# ABNORMALITY CLASSIFICATION OF ECG SIGNAL USING DSP PROCESSOR


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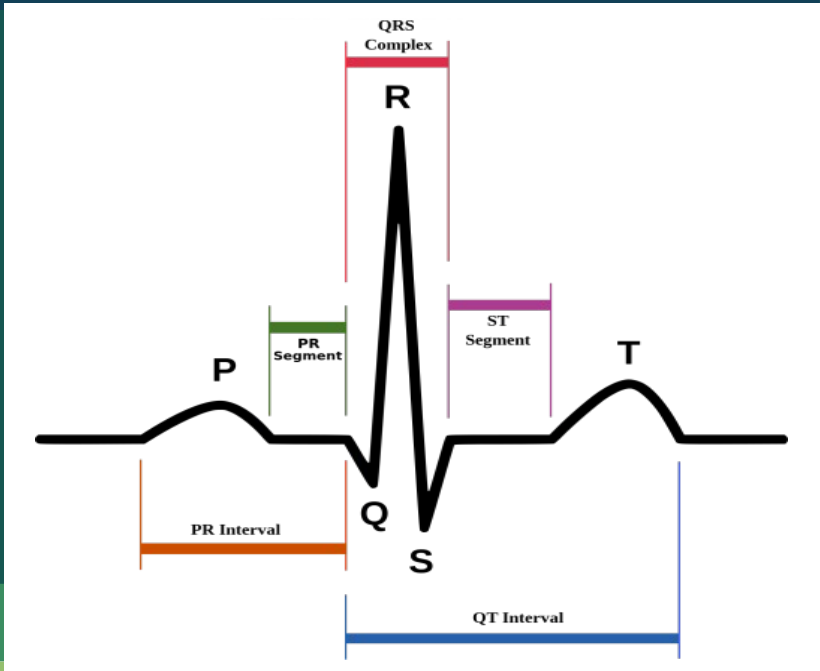
# MOTIVATION

- The electrocardiogram (ECG) is one of the simplest and oldest cardiac investigations available. And it provides a wealth of information about the heart of the patient.

- This work implements an algorithm that classifies the abnormalities in the ECG signals.

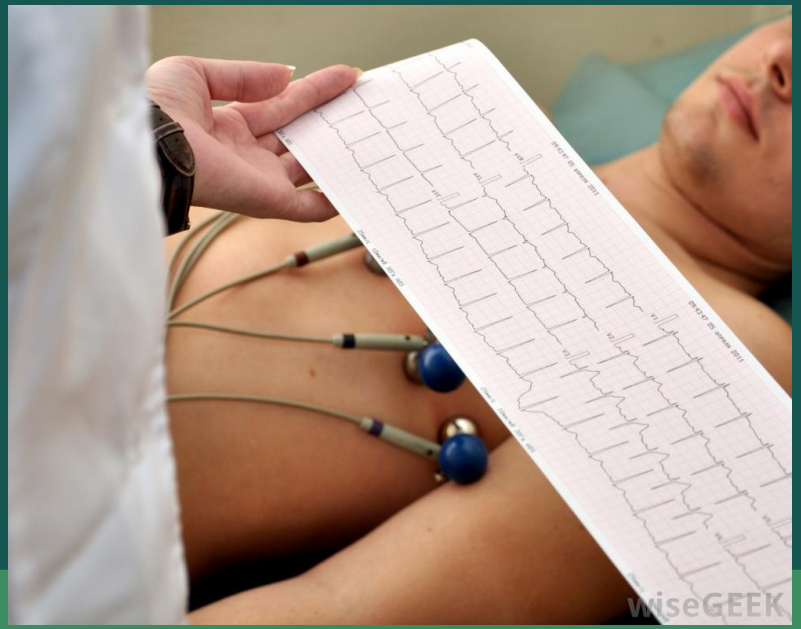
# WHAT IS AN ECG?

- An ECG is simply a representation of the electrical activity of the heart muscle as it changes with time, usually printed on paper.



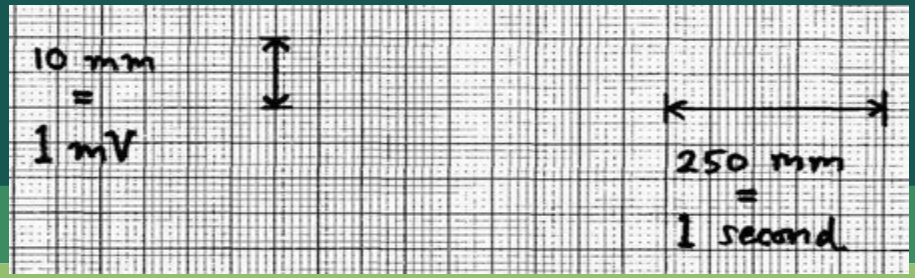
# AN ACTUAL ECG SIGNAL ON PAPER

- Here we can see there are many intricate details printed on this paper.



# TRADIOTIONAL METHOD OF READING ECG

- ECG paper is marked with a grid of small and large squares. Each small square represents 40 milliseconds (ms) in time along the horizontal axis and each larger square contains 5 small squares, thus representing 200 ms. Standard paper speeds and square markings allow easy measurement of cardiac timing intervals. This enables calculation of heart rates and identification of abnormal electrical conduction within the heart
- 5 - the HR is 60 beats per minute.
- 3 - the HR is 100 per minute.
- 2 - the HR is 150 per minute.



# DRAWBACKS OF THE TRADITIONAL METHOD

- Because of intricacies of details there is a chance of error in measurements.
- It is a tedious and time consuming process.
- Requires an experienced physician or technician.

# Literature review

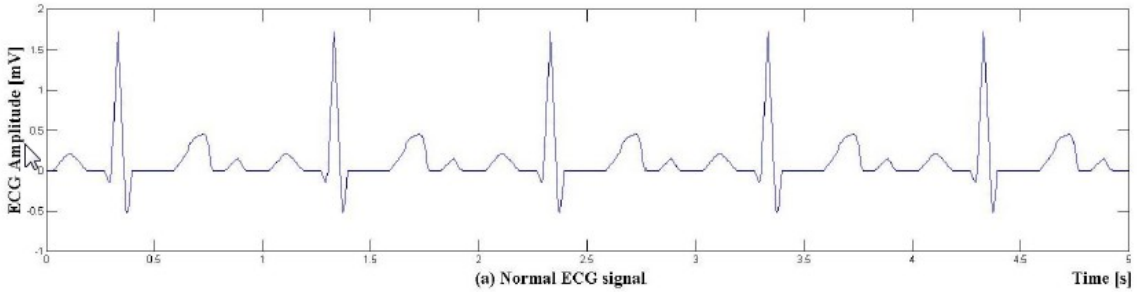
Let’s have a look at the work previously done

# 1. Study of ECG signal processing using wavelet transform

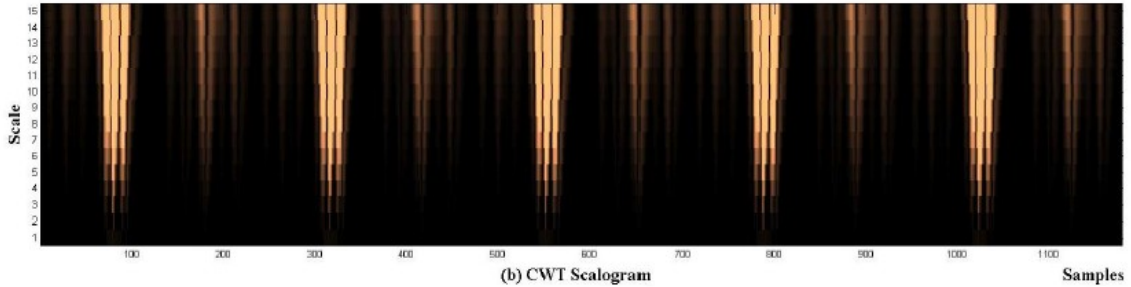
- **Authors:** Meddour Cherif, Malika-Djahida Kedir-Talha, Malika Tighidet
- **Publisher**: International symposium on advanced topics in electrical engineering, IEEE
- **Year: 2015**

- In this paper, authors have acquired a noisy ECG signal from database recording and processed it for noise removal.
- Then they used continuous wavelet transform to detect different pathologies.
- Their main focus was towards de-noising.
- Authors used MATLAB which is a very powerful signal analyzing tool.

# 1. Study of ECG signal processing using wavelet transform

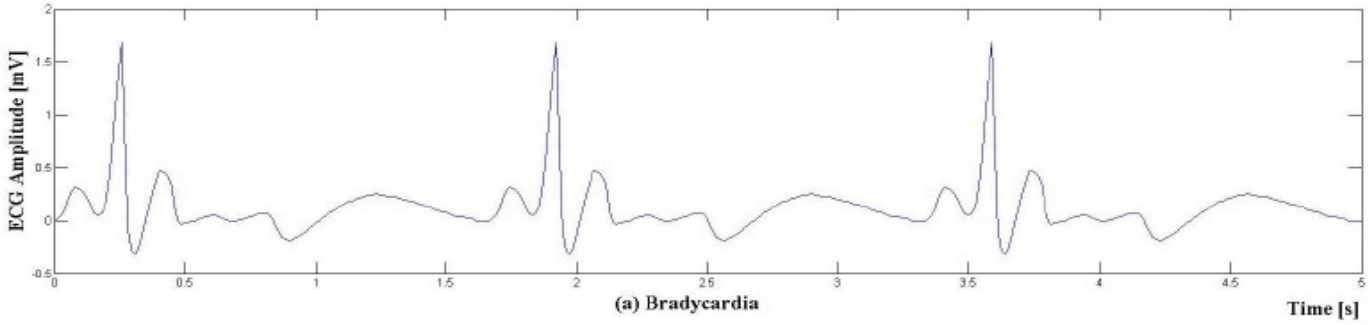



(a) Normal ECG signal

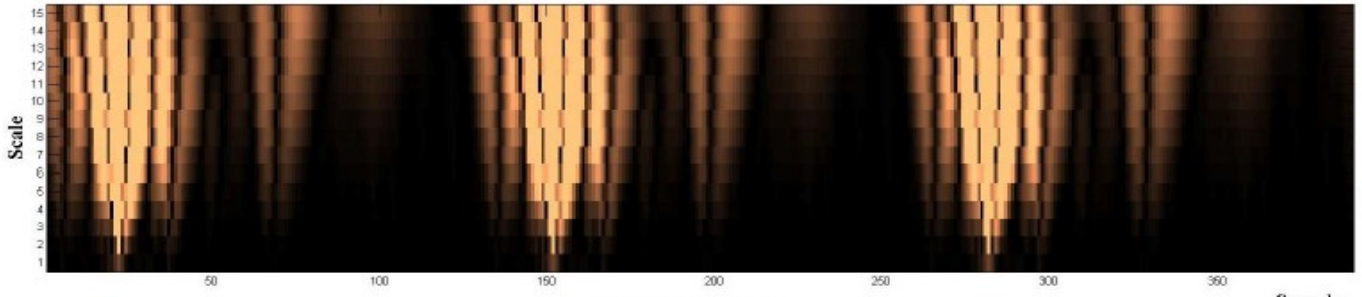



(b) CWT Scalogram

# 1. Study of ECG signal processing using wavelet transform




(a) Bradycardia

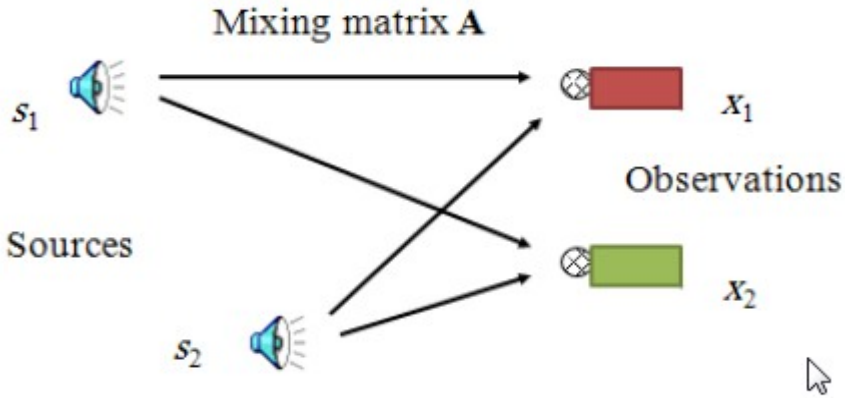



(b) CWT Scalogram

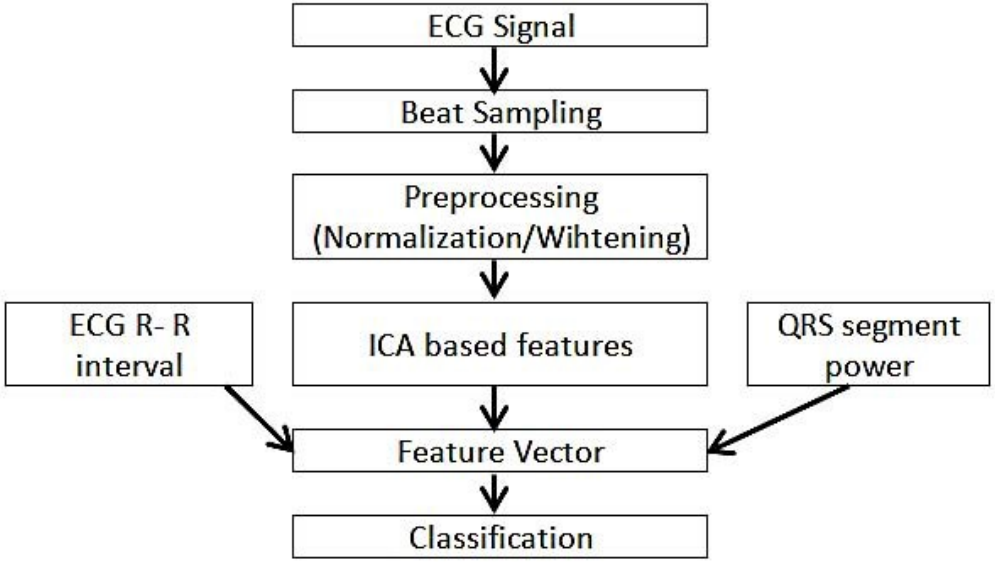
# 2. Using Independent Component Analysis to Obtain Feature Space for Reliable ECG Arrhythmia Classification

- **Authors:** Mohammad Sarfraz, Ateeq Ahmed Khan and Francis F. Li
- **Publisher**: IEEE International Conference on Bioinformatics and Biomedicine.
- **Year: 2014**

- In this paper the authors have proposed an algorithm that uses independent component analysis (ICA) to improve the performance of ECG pattern recognition.
- ICA is a statistical method for that is used to identify underlying factors or components that are statistically independent.



# 2. Using Independent Component Analysis to Obtain Feature Space for Reliable ECG Arrhythmia Classification

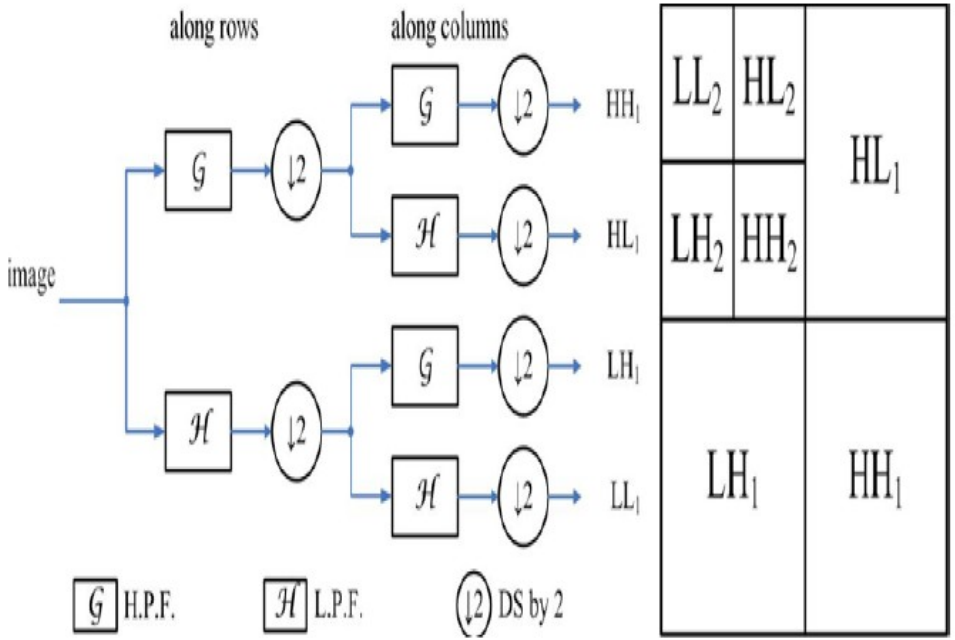


# 3. ECG Signal Feature Extraction and Classification using Harr Wavelet Transform and Neural Network

- **Authors:** K.Muthuvel, L.Padma Suresh, S.H.Krishna Veni ,K.Bharathi Kannan
- **Publisher** International Conference on Circuit, Power and Computing Technologies [ICCPCT] IEEE
- **Year: 2014**

- In this paper, Harr Wavelet Transform (HWT) is used in order to extract features from the ECG signal. Pre-processing and the classification of ECG signals is done using Forward Feed Neural Network.

# 3. ECG Signal Feature Extraction and Classification using Harr




Harr wavelet transform decomposes signal into elementary building blocks that are well organized in time and frequency.

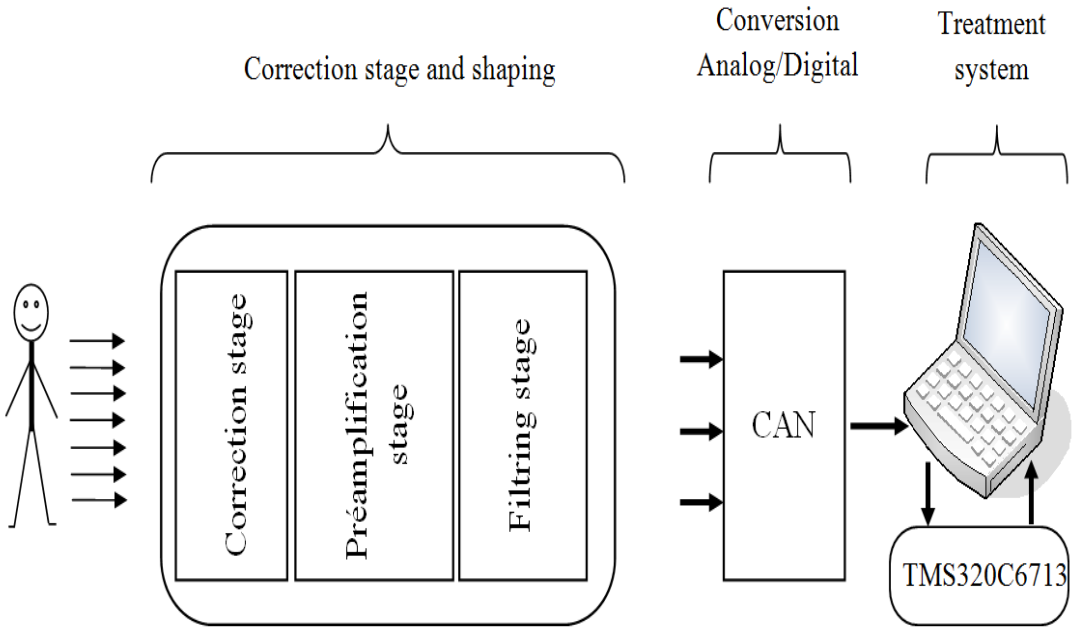
# 4. Acquisition and processing on DSP of a cardiac signal

- **Authors:** Meddour Cherif, Malika-Djahida Kedir-Talha, Malika Tighidet
- **Publisher** : IEEE 5th International Conference on Information and Communication Systems (ICICS), IEEE
- **Year: 2014**

- In this paper, a system for collecting cardiac signals with minimal equipment is proposed.

- This system reduces the size of the circuitry by using a processor specializing in audio processing which is the Texas Instruments TMS320C6713 DSP development board.

# 4. Acquisition and processing on DSP of a cardiac signal

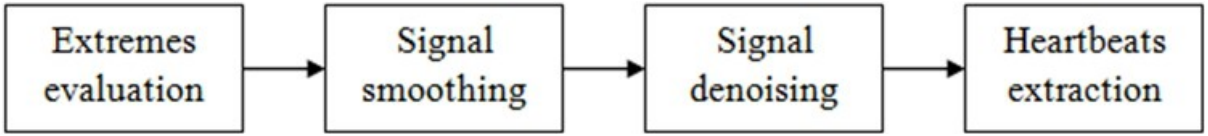


# 5. A New Method for ECG Signal Feature Extraction

- **Authors:** Adam Szczepa´nski, Khalid Saied, and Alois Ferscha
- **Publisher** : Springer-Verlag Berlin Heidelberg
- **Year: 2010**

- The authors have introduced a new method for ECG signal analysis.

- In this paper, authors have analyzed the ECG signal on the basis of voltage extremes and the time distribution of voltage extreme values.




The flow of the system

# 6. USING CORRELATION COEFFICIENT IN ECG WAVEFORM FOR ARRHYTHMIA DETECTION

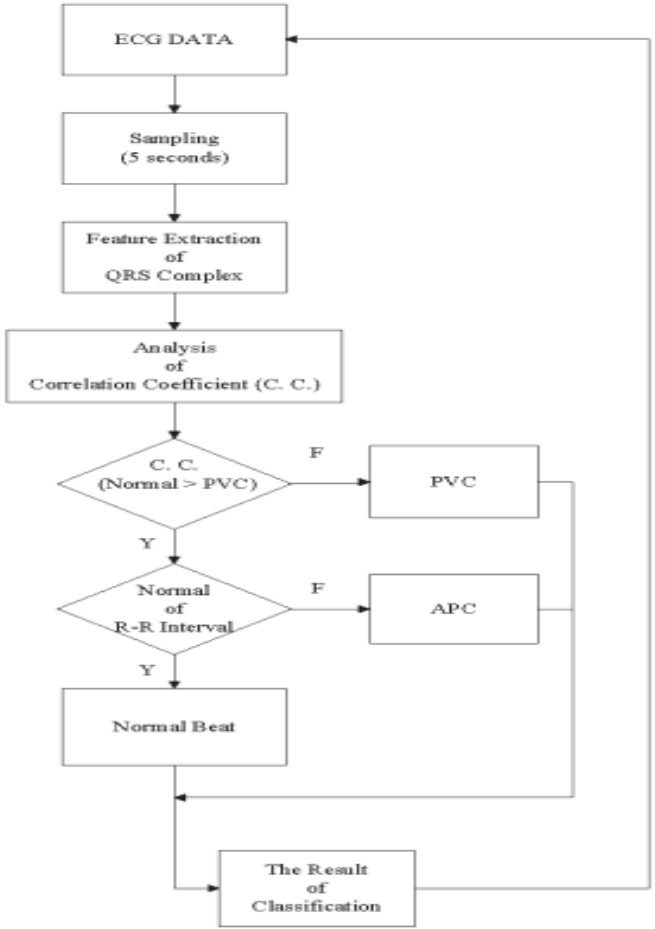
- **Authors:** CHUANG-CHIEN CHIU1,2, TONG-HONG LIN1 and BEN-YI LIAU

**Publisher**: BIOMEDICAL ENGINEERING APPLICATIONS, BASIS & COMMUNICATIONS

- **Year: 2013**

- *The main purpose of this study is to develop an efficient arrhythmia detection algorithm based on the morphology characteristics of arrhythmias using correlation coefficient in ECG signal.*
- The *algorithm was used to find the locations of QRS complexes. When the QRS complexes were detected, the correlation coefficient and RR-interval were utilized to calculate the similarity of arrhythmias*.
- The authors addressed two arrhythmias.
- Ventricular Premature Contraction (VPC)
- Atrial Premature Contraction (APC)

# 6. USING CORRELATION COEFFICIENT IN ECG WAVEFORM FOR ARRHYTHMIA DETECTION

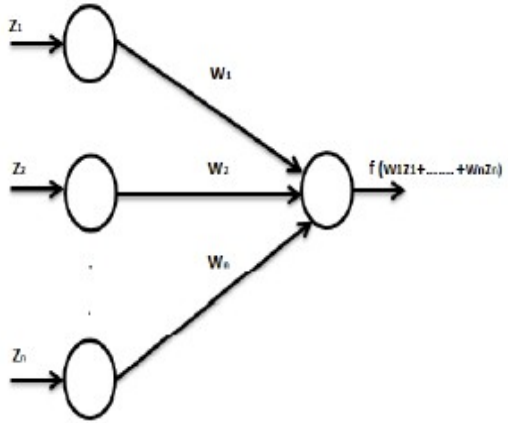


# 7. DSP Based ECG Abnormality Classification using Artificial Neural Network

- **Authors:** Prof. R.D.Thakare, Mr. V. P. Meshram, Mr. I. S. Chintawar and Mr. I. A. Patil
- **Publisher**: **:** International Journal of Advanced Research in Computer Science and Software Engineering
- **Year: 2014**

- The paper presents processing system based on a DSP Processor TMS 320C6711 for classification of various abnormalities.
- Authors have used Fourier transform for extracting the features of ECG signal.
- After getting the dataset, they are trained by using ANN.
- Authors trained the dataset on MATLAB.

# 7. DSP Based ECG Abnormality Classification using Artificial Neural Network



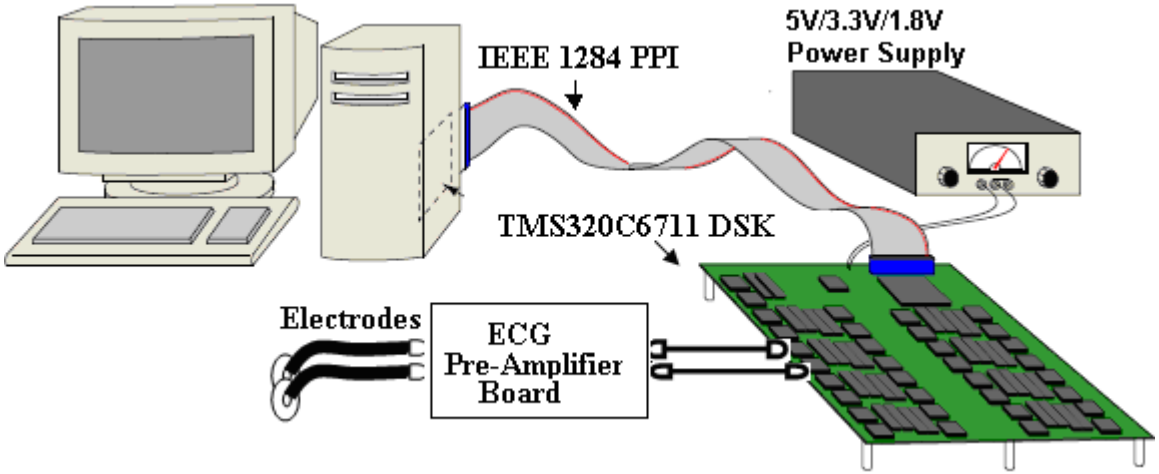

- ANN are parallel computation models as shown in figure.
- Here the individual element input z1,z2,……zn and multiply by weight w1,w2,….wn. The neuron has bias, which is summed with weight input to form net input.

# 8. Implementation of ECG Signal Processing and Analysis Techniques in Digital Signal Processor based System

- **Authors:** D. Balasubramaniam and D. Nedumaran
- **Publisher**: IEEE TRANSACTIONS ON INFORMATION TECHNOLOGY IN BIOMEDICINE
- **Year: 2014**

- *This work describes the implementation of wavelet-based de noising algorithm on electrocardiogram (ECG) signal and detection of important parameter such as heart rate, amplitude, timings of the ECG, etc.*
- *The algorithm is implemented in DSP (TI TMS320C67x) based starter kit (DSK) with a two-electrode ECG preamplifier. The signal from the ECG preamplifier is acquired through the Codec input of the DSP starter kit.*
- *The acquired data is subjected to signal processing techniques such as removal of power line frequencies and high frequency component removal using wavelet de-noising.*
- *technique. ECG component analysis such as QRS peak detection, heart rate calculation, etc is performed using nonlinear filter technique called first order derivative and moving average filter.*

# 8. Implementation of ECG Signal Processing and Analysis Techniques in Digital Signal Processor based System



# Conclusions from literature review

## What I will be adding in this field

# Conclusions from literature review

- Various methods for feature extraction and classification of ECG signal.

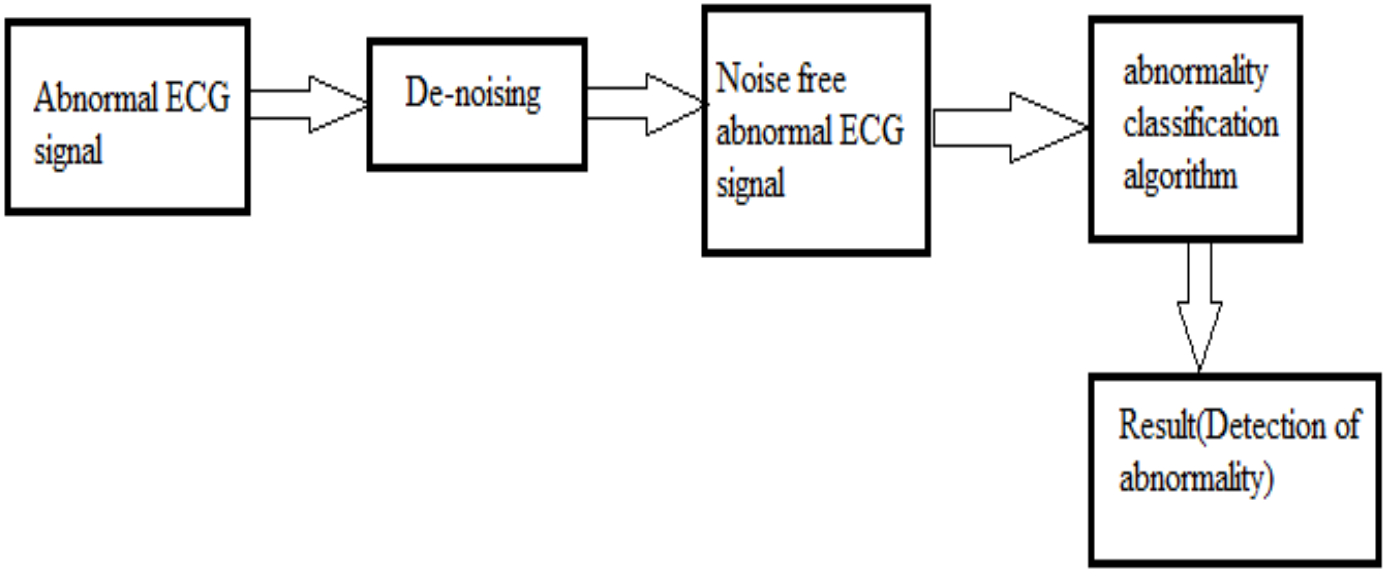
- Wavelet transform
- Principal Component Analysis(PCA)
- **Correlation**
- Artificial Neural Network(ANN)

# Conclusions from literature review

- We can see that there is no system which classifies the abnormalities of the ECG signal solely on a DSP.
- This fact makes these systems unattractive for real time use.
- The complexity level of the algorithms used in this systems is also quite high.(i.e. ANN). This makes their implementation very difficult.

# Overview of System

# Block diagram of the proposed system



# Morphology

- In a general sense, morphology means the study of shape. Different objects having different appearance and shape have different morphology. Morphology is how we perceive an object by studying its appearance.
- Different morphological characteristics of the ECG signal are listed below

1. Voltage extremes (amplitude)
2. Frequency
3. Time interval
4. Slope

- These are different morphological characteristics of ECG signal. We use them in our system to classify the ECG signal.
- This way of identifying signals with distinguish characteristics is an unorthodox approach and needs some more exploring.

# System components

# Texas Instruments TMS320C6713 DSP

- Features

  - 32bit floating point processor
  - operating frequency of 225MHz
  - Embedded JTAG support via USB
  - High-quality 24-bit stereo codec
  - Four 3.5mm audio jacks for microphone, line in, speaker and line out
  - 512K words of Flash and 16 MB SDRAM
  - Expansion port connector for plug-in modules
  - On-board standard IEEE JTAG interface
  - +5V universal power supply

# Software development tool

- **Code Composer Studio** (CCStudio or CCS) is an integrated development environment (IDE) to develop applications for Texas Instruments (TI) embedded processors.
- It includes an optimizing C/C++ compiler, source code editor, project build environment, debugger, profiler, and many other features.

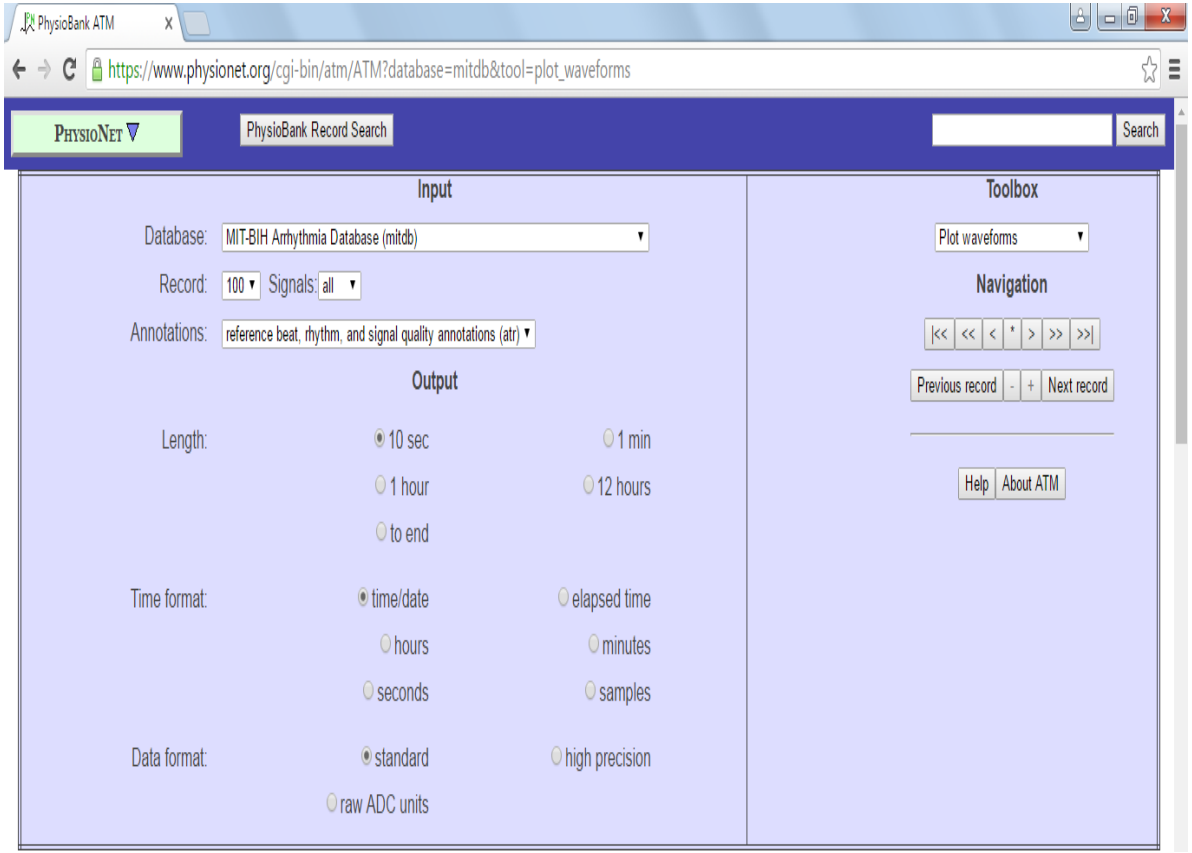
# Constraints with the CCS

- The main constraint with CCS was that until recently there were no Board Support Package(BSP) of TMS320C6713 for recent OSs like windows 7 & 8.
- These BSPs only supported OSs like windows xp and 2000 which are obsolete nowadays.
- It was crucial for me to find a BSP so I could work on my system at my home.
- I contacted the support forum of TI and found the BSP for windows 7.

# Work done

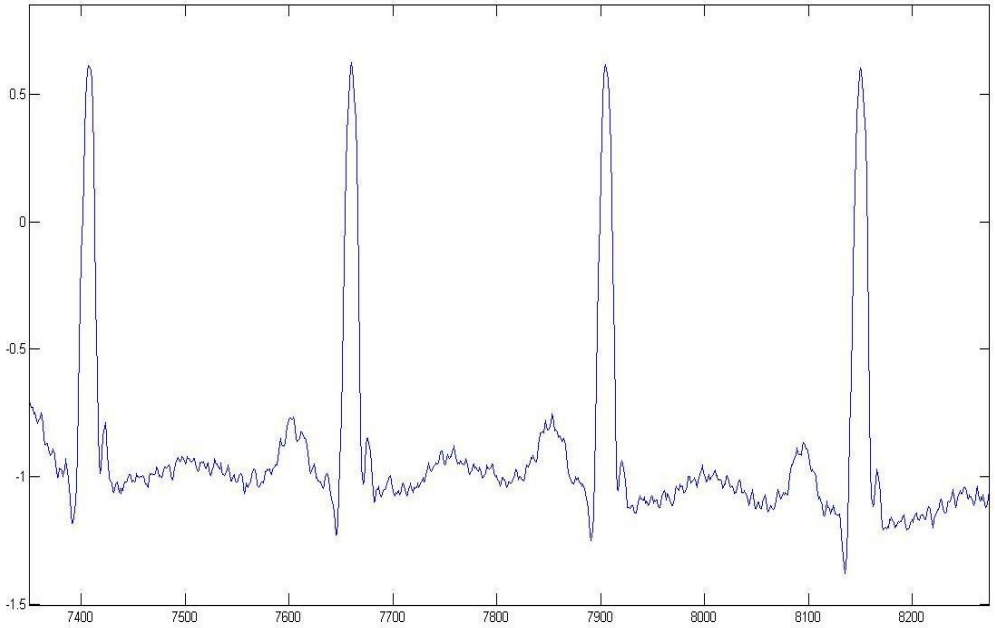
# MIT-BIH database

- All the ECG signals whether they are normal or abnormal are downloaded from the online database of MIT-BIH. This database and many other databases are on contained in a database called ‘PhysioNet ATM [14]’.
- This database contains the ECG data in many formats like .atr file format, .hea file format, .dat file format and it also gives data in text files. The data in this database are taw data, meaning they have not gone under any processing. So, we have to do some pre-processing like noise removal before we actually use the data.



# Pre-processing the ECG signal

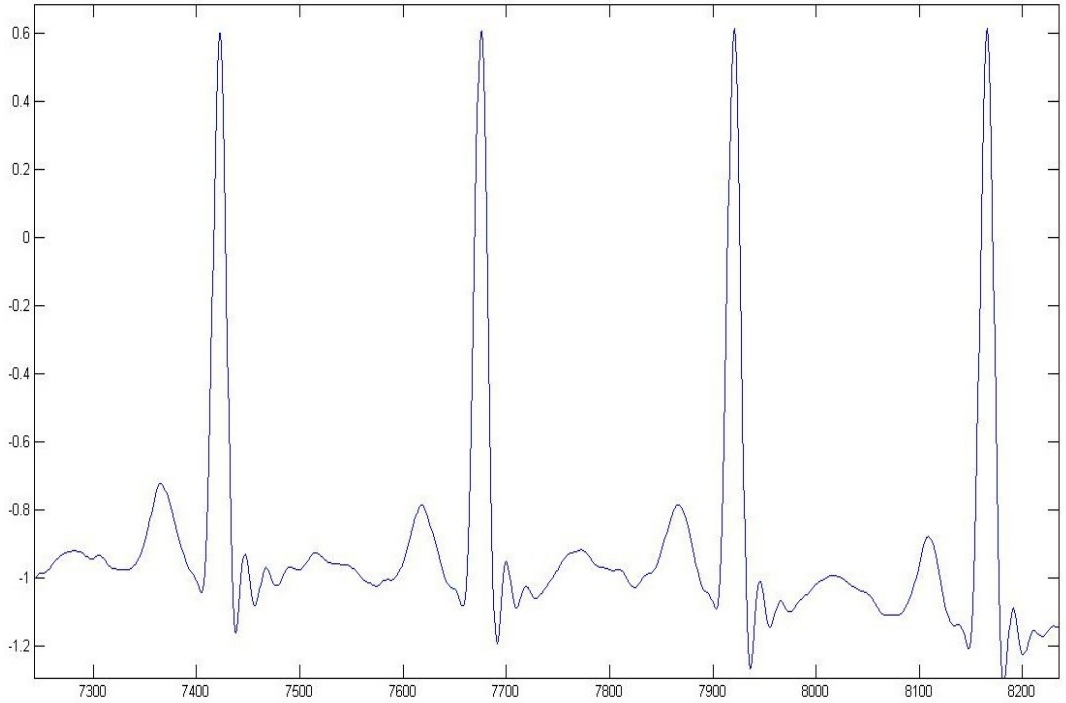
Noisy signal




- Here a noisy ECG signal is shown.
- To classify the signal it is very important to remove the noise from it.

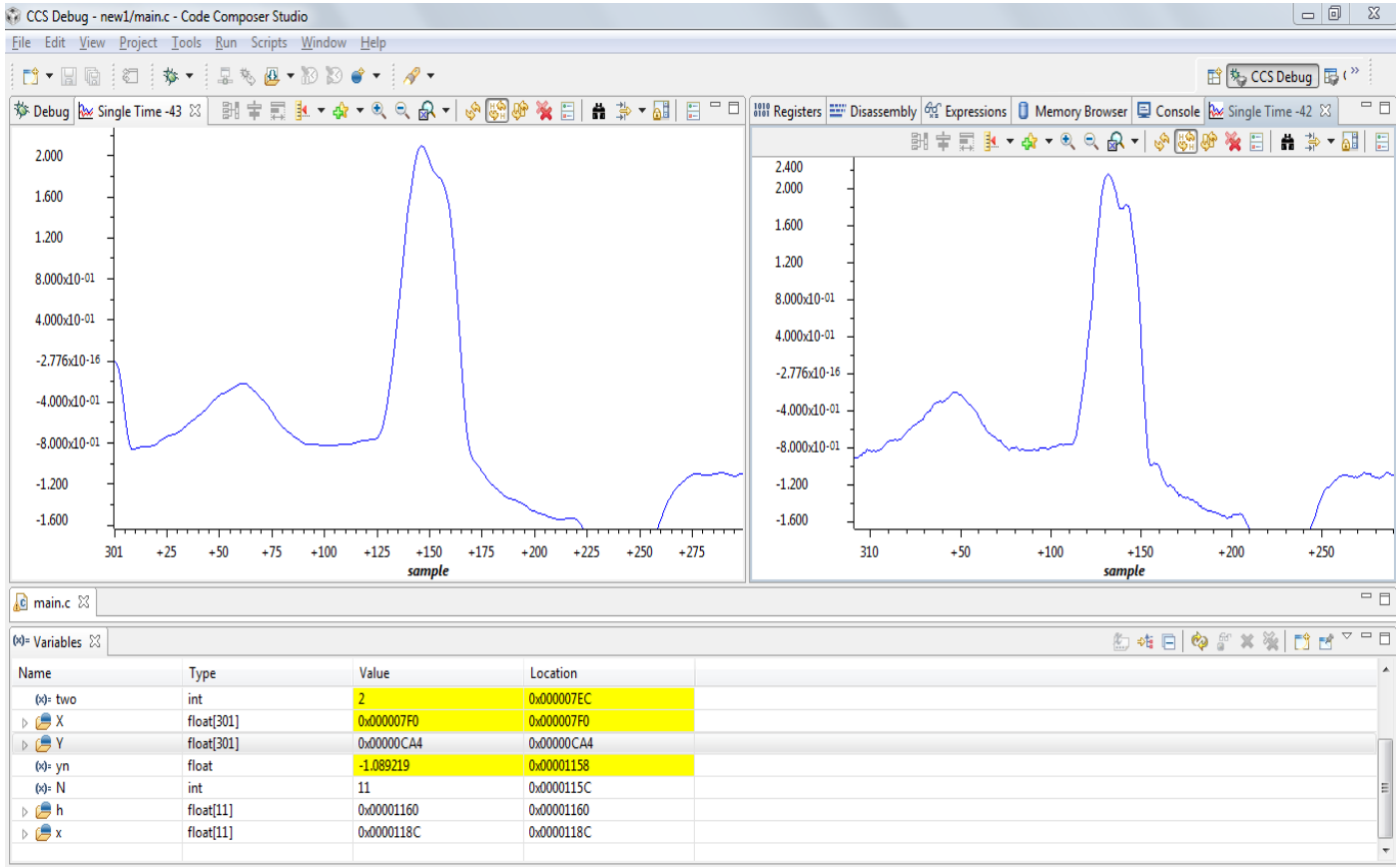
# Pre-processing the ECG signal

De-noised signal




- The de-noised signal is shown here.
- Here, we can see that the 50-60 Hz noise is removed and the signal is quite smooth.

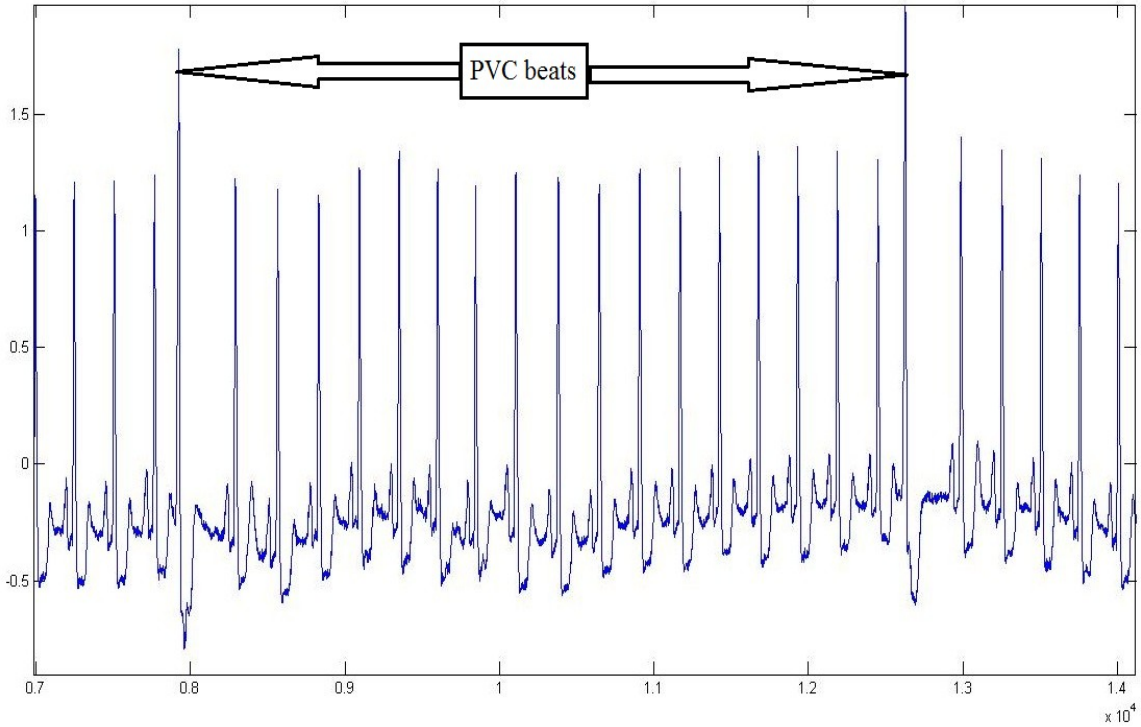
# filtering of ECG2 on DSP kit (record 106 of MIT-BIH)



# Abnormalities Addressed

# Pre-mature Ventricular Contraction(PVC)

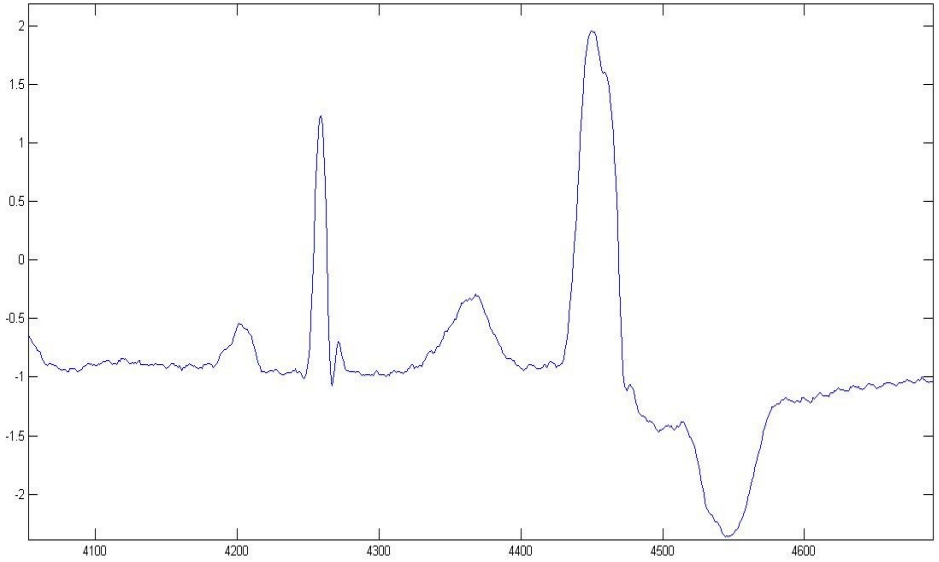
What is PVC???




Record 105

- Essentially PVC is a premature beat which arises between two regular beats.
- As the name suggests this premature beat occurs in the lower region of the heart (ventricles).
- This abnormality feels like a skipped beat in our chest.

# Pre-mature Ventricular Contraction(PVC)




- As we can see this abnormality has a distinctive characteristic in terms of amplitude and the slope of QRS complex of this beat is lower than that of a regular QRS complex.
- Utilizing these characteristics we can classify the signal.

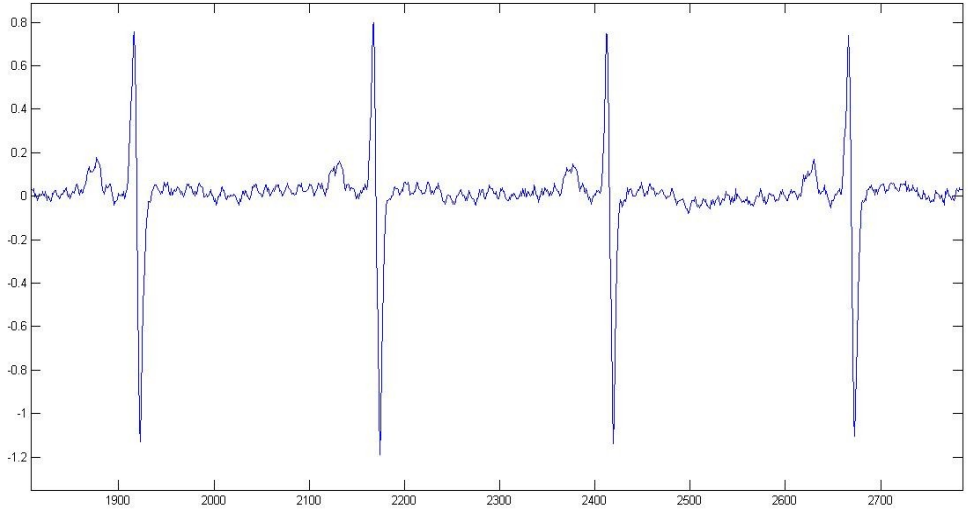
Record 109

# Atrial Fibrillation

Atrial fibrillation is a combination of rapid and irregular beating of heart. The QRS-complexes are not regular and sometimes P and T wave seem indistinguishable.

# Atrial Fibrillation

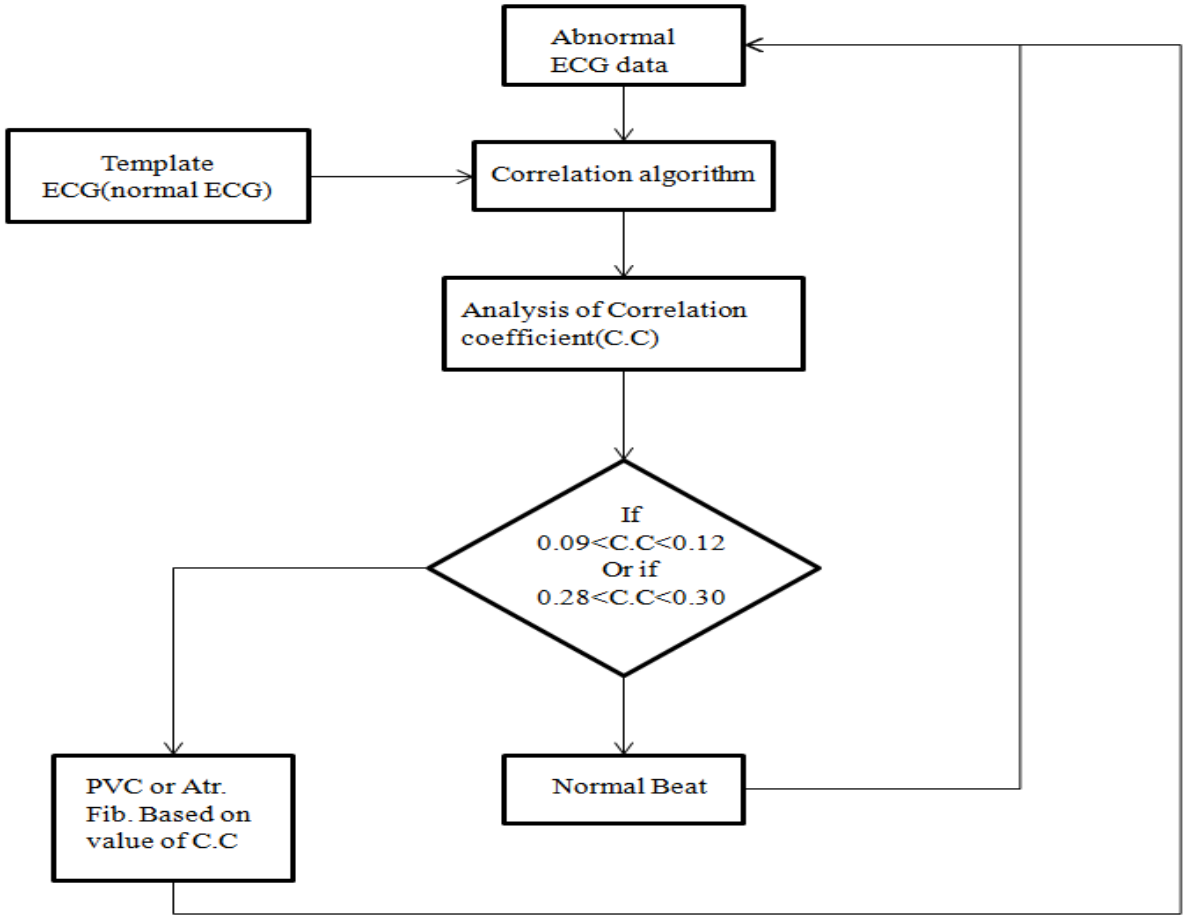
Actual atrial fibrillation signal taken from the MIT-BIH database record 05091 is shown below.



# Correlation Classification Algorithm

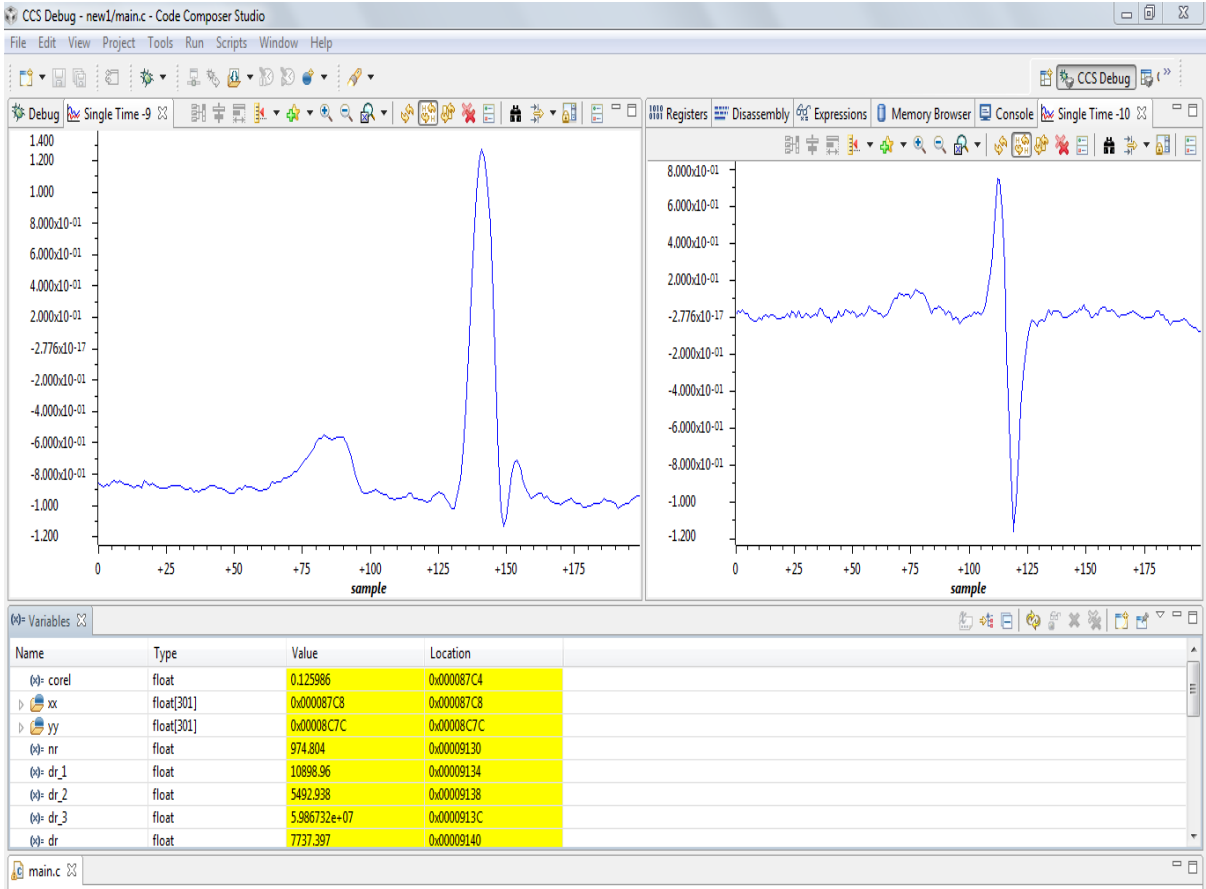
# Correlation classification algorithm

- This algorithm uses the distinguishing characteristics of abnormal signals in general to classify them.
- Meaning, all the abnormal signal have a set of features that make it different than others.
- Using this fact we developed an algorithm to correlate a template signal which is a normal signal and depending upon the value or rather the range of values the abnormal signals are classified.



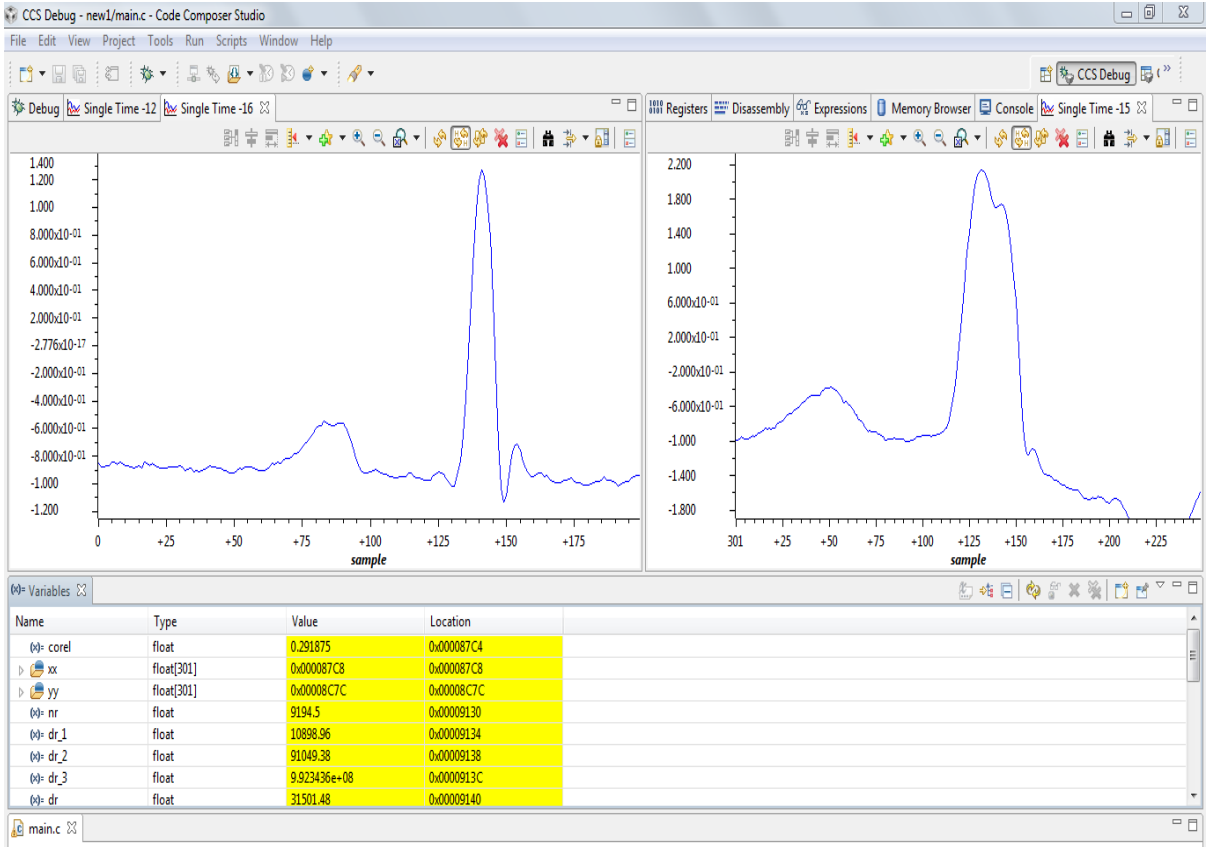
# Correlation classification algorithm for atrial fibrillation

- Here the screen shot of the digital signal processor is shown.
- The value of correlation coefficient for a normal beat and an abnormal beat with atrial fibrillation as abnormality comes in the range of 0.09 to 0.12.
- So for beats which have correlation coefficient in this range is classified as an abnormal beat having atrial fibrillation as an abnormality.



# Correlation classification algorithm for PVC

- The figure shows the result of correlation between a normal and an abnormal beat with premature ventricular contraction.
- The range for correlation coefficient for PVC beat and normal beat is in the range of 0.28 to 0.30.
- So the beats having the correlation coefficients in this range are classified as beats with PVC as abnormality.



# Results of Correlation classification algorithm for atrial fibrillation

| Sample file no. | Number of atrial fibrillation beats | Detected atrial fibrillation beat number | Accuracy |
|---|---|---|---|
| 05091 | 40 | 25 | 62.5% |
| 06695 | 35 | 22 | 62.8% |
| 06426 | 43 | 29 | 67.4% |
| | Total beats=118 | Total detected beats=76 | 64.06% |

# Results of Correlation classification algorithm for PVC

| Sample file No. | No. of PVC beats | No. of detected PVC beats | Accuracy |
|---|---|---|---|
| 119 | 37 | 26 | 70.27% |
| 106 | 30 | 21 | 70% |
| 105 | 07 | 04 | 57.14% |
| 215 | 19 | 12 | 63.15% |
| | Total beats=93 | Total detected beats=63 | Overall Accuracy=67.41% |

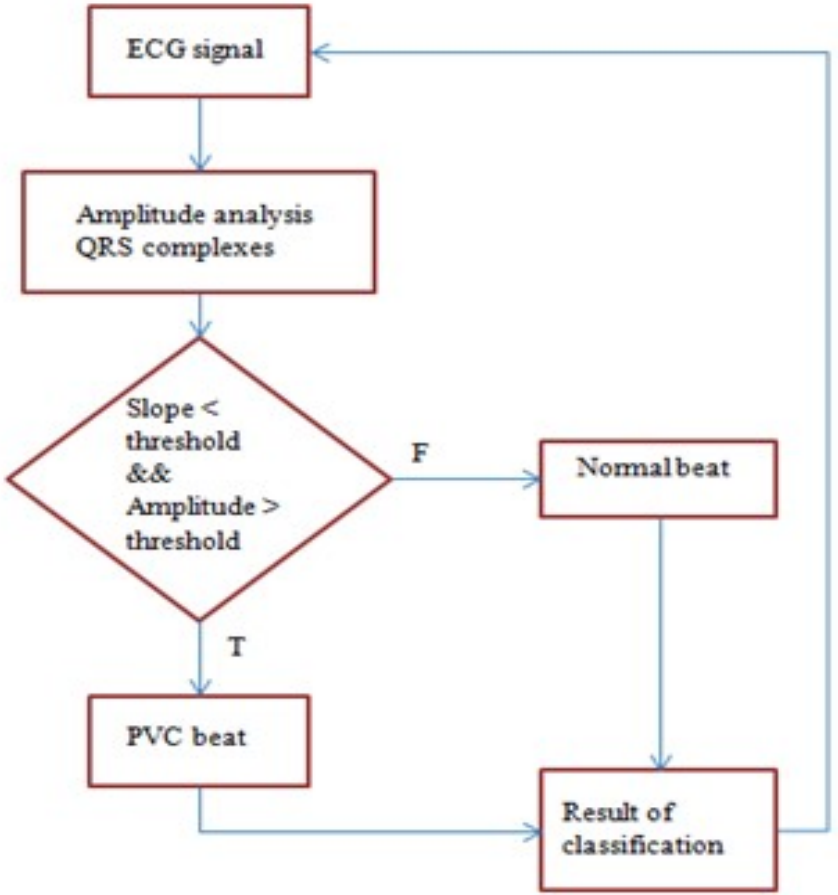
# QRS-Complex slope based Classification Algorithm

# QRS-Complex slope based Classification Algorithm

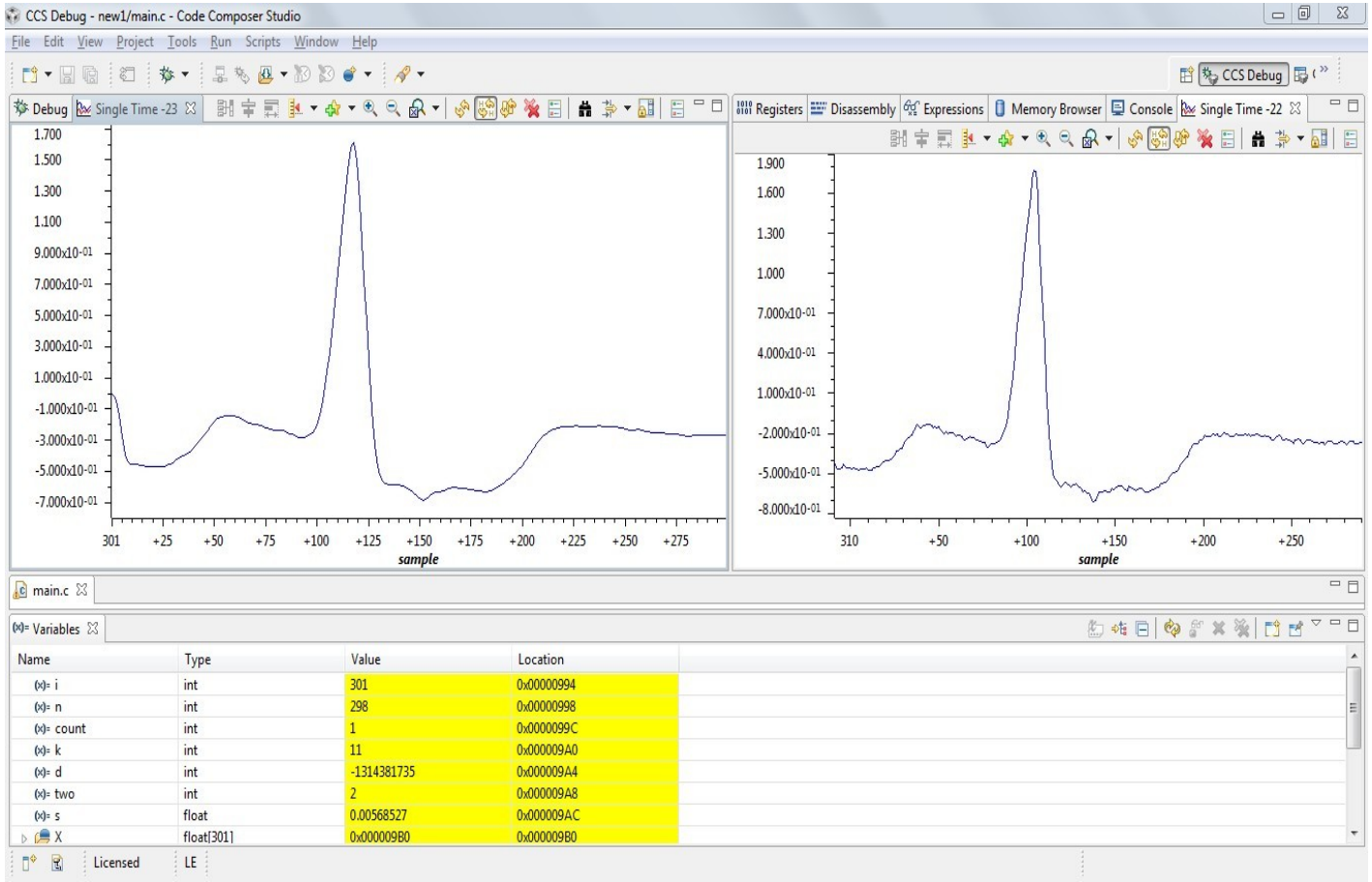
In this, algorithm two parameters slope and amplitude are used to classify the abnormal beats. As explained earlier, the PVC has broader waveform and higher amplitude than the regular normal QRS-waves. Using this fact to our advantage we classified the abnormal beat. The amplitude parameter is self-explanatory but the formula used for slope is given below.

$$slope = -2 \times x(n-2) - x(n-1) + x(n+1) + 2 \times x(n+2)$$

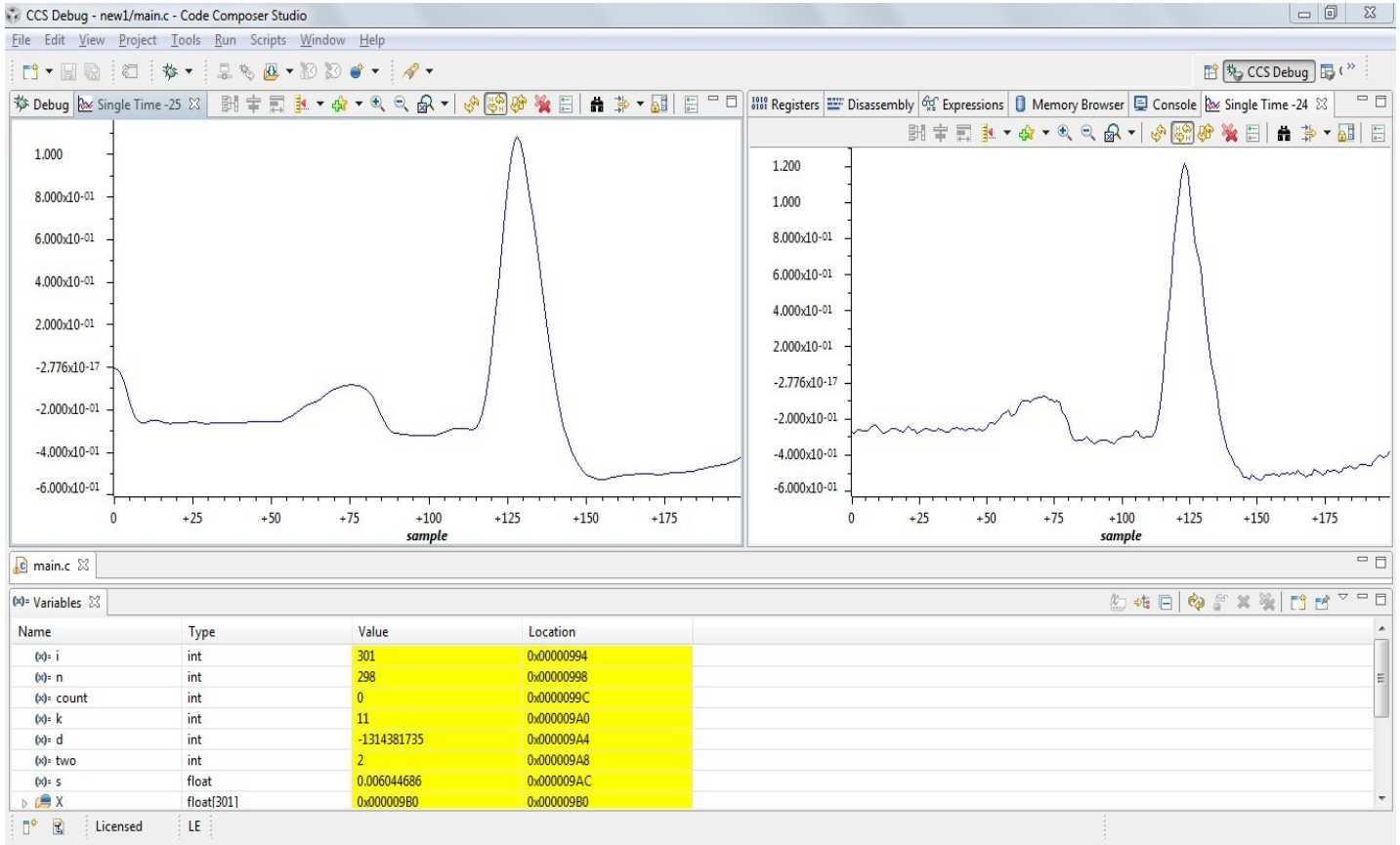
The reason for using four elements to count the slope is to increase the resolution of the end result which increases the margin between the value of slop for PVC beat and that of the normal beat.



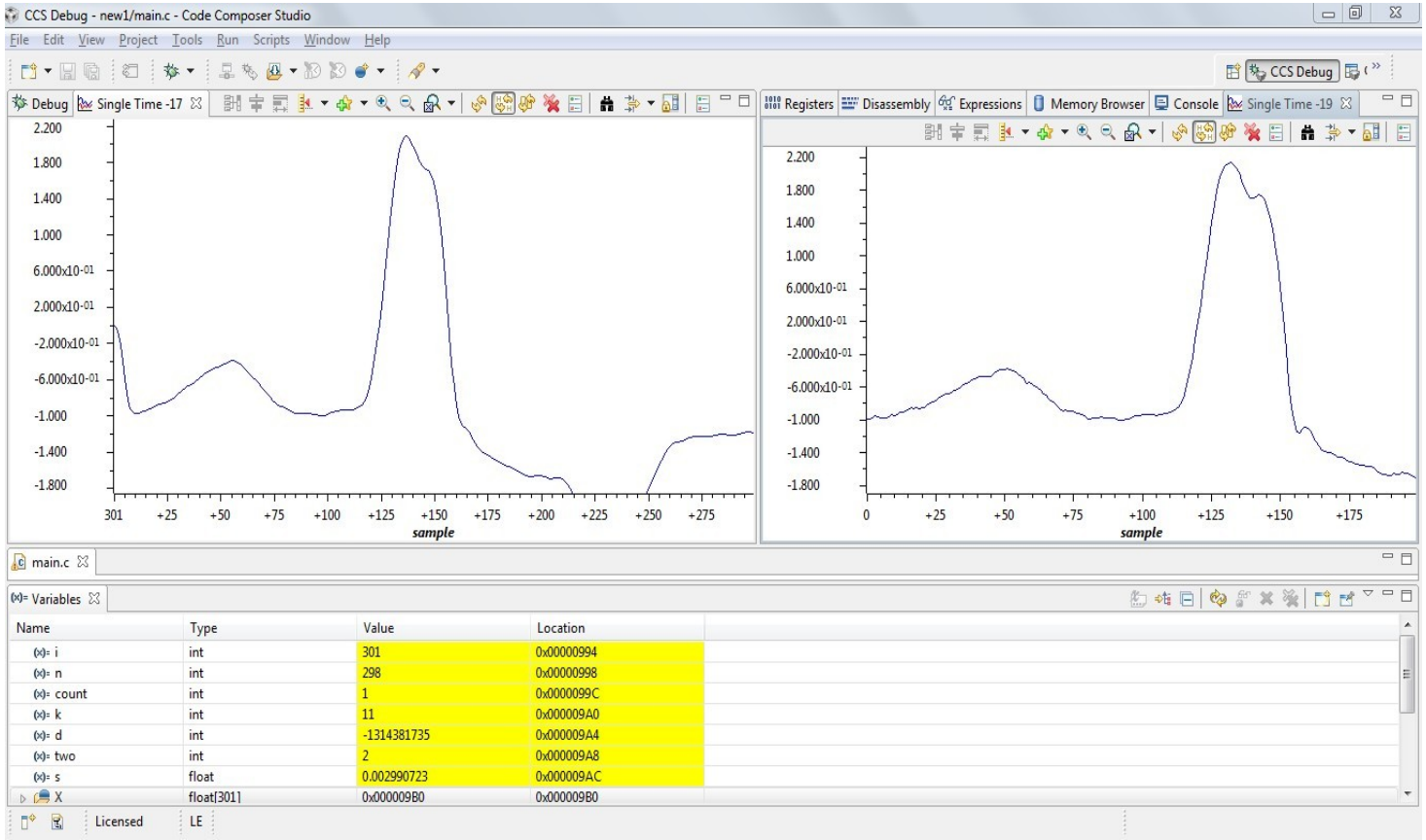
# Classification result of PVC beat of record 105 of MIT-BIH



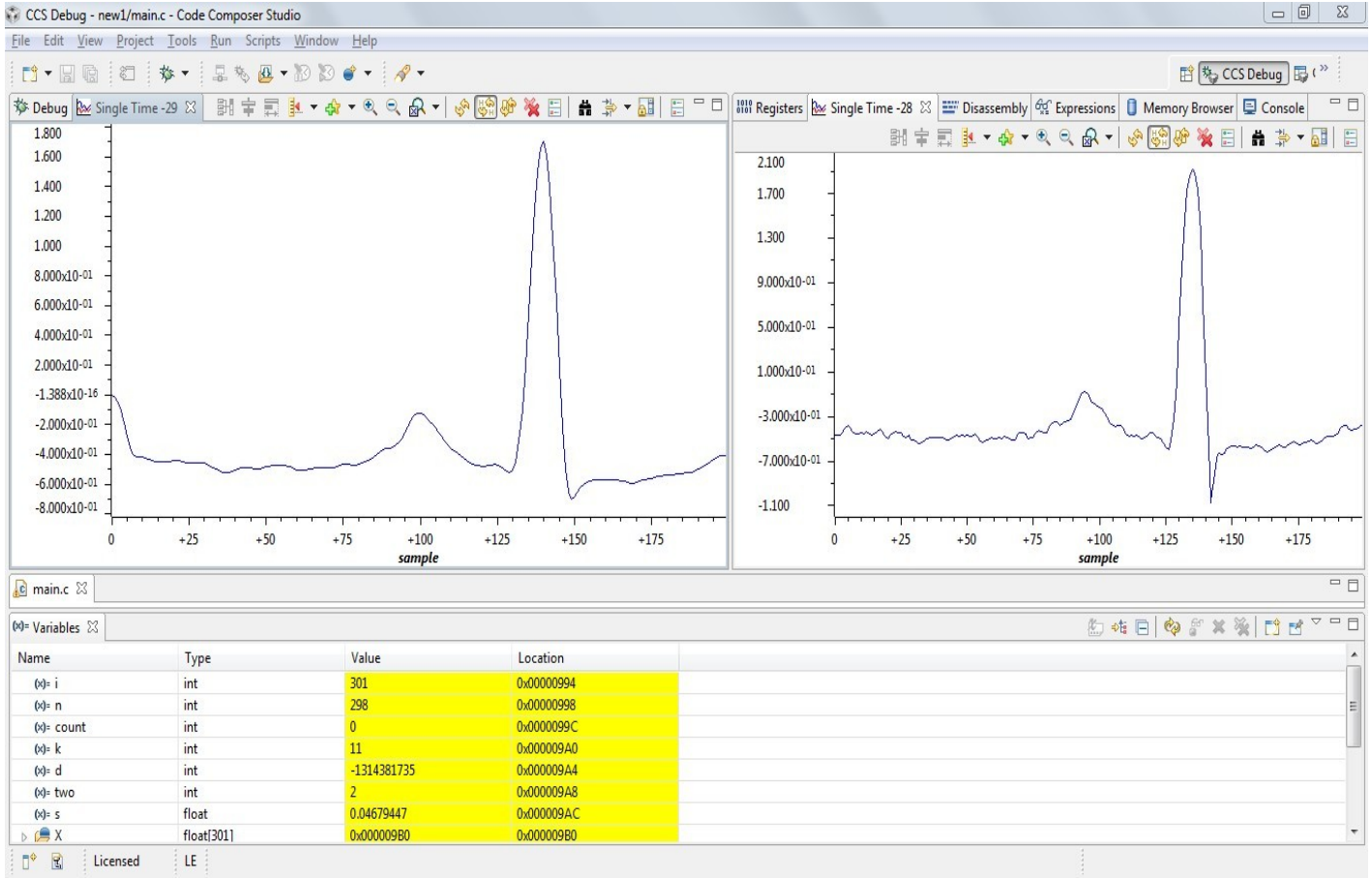
# Classification result of normal beat of record 105 of MIT-BIH



# Classification result of PVC beat of record 106 of MIT-BIH



# Classification result of normal beat of record 106 of MIT-BIH



# Results of the classification algorithm on MATLAB

| Sample file No. | No. of PVC beats | No. of detected PVC beats | Accuracy |
|---|---|---|---|
| 119 | 107 | 106 | 99.06% |
| 106 | 51 | 50 | 98.03% |
| 105 | 12 | 12 | 100% |
| 112 | 00 | 00 | 100% |
| 215 | 20 | 20 | 100% |
| | Total beats=190 | Total detected beats=188 | Overall Accuracy=98.94% |

# Results of the classification algorithm on DSP processor

| Sample file No. | No. of PVC beats | No. of detected PVC beats | Accuracy |
|---|---|---|---|
| 119 | 23 | 23 | 100% |
| 106 | 30 | 29 | 97% |
| 105 | 07 | 07 | 100% |
| 112 | 00 | 00 | 100% |
| 215 | 05 | 05 | 100% |
| | Total beats=65 | Total detected beats=64 | Overall Accuracy=98.46% |

# Paper publication

- A paper titled ‘abnormality classification of ECG signal using DSP processor’ has been accepted in the ”International Conference on Electrical Engineering and Computer Sciences(ICEECS) 2016”.

# Conclusions

- After surveying the literature we came to know that more focus is laid upon implementing classification algorithms on signal processing software and hardware implementation is being given less importance. Hardware implementation of algorithm makes it possible to use the system ideal for using it in real time.
- The exploitation of morphological characteristics of signals make it possible to reduce the computing efforts required to classify the signal.

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Thank you