_j\right)\left(1 - y_j^2\right) w_{ji}\right)\frac{net_i}{2}\left(1 - y_i^2\right) \tag{12}$$

Therefore, the parameters on the FFNN are adjusted through the gradient descent rule when the output neuron j is considered as:

$$w_{ji}(n+1) = w_{ji}(n) - \eta \frac{\beta_j}{2}\left(y_j - d_j\right)\left(1 - y_j^2\right) y_i \tag{13}$$

$$\theta_j(n+1) = \theta_j(n) - \eta \frac{\beta_j}{2}\left(y_j - d_j\right)\left(1 - y_j^2\right) \tag{14}$$

$$\beta_j(n+1) = \beta_j(n) - \eta\left(y_j - d_j\right)\frac{net_j}{2}\left(1 - y_j^2\right) \tag{15}$$

When the hidden neuron i is considered, the parameters on the FFNN are adjusted as:

$$w_{ik}(n+1) = w_{ik}(n) - \eta \frac{\beta_i}{2}\left(\sum_{j=1}^{n} \frac{\beta_j}{2}\left(y_j - d_j\right)\left(1 - y_j^2\right) w_{ji}\right)\left(1 - y_i^2\right) \cdot x_{ki} \tag{16}$$

$$\theta_i(n+1) = \theta_i(n) - \eta \frac{\beta_i}{2}\left(\sum_{j=1}^{n} \frac{\beta_j}{2}\left(y_j - d_j\right)\left(1 - y_j^2\right) w_{ji}\right)\left(1 - y_i^2\right) \tag{17}$$

$$\beta_i(n+1) = \beta_i(n) - \eta\left(\sum_{j=1}^{n} \frac{\beta_j}{2}\left(y_j - d_j\right)\left(1 - y_j^2\right) w_{ji}\right)\frac{net_i}{2}\left(1 - y_i^2\right) \tag{18}$$

The adaptive activation-based algorithm is considered as an improvement of the conventional back propagation it includes the traditional fixed activation function as a particular case therefore, it provides more suppleness and nonlinearity to the MLP structure. The proposed algorithm has a higher probability of not getting stuck in local minima. This is principally due to the effect of change in the value of the slope parameter.

Results and Discussion

In our simulations we use an FFNN structure with a single hidden layer and a single node in the output layer. We perform several simulations to reveal the ability and the convergence properties provided by the proposed approach. All simulation results were realized using MATLAB.

Channel Model

We adopt nonlinear channel equalization problems, widely used in literature to evaluate the performance of the equalizers (Corral et al., 2010; Zerguine et al., 200). Nonlinear channel models (*NCh₁* and *NCh₂)* are composed by a linear channel (Ch1 and Ch2) followed by a memory less nonlinearity. The linear channels are represented by their impulses responses coefficients by the following equations:

$$Ch_1=[0.6963 \;\; 0.6964 \;\; 0.1741] \tag{19}$$

$$Ch_2=[0.2600 \;\; 0.9300 \;\; 0.2600] \tag{20}$$

Ch_1 is a linear minimum phase channel where Ch_2 is a linear non minimum phase channel. The nonlinearity is of polynomial type, described by the above equation:

$$v_k = a_1 u_k + a_2 u_k^2 + a_3 u_k^3 \tag{21}$$

The linear channel output is u_k , whereas v_k is the output of the memory less nonlinearity. Coefficients a_i are scalars, which control the nonlinearity degree (Corral et al., 2010; Zerguine et al., 200). Parameters, a_1, a_2, and a_3 of (21) are set to 1, 0.2, and -0, 1 respectively as given in (Corral et al., 2010).

Performance's Measure

Mean square error convergence

Figure 2 illustrates the convergence behavior of the FFNN for the BP and BPAAF algorithms considering nonlinear channels NCh1and NCh_2. The proposed algorithm BPAAF shows a clear improvement in the convergence time and the steady state value of averaged square error produced than the BP. Despite the nonlinearity the BPAAF achieves the best performance in steady state MSE, it achieves -32dB and -30dB for Nch_1 and Nch_2 respectively. While the steady state MSE reached by the BP is about -25dB and -22dB for Nch_1 and Nch_2 respectively. Thus resulting of a gain of 7dB and 8dB over the BP for Nch_1 and Nch_2 respectively. These improvements are summarized in Table1.

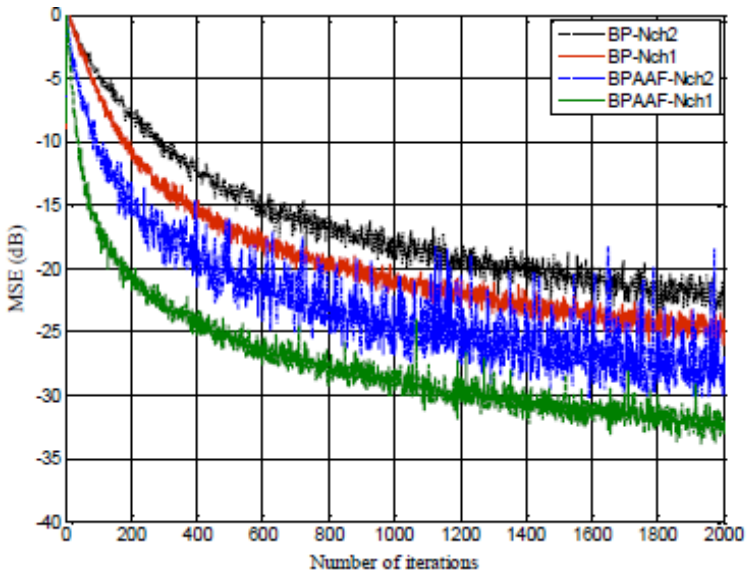

Figure 2. Convergence of the algorithms for nonlinear channels

Bit error rate Study

Figures 3 illustrate the BER curves for the BPAAF and the BP algorithms through nonlinear channels $NCh_{1,}$ $_{NCh2}$. The BPAAF still consistently behaving better than the BP; it shows a gain of about 1.8 dB and 1.7dB over the BP at a BER of 10^{-3}. We can also notice that the BPAAF achieves the minimum BER is about $10^{-3.4}$ at the SNR of 14 dB where the BP realizes a BER of $10^{-2.7}$ at the same SNR for the nonlinear channel $NCh_{1.}$

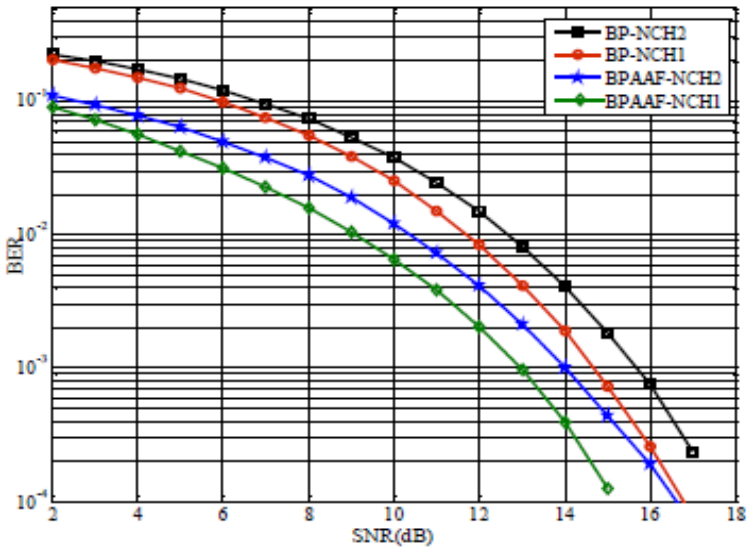

Figure 3. BER curves of the algorithms for nonlinear channels NCh_1, NCh_2

Table 1. Performance analysis of the proposed algorithm (BPAAF)

Channels	Nature	Convergence time of BPAAF over BP (iterations)	Steady state MSE of BPAAF over BP (dB)	SNR at 10^{-3} BER of BPAAF over BP (dB)
Ch1	Linear	440	7.3	1.9
Ch2	Linear	840	8	1.6
Nch1	Nonlinear	602	7	1.8
Nch2	Nonlinear	950	8	1.7

Conclusion

We proposed an algorithm that adapts the sigmoid activation function slope for the FFNN based equaliser. Our approach performs quite well for on nonlinear channels which are difficult to equalize. The proposal BPAA manifests a fast convergence and a lower steady state MSE than the BP. For the BER performance the BPAAF accomplishes all the time the minimum BER. It can be seen from the entire scenarios presented that the BPAAF achieves accurately the best performance. Simulations illustrate that as the severity of the channel increases, the steady state error of BP and BPAA also increase. However, the BPAAF all the times holds lower steady state error.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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Microstrip Patch Antenna System Design for In-Cabin Wireless Communications and Internet Services

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Abstract: Due to the increasing communication requirements, using the internet when air traveling is no longer luxury but it is a necessity. In this paper, a microstrip patch antenna system has been designed which can be used as an access point and provide internet connections at the 5GHz band in the Airbus A321 type of aircraft. The electromagnetic field radiation simulation and positioning of the designed antennas in the aircraft cabin have been performed also. The microstrip antennas have been designed within IEEE 802.11 ac/ax standard. 5GHz WiFi internet service is providing at 5300 MHz (CH 60) center frequency with 4 antennas which FR-4 dielectric material was used. The designed antennas are used as access points and they are connected with a fiber connection. The electromagnetic field radiation of the antennas placed in the cabin was simulated with the HFSS simulation program. As a result of the simulations, these antennas have been observed to be useful.

Keywords: Microstrip patch antenna, 5G, WIFI/WLAN, In-flight connectivity (IFE), Airbus A321

Introduction

Today, as in all transportation vehicles, the internet usage needs is inevitable for passengers in the air transportation as well. For this reason, it has become a necessity for airline companies to both supply with the wireless internet using and in-flight entertainment (IFE) service. Thus, passengers is have beatifically time during the flight.(Akl et al., 2011).

Leading airline companies in the world use many different aircrafts which have different brands and models in accordance with the purpose of the travel. This article is based on the Airbus A321 type aircraft model.These planes have a cabin length of 34.4 m, a cabin height of 2.18 m, and a cabin width of 3.7 m and frequently included in their squadrons of the airline companies.(Airbus, 2005). Wireless access points (APs) have been placed in the aircraft cabin in order to meet the wireless internet access at a sufficient level for each user. These access points are designed with microstrip patch antennas due to today's technology and easy applicability.

Microstrip patch antennas have become more popular in recent years and have begun to be used in more areas, thanks to their lightness, easy adaptation to the surface on which they are applied, ease of production and low cost (Dündar, Gültekin & Uzer, 2019). In this article, the design details and simulation values of microstrip antennas to be used as access points in aircraft are mentioned.

Table 1. Table of the regions using the CH60 frequency band

Channel	Center Frequency (MHz)	Frequency Range (MHz)	Bandwith (MHz)	United States FCC U-NII Band(s)	United States / Canada / Singapore / Mainland China / Korea / New Zealand / Vietnam	Europe / Japan / Israel / Turkey / Australia / South Africa / Bahrain	Russia	India / Brazil / Indonesia	Taiwan
60	5300	5290 - 5310	160	U-NII-2A	DFS/TPC	Indoors/DFS/TPC	Indoors/TPC	Indoors	DFS

Currently, the 5 GHz frequency band is quite popular for WiFi WLAN. Table 1 shows the list of countries using the CH60 frequency band. Microstrip antenna design has been carried out to cover the WLAN CH60 frequency band 5290-5310 MHz in order to cover both domestic and international travels and to be valid and usable in all continents as much as possible. In addition to being compatible with the IEEE802.11 a/h/j/n/ac/ax standards, the CH60 band is in a range that will not interfere with other in-flight wireless communication systems (Chilakala, 2008). Avionic communication frequency bands are shown in Table 2 (Gutton & Baissinot, 1995).

Table 2. Avionic communication frequency bands

Frequency Range	System
190 – 1750 kHz	Automatic Direction Finder (ADF)
2-30 MHz	High Frequency (HF) Radio
75 MHz	Marker Beacon
108 – 112 MHz	Localizer (LOC)
108 – 118 MHz	VHF Omnidirectional Range (VOR)
118 – 137 MHz	Very High Frequency (VHF) Radio
329 – 335 MHz	Glide Slope
962 – 1213 MHz	Distance Measuring Equipment
1030, 1090 MHz	Traffic Alert and Collision Avoidance (TCAS)
1030, 1090 MHz	Air Traffic Control (ATC)
1530 – 1660 MHz	Satellite Communication (SATCOM)
1575.42 MHz	Global Position Satellite (GPS)
4235 – 4365 MHz	Radio Altimeter
5031 – 5091 MHz	Microwave Landing System (MLS)
5440, 9350 MHz	Weather Radar

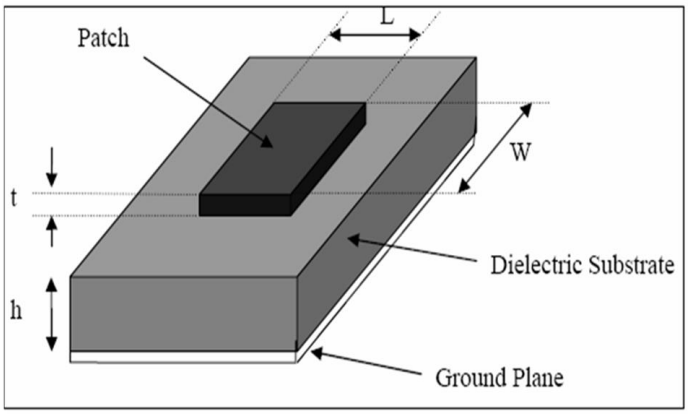

Figure 1. Standard microstrip patch antenna structure

Figure 1 shows the microstrip antenna structure. At the bottom is the ground layer. The material used in the ground layer is conductive and enables the antenna to radiate in one direction (Kütük & Taşneli, 2013). On top of the ground layer, there is a dielectric layer consisting of dielectric material. For ideally situation the dielectric constant should be less than 2.5 (Balanis, 1982). The thickness of the dielectric layer generally ranges from 0.05 mm to 6.35 mm. At the top is the patch layer, which is positioned to radiate. The patch layer is conductive. The patch layer can be used with conductors such as gold and silver, usually copper. Patch design can be made in different ways. The thickness of the patch layer varies between 0.035 mm and 0.070 mm (Bazan, 2010). Variables such as the shape of the patch and the feeding technique differences directly affect the parameters of the antenna (Sainati, 1996).

Method

Microstrip Patch Antenna Design

The designed antenna is required to operate at 5300 Mhz center frequency. Based on this, FR-4 with relative dielectric constant $\mathcal{E}_r$ = 4.9, loss tangent tanδ = 0.02 was chosen as the substrate material, and the dielectric material thickness was determined as 0.7 mm. The next step in the design is to calculate the patch dimensions using the material's dielectric constant, thickness. The patch width W is calculated using equation 1 as follows.

$$W = \frac{c_0}{2f_c\sqrt{\frac{2}{\mathcal{E}_r+1}}} \tag{1}$$

In the formula c_0 is the speed of the light and f_c is the center frequency. For f_c = 5.3 GHz center frequency, W = 16.316595971 mm. If $\frac{W}{h} \geq 1$, the effective dielectric constant ($\mathcal{E}_{reff}$) is calculated by equation 2 [1];

$$\mathcal{E}_{reff} = \frac{\mathcal{E}_r+1}{2} + \frac{\mathcal{E}_r-1}{2}[1+12\frac{h}{W}]^{-\frac{1}{2}} \tag{2}$$

For $\mathcal{E}_r$= 4.9, h=0.7 mm and W = 16.316 mm values, $\mathcal{E}_{reff}$=4.534 is obtained.

$$L_{eff} = \frac{c_0}{2f_c\sqrt{\mathcal{E}_{reff}}} \tag{3}$$

The effective length L_{eff} given by equation 3 is calculated as 13.281 mm by using c_0=3x10^8 m/s,

$\mathcal{E}_{reff}$=4.534 ve f_c = 5.3 GHz.

$$\Delta L = dL = 0.412\frac{(\mathcal{E}_{reff}+0.3)(\frac{W}{h}+0.264)h}{(\mathcal{E}_{reff}-0.258)(\frac{W}{h}+0.8)} \tag{4}$$

$$L = \frac{c_0}{2f_c\sqrt{\mathcal{E}_{reff}}} - 2\Delta L \tag{5}$$

Length extension (ΔL) and patch length (L) is calculated via equation 4 and equation 5 with use the values W = 16.316 mm, c_0=3x10^8 m/s, $\mathcal{E}_{reff}$=4.534, ve f_c = 5.3 GHz, L_{eff} = 13.281 mm, h=0.7 mm. ΔL=0.318mm and L=12.494 mm has been found. As a result of the calculations, our patch sizes were found to be W = 16.316 mm and L=12.494 mm.

Table 3. Antenna Parameters

Parameters	Value
Dielectric Material	FR-4
W	16.316 mm
L	12.494 mm
$\mathcal{E}_r$	4.9
$\mathcal{E}_{reff}$	4.534
L_{eff}	13.281 mm
f_c	5.3 GHz
ΔL	0.318 mm
c_0	3x10^8 m/s

The parameters of the designed antenna are given in Table 3 with the calculated values.

Access Point Placement and Calculations

Access points has placed in the middle of the ceiling of the aircraft and spaced evenly in the aircraft cabin. Pleaced 4 access points have provide sufficient level of wireless internet access for all passengers.

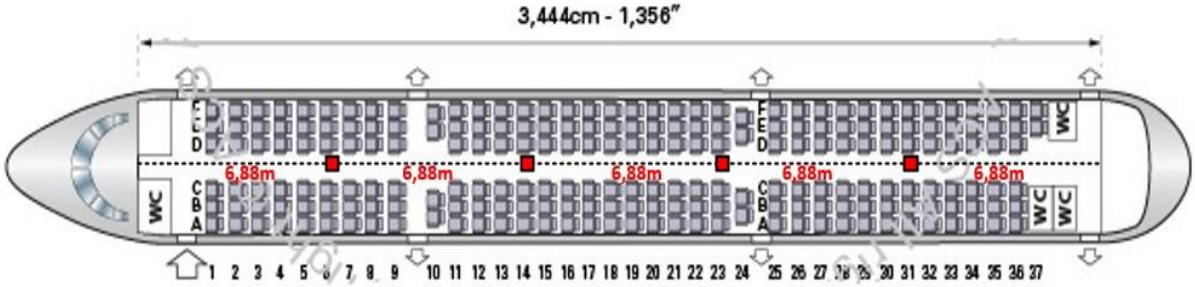

Figure 2. Access points places in the aircraft cabin

As can be seen in Figure 2, when the access points are evenly spaced, there is a distance of 6.88m between them. Each access point is required to radiated signal up to 3.44m. The free space path loss for access points is calculated as follows (Chilakala, 2008);

$$FSPL = 20\log_{10} d + 20\log_{10}\left(\frac{4\pi}{c}\right) - G_t - G_r \tag{6}$$

Considering that a passenger at 3.44m from the access point uses a mobile phone with a 2 dB receive gain, the free space path loss value is calculated as 52.74 dB. The signal strength received by the passenger mobile phone was calculated from the equation 7.

$$P_{out} = P_t + G_t - L_t - L_{fs} - L_m + G_r - L_r \tag{7}$$

When the required values are put in equations, it is expect that a passenger using a mobile phone at a distance of 3.44m from the access point will receive a signal with a strength of -49.82 dBm.

Connections Between Access Points

In order for the data transmission between the APs to not cause any electromagnetic interference (EMI) to the avionic system and flight safety within the aircraft, they are connected to each other as a fiber connection with RF Over Fiber (RFoF) technology as in Figure 2. With the RFoF system, due to the low emission power of the antennas and the fiber links that do not contain electromagnetic radiation, it can effectively reduce the EMI threats from wireless access during flight (Zhang et al., 2013). Compared to the standard system, it is thought that a 4-8 dB reduction in electric field strength can be achieved by using RFoF based access in the cabinet. At the same time, a higher energy efficiency is achieved as well.

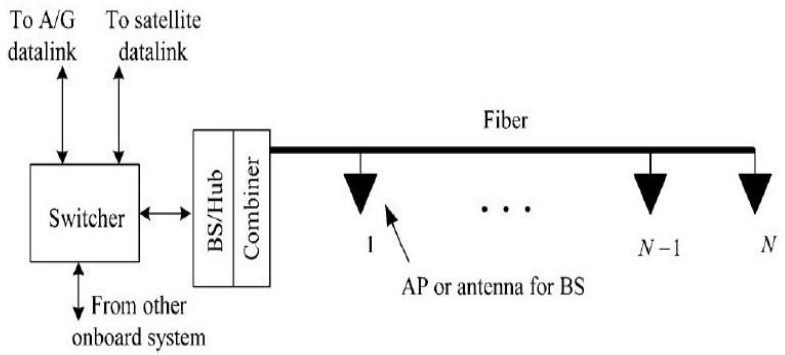

Figure 3. RFoF system connection diagram

Results and Discussion

In this study, the antenna design was simulated in the HFSS simulation program as in Figure 3 and the design values were obtained. Looking at the graph of the designed microstrip antenna in S_{11} parameter Figure 4, the Center Frequency was obtained as -18.72 dBm at 5300 MHz.

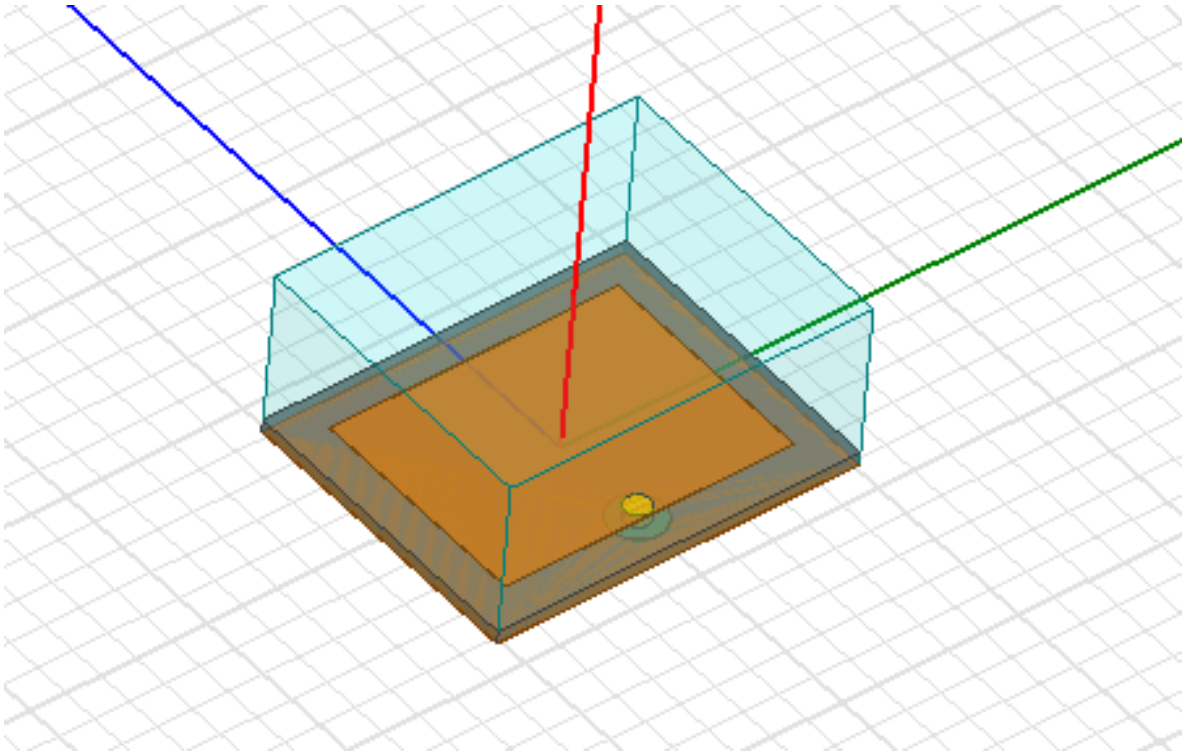

Figure 4. Designed microstrip patch antenna view

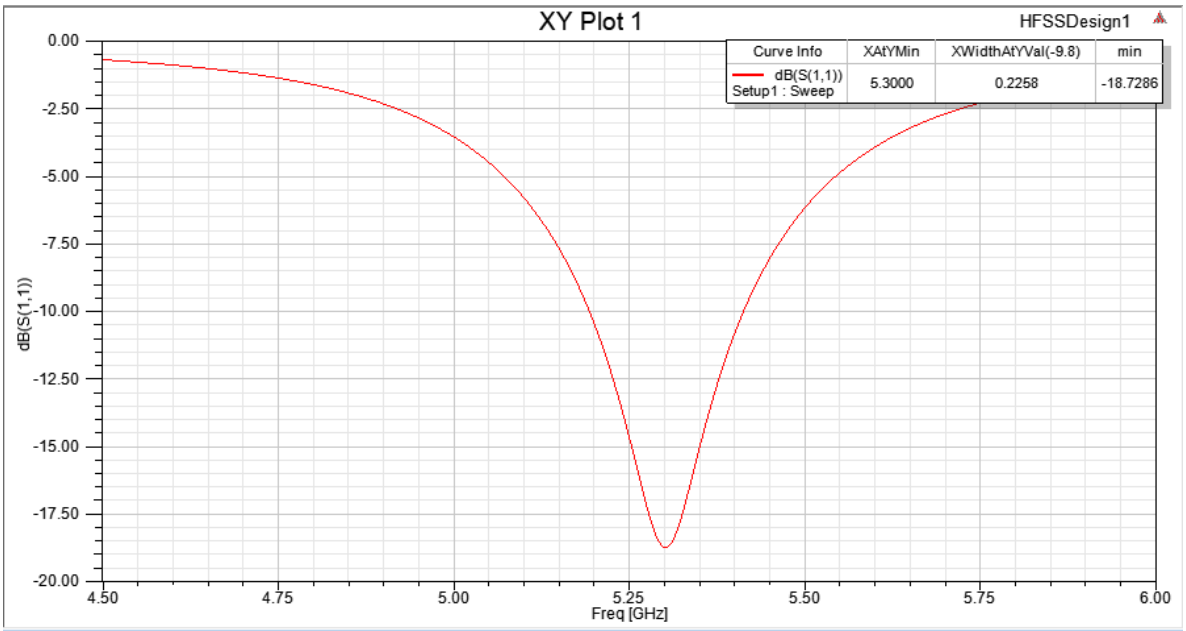

Figure 5. Microstrip patch antenna S11 parameter graph

When we look at the area below the -10dB reference value, it is seen that an antenna with a bandwidth of 225MHz has been designed. When these values are considered, the compatibility of the antenna with the CH60 WLAN class is seen.

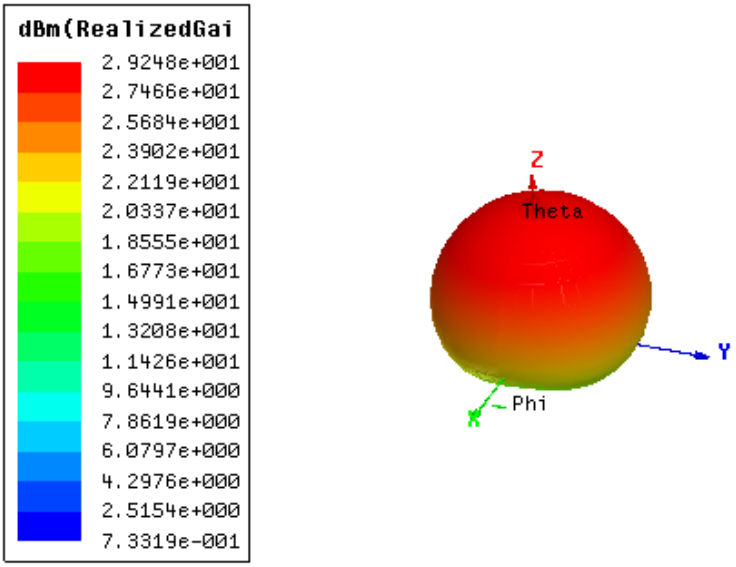

Figure 6. Gain plot of microstrip patch antenna

When the gain graph of the designed microstrip antenna in Figure 5 is examined, it is seen that the gain value is sufficient to be used for WiFi AP with both the radiation pattern and 2.92 dBm gain.

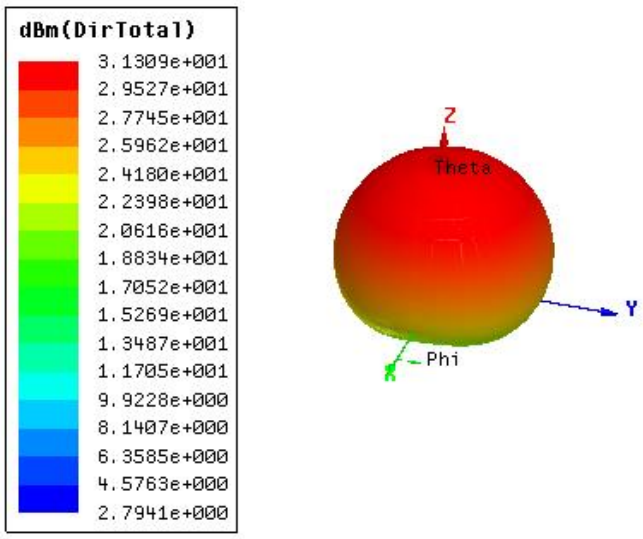

Figure 7. Directivity plot of microstrip patch antenna

Similarly, when the 3D directivity graph of the antenna in Figure 6 is examined, it is seen that the directivity is at a sufficient level.

Conclusion

As a result of the design, calculations and simulations, it has been seen that the antenna design with -18.72 dBm and 225 MHz bandwidth is suitable for APs that will operate at 5300 MHz center frequency. With a gain of 2.92 dBi, it has been calculated that the radiated in the cabin is at a sufficient level. When 4 of the microstrip patch antennas designed as AP are used and placed inside the aircraft at 6.88m intervals, a distribution with a signal reception power of at least -49.82 dBm is provided on the user's side. Via connecting the designed APs to each other with RF over Fiber technology, it has both minimized electromagnetic interference (EMI) on the avionic system and made it safer for aircraft systems. It has been determined that the antenna designed for Airbus A321 type aircraft cabin wireless internet distribution can be used for internet distribution and In-Flight Entertainment (IFE) applications.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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Monitoring Grain Silos Instantly with IoT Based Control System

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Abstract: The need of preserving variable products' amount and quality the best and the longest time aroused the need of storage. Especially cereals can be stored long times without losing their quality under favorable conditions. These favorable conditions can be provided with silos for cereals. The products stored in silos to be used in times of need, must be protected well and durable. Yet, humidity and temperature like factors can make silos unsafe. With the development of technology, especially the concept of Internet of Things, silos can be monitored in real-time and kept under control. Regular silos can be turned into smart silos thanks to systems created via Internet of Things. In this study, the humidity and temperature values of the cereals in a silo created as a prototype, measured with an IoT based real-time system and data gathered were monitored instantly via a web-based software. Hence, without the need of much manpower, cereals could be kept under favorable temperature and humidity levels.

Keywords: IoT, Silo, Sensor, Real-time Communication, Node MCU

Introduction

Since the need of usage through whole year grains, which are staple food since the transition to settled life of humanity and has still great importance contemporarily, must be stored and preserved. Grain storages (silos) are used for this purpose (Yaldıran, 2018). Silos are convenient for grains to be stored long times without decaying. Stored items can be processed easily because of silos' loaders and dischargers. Preservation of the yields which are harvested with toil has utmost importance for continuity of agriculture, thus silos are needed every time. Silos are generally built from reinforced concrete, stainless steel or galvanized iron sheets (Dalmış, 2018). Below are the silos in Figure 1.

Silos can be in various types for different products. For grains, generally tower silos are used. In order to preserve the products stored in the silos without losing any of their qualifications for a long time their atmosphere, that is the values like humidity and temperature of the silos, should be under control at all times. In any case where the relative humidity of storage is higher than 65%, because of the hygroscopic (moisture sensitive) feature of grains, the water content of the grain kernels is monitored to rise over 14% and a speed up in deterioration rate is detected (Baykara, 2018).

Due to the importance of the storage, there have been significant studies carried out in recent years. Özel (2007) conducted a thesis study about the design of steel silos which has different characteristics and widely used in our country as in the world. Satuk (2011), in his study measured the temperature and humidity values of the grains

stored in the silos with an electronic circuit and kept the temperature and humidity values of the grains convenient via a desktop computer software. Mısır (2015), created a receptor network with Control Area Network (CAN) communication protocol in order to monitor silo control systems. Baykara (2018) in his study designed a new Grain Control System for grain bagging systems.

Figure 1. Silos

In this designed system humidity and temperature values, which are important parameters in safe grain storage instead of CO2 rates, can be obtained automatically via wireless censor nodes and these data can be saved to database of the system for later monitoring and interpretation with a user interface instantly. Gupta (2018), has designed a smart medicine storage system which allows real time monitoring by using Internet of Things (IoT). Kumar (2019), has designed an irrigation system which allows real time monitoring by using IoT. In this study; on the basis of humidity and temperature problem in silos, it is aimed to develop an IoT based prototype system to monitor the silos by keeping them under control in real time web platform.

Material and Method

Embedded architecture and NodeMCU micro controller with Wi-Fi module are used for the IoT based generated system. Temperature values of the silo's inside is gathered with DS18B20 temperature sensor. The humidity values of the silo's inside is gathered with DHT 11 temperature and humidity sensor. The materials used are like this:

NodeMCU

It has a modular structure with Wi-Fi feature installed on it. Since it can be programmed, we can develop Internet of Things applications with low cost. It has analog input, PWM output, and digital input/output units and can provide communication assistance. Pin connection structure belonging to NodeMCU micro controller is shown in Figure 2.

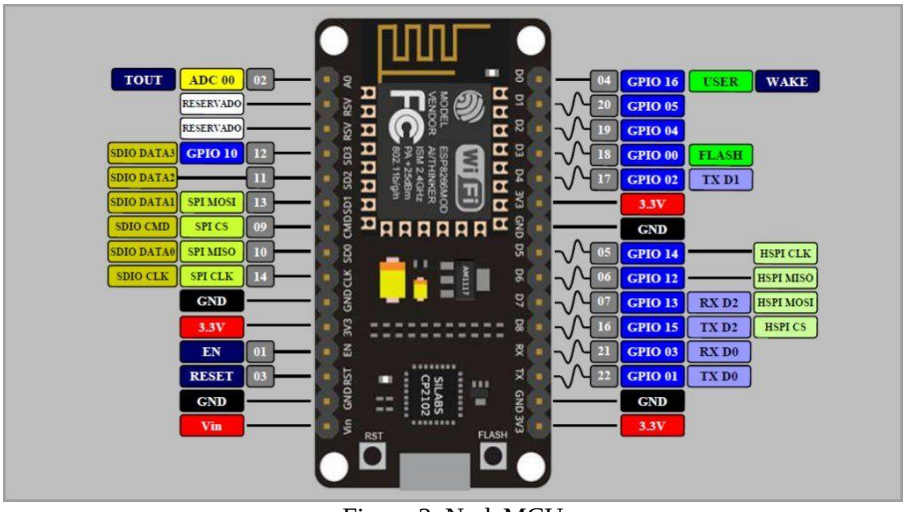

Figure 2. NodeMCU

NodeMCU, is a widely used IoT controller with an internal Wi-Fi module. It contains a 32-bit RISC Tensilica LX106 micro controller working at 160 MHz. To program the NodeMCU Arduino IDE compiler is used with C++ programming. In Table 1 is shown the technical features of the controller.

Table 1. NodeMCU technical features

Features	Value
MCU	32 bit Tensilica L106
CPU Frekans	80/160 MHz
Input/Output	13xDIO
ADC Pin	1x10 bit (1V)
Working Voltage	3.0 - 3.6 V
Working Current	12-200 mA
Program Memory	4MB
WiFi	IEEE 802.11 b/g/n
Sleep Mode Current	<10uA
Standby Mode Current	<10mA

DHT 11 Temperature and Humidity Sensor

In this study, in order to measure the humidity level of silo's inside a DHT 11 temperature and humidity sensor is used. This sensor is shown in Figure 3 and its technical features are shown in Table 2.

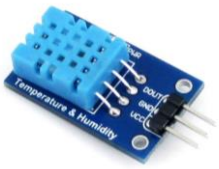

Figure 3. DHT 11 Sensor

Table 2. DHT 11 Technical features

Output Type:	Digital Signal.
Current Voltage:	3V ~ 5.5V (Tipik: 5V)
Working Current (mA):	0.5 ~ 2.5.
Temperature Sensing Range (°C)	0 ~ +50.
Humidity Detection Range (%RH):	20 ~ 90.
Sensor Temperature Sensitivity:	±2 °C.

DS18B20 Temperature Sensor

It uses 1 wire interface and communicates with Micro controller on a single line. Each sensor has a unique 64 bit serial code which was generated during the fabrication in ROM memory. Thanks to this code multiple sensors can communicate on a single line. In Figure 4 is shown DS18B20 sensor and in Table 3 its technical features are shown.

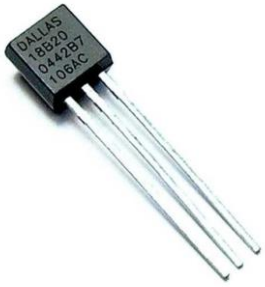

Figure 4. DS18B20 Sensor

Table 3. DS18B20 technical features

Working Voltage:	3V ~ 5.5V
Temperature Sensing Range (°C)	-55 ~ +125
Sensor Temperature Sensitivity:	±0.5 °C.

Application

Silos are the safest storage areas yet, their control is troublesome. Especially in a filled silo, to control the lower level products technology is needed (Mondal, 2018). The pioneer problems of silos are humidity and temperature. Humidity under no control can cause a series of problems which goes all the way to the decaying (Dizlek, 2012). Likewise, the temperature problem can cause especially the bug problem. In order to solve these temperature and humidity problems a prototype is generated. This generated prototype is designed as four layers as hardware, gathering the sensor data and wireless communication with the program part developed with C++, Web host and user interface. Design layers are shown in Figure 5.

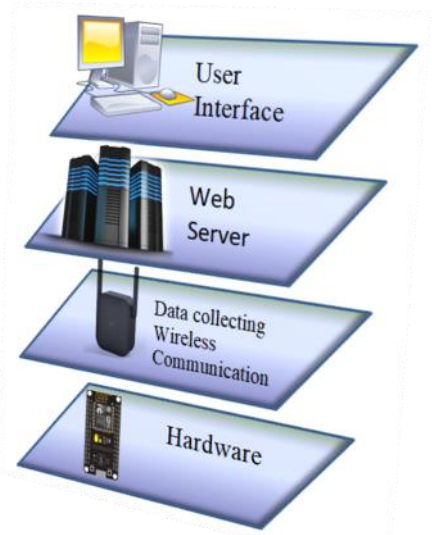

Figure 5. Design layers

The methodology followed to control humidity and temperature in the generated prototype is shown in Figure 6.

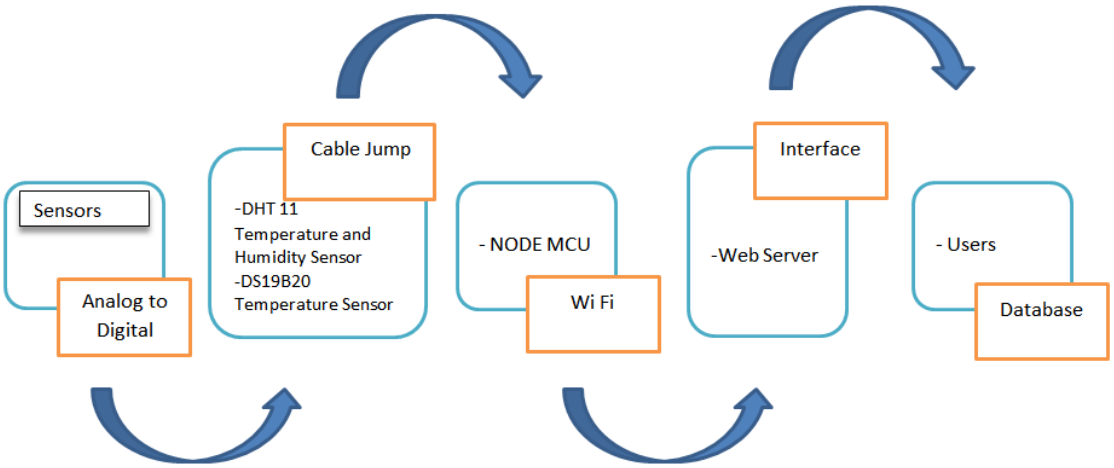

Figure 6. System methodology

Block diagram of IoT based prototype system developed in the framework of determined methodology is shown in Figure 7.

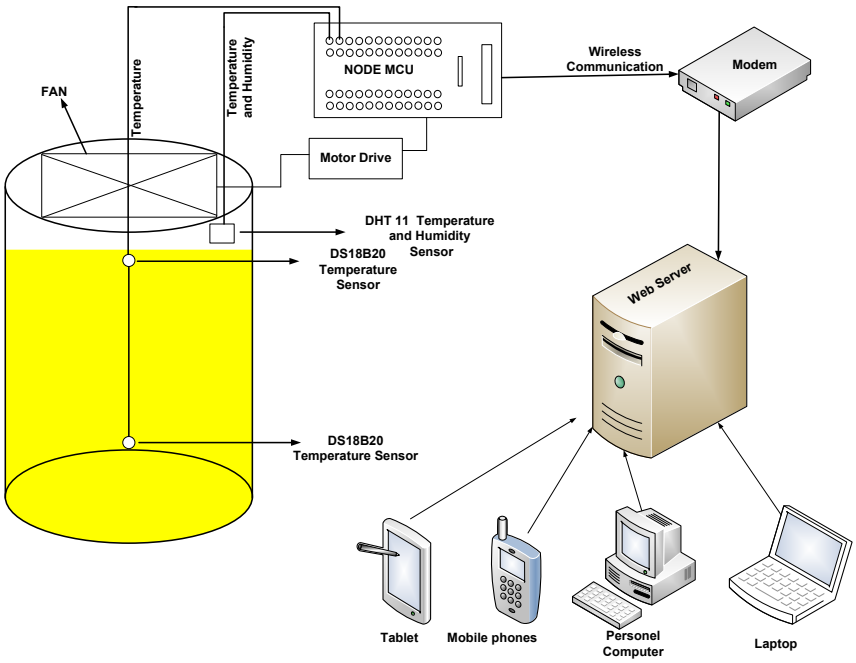

Figure 7. Block diagram of IoT based prototype system

Flow diagram to follow in order to solve the problem in generated prototype is shown in Figure 8.

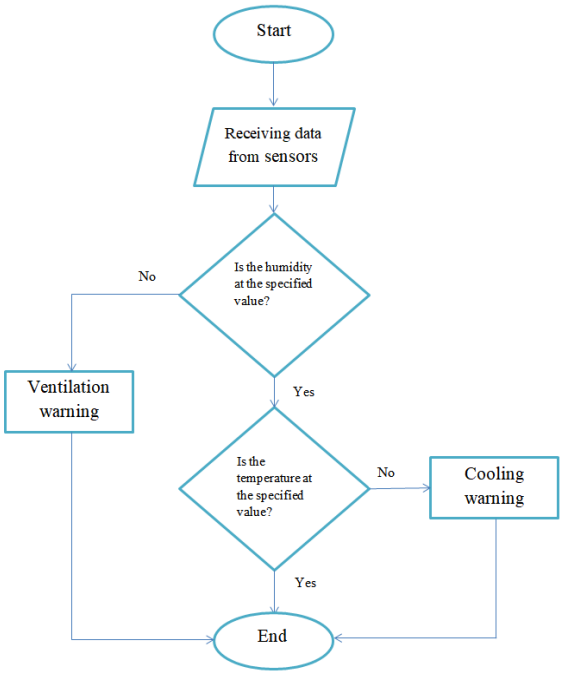

Figure 8. Flow diagram

As shown in Figure 8, temperature and humidity sensors are installed inside of the prototype silo generated in hardware layer and the data from these sensors are transferred to NodeMCU used as sensor node IoT. At the second layer the temperature and humidity data gathered are transferred to a host computer with the help of wireless technology. At the third layer an infrastructure is created to reach the data from a Web host including mobile platforms. At the last layer thanks to a web based interface software, users are ensured to monitor the data. After the system installation, the temperature and humidity values are interfered in to test the ability to monitor authentic data from computer. These data is saved at the database at the same time. This system is shown in Figure 9.

Figure 9. Created system

The stages of the system shown on Figure 9 are like below:

Hardware: A prototype tower type silo, which is especially used for grains, is created by using aluminum material (Duysak, 2020). One DHT 11 temperature and humidity sensor is installed in the middle part of the silo in order to measure humidity. Two DS18B20 temperature sensor are installed at the middle and lower part of the silo. According to pin table the power and input/output cables from sensors are connected to NodeMCU IoT. Sensor data is gathered with C++ code

Communication: Wi-Fi module integrated with NodeMCU is used for communication. The Wi-Fi module is ensured to communicate with monitoring computer.

Web Host: A Php Web host is used on a local computer.

Interface Program: A web based interface program is written so that a user can see the data from silos. The written program is ensured to be reachable from a computer with internet connection. In this created interface the data from sensors are replenished in every 30 minutes (Alanso, 2020, Rehena, 2018). The interface program is shown in Figure 10 below.

Figure 10. Monitoring program

Data Control: Sensor data is ensured to reach the web page created after filling the silo with grain. To change the temperature value the setting is heated. To change the humidity value on the other hand, a vapor device is used. In a room, in different periods of various parts of a day the humidity and temperature values are measured with the created system inside the silo in ten minutes intervals. The following three days the humidity and

temperature inside the silo is interfered in and again in ten minutes intervals system has measured the data. Whether the values are changing or not is controlled via interface. When the temperature and humidity levels rise the user interface has given warnings of risky and dangerous product. The integrated fan of the system is checked to see if it becomes active to cool down or ventilate.

Results and Discussion

On the basis of the most significant problem of silos, temperature and humidity problems, a prototype is constructed to control the humidity and temperature of the silo. Some values are determined as benchmarks and the product is classified as secure, risky and in danger according to these values. For humidity, relative humidity values are determined for secure grain between 42-48%, for risky grain between 82-85%, for in danger grain 92-99% (Baykara, 2018). For temperature control, the values for secure grains is below 18 ° C and for risky grains it is above 18 ° C (Erbaş, 2013). The results of the measurements in determined periods for four days in total is shown in Table 4.

Table 4. Results

Day	Period (Hour)	Average Temperature Value	Temperature Status	Average Moisture Value	Humidity Status	Warning	Explanation
Day 1	Periyod 1 (06.00-14.00)	21,5	Normal	43	Normal	Risky Product	Room Conditions
	Period 2 (14.00-22.00)	23	Normal	45	Normal	Risky Product	
	Period 3 (22.00-06.00)	20	Normal	44	Normal	Risky Product	
Day 2	Period 1 (08.00-09.00)	28	Risky	45	Normal	Risky Product	Temperature Increased.
	Period 2 (09.00-10.00)	18	Normal	45	Normal	Safe Product	Fan Enabled.
	Period 3 (21.00-22.00)	26	Risky	44	Normal	Risky Product	Temperature Increased.
	Period 4 (22.00-23.00)	18	Normal	44	Normal	Safe Product	Fan Enabled.
Day 3	Period 1 (08.00-09.00)	17	Normal	85	Risky	Risky Product	Humidity Increased.
	Period 2 (09.00-10.00)	17	Normal	50	Normal	Safe Product	Fan Enabled.
	Period 3 (21.00-22.00)	18	Normal	93	Risky	Risky Product	Humidity Increased.
	Period 4 (22.00-23.00)	18	Normal	55	Normal	Safe Product	Fan Enabled.
Day 4	Period 1 (06.00-14.00)	28	Risky	85	Risky	Risky Product	Temperature and Humidity Increased.
	Period 2 (14.00-22.00)	18	Normal	55	Normal	Safe Product	Fan Enabled.
	Periyod 3 (22.00-06.00)	32	Risky	95	Risky	Risky Product	Temperature and Humidity Increased.
	Period 4 (22.00-23.00)	18	Normal	50	Normal	Safe Product	Fan Enabled.

As seen on Table 4 the first day measurement wan in normal room conditions and both temperature and humidity classified as risky. The following three days humidity and temperature are interfered in and as a result of increase in temperature and humidity, the fan was activated to cool down and ventilate.

The written interface also generates weekly average graphic of temperature and humidity values. The example generated weekly average temperature and humidity value change graphic is shown in Figure 11.

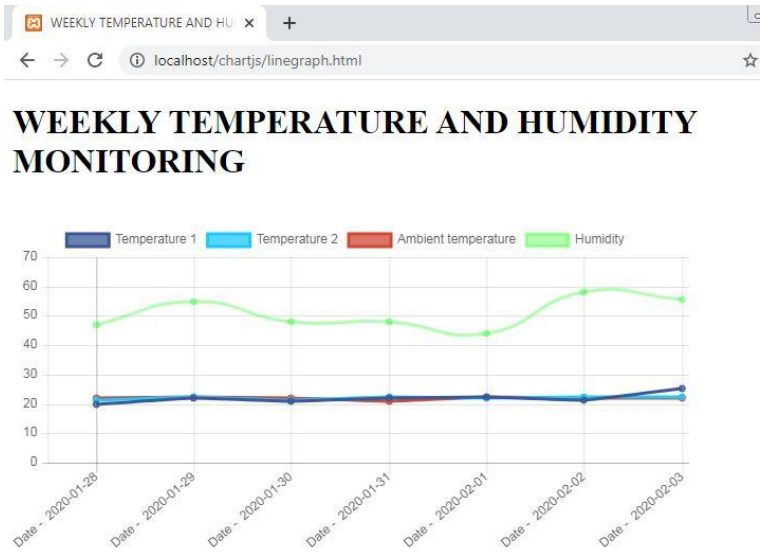

Figure 11. Weekly average temperature and humidity values

Conclusion

In order to keep the temperature and humidity which are the most significant problems of silos under control, a system IoT based, low cost and constantly monitor-able even from portable internet connected devices, is designed. With the created system, it was aimed to prevent human errors and it was ensured that more accurate and reliable results could be obtained.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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A New Friedman's Model for Evolutionary Game Problem

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Abstract: The term game in game theory means a problem, where some of the people or groups (players) share a set of rules and regulations that create the conditions and events that make up the beginning of the game. For instance, in the trade market, the buyers and sellers of some commodities interact in a random way. The reputation of sellers effects on increasing of selling. e.g., honest sellers are more attractive than cheaters for the buyers and the buyers can examine the products or unexamined. In this paper, a non-linear discrete dynamical system of Friedman model was considered. Also, we proposed a new model of interaction between these two populations (buyers and sellers). investigate its limit run behavior where we found the limit converges to a fixed point (0,0) i.e., the sellers will always cheat and the sellers will not examine according to Friedman's model which is denoted by the fixed point (0.0).

Keywords: Discrete dynamical system, Evolutionary game, Friedman's godel, Simplex

Introduction

In evolutionary game theory, each individual has the ability to choose among the strategies in such their payoff depend on the others choice. Then, the behavior of players evolves over time in a population where appropriate strategies will be more prevalent (Sandholm, 2020). Also, the changes of these strategies to be more fit or less fit may increase the complexity of the dynamics of the game. It is natural to ask the following question: which of such behaviors or strategies will be dominant and which extinct in the future and may this system converge to a stable steady state? In heredity model, biologists took into account the interaction between random individuals in one population and analyzed according to steady equilibrium shortly (Evolutionary Steady Stable) for a fixed evolutionary strategy. The population state of species probabilities can be represented by *m*-tuple $(x_1, x_2, \dots, x_m)$, where each x_k represents a fraction of the species k in all the population (Haozhen, 2020). The original pairs (parents) i and j in the case of random interbreeding create for a fixed state $x = (x_1, x_2, \dots, x_m)$ with the probability $x_i x_j$. The scale of species was assumed is such that without doubt for the species of parents i, j determines of the probability $p_{ij,k}$ of each types k in the first descent during the direct posterity of the strategy i and strategy j. where $p_{ij,k}$ is called the coefficient of heredity. Hence the overall probability of the species k in the first generation of direct offspring is defined by:

$$\sum_{i,j=1}^{m} p_{ij,k} x_i x_j \quad (k = 1,2,\dots,m) \tag{1}$$

Let

$$S^{m-1} = \left\{ y = (y_1, y_2, \dots, y_m) \in R^m ; y_i \geq 0, \sum_{k=1}^{m} y_k = 1 \right\} \tag{2}$$

be $m-1$-dimensional simplex. A map V of S^{m-1} into itself, which denoted as

$$(Vy)_k = \sum_{i,j=1}^{m} p_{ij,k} y_i y_j \tag{3}$$

is called a quadratic stochastic operator if for any $y \in S^{m-1}$and for all $k = 1,2,\dots,m$:

$$i)\ p_{ij,k} \geq 0, \qquad ii)\ p_{ij,k} = p_{ji,k}, \qquad iii)\ \sum_{k=1}^{m} p_{ij,k} = 1.$$

For any initial point $y_0 \in S^{m-1}$, assume that $\left\{ y_0^{(n)} \in S^{m-1}; n = 1,2,\dots \right\}$. The trajectory of operator V is denoted by $y^{(n+1)} = V\left(y^{(n)}\right) \forall\, n = 0,1,2,\dots$, where $y^{(0)} = y$.

A fixed point of the quadratic stochastic operators V is a point $y_0 \in S^{m-1}$ satisfies $V(y_0) = y_0$.

If all eigen values at the fixed point α of Jacobian matrix of the dynamical system are real numbers or complex with absolute value less than 1 then the point α is called stable fixed point. The fixed point is unstable if at least one of them has absolute value greater than one.

For any initial point $y_0 \in R^m$, if the limit

$$\lim_{n\to\infty} V^n(y_0), \tag{4}$$

exists. Then, the quadratic stochastic operator V is called regular operator.

Note that for a quadratic stochastic operator V the limit point is a fixed point. Thus, the limit behavior of trajectory for any initial point can be described by the fixed points. The fixed points of quadratic stochastic operators and behavior of their trajectories have a main role in many research problems such as mathematics (Saburov et. al., 2019), computer science (Hofbauer et. al. 1988), and biology (Jamilov et. al., 2020). For example, in mathematical genetic models, the family of Volterra quadratic stochastic operators can describe dynamics of bisexual populations (Friedman, 1991).

Many ideas introduced by biologists was transferred to the field of economic. but the difference is that the biology viewpoint focused on expand and adapt of the species (Sandholm, 2020; Friedman, 1998). Also, the biologists almost treat with the genetic mechanism of natural selection (Zeeman, 1980; Castanos, 2018; Nachbar, 1990). On the other hand, economists consider the mechanisms of genetics are less importance than learning or imitation (Friedman, 1991; Bernstein, 1924).

In (Castanos et. al., 2018; Leibo et. al., 2019), a biological model was considered differ from the economic models which the authors established the bisexual population system with the difference of the gender. Nowadays, there are only a small number of studies on dynamical phenomena on higher dimensional systems that are presently comprehended, even though they are very important. The below model features interaction of many populations which strategically featured to represent the relations between two sides buyers and sellers.

A Model of Interaction Between Two Population

A two-player game can be represented by a bimatrix$[A, B]$, where A and B are $(n+1) \times (m+1)$, with $n + 1$ is the number of strategies of the first player and $m + 1$ is the number of strategies for the second player (9), (11). if player 1 and player 2 play the ith and jth strategies, then the payoff of the player 1 given by the element a_{ij}. Similarly, the payoff for the player 2 given by b_{ij} under same strategies. In (Friedman, 1991) Friedman provided the following model of interaction between two populations. Considered an appropriate mutual influence between two populations sellers and buyers. two possible options are available for each buyer $i = 1$ (examined) and $i = 2$ (unexamined). also, two alternative available options for each seller $i = 1$ (honest) and $i = 2$ (cheat). The strategy state $s = \left((s_1^1, s_2^1), (s_1^2, s_2^2)\right)$ can be described by a point (p, q) in the unit square $[0,1] \times [0,1]$ because the state of strategies is in one-dimensional. The fraction of examining buyers is $(s_1^1 = p)$ and the fraction of seller who are honest is $(s_2^1 = q)$. Then, $s_2^1 = 1 - p$ and $s_2^2 = 1 - q$.

As an example, the game 72 in (Friedman, 1991), consider two-person game that is characterized by a payoff matrix of the form:

$$A = \begin{array}{c} \\ \text{BI} \\ \text{BDI} \end{array} \begin{array}{c} \begin{array}{cc} \text{SH} & \text{SC} \end{array} \\ \begin{vmatrix} 3 & 2 \\ 4 & 1 \end{vmatrix} \end{array}$$

and

$$B = \begin{array}{c} \\ \text{BI} \\ \text{BDI} \end{array} \begin{array}{c} \begin{array}{cc} \text{SH} & \text{SC} \end{array} \\ \begin{vmatrix} 3 & 2 \\ 4 & 1 \end{vmatrix} \end{array}$$

The fitness function investigates how close a solution is to the ideal solution of the given problem and determine how Suitable of the solution. According to (6), the buyer fitness is defined as

$$A.(q, 1-q) = \big(3q + 2(1-q), 4q + 1(1-q)\big) = (q + 2, 3q + 1),$$

and the population average fitness among buyers is:

$$(q + 2) - p(q + 2) - (1-q)(3q + 1) = (1-q)(1-2q).$$

Respectively, the seller's fitness is defined as

$$(p, 1-p)\text{B} = \big(2p + 3(1-p), 1p + 4(1-p)\big) = (3-p, 4-3p),$$

and the population average fitness among buyers is:

$$3 - p - [q(3-p) + (1-q)(4-3p)] = (1-q)(2p-1).$$

As for the dynamics of population of *p* and *q*, it is assumed to be Malthusian (for Malthusian population dynamics see (Kenneth, 1951) That the strategy's growth rate is proportional to its relative fitness (with a suitable time scale). Hence, the following system of differential equations is obtained:

$$p' = p(1-p)(1-2q), \tag{5}$$

$$q' = q(1-q)(2p-1).$$

It is easy to verify that the system of differential equations "5" has exactly five fixed points, i.e., four fixed points at the four corners of the unit square $p - q$ and one at the center. It can be shown that all other points are periodic, and their direction is counterclockwise around center. So that, under Malthusian dynamics the four fixed points at the corners are unstable points, while the fixed point at the center is neither asymptotically stable nor unstable (neutral point). Below, a discrete dynamical system for the considered model "5" was produced because the discrete dynamical systems are of partial importance because computer simulations are discrete in essence (Nachbar, 1990). Despite the complexity of the discrete dynamical systems that sometimes happened, many of discussion, theorems, propositions, and its proofs will be for such discrete systems.

Discrete Friedman's Model

Consider a discrete dynamical system for model considered by Friedman. As noted above the discrete systems are of partial importance because computer simulations are discrete in nature. The discrete time dynamical system that corresponding to the system "5" is defined as follows:

$$p' = p(2 - p - 2q + 2pq),$$
$$q' = q(2p + q - 2pq). \quad (6)$$

To find the fixed points of "6", the following system of equations should be solved.

$$p = p(2 - p - 2q + 2pq),$$
$$q = q(2p + q - 2pq). \quad (7)$$

By solving the system of equations "6", it has also five fixed points at the center $M_0 = (\frac{1}{2}, \frac{1}{2})$ and at the four corners $M_1 = (0,0),\ M_2 = (0,1),\ M_3 = (1,0),\ M_4 = (1,1)$ of the $p - q$ unit square. A Jacobian matrix for dynamical system "3" has the form:

$$J(p,q) = \begin{bmatrix} 2 - 2p - 2q + 4pq & -2p + 2p^2 \\ 2q - 2q^2 & 2p + 2q - 4pq \end{bmatrix}.$$

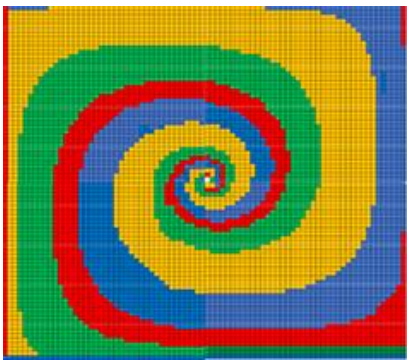


Figure 1 Phase diagram of discrete friedman's model here for arbitrary ınitial blue point: a trajectory converges to point (1,0) and respectively for red point converges to (0,0); for orange point converges to (1,1) and for green point converges to (0,1).

At the corners M_1 and M_4 the Jacobian matrix:

$$J(M_1) = J(M_4) = \begin{bmatrix} 2 & 0 \\ 0 & 0 \end{bmatrix},$$

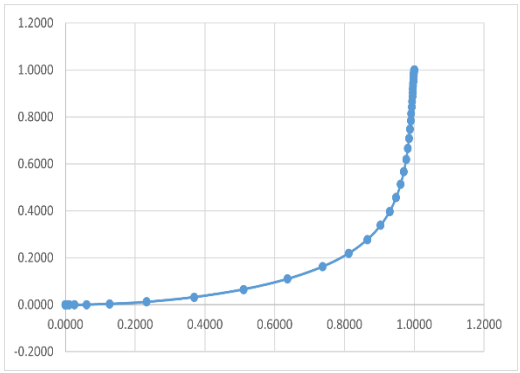
and at the corners M_2 and M_3 Jacobian matrix:

$$J(M_2) = J(M_3) = \begin{bmatrix} 0 & 0 \\ 0 & 2 \end{bmatrix}.$$

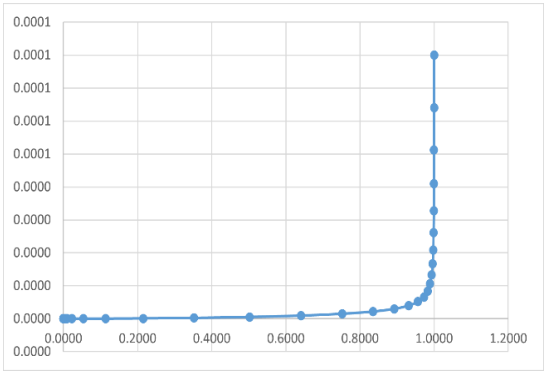
Also, at the center M_0 Jacobian matrix:

$$J(M_0) = \begin{bmatrix} 1 & -\frac{1}{2} \\ \frac{1}{2} & 1 \end{bmatrix}.$$

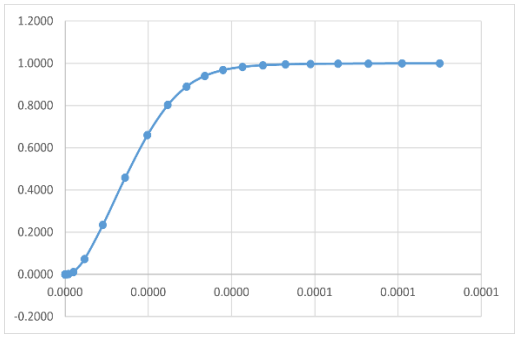
Numerically one can check that the transformation "6" is the regular, that is the trajectory for any initial point converges to one of 5 fixed points "Fig1". Recall that if the Jacobian matrix at the fixed point of a dynamical system can describe the stability of such system i.e., the fixed point is asymptotically stable if the real part of all the eigenvalues is exactly less than zero. It is easy to verify that all 5 fixed points are non-asymptotically stable. It is easy to verify that all 5 fixed points are non-asymptotically stable.



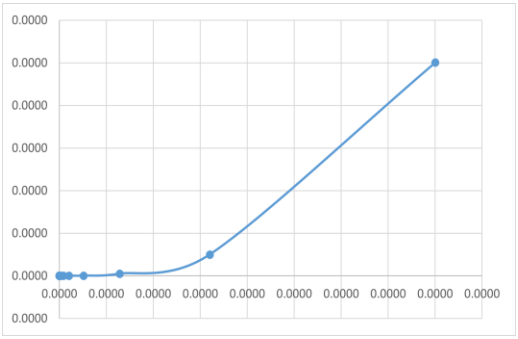
a) *x*= (0.9999,0.9999)



b) *x*= (0.9999,0.0001)



c) *x*= (0.0001,0.9999)



d) *x*= (0.0001,0.0001)

Figure 2. Trajectory of the discrete-dynamical system "9" for a different initial point, *x*.

New discrete Friedman's model

We propose a two-person game, as a modification of the game 72 (3), which is characterized by the following payoff matrix of the form:

$$A = \begin{matrix} & \text{SH} & \text{SC} \\ \text{BI} & 3 & 1.4 \\ \text{BDI} & 3.1 & 2 \end{matrix},$$

and

$$\begin{matrix} & \text{SH} & \text{SC} \end{matrix}$$

$$B = \begin{matrix} \\ \text{BI} \\ \text{BDI} \end{matrix} \begin{vmatrix} 2.3 & 2.5 \\ 3 & 3.9 \end{vmatrix}.$$

Using the definition of the same fitness function as above, one can produce the following differential equations:

$$f' = f(1-f)(0.5h - 0.6),$$

$$h' = h(1-h)(0.7f - 0.9). \tag{8}$$

The discrete time dynamical system that corresponding to the system "8" is defined as follows:

$$f' = f[1 + (1-f)(0.5h - 0.6)],$$

$$h' = h[1 + (1-h)(0.7f - 0.9)]. \tag{9}$$

It is easy to verify that the system of coupled equations "9" has four fixed points at the four corners $T_1 = (0,0),\ T_2 = (0,1),\ T_3 = (1,0),\ T_4 = (1,1)$ of the *f-h* unit square. and T_1 is attractive fixed point. Thus, for any initial point a trajectory converges to the point T_1 "Fig 2 (a), (b), (c), (d) for some fixed initial points". No matter what the initial population is, eventually all buyers do not examine, and all sellers are cheating (for illustration of the trajectory with different initial points, see "fig 2(a), (b), (c), (d)".

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Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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New Trends and Functionalities in Automotive Tail Lighting

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Feka Otomotiv Mamulleri Sanayi ve Ticaret A.S.

Abstract: Styling of automotive tail lighting has become more and more important and evolved to a strong pusher for innovation in exterior lighting in recent years. Next generation and futuristic ideas of automotive exterior tail lighting which are considered within functionality and standards (Lee, 2019). The automobile industry is highly demanding for innovative technologies to equip luxury vehicles and low volume special series with unique lighting solutions. Beyond more and more homogenous rear lamps, all customers are asking for the next evolution or better revolution with marketing required wow-effect. All this in an environment of reduced space, shorter development cycles and higher quality expectations. Digitalization and automated driving will revolutionize our automotive lighting. The main purpose of lighting will no longer be the best visibility for the vehicle. Pedestrians and bicyclists are the new focus group. How we can give clear signals and information to them? The information has to come from the vehicle, not from the driver. What sort of lamps, lights or displays are needs? How could future vehicles then look like? (Berlitz, 2017). This paper will give a status to upcoming lighting solutions for communication. OLED, matrix lighting and projection lighting are shown as new concept vehicles enable the vehicle to interact with humans as well style attraction. These lighting technologies throw a glance on future possibilities for our automotive lighting business.

Keywords: OLED, Matrix Light, Projection, Tail Lighting

Introduction

Rear lamps have been used mainly for signaling. As a matter of fact, we noticed that rear lamps have a increasingly important role to define the style of the vehicle. Signalling needs to be beautiful. Therefore, we see that investment made by OEMs for their rear lamps has more than doubled in the past 5 years. Unlike front lighting, where “what you pay is what you see”, rear lighting value is “paid” by someone else than the driver: The OEM itself or a third party, as we move into the automated/autonomous vehicle (Evrard et. al., 2017). Road projection i.e. light signal projected on the road, offers the great possibility to design a new way of communication between the vehicle and other road users, paving the way to digital light interaction between the autonomous vehicle and its environment (Neumann, 2017). Lighting functions using road projection could hence represent an important step towards dedicated communication of autonomous vehicles with vulnerable road users (Pernkopf, 2017), and thus could contribute to the positive acceptance of autonomous vehicles (Neumann, 2017).

New Generation Lighting Style and Communication

OLED

OLED technology accomplishes entirely new design options for light sources and gains huge interest among customers in the automotive industry. OLEDs are flat light sources that achieve more homogeneity and can be steplessly and individually dimmed. Today the light emitted by the flexible OLED already fulfils the relevant

ECE standards for luminious intensity and emission colours for rear position lamps. With the successful completion of the project and the first mass produced vehicles with ultra low-profile but rigid glass-based OLEDs appearing right now on the market, flexible OLEDs are expected to be ready for series production in only a few years' time (Rosenauer, 2021).

OLED technology is showing increasing interest in rear lamp applications due to new style and design opportunities. The use of OLED into rear lamp has highlighted the need for new simulation tool. This communication describes the development of new in house tools to predict electro-optical behaviour of OLED source (including electrode and current density simulation), photometric light intensity simulation and color. In the last years, OLED technology has started to be more interesting in automotive market for rear lamps, especially fort the great number of possibilities it gives in terms of new aesthetical solutions and for the possibility to realize high homogenous lighting functions which is illustrated as sample in Figure 1.

(a) OLED Tail light of BMW M4 GTS (Osram, 2017) (b) OLED Tail light of AUDI TT (Audi, 2016)

Figure 1. OLED automotive tail lights

Widespread LED technology can be optically simulated with raytracing software: from standard rayfiles provided by suppliers, it is possible to simulate light propagation inside optical elements with high accuracy. On the opposite side, OLEDs are custom shaped objects and need to be specially modeled in the optical simulator wit the design department input. The different iterations design can introduce a prohibitive lead-time when the OLED performance must be checked at each steps. I order to give to customer an answer regarding photometrical performance and luminance as fast as possible without an iterative loop between OEM-TIER1-TIER2, two tools have been developed by Automotive Lighting (Bianco et al., 2017), which is illustrated OLED technology studies of AUDI in Figure 2.

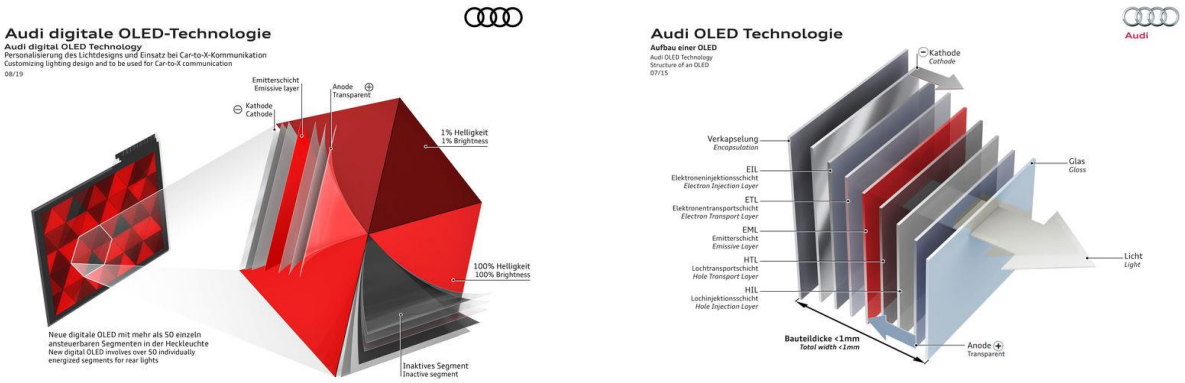


Figure 2. OLED Technology studies of AUDI (Audi, 2020)

Next to design driven modifications of the taillight signature, it is now also possible to take this highly segmented taillight to display further information in the rear of a vehicle, e.g. for following traffic or pedestrians. While sticking to the possibilities that are provided by current regulation, digital information within the vehicle or provided by the swarm of connected vehicles and infrastructure can help to improve the safety and gain trust in the field of autonomous driving vehicles.

With a high number of segments on each OLED element automotive exterior displays can be created within a tail lamp The usage of those Digital OLEDs will lead the way to Premium Car2X communication. In combination with new approaches on bendable glas to produce an OLED Audi will lead the application of the

most flexible display technology in taillighting. OLEDs create homogenous surface light directly within their full active region. Flexible OLED based tail lighting of AUDI is illustrated in Figure 3.

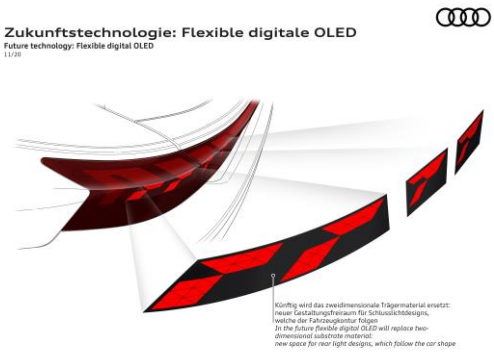


Figure 3. Flexible OLED of AUDI (Audi, 2020)

Flexible substrate technologies are needed and have to be adapted for the usage in automotive lighting applications. The flexibility of the substrates can be used as means to bend the OLED in the lamp production, creating a 3D OLED module that fits the curvature of the vehicle. In combination with its viewing angle independent color point stability and homogeneity, light weighted thin flexible OLEDs will be a unique light source for tail lamps which can never be mimicked by any other light source. The most flexible display for exterior lighting is born: FLEXIBLE-DIGITAL OLED (Kruppa et. al., 2019)

Matrix Lighting

Micro LED system has a key for the solution which has micro size of hundreds LED light sources with imaging optic. Imaging optic can match the each beam pattern to each single LED. Therefore, before developed a micro LED, it needs to be defined a certain beam pattern which can meet functionalities properly (Lee, 2019). In rear lighting World the idea of matrix technology is rather unknown. Unlike the individual switching of segments in rear lighting. Rear lighting is dominated by signal lighting, with the task to visualize the vehicle information on geometry, dynamic speed and direction indication. In future applications, also the segmentations will give the chance to either generate different patterns or combination of segments, or to attract the following driver's attention to the activated function (Hamm, 2017).

The next evolution step of the customizable tail light signature is the matrix tail light, illustrated in Figure 4 (Audi, 2021; Epic Photonics, 2020). Like the customizable tail light, this concept also has a static surrounding signature that fulfills legal requirements. The interior is equipped with a matrix that can be personalized in a wider range. Not only by means of light graphics, but also –as a type of display- with symbols and text. The matrix opens a new communication channel allowing clear warnings such as a "snowflake" in the matrix area of the tail light to indicate slippery road conditions. This can be done manually by the driver and also automatically via vehicle-to-x communication. It could also be possible to give an early warning at the end of traffic jam and thus help to prevent dangerous rear-end accidents.

(a) Individual lighting design (Audi, 2021) (b) Warning lighting function (Volkswagen, 2018)

Figure 4. Customizable tail light signature

Also, it will be important that assisted or driverless moving vehicles communicate with their environment e.g. via tail lights. Of course, clearly identifiable and distinct symbols are necessary to support traffic safety in that case. Additionally, countless other functions are conceivable such as a coming or leaving home animation that could be personalized. Or electric vehicles could display the current charge status via tail lights. The advantage is that no other component would have to be integrated as the tail light is always present. As soon as the relevant legislation allows its use, the final implementation could start. Furthermore, upcoming user studies are planned, in order to investigate symbols that are well perceivable as well as understandable. Of course, the matrix tail light would also be updateable so that a large range of different signatures and safety functions are certainly conceivable (Studeny, 2019).

Classical communication between drivers and road users outside the vehicle, such as making eye contact, nodding one's head or giving hand signs may will no longer be possible. Concerns are arising about safety and also acceptance by pedestrians and bicyclist. Many concepts and proposals for autonomous driving vehicles and automated-driving lights have been made, so we need to discuss on standards. However there is still no standard (s). This could lead to important discrepancies between regulations worldwide, making it very difficult and expensive for vehicle manufacturers to develop autonomous driving vehicles for a global market. The future focus of automotive lighting will no longer be optimized illumination for the driver but optimized signal lights for all other road users. First of all pedestrians and bicyclists, but mainly at least for the next few years the huge number of drivers in conventional non-automated driving vehicles. Optimized illumination instance for pedestrians and bicyclists is illustrated in Figure 5.

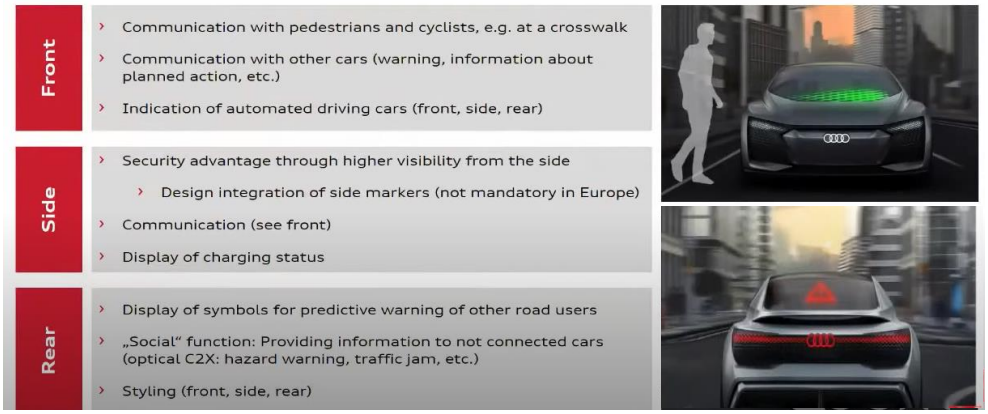


Figure 5. Optimized illumination for the pedestrians and bicyclists (Epic Photonics, 2020)

The mega trend digitalization will generate completely new players in the automotive and also automotive lighting market. New sensor technologies, unimaginable high computing power and the fast progress of the internet of things (IoT) with all the connected electronic smart devices enable complete new functionalities and business opportunities. The digital world will take over the automotive world. The rules of the game are changing and we will have to adopt our regulations to be compatible with our automotive lighting. Otherwise global lighting and mobile devices will occupy the new lighting, business and driven safety opportunities outside the vehicle (Berlitz, 2017). Communication instance between vehicle and pedestrian is illustrated in Figure 6.

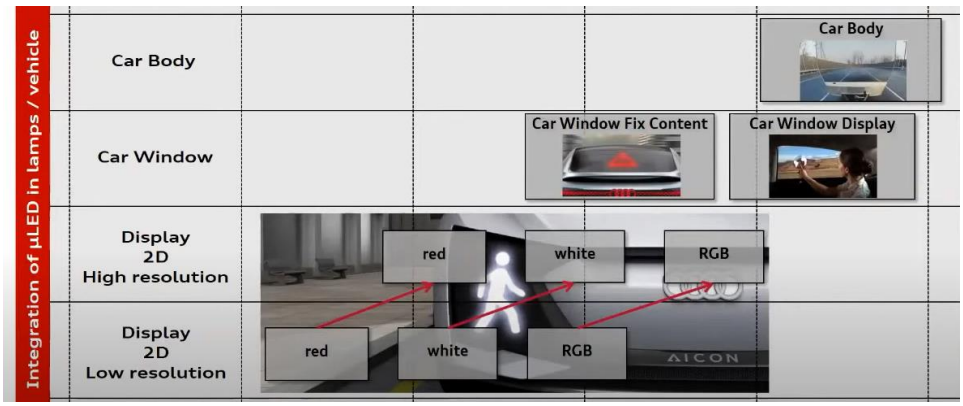


Figure 6. Communication between vehicle and pedestrian (Epic Photonics, 2020)

Projection Lighting

The area lighting of the vehicle only covers the lateral area net to the vehicle and thus offers a support for a better orientation when approaching the vehicle or getting in and out. Often these lights realize patterns or graphics, providing an attractive design and a high customer value. Volkswagen now extends the functional scope of the area lighting respectively the manuevering lighting. Usually these lights are installed in the sill, the door handle or at Volkswagen in the side mirror or door trim. The idea of the so called "Optical Park Assist" developed by Volkswagen is the functional enhancement of area lighting (Volkswagen, 2018).

The aim of this function is to project information and navigation support of any kind on the ground behind, next to or in front of the vehicle. For example, this information can be used to clarify the driver's intention. This can contribute to increase traffic safety. In the case of the "Optical Park Assist" (Studeny, 2019), White stripes are projected behind the vehicle that indicates the width of the vehicle as illustrated in Figure 7. These stripes are perfectly visible through the side mirrors and provide an intuitive orientation support while parking. A conceivable option would be to integrate such a module in the tail light or in the bumper. The "Optical Park Assist" uses a micro lens array MLA and LEDs as a light source to project an arbitrary image. This technology offers a very high image quality as well as a compact space (Gocke et. al., 2015).

Figure 7. Optical park assist (Volkswagen, 2018)

In near future parking maneuvers will be fully automated with no drivers around. In this case the maneuvering path can be projected onto the road via the lines in order to communicate the parking process to other road users. This new function also provides additional safety in the event of a breakdown or opening doors. In this case, a safety zone or a light barrier around the vehicle can be projected on the ground to indicate the situation. In order to achieve a higher warning effect especially fort the last two use cases red or yellow would be a useful light color. However, these colors are actually not possible according to the current state of regulation. A discussion regarding updated regulations would be desirable due to the usage for these light functions and an enhancement of traffic safety should be evaluated by users studies (Volkswagen, 2018). Projection function of signal lighting on the ground is illustrated in Figure 8.

(a) Projection of signalling in tail light (Volkswagen, 2018) (b) Projection of signalling in front light (Blain, 2018)

Figure 8. Projection function of signal lighting

Safety Distance Projection

When the ego vehicle is getting too close from the leading one, alert messages as simple as highlighted zones or series of transversal light bars could be used. The setting of these bars, as well as the projection distance can be defined by the user, while their activation can be coupled with the front radar or LIDAR (Reiss et. al., 2019). Warning stripes of vehicle by projection lighting is illustrated in Figure 9.

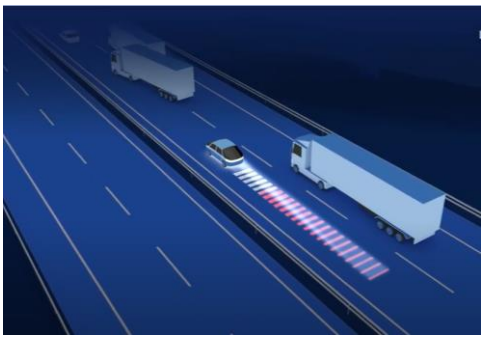
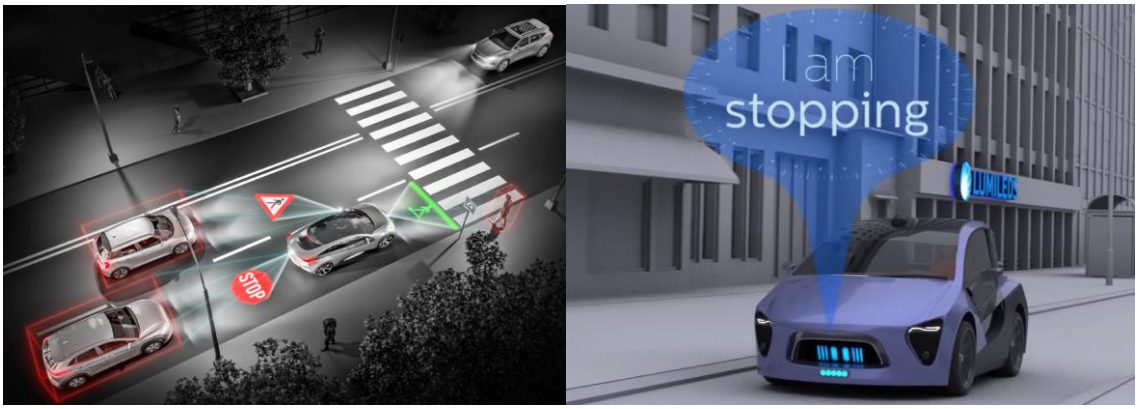


Figure 9. Warning stripes of vehicle by projection lighting (ZKW, 2021)

Digitalization, electrification, user experience and new mobility concepts – these megatrends will shape the future of automotive lighting. Intelligent lighting that automatically adapts to the situation on the road, and light for communication between the driver, vehicle and environment – a crucial factor in the development of autonomous driving. Exterior projections will ensure better visibility of turn signals and brake lights, among other things, and will display relevant driving information on the road. Interior projections will be used to improve the comfort, convenience and well-being of the occupants. In the future, projections will support autonomous vehicles in their direct communication and interaction with all road users (Rosenauer, 2021). Communication of vehicle between other vehicles and pedestrians on the road is illustrated in Figure 10.



(a) Communication of vehicle on the road (Osram) (b) Illustration of vehicle's behaviour (BestRide, 2017)

Figure 10. Communication of vehicle between other vehicles and pedestrians on the road

Projection systems expand the possibilities of classic headlamp technology. The use of light projections transforms the vehicle and its surroundings into a canvas for OEMs and mobility providers. Not only does light have the ability to increase safety and functionality, but it also affords the opportunity to differentiate their vehicles with lighting design and create customizable driving experiences that can evoke a sense of well-being for the driver. With the development towards autonomous driving, light will not only be needed for better visibility, but will also play a pivotal role for the communication of a vehicle to its environment (car2x), thereby contributing to the acceptance of autonomous vehicles. The advantages of light projections to create an emotional impact are already used widely in everyday life, for example to illuminate building facades for events. It is not only because of these emotional aspects that light projections are increasingly finding their way into the automotive sector. Exterior projection systems extend already existing lighting functions in relevant situations – for example clearer visibility of indicator or brake lights (Rosenauer, 2021). Projection based hologram and signal lighting is illustrated in Figure 11.

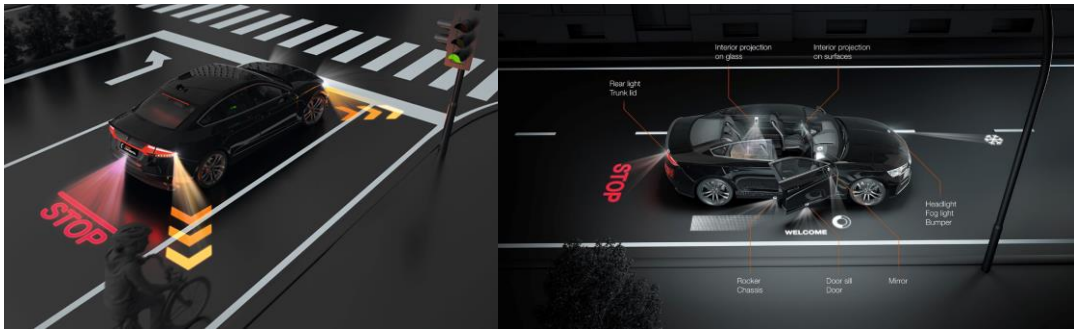


Figure 11. Projection based hologram and signal lighting (Osram)

New lighting Technologies as projector systems or displays and all the architecture for digitalization increase the costs for the systems and components. The safety benefit with better communication possibilities is obvious. Nevertheless, all OEMs will have to increase their investment in lighting technology. But, there are also ideas for using these new Technologies for new business plans. That is probably also the main reason for IT-companies to step in the automotive business. Projecting information outside the vehicle or displaying information on the outer side of the vehicle brings attention and is therefore idea for all applications where you want attention for your product (Berlitz, 2017).

Conclusion

In this paper, various new Technologies and functions for signal lighting were shown. These could soon open a large new spectrum of lighting functions and design. Many of the presented features have the potential to increase traffic safety (Studeny, 2019). Automated driving and digitization will revolutionize our automotive lighting business, new technologies will extend the communication with other traffic participants This will lead to increasing traffic safety. On the other hand, the light distribution will get completely personalized for safety but also for entertainment and commercial possibilities. Enriching the user experience will lead to more attractive lighting products and will lead to higher take rates and faster market penetration. This again will bring the modern lighting technology easier into market and can then increase traffic safety for all participants. All these ideas could be an opportunity for the automotive industry if development or regulation takes too long then IT-companies and service companies will take over this market and the chance to finance increasing vehicle safety with new business plans will be gone (Berlitz, 2017).

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

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Gender Classification from Eye Images by Using Pretrained Convolutional Neural Networks

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Abstract: Automatic gender classification from face images has been a popular topic among researchers for a decade. Feature extraction and classification methods are very important to create a successful automatic classification system. Due to the richness of face image datasets today, many successful machine learning and deep learning methods has been implemented. It is very critical to extract accurate features from the datasets to achieve promising classification scores when traditional machine learning methods are used. However, deep learning models have been designed to extract the features automatically from the raw data directly. This also automatize the feature extraction process besides classification. The hidden and unpredictable feature sets can be explored by the deep neural networks which can increase the classification performance comparing to traditional machine learning methods. Convolutional Neural Networks (CNN) as one of the effective classes of deep models have been adopted by many scientists for solving the gender classification problem. It can solve the problem of the fact that facial cues can change from origin to origin which makes the accurate feature extraction harder. There are several state-of-the art pretrained CNN structures which are very successful for image classification problems. The performance of CNNs is generally higher when the number of the input data is high. However, in this study, the success of the pretrained CNN models is investigated when the data is limited. Considering this fact, in this study, rather than using complete face images, only the one eye image regions with eyebrows are used for the gender classification. The performance results present that the best CNN models are NASNetLarge and Xception models.

Keywords: Eye region, facial data, Classification with CNN, Layer structure

Introduction

Today, artificial intelligence solves many problems related to human recognition. For instance, the face, fingerprint (Cimtay et al., 2021), speech, iris are some of the human data to be used by artificial intelligence models. Human gender recognition from face data is also a challenging topic today due to the rapid change of human face. The performance of the methods may easily decline by the change of the face like with/without moustache, beard or with aging. It can also be affected by the orientation of the head. In literature, many methods and models have been developed by researchers to solve those kinds of problems and provide accurate results (Danisman et al., 2015).

Deep learning has gained much more interests in the application areas of automatic feature extraction, object recognition, classification, etc. Especially, more complex and deep convolutional neural networks perform high accuracy. By drawing inspiration from various areas, deep learning has been also applied for gender classification from face images. The study in (Janahiraman et. al., 2019) creates a dataset which is composed of the facial images of Caucasian and Malaysians people and applies various Convolutional Neural Network

(CNN) architectures to conduct a gender classification. It reports 88%, 85% and 49% accuracy by using VGG-16, ResNet-50 and MobileNet models respectively. The study conducted by (Akbulut et al., 2017) applies CNN and Local Recipient Areas Excessive Learning Machine (LRA-ELM) methods on Adience dataset (Eidinger et al., 2014) and achieves 80% and 87.13% for LRA-ELM and CNN, respectively. The study in (Arora et. al., 2018), approximately uses 1500 face images where most of them were chosen from CASIA dataset (Dong et al., 2011). It develops a CNN and achieves 98.5% gender classification accuracy. The study conducted by (Raza et al., 2018) develops a deep learning method for classifying pedestrian gender. The pedestrian was segmented from the picture using a preprocessing step. Then, for classification, stacked auto encoders with a softmax classifier were utilized. It achieves accuracy rates of 82.9%, 81.8%, and 82.4% percent in the front, posterior, and mixed views, respectively on MIT dataset (*Pedestrian Data, 2021*), and about 91.5% in the PETA dataset (Deng et al., 2014). In (Gündüz et. al., 2019), a comparative analysis is performed between the CNN models: Proposed CNN, AlexNet and VGG-16. 72.20%, 65.63% and 99.41% accuracies have been obtained respectively. Another study in (Levi et. al., 2019) proposes a simple CNN to improve the performance of gender classification. Promising accuracy results have been obtained on Adience dataset. A Resnet-101 CNN based method called Hyperface is proposed in (Ranjan et al., 2017). This method increases the gender recognition rate and speed.

The study in (Abdalrady et. al., 2020) reports the interchange of traditional CNN models with the PCANet model for gender categorization. In addition, by using PCANet, it is able to decrease the size of the network design in complicated CNN models. For gender categorization, this technique has an accuracy of 89.65%. In (Yu et al., 2017) researchers proposes a CNN with reduced number of layers. By applying the method on a dataset composed of 1496 body images, it achieves 91.5% accuracy.

In this study, gender classification from facial images is reduced to gender classification from eye images. Therefore the dataset and region of interest is narrowed. Since, pretrained CNN models perform very promising scores on image classification problems, in this study, several state-of-the-art CNN models which have not been applied on that specific classification problem, are employed on a well-structured eye images dataset. The rest of the paper is organized as follows. Section II provides some information about the dataset used in this study and provides the details of our methodology. In Section IV, the classification results are presented. Finally, the paper is completed with concluding remarks.

Materials and Methods

Figure 1. Selected female eye images from the dataset

Figure 2. Selected male eye images from the dataset

Datasets

There are many face datasets such as Adience, FERET (*color-feret-database*, 2021), Gallagher's dataset (Gallagher et. al., 2008), LFW (Huang et al., 2007) which have been used for gender classification in the literature. However, they all provide the whole face imagery and segmentation of eye is an additional work for the researchers. Since this study conducts a comparative analysis between state-of-the-art CNN models only by using the eye images, we use the dataset named "Female and Male" which is referenced in (*eyes-rtte*, 2021). This dataset includes only the eye images which are extracted from whole face images. Note that it usually includes either complete or some part of eyebrows also. Moreover, it includes 5202 female and 6323 male eye images. Figure 1 and 2 show female and male eye image examples from this dataset.

Method

In this study, authors aim to investigate the success of different state-of-the art pretrained deep learning models on gender classification from eye images. For that purpose, InceptionV3, InceptionResnetV2, Xception, NASNetLarge models are used as the base model. The base model is supported with GlobalAveragePooling, Dropout and Dense layers. Dropout layer is used to prevent the network from a possible overfitting problem.

In this study, to remove the effect of different lighting conditions, each eye image in the dataset is normalized. We use 4-fold cross validation to train and test the deep models. Image dataset is first shuffled and then randomly divided into 4-folds. Therefore, for each fold, 75% of eye images are assigned as training set and 25% is assigned as test set. The training is implemented by using Keras on Python environment. The image sizes are adjusted as 75x75. The designed layer structures are given in Table 1.

Table 1. Layer description of CNN models

Layer number	Layer Type	Output shape
1	InceptionV3 InceptionResnetV2 Xception NASNetLarge	(None, 75, 75, 3)
2	InceptionV3 InceptionResnetV2 Xception NASNetLarge (functions)	(None, 8, 8, 2048)
3	GlobalAveragePooling2D	(None, 2048)
4	Dropout	(None, 2048)
5	Dense	(None, 2)

The training parameters of CNNs are given in Table 2.

Table 2. Training parameters of CNN models

Parameter	Value
optimizer	Adam
loss	categorical_crossentropy
shuffle	True
Number of epochs	30
batch_size	64

Table 3. Keras models

Model	Size (MB)	Top-1 Accuracy	Top-5 Accuracy	Parameters	Depth	Time (ms) per inference step (CPU)	Time (ms) per inference step (GPU)
InceptionV3	92	0.779	0.937	23,851,784	159	42.25	6.86
InceptionResNetV2	215	0.803	0.953	55,873,736	572	130.19	10.02
Xception	88	0.790	0.945	22,910,480	126	109.42	8.06
NASNetLarge	343	0.825	0.960	88,949,818	-	344.51	19.96

The model's size, accuracy, number of parameters, depth and time inference steps for CPU and GPU are given in Table 3 (*Keras applications*, 2021). NASNetLarge model has a huge number of parameters however the maximum top-1 and top-5 accuracy.

Results and Discussion

In this study, authors aim to investigate the use of pretrained deep models on gender classification from eye images. The most successful pretrained deep models namely InceptionV3, InceptionResnetV2, Xception and NasNetLarge are used. The mean confusion matrixes for different deep models are given in Tables 4-7. The right bottom corner of each table provides the general mean accuracy and standard deviation which is calculated from the accuracy scores of the folds. Furthermore, the mean Recall, Precision and F1 scores are also presented. As it can be obtained from the tables, very promising classification performances are handled.

Table 4. Confusion matrix for InceptionV3 model

	Model : InceptionV3			Recall	Precision	F1
Target class	Female	1251	50	96.19	95.20	95.69
	Male	63	1518	96.01	96.84	96.42
		Female	Male			
		Predicted class		Accuracy : 96.09±0.3		

Table 5. Confusion matrix for InceptionResnetV2 model

	Model: InceptionResnetV2			Recall	Precision	F1
Target class	Female	1246	55	95.79	95.13	95.45
	Male	64	1517	95.96	96.51	96.23
		Female	Male			
	precision	Predicted class		Accuracy: 95.88±0.6		

Table 6. Confusion matrix for Xception model

	Model: Xception			Recall	Precision	F1
Target class	Female	1251	49	96.21	97.09	96.64
	Male	38	1544	97.62	96.90	97.25
		Female	Male			
		Predicted class		Accuracy: 96.98±0.2		

Table 7. Confusion matrix for NasNetLarge model

	Model: NasNetLarge			Recall	Precision	F1
Target class	Female	1256	44	96.57	94.36	95.45
	Male	75	1506	95.25	97.12	96.17
		Female	Male			
		Predicted class		Accuracy: 95.85±0.8		

Although all of the models used in this study achieves very good results, the best model according to Recall, Precision and F1 scores are given in Table 8. As can be observed from the table, Xception and NASNetLarge deep CNN models are determined as the best ones.

Table 8. Best models for recall, precision and F1 scores

Criteria	Best Model
Mean Accuracy	Xception
Male Recall	Xception
Female Recall	NASNetLarge
Male Precision	NASNetLarge
Female Precision	Xception
Male_F1	Xception
Female_F1	Xception

Conclusion

This study presents the classification performance of state-of-the-art deep CNN models: InceptionV3, InceptionResnetV2, Xception and NASNetLarge on gender classification from eye images. These models have been trained with "Female and Male" dataset. Results have shown that although the facial data is limited to the single eye region, the accuracy, recall, precision and F1 scores are still very high. This shows that the feature points on the eye region are determinative on gender classification. This is due to the physical differences between male and female eyes like the shape and slant, and also the shape and smoothness of eye brows. The employed models are all very successful, however according to the scores, NASNetLarge and Xception models are the best ones.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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Application of Augmented Reality in Music Education

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Abstract: Music Education has been given in many ways from the past to the present, but the development of technology has been the turning point for this education. The increasing use of mobile devices in recent years has offered people the advantages of using technology in education. 3D applications developed for mobile devices have enabled Augmented Reality (AR) technology to be used in many areas. While the importance of Music Education has been better understood recently, its benefits and necessity continue to be the subject of research by many scientists. Studies have observed that in addition to music education, taking an instrument education contributes to the increasing success of students in other lessons. In this thesis study, musical notation education on the flute was aimed for primary school students, and after the necessary teachings were made, it was ensured that two different music pieces were played over the AR-Flute application.

Keywords: Augmented reality, AR in education, AR-flute, Education of instrument, Musical education with technology

Introduction

The increasing use of mobile devices in recent years offers people the advantages of using technology in education. Humanity has learned to live in harmony with mobile devices such as smartphones and tablets. Therefore, the use of portable devices has become an indispensable part of life.

Augmented Reality (AR) technology enables visual and audio information to be included in the real world in real time. Besides, AR can enable the development of video, 3D modeling, images and animations for display presentation in Education. It is also a key element of AR Industry 4.0 (Suwichai, 2014).

AR takes the vision of the real world and adds virtual information to it. In different expressions, AR combines the real and partially virtual world and presents every synthetic light and natural light with its real-world elements. The low cost of Augmented Reality compared to Virtual Reality is an advantage to be considered. HeadMountedDisplay used in Virtual Reality technology, data gloves and a non-traditional interaction tool with concaves are not required and often costly, these devices are also expensive.

In order to gain physical competencies, the person involved in the education process also benefits from important lessons such as music in order to gain internal and spiritual competencies in the same process. All the activities performed as listening, singing, playing and moving are of great importance in the music lesson for the acquisition of values, which are defined as human qualities, which are an individual and social necessity.

A study conducted during a Science Festival in Denmark showed that children who play a musical instrument also do better in other subjects, such as math or dance. Although increased skills in other subjects are not directly related to the ability to play a musical instrument, music education has shown to improve cognitive skills such as verbal memory and reading ability (Serafin et. al., 2017).

Learning to play a musical instrument is a challenge, especially for children. In this study, notation knowledge for primary school students was emphasized and after the necessary teachings were made, two different pieces of music were played through the application. The application of Ar-Flute starts working by showing the pointers to the camera. There are 11 markers for the nine (Do, Re, Mi, Fa, Sol, La, Si, fine Do, fine Re) notes, two of which are for the song notes to be played. For example, when the pointer with the image of the Do note on the stave is shown to the camera, the explanation of how the user will place his fingers on the 3D Flute will appear. In this way, he will both hear the do sound and see the holes that need to be closed. According to the notation, the holes on the 3D flute will be marked with a red light.Thanks to the mobile software developed in this way, the learning of all notes will be completed, respectively. In the next stage, 2 songs can be played at different tempos.

Our first song after the musical notation training is Happy Birth Day. The reason for choosing this song is its slow tempo. There is note writing of the Happy Birth Day song on the stave on the pointer, and when it is shown to the camera, the 3D flute starts to play the song, and the red light is informed which holes will be closed for the playing notes. In addition, the playing notes appear on the screen the 3D flute next to a different colours with 2D text image. The other song is Little Frog song. The practice system is the same, but the tempo is normal, designed to help the user improve his flute practice

Music Education and Its Importance

Music education not only creates musical knowledge, ability and pleasure, but also enables the acquisition of many individual, social and cultural characteristics. Music has a very effective place in many areas of our brain such as literacy and numeracy. Music helps us express and interact with our emotions. Music helps us understand the world around us and is an ancient and universal language common to every human culture (Brief History of Music Education,2020)..

In his book Plato outlines that in the ideal state the rights to have equal opportunities to study are not given to all citizens. As a result, he proposed to create different training programs for the different classes of future artisans, military and philosopher-kings. “Plato encouraged that children should be separated from their families at an early age and be subject to relevant secular education – literature, music and physical education. The cultivation of moral values was necessary for the development of the character in order to maintain a fair state.” Confucius exalted music **“**If one should desire to know whether a kingdom is well governed, if its morals are good or bad, the quality of its music will furnish the answer**”** to the point of saying.

Various studies have found that interacting with music can lead to improved brain development in students. A Northwestern University study found better neural processing in students who played musical instruments compared to students who just listened to music. This study shows that getting music education can be very beneficial in job training.

The National Music Education Association (NAMC) has reported the categories in which music education is beneficial under 4 headings on the Music Education Facts and Figures website. These;

• Success in society,
• Success at school,
• Success in development
• Intelligence and success in life
listed as.

An example of these advantages can be given as follows:

The National Association For Music Education (NAMC) suggests in their Music Education Facts and Figures website' four categories of benefits of music education; these categories are: success in society, success in school, success in developing intelligence, and success in life. NAMC cites the Texas Commission on Drugs and Alcohol Abuse Report as reported in the January 1988 Houston Chronicle that said "Secondary students

who participated in band or orchestra reported the lowest lifetime and current use of all substances (alcohol, tobacco, illicit drugs)" (Petress, 2005).

Scientific findings have proven that artistic education makes math and science better. In addition, music education improves spatial intelligence in newborn babies and can be a convincing solution for violent youth. Traditional music education places a large emphasis on individual practice. Studies have shown that individual practice is frequently not very productive due to limited feedback and students lacking interest and motivation (Hargreaves, 1999).

According to Gardner, seven types of intelligence are present at different levels in every child from birth, and all intelligence types can be developed throughout life, starting from a young age. Many children can learn to use their voice more accurately with education and begin to sing beautifully; Being enthusiastic or willing to play a musical instrument, likes to listen to music, enjoys singing the songs they learned outside of school, enjoying participating in the choir or similar activities are related to "musical intelligence".

A child who receives a comprehensive musical education leads to the development of many talents;

- comes in a ready-made form for artistic education,
- develops creativity through improvisations,
- expressing oneself with music (language, movement, music),
- realizes his place in society, his duties,
- develops internal and external discipline,
- gets acquainted with the basic rules of music and different instruments, (increases musical knowledge and skills),
- can sing,
- can dance in harmony
- and the child's sense of rhythm, ability to use his voice and musical hearing, music taste, etc. develops

Method

Augmented Reality Technology in Music Education

Augmented Reality is a technology that takes the vision of the real world and adds virtual information on it. AR adds sounds, videos, graphics directly to the look of an existing environment. With the rapid development of modern information technology, multimedia technology and network communication technology, especially augmented reality technology has been widely used in the field of education.

Azuma (1997) provides an overview of a wide range of sciences using augmented reality, such as medical education, military aircraft navigation, and industrial training. His study shows that AR has been used successfully in many educational applications. The main advantage of AR is the perceptual and cognitive representation of instructions on how to use a physical object (eg an instrument) (Azuma, 1997).

The operation and presentation of many education and training resources has been transformed from traditional two-dimensional to three-dimensional. This learning mode change not only enriches the delivery of learning content, but gradually improves learner interaction. Thus, it allows students to experience virtual, self-discovery and interactive learning activities. It effectively motivates learning efficiency (Akçayır et. al., 2016).

In AR, it is accomplished by interacting with a camera from any device, such as a tablet and smartphone, along with beacons. In addition, AR does not require a high-tech webcam to work. This makes AR more accessible to many users. Not everyone can afford to take music and instrument playing lessons due to financial difficulties and impossibilities. In addition, many people live in areas where educational conditions are difficult and there are not enough teachers. AR music education has the potential to solve both of these challenges. It offers convenience for those who want to learn how to play a musical instrument but do not have enough time.

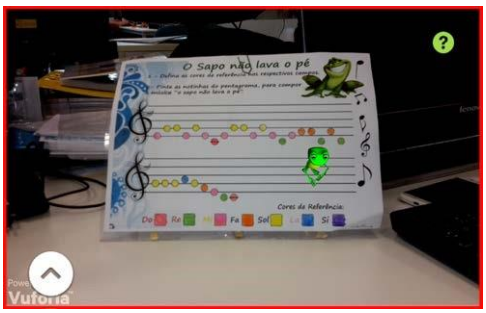
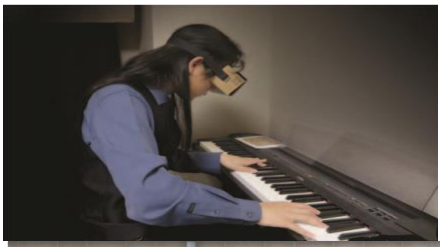
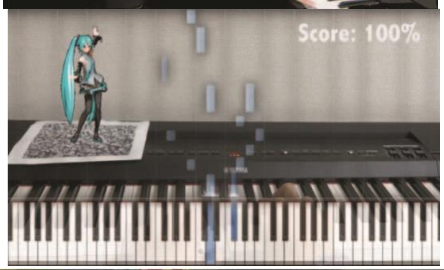
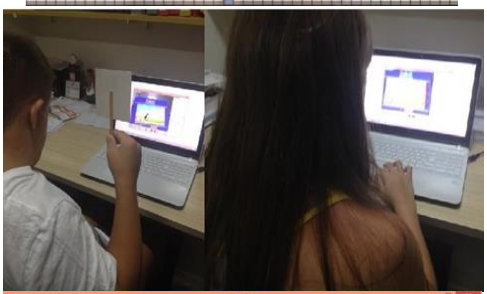
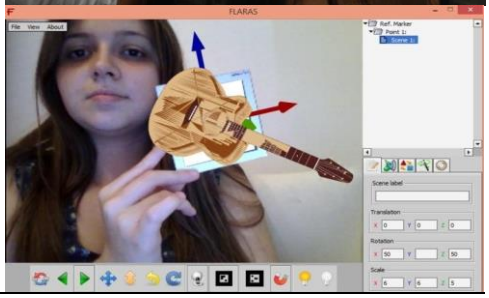
Augmented Reality Trends in Music Education

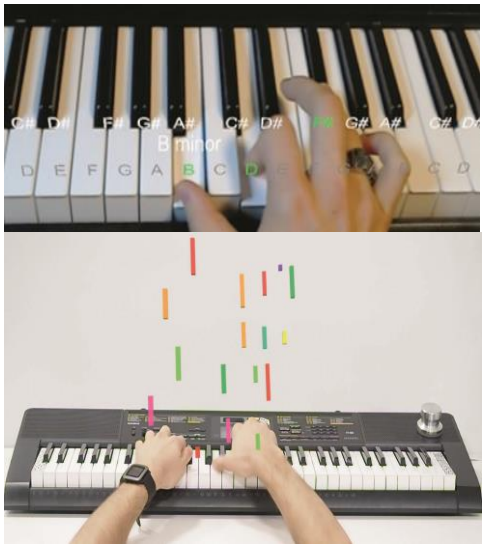
Playing an instrument requires a lot of brain power, muscle memory and neurological control. People who play instruments have better memory and are able to control their cognitive and motor functions better than those who do not play instruments. Children who receive music education do better in academic areas such as reading and math skills.

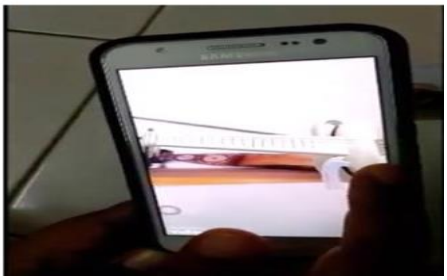
Recently, many different applications have been realized by combining Augmented Reality with the technologies used in music education. In Table 1, applications made or designed using AR technology in Music Education are shown. The advantages and disadvantages of prepared articles and studies are presented in the Table 1.

Table. 1 Augmented reality trends in music education

Source	Method/ Model	Advantages and Disadvantages	
(Suwichai ,2014)	Augmented Reality (AR) is used to promote traditional folk musical instruments. The method allows users to view and sound the environment in 2D modeling using a trigger image on a postcard via mobile device.	Advantages : 1) This approach can encourage participation in the classroom so students will be more eager to learn during the classroom. 2) The method can also be effective for students to improve their understanding and deepen their knowledge. Disadvantages: 1) Requires internet usage. 2) Modeling is designed as 2D (2D)	 
(Serafin et. al., 2017)	Considerations Regarding the Use of Virtual and Augmented Reality Technologies in Music Education have been observed. Virtual and Augmented reality offer an alternative approach to acquiring musical skills, especially in children.	Advantages: 1) Virtual Reality and Augmented Reality can be a helpful tool in improving musical skills, which are often known to be boring, repetitive and challenging. Disadvantages: 1) The lack of design needs to be taken into account.	
(Chow et. al., 2013)	"Music Education using Augmented Reality with a Head Mounted Display " It is an AR application aimed at increasing learning efficiency and creating an immersive experience for beginner piano students. The opportunity to play is provided to	Advantages: 1) It can increase students' interest in music and the process of learning musical instruments. 2) Head-mounted displays can provide the user with instrument playing skills . Disadvantages: 1) In practice, performance analysis was not included in the evaluation. 2) The application was designed with an	

	encourage and encourage the development of musical notation literacy.	expensive system in terms of cost. 3) Appropriate user studies have not been conducted to determine the usability and effectiveness of piano instruction.	
(Ana et. al., 2016)	Augmented Reality Musical App to Support Children's Musical The application works by verifying whether the strings are colored correctly on a printed sheet of music.	Advantages: 1) Augmented Reality can reduce the initial difficulties of traditional teaching materials in learning music. 2) It is an affordable application in terms of cost. Disadvantages: 1. The Evaluation Population was made with only six children.	
(Carlos et. al., 2016)	He recommends using Augmented Reality to play keyboard instruments. Used Google Cardboard to allow users to visualize a virtual character and instructions.	Advantages: 1) Interaction with an animated 3D character can help maintain motivation in teaching music. Disadvantages: 1) No musical instruments and not allowing users to add their own songs and dance moves for the character	 
(Martins et. al., 2015)	MUSIC-AR uses Augmented Reality technology. MUSIC-AR, 1) allow children to control virtual items that like sounds, 2) focus on the concept of sound intensity, 3) the duration of the sound and 4) It consists of 4 small applications related to timbre.	Advantages: 1) Children can understand more easily by using Augmented Reality. 2) It motivates children to use technology. Disadvantages: 1) Inadequate number of games in terms of effectiveness of teaching in practice.	 

(Lim et. al., 2012)	Three different learning modes are proposed that support the natural learning process, including live feedback and performance evaluation, as well as augmenting the system with gamification aspects to achieve early success experiences.	Advantages: 1) It can provide assistance in learning to play the piano without having the experience of traditional music notation. Disadvantages: 1) The complexity of traditional note notation and the lack of notes that cannot match the expressiveness 2) Lack of comprehensive user studies to evaluate learning support	
(Trujano et. al., 2018)	Using Augmented Reality, ARPiano enriches the physical keyboard with motion graphics and descriptions with Effective Music Learning and receives input from the keyboard to support various interactions. The ARPiano has a modular design in the form of Keyboard Components. ARPiano can precisely locate a physical keyboard to cover various objects around the keyboard and on individual keys ARPiano is designed to provide better visual music learning.	Advantages: 1. ARPiano is a highly advanced application in terms of AR technology. 2. An app that will encourage users to learn to play the piano and have fun while learning Disadvantages: 1) It should be noted that the limited field of view of the Hololens makes it difficult to play notes more than an octave and a half apart from each other. For example, in the part where a single high note should be played, they could not see the note coming to the keyboard, causing them to make mistakes. Since it is an application that requires the use of Hololens, it is an expensive application.	
(Li, 2018)	Application of Augmented Reality Technology in Piano Teaching System Design It is an article that recommends Unity 3D development engine and augmented reality development plug-ins in the piano teaching system. The application can be used on Android systems. The piano	Advantages: 1) The application can arouse great interest in AR technology in students. 2) It can be easier and exciting to learn compared to classical piano teaching. 3) The cost is low as the required device to use the application is any android-based smart device.. Disadvantages: However, some flaws of this system were also	

	teaching system consists of three modules: piano indication and control module, piano playing module and piano sound processing module. The aim is to compare the learning status of students before and after the experiment to show the teaching effect after using the piano teaching system.	found, proving there is still a long way to go for improvement. Some students emphasized that the time devoted to teaching is not equal at all levels..	
(Tan et. al., 2018)	Malaysian Music Augmented Reality (MMAR) It is an Android application that makes music education more interactive and fun for children and aims to learn traditional musical instruments. In general, MMAR consists of four modules: 1) 3D Object Design, 2) Acoustic Model, 3) Instrument Briefing 4) Evaluation.	Advantages: 1) The application is a useful model that makes the education that arouses curiosity in children permanent. Disadvantages: 1) Limiting instrument training to traditional ones only.	 
(Huang et. al., 2011)	This article presents a piano teaching system that tracks 3D fingers on the real keyboard of the piano. Virtual hands created on the keyboard are created with the signless-based feature of augmented reality.	Advantages: 1) An interesting and enjoyable application for beginners to play the piano 2) The use of Markerless Augmented Reality can shed light on future applications. Disadvantages: 1) When the keyboard is divided into several parts by some blocks, the recognition effect is lost.	

It can be thought that the applications and researches for AR in music education will continue and should be doing in the following years. This study includes an application of the field of music education. The application will provide Flute training experience using Augmented Reality technology. Although the user age range of Ar-Flute application is 6-12, It is thought that it will attract attention on all age groups. The first reason why the preferred instrument is the flute is that it is an instrument that can be reached by many segments in terms of supply and cost. Generally, people prefer to take flute lessons to improve their musical talent. The benefits of music education are huge and very beneficial to students. Music positively affects the academic performance of the child, helps to develop social skills and provides an outlet for creativity, which is very important to the child's development. Music education takes a child's learning to new heights and, as such, should always be considered an essential part of a child's educational process. Music education develops and improves language skills in children.

Music education takes a child's learning to new heights and therefore the hFlute is one of the oldest instruments invented thousands of years ago, which adds to the permanence of the musical experience. Learning the flute, like almost any instrument, requires patience and perseverance, it will provide a lifetime of fun and satisfaction. It should always be considered an important part of a child's educational process. Music education develops and improves language skills in children. As an instrument that can offer countless different musical ensemble options, the Flute will be the right choice. Some of the different ensembles where flutes are often used include concert and jazz bands, orchestra, wind bands, flute choirs, military bands, and more. However, taking flute lessons can improve more than just playing ability. Playing the flute requires good body coordination, especially with the hands, eyes and mouth . You have to read the notes, play the keys and blow to the mouthpiece of one sitting. Therefore, your body coordination is likely to improve as well. As a windpipe instrument, the flute is played by blowing air into a mouthpiece.

A virtual flute created with Augmented Reality will offer a different experience of the user. The flute, which will function like a real flute in the real world, will attract the attention to the user and can be a solution to the problem of paying attention, which is fundamental to education, and when it is lacking in students, teaching cannot be carried out. Augmented Reality has the potential to be used in music education, to be the newest, most interesting, and to shape many ideas in terms of being developed.

Results and Discussion

In this section, Ar-Flute application, which provides flute training developed with Augmented Reality technology, is explained. It is an application intended to be used in Android operating systems, which will give the user the ability to play a simple flute, and will arouse curiosity and desire with its interesting 3D image, mostly for primary school students. There are many platforms to develop an Augmented Reality application. It was created with Ar-Flute Unity and developed with infrastructure supported by vuforia. Unity version 9F1 is used. The technical equipment required to develop the application is a HP pavilion laptop 15-cc106nt model computer.

AR-Flute App Overview

In the Ar-Flute application, there are musical notes and 2 sample songs on the flute. The visuals of 9 notes, “Do, Re, Mi, Fa, Sol, La, Si, Thin Do, Thin Re” were used as a marker (Figure 1). With the explanation explaining how the student should hold the flute, both visual and auditory information is provided by ensuring that the holes that need to be closed according to the notes turn red and the sound of the note is announced to the user at the same time.

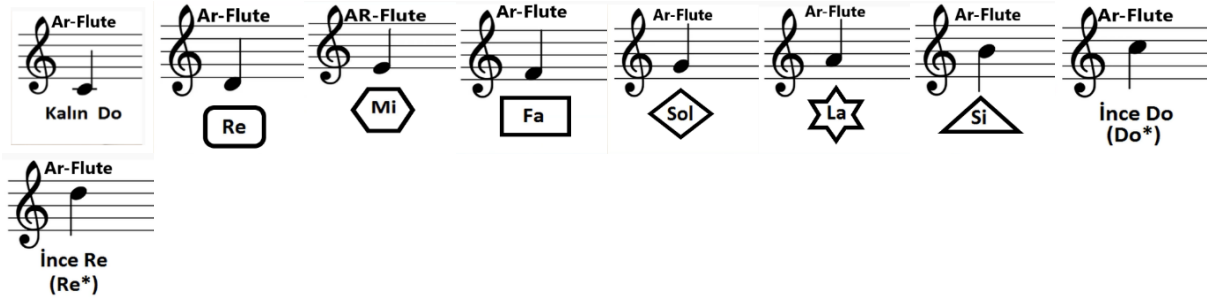


Figure 1 Pointers used in the note training part of the Ar-Flute Application.

The first song to be played to reinforce what the user has learned, who has completed the musical notation training, is the song "Happy Birthday To You" (Figure 2.a). This song has been preferred because it is thought that it will not force the user with simple notes on the first try. At the same time, since today's children are familiar with the melody of this song, it was thought that it would be easier to grasp the melody and that the children would be more eager to play it. The tempo of the song is setting slower than normal , and it is thought that the first experience will progress from easy about difficult . The marker required for the song to play is shown in Figure 2.b

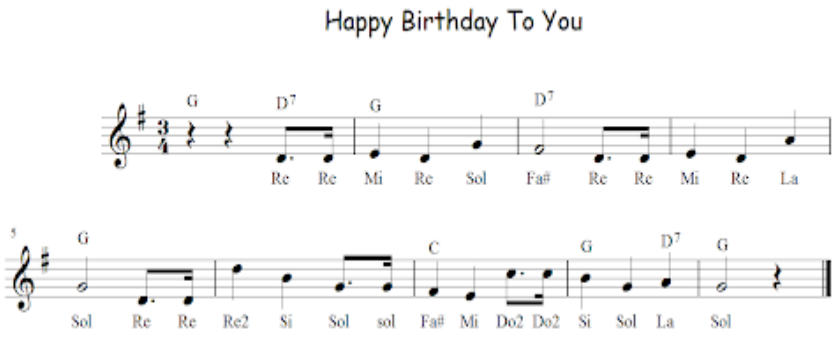


Figure 2.a Flute notes of Happy Birthday To You song.

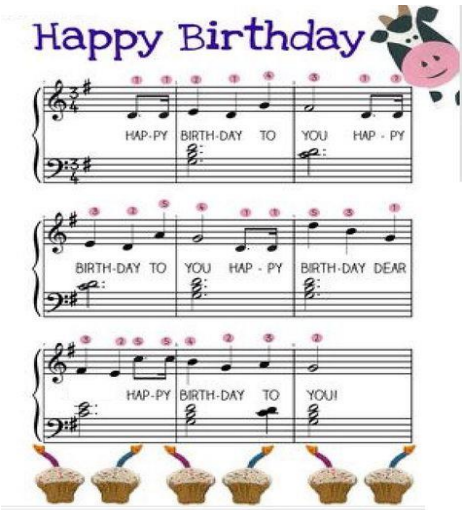


Figure 2.b Necessary pointer to play Happy Birthday To You song in Ar-Flute app.

The second song are the " Little Frog " song , which the children will enjoy while playing and are familiar with the melody of their ears (Figure 3 a) . Its tempo is at normal tempo compared to the first song . The marker used to play the Little Frog song is shown in Figure 3.b.

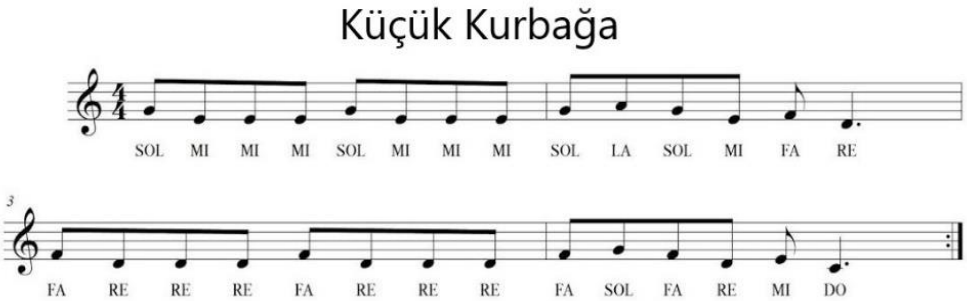


Figure 3.a Flute notes of Little Frog song

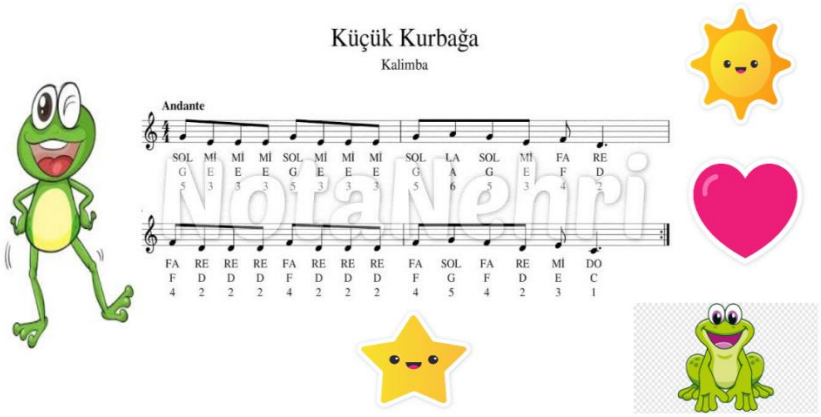


Figure 3.b Necessary marker for Little Frog song to play in Ar-Flute application.

Ar-Flute application can be installed on any device with an android operating system and a camera. After Ar-Flute is loaded, it is opened by double-clicking on it and the device is held on the specially printed card with the note. When the camera notices the note on the card, the 3D Flute appears and starts playing the notes of the song written on the card it is on. While playing, the light comes on in the holes that should be on the fingers according to the notes, and by the student blowing the flute and moving his fingers on the flute according to these lights, Ar-Flute is experienced in the accompaniment of the 3D flute in practice [Figures 4.a and 4.b].

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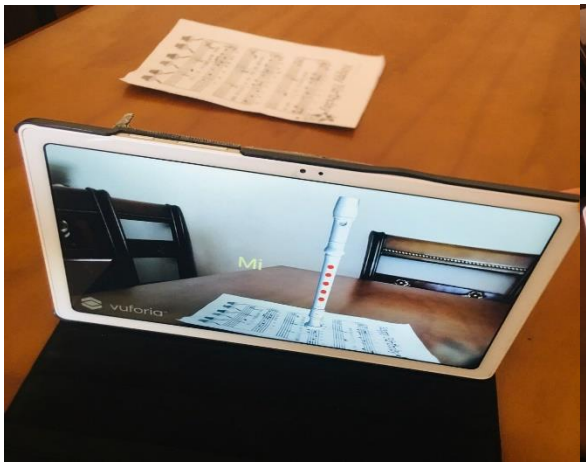

Figure 4.a Happy Birthday to You Song

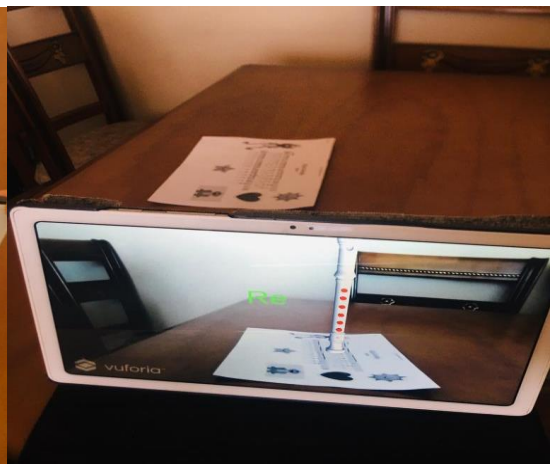

Figure 4.b Little Frog Song

Ar-Flute starts playing the song notes when the camera notices the pointer, and red lights appear on the left of the notes played with a randomly assigned color, the sound and the holes that need to be closed according to the note.

Results and Discussion

AR is a new technology that has emerged as the potential for application of education. While much research has been done on AR, very little has been done in the field of music education. In recent years, the number of studies on AR has been increasing due to the effectiveness of this technology. In particular, AR provides an efficient way to represent a model that needs visualization. AR also supports seamless interaction between real and virtual environments.

Technology has become embedded in education and results have shown a positive impact on learning and teaching styles. Lessons powered by technology will lead to more innovative ways of teaching and learning. This is because the use of technology involves real-world problems, available information resources, simulations of concepts, and communication with professionals in the field. It is also believed that learning using technology will complement traditional forms of teaching and learning. The integration of technology also provides a means to increase student learning and engagement. Therefore, recent studies have aimed to better understand from the students ' perspective the applications adapted to the lessons, including multimedia, computer-based simulations, animations and statistical software.

Research shows that musical training truly to enlarge your brain, stimulating new neural connections that act as a defense against memory loss, cognitive decline, and decreased auditory function. Your brain works every time you play, and just like training in the gym – the more you play, the greater and longer-lasting the benefits. Music is an excellent tool for memory skills. Remembering the words of a song we listened to after a long time is perhaps the proof of this. On the other hand, students increase their mental abilities in various ways while participating in music education. Studying music is an excellent way to improve memorization skills. In Figures 2.a, 2.b and 2.c, the interest and motivation of the student that has experienced music education with the Ar-Flute application for the first time can be seen.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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A Comparative Study on Industrial Communication Protocols Using IoT Platforms

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Abstract: In this study, the industrial communication protocols used in internet of things platforms are explained and compared with respect to pre-defined metrics which are gathered from devices in the industrial area, communication protocol principles, customer feedback and device hardware capabilities. They are explained in detail for end users and systems. Communication protocols in industrial area are given and illustrated with comparative table. The presented information and comparisons provide guidance for industrial internet of things projects. The selection of communication protocol is a critical process for surviving and sustaining of IoT platforms. IoT platforms provide solutions for industrial area for both on premise and cloud based applications compatible with industrial communication protocols. This study is shaped by the IoT platform which is developed by Klemsan, improved by industrial communication protocols which are widely used in industrial area, are explained briefly. There are 13 evaluation metrics which are presented in detail that is necessary to be chosen between industrial communication protocols for IoT platforms.

Keywords: Communication, Protocol, Internet of things

Introduction

Digital communication is comprised of distributed computer control systems in both production lines and process control. Launching of wired systems and deployment of distributed industrial automation systems give importance to device autonomy and decentralized decision-making and control loops.

Today, wired systems are standardized and they are the most important communication systems used in commercial control installations. On the other hand, Ethernet is one of the most important communication technologies in the office space. For this reason, the usage of Ethernet is widespread in the industrial applications. Besides, Ethernet based (wired) industrial communication protocols are utilized in the industrial automations, the use of wireless technologies in the industrial area is also increasing, and thus heterogeneous networks are getting better included wired and wireless communication systems as well as local and wide area networks.

Various communication protocols have evolved due to the development of network structures and communication technologies and thus these protocols bring connected devices to access Internet gathering their measurement values into IoT (Internet of Things) platforms. This causes some problems such as speed, complexity, bandwidth, connection distances and data quality. This paper illustrates the commonly used industrial communication protocols in IoT platforms.

Communication Protocols

Data communication is the transfer of an information or data between a transmitter and a receiver as digital or analogous via connection element. Communication protocols are used in the industry to connect various control devices (Online, 2019). Industrial automation control systems such as SCADA (Supervisory Control and Data Acquisition), PLC (Programmable Logic Controller) and DCS (Distributed Control System) use various communication protocols to transfer data collecting from the shop floor to the related software tools and external systems.

Industrial communication protocols provide data communication over a certain communication standard and network. The most commonly used interaction models of communication protocols are request/response and publish/subscribe (Dizdarevic, Carpio, Jukan, & Bruin, 2019). Each communication protocol specializes in a private task and their usage depends on the application. A protocol cannot meet all the requirements of a complex application and eventually multiple protocols are combined. For this reason, complex applications transform into OPC UA (Open Platform Communication and Unified Architecture) and DDS (Data Distribution Service) with the development of Industry 4.0 applications.

Internet of Things

Internet of Things refers to the interconnection of uniquely identifiable devices within the existing internet infrastructure. Internet of Things are smart services and applications that facilitates people's living standards (Gündüz & Daş, 2018). Moreover, Internet of Things can be called smart network device systems that connect and share information with various communication protocols (Altınpulluk, 2018). Internet of Things concept which includes objects managed via the Internet, known as M2M (Machine-to-Machine) technology in the history. Furthermore, Internet of Things concept is expected to go beyond M2M communication to offer advanced connectivity to devices, systems and services through a variety of protocols.

Sensors, embedded devices and the Internet used in internet of things will disrupt the transformation in production area. Moreover, robotics and artificial intelligence techniques used in shop floor area provide added-value to the companies in terms of quality and speed, on the other hand, RFID technologies used in logistics and raw materials will be a beneficial method for products to reach the end users and customers in the supply chain (Öz & Arslan, 2019). Furthermore, Internet of things is the methodology that enables the application processes to be controlled at the high level by connecting smart device to the Internet.

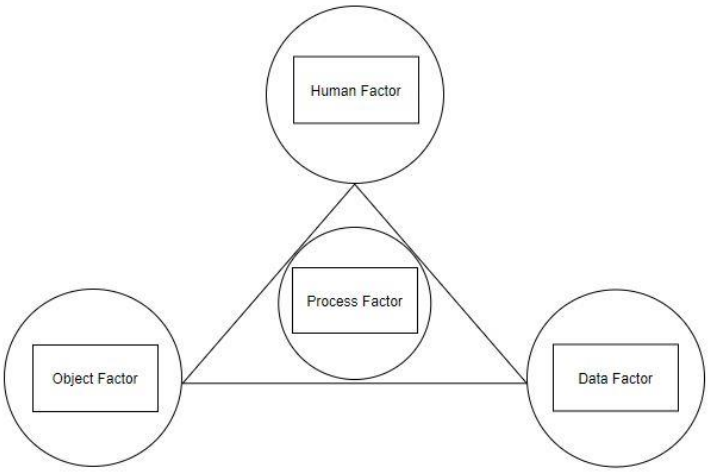

Figure 1. IOT Factors

Internet of things consists of four main factors. Fig. 1 shows these four factors. The human factor is necessary to make the data meaningful and analyze it from objects (devices). Object factor is a device or sensor which is connected to the Internet, generates data in the shop floor. The data factor is the structured or unstructured clusters produced by the objects (devices) in the production. This data becomes a big data by hosting in local, central or distributed servers. The process factor is a process that provides interaction and interoperability between object, human and data.Internet of things can be applied to many sectors. IoT appears in smart home and building automation, smart wearable technologies, smart energy, smart cities, smart agriculture and health applications.

IoT Platform

IoT platform provides the necessary infrastructure for all the services such as data storage, inter-connected device communication, device configuration and various software services. There are three basic service principles in IoT platforms; software as a service (SAAS), platform as a service (PAAS) and infrastructure as a service (IAAS). IoT platforms are deployed both on premise and cloud based.

IoT platforms have some advantages from SCADA systems in production and industrial facilities (IOT Online, 2021).

- Interoperability of the devices
- Data analysis and interpretation
- Scalability
- Standards and protocols
- Cost

As Klemsan, KIO (Klemsan Internet Objects) which we have developed in-house, offers solutions to the customers in the field of energy efficiency and savings. KIO IoT platform can communicate with energy measurement devices, sensors, input / output units, electricity, water, natural gas and heat meters by adding brand-independent structure.

KIO is located at a position in Fig. 2 in vertical integration. Not only collecting data of the devices in shop floor, but also transferring data to KIO via PLC or SCADA. KIO IoT platform which can also be integrated with MES (Manufacturing Execution System) and ERP (Enterprise Resource Planning) systems, can provide data transfer to these systems via web services.

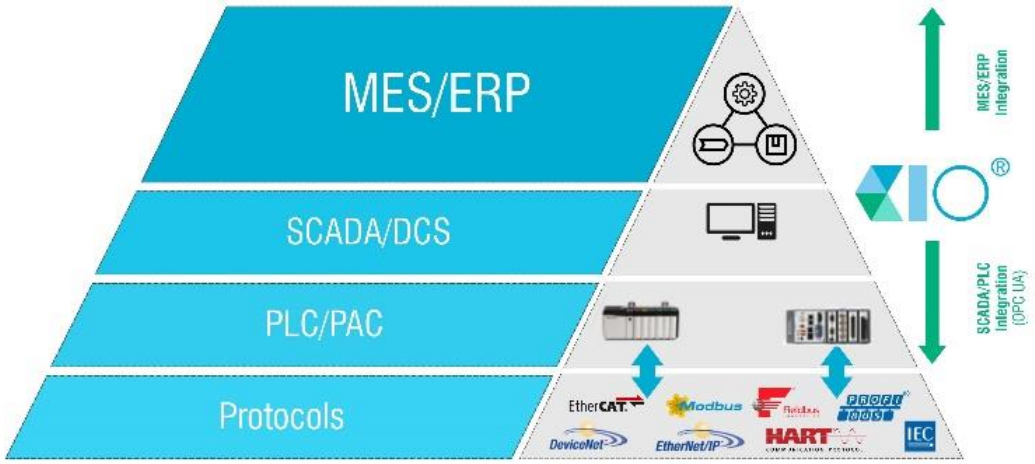

Figure 2. Vertical integration in KIO

Industrial Communication Protocols in IoT Platform

As Klemsan, KIO supports industrial communication protocols collecting data from production area. The protocols that are used in KIO IoT platform listed below.

Modbus

Modbus is a serial communication protocol developed by Modicon in 1979 for use with PLCs (Modbus Online, 2020). Modbus protocol provides solutions for serial and Ethernet based communication. Modbus RTU (Remote Telemetry Unit) is used for serial communication, Modbus TCP/IP (Transmission Control Protocol/Internet Protocol) is used for Ethernet communication. Modbus TCP/IP uses TCP/IP model to move data of the Modbus message structure between compatible devices. Modbus TCP/IP message is a simple Modbus communication encapsulated in a TCP/IP packet (Irmak & Erkek, 2018).

Modbus protocol is the most widely used communication protocol among the industrial communication protocols. There are multiple reasons listed below:

- Simple to understand and integrate with systems / devices
- Master/Slave structure. For example, there is one RS485 (Balance Data Transmission) line including one master and more than one slave devices. The master refers to device / system that needs the data. The slave refers to system that contains the data to be accessed. Due to not requiring any session initiation for communication, querying data can be done at high speed depending on the speed of the communication line.

Another reason for its frequent usage is that there were little alternatives in that period. Today, the usage rate of Modbus TCP/IP is 50% (Modbus IDA Online, 2006).

IEC 60870-5

This protocol was developed by TC (Technical Committee) 57 working group of IEC (International Electro technical Commission) technical committees. TC 57 is responsible for development of the standards for information exchange between power systems and other related systems including energy management systems, SCADA, distribution automation and protection.

IEC 60870-5-101 is the version of protocol that works on serial communication. The version used on TCP/IP is IEC 60870-5-104. Today, the devices whose protocol known as IEC 104 is widely used on RTU (Remote Terminal Unit) devices and electrical grid products. These devices are controlled through SCADA systems.

MQTT

MQTT (Message Queuing Telemetry Transport) is a lightweight messaging protocol that provides a simple way to distribute telemetry information for resource constrained network clients. The protocol uses publish / subscribe communication model which is determined by M2M communication and plays an important role in IoT (MQTT Online, 2020).

MQTT protocol consists of client and broker. Messages sent by the client are inspected and transmitted with broker. Each message sent by the client is tagged into a topic. The broker separates and sends messages to clients subscribed to the specified topic. The client who wants to forward its message to the relevant recipient, wants to send the recorded message topic to the broker. While a client can subscribe to a topic, more clients can also subscribe to it.

It is the most widely used protocol of today's IoT platform. It is used in IoT platforms with TLS (Transport Layer Security)/SSL (Secure Sockets Layer) security support.

OPC UA

OPC UA is an open standard that determines the exchange of information in industrial communications. This standard applies devices within the machines, between machines and communication with machines and systems that bring together IT (Information Technology) and OT (Operational Technology). OPC was first appeared for working specific standard in Microsoft operating systems. Due to service-oriented architecture and security issues, OPC UA developed with respect to scalable and extensible structure including open platform architecture (OPC Online, 2020).

OPC UA is a suitable standard for closed network or over the Internet. Security is guaranteed by embedded protocol in the form of authentication and encryption in access control (OPC Online, 2018).

Comparison Metrics for Industrial Communication Protocols in IoT Platform

As Klemsan, our IoT platform supports industrial communication protocols explained above. These protocols are widespread and valid protocols in industrial automation area. We state that we make out some metrics for comparison in industrial communication protocols experienced in our IoT platform.

Finding Versions That Can Run on Serial Communication and TCP/IP

When a device or a sensor has been developed for the first time, the device or the sensor which has similar functions, should be searched in the market. If the device is specified for development, communication protocol should also be evaluated with widely usage and compatibility. Communication protocol is an important factor to specify hardware costs. If the device is designed as cost-oriented, it should be chosen as serial communication, otherwise it runs on TCP/IP side with the communication interface such as Ethernet, Wifi or GSM. Nowadays, manufacturers start to add both serial communication and TCP/IP versions for communication protocols. Communication protocols for both serial communication and TCP/IP versions are shown in the below table.

Table 1. Communication protocols for serial and tcp/ip

Serial Communication	TCP/IP Communication
Modbus RTU / Modbus ASCII	Modbus TCP
IEC60870-5-101	IEC60870-5-104
Profibus	ProfiNET
EtherCAT	EtherNET/IP

No Need for Static IP

Serial communication can be considered as a permanent cable between two devices. This cable length can be 30 cm or kilometers. Since the communication line is always available in serial communication, data exchange can be done at any time. On the other hand, a virtual cable/bridge should be established in TCP/IP world so that the systems communicate with each other. The bridge is known as a socket connection. The socket connection uses many applications such as web sites, mobile application and database connection. A server and a client software are required in order to establish the socket connection. Connection direction is from clients to server. For this reason, clients must know the server's IP address to connect to the server. Today, there are thousands of servers on the Internet. Not only knowing of the IP adress is enough, but also communication port is used for communication. There is not any restriction as only one communication protocol will work on the servers. A total of 65536 ports can be opened on a server.

In some conditions, static IP is needed when connecting to high number of devices in some communication protocols. For example, if the devices connect with the communication protocols as Modbus TCP/IP in the local network or on the Internet, the device must have an unchangeable static IP. In this case, port forwarding will be able to be done on the modem/router.

Internet static IP is not preferred in GSM (Global System for Mobile Communications)-based systems due to both cost and security reasons. Enterprise private APNs (Access Point Name) are the most widely used M2M communication type. The biggest problem of private APNs is the difficulty in operation management. If the system includes 10000 SIM (Subscriber Identity Module) cards, this is very hard to manage for businesses. The most comfortable and simple management systems with high point numbers to choose devices and protocols that do not need static IP.

Some communication protocols do not require static IP. MQTT is an example protocol that uses dynamic IP. MQTT clients (device, sensor, central software) are only connected to Broker service over the socket connection. All MQTT clients can be found in dynamic IP in the system where this protocol is used.

One of the biggest problems of the protocols that need static IP is security. All applications in the network can request a socket connection to the server which includes devices without an IP restriction. In this case, unwanted situations may occur with attacks. In industrial facilities, static IP does not cause a great risk as it is solved in the local network and is not opened on the Internet. However, a penetration into network may affect the devices which have static IPs of the local network.

Session Based Communication

Security is one of the most important criteria in the selection of the communication protocol. Attacks from unknown resources can cause the system to be in undesirable situations. The system can be made more secure with session management in some protocols. Unwanted access can be prevented by a session to any device or broker. Session should be started with a username and a password. Some systems only require a password. Although session management is beneficial for security, a username and a password can be stolen with network sniffing tools.

TLS/SSL Based High-Level Security

Security is an inevitable feature for a communication protocol. TLS is the current and updated version of SSL. TLS/SSL option maximizes the security of the protocol. Today, TLS/SSL option is available in many protocols such as IEC 60870-5, OPC UA and MQTT. On the other hand, Modbus protocol has existed without TLS/SSL for many years. Few manufacturers have added TLS/SSL option to their systems.

Disconnection Detection Mechanism

While the protocols are working in the communication layers, communication problems may occur due to the fact that connection breaks are not detected in some cases. The most common example of this situation occurs in GSM communication. These breaks can be detected late in the devices on which the protocol works. In order to prevent this situation, manufacturers take extra precautions. In protocols such as MQTT, two extra connections are kept for communication health status control. In one of these two connections, the client tests its connection to the broker. In the other connection, the broker checks its connection to the client. If there is no data exchange during the periods of non-communication intervals, both parties understand that the connection between each other has been broken.

Data Size Optimization

High data traffic is observed in communication systems. The data download and upload amount of a device in Modbus TCP/IP protocol is as much as the communication with the application requesting data from this device. Multiple interrogations of this device can double the amount of the data. If the device was developed with a cost-oriented approach, there may even be a single socket operation of the device. The best method is to minimize the communication with the device in such cases. As in MQTT protocol, If all clients are only in communication with the broker, the communication with the devices in the field will be reduced to minimum levels.

Quality of Service Support

It is a metric seen in advanced level communication protocols. A quality information is assigned to each message with the data in protocols such as IEC 60870-5 and MQTT. It is possible for each message to be successfully delivered to the clients one, as well as for non-critical messages to be delivered or not delivered one or more times in order to not to occupy the network traffic.

Lightweight

It is very important that the protocol is simple and can run on the lowest hardware resources in the industry. This is one of the most important details in the usage of Modbus protocol. Despite its advanced structure in

MQTT protocol, it can work with low hardware resources. However, since some protocols were developed without considering this basic requirement, it is not possible to become widespread.

Availability of Open Source Libraries in Programming Languages for Communication Protocols

Protocols and their standards are created by organizations and commissions such as IEC. After the development process of the protocols, commissions such as IEC sell the technical details of the protocols on the web site for a fee. After these technical documents are purchased and examined, the implementation of the protocol on a device takes a long time. Therefore, this technical document is very hard to understand and difficult to implement for producing new devices. For this reason, some protocols are simple to embed for the devices and can be accessed over the Internet. There are many simulation programs such as Modbus protocol. On the other hand, MQTT protocol has become widespread as well as its many advanced features. The technical documents of MQTT protocol can be obtained from the Internet supported by giant technology companies such as IBM (International Business Machines). Moreover, open source libraries for each programming language can be downloaded freely and turned into distributable software packages.

Communication Pattern

There are two types of communication patterns in insdutrial communication protocols which are request / response and publish / subscribe. Modbus and OPC UA protocols only use request / response structure. Not only IEC60870-5 protocol has “request / response” structure, but also it has “ send when value changes”. On the contrary, MQTT protocol has publish / subscribe structure. MQTT client automatically sends the data to the broker at certain periods or when the value changes.

Bidirectional Communication

Regarding to communication protocols, bidirectional communication can be considered in two different ways:

- Reading data from the field and writing the data to the field (sending command)
- While sending data from the field to the center / server, it is possible to send data from the center / server to the field at the same time.

Both ways provide bidirectional communication. However, the first way is a common structure in all communication protocols. The second way is known as an asynchronous communication. For instance, while a 2 MB file is transmitted from the client to the broker, a subscribed message can be transferred from the broker to the client at the same time.

Timestamp Based Data Transmission and Data Pools

Timestamp data transmission has been developed to eliminate the problem of not being able to transfer data at a certain time interval due to the lack of communication. In this case, data is accumalted in a data pool and transmitted to the center after the communication returns to normal. This feature is not included in every protocol. IEC 60870-5 has this feature. Owing to this structure, data loss are prevented for certain levels as a result of communication breaks.

Continuous Improvement

This is a necessary metric for today’s industrial communication protocols. The protocol which is alive, is continued to be developed showing that it is still being invested and new features are being added. Many protocols lose their updates as they complete the development phase. On the other hand, MQTT protocol continues to be developed with version five in the current situation.

All metrics are shown in one table in the following. It is overviewed and seen briefly. The rows in the table represent the metrics of industrial communication protocols. The columns in the table represent the

communication protocols that are stated in this study. It is analyzed that IEC 60870-5 and MQTT protocols are supporting metrics for almost all.

Table 2. Comparison table for communication protocols

Metrics	MOBUS	IEC 60870-5	OPC UA	MQTT
Finding versions that can run on serial communications and TCP-UP	✓	✓		
No need for static IP				✓
Session based communications		✓	✓	✓
TLS-SSL based high-level security		✓	✓	✓
Disconnection detection mechanism		✓	✓	✓
Data size optimization				✓
Quality of service support		✓		✓
Lightweight	✓			✓
Availability of open source libraries in programming languages for communication protocols	✓			✓
Communication pattern	✓	✓	✓	✓
Bidirectional communication		✓		✓
Timestamp based data transmission and data pools		✓		
Continuous improvement				✓

Results

Communication protocol selection is a critical process. Selection of communication protocols; it is a decision that needs to be performed when a new device is developed, when an existing device needs to be improved or when scoping an IOT system at the initial stage. As Klemsan, our IOT platform (KIO) which supported Modbus and IEC62056-21, was first introduced to the market. Afterwards, OPC UA and MQTT protocols were added to the platform according to market research and customer requests. Nowadays, our platform communicates many industrial devices with supporting the variety of industrial communication protocols. Devices with many communication protocols in the field start to connect to the outside world over OPC UA with supported devices or MQTT with hardware gateways. For this reason, it is expected that MQTT will become widespread in the market.

In this study, the widely used industrial communication protocols in IOT platforms have been explained and compared with respect to some metrics. There are important metrics that shows us to choose industrial communication protocols which are compatible with IOT platforms. Security, structure of data, communication infrastructure, and continuous improvement are the critical factors to be chosen communication protocol in industrial area. SCADA is still preferred application in the industry, for this reason IEC 60870-5 protocol meets communication protocol metrics. In addition, MQTT protocol has almost metrics to be chosen for generating a new device or implementing in IOT platform. Learning the protocol, implementing it on a software or a device is one of the most accurate decisions for the companies.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors

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