ANIMALS' BEHAVIORAL DATA ANALYSIS BASED ON BEHAVIOR PARAMETERS VISUALIZATION AND FRACTAL DIMENSION METHOD

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ABSTRACT
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. The following behavior parameters data were used for calculations – distance, presence in zones and different animal's positions. Data preparation for zones and positions was done using specific coding procedure. A 3-D array was created and thereafter used for manipulations.
In the first step of our algorithm 3-D plot of observation data was calculated, this gave possibility to conduct visual data analysis. In the second step Euclidean points from 3-D array were calculated and obtained time series data. Finally, fractal dimension was calculated from time series. We observed that animals with low behavior activity had lower fractal dimension values.

KEY WORDS: behaviour, rats, fractal dimension, calculation method.

INTRODUCTION

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 usually Student t-test and/or analysis of variance. Nonetheless in some cases variation of the behavior parameters during experiment is "masked by mean value", another disadvantage of such way of analysis is that measured behavior parameters are looking "unrelated". Combination of two factors – measured parameters changes in time and interaction between observed parameters seem allow to take different behavior picture. Using fractal dimension mathematical apparatus may solve this task (4). Different fractal dimension methods are widely used in biological research.

The fractal dimension calculations were used in a research on the influence of the electromagnetic field on movements of a C.elegans nematode. After two-day exposition of the electromagnetic field (900 MHz 100V/m) the nematodes were video recorded for 10 minutes. The obtained pictures with the nematode's movements in the Petri container were analyzed with 2.5-minute periodicity. It was observed that the fractal dimension of the electromagnetic field changes from 1.36 to 1.44, while for the group not under the influence it changes from 1.35 to 1.58, which means more movement activity (1).

The work by Nams is very interesting, in which he develops methodology for detecting animal movement track dependence from external environment (field, field with a few trees or bushes, forest). If conditions change, also the movement tactic of an animal changes, which is represented in the line segment length used for the calculation of the fractal dimension (5). His methodology is turned to comparison of the obtained under different conditions distance FD values using dispersion analysis, thus getting much more precise characterization of the behaviour. For example, a life areal of a field mouse C.gapperi is approximately 50x50m2 and the FD value of covered 50 m in this area was 1.11 – almost straight. However after using the VFractal method it turned out that the animal movement is best characterized by calculation step from 10 to 50 cm, biological interpretation of these results are the following: although the animal moves between two points as straight as possible, it tries to go round all obstacles.

Foss group (2) examinate time variability of fluctuations of spontaneous pain in patients suffering from chronic back pain and chronic post-herpetic neuropathy, and contrast properties of these ratings to normal subjects' ratings of either acute thermal painful stimuli or of imagined back pain. They observed that the fluctuations of spontaneous pain do not possess stable mean or variance, implying that these time-series can be better characterized by fractal analysis, applying time and frequency domain techniques to characterize variability of pain ratings with a single parameter - fractal dimension. Observed correlation between fractal dimension for pain ratings and for brain activity, in chronic back pain patients using fMRI.

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.

MATERIALS AND METHODS

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.

Our procedure for data analysis contain following steps – behavior parameters encoding, 3-D array creation and data visualization, calculation of time series from 3-D array and calculation of fractal dimension value. The special application in Matlab was developed for calculation of fractal dimension using correlation dimension formula from Grassberger and Procaccia (3) paper see Equation 1.

First step, encoding of the behavior parameters. 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, and walking 0 points, scratching -15 and grooming -30 points.

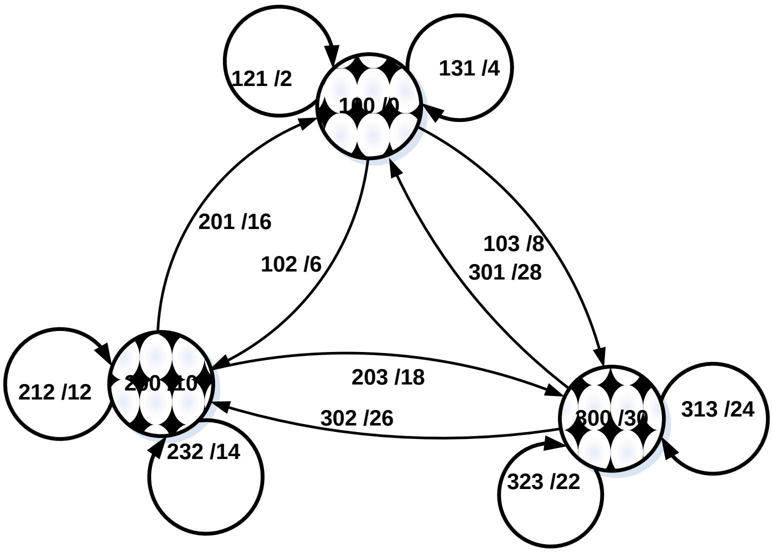
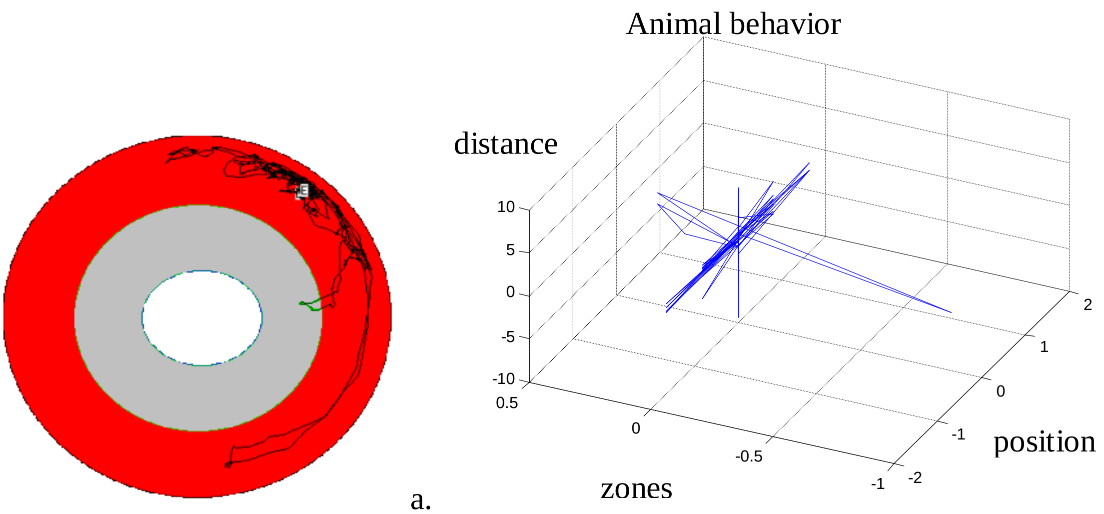


Figure 1. **Graph of animal movements in the open field zone; first number movement in the zones, second number coding value for this movement**

Second step, 3-D array was created and thereafter used for manipulations. We assume that parameters that describe behavior have the same weight. Values of movements in zones and behavior position were divided by mean value of walking distance, as a result all scales that represent animal behavior are equal and describe animal individually. The main reason for the 3-D array creation was only human perception limit; from mathematical point of view there is no limit for adding another dimension (behavior parameter) to the array.

Also in this step 3-D plot (presence in zones, animal positions and distance covered) of observation data was calculated, this gave the possibility to conduct visual data analysis. In figures 2 and 3 there are 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.). During the experiment this animal was also less active in parameters of position and covered distance.

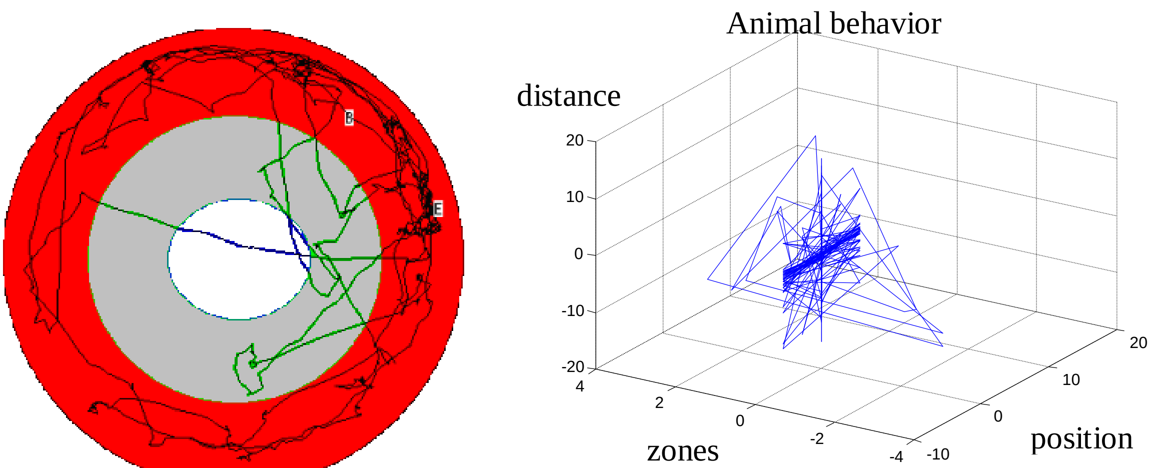


a.

b.

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

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.

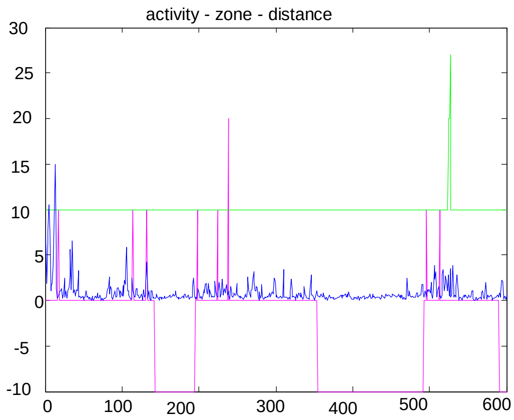


a.

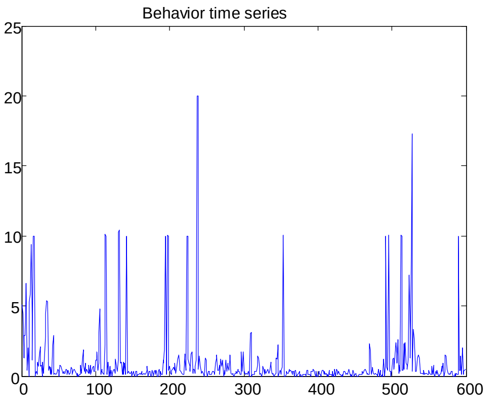
b.

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

In the third step Euclidean points from the 3-D array were calculated. As a result of this manipulation we obtained integrative behavior time series line. These data were used for calculation of value of “correlation dimension”. Figure 4.a. displays examples of plots of the data from the 3-D array and Figure 4.b. represents the calculated time series line.



a.



b.

Figure 4. **Animal behavior parameters: a. plot of the 3-D array, b. plot of the behavior time series**

In the last step calculation of the fractal dimension value took place. We assumed that correlation dimension represents complexity of animal behavior. Mathematical equation for calculation of the correlation dimension – *Dcor* is the following:

$$Dcor = \lim_{r \to 0} \frac{\ln C(r)}{\ln r} \text{, where } C(r) = \frac{\| \mathrm{Xi - Xj} \| <= \mathrm{r}}{n^2} \quad (1)$$

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 and *Dcor* – correlation dimension.

Besides, the length of line segment used for the 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 covered distance, in order to gain maximally even data representation on the graphic scale. Finally, fractal dimension was calculated. After finding ln*C(r)* and ln*r* values, correlation dimension *Dcor* was calculated using regression analysis where *Dcor* is a coefficient in the regression equation.

RESULTS AND DISCUSSION

We observed that animals with low behavior activity had lower correlation (fractal) dimension values. For example, less active animal correlation 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.

Obtained fractal dimension values may be investigated by standard statistical observation method, for example, by visual method, correlation or clusterization.

There are some advantages of our method, like new behavior data visualization technique, that allows making simple animal classification based on their integrative activity. Second, variations of the parameters weight coefficients allow manipulation with behavior parameter influence on the final result. Third, formally there is no limit for adding behavior parameters to the array that describes behavior. Integrative behavior time series, which we obtained after these parameters recalculation with Euclidean method, may be analyzed using different statistical methods. Another advantage of this step is that we can see dynamics of animal's behavior.

From another side the same *Dcor* value is observed in the case when animals have different behavior patterns – animal with active movements and less changes in positions and vice versa.

Finally our method allows overall evaluating of animal behavior. An animal's behavior is visualized using 3-D or time series plots and correlation dimension gives it a numerical value.

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