Animals' behavioral data analysis using fractal dimension method

Viktor Veliks[1,2] and Alexander Grakovski[2]

[1]Department of Human and animals physiology, Faculty of Biology, University of Latvia, Riga, Latvia, viktor.veliks@gmail.com
[2]Department of Electronic and Telecommunication, Transport and Telecommunication Institute, Riga, Latvia

During statistical analysis of behavioral data it is important to look on behavior as a complex process during observation period. Usually analysis of aggregated observation data (typically by mean or sum values) is conducted using standard statistical procedures and as a result variation of the behavior parameters during experiment is lost, another specific of such way of analysis is that measured behavior parameters are looking "unrelated".

The aim of this study was to develop advanced method of animals' behavior data representation which combined different behavior parameters and time-depending variation of these parameters.

Experimental data from animals' observation in round open field were used for the analysis. Animals' behavior was recorded using SMART software (v 1.2, Barcelona, Spain). The following behavior parameters data were used for calculations – distance, presence in zones and different animal's positions. Values of these parameters were calculated for each second. Data preparation for zones and positions was done using specific coding procedure. Presence in a zone and directions of zone changing were coded by positive numbers.

For activities in zones, a graph of possible animals' movements was used. Encoding, longer distance covered by the animal from one zone to another in a round open field is given higher value. In the graph the first number represents movement in the round open field zones, see figure 1. For example, 131 means that animal stayed in zone 1 then moved in to the zone 3 (center of open field) and returned back in to zone 1. Second number shows value that encodes this movement. Animal's positions were coded with negative numbers for scratching and grooming parameters and with positive numbers for vertical activities, holes observations and walking. Behavior position was recoded using the following values: any vertical position 30 points, holes investigation 15, walking 0 points, scratching -15 and grooming -30 points.
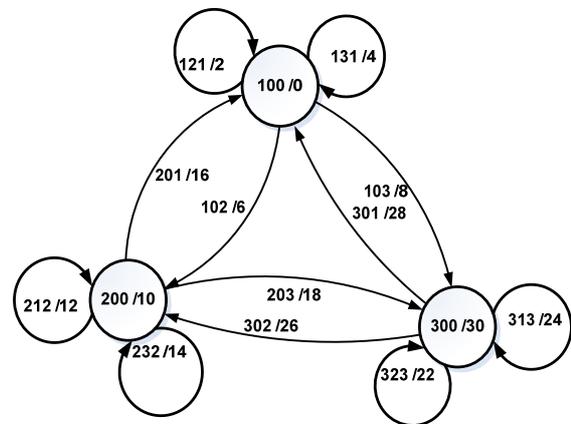

Figure 1. Graph of animal movements in the open field zone; first number movement in the zones, second number coding value for this movement.

After that a 3-D array was created and thereafter used for manipulations. Values of movements in zones and behavior position were divided by mean value of walking distance, as result all scales that represents animal behavior are equal. The special application in Matlab was developed for calculation of fractal dimension using correlation dimension from Grassberger and Procaccia [1].

In the first step of our algorithm 3-D plot (presence in zones, animal positions and distance covered) of observation data was calculated, this gave possibility to conduct visual data analysis. In figures 2 and 3 there is 3-D plots showing two animals' summary of behavior activities comparing to their movement track recorded during the experiment. Each point in 3-D plot represents behavior activity by values of animal positions, zones and distance covered during interval of one second. Figure 2 displays an animal behavior data with a low movement activity. A figure (2.b.) of relatively simple animal behavior phase with one pike on the zone axes can be seen that characterizes the animal entrance in the second zone (2.a.). Also during experiment this animal was less active in
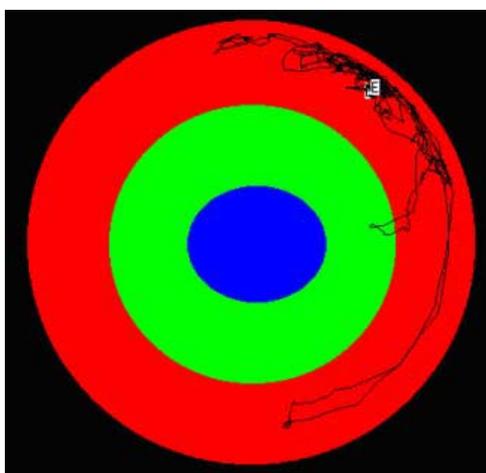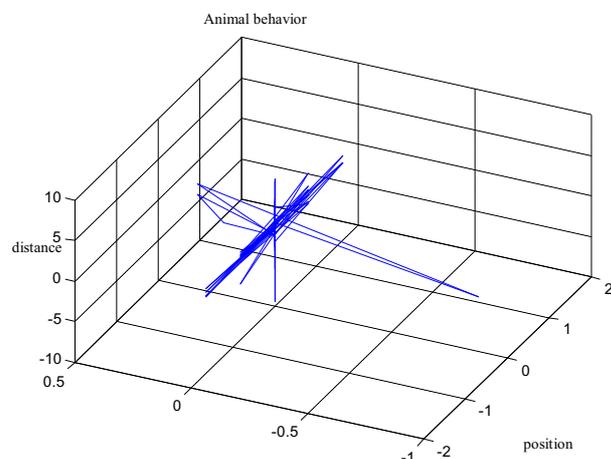

Figure 2. Animal with low behavior activity: a. walking path in open field zones, b. 3-D plot of animal behavior.

Proceedings of Measuring Behavior 2008 (Maastricht, The Netherlands, August 26-29, 2008)
Eds. A.J. Spink, M.R. Ballintijn, N.D. Bogers, F. Grieco, L.W.S. Loijens, L.P.J.J. Noldus, G. Smit, and P.H. Zimmerman

292
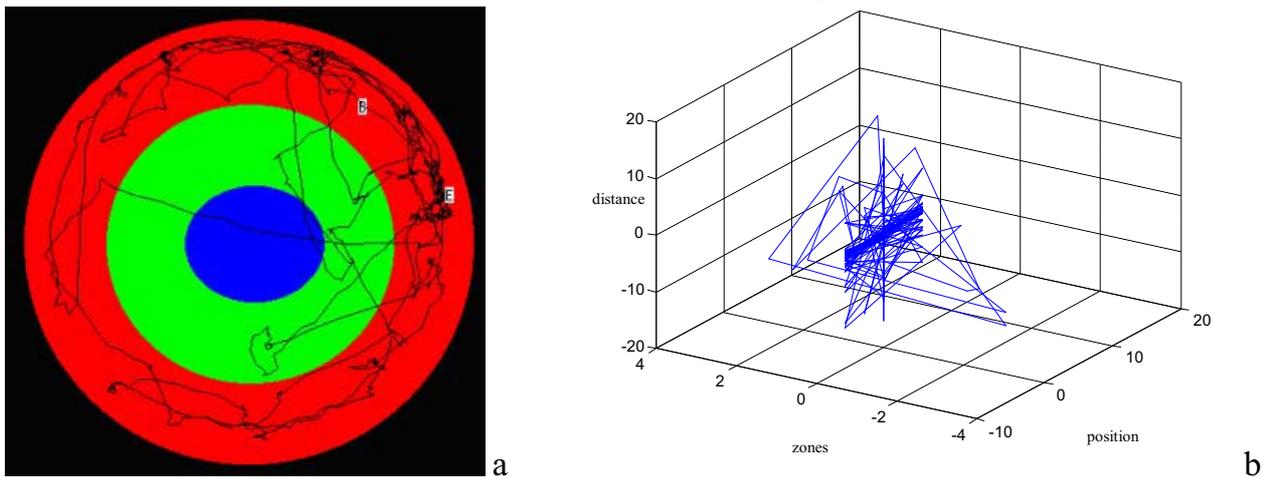
Figure 3. *Animal with high behavior activity: a. walking path in open field zones, b. 3-D plot of animal behavior.*

parameters of position and covered distance.

Figure 3 displays an animal behavior with a very high movement activity. Figure (3.b.) of the behavior phase is already considerably different, the animal actively investigates the territory and even crosses the center of the open field (3.a.) and its behavior is much more varied.

In the second step Euclidean points from 3-D array were calculated. These data used for calculation of value of "correlation dimension". We assume that "correlation dimension" represents complexity of animal behavior. Mathematical formula of the algorithm "correlation dimension" – *Dcor* is the following:

$$Dcor = \lim_{r \to 0} \frac{\ln C(r)}{\ln r} \quad , \text{ where } C(r) = \frac{\| Xi - Xj \| <= r}{\dfrac{2}{n}}$$

where, r – length of square side,

||Xi-Xj||<= r – distance between points which are lower or equal to r,

n – number of points in the experimental data,

Dcor – correlation dimension.

Besides, the length of line segment used for calculations – r was taken from the data of animal movements: from the minimal value to the maximal. This method allows using biologically significant step sizes. For fifty r values logarithms were generated, starting with logarithm of minimal to logarithm of maximal value of the walked distance, in order to gain maximally even data representation on the graphic scale.

Finally, fractal dimension was calculated [2]. After finding of $\ln C(r)$ and $\ln r$ values correlation dimension *Dcor* was calculated using regression analysis where *Dcor* is a coefficient in regression equation. We observed that animals with low behavior activity had lower correlation (fractal) dimension values. For example, less active animal fractal dimension *Dcor* value is 0,33264 and for more active animal *Dcor* is 0,59863. That means that animal with low behavior activity (short covered distance, zones and taken positions) has also the simplest behavior patterns.

The results of obtained fractal dimension data may be investigated by standard statistical observation method, for example, by visual method, correlation or clusterization.

This method allows evaluating animal's behavior overall. Animal's behavior data are visualized using 3-D plots, but from the other side "correlation dimension" – *Dcor* gives to behavior numerical value. Another plus of this method is that we can see dynamics of animal's behavior.

References

1. P. Grassberger and I. Procaccia (1983). Characterization of Strange Attractors. *Physical Review Letters, 50(5)*, 346-349.
2. Mandelbrot, B. B., *The Fractal Geometry of Nature*, New York: Freeman, 1982.

Proceedings of Measuring Behavior 2008 (Maastricht, The Netherlands, August 26-29, 2008)
Eds. A.J. Spink, M.R. Ballintijn, N.D. Bogers, F. Grieco, L.W.S. Loijens, L.P.J.J. Noldus, G. Smit, and P.H. Zimmerman

293