Characterization of Blood Glucose Levels in Human as Chaotic Biological Signal

R. Penev[1] and M. Wada[2]

Abstract – **The Characterization method of the chaotic bi-signal in human is investigated. For the measured time series of bio-data, the internal dynamics with a form of vector field by using embedding method is constructed. In order to characterize and recognize such dynamic structure, we will be constructing in next paper the chaotic neural system artificially. Then we characterize the similarity by the synchronized or de-synchronized Responses among the artificial dynamics and the target internal dynamics of bio-signal.**

I. Introduction

Self-monitoring of blood glucose is an effective method to determine of the glucose levels [1-3]. The method is currently used by many diabetics for their treatment and blood glucose control. Typical values of the blood glucose [4,5] is as following scheme

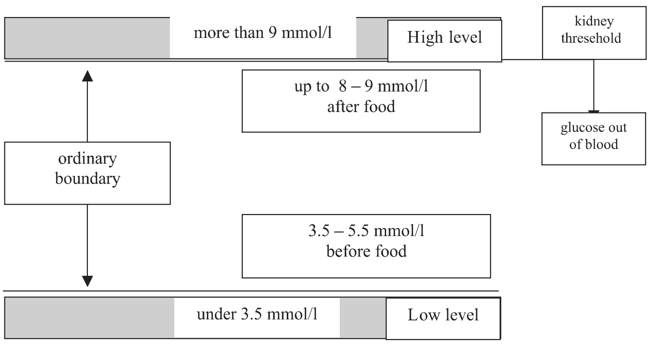

Fig. 1.

Good rectification

- level of blood glucose $<$ 10 mmol/l during twenty-four hours;
- before food $<$ 4 to 7 mmol/l
- 1 hour after food $<$ 10 mmol/l
- 2 hour after food $<$ 8 mmol/l
- level of hemoglobin **A1c** – from 4.5% to 7.5%
- glucoside hemoglobin **HbA 1c** – under 7.5%

Now, measurement of glucose in whole blood !

!!! An exception (See GLUCOWATCH of *Cygnus*)

Each measurements, used in this papers, are conducted by means of glucometer with characteristics described below:

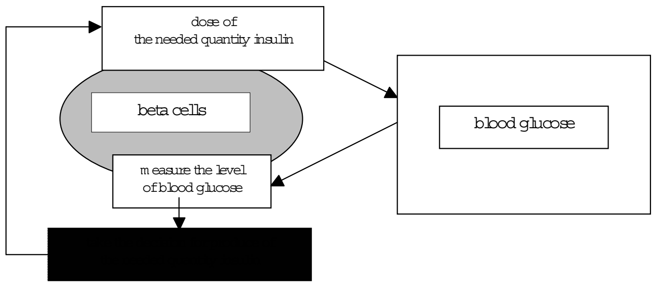

Fig. 2.

GLUCOCARD II (blood glucose test meter) – part from Operating Manual manufactured by: KDK KORPORATION, 57 NISHI AKETA-CHO, HIGASHI-KUJO, MINAMI-KU, KYOTO 601, JAPAN

Test: Glucose in whole blood

Sample size: Approximately 5μl

Measuring Range: 40-500 mg/dl (2.2-27.8 mmol/l)

Measuring Time: 60 seconds

Temperature Compensation: Automatically compensation using a built-in thermo-sensor

Calibration: Automatically selects the appropriate calibration curve by using a CALIBRATION Strip

Principle: The blood sample is drawn into the Test Strip through capillary action. Glucose in the sample reacts with glucose oxidase and potassium ferricyanide in the strip, producing potassium ferrocyanide. Potassium ferrocianyde is produced in proportion to the glucose concentration of the blood sample. Oxidation of the potassium ferrocyanide produces an electrical current which is then converted by the meter to display the glucose concentration.

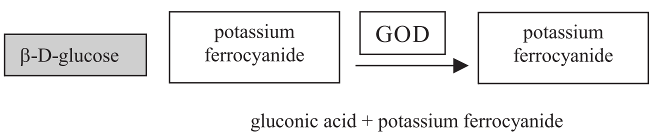

Fig. 3.

Following pages show experimental results from processing of data in environment of Matlab software

II. A Possibly Experimental System (A proposal for scheme of the measurements)

The experimental system is identical as described in [1-3]. In advance it is known that:

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- The hemoglobin has a property of adsorption of infrared ray [1-4]
- The hemoglobin contains an information for blood glucose [4,5]
- hemoglobin **A1c** – from 4.5% to 7.5% (good values)
- glucoside hemoglobin **HbA 1c** – under 7.5% (good values)

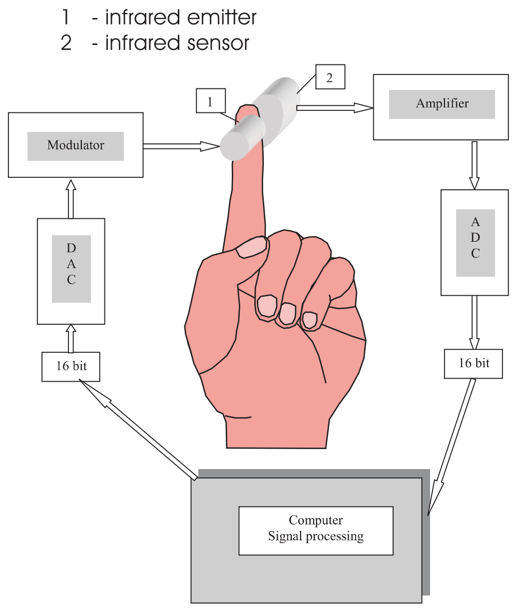


Fig. 4.

Outcome results: Time series as biological signal which contain information for the instantaneous values of levels of blood glucose

Problems: – How we can extract that information?
– What kind modulation will be effective with accordance of pursue goals?

Possible decisions (Application of Chaos Theory)

1. Embedding method
2. Mutual information
3. Correlation dimension
4. Time delay
5. Lyapunov exponent
6. Unstable Periodic Orbits

Images below are by means of [16] Software package NDT (Nonlinear Dynamics Toolbox)

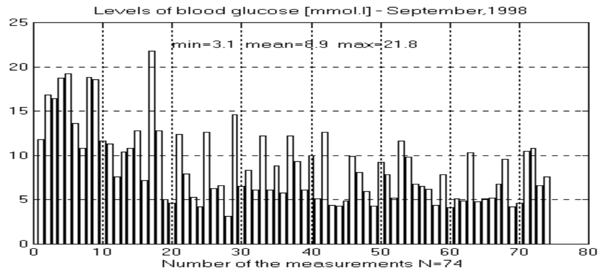


Fig. 5a.

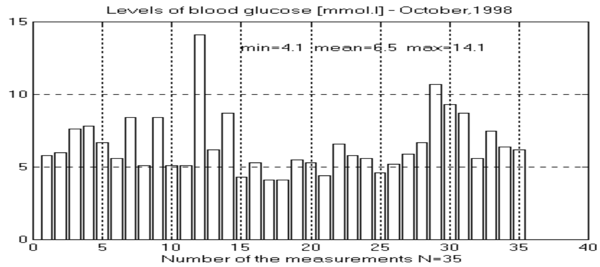


Fig. 5b.

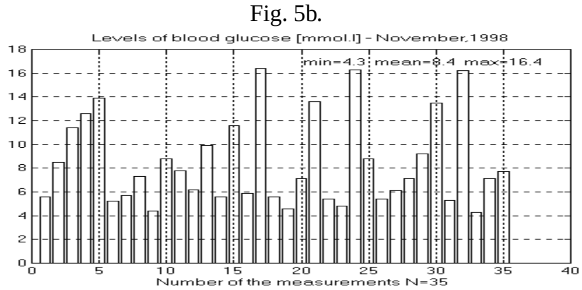


Fig. 5c.

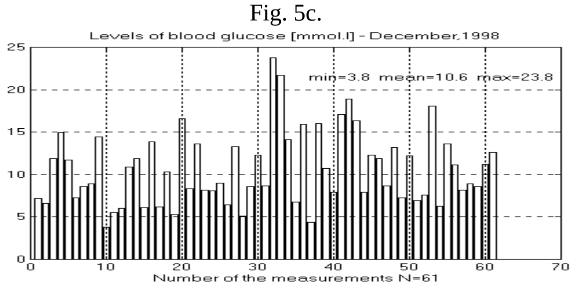


Fig. 5d.

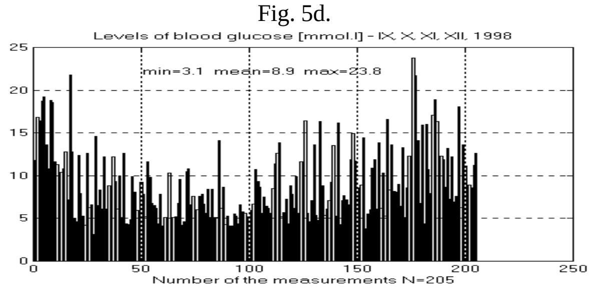


Fig. 5e.

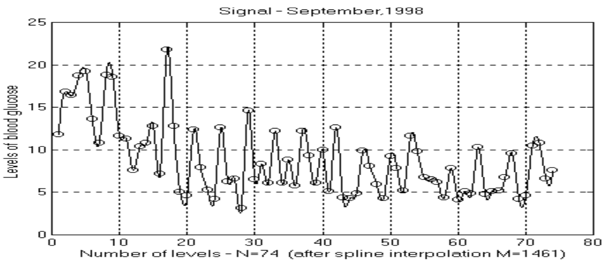


Fig. 6a.

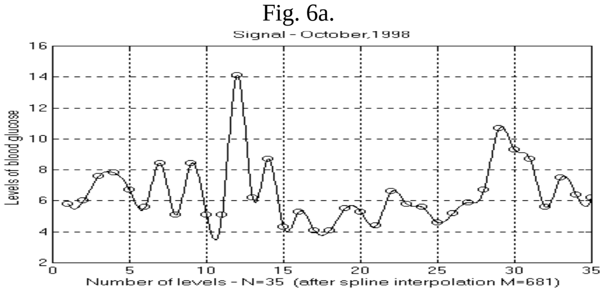
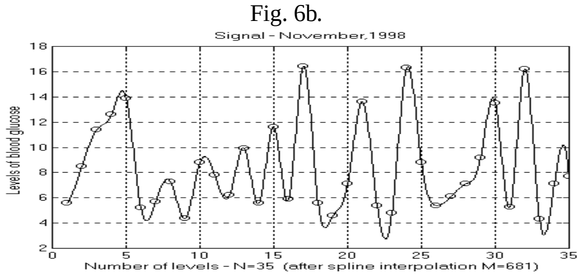


Fig. 6b.



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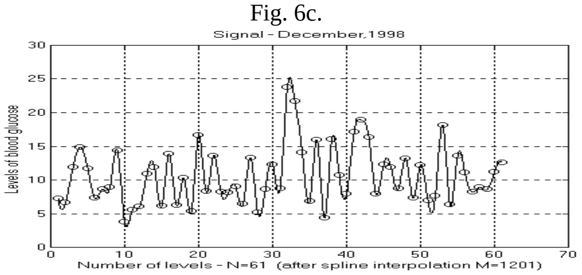


Fig. 6d.

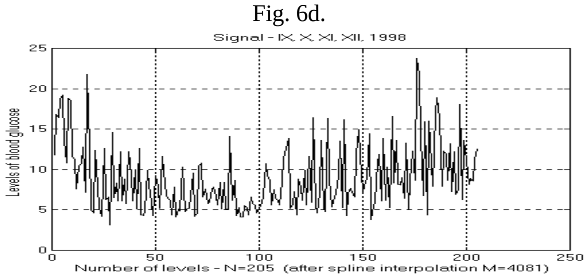


Fig. 6e.

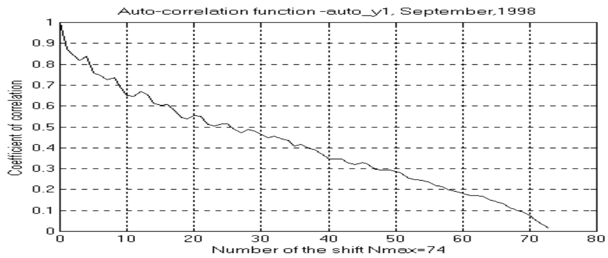


Fig. 7a.

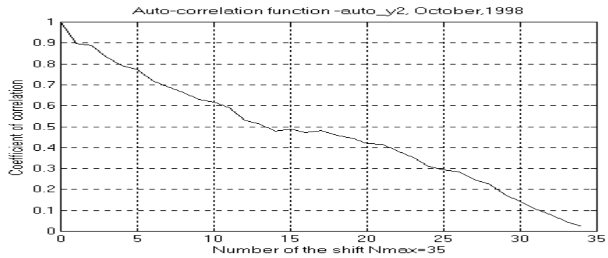
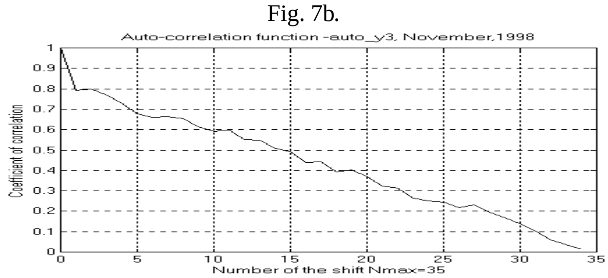


Fig. 7b.



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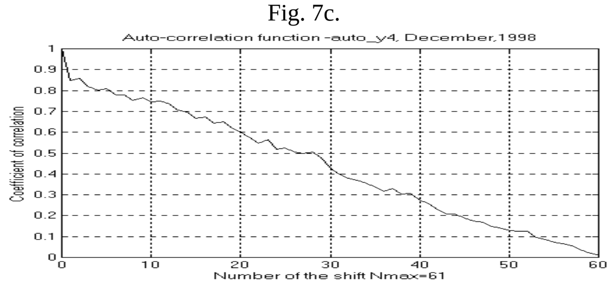


Fig. 7d.

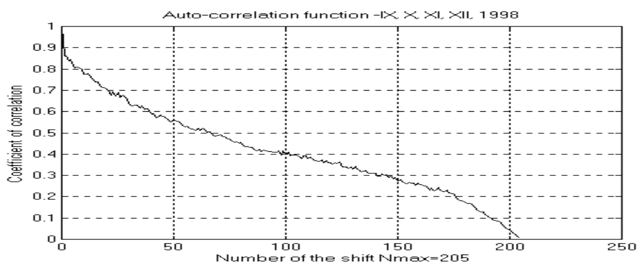


Fig. 7e.

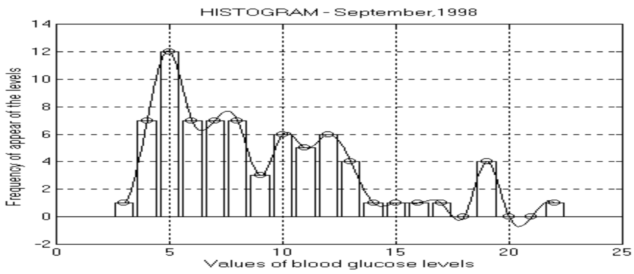
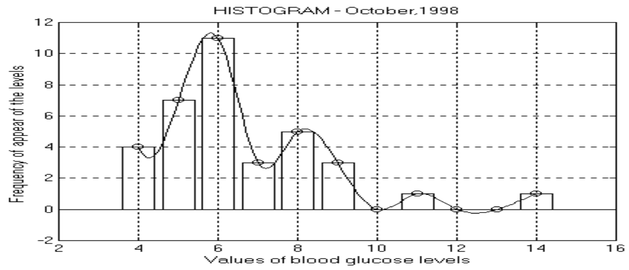


Fig. 8a.



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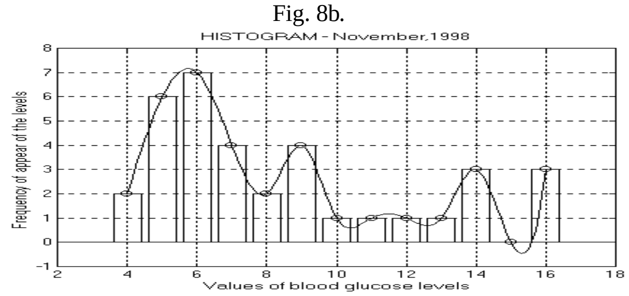


Fig. 8c.

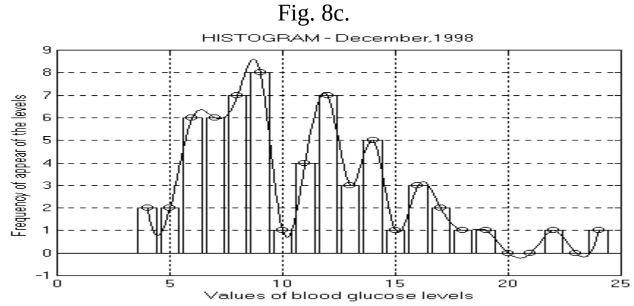
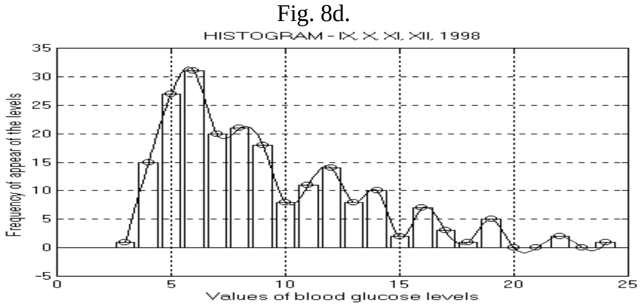


Fig. 8d.



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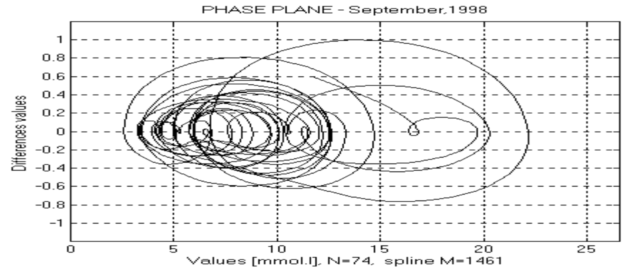


Fig. 9a.

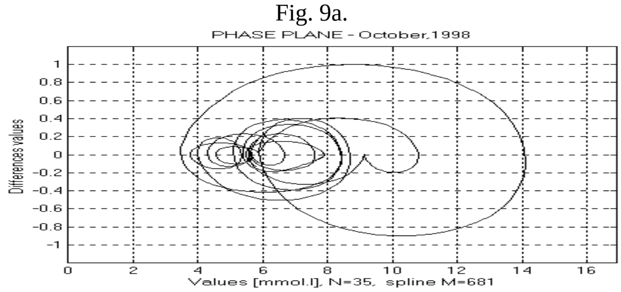


Fig. 9b.

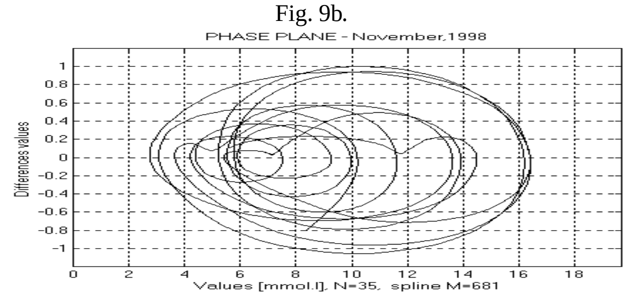
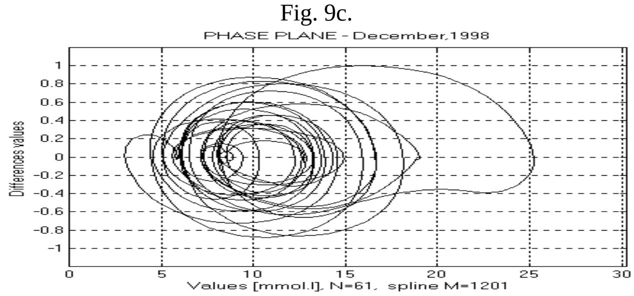


Fig. 9c.



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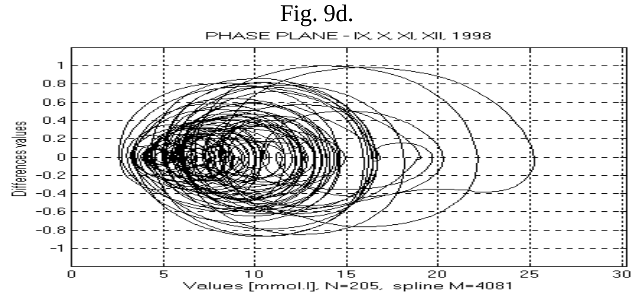

Fig. 9e.

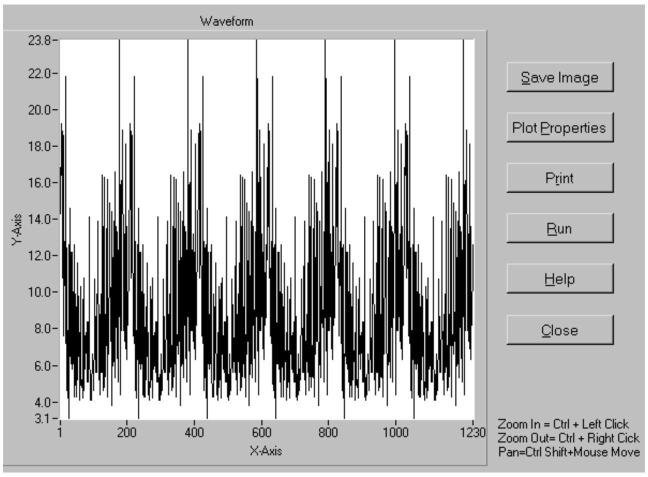

Fig. 10.

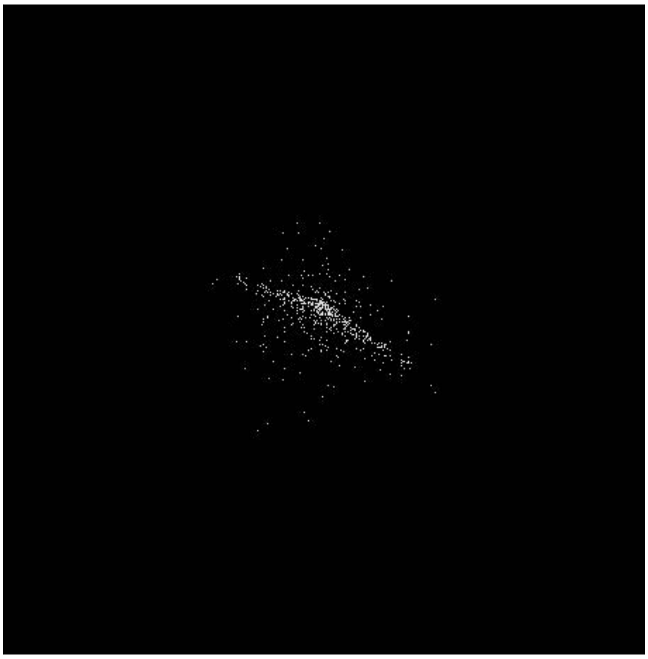

Fig. 11. 3-D plot of embedding data

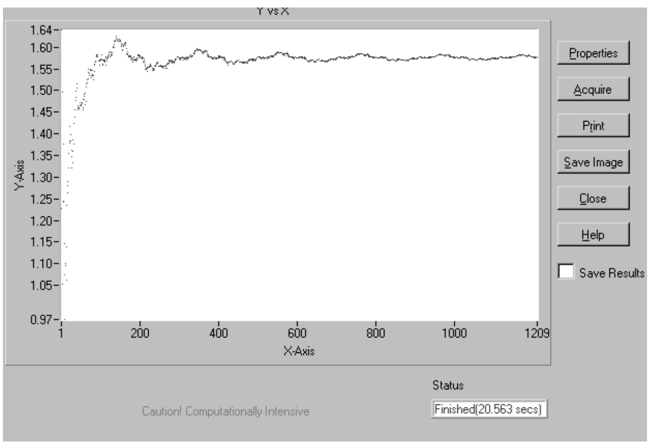

Fig. 12. Dominate Lyapunov exp.

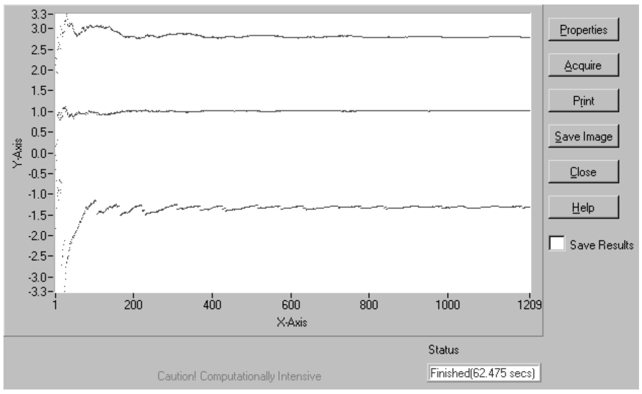

Fig. 13. Lyapunov spectrum

III. Conclusion

We found chaotic property in time series of data of human blood glucose levels. See positive Lyapunov spectrum and Lyapunov exponent. This is meaning that tools of analysis of chaotic signals are appropriate for this bio signal.

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