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Optimizing and Validating the Hypothalamic Hunger Regulation Mathematical Model

Ms. Divya, Dr. Saurabh Mukherjee
Department of Computer Science, AIM & ACT, Banasthali University, Banasthali-304022.

Abstract – Hypothalamus has a significant effect on the physiological functions of human body like Hunger regulation, Energy balance etc. A mathematical model is being developed which mathematically explains the functionality of Hunger Regulation. Some hormones also acts effectively during this process plays as important role in this model. Hypothalamic Hunger RegulationMathematical Model (HhRM). We are using statistical optimization tools to optimize and validate this Model. The concept of correlation and association based measures are used for validation and optimization.

Index Terms – Hypothalamic Hunger Regulation Model, Homeostasis, Correlation, Optimization

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1. INTRODUCTION

Hunger regulation is an important physiological function of human body. It involves three sub-processes i.e. Identification of the feeling of Hunger, Regulating this feeling from internal organs to Central Nervous system and Identifying the feeling of fullness which complete the homeostatic process. A number of Hormones also plays a significant role in the above three sub process of Hunger Regulation. These hormones are Ghrelin, Neuropeptide YY (NPY), Peptide YY and Cholecystokinin (CCK) and Amylin[4] [5] [6] [7]. These hormones are responsible for the Hormonal signals which generate the feeling of hunger, feeling of fullness and regulating the whole process from internal organ to brain via Vegal nerve (Vagus Nerve) [4][11].

This Hunger Regulation process is simulated with the help of Hypothalamic Hunger Regulating Mathematical Model (HhRM)[2]. HhRM is a mathematical approach for this homeostatic function of human body.HhRM divided into five different steps. Each step represents the combination of mathematical functions and variables. A simple binary function G (h) shows that whether the hormones are secreted by internal organs or not. The hormonal signals explain by the random numbers.Daubechies Wavelet function interprets the movement of Hormonal signals through Vegal Nerve.The response to the Hormonal Signals is being generated by the hypothalamic receptors. For this the concept of signal generation is used with scaling function with Entropy. The receptors signals transferred to Central Nervous system.

The mathematical model HhRM is as follows:

$$\frac{dH}{dt} = G'(h) + f(h)D4'(h) + \mathbf{Em}(s)Sc'(s)$$

Where$\frac{dH}{dt}$is the change in the processing of Hypothalamus, **H** with respect to Time t, **G(h)** is the binary function **f(h)** is fractal function, **D4'(h)** is the Daubechies function, **Em(s)** is entropy measure and **Sc'(s)** scaling function.

2. OBJECTIVE

The objective of our study is to optimize the mathematical model HhRM. In previous version of HhRM the simple scaling function was being used. Here our objective is to study the changes occur by using Gaussian function and B-spline Scaling function instead of simple scaling function and using the concept of power spectrum estimation for the Hormonal signals.

3. MOTIVATION

The following points instigate for the optimization of HhRM model:

- Gaussian function is recognized as a function which is optimal in time frequency localization [1].
- The Frequency Band selected for Neurogenic activity on the basis of local minima of average scolograms and physiological knowledge is 0.02 Hz - 0.06 Hz [8].
- Skewness i.e. the measure of the Lack of Symmetry can be applied on the receptor signals.

4. RESEARCH METHODOLOGY

The following set of steps explains the optimization process for the mathematical model HhRM:

Step-1: Instead of the simple random numbers generatorused in HhRM, we are usinga normally distributed random number generator which interprets the secretion of hormones from the internal organs like Stomach, Pancreas etc.

Step-2: Daubechies Wavelet function **D4 (h)**will be the same for the Hormonal Signal regulation via blood from internal organs to brain via vegal nerve with no optimization changes.

Step-3: In HhRM, a simpleScaling function (Sin Function)was used to generate the Receptor signals and a scalar Entropy measure function **Em(s)**was also being used to estimate the uncertainty in Receptor signals.

With our optimization strategies the given scaling function of HhRM is replaced by an optimal time frequency functions i.e. Gaussian Function with B-spline scale space. A suitably standardized uniform B-Splines can approximate the Gaussian function. By using B- splines scale function we can reach to the Scaled Gaussian Function i.e. a Gaussian function with uncertainty bound [1][3].

Step-4: To generate the Receptor signals, we also need the Entropy measure which gives us the hypothalamic signals. Our optimization strategy include the changes occur in Hypothalamic signal due to different Entropy measures which are Shannon Entropy, log energy Entropy and Threshold Entropy because with multiscale entropy we can analyze physiological data [10]. Since we are having neurogenic signals, we can set the threshold value to 0.06Hz which is the highest frequency from the frequency band based on the local minima of physiological studies and average scolograms for neurogenic activity.

Step-5: The hypothalamic receptors generate the signals based on the input came from internal organs as Hormonal signals. Thus we can say that the two set of signals are related linearly. As the result of it we can find correlation between the two set of signals (random numbers) using the Coefficient of correlation. This correlation must be positive as the increase in hormonal signals must increase the receptors signals i.e. the both set must have a positive correlation (Validation).

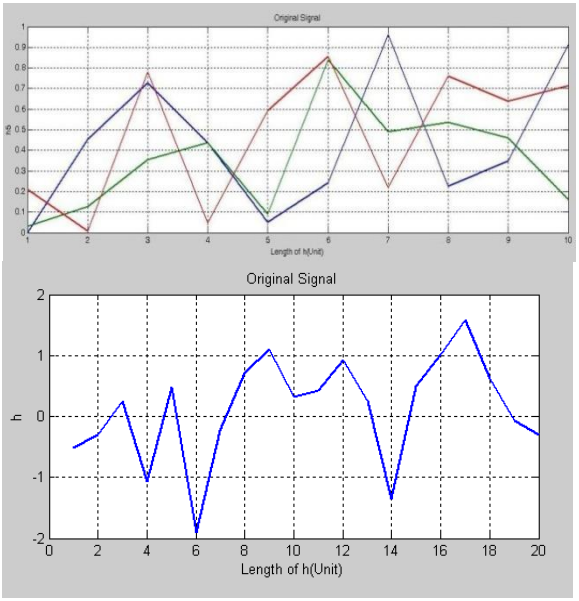
Table 1: The summary of the steps applied for optimizing the HhRM*

S. No.	Hunger Regulation Sub-Process	Function Used in HhRM	Function used to Optimize HhRM	Status
1	Hormone Secretion	**G(h): Binary Function**	G(h): binary function	No Change
		rand(r,c): Random number	Normally distributed random numbers	Change
2	Hormonal Signals	**Daubechies Wavelet function(D4(h))**	Daubechies Wavelet function(D4(h))	No Change
3	Signal generated by Hypothalamic Receptors	**Simple scaling function (Sinus Function)**	Gaussian Function with B-splines Scaling function	Change
4	Uncertainty	**Scalar Entropy function**	Wavelet Entropy function	Change
5.	Correlation and Measuring the Symmetry (Validate)	**Coefficient of Correlation**	Coefficient of Correlationand Skewness	

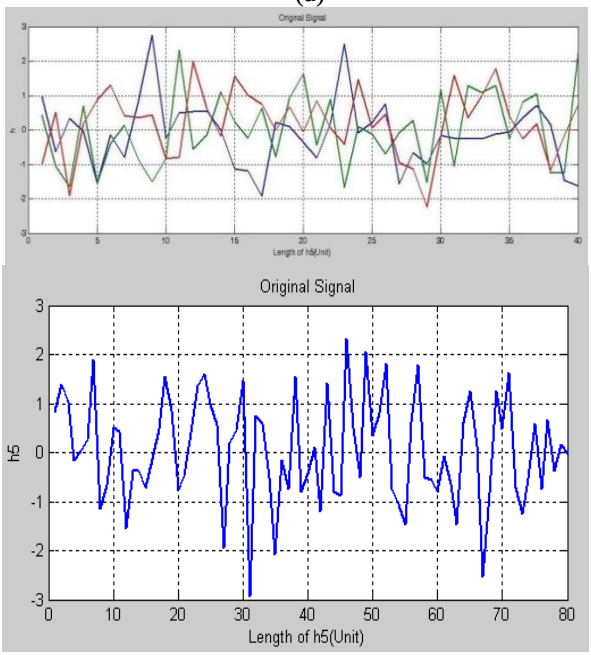
* **HhRM:** Hypothalamic Hunger Regulation Model

5. RESULTS AND DISCUSSIONS

In Figure (1) we can see the difference between the Hormonal signals generated by a uniformly distributed pseudorandom number(Figure 1(a)) and normally distributed random numberswith mean=0 and standard deviation =1(Figure 1(b)). We can get more scale in signals with the distributed random numbers. Also if mean=0 the than there is less stability in the frequency of signals.



(a)



(b)

Figure 1(a) & 1(b). The changes occur in Hormonal Signals after applying Step -1

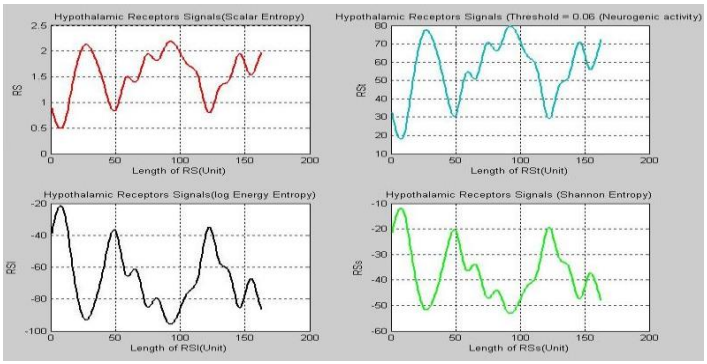


Figure 2. The change occur to Receptor signals if we replace scalar Entropy measure with Wavelet Entropy Measure with Log energy, Shannon Entropy and Threshold Entropy in HhRM(Step 4).

The Entropy measure function shows the additive type property of the hormonal signals. The signals plot In Figure 2 are the hypothalamic signals generated with the change in Entropy measures from Scalar Entropy measure to Wavelet Entropy measures i.e. Shannon Entropy, Log Energy entropy and Threshold Entropy. The threshold entropy calculated for the threshold value= 0.06Hz.

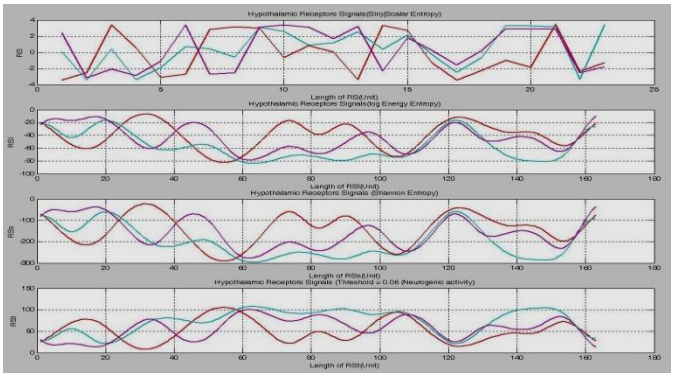


Figure 3 The optimized result i.e. the Receptors Signals after applying all the Steps discuss in Table-1.

The first sub-window of Figure 3 shows the Receptors Signals generated by previous HhRM and the other three sub-windows of Figure 4 shows the Receptors signals generated by the optimized HhRM. As we can see that the results (Receptors Signals) generated by the Optimized HhRM with Normally distributed random numbers, Gaussian Function with B-splines Scaling Function and Wavelet Entropy measures(Shannon, log energy, threshold), is more smooth than the previous HhRM.

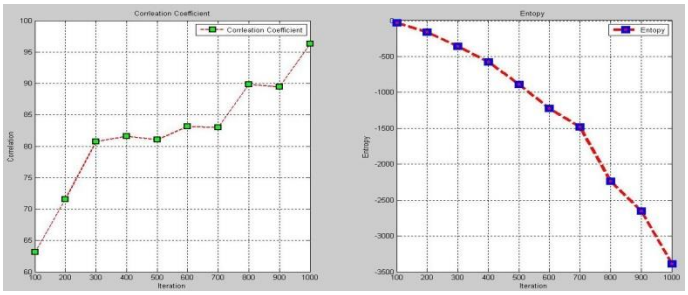


Figure 4.The change in Entropy measure and Correlation Coefficient as per the increase in dimension of the H(s), the Hormonal Signals (from dim = 100 to 1000) (Step-4 and 5).

There are two graphs in Figure 4. The graph in Figure 4(a) and (b) depict the changes in entropy values (log entropy) and Correlation Coefficient occurs as we increase the dimension of the Hormonal Signals (from 100, 200, 300 …..1000). The Entropy values decrease and the Correlation Coefficient values increases with the increase in dimension. Thus we are having a positive correlation between the Hormonal Signals and the hypothalamic Receptors Signals which also increases if increase the dimensions of the set of the signals which validate our result.

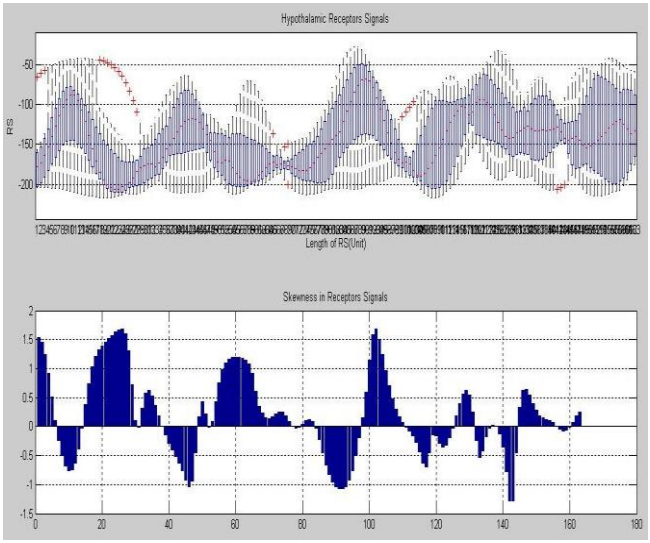


Figure 5(a) : The Skewness in Receptors Signals (Step-5)

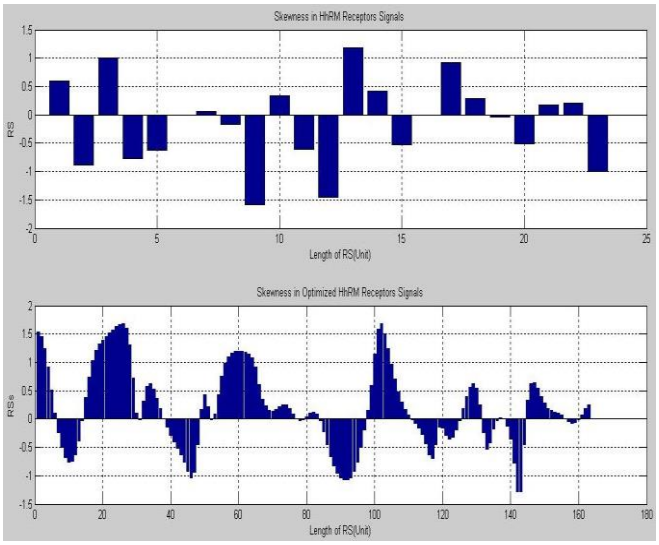


Figure 5(b): The Comparison between the Skewness in Receptors Signals resulted from HhRM and Optimized HhRM

The Skewness in receptors signals depicts the lack of symmetry in Receptors signals. In Figure 5(a) we can see that the Skewness for some signals is positive and for some its negative. The positive Skewness shows that Mean value of the Signals is greater than its mode or median and for negative Skewness it's vice versa. In Figure 5(b), the comparison shows more symmetry between the Hypothalamic Receptors signals of Optimized HhRM than the Receptors Signals of HhRM.

6. CONCLUSION

From the above results and discussion we can conclude that the Hypothalamic Hunger Regulation Model (HhRM)with Gaussian function and B-splines scaling functions and Entropy measure functions (Shannon Entropy, Log Energy entropy and threshold Entropy) gives better result than its predecessor. We can validate our results by two validating factors, Correlation Coefficients and Skewness. By using Skewness, we can measure the symmetry (lack of symmetry) in the Hypothalamic Receptor Signals and using Correlation Coefficient we can validate the correlation between the Hormonal Signals and the Receptors Signals which is positive.

7. FUTURE WORK

We can use Power spectrum Estimates techniques for signal representation in future. When hormonal signals travel via blood flow through vegal nerve, repeated patterns occurs where the significant role of fractals exhibits. Thus we can develop a fractal function which will represent the repeated pattern of shows in Vegal nerve's blood circulation.

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