Investigation of Digestive System Disorders with Cutaneous Electrogastrogram (EGG) Signal - An Engineering Approach

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Abstract

The aim of this study is to develop an Electrogastrogram [EGG] acquisition procedure and different engineering methods for EGG signal analysis and comparing the different methods for the classification of normal subjects and abnormal subjects in order to guide the physician in the investigation digestive system disorders in fair amount of accuracy before the unwanted endoscopy procedure. Digestive system plays a vital role in human body because it helps to regulate the metabolic activity based on the food intake. However, the normal function of the digestive system is affected by many disorders such as nausea, dyspepsia gastritis, ulcer, vomiting, etc. Currently the physician for investigation of digestive disorders adopts the endoscope procedure, which is invasive and costly. This paper discusses the EGG acquisition procedure for collecting the EGG database about more than 150 subjects and the EGG analysis by three phases. In phase 1, EGG signal is analyzed using Fast Fourier Transform [FFT]. It classifies the signal for a normal subject or abnormal subject based on the frequency. In phase 2, EGG signal is analyzed with wavelet transform. It classifies the signal for a normal subject or abnormal subject based on the error. In phase 3, EGG signal is analyzed with Neural Network algorithms. It classifies the signal for a normal subject or abnormal subject based on the Mean Square Error [MSE] and Epochs. In the FFT analysis, the normal subject will have the frequency range 0.048 Hz < f < 0.051 Hz and for the abnormal subject it have frequency f< 0.048 Hz and f > 0.051 Hz. From the wavelet analysis, the normal subjects have the percentage of error value at 22.21% whereas the abnormal subjects have the percentage of error value at 15.45% for frequency below 0.048 Hz and the percentage of error value range from 25% to 41% for frequency above 0.051 Hz depending on disorders. In the Neural network analysis, different Back Propagation Network [BPN] training algorithm included but out of these three algorithm namely trainrp, traincfg and trainoss satisfies the condition but trainrp is more suitable for the classifications of normal subjects and abnormal subjects. From the
above three phases of analysis of EGG signal, it is found that the methodologies adopted here able to analysis the EGG signal with a fair amount of accuracy to assist the physician either individually or combination of all in the investigation of digestive system disorders.

**Keywords:** Fast Fourier Transform, Wavelet Transform, Back Propagation Network, Mean Square Error, Digestive system disorders

1. **Introduction**

Electrogastrogram is a non-invasive method of assessing the gastric myoelectrical activity of the stomach [1]. The rapid development in Electrogastrography in the past few years is reflected in the attention among investigators and physician. Currently more research on this interesting field was triggered among the research scholars, investigators, physician, etc. due to disseminated digestive system disorders globally because of fast and junk food habit. The acquisition of gastric activity of the stomach is obtained cutaneously from the human subjects. Unlike other electrophysiological methods, visual analysis is unlikely to provide the investigator with meaningful and accurate information. Therefore, a major breakthrough was noted in the late 1970s after the introduction of computerized frequency analysis, which provided investigators a better and more accurate way of analyzing data [2, 3]. Computerized analysis of EGG with advanced spectral analysis provided the subsequent extraction of more accurate information and clinical experience accumulated in gastrointestinal motility.

In this paper the EGG is analysed using three methodologies namely Fast Fourier Transform, Wavelet Transform and Neural Network. The normal subject frequency is found to be in the range $0.048 \, \text{Hz} < f < 0.051 \, \text{Hz}$ and for the abnormal subject the frequency is found to be $f < 0.048 \, \text{Hz}$ and $f > 0.051 \, \text{Hz}$ from FFT analysis. The normal subjects have the percentage of error value at 22.21% whereas the abnormal subject have the percentage of error value at 15.45% for frequency below 0.048 Hz and the percentage of error value range from 25% to 41% for frequency above 0.051 Hz depending on disorders from the wavelet analysis. Back Propagation Network [BPN] training algorithm namely trainrp, traincgf and trainoss satisfies the condition but trainrp is more suitable for the classifications of normal subjects and abnormal subjects in the Neural Network analysis.

2. **Proposed Electrogastrogram Recording Setup**

Electrogastrogram recording setup is shown in the Figure 1. The bio signal from the stomach due to motility is tapped with active electrodes or Ag/AgCl surface electrodes cutaneously [4, 5, 6, 17]. The electrodes output is given as an input to the Signal Conditioning Unit [SCU] which consists of Instrumentation amplifier, Band pass filter, Notch filter and Gain control. SCU includes amplification, filtering, converting, range matching, isolation and any other processes required to make sensor output suitable for further processing. In SCU, an instrumentation amplifier is used to amplify the potential detected by the electrodes. An amplifier accepts a voltage signal as an input and produces a linearly scaled version of this signal at the output. It is a closed-loop fixed-gain amplifier, usually differential, and has high input impedance, low drift and high common-mode rejection ratio over a wide range of frequencies. A band-pass filter is a device that passes frequencies within a certain range and rejects frequencies outside that range. Notch filter is known as band-cut filter or band-reject filter. The function of this filter is to remove some frequency portion of a signal. It is used to reduce or prevent feedback. Gain control is an adaptive system found in many electronic devices. The average output signal level is fed back to adjust the gain to an appropriate level for a range of input signal levels. Signal conditioning unit primarily utilized for data acquisition, in which sensor signals must normalized, filtered to levels suitable for analog-to-digital conversion to recording and analyzing using computer processor. A Datascope is used for capturing and analyzing EGG signals. It is an 8 channel
data acquisition system which amplifies the data and converts into digital format, which would be input to the personal computer through a serial port (RS232). The personal computer acts as a monitoring, analyzing and display device. The electrode position and real time EGG acquisition is shown in Figure 2.

**Figure 1:** Electrogastrogram recording setup

![Figure 1: Electrogastrogram recording setup](image1)

**Figure 2:** Real Time Electrogastrogram recording process

![Figure 2: Real Time Electrogastrogram recording process](image2)

3. Acquisition and Analysis of Electrogastrogram
The EGG is recorded for about more than hundred subjects, which includes both normal and abnormal subjects [7, 8]. Details of subjects recorded under each abnormality are listed in table 1.
Table 1: Sex and Age Distribution of Subjects

<table>
<thead>
<tr>
<th>Disorders</th>
<th>Mean Age (years)</th>
<th>No. of Male</th>
<th>No. of Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyspepsia(D)</td>
<td>38</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>Stomach Ulcer(SU)</td>
<td>31</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Nausea(N)</td>
<td>45</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Gastritis(G)</td>
<td>28</td>
<td>12</td>
<td>08</td>
</tr>
<tr>
<td>Vomiting(V)</td>
<td>35</td>
<td>09</td>
<td>11</td>
</tr>
</tbody>
</table>

The acquired EGG data [10, 11, 12] are analyzed in three phases such as FFT analysis, Wavelet analysis, and neural network analysis. It is compared with normal subjects’ benchmark database for the classification normal subject and subjects with disorders. The results of each analysis is compared individually or combining of all method of analysis to direct the physician to detect the disorders noninvasively as shown in Figure 3.

**Figure 3: Block diagram for Electrogastrogram Analysis**

3.1. Analysis of Electrogastrogram by FFT

The EGG is analyzed using Fast Fourier Transform and is classified as normal subjects and abnormal subjects based on their signal frequency [13]. The normal EGG signal has a frequency range of about 0.05 Hz (3cpm) and the frequency range below or above this value is considered as abnormal. The algorithm for EGG analysis using FFT follows:

1. **Step 1:** Enter the number of points (N) and sampling frequency (fs).
2. **Step 2:** Load the input EGG signal.
3. **Step 3:** Calculate the FFT for the input EGG signal.
4. **Step 4:** Plot the frequency spectrum for the EGG signal.
5. **Step 5:** Calculate the frequency of the EGG signal from the spectrum.

The FFT analysis output is shown in Figure 4. From the output of the FFT it is clearly observed that the frequency for normal subject is around 0.04688Hz and for abnormal subject (Nausea) is around 0.07813Hz.
3.2. Analysis of Electrogastrogram by Wavelet Transform

The EGG is analyzed using Discrete Wavelet Transform [15, 16, 18], which has two stage processes namely Decomposition and Reconstruction. Although there are many types of transform in wavelet families, daubechies (db4) is used since it is the best type for EGG signal analysis. The normal and abnormal signals are classified based on their error values obtained after analysis. The algorithm for EGG analysis using wavelet analysis follows:

Step 1: Load the acquired EGG signal as input.
Step 2: Wavelet decomposition is performed for the given input signal using db4.
Step 3: Calculate the approximation and detail coefficient and plot their output.
Step 4: Construct the Denoised EGG signal with the help of approximation and detail coefficients.
Step 5: Calculate the error value from the original input signal and denoised signal.
Step 6: Based on the error value, classify the EGG signal as normal and abnormal signals.

The db4 wavelet analysis output is shown in Figure 5. From the output of the wavelet analysis it is the normal subjects have the percentage of error value at 22.21% whereas the abnormal subjects have the percentage of error value at 37.12%.
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Figure 5: Electrogastrogram Analysis by Wavelet. A. db4 wavelet output for Normal subjects B. db4 wavelet output for abnormal subjects.

3.3. Analysis of Electrogastrogram by Neural Network

The EGG signal is trained by feed forward network [9, 14] using nine different BPN algorithms. Among these three algorithms namely Resilient back propagation (RP), Fletcher-Powell Conjugate
Gradient (CGF), One-Step Secant (OSS) gives best result for EGG application by satisfying the following condition 1). If epoch increases, Mean Square Error [MSE] value decreases i.e. Epoch is inversely proportional to MSE, 2). MSE values decreases when epochs increase for normal subjects as shown in table 2.

**Table 2:** Epoch and MSE Values for Different Algorithms

<table>
<thead>
<tr>
<th>BPN Training Algorithm</th>
<th>Normal (f=0.48 Hz to 0.051 Hz)</th>
<th>Abnormal (f&lt;0.048 Hz)</th>
<th>Abnormal (f&gt;0.051 Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Epoch</td>
<td>%MSE</td>
<td>No. of Epoch</td>
</tr>
<tr>
<td>LM</td>
<td>100</td>
<td>0.174</td>
<td>18</td>
</tr>
<tr>
<td>BFG</td>
<td>105</td>
<td>0.159</td>
<td>23</td>
</tr>
<tr>
<td><strong>RP</strong></td>
<td>159</td>
<td><strong>0.071</strong></td>
<td>22</td>
</tr>
<tr>
<td>SCG</td>
<td>92</td>
<td>0.022</td>
<td>8</td>
</tr>
<tr>
<td>CGB</td>
<td>55</td>
<td>0.009</td>
<td>12</td>
</tr>
<tr>
<td><strong>CGF</strong></td>
<td>72</td>
<td><strong>0.096</strong></td>
<td>25</td>
</tr>
<tr>
<td>CGP</td>
<td>95</td>
<td>0.016</td>
<td>22</td>
</tr>
<tr>
<td><strong>OSS</strong></td>
<td>168</td>
<td><strong>0.019</strong></td>
<td>26</td>
</tr>
<tr>
<td>GDX</td>
<td>42</td>
<td>4.854</td>
<td>32</td>
</tr>
</tbody>
</table>

MSE value is considered as a performance of training algorithms for classifying the EGG signals according to the abnormalities. The algorithm for EGG classification using Neural Network is follows:

1. **Step 1:** Load the acquired EGG signal as input.
2. **Step 2:** Set the EGG signal having 0.05Hz frequency as target value.
3. **Step 3:** Create a new feed forward BPN in neural network toolbox.
4. **Step 4:** Train the network using different training algorithms.
5. **Step 5:** Calculate the MSE values.
6. **Step 6:** Classify the EGG signal as normal and abnormal based on MSE value Values.

Normal and Abnormal subjects were trained using nine algorithms and performance for each algorithm calculated as a function of MSE and the same was plotted as a comparison of response that is shown in Figure 6. From the chart it clear that the following algorithms RP, CGF and OSS satisfies the condition and more suit to classify the disorders among the various subjects when compare to other algorithms.

**Figure 6:** Performance of different BPN training algorithms
4. Results
Electrogastrogram is a non-invasive and inexpensive method of diagnosing the gastric disorders. About 120 subjects EGG of different age group is taken for analysis.

**Figure 7:** Result of FFT Analysis

![FFT Analysis](image)

Analysis of EGG signal using FFT is shown in Figure 7. From the above graph, we can observe the frequency of normal signal approximately 0.05Hz. EGG signal have frequency greater than or lesser than 0.05Hz is said to be the abnormal signal.

**Figure 8:** Classification using Wavelet

![Wavelet Analysis](image)
The EGG classification using wavelet analysis is shown in Figure 8. From the figure, it is found that the percentage error of normal signals lies from 20 to 22. For the abnormal signals percentage error may be lesser than or greater than normal signal range. The error comparison is shown in Figure 9.

Figure 10: Electrogastrogram Analysis by Neural Network. A. Performance of RP Algorithm, B. Performance of CGF Algorithm, C. Performance of OSS Algorithm for the classification subjects.
The performance of the RP, CGF, and OSS algorithms for EGG signal analysis are shown in Figure 10 as A, B, and C respectively. By comparing the results, we can conclude that MSE values and Epochs are inversely proportional. MSE values decrease when epochs increase for normal subjects. However, for abnormal subjects, the percentage variation of MSE values with respect to epochs is less compared to normal subjects. The performance comparison of different algorithms is shown in Table 3.

Table 3: Performance Comparison of Different Algorithm

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>No. of subjects</th>
<th>Correctly Classified</th>
<th>% Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resilient back propagation (RP)</td>
<td>15</td>
<td>14</td>
<td>93.33</td>
</tr>
<tr>
<td>One-Step Secant (OSS)</td>
<td>15</td>
<td>13</td>
<td>86.66</td>
</tr>
<tr>
<td>Fletcher-Powell Conjugate Gradient (CGF)</td>
<td>15</td>
<td>11</td>
<td>73.33</td>
</tr>
</tbody>
</table>

5. Conclusion
In this paper, we introduced a novel approach for analysis and classification of EGG signals. Here three different engineering methods are used for the analysis of EGG signals. They are FFT analysis,
Wavelet analysis and Neural network analysis. FFT classify the signals accurately based on the frequency. Wavelet uses the percentage of error for classifications and neural network classify the data according to their % MSE and epochs. By comparing the results of these three methods, neural network classify the EGG signal of normal and abnormal subject at fair amount of accuracy. In neural network analysis, BPN network is used. This network is trained and analyzed using nine different training algorithms. By comparing the result of all algorithm, three algorithm namely Resilient back propagation (RP), Fletcher-Powell Conjugate Gradient (CGF), One-Step Secant (OSS) performance classify the normal and abnormal subjects in best way. Among these three algorithm ,RP algorithm is more suitable for the classification with an accuracy of 93.33 percentage compared to other algorithms and it is the best choice for the analysis and classification EGG signal with the help of BPN network. From this, it is concluded that the method adopted here is able to classify the signal accurately with less time and the physician is directed for the investigation of digestive disorders noninvasively.

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References


