A Soft Computing Approach for the Memory Storage of a Sound Signal Processor

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Abstract—**This paper tries to create a new biologically-inspired abstract model for the sound signal processing. The abstract model also shows the memory storage for the sound signal processor. This research adapts the functions from the biologically-inspired entities, which are the human auditory system and the human brain. This research aims to provide integrated and structured database to store the sound signal processing data. This research provides the framework to the implementation of the soft computing approach for the memory storage of a sound signal processor. This paper is a preliminary investigation paper. Therefore, this research creates the abstract model for the Biologically-Inspired Sound Signal Analyzer (BISSA) as a new idea for information gathering.**

Information retrieval; software engineering; information retrieval; noise filtering; signal processing, biologically-inspired

I. Introduction

Sound is one of the media that brings information to human. However this information also distracted by noises that surround us. Human can recognize to the required sound. Human can learn to the new sound. Human can concentrate to the sound that we want to listen only. Therefore, this research investigates the human auditory system and the human brain as the motivation to create an abstract model that capable to concentrate on specific required sound signal [1, 2, and 3].

There are several issues that related to signal processing and their storage. Here, for instances are some research that associated with the same issues. First we can see in the image processing area, the image captured often not clear and distorted by noise thus compromise the level detail of data. After that we have speech recognition research; it detects specific words or sentences only. Last but not least is the metal detector, the magnetic pole only discovers metal and cannot locate other structure [4, 5, 6, 7, 8, and 9]. All these area have the unstructured and unorganized storage for the signal processing. Hence, this research focuses on the sound signal processing and the storage to solve the unstructured and unorganized sound signal data storage. Thus, this research tries to create a solution for that is known as Biologically-Inspired Sound Signal Analyzer (BISSA).

Many related works have been attempting their own technique to handle the problems in this area. This research listed specific research questions to tackle the above problems. There are categorized in three (3) different perspectives.

- How can we design an abstract model that capable to demonstrate the sound signal analysis? Is it possible to show the process and storage for the sound signal analyzer?
- Is it possible to map the human auditory system and the human brain to be a sound signal analyzing system? How can we adapt the attributes from the biologically-inspired entities to analyzing the sound signal?
- How to develop a sound signal analyzer that responds comparable to the biologically-inspired entities?

Research goals give the answer to the research questions. These goals contribute solutions upon the problem in the area of information retrieval and information technology.

- To analyze the human auditory system and the human brain by studying how the sound signal can be detected, filtered, recognized, learned, and stored. Then, design the structural architecture of the abstract model for BISSA.
- To analyze the specific requirement of the biologically-inspired abstract model for sound signal analyzer by performing the preliminary and detail design for the sound signal analyzer. Then, propose a new algorithm for the sound signal analyzer.
- Apply the algorithm to an experimental application by simulating the sound signal analyzer and observe the accuracy of the result obtained.

This research brings many expected contributions. It solved the problem of recognizing and learning the sound signal by occupying the database model from the human brain attribute. The research will contribute to the information technology field in the following ways:

- A new theory for the process and storage of the sound signal analyzer; this presumption is by providing the sound signal analyzer with memory storage with less complexity in the database.

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- A new algorithm that capable to recognize specific record of sound signal; the order is by comparing the temporary detected sound signal with the predefined memory in the internal memory.
- A new algorithm that capable to learn the records of sound signal; which has a learning mechanism for any unmatched records and the records are kept for auto recognition in the future.
- A new application that capable to generate faster and better result with high accuracy; this result can be achieved by conducting a performance and performance analysis, and then propose benchmarking.

II. Construction of the Theory for BISSA

For BISSA, the intended signal frequency is called as definite sound. This definite sound is also the recognized signal frequency. Other than the definite sound are the noises or distortions. These signals are the learned signal frequencies. After analyzing the component of complex sound, this research found that the complex sound consists of the learned sound, recognized sound and the definite sound. Hence, the elements of the complex sound are represented as; Complex sound = {learned sound, {recognized sound {definite sound}}} [15]. Figure 4 shows the element of these sounds in the diagram form which built the component of the sound set. With the findings from the component of the sound set, it is used to set up the process flow for the sound signal analyzer.

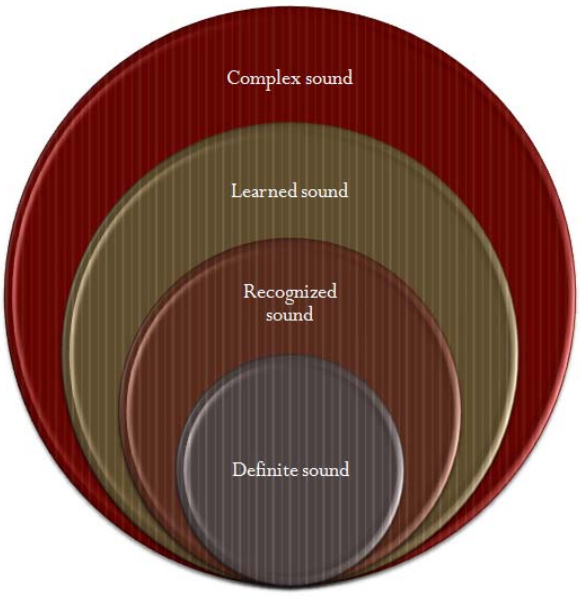

Figure 1. Sound Set [15]

The work of this paper adapts the biologically-inspired ability from the human auditory system and the human brain [10, 11, 12, 13, 14]. This paper observed the sound signal pathway from the outer ear, to the middle ear, and then the inner ear to the brain and the memory storage in the brain (see figure 2).

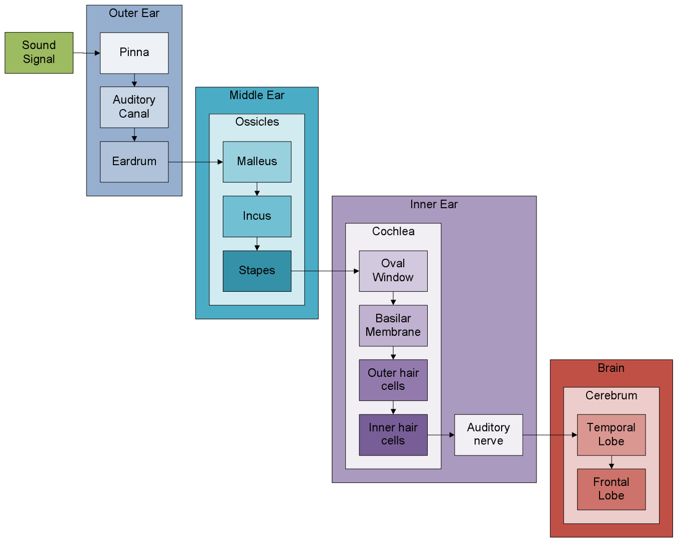

Figure 2. Sound Signal Pathway and Memory Storage

III. Abstract Model for BISSA

With the observation, a mapping of the biologically-inspired entities to a computational process is made. It helps to discover the functions to create BISSA. It also depicts the high level perspective of the system model. Table 1 shows the details.

TABLE I. Mapping the Biologically-Inspired Entities to the Computational Process

Biologically-Inspired Entities		Function	Description
Ear	Eardrum	Detect	Load the sound file into the system.
	Cochlea	Filter	System arranges the detected sound signal into different signal frequency ranges and updates the records into the noise table in the temporary storage.
Brain	Temporal Lobe	Temporary storage	Provide the noise table to store the temporary sound signal records.
			Provide the recognized table to view the definite sound signal records.
		Recognize	System compares the sound signal records from the noise table with the matched table in the internal memory and updates the matched records into the recognized table in the internal memory, and then retrieves the definite sound.
	Frontal Lobe	Internal memory	Provide the matched table to store the permanent sound signal records.
			Provides the learned table to view the learned sound signal records.
		Learn	System identifies the non-match sound signal records from noise table with the match table records and updates the learned sound signal records into learned table.

From the table, an abstract model is created. With this abstract model, it accomplished the first goal of this research which is to analyze the human auditory system and the human brain and study how the sound signal can be detected, filtered, recognized, learned, and stored.

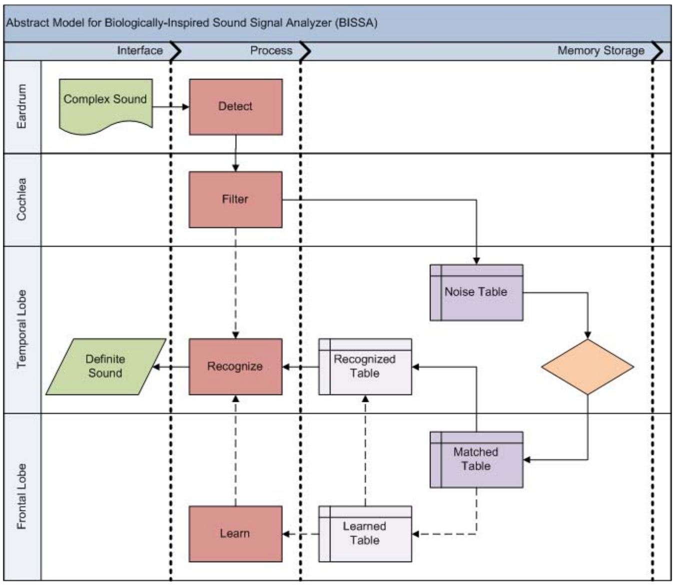

Figure 3. Abstract Model for BISSA

This paper planned necessary unique points for the abstract model. These unique points are the specific characteristics for BISSA, such listed below:

- BISSA MUST have user interfaces for receiving the input and displaying the output.
- BISSA MUST have specific processes for the sound signal analyzer.
- BISSA MUST have temporary storage (noise table) and internal memory (matched table) for the sound signal records.
- BISSA MUST have auto recognition mechanism and auto learning mechanism that compares temporary storage with the internal memory.
- BISSA MUST have the feature to view the recognized and learned records.
- BISSA MUST capable to generate the output which is the definite sound.Development of the Abstract Model for BISSA.

These specific characteristics are the requirement specifications needed for the development of the application for BISSA. With these requirements, it provides better solution for the design and the development of the sound signal analyzer.

IV. THE RELATIONAL MODEL AND ALGORITHM

With the analysis of the specific requirements for BISSA, this paper continues with the development of the second objective for this research which is to propose a new algorithm for the sound signal analyzer. The relational model and algorithm use symbols to represent the meaning of each entity. Therefore, a notations and definitions table is made to help a better understandings for the symbols used for the relational model and algorithm of BISSA.

TABLE II. NOTATIONS AND DEFINITIONS

Notations	Definitions
E	Eardrum
δ	Detect
C	Cochlea
φ	Filter
TL	Temporal Lobe
FL	Frontal Lobe
Γ	Recognize
ε	Learn
χ:σ	Complex Sound
Ψ:σ	Definite Sound
μ:Θ	Matched Table
ν:Θ	Noise Table
ε:Θ	Learned Table
Γ:Θ	Recognized Table

The relational model for this research is divided into two sectors which are the human ear sector and the human brain sector.

A. *Relational Model (Ear)*

The ear is divided into three sections: the external, middle and inner ear. The external ear consists of the pinna (or auricle), the external auditory canal (or ear canal), and the tympanic membrane (or eardrum). The inner ear is separated from the middle ear by another membrane, called the oval window. The middle ear contains three ossicles, or bones; malleus, incus and stapes, which connect both of these membranes and transmit sound to the inner ear [10]. As a consequence, the detection of sound signal is made by the eardrum and the filtration of signal frequency is made by the cochlea.

Within the bone of the cochlea are three fluid-filled chambers that are separated by two membranes. The input to the cochlea is in the scala vestibuli, which is connected at the apical end to the scala tympani. Pressure differences between these two chambers leads to movement in the basilar membrane. The scala media is isolated from the other two chambers. The human cochlea has different tonotopic area in the basilar membrane which exponential changes in the resonance frequency for linear distances down the length of the cochlea [11]. Accordingly, the sound signals are accumulated into signal noise and sorted in the cochlea for the brain to proceed with the next step of recognizing and learning the sound signals. Then, the sound signal travels through the auditory nerve that connected the human auditory system with the brain.

Let E = eardrum, where E is capable to detect sound signal. When E = detect, therefore δ = detect(). Let χ:σ = complex sound, where δ() convert the signal frequency file into binary records. Hence E = δ().

Let ν:Θ = noise table. Let C = cochlea, where C is capable to filter the binary records and store the records in the ν:Θ. When C = filter, therefore φ = filter(). Hence C = φ(), where φ() uses soft computing approach to arrange the binary records into sorted signal frequencies ranges and stores them in the ν:Θ.

B. *Relational Model (Brain)*

The human brain is interconnections of 100 billions of nerve cells that communicate with many others to overwhelm the neural circuit of the complex organization in brain. Each brain cell structure can receive input and process the output within the neuron cell. The auditory system in the brain concurrently interprets many sound criteria such as loudness, pitch, harmonics, and the timing of numerous sounds and from the resource. The cerebral cortex of the brain is divided into four (4) divisions. The important division of this research adapts the frontal lobe and the temporal lobe. The frontal lobe function's are for long term memory, problem solving, attention, creative thought, intellect, judgment, and others. Meanwhile the temporal lobe functions are short term memory, auditory memories, some hearing, music, some language, some speech, sense of identity, and other memory [13]. The important function of the brain is learning. "Glueing" or learning is based on Darwinian survival. Most connections between brain cells only last when they are used again. If used frequently dendrites and axons bond well together. This principle is called re-entry; to learn a new word you need to repeat it several times before you will remember it [14]. At this point, recognition and learning of the sound signal are made in the brain and the information can be observed out of the data collected.

Let $\mu{:}\Theta$ = matched table, $\varepsilon{:}\Theta$ = learned table, and $\Gamma{:}\Theta$ = recognized table. Let $\Psi{:}\sigma$ = definite sound. Let TL = temporal lobe, where TL is capable to recognize the $\Psi{:}\sigma$. When TL = recognize, therefore Γ = recognize(). Hence TL = $\Gamma()$, where $\Gamma()$ uses soft computing approach to compare the records in the $\nu{:}\Theta$ with the $\mu{:}\Theta$. Therefore, $\Gamma() = (\nu{:}\Theta \cap \mu{:}\Theta)$. View the $\Gamma() = (\nu{:}\Theta \cap \mu{:}\Theta)$ records in $\Gamma{:}\Theta$. Retrieve $\Psi{:}\sigma$ from the $\Gamma{:}\Theta$

Let FL = frontal lobe, where FL is capable to learn the $\Psi{:}\sigma$. When FL = learn, therefore ε = learn(). Hence, FL = $\varepsilon()$, where $\varepsilon()$ uses soft computing approach to compare the records in the $\nu{:}\Theta$ with the $\mu{:}\Theta$. Therefore, $\varepsilon() = ((\mu{:}\Theta)' \cap \nu{:}\Theta)$. View $\varepsilon() = ((\mu{:}\Theta)' \cap \nu{:}\Theta)$ records in $\varepsilon{:}\Theta$.

C. *Summary Ear + Brain*

Therefore,

- $\chi{:}\sigma \rightarrow (E + C + B) \rightarrow \Psi{:}\sigma$
- $E = \delta$
- $C = \varphi$
- $B = \Gamma + \varepsilon$
- $\Gamma = (\nu{:}\Theta \cap \mu{:}\Theta)$
- $\varepsilon = ((\mu{:}\Theta)' \cap \nu{:}\Theta)$

D. *Algorithm*

The algorithm is made based on the flow control for the application developed using the m-program in matlab, however the improvement will be updated during advanced development. The advanced technique of soft computing approach is still in the progress. Currently, we are attempting to show the sound signal processing and the memory storage based on BISSA application.

```
START
BEGIN E = δ()
CONVERT χ:σ → binary records
BEGIN C = φ(binary records) // using
  soft computing approach
STORE binary records → ν:Θ
BEGIN TL =  Γ() = (ν:Θ ∩ μ:Θ) //
  using soft computing approach
VIEW the Γ() = (ν:Θ ∩ μ:Θ) records ←
  Γ:Θ.
GET Ψ:σ → Γ:Θ
BEGIN FL = ε() = ((μ:Θ)' ∩ ν:Θ)
  //using soft computing approach
VIEW ε() = ((μ:Θ)' ∩ ν:Θ) records ←
  ε:Θ
END
```

The detect function does not need any new algorithm. This function only converts the sound file into binary form. This can be made using matlab. The filter, recognize and learn functions will implement the soft computing approach. The suitable approach to be used will be determined later. Examples of the advanced soft computing approaches are the implementation of neural network and fuzzy-logic to BISSA application. Hence, the dedicated approach will be justified. For the moment, we are trying to look the correlation of the records to produce output.

V. FUTURE PLAN

This research undergoes the following research activities:

- This research analyzed the issue for the memory storage for the sound signal processing.
- This research investigated the human biologically-inspired features and adapted their capability to create an abstract model for sound signal analyzer.
- This research developed an abstract model called BISSA [1, 2, 3].
- Currently, this research is developing a simulator using Simulink and Matlab to visualize how the abstract will execute. The status for the development of this simulator is currently in progress.
- In the future, to validate the process for BISSA, this research plan several experimental testing to prove that BISSA can work.
- Furthermore, this research will conduct a comparative analysis with other research to analyze the result for optimizing the memory storage for the abstract model of BISSA.
- After that, this research will make benchmarking for BISSA with the other research for better improvement.

VI. CONCLUSION

This paper is a preliminary investigation paper. There is no technical or scientific research presented in this paper. For the moment, this paper accomplished to settle two goals of this research. The first goal is to create an abstract model for BISSA. Then continue with the second goal which is to create an algorithm for BISSA. The final goal is to implement the abstract model to an application that can visualize the applicable of BISSA. This part is now in progress which is still developed.

On the other hand, the findings for the current research are such as the development sound set, mapping table of the biologically-inspired entities to the computational process, the abstract model for sound signal processing and storage which is built using block diagram, and the relational model and language for BISSA. Currently a Matlab application has been developing in progress to show an experimental application for BISSA. Upon the completion of BISSA experimental application, a performance and comparative analysis will be conducted. Therefore, benchmarking can be established for the current sound signal processing with memory storage application.

There are several issues during the Matlab application development based on the abstract model of BISSA. One of them is about specifying the attributes, by converting to signal frequency into the binary units for the storage. This could help to make the database storage much simpler and less complexity commencing to the contribution of this research. Other topic that is discussed during the application development is the implementation of neural network to the recognition process for BISSA. This matter is the same for the execution of fuzzy logic to the part of the learning process for BISSA. With all this concepts functioning through the application, this research looking forward to verify the abstract model by conducting the performance and comparative analysis. Hence, this research completes the whole objectives.

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