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Articles

Smart Antenna System Implementation under Multipath Propagation Using JADE-MVDR and LMS Algorithms

Ahmad Aminu[1,2], Mustafa Secmen[2], Munir Aminu Husein[2]
[1]Department of Electrical and Electronics Engineering
School of Technology, Kano State Polytechnic
Kano, Nigeria
[2]Department of Electrical and Electronics Engineering
Yasar University
Izmir, Turkey

ahmadkksr@gmail.com, mustafa.secmen@yasar.edu.tr,
munneer@yahoo.com

Abstract— This paper considers the implementation of smart antenna system under multipath propagation. Here, it is considered different non-coherent signal groups each containing direct and multipath signals. The direction of arrival (DOA) of all the signals in each group is estimated using Minimum Variance Distortionless Response (MVDR) in conjunction with joint approximate diagonalization of eigenmatrices (JADE) algorithm. The generalized steering vectors are first estimated using JADE algorithm, and then the MVDR method is realized to estimate the DOA of each signal. The computation times of JADE-MVDR and JADE-MUSIC algorithms are compared for a single iteration and the results show that JADE-MUSIC has slightly lower runtime. Besides, RMSE performances are compared for different scenarios and JADE-MVDR is found to be more effective. The DOAs obtained are then processed using LMS adaptive beamforming algorithm to steer the main lobes of the radiation pattern toward the signal of interest angles and the nulls toward the signals not of interest angles. In addition, a new measure of the power level reduction under different scenarios (snapshots and array elements) is presented. The simulation results reveal that a maximum power drop of 0.4 dB is observed, and adaptive beamforming is successfully done by mitigating the effects of multipath significantly.

Keywords— direction of arrival; adaptive beam forming; joint approximate diagonalization of eigenmatrices; least mean square algorithm; minimum variance distortionless response

I. **Introduction**

Direction of arrival (DOA) estimation and adaptive beamforming are very crucial in the area of wireless communications (especially smart antenna system application) for the past few decades when there is a strong

correlation between signals. Many researches are conducted and several literatures are written concerning suitable methods for estimating coherent signals parameters. Two signals are said to be coherent when a delay replica of the original is produced due to multipath and fading phenomena (Yuen, & Friedlander, 1997). Multipath propagation is occurred due to the multiple reflections caused by reflectors and scatterers in the environment (Al-Zuraiqi, 2004). The separation of main (direct) signals from these reflected (interference) signals usually impinging from different angles than that of direct signal is very critical to increase the performance (signal level) of communication system. Therefore, DOAs and the fading coefficients of these correlated signals should be extracted properly, and the one having highest fading coefficient should be filtered out to arrange a steady communication.

The correlated signals cause spatial covariance matrix to be singular, which is non-invertible due to rank loss. This causes most of the existing classical and second order subspace methods fail to resolve the signals in the correct manner and hence makes DOA estimation impossible. Several methods are developed to restore this rank loss such as spatial smoothing based methods (Pillai, 1989), which are pre-processing schemes that subdivide the array elements into overlapping sub-arrays and then estimate the steering vectors as well as the covariance matrix of each sub-array.

The outlined procedure is followed by estimating DOAs of each sub-array using any DOA estimation algorithm. Matrix-pencil based method (Yilmazer, et al., 2006), (Hua, & Sarkar, 1988), maximum likelihood (Stoica, et al., 1996) and depletion approach (Xu, et al., 2006), where a Toeplitz matrix is constructed for DOA estimation of the coherent sources after the noncoherent sources are estimated with conventional subspace methods. All these methods have in one way or the other some shortcoming(s) (Yuen, et al., 1997) ranging from loss of array aperture, intensive computation, increased number of sensors and some fail in noisy environment as in the case of matrix pencil based methods.

Joint approximate diagonalization of eigenmatrices (JADE) based algorithms have been successfully applied to different DOA estimation as in (Zhang, et al., 2008; Lie, et al., 2006; Xu, et al., 2009; Ye & Zhang, 2009; Jia & Jing-Shu, 2010; Moghaddam, & Nasab, 2013; Moghaddam et al., 2013; Aminu, et al., 2014) since array response vectors estimated without having a prior knowledge of the array manifold (Cardoso & Souloumac, 1993). In this paper, DOA estimation using JADE based MVDR method for signal groups is

realized and the results are compared with those of JADE based MUSIC method. The RMSE performance measure is used to evaluate the effectiveness of the proposed method, which shows that JADE based MVDR can estimate DOAs in noisy environment.

The next part in this study is the implementation of the estimated DOAs on the adaptive antenna array beamforming. The current wireless communication systems generally use antennas/antenna arrays having very wide bandwidths to cover the whole space effectively. For instance, base station antennas with 3-sector configuration have almost 120 degrees beamwidth. However, in the cases with strong fading, the undesired signals coming from different DOAs due to multipath can severely reduce the magnitude of desired signal with desired DOA when undesired and desired signals are out of phase. Therefore, the radiation pattern (beam) of the antenna array should be modified (reformed) to get maximum signal for desired angle and minimum signals for undesired angles as possible. By using classical phased array technology (Mailloux, 2005) with the proper arrangement of phase coefficients of the antenna elements, the maximum of the array beam can be directed to the desired angle. Nevertheless, the undesired angles may coincide with the sidelobes of the radiation pattern, and consequently, a reduction of signal power can be still valid. For this purpose, an intelligent adaptive beamforming (radiation pattern) is needed to suppress the levels of undesired signals without changing the power level of the desired signal significantly. The well-known least mean square algorithm (LMS) is used for the adaptive beamforming purpose, and the performance is evaluated with a new measure of "power down in dB". This measure can be explained as the reduction of power in dB for the worst case where all undesired signals are out of phase to the desired signal. The simulation results present that in spite of challenging environment with strong fading coefficients, the algorithm is able to make a successful beamform adaptively such that the power reduction is observed as 0.4 dB at most.

II. Signal Model

Let us consider a situation where G narrowband, far-field noncoherent sources/groups impinge on a uniform linear and isotropic M element antenna array with element interspacing d equals to half wavelength of the signals. Here, it is assumed that each group contains L coherent signals one of which is handled as "desired" signals (having the highest amplitude), and other L-1 number of delayed and scaled replicas of the original (desired) signal in each group due to multipath and fading phenomena are called as "undesired" signals. Therefore, the total number of

signals is N = L × G. The output of the array, which is an M × 1 vector can be written as:

$$\mathbf{X}(k) = \mathbf{A}\mathbf{s}(k) + \mathbf{n}(k) \quad for\ k = 0,...,N_s - 1 \quad (1)$$

where $a(\theta_{G,L})$ is and n are the signal sources and additive noise respectively, Ns is the number of snapshots (data) and the matrix A is given by:

$$\mathbf{A} = \left[a(\theta_{1,1})\ a(\theta_{1,2}) \ldots\ a(\theta_{1,L}) \ldots\ a(\theta_{G,L}) \right] \quad (2)$$

where $a(\theta_{G,L})$ is the steering vector L in the G^{th} group as

$$a(\theta_{G,L}) = \left[1 \quad e^{\frac{j2\pi d \sin\theta_{(G,L)}}{\lambda}} \ldots e^{\frac{j2(M-1)\pi d \sin\theta_{(G,L)}}{\lambda}} \right]^T \quad (3)$$

$\theta_{G,L}$ is DOA of signal L in the Gth noncoherent group and λ is the wavelength of the signals. The signal matrix s can be expressed as

$$\mathbf{s}(k) = \left[s_{1,1}(k)\ s_{1,2}(k) \ldots\ s_{1,L}(k) \ldots s_{G,L}(k) \right]^T \quad (4)$$

where each signal contains the information about the fading coefficient. The noise matrix n is assumed to have zero mean entries and spatial covariance matrix being equal to $\sigma_n^2 \mathbf{I}_{\mathbf{M\times M}}$ where σn2 is the variance of the noise, and $\mathbf{I}_{\mathbf{M\times M}}$ is unit matrix of size M.

III. Estimation of the Steering Vector Using Jade Algorithm

JADE algorithm is applied to estimate the generalized steering vectors of the matrix X in (1). It is summarized as follows (Moghaddam, et al., 2013).

Step 1: Compute the spatial covariance matrix, Rxx of the signals in (1) with (Chen et al., 2010):

$$\mathbf{R}_{\mathbf{xx}} = E\left\{ \mathbf{X}(\mathrm{k})\, \mathbf{X}^H(\mathrm{k}) \right\} \quad (5)$$

where E{} is the expected operator, and H is the Hermitian (complex conjugate transpose) operator.

Step 2: Compute a whitening matrix W from the covariance matrix. Then, whitening process can be expressed as:

$$\mathbf{Z}(k) = \mathbf{W}\,\mathbf{X}(k) \quad (6)$$

Step 3: Form fourth order cumulants of Z(k) and compute G most significant eigenpairs

Step 4: Jointly diagonalize the set $\{\lambda_{zr}, M_{zr} \,|\, 1 \le r \le G\}$ by a unitary matrix U.

Step 5: An estimate of the generalized array response matrix:

$$\mathbf{Y} = \mathbf{W}^{\dagger}\mathbf{U} = \left[\mathbf{y_1} \quad \mathbf{y_2} \quad \ldots \quad \mathbf{y_G} \right] \quad (7)$$

where the column vectors y1, y2, …, yG are the generalized steering vectors belonging to each noncoherent source group in the total signal.

IV. DOA Estimation Using Jade Based Spectral MVDR Algorithm

The details of steps of Minimum Variance Distortionless Response (MVDR) can be found in many books and papers of (Foutz, et al., 2008), (Al-Nuaimi, et al., 2004) but are also summarized here.

The main aim of this method is to obtain the possible directions of all the received signals from the peaks of the spectrum of MVDR. Mathematically, MVDR can be expressed as:

$$\min_{w} p(\mathbf{w}) \quad subject\ to\ \mathbf{w}^H a(\theta) = 1 \qquad (8)$$

where $a(\theta)$ is given in (3), and w is the weight vector. For the first noncoherent source group containing L coherent signals, the corresponding steering column vector is obtained as y1 from previous chapter. Then, the weight vector for this group can be found using (9) below as:

$$\mathbf{w}_{MVDR} = \frac{\hat{\mathbf{R}}_{\mathbf{y_1y_1}}^{-1} a(\theta)}{a^H(\theta)\hat{\mathbf{R}}_{\mathbf{y_1y_1}}^{-1} a(\theta)} \qquad (9)$$

where $\hat{\mathbf{R}}_{\mathbf{y_1y_1}}$ is an estimate of the covariance matrix of y1. Finally, the output power spectrum is expressed in (10) where DOAs are estimated from the angles giving peak values at this spectrum.

$$p(\theta) = p_{MVDR} = \frac{1}{a^H(\theta)\hat{\mathbf{R}}_{\mathbf{y_1y_1}}^{-1} a(\theta)} \qquad (10)$$

This process is repeated for all other possible noncoherent signal groups by just replacing y1 with other generalized column steering vectors of y2,…, yG, and corresponding DOAs are acquired.

V. Adaptive Beamfroming and Power Reduction Measure

After successfully estimating the direction of arrivals of all the signals including the interfering ones using MVDR spectral method, these values and fading coefficients obtained with MVDR are used in the adaptive beamforming part of the study. Adaptive beamforming involves exploiting the arrangement of excitation coefficients of antenna array adaptively in order to achieve optimum reception of the desired signals in one direction and strongly rejecting the interfering ones in any other direction. In this paper, Least Mean Square (LMS) adaptive beamforming algorithm is used due to its simplicity and robustness.

The LMS algorithm was derived by Widow and Hoff (Haykin, 1991) in 1959 and it is widely used in many applications. It involves new observations and iteratively minimizes linearly the mean square error between the estimated and desired signals. In our adaptive antenna array beamforming, the DOA and fading coefficient of desired signal in each group are utilized to acquire the noiseless desired signal d(t) at Np snapshots. Here, Np can be much lower than Ns to save computational time.

Then, for each group, the total signal at each antenna element is calculated by using all DOAs and fading coefficients of the group. Accordingly, these total signals can be considered as the noise-free (clear) version of X in (1) for each group, named as Xg,clear. Then, for the gth noncoherent source group, the LMS algorithm equation to adaptively update the excitation coefficients of the antenna array is expressed as (Haykin, 1991):

$$w(t+1) = w(t) + \mu e(t) \mathbf{X}_{g,clear}^{*}(t), \; t = 0,...,N_p - 1 \qquad (11)$$

where

$w(t) = \left[w_1(t) \quad w_2(t) \quad \ldots \quad w_M(t) \right]^T$ are the excitation coefficients of the antenna array at the tth iteration; μ is the step-size parameter which controls the immediate change of the updating factor, and e(t) is the error between the desired and output signal which is given by (Hayes, 1996):

$$e(t) = d(t) - w(t)^H \mathbf{X}_{g,clear}(t) \qquad (12)$$

The step-size parameter has significant effect on the LMS algorithm such that, if it is too small, the convergence to optimal solution takes longer time while if it is high, the stability of the system is affected. For stability, the following condition (Chen et al., 2010) must be satisfied.

$$0 < \mu < \frac{1}{\lambda_{\max}} \qquad (13)$$

where λmax is the maximum eigenvalue of the autocorrelation matrix.

After the optimum excitation coefficients of each antenna elements are obtained by LMS, the normalized array factor (AFn) of the antenna array is calculated. Next, the degradation in desired signal power level is evaluated with a new measure of "power down in dB". In this measure, the power difference in dB between maximum available power and power with the optimized coefficients in the worst case is used. The received power in dB for each group can be given as

$$P(dB) = 20\log_{10}\left| \rho_d AF_n(\theta_d) + \sum_{i=1}^{L-1} \rho_{i,u} AF_n(\theta_{i,u}) \right| \qquad (14)$$

where ρd and AFn(θd) are fading coefficient and normalized array factor at DOA of the desired signal, respectively; and ρi,u (where $|\rho i,u| < 1$) and AFn(θi,u) for i =1,…, L-1 are those of undesired signals. In mobile wireless communication systems, although the magnitudes of fading coefficients change slowly, the phase terms are very sensitive especially to the relative distances between sources and antennas such that the phase value can jump 180 degrees even with a small change in the distance. Therefore, the phase terms of undesired signals' contributions in the summation in (14) can all be out of phase relative to desired signal, which results in reduction at the power level of desired signals.

By assuming ρd = 1 and AFn(θd)=1, this worst power (Pw) can be expressed as

$$P_w(dB)=\begin{cases}20\log_{10}\left(1-\sum_{i=1}^{L-1}\left|\rho_{i,u}\right|\left|AF_n\left(\theta_{i,u}\right)\right|\right), if \sum_{i=1}^{L-1}\left|\rho_{i,u}\right|\left|AF_n\left(\theta_{i,u}\right)\right|\le 1\\ -\infty\ dB \qquad\qquad ,if \sum_{i=1}^{L-1}\left|\rho_{i,u}\right|\left|AF_n\left(\theta_{i,u}\right)\right|>1\end{cases} \quad (15)$$

Regardingly, for nonzero fading coefficients of undesired signals, the theoretical maximum available power can be only achieved when a maximum in AF is at the DOA of desired signals, i.e. AFn(θd)=1; and the nulls are at the DOA of undesired signals, i.e. AFn(θi,u)=0. So, according to (15), Pmax(dB) becomes 0 dB, and the power down in dB can be formulated as

$$P_{down}(dB)=P_{\max}(dB)-P_w(dB)=0-P_w(dB) \quad (16)$$

Here, for instance, 3 dB of Pdown means the loss of half of the power of the desired signal, and ∞ dB of Pdown corresponds to no received desired signal.

VI. Simulation Results and Discussions

In this part, the simulation of JADE Based Minimum Variance Distortionless Response Algorithm for DOA estimation is first carried out, and then the DOAs obtained are implemented using LMS adaptive beamforming algorithm for smart antenna application. The root mean square error (RMSE) is utilized as performance measure to determine the effectiveness of the method. RMSE is defined in (17) below as follows (Zhang, et al., 2008):

$$RMSE=\sqrt{\frac{1}{NT}\sum_{t=1}^{T}\sum_{n=1}^{N}\left(\hat{\theta}_n(t)-\theta_n\right)^2} \quad (17)$$

where $\hat{\theta}_n(t)$ is the estimate of for tth Monte Carlo trials.

The simulation considers three sources of uncorrelated groups of signals each containing one original signal and three multipath signals. Table I below gives the true directions and fading coefficients of the signals:

TABLE I. True Arrival Angles and Fading Coefficients of the Signals

Group	True DOAs (deg)	True Fading coefficients
First	–41	1
	–14	–0.6426+0.7266j
	12	0.8677+0.0632j
	39	0.7319-0.1639j
Second	–49	1
	–25	0.8262+0.4690j
	1	0.1897-0.8593j
	48	0.2049-0.7630j

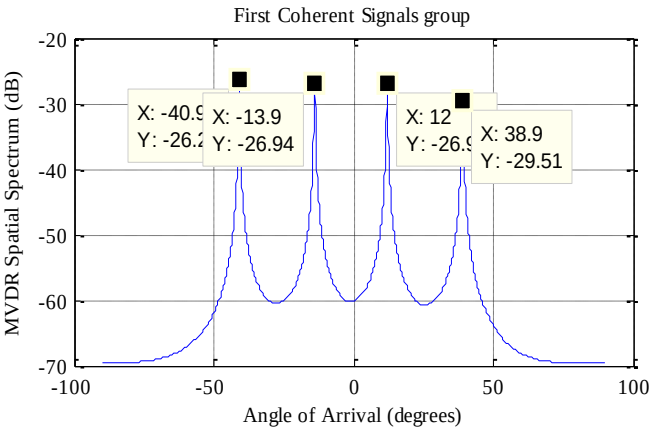
Third	–46	1
	–22	0.1681-0.9045j
	4	-0.7293-0.1750j
	44	0.6102+0.1565j

The angles are deliberately chosen within the range between -60 and 60 degrees to be consistent with base station applications at which the antenna of each sector has 120 degrees beamwidth. In the above table, the fading coefficient of "1" in each group belongs to desired signal and other coefficients are for the undesired ones. Since the sum of magnitudes of the fading coefficients of undesired ones is greater than 1 for each group, by considering (15) there is a possibility of receiving no desired signal (power down of ∞ dB) with the random changes of phases when no adaptive beamforming is employed.

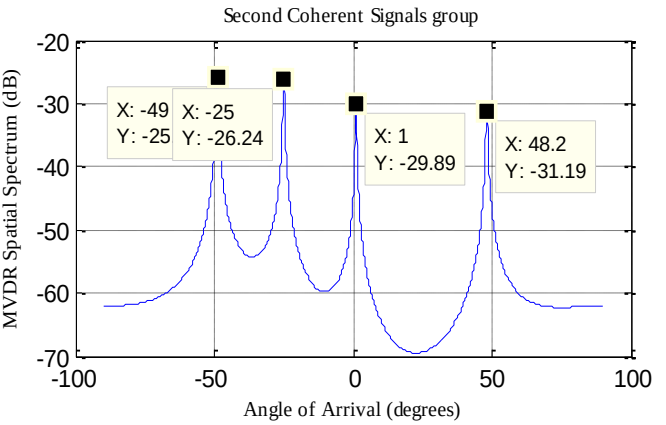
These signals impinge on a uniform linear array with M = 10 array elements with equal distances of d = 0.5λ. The signals having Ns = 2000 snapshots in (1) are corrupted with a Gaussian noise with SNR= 0 dB, and T = 50 trials are performed for each analysis to be described in the next parts.

The JADE-MVDR spectrums for each coherent signal group are shown in Fig. 1 for a sample trial. Here, the sharp peaks indicate the angle of arrival (DOA) of each signal. From the results, it can be observed that the method succeeds in resolving coherent signals correctly with 0.2 degrees error at most for this trial.

In this simulation, the proposed algorithm is compared with JADE based MUSIC (Zhang, et al., 2008). The RMSE performances of two algorithms are analyzed in terms of the parameters of number of array elements (M), number of snapshots (Ns), and signal to noise ratio (SNR).



(a)



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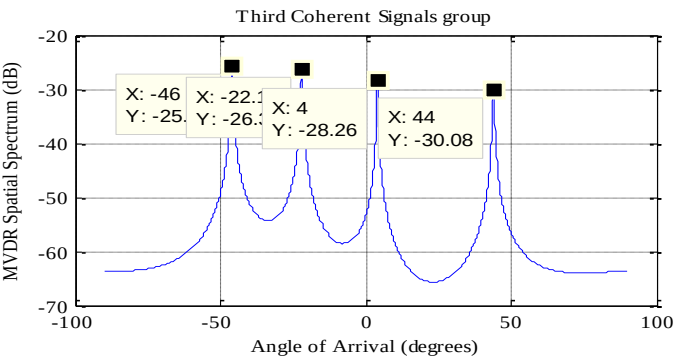

(c)

Fig. 1.The estimation of JADE base MVDR spectrum for each coherent signals group with the sharp peaks indicating the estimated DOAs of the coherent signals.

In the first analysis, the RMSE performance is compared for different M numbers by fixing SNR = 0 dB and Ns = 2000. The corresponding results are depicted in Fig. 2 such that JADE-MVDR has less RMSE at low M values meaning to have better performance than JADE-MUSIC. However, as the number of antenna increases 16 and beyond, two algorithms have equal performances with less than 0.04 degrees error.

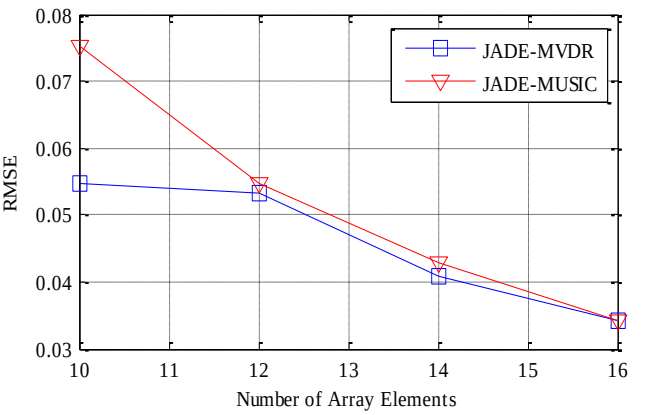

Fig. 2.Variation of RMSE with Number of Array Elements for JADE-MVDR and JADE-MUSIC for SNR = 0 dB and Ns = 2000.

In the second analysis, the RMSE performance is compared for different Ns numbers by fixing SNR = 0 dB and M = 10, and the corresponding results are given in Fig. 3. As it can be seen from Fig. 3 that JADE-MVDR has superior performance compared to JADE-MUSIC even at the low number of snapshots.

The last analysis of SNR is realized by fixing Ns = 500 and M = 10 which are the worst cases of the previous analyses. The results can be seen in Fig. 4 that both methods have almost equal performance for the worst case with minimum number of snapshots and antenna elements. RMSE value lower than 0.8 degrees is achieved even for the case of SNR = -10 dB, Ns = 500 and M =10, which shows the effectiveness of the proposed JADE based MVDR algorithm.

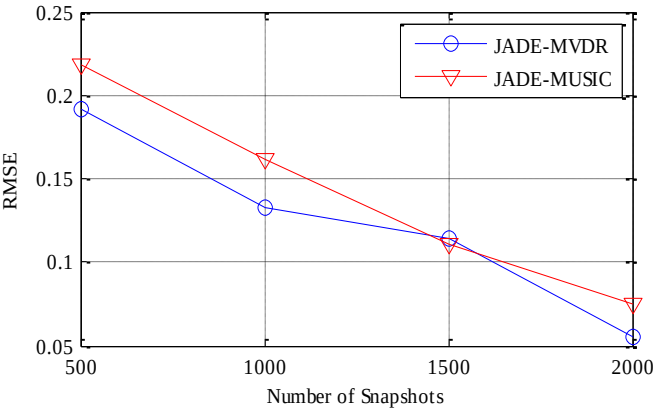

Fig.3 Variation of RMSE with Number of Snapshots for JADE-MVDR and JADE-MUSIC for *SNR* = 0 dB and *M* = 10.

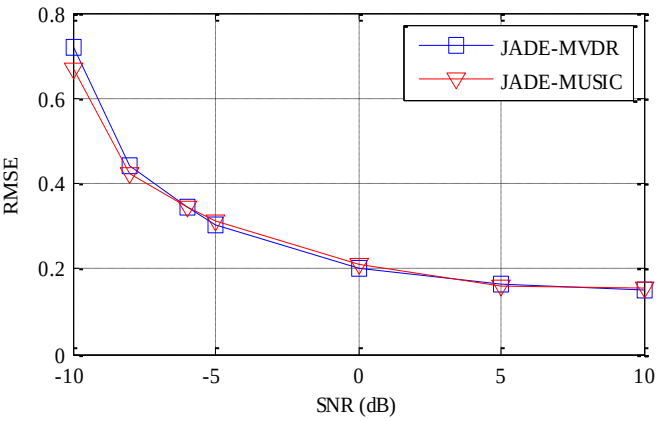

Fig. 4 Variation of RMSE with SNR for JADE-MVDR and JADE-MUSIC for *Ns* = 500 and *M* = 10.

The estimated DOA angles in the above simulation results are well separated. Therefore, the calculated RMSE is below 0.8 degrees even for this challenging case. When the angles belonging to coherent signals are closer to each other, the results may degrade (Yuen, et al., 1997); however, the JADE based MVDR is still expected to give sufficient results.

The computation times of JADE-MVDR and JADE-MUSIC algorithms are also compared for a single iteration, and the results are shown in Table II. These results are obtained in MATLAB environment with a HP Personal Computer, which has Intel Core i3-2328M processor at 2.2GHz and 4GB (929 usable) RAM.

TABLE II. COMPARISON OF COMPUTATION TIME OF JADE-MVDR AND JADE-MUSIC ALGORITHMS

	JADE-MVDR	**JADE-MUSIC**
Run Time/Iteration (sec)	6.53	5.6

The results show that JADE-MUSIC has slightly lower run time than JADE-MVDR, and it is probably due to the additional time spent by the MVDR to take the inverse of the covariance matrix.

After the estimation of DOAs and fading coefficients with MVDR is completed for the parameters of SNR = 0 dB, N_s = 2000 and M = 10, these values are used to adaptively optimize the excitation coefficients of the antenna array. In the beamforming part, a small portion of entire signal is used (N_p = 300 snapshots) to reduce computational complexity. In all simulations the step-size of LMS is fixed to μ = 0.0014. The normalized array factors (radiation patterns) for a sample trial are shown in Fig. 5

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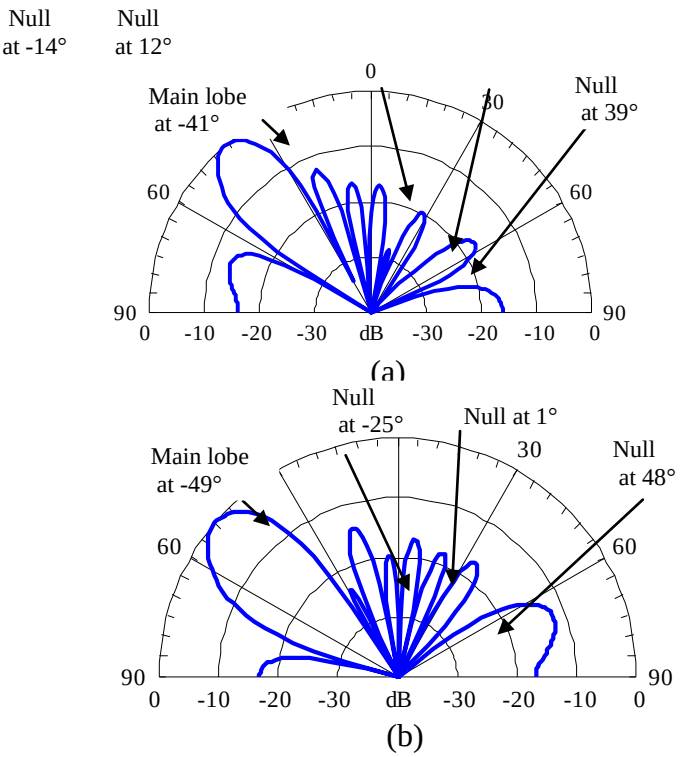

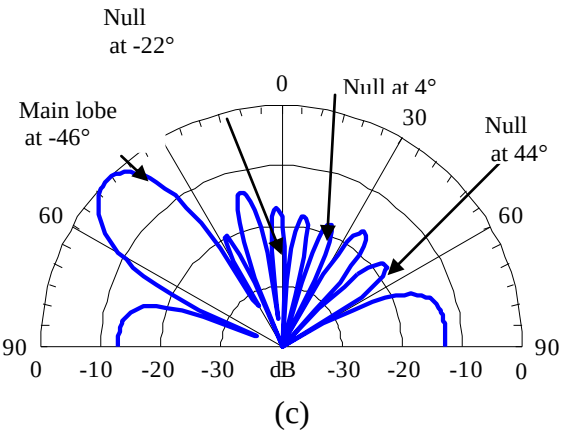

(c)

Fig. 5 Polar radiation plot of the adaptive beamforming for (a) the first signal group (b) the second signal group (c) the third signal group.

In Fig. 5, it can be clearly seen that the main lobes of the adaptive beamforming patterns are directed toward the angles of desired signals (θ_d) in all three groups, which are -41°, -49° and -46° in the first, second and third groups, respectively; while all other angles of undesired signals ($\theta_{i,u}$) are directed toward the nulls. For this sample trial, the maximum power reduction is calculated to be at most 0.4 dB for all three groups.

The additional simulation involves the analysis of measure of the power reduction, P_{down} (dB) in (16), for different scenarios (different number of snapshots and array elements). Figure 6 shows the results of the variation of power reduction with respect to snapshots used in the beamforming part, N_p. As it can be seen in Fig. 6, even if 50 snapshots are used for beamforming part, maximum power drop is found as 0.4 dB, which is reasonable. Besides, it is clear that the results are not significantly affected by either increase or decrease in the number of snapshots.

Similarly, Fig. 7 shows the power reduction with respect to number of antenna elements by fixing N_p = 300. The related results indicate that the power level down in dB remains slightly constant for all the three groups as the number of antenna elements increasing from 10 to 14, while it increases with the number of antenna elements above 16 for first and second groups. First and second groups have minimum power reductions when 14 and 16 antenna elements are used, respectively. Again, the maximum power level drop is found to be no more than 0.4 dB meaning a very negligible loss in the desired signal power level.

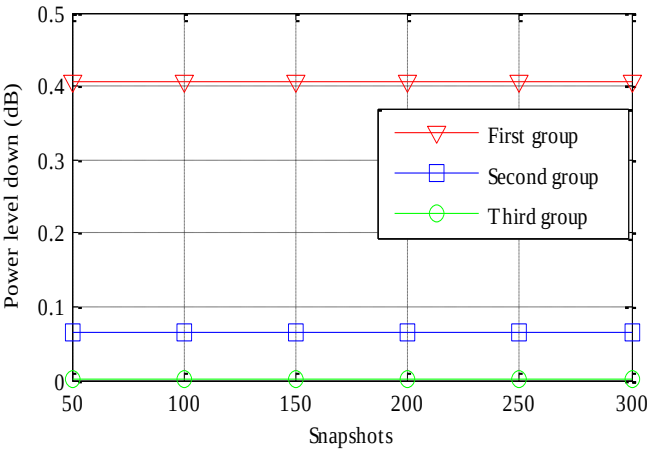

Fig. 6 Variation of Power level down with N_p for the signal groups.

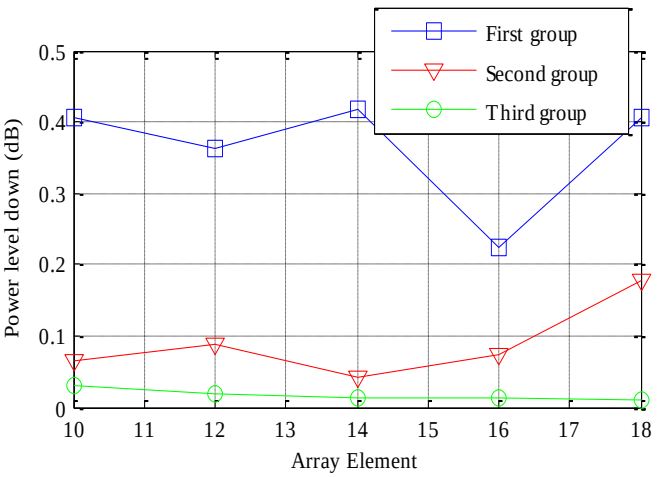

Fig. 7 Variation of Power level down with array element for the signal groups.

VII. Conclusions

In this paper, DOAs in multipath propagation are examined and estimated using two-step approach, which involves estimating the generalized steering vectors using JADE algorithm followed by estimating the angle of arrival using MVDR algorithm. The case of noncoherent signal groups with each containing coherent signals having strong multipath effects is used throughout the simulations. The performance of JADE-MVDR algorithm is compared with that of JADE-MUSIC in different scenarios and simulation results show that JADE-MVDR algorithm which is emphasized in this paper has slightly better performance than JADE-MUSIC. The DOAs and fading coefficients obtained by the JADE-MVDR algorithm are processed using LMS adaptive beamforming algorithm. The main lobes of the adaptive beamforming

patterns are successfully steered to the desired signal and the nulls to the undesired signals in each noncoherent group giving the maximum power reduction of 0.4 dB with the new measure of "power down in dB". As a conclusion, the proposed method can be used effectively for the smart antenna system applications and implementations.

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Incorporating Biometric And Mobile Systems In Social Safety Nets In Sub-Saharan Africa

Okewu Emmanuel
Centre for Information Technology and Systems
University of Lagos, Nigeria
eokewu@unilag.edu.ng, okewue@yahoo.com

Abstract - This paper measured poverty and corruption in Sub-Saharan Africa and modelled a biometric/mobile solution for curbing corrupt practices in social safety programmes. This is against the backdrop that efforts to better the lives of the vulnerable groups - unemployed, rural poor, women and persons with disabilities - are being frustrated by corruption in social security schemes mounted by various government to cater for these groups. The fallout is that planned benefits don't get to the target audience, precipitating conflicts and social tensions. Even more worrisome is that this segment of the society becomes easy recruits for social menace like kidnapping, terrorism, vandalism, prostitution, among others. Using Nigeria as case study, the study applied biometric system for the documentation and authentication of social safety net beneficiaries so that only genuine persons get the social benefits. Equally, mobile applications and devices are integrated for disseminating information about planned and released social packages from government ministries, departments and agencies (MDAs) to the target audience. The research resulted in an integrated Information and Communication Technologies (ICTs) design that substantially mitigates corrupt practices in social safety nets.

Keywords - Biometric system, Corruption, ICT, Mobile System, Poverty, Social safety net , Vulnerable groups

1. Introduction

The economy of Africa encompasses trade, industry, agriculture, and human resources of the continent. In 2012, approximately 1.07 billion people were living in 54 different countries in Africa. Africa is a resource-rich continent though many African people are poor. In March 2013, Africa was identified as the world's poorest inhabited continent. Sub Saharan Africa, in particular, is expected to reach a gross domestic product (GDP) of $29 trillion by 2050 but its income inequality will be a major deterrent in wealth distribution (Oliver, 2013).

There is a general consensus that African countries need social security systems that would prevent people from acting desperately

before they can make meaningful progress across the socio--economic spectrum. This is against the backdrop that there cannot be harmony without security. A coordinated and holistic social security system that will not only protect its citizenry from economic and social risks but also help in reducing the high rate of poverty on the continent. Social security places responsibility on the state to protect and provide for the individual when he is unemployed, or losses his job as a result of occupational injury, accident , when he or she grows old and when a woman is on maternal leave or economically challenged, just to mention a few. The state of vulnerable groups like women, persons with disabilities, and the thousands of unemployed youths on the continent underscores the fact that all challenges that have impinged on successful implementation of social security system for several decades need to be urgently addressed. Over time, Information and Communication Technology (ICTs) have proven to be useful in scaling upward the productive capacity of people either directly or indirectly. The economic productivity it induces brings about development and social transformation. The bottom line is that in the face of economic prosperity and social transformation, people find social ills unattractive and the continent is the better for it. Whereas directly ICTs provide skills, empowerment, jobs and income for the underprivileged and help secure their socio-economic future, it has also found relevance in entrenching accountability, transparency, probity and equity in initiatives that touch on the vulnerable groups. This study examined the strategic roll of biometrics and mobile technology in this regard.

Biometrics refers to metrics related to human characteristics and traits. Biometrics authentication (or realistic authentication) is used in computer science as a form of identification and access control. It is also used to identify individuals in groups that are under surveillance.

Biometric identifiers are the distinctive, measurable characteristics used to label and describe individuals (Jain et al., 1999): They are often categorized as physiological versus behavioural characteristics (Jain et al., 2012).

Physiological characteristics (Figure 1) are related to the shape of the body e.g. fingerprint, palm veins, face recognition, DNA, palm print, hand geometry, iris recognition, retina and odour/scent. Behavioral characteristics (Figure 2) are related to the pattern of behaviour of a person e.g. typing rhythm, gait (walking mode), and voice. Some researchers have coined the term behaviometrics to describe the latter class of biometrics.

FIGURE 1. BIOMETRIC IDENTIFIER - PHYSIOLOGICAL

FIGURE 2. BIOMETRIC IDENTIFIER - BEHAVIOURAL

More traditional means of access control include token-based identification systems, such as a driver's license or passport or passport, and knowledge-based identification systems, such as a password or personal identification number (PIN).

Since biometric identifiers are unique to individuals, they are more reliable in verifying identity than token and knowledge-based methods; however, the collection of biometric identifiers raises privacy concerns about the ultimate use of this information (Jain et al., 1999), (Weaver, 2006). Biometrics introduces new security procedures.

Cutting-edge biometric security devices include fingerprint readers, retinal eye scanners and hand geometry readers.

FIGURE 3. BIOMETRIC SOLUTION ARCHITECTURE

Unlike keys, cards or number sequences, biometric security readers provide access control that cannot be transferred. A person

must be physically present at the point of identification in order to gain access (Figure 3).

A mobile system is an arrangement that comprises mobile operating system that operates a smartphone, tablet, PDA, or other mobile device. Modern mobile operating systems combine the features of a personal computer operating system with other features, including a touch screen, cellular, Bluetooth, Wi-Fi, GPS mobile navigation, camera, video camera, speech recognition, voice recorder, music player, near field communication and infrared blaster.

According to ITU, mobile communications and technology has emerged as the primary technology that will bridge in the least developed countries. As evidence, countries in Africa have recorded magnificent growth in using mobile phones to access the Internet. A case in point: In Nigeria, 77% of individuals aged 16 and above use their mobile phones to access the Internet as compared to a mere 13% who use computers to go online. This unfolding scenario in developing countries will bridge the digital divide between least-developed countries and developed countries (Figure 4) although there are still hiccups in making these services affordable.

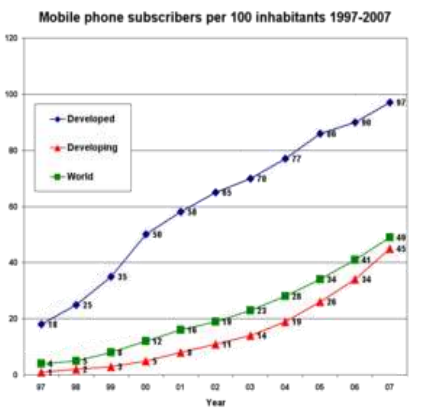

FIGURE 4. MOBILE PHONE SUBSCRIBERS PER 100 INHABITANTS GROWTH IN DEVELOPED AND DEVELOPING WORLD BETWEEN 1997 AND 2007 (SOURCE: ITU)

The use of mobile phones as key component of Information and Communication Technology for Development (ICT4D) initiatives has been successful as the widespread distribution of mobile telephony has made it possible for poor people to have easy access to useful and interactive information (Languepin, 2010). In India, for example, the total number of mobile phone subscriptions reached 851.70 million in June 2011, among which 289.57 million came

from rural areas, with a higher percentage of increase than that in urban areas. This unprecedented growth of affordability and coverage of mobile telephony services has underscored its importance not just as a means of two way communication but that of ease-of-access to information as well.

A social safety net is a strategic intervention aimed at empowering the socially vulnerable so that they will apply their minds productively for developmental purposes. According to Paime (1992), there is a correlation between security and survival. Whereas survival is an essential condition, security is viewed as safety, confidence, free from danger, fear, doubt, among others. Therefore, security is 'survival-plus' and the word 'plus' could be understood from the standpoint of being able to enjoy some freedom from life-determining threats and some life choices (Booth, 2007). Therefore, making available social safety nets is a developmental agenda that channels the energies of economically challenged people into national development.

2. Information and Communication Technologies for Social Security (ICT4SS)

This study examined the ongoing Boko Haram insurgency in Nigeria and acknowledged the sect has been recruiting members of the vulnerable groups for nefarious activities in Nigeria (Table 1), particularly as suicide bombers who detonate Improvised Explosive Devices (IEDs):

TABLE 1. ENGAGEMENT OF VULNERABLE GROUPS IN BOKO HARAM INSURGENCY

SN	Vulnerable Group	Insecurity mission
1.	Persons with disability	Used as suicide bombers to detonate IEDs
2.	Unemployed young women	Used as suicide bombers to detonate IEDs
3.	Unemployed young men	Engaged as foot soldiers for gorilla welfare and as suicide bombers

Nwagboso (2012) examines the security challenges in Nigeria and the extent to which the insurgencies of different militia groups as well as the prevailing internal insurrections across the country have adversely affected the Nigerian economy. The Nigerian experience is a reflection of security threats across Africa as are highlighted in Table 2.

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TABLE 2: SELECT SECURITY THREATS IN AFRICA

SN	Security threat	Period	Country
1.	Ethnic cleansing	April - June 1994	Rwanda
2.	Civil War	1989 - 1996, 1999 - 2003	Liberia
3.	Arab Spring	2011 - 2012	Egypt
4.	Arab Spring	2011	Tunisia
5.	Arab Spring	2011 - to date	Libya
6.	Civil War	1991 - 2002	Sierra Leone
7.	Niger Delta crisis	1999-2007	Nigeria
8.	Jos crisis	2001- to date	Nigeria
9.	Civil War	2013- to date	South Sudan
10.	Militia uprising	2013 - to date	Central African Republic
11.	Boko Haram crisis	2009 – to date	Nigeria

On the other hand, Information and communication technologies (ICTs) include any communication device—encompassing radio, television, cellular phones, computer and network hardware and software, satellite systems and so on, as well as the various services and applications associated with them, such as videoconferencing and distance learning. This research study revealed that the application of ICTs in the field of social security has popularized the concept of Information and Communication Technologies for Social Security (ICT4SS) as both a developmental agenda and academic discipline.

Information and Communication Technologies for Social Security (ICT4SS) refers to the use of Information and Communication Technologies (ICTs) in enhancing the socioeconomic wellbeing of the poor, disable, unemployed and vulnerable women. The theory behind this is that more and better information and communication usage in social safety nets furthers the development of a society. The concern is less on e-readiness and more on the impact of ICTs on development. Additionally, there is more focus on the poor as producers and innovators with ICTs (as opposed to being consumers of ICT-based information).

After a study of the role of technology as a tool for development and social transformation over decades of economic evolution, the author tabulated findings as follows:

TABLE 3: ECONOMIC EVOLUTION AND TECHNOLOGIES USED

Economic phase	Period	Technology Used
1st phase (Industrial revolution)	1770 - 1850	Water-powered mechanization
2nd phase (Kondratiev wave)	1850 - 1900	Steam-powered technology
3rd phase	1900 - 1940	Electrification of social and productive organization
4th phase	1940 - 1970	Motorization and automated mobilization of society
5th phase	1970 - to date	Digitalization of social systems

Despite the potentials of ICT4SS for development, social transformation and improved security, developing countries far lag developed nations in computer use and internet access/usage as shown in Fig. 5. Studies have shown that, on average only 1 in 130 people in Africa has a computer while in North America and Europe 1 in every 2 people have access to the Internet. 90% of students in Africa have never touched a computer.

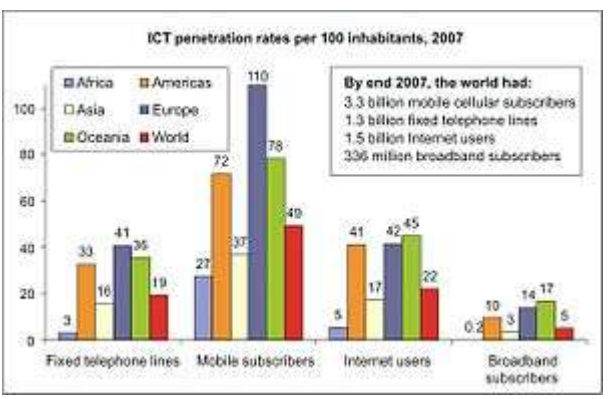

FIGURE 5. GRAPH OF ICT PENETRATION PER 100 INHABITANTS BY INTERNATIONAL TELECOMMUNICATION UNION(ITU)

As laudable as ICT interventions in social protection are, there is need for greater surveillance to curb unwholesome practices that may prevent the vulnerable groups from enjoying the dividends the schemes are meant to deliver. In this paper, the author proposes a biometric system for capturing and validating the particulars of would-be

beneficiaries of the scheme as antidote to tackling the corrupt practices.

In next section, various direct applications of ICT are studied. Under Related Works, a number of case studies in this field are analyzed. The succeeding section, Proposed ICT Solution, presents the proposed biometric system design. In the second to last section, Discussion, the study analysis the proposed system. The last section, Conclusion and Further Work, wraps up this research paper with details about further work on the proposed solution.

3. Direct ICT Interventions in Socio-Economic Empowerment of Vulnerable Groups

There are various direct applications of ICTs that have empowered the less privileged across Africa (Table 4):

TABLE 4: EMPOWERMENT OF THE LESS PRIVILEGED ACROSS AFRICA VIA ICT INITIATIVES

SN	Country	Government Initiative
1.	Nigeria	e-wallet system for providing information about distribution of agricultural inputs to rural farmers using mobile technology. So far, 12 million farmers have benefitted from the scheme.
2.	Gambia	The telecentre application used to disseminate information on development issues such as agriculture extension, health, and education to poor communities.
3.	Mali	Wi-Fi antenna set up in Mali to relay information to the rural areas.
4.	Ghana	Satellite Internet access via VSAT under the Ecamic Project is used to make information available to the rural poor.
5.	Uganda	Charging mobile phone from car battery is to enable the less privileged to keep their mobile phones alive for information access.
6.	Burundi	Use of mobile telecommunications and radio broadcasting to fight political corruption in Burundi.
7.	Tanzania	Study shows the use of mobile phones has impacted rural living in the following ways (Bhavni et al., 2008): entrepreneurship and job search, easy access to information, correcting market inefficiencies, transport substitution, disaster relief, education and health, social capital and social cohesion.
8.	Kenya	Study identified innovation in mobile technologies for development (Masiero, 2013), in particular the success of M-PESA mobile banking which impacts on sectors like m-

		agriculture and m-health.
	Ethiopia	Evidence from Ethiopia indicates that farmers use mobile phones for interactions but may feel reluctant to call individuals whom they have never met personally, which restrains the usability of mobile phones in regions with limited transportation options (Matous, 2014).

According to the literature, the livelihoods of the following vulnerable groups have been greatly enhanced by ICTs (Deepak, 2012; Watkins, 2012; Motes, 2014; Maier (2007):

- People with disabilities
- Rural farmers
- Women empowerment
- The unemployed

4. Corruption and Poverty Perceptions Indices

Transparency International, the global coalition against corruption, says the Corruption Perceptions Index 2013 serves as a reminder that the abuse of power, secret dealings and bribery continue to ravage societies around the world.

The Index scored 177 countries and territories on a scale from 0 (highly corrupt) to 100 (very clean). Although no country has a perfect score, about two-thirds of countries scored below 50 and African countries are reputed for falling within this bracket. This indicates a serious, worldwide corruption problem.

The world urgently needs a renewed effort to crack down on money laundering, clean up political finance, pursue the return of stolen assets and build more transparent public institutions.

To underscore corruption levels in Sub-Saharan Africa, the study statistically modelled corruption prevalence in select countries (Table 5) whose social security schemes were examined in this work.

TABLE 5: CORRUPTION RANKINGS OF SELECT AFRICAN COUNTRIES (SOURCE: TRANSPARENCY INTERNATIONAL - HTTP://WWW.TRANSPARENCY.ORG)

SN	Country	Year 2013 Score (over 100)	Ranking (out of 177 countries)
1.	Nigeria	25	144
2.	Gambia	28	127
3.	Mali	28	127
4.	Ghana	46	63
5.	Uganda	26	140
6.	Burundi	19	172
7.	Tanzania	33	111
8.	Kenya	27	136

On the other hand, The Global Multidimensional Poverty Index (MPI) Interactive Databank presents data on acute poverty in 108 developing countries around the world. It is a measure of poverty and human development and ranks for multidimensional poverty and destitution. After connecting Tables 5 and 6, it became apparent that there is a strong link between corruption and poverty in Africa and by extension, insecurity.

TABLE 6. POPULATION IN MULTIDIMENSIONAL POVERTY (SOURCE: OXFORD POVERTY AND HUMAN DEVELOPMENT INITIATIVE (2014) GLOBAL MULTIDIMENSIONAL POVERTY INDEX DATABANK. OPHI, UNIVERSITY OF OXFORD

SN	Country	MPI Poor (%)	Destitute (%)	Population living on less than $1.25 per day (%)
1.	Nigeria	20	30	65
2.	Gambia	58	0	30
3.	Mali	88	0	50
4.	Ghana	17	8	25
5.	Uganda	50	25	30
6.	Burundi	40	40	80
7.	Tanzania	43	22	65
8.	Kenya	45	0	43

5. Related Work

The deliberate use of communication to facilitate development is not new. The essence of ICT-for-development (ICT4D) is to make use of this ongoing transformation by actively using the enabling technology to improve the living conditions of societies and segments of society. Social transformations over time such as industrial revolution had culminated in an interplay between enabling technology, desired guiding policies and strategies, and resultant social change (Freeman and Louçã, 2002; Schumpeter 1939; Perez, 2004). This three-dimensional interplay has been depicted by Hilbert (2012) as a cube shown in Fig. 6 in tandem with the Schumpeterian school of thought. Put in another fashion, the three factors enabling socio-economic transformations are technology (infrastructure, generic services and capacities/knowledge), social services (education, health, business, government) and policies (regulation and incentives). When ICT practices are applied in a regulated and incentivized manner to scale up productivity in the social sectors, we have improved social services variants like e-government, e-business, e-health and e-education catalyze transformation, development and social security.

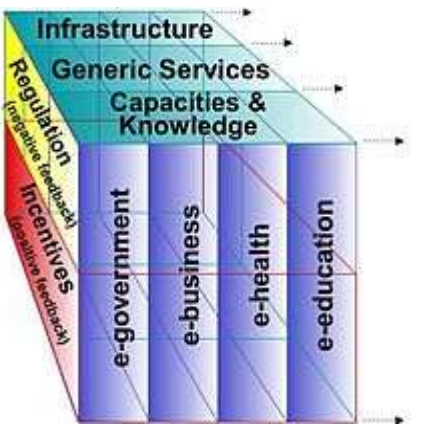

FIGURE 6. ICT4D CUBE (SOURCE: HILBERT, M. 2012. TOWARDS A CONCEPTUAL FRAMEWORK FOR ICT FOR DEVELOPMENT)

Many development partners and researchers have leveraged on the ICT4D cube framework to impact positively on the livelihoods of the vulnerable groups in Africa - the poor, unemployed, women and the disabled using ICT. For that purpose they initiated various ICT policies, programmes and projects (Dymond and Oestermann 2004; Languepin, 2010):

- International Telecommunication Union (ITU)
- World Bank
- Catholic Relief Services (CRS) ICT4D Conference
- ICT4D in Africa
- Mobile Technologies Providers

After careful analysis of existing case studies, the author observed with concern that none fulfilled all of the following criteria:

- a study that highlights social security initiatives by African governments as a matter of deliberate policy.
- a current study on corrupt practices inherent in social protection schemes in Africa.
- a study modeling an integrated biometric/mobile system for curbing corrupt practices in social security initiatives.

This study thus proposed a new model that fulfilled these criteria. Whereas the underlying logic is to ensure the deliverables meant for the vulnerable groups get to them, the strategy is integration of biometric enrolment and verification system and mobile devices into social security schemes.

As seen from above direct applications, the integration of ICT in the drive to empower the less privileged adds significant value to socio-economic transformation and indirectly offers social protection

for this segment of the society. Notwithstanding, governments across Africa still mount social security schemes as a matter of deliberate policy to impact positively on the same set of people and ICT plays vital role. When mainstreamed in social protection efforts, ICT safeguards numerous government social security schemes from abuse owing to corrupt practices. In Burundi, for example, it is popular to use mobile telecommunications and radio broadcasting to fight political corruption. This study revealed further that deliverables of social safety nets such as conditional cash transfer and free medical care for the vulnerable groups are being diverted by unscrupulous elements for personal gains. Even when benefits are delivered, they are in less than budgeted measure. Hence, there is need to integrate a biometric system and mobile devices into such schemes for validating genuine beneficiaries as well as disseminating information to them on the release and allocation of resources by government agencies. The following session outlines a blueprint for the electronic design of a social safety net.

6. Proposed ICT Solution

Nigeria accounts for about 25% of Africa's population and remains the most populous black country in the world. The researcher considered that social security initiatives in Nigeria are, to a reasonable extent, quiet representative of trends on the continent. On analyzing select social security schemes in Nigeria, a table (Table 5) was developed to highlight various governments' social security schemes.

TABLE 5. SELECT SOCIAL SECURITY PROGRAMMES IN NIGERIA (SOURCE: OKEWU'S FIELD SURVEY, 2014)

SN	Code Name	Government	Type	Target	Commencement date	Status	Supervising ministry
1.	SURE-P (Subsidy Reinvestment Programme)	Federal Government	Safety-net tagged Community Service Scheme (CSS)	Women, disabled and unemployed	2012	Take-off stage – capacity building and empowerment of women, unemployed youths and disabled. Stipends and seed money offered.	Ministry of Labour and Productivity
2.	National Social Insurance Trust	Federal Government	Social insurance	All categories	1961	Passive – the common man is yet to feel its impact	Fed. Min. of Labour & Productivity

	Fund						
3.	Social Security	Ekiti State	Social pension	The elderly – 65 years and above	October 2011	Functional – beneficiaries receive monthly stipend of 5,000 naira	State Ministry Labour, Productivity and Human Capital Development
4.	Project Comfort	Cross River	Safety Net – conditional cash transfer	Poor (vulnerable) households	2012	Functional - beneficiaries receive monthly stipend of 5,000 naira	State Ministry of Social Welfare
5.	*Agba Osun*	Osun State	Social pension	The elderly – 65 years and above	November 2012	Functional - beneficiaries receive monthly stipend of 5,000 naira	Office of the Governor
6.	National Health Insurance Scheme (NHIS)	Federal Government	Social protection	All ages	1989	Passive – the common man is yet to feel its impact	Fed. Min. of Health
7.	Project Hope	Cross River	Safety Net – free health care services	Women and children under 5 years	2012	Functional – 7 local governments receiving free health care	State Ministry of Social Welfare

From the above table it is observed that the downtrodden are clearly targeted by the various governments for delivery of social benefits like free medical care, conditional cash transfer, among others. Hence, the author proposed a biometric system that captures beneficiaries' information and validates same at the point of disbursing the benefits with a view to curtailing the activities of fraudsters who intend to divert same for selfish purposes.

While designing the biometric verification system, the following were taken into cognizance (Ndeh-Che, 2008; Okewu, 2013):

- Engagement of Systems Integrator that:
  - possessed a deep understanding of, and the resources for, the analysis, design, development, deployment and maintenance of the systems and processes

for the social security programme.
    - demonstrated proven track record of outstanding work in the area of biometric enrolment and verification, as well application development, deployment and integration.
- The systems integrators would:
    - integrate reliable systems for identifying and registering eligible beneficiaries,
    - setup systems to support delivery of benefits, accounting for benefits, and monitoring and evaluation of the Social Benefit Scheme.
- Effort should be geared towards production of systems, processes and human resource requirements which will serve as an information platform; and as a service delivery medium for all stakeholders.

Systems integrator firms are saddled with the provision of systems integration services as needed by the government. They will assist government in the conceptualization, analysis, design, development, and deployment and maintenance of information systems that will ensure effective and secure management of the benefits scheme including, inter alia, (a) enrolment system for bona-fide beneficiaries, (b) biometric identity management and verification, (c) ID card production, and (d) system for the accounting of benefits.

On considering the above guidelines, the work outlined the following as procedures of the proposed biometric/mobile design (Okewu, 2013):

1. Software and services for development and deployment of biometric enrolment system and training of technical personnel and provision of technical support during verification and enrolment effort – Personal and biometric data were captured and stored in a relational database system. Human error could be mitigated by using state-of-art forms processing systems, whilst time-tested biometric approach shall eliminate multiple enrolments of the same individual. During the exercise, beneficiaries will also have their supporting documents scanned, converted into e-forms and archived in a document management system. Support team will be on ground throughout, in order to ensure that the enrolment

exercise runs smoothly. After the initial phase of the verification and enrolment exercise, continuous verification and enrolment will continue to ensure that new potential beneficiaries are properly verified and registered. Figure 7 and Figure 8 highlight enrolment infrastructure and enrolment process respectively.

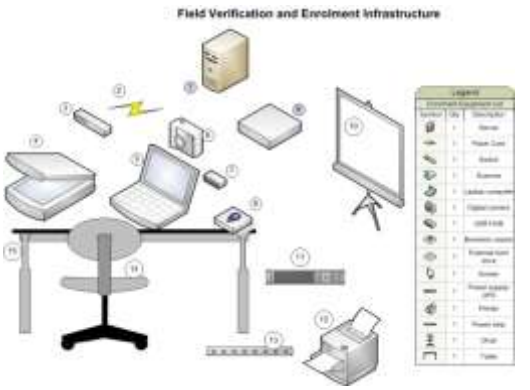

FIGURE 7. THE ENROLMENT INFRASTRUCTURE FOR AN ENROLMENT CENTRE

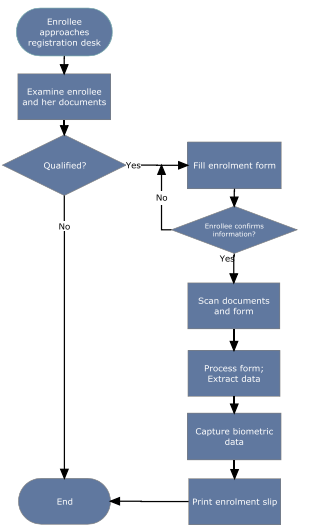

FIGURE 8. THE ENROLMENT PROCESS

2. Systems integration for biometric enrolment database and identity management system –After field enrolment, the various biometric enrolment databases from enrolment centres, the scanned documents and the e-forms, are consolidated in a central database. To avoid duplicate enrolments across enrolment centres, an Automated Fingerprint Identification System (AFIS)

should be deployed. An identity management system can be set up, based on the consolidated database, to provide identification services. Figures 9 and 10 respectively model a consolidated view and the consolidation process.

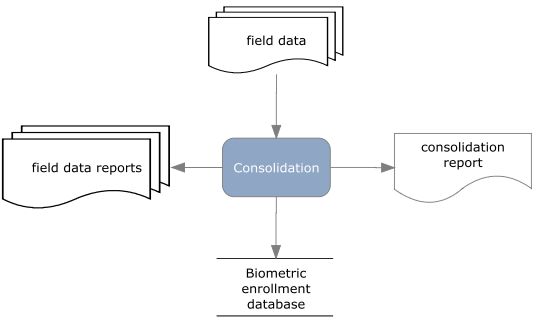

FIGURE 9. CONSOLIDATED VIEW

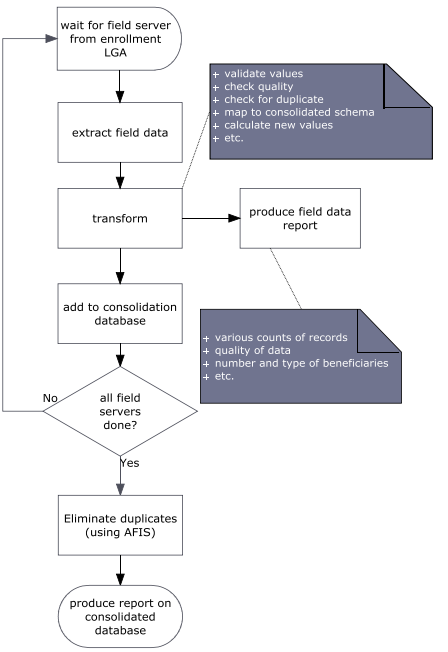

FIGURE 10. CONSOLIDATION PROCESS

3. Systems integration for ID card production, card acceptance devices and identity verification system – A likely outcome of the exercise is the production of authentic identity card (ID card). Beneficiaries can be provided with secure smart ID cards as proof of eligibility to receive benefits. Each card contains biometric information

to verify the beneficiary on location, as well as other data as may be decided from time to time by the government. In the absence of the ID card, verification will still be possible over a remote connection to the central identity system. A production station should be set up for the design and production of the smart ID cards. The ID cards and ID card verification systems should be deployed at strategic locations (e.g. Benefits Stations) to prevent abuse of the scheme. Figure 11 shows a typical card printing infrastructure just as Figure 12 presents an ID card-enabled verification process. In the event a beneficiary has no card, he/she can still be verified remotely using finger print as captured in Figure 13**.**

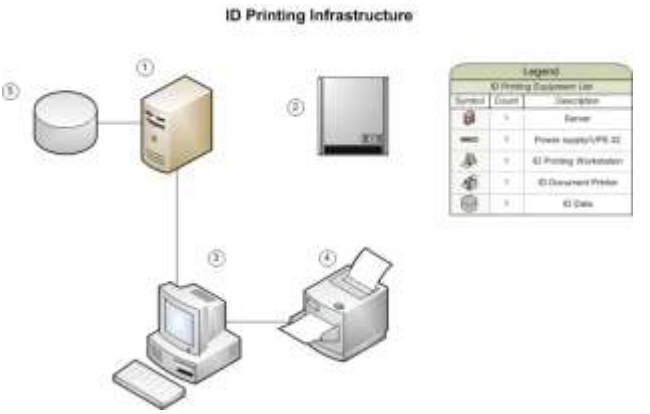

FIGURE 11. CARD PRINTING INFRASTRUCTURE

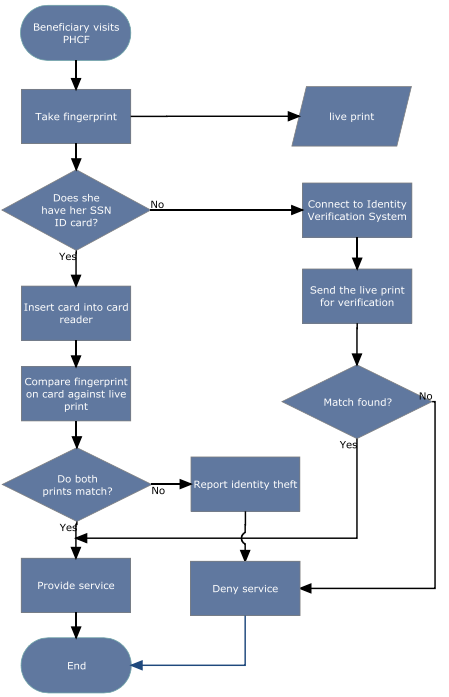

FIGURE 12. ID CARD VERIFICATION PROCESS

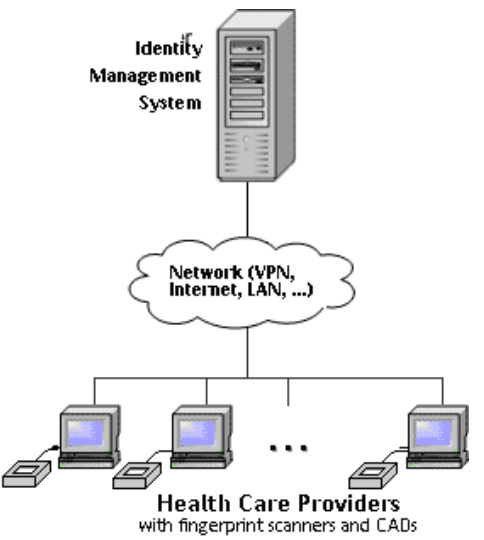

FIGURE 13. IDENTITY VERIFICATION PROCESS

4. Software and services for development and deployment of Benefits Accounting System – In order to ensure proper management

of benefits accruing to citizens under any social safety net, system integrators should partner with the government to develop a benefits administration system. This system will be custom-built to suit the specific requirements of the respective social safety net programme.

5. Technical and End-User Training – The need for adequate capacity building cannot be overemphasized. System Integration firms should provide comprehensive capacity building services to ensure that all human resources participating in the social protection programme are able to carry out their roles and responsibilities. Training categories could include i) Enrolment Officers, ii) Identity Management System Administrators, iii) Benefits Administration System End Users and iv) Benefits Administration Support Personnel.

6. Ongoing Support and Maintenance – To ensure smooth running of all systems deployed, the system integrator will provide ongoing support and maintenance services to the government.

The system integration firm should deploy a multi-disciplinary team of professionals and support personnel, working over a stated period to complete and roll out the systems for the scheme. Emphasis should be placed on the engagement of a reputable firm to assist the government in realizing its vision of delivering social welfare packages such as free health care for, and financial assistance to the under-privileged. References of track record of successfully delivering expected project outcomes in similar engagements for other clients should be taken into cognizance. The firm should understand the challenges, possess the skill sets and emphasize client collaboration. Modalities should be put in place to guarantee fruitful working relationship between the firm and government.

The proposed solution will succeed if the following measures serve as guidelines (Nde-Che, 2008):

- Establishment of a uniform, clearly defined and objective criteria for determining eligibility for the scheme
- Collection of realistic baseline data on poverty for target setting
- Establishment of realistic targets and timeframes
- Establishment of a comprehensive Monitoring & Evaluation (M&E) Framework for all aspects of the scheme
- Sensitization of beneficiaries and stakeholders
- Institutionalizing transparency, accountability and good corporate governance in the scheme from the onset.

- Proper identification and registration of beneficiaries using the latest advances in identity management technologies
- Adoption of a holistic approach to achieving scheme objectives
- Reuse of data and resources from complementary initiatives such as census data and images and Roll Back Malaria initiative

7. Discussion

This study revealed that mainstreaming ICT in rural Africa makes inroads into development and hence can curb social tensions and crisis. However, poor ICT infrastructure, cultural inhibitions, lack of proper disposal/recycling facilities, illiteracy, et al. are challenges confronting Information and Communication Technologies for Social Security (ICT4SS). Notwithstanding, vital lessons have been learnt from implementation of various ICT pilot programmes for the vulnerable groups and these have culminated in the following recommendations (Batchelor, 2003):

- Involve target groups in project design and monitoring.
- When choosing the technology for a poverty intervention project, pay particular attention to infrastructure requirements, local availability, training requirements, disposal and technical challenges. Simpler technology often produces better results.
- Existing technologies—particularly the telephone, radio, and television—can often convey information less expensively, in local languages, and to larger numbers of people than can newer technologies. In some cases, the former can enhance the capacity of the latter.
- ICT projects that reach out to rural areas might contribute more to the MDGs than projects based in urban areas and hence should be prioritized.
- Financial sustainability for ICT-for-development initiatives should be factored in.
- Projects that focus on ICT training should include a job placement component.

8. Conclusion and Further Work

Though the social safety net is a new concept in Africa and indeed in Nigeria, it has come to stay. Countries like Zambia, South Africa, Libya and Egypt have edged in social security programmes for citizens. There is need for the above biometric design to be developed for implementation in Nigeria. Secondly, for external and general validity of this model, it has to be tested in other African countries. As Africa joins the league of continents whose

governments' execute ICT-driven socially responsible programmes for need-based citizens, it will gather lost confidence from citizens with far-flung expectations. And more importantly, idle minds will be engaged productively hence mitigating the chances of such citizens being indoctrinated and used as foot soldiers for fuelling crisis.

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An Assessment of ICT Literacy Among Secondary School Students in a Rural Area of Kwara State, Nigeria: A Community Advocacy Approach

Mabayoje, M.A. [1],
Isah, A. [2],
Bajeh, A. O. [3],
Oyekunle R. A. [4]

Department of Computer Science, Faculty of Communication and Information Sciences, University of Ilorin, Ilorin
[1]mmabayoje@gmail(yahoo).com
Department of Library and Information Science, Faculty of Communication and Information Sciences, University of Ilorin, Ilorin
[2]abdulmumin.isah@yahoo.com
Department of Computer Science, Faculty of Communication and Information Sciences, University of Ilorin, Ilorin
[3]bajeh_amos@yahoo.com
Department of Information and Communication Science, Faculty of Communication and Information Sciences, University of Ilorin, Ilorin
[4]Oyekunle.ra@unilorin.edu.ng

Abstract: In recent times, public schools in Nigeria have enjoyed some benefits in terms of deployment of Information and Communication Technologies (ICTs), but no constant attention and continuous interest is paid to fill the digital gap between schools in the rural and urban areas. The contribution of private sectors in the education system has elevated the use of ICT in both private and public schools especially in the urban areas of Nigeria. However, schools in rural areas have not benefitted much in this area. This research used community advocacy program referred to as COBES (Community Based Experience Scheme) to assess ICT literacy of secondary school students in a rural area of Kwara State, Nigeria. The study employed mixed research approach that combined both quantitative and qualitative data collection strategies. The initial findings of the study revealed low level of ICT skills among secondary school students in the rural area. Although, majority of the students who served as the respondents claimed they have computer teacher and can operate computer systems, yet, the study showed that there is dearth of ICT facilities for hands-on training. Nevertheless, through the one week long COBES program, the findings from three focus group discussion conducted at the end of the COBES program showed that students' interest to use ICT increased and majority of them expressed their willingness to continue interacting with computer and internet facilities. Findings

further revealed that the main reason for low ICT skills is the lack of ICT facilities for teaching and learning. The study recommended that ICT project implementation should be uniform in all public schools in Nigeria, irrespective of whether it is located in the urban or rural area, adequate and skilled computer studies teachers should be made available and government should put in place mechanisms that will ensure proper maintenance of the ICT facilities

Keywords: COBES, Education, ICT, learning, Secondary, Training

1. Introduction

In a global economy that is driven by Information and Communication Technology (ICT), knowledge of ICT has become an important aspect of information literacy campaign, Moreover, ICT application in the education sector has revolutionized the methods of teaching and learning. Teaching and learning in the ICT driven environment is no longer restricted to the four wall of classroom as students and teachers can now communicate and interact in the virtual classroom. This advancement in technology has equally bridged the digital divide between information rich and poor society. According to Tinio (2002) ICT has the potentials of increasing relevance and quality of education in developing countries and the field of education has been affected by ICTs, which have indisputably affected teaching, learning, and research. A lot of research works have proven the benefits of ICTs to the quality of education (Yusuf, 2005), and as noted by Yuen and Tsui (2010), "the speed at which information can travel using vehicles provided by ICT and the vast storage space available, makes possible the free flow of information and knowledge". Any institution of learning that fails to embrace the evolution of ICT for teaching and learning will find it difficult to operate and compete favorably with their peers in the age of e-learning.

In response to the global influence of ICT on education, governments and nongovernmental organizations in developing countries are now investing on educational technologies with a view to bridge digital divide and enhance teaching and learning in the new information society. In line with this global development, the Federal Government of Nigeria, in the National Policy on Education (Federal Republic of Nigeria, 2004), recognizes the prominent role of ICTs in the modern world, and has integrated ICTs into education in Nigeria. For example, in 1987, the Federal Government, at the 32nd Ministerial Council Meeting of the National Council on Education, inaugurated a National Committee on Computer Education, which was charged with the responsibility of establishing a National Policy on Computer Education. The general objectives of the policy are to ensure that the general populace appreciates the

impact of information and computer technology on today's society; and to enable the present generation of school children at all levels to appreciate the potentials of the computer and to enable them to be able to use the computer in various aspects of life and later occupations (Jegede and Owolabi, 2003).

In order to ensure full implementation of the National Policy on Computer Education in Nigeria, the state governments introduced computer education and literacy into secondary schools in 1997 (Bada, Ajibade & Ojedokun, 2009, and Adomi & Kpangban, 2010). The general objectives of the computer literacy programme are to: bring about computer literacy in each state in Nigeria; develop the use of computers as a teaching tool in all subject areas and to familiarize students with the use of computer technology; enable the present generation of school children at the secondary school level to appreciate the potentials of the computer and to be able to utilize the computer in various aspects of life and later occupations; and to expose teachers and students to the latest scientific knowledge and skills.

Another major effort towards improving ICT integration in the Nigeria society was the 2001 National Policy on Information Technology, tagged "Use IT" (Yusuf, 2007). As a result of these steps, over the years, education sector has witness tremendous improvement in the area of application of ICT for teaching and learning in all facets of education systems (i.e. from tertiary to primary level). However, the situations in schools especially secondary and primary schools in rural areas have not been fully addressed. More than a decade ago, Jegede and Owolabi (2003) compares Nigeria National Computer Policy of 1987 with the existing school practice and found that computer education in Nigeria was limited to Federal Unity Schools and was scarcely offered in any of the state secondary schools which constitute more than 80% of Nigerian schools. However, the contribution of private sectors in education system has elevated the use of ICT in both private and public schools especially in the urban areas of Nigeria. For example, in a recent study of level of computer literacy in private and public secondary school students in an urban area of Nigeria, Osunwusi and Abifarin (2013) found that private secondary school students have access to, and use, the computer in higher measures than public secondary school students. No statistically significant differences were found in terms of access to the internet. Given the situation with the schools in the urban areas, knowledge of the state of computer literacy in rural areas remained under-researched. Are the schools in the rural areas

implementing the National Policy on Education in Nigeria? And how are the school children in the rural areas responding to this new technology in their environment? These call for a research of this nature for better understanding of how students in the rural areas of Nigeria are responding to the technology of the new information society.

The main objective of this study is to find out how secondary school students in the rural area of Nigeria are responding to the computer literacy program of the Nigerian Government. The specific objectives of the study are to:

(1) Assess awareness of ICT among secondary school students in rural area of Nigeria;
(2) Find out the level of ICT implementation in Secondary Schools in rural areas of Nigeria;
(3) Assess level of Computer literacy of secondary school students in rural areas of Nigeria; and
(4) Determine the perception of secondary school students on the usage of ICT for teaching and learning

2. Literature Review

ICT has been defined in various ways by several authors. According to Ogunsola (2005), ICT "is an electronic based system of information transmission, reception, processing and retrieval, which has drastically changed the way we think, the way we live and the environment in which we live". In another dimension, Onyije and Opara (2013) defined ICT as tools or resources that could be used to process, store, perverse, retrieve and disseminate information with ease. Another definition of ICT in the Oxford Advanced Learners' Dictionary is an electronic media used in processing, analyzing, storing and sending out information. All these definitions of ICT have been captured in the description of ICT as advanced by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as:

> the tools and the processes to access, retrieve, store, organise, manipulate, produce, present and exchange information by electronic and other automated means. These include hardware, software and telecommunications in the forms of personal computers, scanners, digital cameras, phones, faxes, modems, CD and DVD players and recorders, digitised video, radio and TV programmes, database programmes and multimedia programmes" (UNESCO Bangkok, 2003, p.75, in Anderson, 2005 p.5).

The application of ICT in education has affected teaching and learning in various dimensions. ICT is said to have the potentials of being used to meet the learning needs of

individual students, promote equality of educational opportunities; offer high quality learning materials, increase self-efficacy and independence of learning among students, and improve teachers' professional development (Abolade and Yusuf, 2005). Its application has also resulted into shift in the methods of teaching and learning in the 21st century classrooms. Zhang (2005) notes that "this shift which has been driven by the plethora of new information and communication devices now increasingly available to students in school and at home, each of which offers new affordances to teachers and students alike for improving student achievement and for meeting the demand for 21st century skills." Studies have identified various types of ICTs available for teaching and learning. According to Tella et al. (2007), ICTs available in classrooms include simple tool-based applications such as word processors, online repositories of scientific data, primary historical documents, handheld computers, closed-circuit television channels, and two-way distance learning classrooms. To successfully operate in the new e-learning environment, knowledge of how these identified ICT tools become necessary for both teachers and students. Lau and Sim (2008) reported that despite the apparent benefits of the use of ICT for educational purpose, studies showed that in many cases, the learning potential of ICT is deprived as many teachers and students are still not fully ICT literate.

The benefits derivable from the application ICT in the education sectors can only be maximized when the potential users are competent in the usage of the new technology. Studies have shown that there is correlation between ICT skills and its application for teaching and learning. And this is why Oni and Adebisi (2011) posits that a person without the working knowledge of computers in the modern technological world, 'will not be able to go far in life as far as his career options are concerned. This is because nothing is there in this world that does not work on computer technology. This is one of the objectives which the Nigerian National Policy on Computer Education of 1978 was designed to address. The employers of labor in the ICT driven societies are now demanding ICT literacy as one of the requirements for employment. Even, employees have realized that computer and other ICT facilities can enhance efficiency and equally can be a threat to their jobs, and the only way to enhance job security is to become computer literate (Adomi and Kpangban, 2010). Studies have shown that using ICT in education enables students to take a more active role in their learning rather than a passive observer or listener

(Balanskat, Blamire, & Kefala, 2006; Tella et al. 2007). Given the role knowledge of ICT literacy plays in the new information society, understanding how National Policy on Computer Education has been implemented in secondary schools in the rural areas of Nigeria become relevant.

Studies on the application and usage of ICT in the Nigeria educational systems have been more concentrated on schools in the urban areas (Tella et al., 2007; Osunwusi, & Abifarin, 2013). Majority of reports on the state of ICT in the rural areas only identified lack of ICT without insight as to how the situation affects students in the rural communities. According to Adomi (2006), ICT development and application are not well established in rural areas of Nigeria because of poor information infrastructure. Suithwood (2004) assert that more than 40 percent of the population of Africa is in areas not covered by telecom services and by implication schools located in such areas will experience ICT connectivity problems.

3. Research Methodology

This research followed mixed methodology approach combining both quantitative and qualitative research approaches. In order to fully understand ICT literacy of secondary school students in the rural areas of Nigeria, the researchers used a community advocacy program called COBES (Community Based Experience and Scheme) to assess ICT literacy of secondary school students in rural areas of Kwara State, Nigeria. The COBES programme involves using ICT to provide solutions to the information needs of secondary school students in the rural communities. The researchers who were the coordinators of the COBES one week long program first employed quantitative approach to examine ICT level of students before the commencement of the COBES training program. The one week training program exposed the participants to various functional areas of computer as they were put through different applications using laptop computer, modem and internet facilities provided by Faculty of Communication and Information Sciences of the University of Ilorin as part of the COBES programme. At the end of the COBES a focus group was carried out to gauge the level of ICT awareness and skills learnt during the week long COBES program since a focus group organized immediately after a training program could be used to gather initial feedback on the success of the program (Greenbaum, 1993).

3.1 Research Setting

Ballah secondary school, kwara state, Nigeria was purposefully selected as the case study for the study. The selection of the school was based on the fact that it is a boarding school, located in a rural

community, and serving educational needs of people living in that rural community.

3.2 Data Collection

Two sets of assessments were carried out across students from junior secondary school (JSS) 1 – 3 and senior secondary school (SSS) 1- 2. The SSS 3 students were excluded from the study because as at the time of this research they were writing their mock examination in preparation for their final year examination. A total of 300 copies of research questionnaire were administered across the five classes (JSS1-3 and SSS1-2). Out of 300 copies of the research questionnaire administered 276 were completed of which 57.6% (159) of the response were male and 42.4% (117) female. The first assessment used a questionnaire that tested awareness and ICT skills. The second assessment which was preceded by the one week COBES programme which involved ICT training, was designed to get feedback and as a means for comparing the perception and attitude of the students before and after the COBES programme. To achieve this, three focus group discussions were organized for selected students across all the levels and three sets of interview were granted to two teachers and the head of the school.

4. Results

The results from the questionnaire and the focus group discussion are presented and discussed in the following sub-sections.

4.1 Findings from Questionnaire

Table 1 gives the summary of the copies of the questionnaire administered to the various classes of respondents. Table 2 - 4, shows the data analysis of the questionnaire that measured ICT awareness, skills, and usage among students in the Ballah secondary school.

Table 1: Distribution of respondents by class

CLASS	RESPONDENTS	PERCENTAGE
JSS1	66	23.9
JSS2	45	16.3
JSS3	66	23.9
SSS1	43	15.6
SSS2	56	20.3
TOTAL	276	100.0

Table one shows the distribution of respondents across all the five (5) classes that participated in the study. The majority of the respondents were from the JSS 1 and 3 classes with 23.9% each. This was followed by SSS 2 with 20.3% and JSS 2 and SSS1 with 16.3% and 15.6% respectively.

Table 2: Awareness of Computer

Items	Yes	%	No	%
I have seen a computer system before the COBES progam	252	91.3	24	8.7
I have heard of the internet before the COBES program	142	51.4	134	48.6
My school has computer teacher	255	92.4	21	7.6
My school has computer system (s) for students	250	90.6	26	9.4
My school has internet facilities	20	7.2	256	92.8

Table 2 above shows that majority of respondents (91.3%) have seen computer before the COBES program. This large awareness shows that computer has become household name that cut across all field of human endeavor. This can also be attributed to the fact that the school has computer system as claimed by majority of the respondents ((90.6%). Despite the large awareness of computer system, the level of awareness of internet (51.4%) is low compare to the awareness of computer systems. The awareness can also be attributed to the school curriculum that makes provision for computer as compulsory subject for all students. This is reflected in the respondents' response on computer studies teacher as majority (90.6%) indicated that they have computer studies teacher.

Table 3: Use of computer system and the Internet

Items	Yes	%	No	%
I know how to operate computer system	218	79.0	58	21.0
I know how to use computer to send e-mail	72	26.0	204	74.0
I use computer for playing games	105	38.0	171	62.0
I use internet for solving my school work/assignments	56	20.3	220	79.7
I know how to use computer for power point	54	19.6	222	80.4
I am competent in using Microsoft word for typing	134	48.6	142	51.4
I am competent in using excel	20	7.2	256	92.8

In table 3 above, more than half of the respondents (79.0%) claimed they know how to operate a computer system, but only few 26.0% and 20.0% indicated that they use computer for sending e-mail and solving school assignments respectively. Although

majority 62.0% indicated that they use computer for playing game, the analysis still shows that few respondents know how to use computer applications for example excel attracted a very low response of 7.2% followed by power point with 19.6% and Microsoft word with 48.6%. These low levels of computer skills could be attributed to the lack of functional computer system as observed during the COBES program.

Table 4: Frequency of Internet usage

	Frequency	Percentage (%)
Daily	5	1.8
Weekly	11	4.0
Monthly	43	15.6
Occasionally	21	7.6
Not at all	196	71.0

On the frequency of Internet usage, table 4 reveals that majority of the respondents (71.0%) do not use the Internet at all. Only 15.6% used internet on monthly basis, while 7.6% used it occasionally. One major factor that accounts for low level of usage is the lack of facilities to access Internet in the school.

4.2 Findings from Focus Group Discussion

This section presents findings from the focus group discussion at the end of the one week COBES program at the Ballah secondary school. Three sets of focus group discussions were conducted and the summary of the findings are presented below.

The COBES program which was preceded with a survey of ICT competence of the students in the Ballah secondary school provided the researchers with background information on the level of ICT competence of the participants for the COBES program. Given the findings generated from the survey, the COBES one week program focused on various applications of computer with practical that exposed the participants to different software packages and their applications. It was observed that the students were not competent in using computer as majorities were unable to operate computer, this revelation contradicted the high claimed competence of computer operation by majority of the respondents during initial survey as indicated in table 3 above. The training exercises was conducted by 300 level students across the faculty of Communication and information sciences (CIS) that comprises Computer science, mass communication, information and Communication Science, Library and Information Science and Telecommunication Science. The researchers monitored the exercise

and observed the participants responses to the training. The computers and internet facilities used for the COBES program were provided by the faculty of CIS. At the end of the One week program three sets of focus group discussion were organized as means of getting the feedback from the students on their opinion perception and attitude to ICT literacy.

The participants for the focus group discussion were selected based on their responses during the initial survey across all the five classes. Three focus group discussions were organized at the end of the COBES training program. Each focus group comprises of ten (10) participants purposively drawn from all the classes based on the following criteria:

1. Those who cannot operate computer before the COBES program
2. Those who do not have computer at home
3. Those who claimed they have computer at home

The focus group was based on low level of ICT skills as identified from the initial survey and how the COBES program has improved the level of ICT skills of the participants. The following are the summary of the findings generated from the three focus group discussions.

ICT Skills

Majority of the participants in the three focus group discussions disclosed that they thought they knew how to use the computer, but the COBES program exposed their ignorance. However, through the program they have learnt different computer software packages that will help them in their educational carriers. The poor ICT literacy was attributed to lack of functional ICT facilities and inadequate computer studies teachers that could cater for all the school students.

Contribution of COBES program

The students welcomed and appreciated the COBES program and considered it as a very good tool for improving ICT skills of students in rural communities. The approach used in the program to impact ICT skills was equally commended and the participants expressed their willingness to continue interacting with computer packages learnt from the COBES program.

5. Discussion and Recommendations

The study has established the fact that schools in the rural areas are not given equal treatment like what is obtainable in schools located in the urban areas in terms of provision of ICT facilities. This corroborates the findings of Jegede and Owolabi (2003) that there is disparity in ICT implementation in Unity schools and schools located in rural areas. Efforts geared towards integration of ICTs into the secondary school system especially schools in rural areas have not had

much impact as shown from the findings of this study. Despite the roles ICTs have been found to play in education, secondary schools in the rural areas of Nigeria are yet to extensively adopt them for teaching and learning.

The poor ICT literacy can be attributed to lack of functional facilities and inadequate computer studies teachers that can cater for all the school students. This assertion supports the finding of a recent study by Osunwusi and Abifarin (2013), who found that private secondary school students who have access to computer system use the systems in higher measures than public secondary school students who lack adequate computer facilities. The COBES proram has proved that when the required facilities that can aid ICT learning are provided for school students in the rural communities, they will be willing to improve their ICT skills and continue to interact with computer packages learnt from the COBES program. It is obvious that the efforts made towards integration of ICTs into the secondary school system have not had much impact in rural areas because of so many factors which include inadequate ICT equipments, lack of maintenance of even the available ICT equipment and inadequate skill teachers to impact the necessary skills. In order to ensure that ICTs are adequately provided, maintained and used especially in secondary schools in the rural areas of Nigeria, the following efforts should be taken into consideration:

i. Government should ensure that ICT policy statements are translated into reality. An ICT policy implementation commission should be created, funded and given the power to provide ICT facilities in the schools and monitor their use.
ii. Secondary schools in rural areas should not be left out of benefiting from ICT projects.
iii. Efforts should be made by Ministry of Education (at Federal and State levels) to ensure that adequate and skilled computer studies teachers are posted to all government secondary irrespective of whether it is located in the rural or urban area.
iv. Special programs/workshop should be organized for all school students and teachers from time to time as this will assist them in improving their ICT skills.

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Classification of Cardiac Beats Using Discrete Wavelet Features

Sani Saminu, Nalan Özkurt

Department of Electrical and Electronics Engineering
Yasar University İzmir, Turkey
sansam4k@gmail.com, nalan.ozkurt@yasar.edu.tr

Abstract—With the growing technology, the tools which continuously monitor the health status of the people are becoming the integral part of our lives. The detection of a cardiac disease or tracking the heart activities for ongoing cardiac conditions is now possible with portable electrocardiography (ECG) monitors. For detection and classification of ECG signals in portable devices, the robust features and efficient classification algorithms are very important. Thus, in this study, a robust feature set based on discrete wavelet transform (DWT) is proposed, and the performance of the classification tools such as artificial neural networks, support vector machines and probabilistic neural networks are compared. After preprocessing, the R peaks are located by the well-known Pan Tompkins algorithm and 200 samples are taken as equivalent R-T interval in the proposed technique. The statistical parameters such as mean, median, standard deviation, maximum, minimum, energy and entropy of DWT coefficients are used as the feature set. The proposed hybrid technique has been tested by classifying three ECG beats as normal, right bundle branch block (Rbbb) and paced beat using the signals from Massachusetts Institute of Technology Beth Israel Hospital (MIT-BIH) arrhythmia database and processed using Matlab 2013 environment. The best accuracy of 99.84% has been obtained by Db4 mother wavelet with artificial neural network as classifier.

Keywords— ECG, DWT, Mobile devices, ECG Feature extraction, Pan Tompkins

1.0 Introduction

Heart is one of the most critical organs in the human body supplying blood to different parts of the body. The cardiovascular diseases (CDV) caused by the problems in the functioning of the heart remain as the dominant reason of death all over the world. According to the statistics of World Health Organization (WHO) approximately 30% of global death is caused by CDV (Murugavel, 2011). Also, according to a recently published (2014) report by Heart failure Working Group of the Turkish Society of Cardiology (TDK), there are 15 million heart-failure patients in Europe and 6 million in the United States (US), in Turkey there are 1 million patients suffering from heart failure. With another 2 million who are at serious risk of this disease

and those figures will increase about two fold within 10 years (Yuksel, 2014). Thus, it is very important to detect and diagnose as early as possible and accurately these cardiac arrhythmias since they usually cause sudden cardiac death.

One of the most powerful diagnostic tools commonly used for the assessment of the functionality of the heart is Electrocardiography (ECG) since it is a real-time non-invasive method (Guyton and Hall, 2006). However, it is tedious and time consuming to use visual inspection in ECG analysis even for an expert cardiologist. Therefore, the usage of computer software to automatically detect and classify the ECG beats using a low cost, accurate and effective system, significantly improves diagnostic accuracy and patient healing outcomes (Bruce, 1966).

In order to improve the quality of the life, the mobile healthcare systems have been growing due their importance. Thus, there is a considerable commercial interest in the wireless systems which acquire ECG signals, classify and monitor them to mobile phones or personal computers. However, extracting significant and useful features from ECG signal characteristics is a very crucial for successful implementation of these devices since they need to be fast, simple and computationally efficient.

There are several studies proposed for the analysis of the ECG beats. Gradient–based algorithm and time domain morphology was presented in (Mazomenos et al., 2012). Also, in (Chatterjee et al., 2011) statistical method of comparison between relative magnitudes of ECG samples and their time domain slope has been described. Another classifier based on ECG morphological features was reported in (Chazal et al., 2004) and (Chazal and Reilly, 2006). Wavelet transform finds application in ECG beats detection and feature extraction as reported in (Li et al., 1995), (Saxena et al., 2003) and (Martinez et al., 2004). Also, Mahesh used wavelet and Pan-Tompkins algorithm to extract time-frequency features for ECG beat detection system (Mahesh, 2014). In (Marlar and Aung, 2014) they presented classification of normal and abnormal signal using R-R interval features of ECG waveform. In (Martis et al., 2013) the principal component of 4th-levels DWT with db4 mother wavelet is used to classify normal and arrhythmic beats with accuracy of 95.60%. Finally, in (Saminu et al., 2014) a hybrid method which uses statistical parameters of discrete wavelet transform coefficients to classify three arrhythmias using artificial neural networks (ANN) is proposed.

As a contribution, in this work, same feature set based on the statistics of discrete wavelet

transform coefficients are used for classification using common classifiers such as ANN, support vector machines (SVM) and probabilistic neural networks (PNN). Three ECG beats as normal, right bundle branch block (Rbbb) and paced are extracted from the signals of Massachusetts Institute of Technology Beth Israel Hospital (MIT-BIH) arrhythmia database and processed using Matlab 2013 environment. Also, the effect of the selection of mother wavelet to classification performance is analyzed. This paper is an extended version of the paper presented in IEEE 6th International Conference on Adaptive Science & Technology ICAST'2014 (Saminu et.al. 2014).

After a brief introduction of the heart anatomy in the following section, ECG wave and arrhythmias considered in Section 3. The wavelets are summarized at Section 4. The acquisition, feature extraction and arrhythmia classification for the proposed method is explained in Section 5. Finally, the results of the experiments are discussed and the conclusions are drawn.

2.0 The Heart Anatomy

The heart contains four chambers that is right atrium, left atrium, right ventricle, left ventricle and several atrioventricular and sinoatrial node as shown in Figure 1. The two upper chambers are called the left and right atria, while the lower two chambers are called the left and right ventricles. The atria are attached to the ventricles by fibrous, non-conductive tissue that keeps the ventricles electrically isolated from the atria. The right atrium and the right ventricle together form a pump to circulate blood to the lungs. Oxygen-poor blood is received through large veins called the superior and inferior vena cava and flows into the right atrium. The right atrium contracts and forces blood into the right ventricle, stretching the ventricle and maximizing its pumping (contraction) efficiency. The right ventricle then pumps the blood to the lungs where the blood is oxygenated. Similarly, the left atrium and the left ventricle together form a pump to circulate oxygen-enriched blood received from the lungs (via the pulmonary veins) to the rest of the body (Acharya et al. 2012).

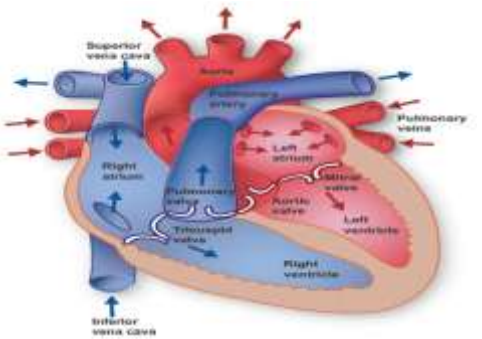


Fig. 1. A full view of Human Heart, with chambers and valves (Texas, 2012)

3.0 Electrocardiography and Arrhythmias

ECG signal is a bioelectrical signal which depicts the cardiac activity of the heart and it is a technique used primarily as a diagnostic tool for various cardiac diseases because of its simplicity. By attaching electrodes at different outer surface of the human skin, electrical cardiac signals can be recorded by an external device. These currents cause the contractions and relaxations of heart by stimulating cardiac muscle (Guyton and Hall, 2006) and travel as electrical signals through the electrodes to the ECG device, which records them as characteristic waves. Different waves and fiducial points of ECG reflect the activity of different parts of the heart which generate the respective flow of electrical currents. Figure 2 below shows a schematic representation of a normal ECG and its various waves.

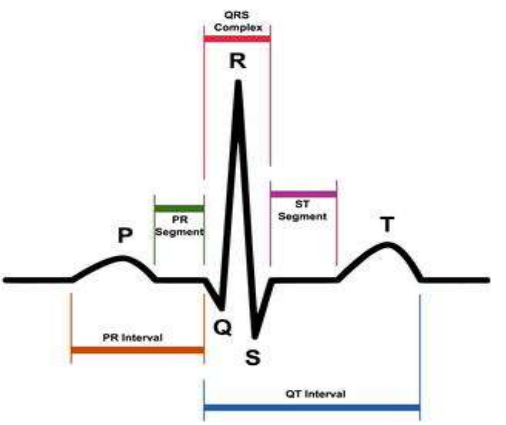


Fig. 2. Normal ECG wave (Yuksel, 2014)

The most important features include the information lying in the P,Q,R,S,and T waves of the ECG signal, ECG beats should be classified based on these features in order to detect different types of cardiovascular diseases. The length of a normal QRS wave is between 80 to 120ms (Williams and Wilkins 2011). R-R interval of a normal sinus rhythm downloaded from MIT-BIH database is shown in Fig.3.

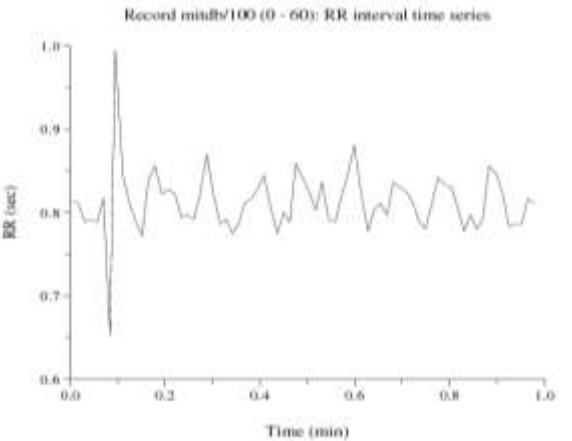


Fig. 3. R-R interval of a normal ECG wave from MIT-BIH

Two different arrhythmias which are not critical in terms of emergent care but important to detect for future cardiac problems are considered in this study: right bundle branch block (Rbbb) and paced beats. When one bundle branch is blocked: Electrical impulse will travel through intact branch and stimulate ventricle supplied by that branch. Ventricle affected by blocked or defective bundle branch is activated indirectly. There is a delay caused by this alternate route and QRS complex will represent widening beyond usual time interval of 0.12 sec. Classified as either complete (QRS measures 0.12 sec or greater) or incomplete blocks (QRS measures between 0.10 and 0.11 second). Sample of an Rbbb beat is illustrated in Fig.4.

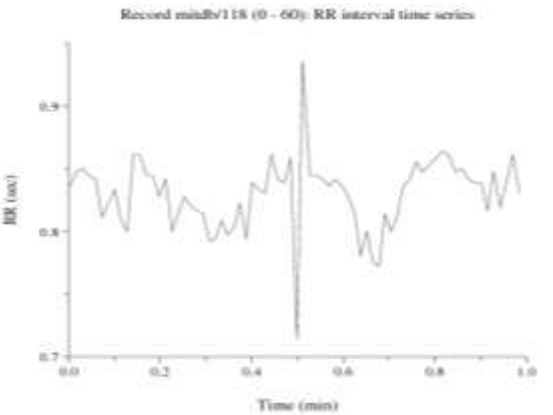


Fig. 4. R-R interval of a RBBB ECG wave from MIT-BIH

The paced beat is the artificial beat form from the device called pacemaker. A pacemaker is a treatment for dangerously slow heart beats. Slow heart beats can be the result of metabolic abnormalities or occur as a result of blocked arteries to the heart's conduction system. These conditions can often be treated and a normal heart beat will resume. Slow heart beats can also be a side effect of certain medications in which case discontinuation of the medicine or a reduction in dose may correct the problem. It can be characterized in ECG by a large peak after QRS complex (Martis et al., 2013). R-R interval of one of the paced beats from MIT-BIH database is shown in Fig. 5.

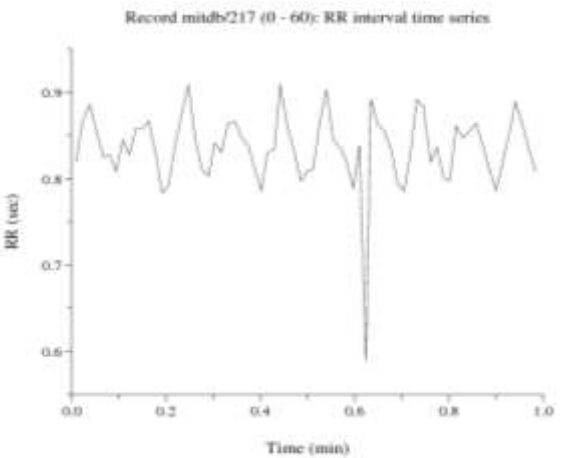


Fig. 5. R-R interval of a paced ECG wave from MIT-BIH

4.0 Wavelet Analysis

The continuous wavelet transform (CWT) has been developed as a method to obtain simultaneous, high resolution time and frequency information about a signal. The CWT unlike Short Time Fourier Transform (STFT) uses a variable sized window region. Since the wavelet may be dilated or compressed; different features of the signal are extracted. While a narrow wavelet extracts high frequency components, a stretched wavelet picks up the lower frequency components of the signal (Addison, 2002).

The CWT is computed by correlating the signal s (t) with families of time-frequency atoms (t), it produce a set of coefficients C(,b) given by :

$$C(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} s(t)\Psi^*\left(\frac{t-b}{a}\right) dt \qquad (1)$$

where is the time location (translation parameter), a is called scale factor and it is inversely proportional to the frequency (a>0), *denotes a complex conjugate and is the analyzing wavelet (mother wavelet). Each coefficient represents the similarity between the signal and the scaled and translated wavelet.

The Discrete Wavelet Transform (DWT) is a time-scale representation of the digital signal and is obtained using digital filtering techniques. It is found to yield a fast computation of wavelet transform, easy to implement and adopts dyadic scales and translations in order to reduce the amount of computation time, which results in better efficiency of calculation. DWT can be obtained by

$$C_{mn} = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} s(t)\Psi_{mn}(t)\, dt \qquad (2)$$

where the dyadic scaled and translated wavelet is defined as

$$\Psi_{mn}(t) = 2^{-m/2}\Psi(2^{-m}t - n) \qquad (3)$$

most common wavelets providing the orthogonality properties are Daubechies, Symlets, Coiflets and Discrete Meyer in order to provide reconstruction using the fast algorithms (Addison, 2002). The successive low-pass and high-pass filters calculating three levels of DWT is shown in Fig.6.

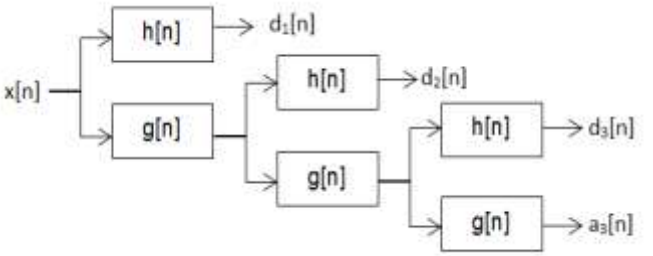


Fig. 6. Three level Wavelet decomposition tree

Each stage consists of two digital filters and two downsamplers by 2 to produce the digitized signal. The low pass filter is denoted by g[n] while the high pass filter is denoted by h[n]. At each level, the high pass filter produces detail information; , while the low pass filter associated with scaling function produces coarse approximations, The filtering and decimation process is continued until the desired level is reached. The maximum number of levels depends on the length of the signal. Only the last level of approximation is save among all levels of details, which provides sufficient data. The filter coefficients can be obtained from mother wavelet and scaling functions (Addison, 2002).

5.0 Data Acquisition and Feature Extraction

The flowchart of the overall working principle of the automatic beat classification system is given in Fig. 7. After the acquisition of the data, the preprocessing steps are applied to remove noise and artifacts, then R waves are detected to localize QRS complexes using Pan-Tompkins algorithm.

For each R-R interval 200 samples are obtained and the features are extracted by the statistics of DWT coefficients. Finally, each ECG beats are classified by artificial neural network due to its simplicity and the performance is analyzed. In this section the details of the procedure will be explained.

5.1 ECG Data Acquisition

In this study, the source of the ECG data used for training and testing is MIT-BIH Arrhythmia database from Physionet website (Physionet, 2014). The database contains 48 recordings of both routinely clinical waveforms and some complex arrhythmias sampled at 360Hz of 30 min durations selected from 24 hr recording with two channels obtained from 47 patients (Goldberger, 2000). Only one channel of 1 min long for each record is used in this work.

5.2 Preprocessing

Preprocessing step involves removal of noise from sources such as electrode contact noise, baseline drift, muscle contraction, power

line interference and motion artifacts. Also QRS detection (Ozbey and Karlik, 1985) was carried out in this stage. A well known and acceptable Pan Tompkins algorithm is employed as a real time QRS detection algorithm based on the analysis of slope, amplitude and width of QRS complexes (Pan and Tompkins, 1985). The steps of preprocessing are given as

- Removing DC component
- Removing high frequency noise (low pass filter)
- Removing low frequency noise (high pass filter)
- Removing power line interference (comb filter)
- Derivative operation
- Squaring operation
- Integrator
- Thresholding
- Search procedure for R-peaks

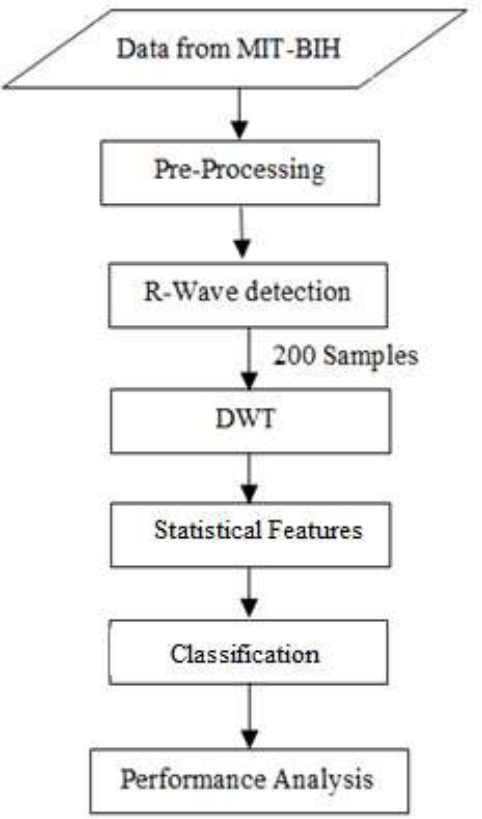
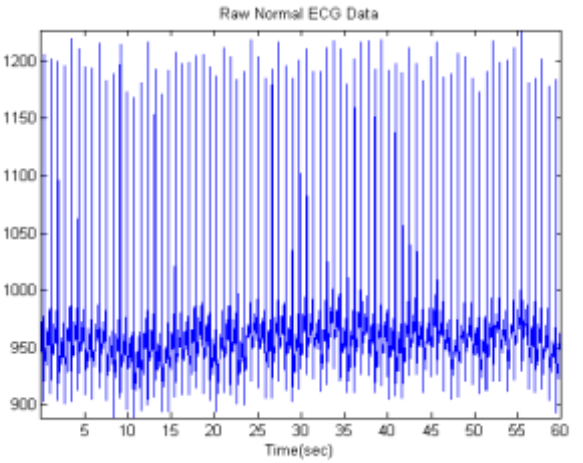
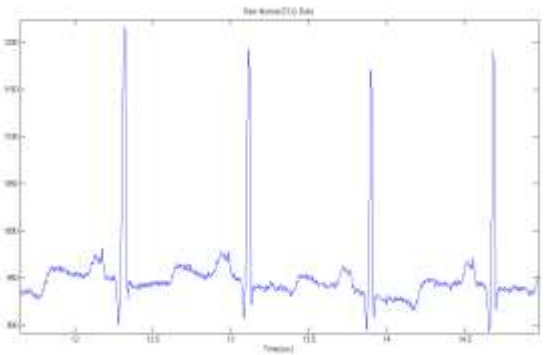


Fig. 7. Automatic ECG Beat Classification System Development Flow Chart

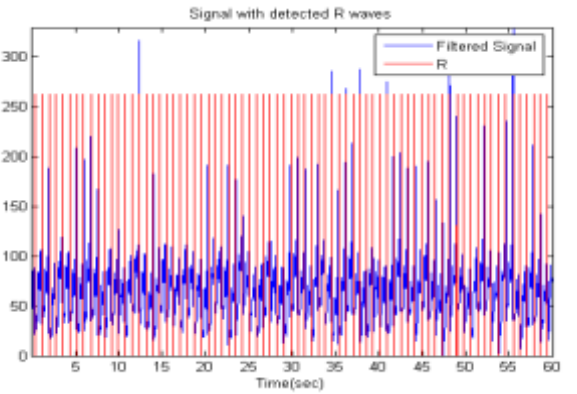
One sample of the original normal ECG recording and preprocessed ECG wave with detected R waves are shown in Fig. 8. The red lines in Fig.8.c point the detected R waves. In the feature calculation R-R intervals are taken into account.



(a)



(b)



(c)

Fig. 8.(a) Original Normal ECG for 1 minute signal, (b)zoomed in for a few beats, (c) preprocessed ECG signal

5.3 Feature extraction

ECG signal consists of many parameters and data points which characterize its behavior, extracting significant and smaller number of parameters without sacrificing accuracy of classifier is particularly important in ECG beat detection and classification using mobile devices. To achieve this, feature extraction in this work are in three stages.

5.3.1 ***Equivalent R-T interval features***: Only 200 samples from detected R-peaks have been extracted from R-R interval which corresponds to R-T interval. The feature vector is constructed depending on the number of R-peaks in each ECG record which is between 60 and 90 per record.

5.3.2 ***Statistics of DWT coefficients***: In this stage, discrete wavelet decomposition is applied to feature vector extracted from R-T interval above. Different wavelet families are considered to find the best and suitable wavelet. Another important point is to select the wavelet decomposition level. The level is chosen to cover the frequency range of the normal and abnormal ECG signals. Then, seven standard statistical parameters are used over the set of wavelet coefficients in order to reduce the feature vector dimension and to increase robustness. The mean, median, maximum, minimum, standard deviation, energy and entropy are the features that represent the time-frequency distribution of the ECG signals.

5.4 Classification

In order to classify ECG beats as normal, right bundle branch block and paced, three common classifiers as artificial neural networks, support vector machines and probabilistic neural networks are used in this study. In this section these three classifiers will be introduced briefly.

5.4.1 Artificial neural networks

The artificial neural networks (ANN) inspired by human nervous system is widely used for function approximation and system modelling. The simplest and most common ANN structure is multi layer feedforward neural network with backpropagation learning which is illustrated in Fig. 9.

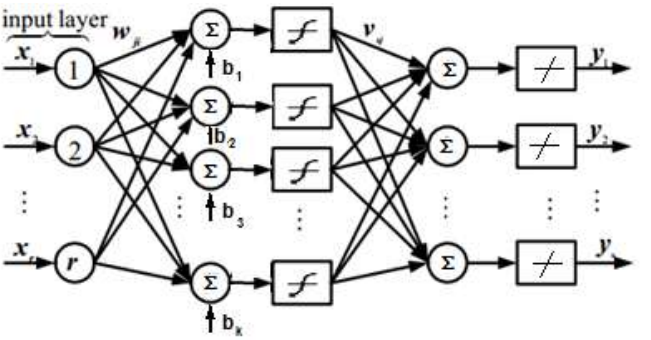


Fig. 9. Multi layer feedforward neural network

After the selection of system structure, number of layers, number of neurons in each layer, ANN is fed with training samples and weights are determined according to the learning algorithm. The basic backpropagation algorithm adjusts the weights in the steepest descent direction (negative of the gradient). This is the direction in which the performance function is decreasing most rapidly. In this study, ANN with one hidden layer containing 15 neurons of Matlab Neural Networks toolbox is used for its simplicity. The number of hidden neurons is selected heuristically. The learning algorithm is the Levenberg-Marquardt algorithm, which is the fastest method for training moderate sized feed-forward neural network (Demuth and Beale, 2001).

5.4.2 Probabilistic neural networks

Probabilistic neural networks (PNN), is another class of neural networks, implements Bayesian classification scheme. The degree of similarity of each input to training is calculated in the pattern layer which is a radial basis network. Then, the probabilities for each class are calculated and the maximum is selected as the output as shown in Fig.10 where denotes input-output training samples, □j,i and vk represents the weights of pattern layer and category layer, respectively.

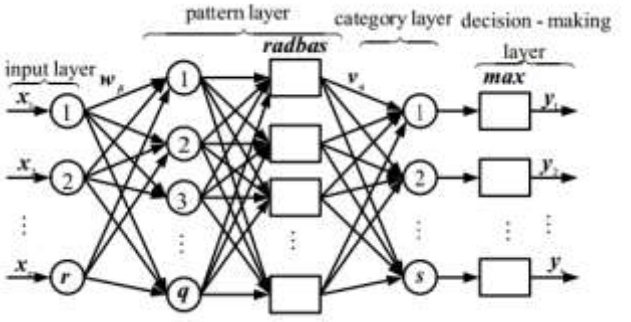


Fig. 10. Block diagram of probabilistic neural network

PNN is faster than ANN in training phase and because of Bayes optimal classification scheme it is more accurate in some classification problems, however it requires more memory space to store the model (Wasserman, 1993). The classification performance is mostly defined by the spread parameter of the radial basis function. In this study, the spread parameter of the network is selected by grid search algorithm to obtain best classification accuracy.

5.4.3 Support vector machines

Support vector machine (SVM) classifiers are binary classifiers which use risk minimization technique. In order to classify the samples which cannot be separated by linear hyperplanes, the feature space is mapped into a higher dimensional feature space by applying transformation function . In this new feature space, an optimal separating hyperplane which maximizes the distance between plane and the nearest data point is searched. Fig.11 illustrates an example of 2-dimensional separable classification problem by denoting the optimal hyperplane and maximum margin. The data points on the margin line are called as support vectors.

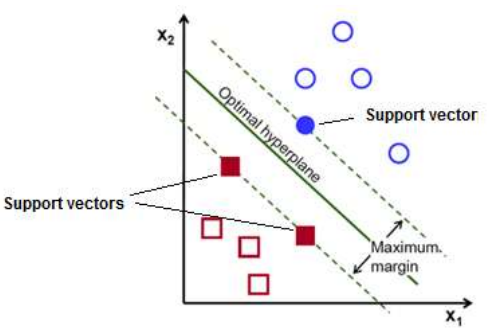


Fig. 11. An example of a separable problem in a 2 dimensional space

For the training set of N input output samples of $(x_j, y_j), j = 1, \ldots, N$ and $y \in \{-1,1\}^N$ the classifier calculates the output as

$$g(x) = sign\left[\sum_{j=1}^{N} \alpha_j y_j \emptyset(x_j)^T \emptyset(x) + b\right] \quad (4)$$

where b is the bias of the hyperplane, and the α_j coefficients are the solution of the convex quadratic optimization problem assuming data is classified correctly defined as

$$\max_{\alpha} \sum_{j=1}^{L} \alpha_j - \frac{1}{2}\sum_{j=1}^{L}\sum_{i=1}^{L} y_j y_i \emptyset(x_i)^T \emptyset(x_j)\alpha_i \alpha_j$$
$$st. \sum_{j=1}^{L} \alpha_j y_j = 0 \qquad 0 \leq \alpha_j \leq C \quad (5)$$

where C is a regularization parameter for controlling the trade off between the margin and misclassification error. The inner product $\emptyset(x_i)^T \emptyset(x_j)$ is not calculated in explicit form but obtained by a kernel function $K(x_i^T, x_j)$ which is known as kernel trick (Cortes and Vapnik,1995). There are several different kernel functions such as radial basis function (RBF), quadratic and polynomial. In this study, all of these kernels are used with the best performing parameter sets found by grid search algorithm. Although, SVM is designed to classify data into two classes, in this study, it is used for a multi-class problem by using one-versus-all approach.

6.0 Results and Disscussion

In this paper, ECG signal from MIT-BIH database were used for training and testing. 40 ECG records were downloaded as .mat files and distributed randomly for classification of normal, paced and rbbb beats. 1602 ECG beats are fed to artificial neural network and approximately 70% is used for training and the remaining is used for validation and testing. The classification performance is considered in terms of sensitivity, specificity, positive predictive value, negative predictive value, accuracy and recognition rate. The used measures are defined as

$$Sensitivity = \frac{TP}{TP + FN} * 100\% \quad (6)$$

$$Specificity = \frac{TN}{TN + FP} * 100\% \quad (7)$$

$$Positive\ Predictive\ Value = \frac{TP}{TP + FP} * 100\% \quad (8)$$

$$Negative\ Predictive\ Value = \frac{TN}{TN + FN} * 100\% \quad (9)$$

$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN} * 100\% \quad (10)$$

$$Recognition\ Rate = \frac{TP}{TP + FP + FN + TN} * 100\% \quad (11)$$

where TP is True Positive (correctly identified), FP is False Positive (incorrectly identified), FN is False Negative (incorrectly rejected), TN is True Negative (correctly rejected) (Han et al. 2011).

6.1 Performance Analysis of Equivalent R-T Interval Features

In order to use as a benchmark, 200 samples taken from the R-T interval is fed to ANN without applying any feature extraction step. Several numbers of hidden layers are experimented in terms of recognition rate and the best result has been obtained with 15 hidden neurons.

Table 1 below shows the performance of equivalent R-T interval features extracted after QRS detection using Pan Tompkins algorithm. Although, accuracy is acceptable, the number of inputs makes the network size large.

TABLE I
PERFORMANCE MEASURES FOR R-T INTERVAL SAMPLES

ECG Class Beat	Sens. (%)	Spec. (%)	Pos. Pred. (%)	Neg. Pred. (%)	Accuracy (%)
Normal	100	98.91	97.85	100	99.27
Rbbb	97.01	97.49	94.89	98.55	97.34
Paced	95.07	99.63	99.26	97.47	98.06
Average	**97.36**	**98.68**	**97.33**	**98.67**	**98.22**

6.2 Performance Analysis of Hybrid Features

After decomposing R-T equivalent features using DWT, statistical parameters of the DWT coefficients have been calculated to further reduce the feature dimension to suit our target. While the raw feature vector contains 200 samples for each beat, after processing the size is reduce to only 77 representing features of hybrid technique. There is an improvement in the proposed hybrid system of approximately 1,6% accuracy as shown in Table 2 below. Also, the performance measures sensitivity, specificity, positive predictive value and negative predictive value show the success of the classification.

TABLE II

THE PERFORMANCE OF PROPOSED FEATURE

ECG Class Beat	Sens. (%)	Spec. (%)	Pos. Pred. (%)	Neg. Pred. (%)	Accuracy (%)
Normal	100	100	100	100	100
Rbbb	99.25	100	100	99.64	99.76
Paced	100	99.63	99.30	100	99.76
Average	**99.75**	**99.88**	**99.77**	**99.88**	**99.84**

6.3 Comparison on Wavelet Families

As another experiment, different wavelet families are classified with ANN and compared in terms of recognition accuracy. Fig. 12 gives the results of this comparison. According to the chart, Daubhechies 4 and 10 and Coiflets 5 perform better than the other wavelets.

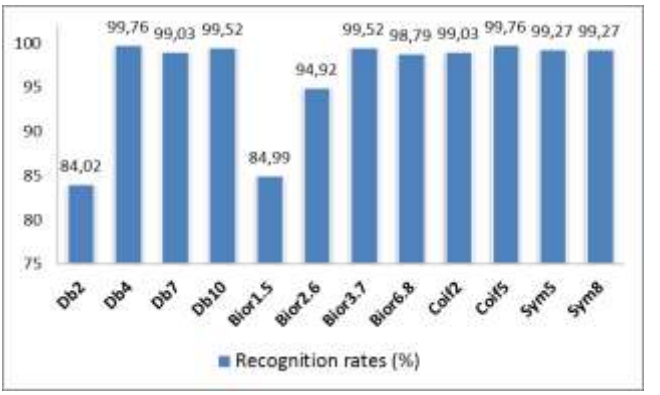


Fig. 12. Comparison of wavelet families

When the shape of the mother wavelet is similar to the analyzed waveform, this wavelet family represents the signal better. The plot of normalized average of the analyzed normal, right bundle branch block and paced beats are given in Fig.13 to compare with Db4 and Coif5 the mother wavelets. The resemblance is quite obvious.

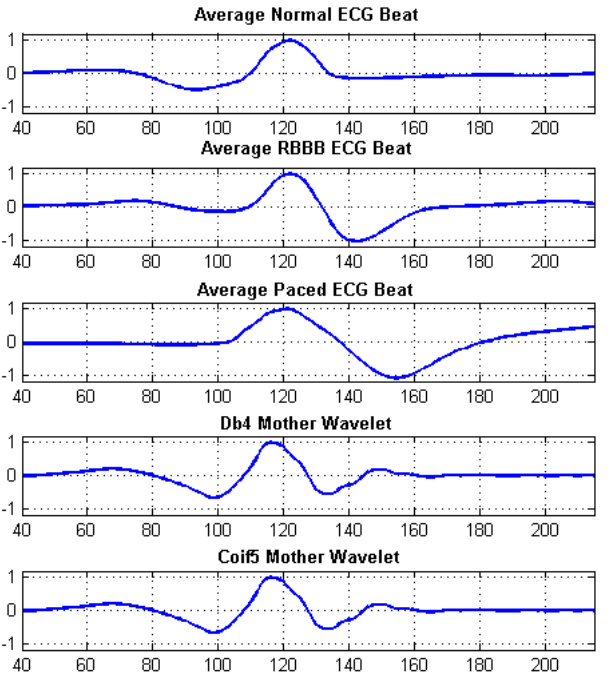


Fig. 13. Normalized average ECG beats and best performing mother wavelets

6.4 Performance Comparison of Classifiers

The discrete wavelet features with Db4 wavelet are also classified with different common classifiers. As an addition to multilayer feed forward artificial neural network with 15 hidden neurons, support vector machine with polynomial kernel of order 3, radial basis kernel, quadratic kernel and probabilistic neural network is used. The best performing parameters for each classifier is obtained by a grid search algorithm. The average sensitivity, specificity and accuracy results are summarized in Fig. 14.

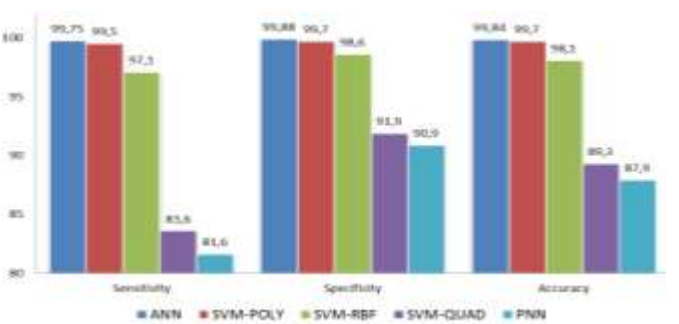


Fig. 14. Comparison of classifiers

For all of the parameters, ANN produces the best results where SVM with polynomial kernel has a performance approaching ANN. This result along with lower performance of quadratic kernel shows that at least third order of nonlinearity in kernel is required to transform the problem into a linearly separable classification task. Although, PNN is a fast algorithm which does not need training, its accuracy is lower than the other classifiers and its sensitivity is unacceptable.

7.0 Conclusion

In this paper, a novel feature extraction technique based on discrete wavelet transform is proposed for the classification of cardiac arrhythmias suitable for ECG portable devices. ECG signals are downloaded from MIT-BIH database and different filters were designed to reduce unwanted signal like baseline wander and power line interference. R peaks are detected using well known and acceptable Pan Tompkins algorithm. R-R intervals features without applying any operation or transform are used as benchmark. DWT was used to decompose R-R intervals and provide a time-frequency representation of the signal. The statistical parameters of DWT coefficients are calculated and used as hybrid feature for training and testing using neural network classifier. Based on the result obtained, RT equivalent feature and DWT with statistical feature gives 98.22% and 99.84% respectively. When different wavelet families are compared in terms of classification performance, Daubhechies 4 and Coiflets 5 performs better than the other wavelets. The more the mother wavelet resembles the ECG waveforms, the beats are represented better.

When the classifiers are compared for the same feature set, it is observed that the artificial neural network classifier and support vector machine with polynomial kernel of order 3 produces best results. Since, the final aim is to propose a classification system suitable for mobile applications; the ANN classifier is preferable due to implementation simplicity.

The design and implementation of a portable ECG recording and arrhythmia detection system which uses the proposed feature extraction algorithms is the concern of the future studies.

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Optimized Controller for Inverted Pendulum

Lukman A. Yusuf
Department of Electrical Engineering
Bayero University
Kano, Nigeria
E-mail: layusuf.ele@buk.edu.ng

Nuraddeen Magaji
Department of Electrical Engineering
Bayero University
Kano, Nigeria
E-mail: nmagaji2000@gmail.com

Abstract: Stability is require in any control system, most system require controller in order to be stable. Tuning is one of the major problems associated with most conventional controllers in existence today. This paper addressesd the difficulties associated with tunning by considering an effective optimized Controller on Inverted pendulum for the control of the angle position. Conventional PID controller was designed separately, to validate the proposed optimized controller. A MATLAB script for genetic algorithm was written with the aim of obtaining optimum PID parameters that would stabilized the pendulum angle at any desired inference inputs (i.e. returns the pendulum to a desire point as quick as possible). This would be achieved by minimizing an objective function (Integral time absolute error ITAE). On the other hand, a convention PID controller was designed using MATLAB/Simulink environment; the PID's gains were manually tuned until an optimum response is achieved. The results obtained in both schemes shows that the optimized controller proves more effective as compared to ordinary conventional PID controller, as optimized controller gives settling time, percentage overshoot of 5.02 seconds and 3% respectively as compared with settling time of 70 seconds and overshoot of 5% for conventional PID controller. Therefore, the proposed optimized controller can serve as a valuable and an effective controller for the control of inverted pendulum.

Keywords/Index Terms: Objective function; Pendulum angle; Genetic Algorithm; Stability, Optimized.

1. Introduction

Inverted pendulum is a pendulum which has its mass above its pivot point. This system is inherently not stable and must be actively balanced by moving the pivot point horizontally which serve as a feedback to the system or by oscillating the support rapidly up and down so that the oscillation is sufficiently strong enough to

restore the pendulum from perturbation in a striking counter intuitive manner (Altinoz, Yilmaz and Weber, 2010). Inverted pendulum is used as benchmark for testing control algorithms due to its high degree of instability and non-linearity. Real application of the system can be found in Missiles guidance, Rockets, heavy Crane lifting containers in shipyards, self balancing Robots and etc.

GA is stochastic global search methods based on the mechanics of natural selection and natural genetic. They are iterative method widely used in optimization problems in general branches of science and technology. It was first proposed by Holland in 1976. GA offer some advantages over other search tools in the following ways (Magaji and Mustafa , 2010):

- GAs search from a population of points not a single point
- GAs use probabilistic transition rules not deterministic ones
- GAs work on encoding parameters set rather than the parameter set itself (except where real-valued individuals are used)
- GAs do not require derivative information or other auxiliary knowledge; only the objective function and the corresponding fitness levels influence the directions of the research.

To obtain a solution to a problem through genetic algorithms, the algorithm is started with a set of solutions (represented by chromosomes) termed as the population. This is Initialization. This is follow by Selection, i.e. choosing random solutions of one population forms a new population base on their evaluation on the objective function. This can be done either by Roulette wheel or Stochastic universal sampling. The formal was used because it ensures that each parent chance of being selected is proportional to its fitness value but possibility also exists to choose the worst population member. The new population is formed assuming that the new one will be better than the old one. Parent solutions are selected from the population to form new solutions (offspring) based on their fitness measure through the application of genetic operators such as crossover (exchange of genes from parents), mutation (sudden change in genes, this should however be introduce on a minimum probability) etc. These processes are repeated over several iterations until a stopping criterion is reached (Sumathi and Paneerselian, 2010).

Several control schemes have been designed and implemented by different researchers using different techniques in order to solve the above problem. In (Anguilar, Unpublished), theoretical and experimental results for balancing a

single inverted pendulum using approximate input-output linearization and sliding mode control was presented, this however involved complex mathematics and as result affect the response of the system and also, it considered only zero input case. In Wang (2011), control laws such as input-output feedback linearization, Lyapunov second theorem and Lasalle's invariant principle were used, this however considered zero input case and also, settling time of 10 seconds was recorded. Wahida, Banu, and Manoj (2011), present a soft computing method for the controller of the inverted pendulum using Adaptive Neuro Fuzzy Inference System (ANFIS), this also consider a small angle variation, sluggish response and a steady state error of 0.2 radians were recorded. In Pandalai and Kataria (Unpublished), PID controller was designed for linearized model of the inverted pendulum; trial and error method was used in tuning the proportional-Interal-differential (PID) controllers, this waste time due to difficulty in tuning and settling time of 69 seconds was obtained. Another most popular method to tune the PID controllers is the Ziegler and Nichols method; this is a practical method for a single output and stable plants. Heuristic tuning of PID was considered in (Van Overschee et al, 2010). More systematic ways to optimize PID parameters has been proposed in, for instance, (Lee, Park and Brosilow, 1998, Lopez, Murrill and Smith, 2009 and Haupt and Haupt., 2002) uses the deterministic optimization methods base on the integrated Absolute Error (IAE) criterion however, these make use of MATLAB toolbox and their tuned parameters are only optimum in certain operational zones and have unsatisfactory design robustness property. In (Altinoz, Yilmaz, and Weber, 2010), Particle swarm optimizer were used to tuned PID gains, this however takes much time to converge and settling time of 8.2 seconds was recorded. Genetic Algorithm has proven to be a powerful search tools used by many researchers to optimize many complex function as well as PID controllers, most of it focus mainly on Integral of absolute error (IAE) as objective function (Haupt and Haupt, 2002). In this work, comparison between conventional PID and GA- PID controller for linearized model of the inverted pendulum is presented. Here a large variation of angle was considered, and ITAE was used as the objective function to improve the convergence, robustness of the Genetic algorithm. The PID controller was designed using MATLAB/Simulink environment and it's gains were tuned until a optimum response is obtained. On the other hand, the GA-PID is designed by writing an m-file that will automatically obtain PID

parameters through the minimization of an objective function Integral time Absolute error (ITAE) using genetic algorithm. The rest of the paper is organized as follows: Section II, presented the model description, Section III, dwells on the controller design, Simulink representation and results comparison are presented in Section IV, and finally Section V concludes the paper.

2. Model Description

The model description of the inverted pendulum was obtained using Lagrange Equation, which is one of many methods that can be used to derive a mathematical modeling for a complex mechanical system like inverted pendulum (Katsuhiko, 2010). The free body diagram of the system is first drawn as shown in Figure 1.

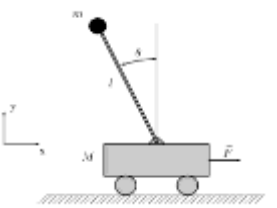


Figure 1.Inverted pendulum on Cart.

The model of inverted pendulum on a cart was derived using Lagrange Equation which base on the difference in Kinetic (K_E) and Potential energy (P_E) of the system. The mathematical model are basically required for the purpose of simulation in MATLAB/Simulink environment and also for the development of controller for the system. The mathematical equation of both the angle of the pendulum and position of the cart are represented in differential equations as:

Langragian (L) natural form is given by

$$L = K_E - P_E \tag{1}$$

$$L = \frac{1}{2}(M+m)\dot{x}^2 - ml\dot{x}\dot{\theta}\cos\theta + \frac{1}{2}ml^2\dot{\theta}^2 - mgl\cos\theta \tag{2}$$

Where: x denote the position of the cart. Using equations (1) and (2)

$$F = \frac{d}{dt}\frac{\partial L}{\partial \dot{x}} - \frac{\partial L}{\partial x} \tag{3}$$

$$0 = \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}}\right) - \frac{\partial L}{\partial \theta} \tag{4}$$

We have:

$$\ddot{\theta} = \frac{F\cos\theta - (M+m)g\sin\theta + ml(\sin\theta\cos\theta)\theta^2}{ml\cos^2\theta - (M+m)l} \tag{5}$$

$$\ddot{x} = \frac{u + ml(\sin\theta)\dot{\theta}^2 - mg\cos\theta\sin\theta}{M + m - m\cos^2\theta} \tag{6}$$

Linearizing (5) and (6) about equilibrium points

$$(\theta = 0, \sin\theta \to \theta, \cos\theta \to 1 and \dot{\theta}^2 \to 0)$$

Equations becomes:

$$\ddot{\theta} = \frac{F - (M+m)g\theta}{Ml} \tag{7}$$

$$\ddot{x} = \frac{F - mg\theta}{M} \tag{8}$$

In state space:

$$\dot{x}(t) = Ax(t) + Bu(t) \quad (9)$$

$$y(t) = Cx(t) + Du(t) \quad (10)$$

$$\frac{d}{dt}\begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \end{bmatrix} = \frac{d}{dt}\begin{bmatrix} \theta \\ \dot{\theta} \\ x \\ \dot{x} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ \frac{(M+m)g}{Ml} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ \frac{-mg}{M} & 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} \theta \\ \dot{\theta} \\ x \\ \dot{x} \end{bmatrix} + \begin{bmatrix} 0 \\ -\frac{1}{Ml} \\ 0 \\ \frac{1}{M} \end{bmatrix} F \quad (11)$$

$$y = \begin{bmatrix} \theta \\ x \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}\begin{bmatrix} \theta \\ \dot{\theta} \\ x \\ \dot{x} \end{bmatrix} \quad (12)$$

TABLE I SYSTEM PARAMETERS

Parameter	***Value***
Length of the pendulum, L	0.35 m
Mass of the cart, M	1.2 kg
Mass of the pendulum bob, m	0.2 kg
Acceleration due to gravity, g	9.8 ms^{-2}

Source [1]

After substation we have

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 32.667 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ -1.633 & 0 & 0 & 0 \end{bmatrix},$$

$$B = \begin{bmatrix} 0 \\ -2.381 \\ 0 \\ 0.833 \end{bmatrix},$$

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}, \quad D = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

3. Controller Design

In this section the two proposed controller design are carried out which are conventional PID and GA-PID controllers. In this section a design procedure of model base PID is presented.

A. PID controller design

The PID Controller is incorporated in the system as shown in Fig. 3,. The general transfer function of the controller is given as:

$$C = K_p + \frac{K_i}{s} + K_d s \quad (13)$$

Where: K_p, K_i and K_d are the controller gains.

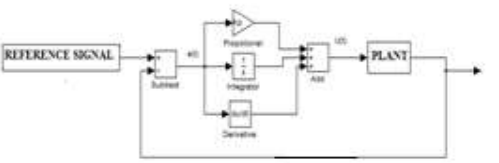
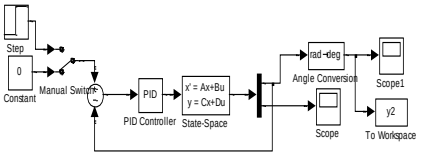


Figure 2.PID Controller Block Diagram

The controller gains were tuned to obtain an optimum response for the system, putting in mind the following guides in TABLEII.

The Simulink block diagram is shown in Fig. 3. The simulation was run under various input conditions.

TABLE I. SYSTEM PARAMETERS



Controller response	*Rise time*	*Over shoot*	*Settling time*	*Steady state error*
K_p	Decrease	Increase	Small change	Decrease
K_i	Decrease	Increase	Increase	Eliminate
K_d	Small change	Decrease	Decrease	No change

Figure 3. PID Smulink block diagram for the system

B. GA-PID Controller Design

In this section a design procedure of model base GA-PID is presented. The GA-PID Controller is incorporated in the system as shown in Fig. 3,.

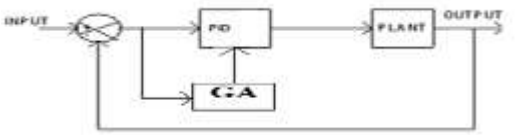


Figure 4. Block diagram of System with GA-PID controller

The errors from the summer serve as the inputs to the genetic Algorithm (GA), the integral time absolute errors of thse error were obtained which serve as the functions needed to be minimized through GA. This is achieved by searching for the controller gains that will best minimized the objective function based on stopping criteria set.

GA-PID controller was designed by writing a program using m-file in MATLAB that will minimize an objective function (ITAE), the program is run under various Input disturbances. The error from the system is fed to GA for minimization. The flow chat for the GA process is shown in Fig. 5. GA is a stochastic algorithm, that is, the result obtained in each time the codes are run is not always the same (Yusuf and Magaji, 2014).

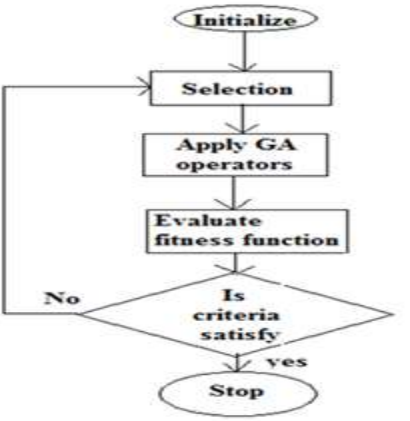


Figure 5. Flow process in application of GA.

4. Results and Discussion

The conventional PID control scheme is implemented in Simulink, and GA base on PID script was written and each of the control schemes was tested under different input conditions.

The result from the two controller schemes are compared in this section. The responses of conventional PID and GA-PID control for pendulum angle are shown in Fig. (6, 7, 8 & 9) under various input steps value. TABLE (III, IV, V and VI) summarizes performance index used for the two controller schemes in two decimal places. The performance indices uses are: Settling time (t_s), Overshoot (M_p), Rise time (t_r).

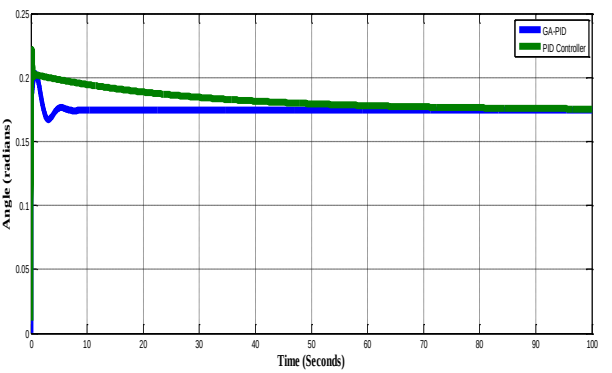


Fig. 1. *Response of the two controller schemes under 10-degree.*

The responses of the system with GA-PID and PID controllers under input of 0.175 radians is shown in Fig. 6., the GA-PID shows sharper response and settled much faster than the conventional PID controller as shown in TABLE III.

TABLE II. RESPONSE UNDER 10-DEGREE OF INPUT

Performance index	***GA-PID***	***PID***
Settling Time (sec)	5.02	70.00
Overshoot	3.00%	5.00%
Rise time (sec)	0.00	0.00

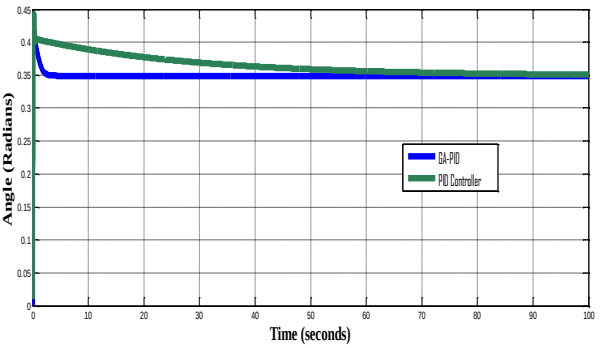


Fig. 2. *Response of the two controller schemes under 20-degree.*

The responses of the system with GA-PID and PID controllers under input of 0.349 radians is shown in Fig. 7, the GA-PID still show sharper response and settled quicker than the conventional PID controller. This is summarized in TABLEIV.

TABLE IV RESPONSE UNDER 20-DEGREE INPUT

Performance index	***GA-PID***	***PID***
Settling Time (sec)	7.00	85.00
Overshoot	6.00%	10.00%
Rise time (sec)	0.00	0.00

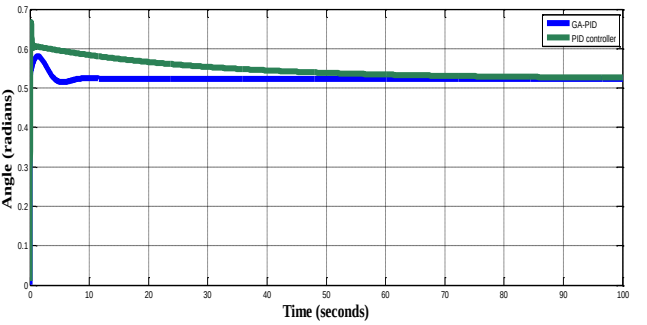


Fig. 3. *Response of the two controller schemes under 30-degree*

The responses of the system with GA-PID and PID controllers under input of 0.524 radians is shown in Fig. 8, the GA-PID shows sharper response and settled much faster than the conventional PID controller as its settling time is much shorter. This is shown TABLE V.

TABLE V RESPONSE UNDER 30-DEGREE INPUT

Performance index	***GA-PID***	***PID***
Settling Time (sec)	7.00	68.00
Overshoot	6.00%	16.00%
Rise time (sec)	0.00	0.00

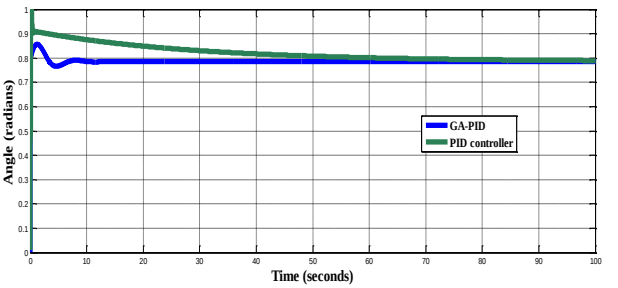


Fig. 4. Response of the two controller schemes under 45-degree.

The responses of the system with GA-PID and PID controllers under 0.7855 radians input is shown in Fig. 9, the GA-PID still demonstrated superiority in term of settling time and overshoot. This is shown in TABLE VI.

TABLE VI RESPONSE UNDER 45-DEGREE INPUT

Performance index	***GA-PID***	***PID***
Settling Time (sec)	6.90	72.00
Overshoot	7.00%	21.00%
Rise time (sec)	0.00	0.00

5. Conclusion

It was observed that the two proposed control schemes(Optimized PID and Conventional PID) performed well in the control of pendulum angle of an inverted pendulum however, the optimized PID controller performs much better than the conventional PID controller when considering settling time, rise time, overshoot as illustrated in TABLE (III to VI). The result shows that the optimized controller gives settling time, percentage overshoot of 5.02 seconds and 3% respectively as compared with settling time of 70 seconds and overshoot of 5% for conventional PID controller. More so, The problems associated with manual tunning of the gains for the PID has been eliminated in Optimized PID controller since it's gains were obtained automatically through an optimization process with Genetic Algorithm. Therefore, the optimized (GA-PID) controller can serves as valuable, easily tunned and effective controller for the system.

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