Critical Points of Extended Phase Space of Instantaneous Cardiac Rhythm as Cardiovascular System State Markers

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According to the World Health Organization (WHO) data as of 2011 reflecting the statistics of global causes of all death events in the universe, the cardiovascular diseases hold a leading position and are 31%.

This statistical data is indicative of the urgency of development of new high-accuracy and effective mathematical and computer aided techniques for cardiac rhythm investigation on the basis of Holter monitoring (HM) and mathematical modeling methods. The critical moment of this program is Holter monitoring-based imaging of mass data on instantaneous cardiac rhythm.

By now, the basic conception of evaluation and prediction of risks of formation of fatal cardiovascular complications is considered to be a cardiac rhythm variability (CRV) analysis. One of the upcoming CRV research trends is an instantaneous cardiac rhythm (ICR) analysis. The Holter recording (HR) technique allows obtaining ICR data within several days. Within 24 hours of HR a data set consisting of about 150000 data points can be obtained.

One of the most effective instantaneous cardiac rhythm (ICR) imaging methods is application of extended phase space (EPS) of ICR[1,2]. In this space, the ICR state is described by a point in the R^3 with coordinates $y(t)$, $v(t)$, $n(t)$, where $y(t)$ – ICR rate, $v(t)$ – ICR change rate, $n(t)$ – retry equal values y and v in different time moments. The numerical values of functions $y(t)$ and v(t) provided hereafter are in units of min^{-1} and $min^{-1}sec^{-1}$, correspondingly.

We wrote down and implemented the MAPLE programs allowing the real-time monitoring of the dynamics of EPS of ICR. In this work, we demonstrate the actual examples of this dynamics based on the results of Holter monitoring of patients of the Tver Cardiology Health Center,

It was demonstrated that the EPS structure corresponded with the patient statuses determined by standard cardiology methods.

There were found critical points of EPS of ICR representing the centres of attraction of phase trajectory. Geometrically this appears as high and narrow EPS peaks. Near the peaks, the phase point spends sufficiently long time thus giving deterministic tone to ICR. The critical points of EPS of ICR are determined by cardiovascular system state features, and undoubtedly can be its markers.

We cite the certain type of “EPS - PS of ICR” of group of the patients of the Tver Regional Cardiology Health Center. We take the HR duration which is short enough and equal to 632 sec. With essentially major HR time intervals, the figures for the EPS and the PS of ICR will not be detailed.

The EPS of ICR of group the patient of interest is shown in Fig. 1.-7.

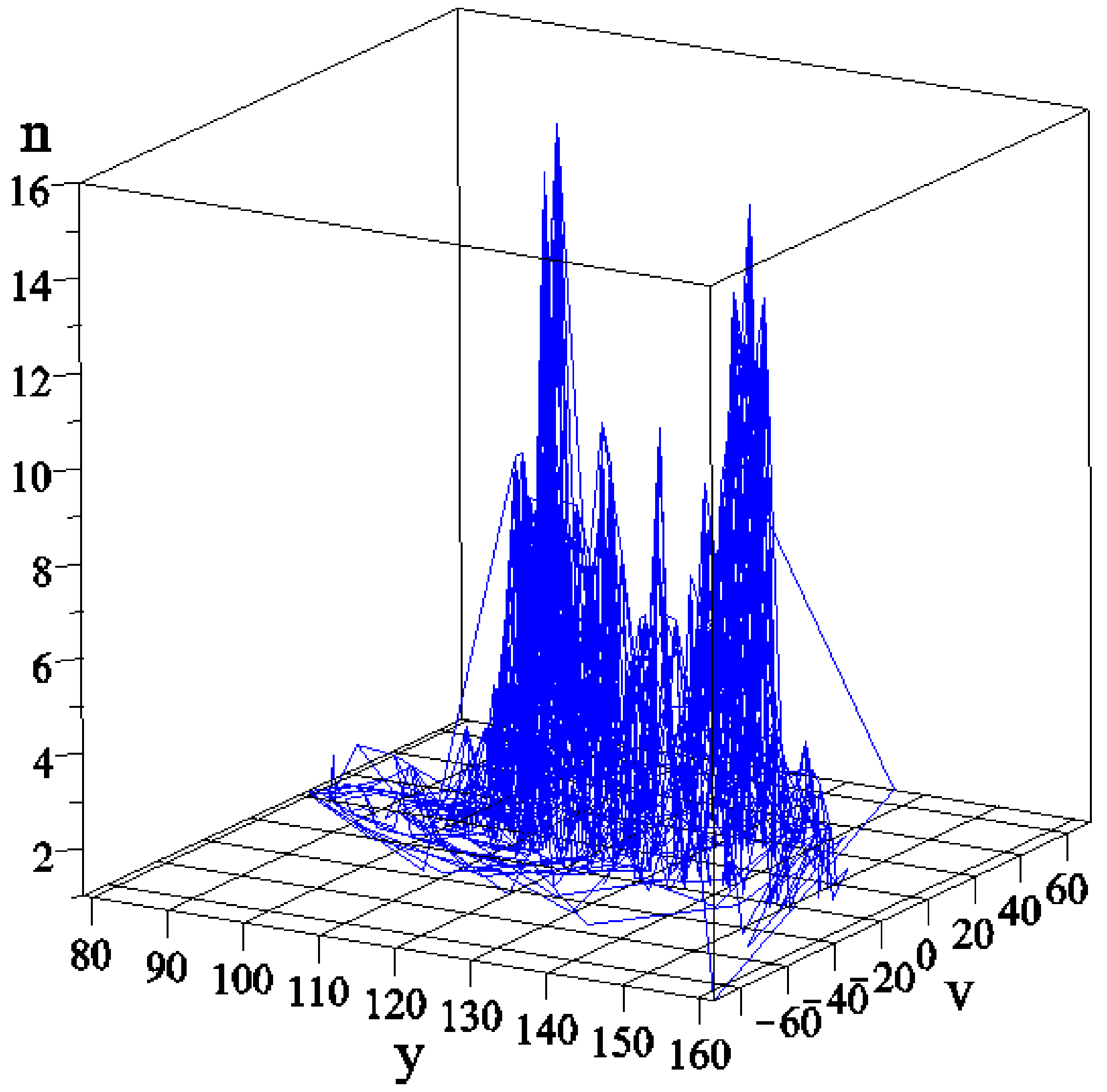


Fig. 1. Diagnosis: Norm

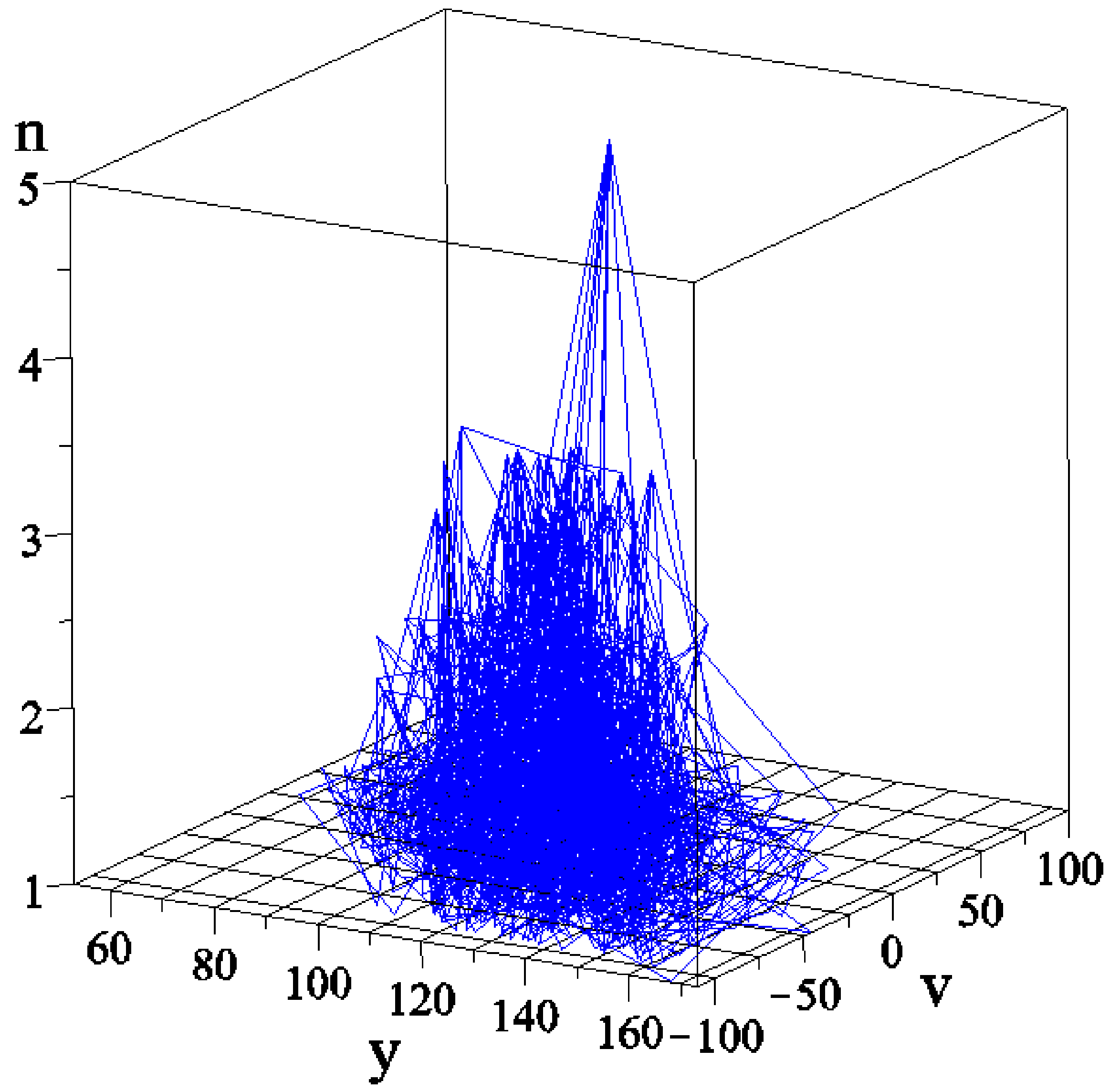


Fig. 2. Diagnosis: Constant norm-form of atrial fibrillation

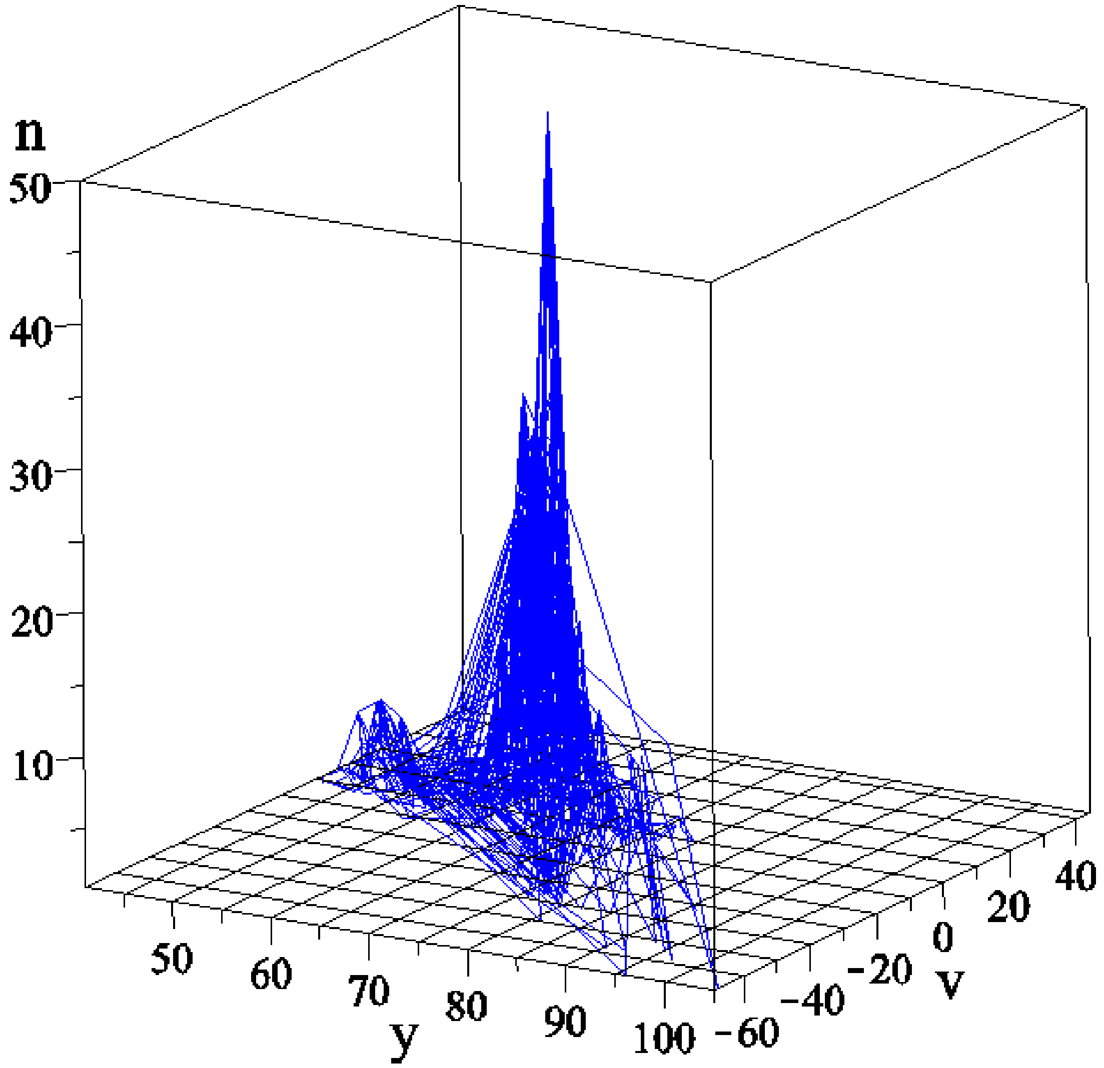


Fig. 3. Diagnosis: Ventricular extrasystole

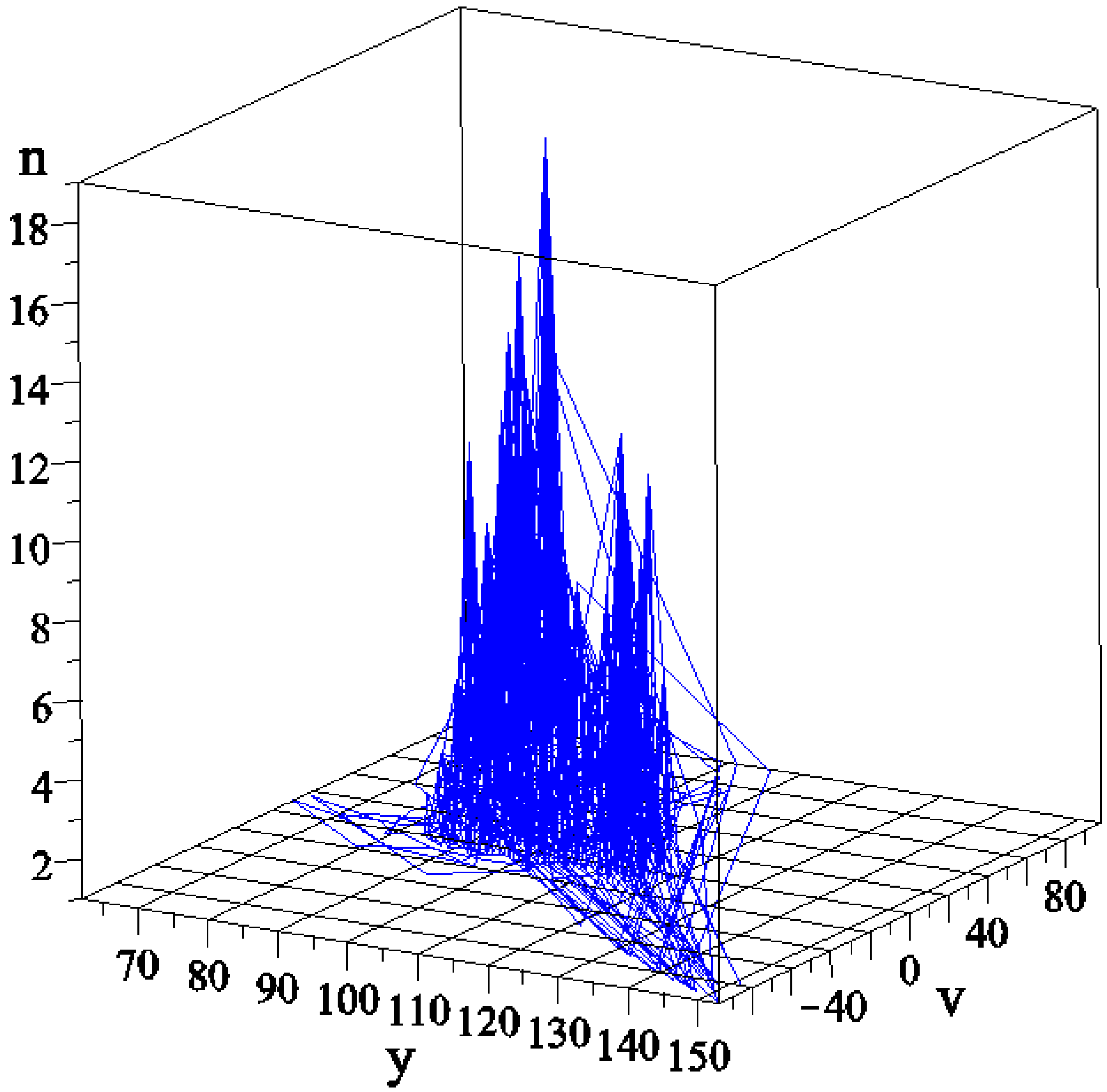


Fig. 4. Diagnosis: Norm

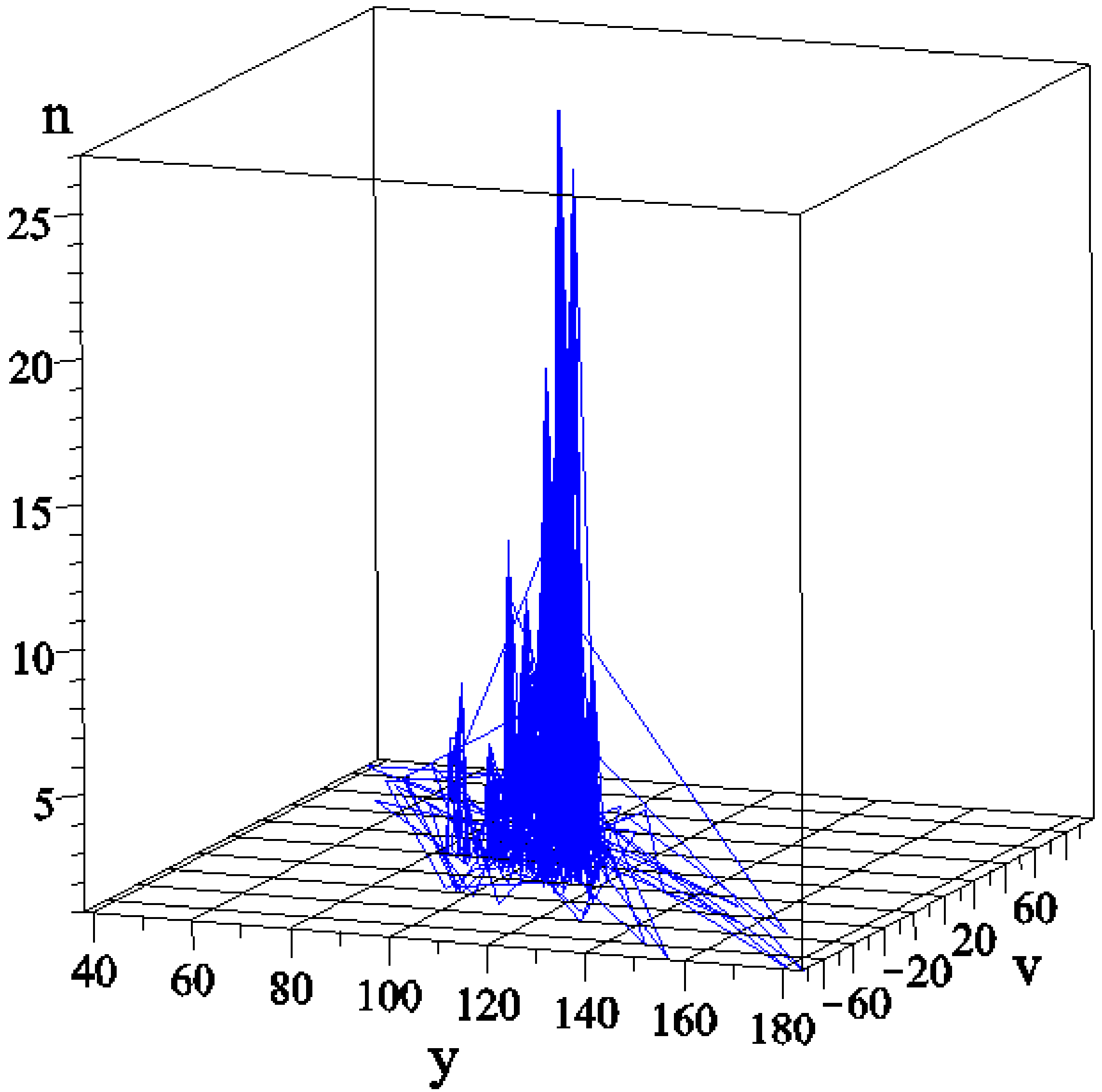


Fig. 5. Diagnosis: Norm

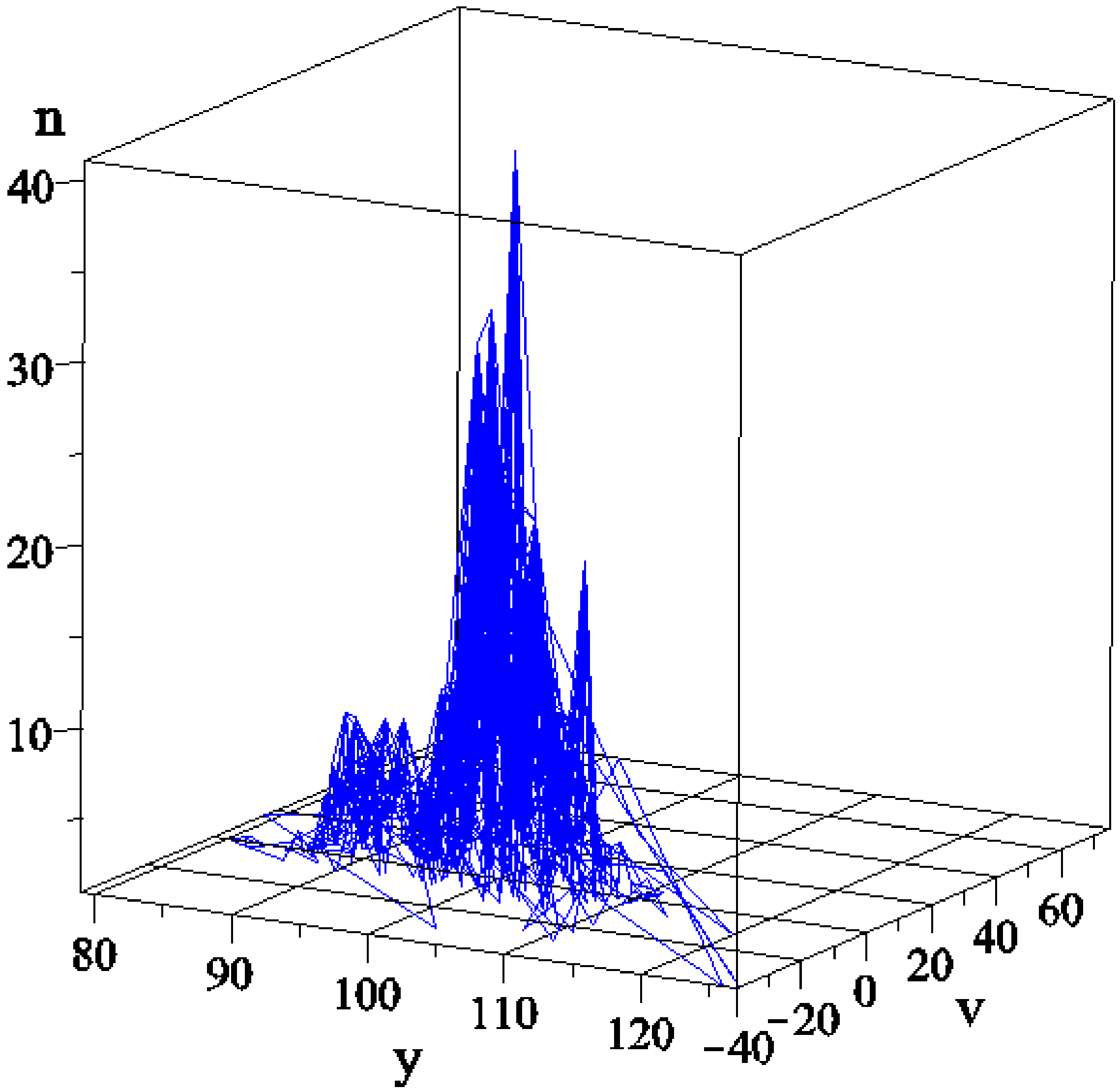


Fig. 6. Diagnosis: Ventricular extrasystole

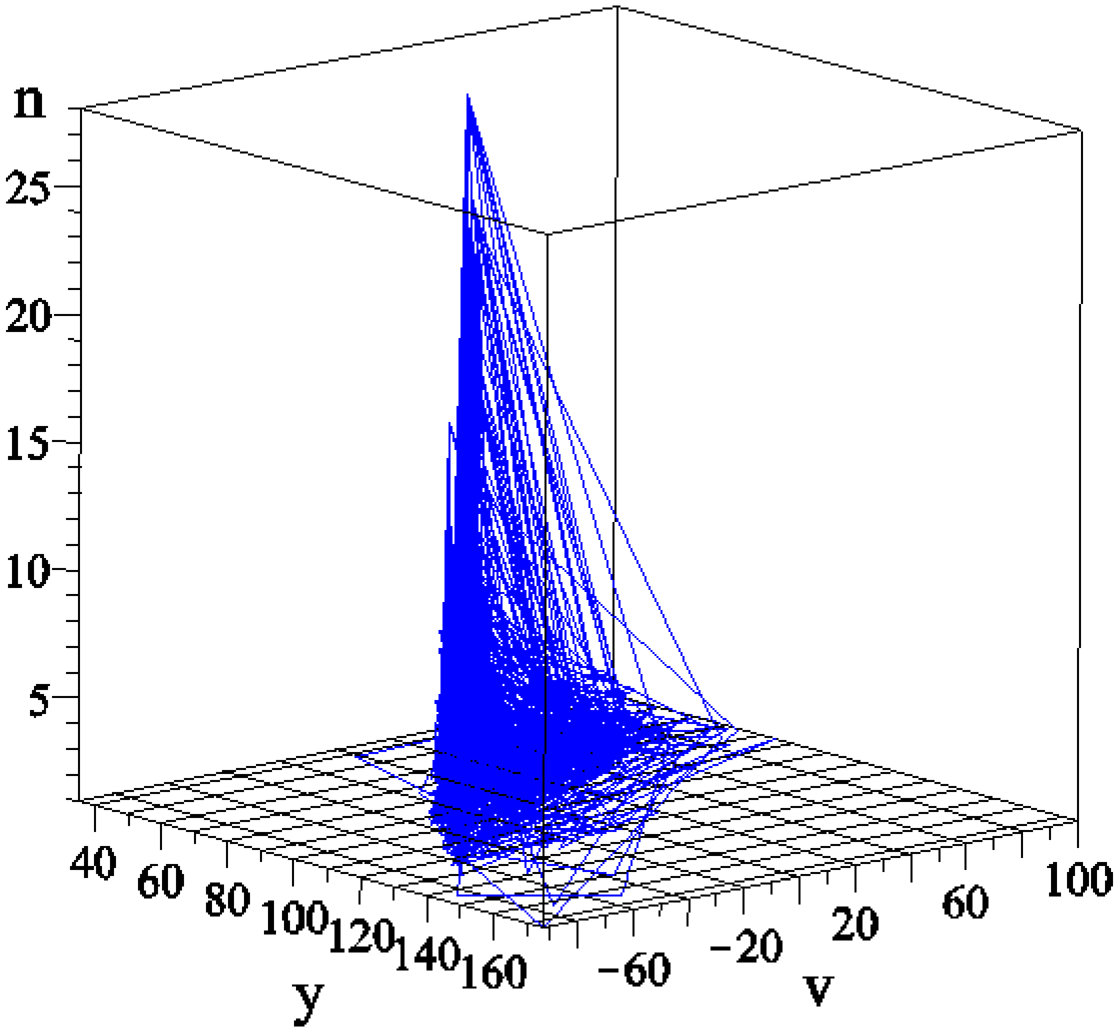
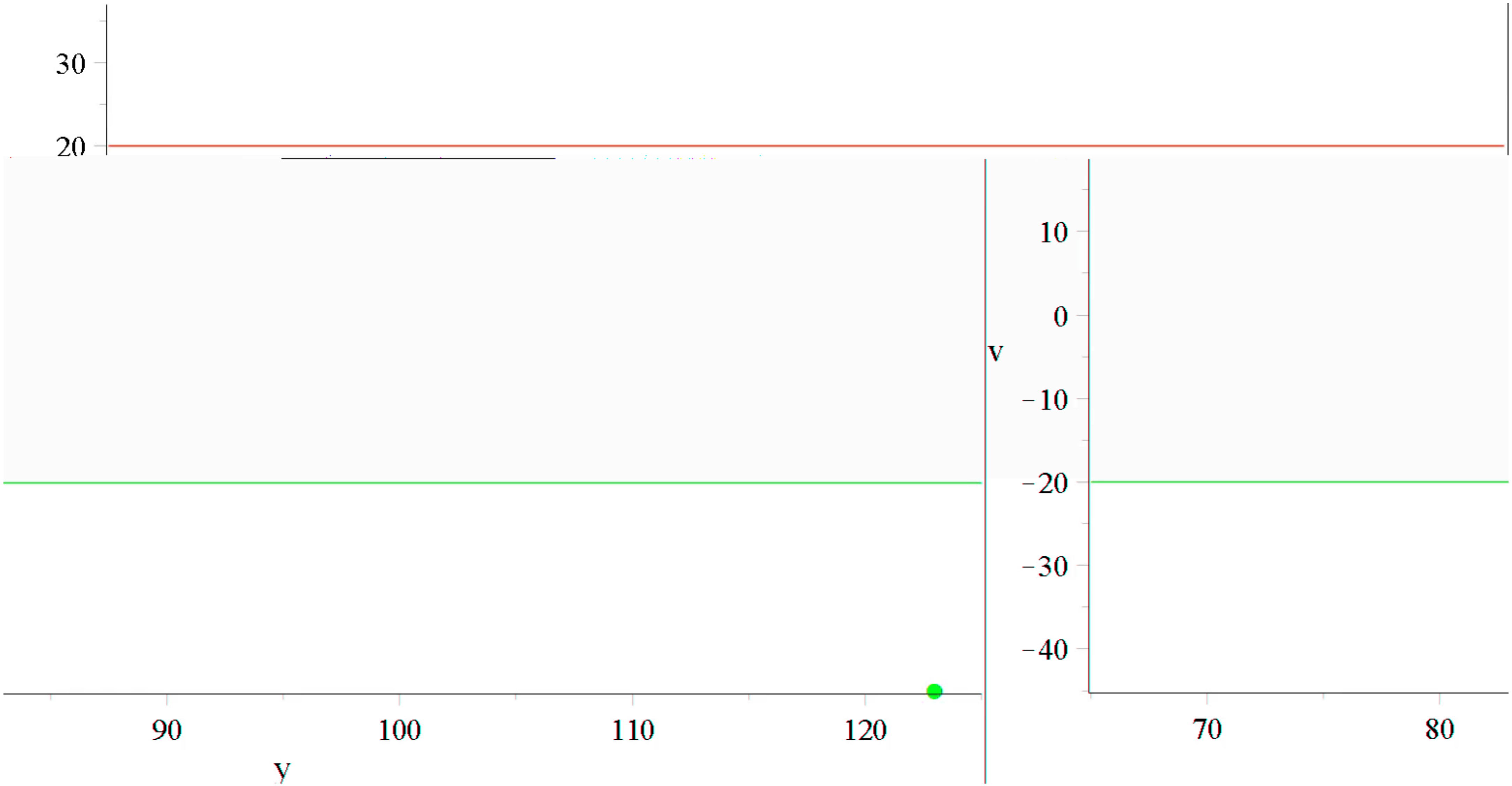
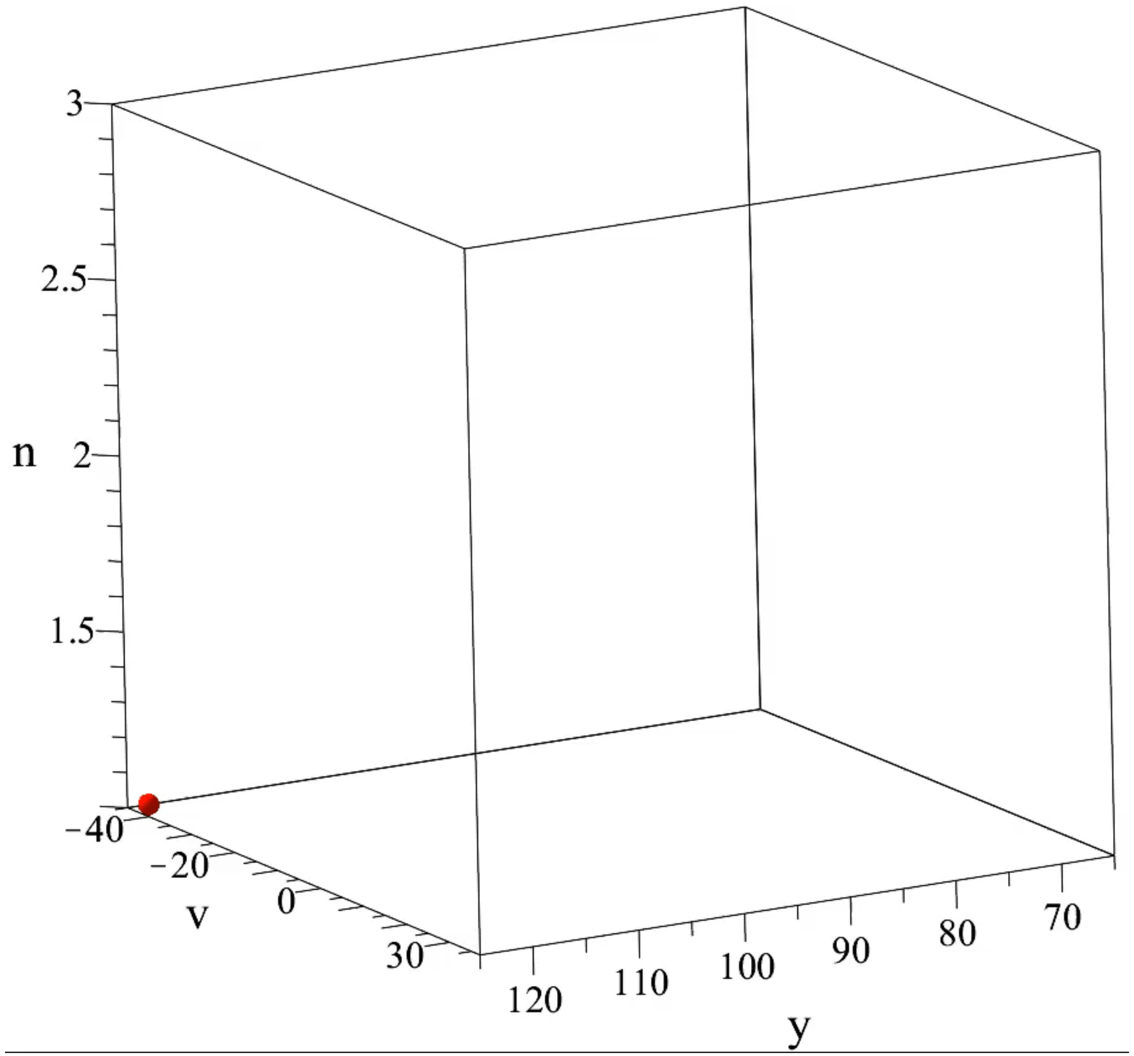


Fig. 7. Diagnosis: Ventricular extrasystole


30
20
10
0
v
-10
-20
-30
-40
90
100
110
120
y
70
80



3
2.5
n
2
1.5
−40
−20
v
0
30
120
110
100
90
80
70
y

From Fig. 1-7 we can see that the phase points (PP) in the EPS describes a complex geometric configuration. The PP condensation point corresponds to the peak in Fig. 1-7. The PP passes through this point 17, 5, 50, 19, 27, 42, 28 times during the HR time. In the neighbor of this ICR point of the patient of interest we can see the maximum time. It is reasonable to call the cardiac rate of the peaks as an intrinsic heart rate of the patients.

The research we have conducted is indicative of a true complex mode of behavior of the functions *y(t)* and *v(t)* characterizing the ICR state. We have demonstrated with specific reference the efficiency of study of these functions based on imaging of mass data on ICR with the use of EPS.

References

1. Ivanov, A.P., Kudinov, A.N., Mikheev, S.A., Tsvetkov, V.P., Tsvetkov, I.V. Phase space-based imaging of mass data on instantaneous cardiac rhythm (2016) // CEUR Workshop Proceedings, 1787, pp. 271-274.

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thank for your attention