

VIDEO TRACKING FOR ANIMAL BEHAVIOR ANALYSIS

**FLORIN ROTARU, SILVIU-IOAN BEJINARIU, MIHAELA LUCA,
RAMONA LUCA and CRISTINA DIANA NIȚĂ**

*Institute of Computer Science, Romanian Academy Iași Branch, Iași, Romania
Corresponding author: florin.rotaru@iit.academiaromana-is.ro*

A procedure for rats behavior analysis using image and video processing methods is proposed. The analyzed scene consists of a plastic box split into three chambers by two walls. Two cages are placed in box marginal areas. Each cage can be populated or not by a rat. A free rat explores all three environment components. The proposed method determines the parameters necessary for overall motion analysis: entries number in each area and visit time. The algorithm consists of two steps. First, the moving rats are tracked and their trajectories are stored. In the final step, trajectories offline analysis is performed.

Keywords: video tracking, trajectory analysis.

1. INTRODUCTION

Laboratory animals, mainly rodents, are widely used in medical research to analyze the behavioral effects of many experimental factors, such as genetic mutations, drug influence, strain differences, brain lesions and various diseases. A large amount of behaviors might be of interest, for example rearing grooming, sitting, chewing, and overall motion in a specific environment. To quantify the behaviors of interest, one of the most used methods is video tracking and motion analysis. In this paper, a method to track the rodent and analyze its overall motion is proposed.

In the last decade, a lot of papers proposed different methods to track animals and to compute behavioral indices based on motion analysis. A method for extracting the scratching patterns of a rat, for analyzing its rapid and periodic behavioral patterns, is proposed in [2]. In a first step, each frame of a high rate video sequence is binarized. Movement detection is done in the consecutive frames differences, by performing the following processing and analysis steps: noise reduction by erosion; nonzero pixels counting; pulse detection; long-term pulse filtering; pulse processing for scratching quantification and scratching time quantification. The result is considered an objective behavioral indicator for atopic dermatitis, which can help the development of new drugs for this disease. In [3], the objective is to evaluate the amount of animal motion dependent on the extent of a specific pathology. Several methods of animal trajectory tracking are proposed: two differential methods based on background subtraction, entropy thresholding methods based on global and local threshold, and color matching with a chosen template containing a searched

spectrum of colors. For daylight trajectories, all methods provide similar results for small rodent movements, while the last two methods failed in case of large movements. Another tracking procedure, proposed in [1], is a two-stage approach. In the first step, the animal is tracked coarsely, using the combination of four features: the histograms of oriented gradients, the histograms of intensity, the quantity of motion and edge density. Finally, the boundaries of the tracked area are refined in order to fit more precisely the boundaries of the animal. The authors report an average of tracking error less than 5%. On the same subject, of animal tracking and trajectory analysis, methods for rat pose model generation, real-time pose estimation and behavior segmentation based on hidden Markov models are proposed in [4]. The authors assert that experiments have demonstrated that the proposed approach shows comparable results or outperforms the conventional methods.

In the case here considered, the analyzed scene consists of a big plastic box with three rooms. A cage is placed in the left room and another in the right room. Each cage can be populated or not by a rat. A free rat explores all three environment components, the only way from one cage to another being through the middle room. Our method is a two-stage approach: 1) a tracking step, where the trajectories of the moving rats are stored and 2) trajectories offline analysis, that computes the entries number of the free rat in each area (cages, middle room) and the visit time. The remainder of this paper is organized as follows. The next section describes the tracking method. Section 3 details the analyzing procedure. The work is concluded in section 4.

2. TRACKING METHOD

The tracking algorithm consists of three main steps. First, vertical and horizontal projections are performed in the current frame. Then, cages localization and the middle room walls are determined by projections analysis. This step is executed at the beginning of the video analysis and whenever parts of the scene are temporarily hidden in the video sequence. In the main loop of the algorithm, a quick check of cages presence is performed by analyzing the column projections of the cage areas, previously localized. If the projections have not the variance and average values in the same range as the ones computed in the first step, this means that the scene was modified, which may happen when an operator extracts or introduces a rat from/in a cage. This type of intervention usually modifies the scene parameters by changing the cage position or by slightly translating or rotating the big plastic box, thus modifying the scene view angle. Consequently, each time a projections parameters mismatch is met, the procedure is resumed from the very first step. Otherwise, for each sequence of three consecutive frames the working image is computed as the difference of the adjacent frame differences. A counting box procedure is employed to localize the most aggregated areas in the working image. The coordinates of the most significant boxes (rectangles) and frame information are stored for the last step. Finally, the stored information is used to

extract the parameters needed for rat behavior analysis. Figure 2 shows: a frame of the original sequence illustrating a free rat wandering through middle room; the working frame with consecutive frames differences result; cages extremities and the middle walls, $c_{11}, c_{12}, c_{21}, c_{22}, b_1, b_2$, shown at the working frame bottom; tracking results indicated by rectangles, including the most aggregated areas in each area. The tracking procedure pseudo-code is (Fig. 1):

Algorithm 1 Tracking procedure

Input: *Video sequence*

Output: *Tracking rectangles coordinatesfile*

1. $c_{11} = c_{12} = c_{21} = c_{22} = b_1 = b_2 = 0$; //clear the cages and plastic box extremities *x-coordinates*
2. for each consecutive three-frame sequence do
3. generate working image by subtracting the differences of two consecutive frames of the sequence;
4. compute row and column projection histograms in the binarized last frame of the current sequence //row/column histogram: each row/column location contains number of object pixels on the corresponding column/row;
5. if $c_{11} = c_{12} = c_{21} = c_{22} = 0$ compute $c_{11}, c_{12}, c_{21}, c_{22}$ by analyzing column projections; end if
6. if $0 < c_{11} < c_{12} < c_{21} < c_{22}$ and $b_1 = b_2 = 0$ compute b_1, b_2 by analyzing the column projections in the interval (c_{12}, c_{21}) ; end if
7. if $0 < c_{11} < c_{12} < b_1 < b_2 < c_{21} < c_{22}$
8. if cages histograms of the current sequence have not the variance and average values in the same range as the ones computed in step 5;
9. $c_{11} = c_{12} = c_{21} = c_{22} = b_1 = b_2 = 0$ and continue; //it happens when the operator enters the scene to change to experiment set-up (introduce a rat in an empty cage or extract a rat from a cage)
10. else go to 12;
11. else continue;
12. identify the moving areas in the working image using a counting box procedure;
13. if there are boxes with a significant number of interest pixels, store the frame index and the mass centre of each significant box; end if
14. end for

Fig. 1. Tracking procedure.

3. FREE RAT TRAJECTORY ANALYSIS

Free rat trajectory analysis, performed to identify each passing from one area to another and to estimate the time spent in each area it is not a trivial task. As

illustrated in Figure 3, for a passing from the first cage area to the middle area, different cases may occur: all tracking rectangles are located in the departure area, or in both departure and destination areas, and finally they get stabilized in the destination area. In addition, during passing, frames with tracking rectangles only in the departure area and frames with rectangles only in destination area can alternate. A four-step algorithm is proposed, to analyze the movement rectangles coordinates list of the frames where movement was detected.

After a first scanning of the whole list, there are identified the frames with movement outside the cages. For each selected frame, the following parameters are computed: area index where movement was found (cage 1 = area 1, middle room = area 2, cage 2 = area 3); the movement rectangle number for each area; an area change indicator is set for each transition movement. Secondly, out of all selected frames in first step there are labeled the consecutives frames with all rectangles located in the same area. Then, a second selected list processing step provides the set of consecutive frames with rectangles coordinates in more than one area or of adjacent frames with rectangle coordinates located in adjacent areas.

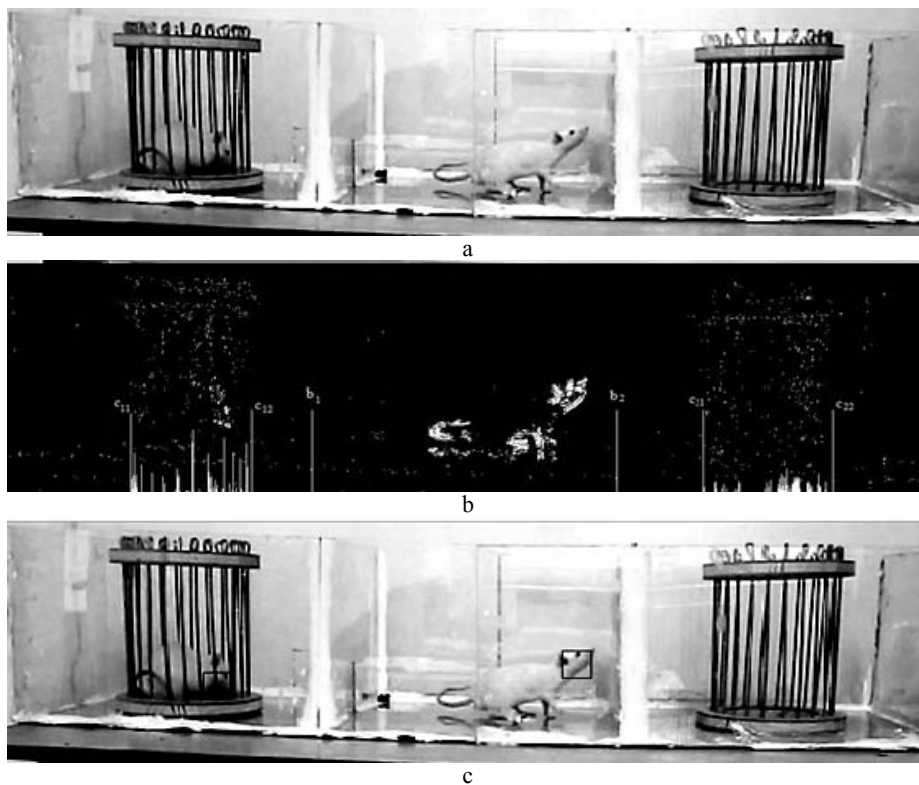


Fig. 2. a) Original frame with free rat wandering through middle room; b) Working frame with consecutive frames differences result. At its bottom, the image also displays the cages and the plastic box extremities: c_{11} , c_{12} , c_{21} , c_{22} , b_1 , b_2 ; c) Tracking result: most of the aggregated areas of the image in each interest zone are framed by rectangles.

Now, the selected list of frames where movement outside the cages was detected is a chain of stationary and transition linked frame sets. The area of the first stationary sequence initializes the free rat location. Then, the stationary/transition pairs sequences are analyzed in order to compute the overall motion indices. If the area of the current stationary set it is not the same as the current free rat location, then the stationary sequence is analyzed frame by frame in order to detect the moment (frame) when the rat entered with the whole body into the new area. If not (the rat did not enter full body), the next stationary sequence of the next pair is checked. Otherwise, the new entry is registered, the stationary area is updated and the time spent in the previous area is calculated.

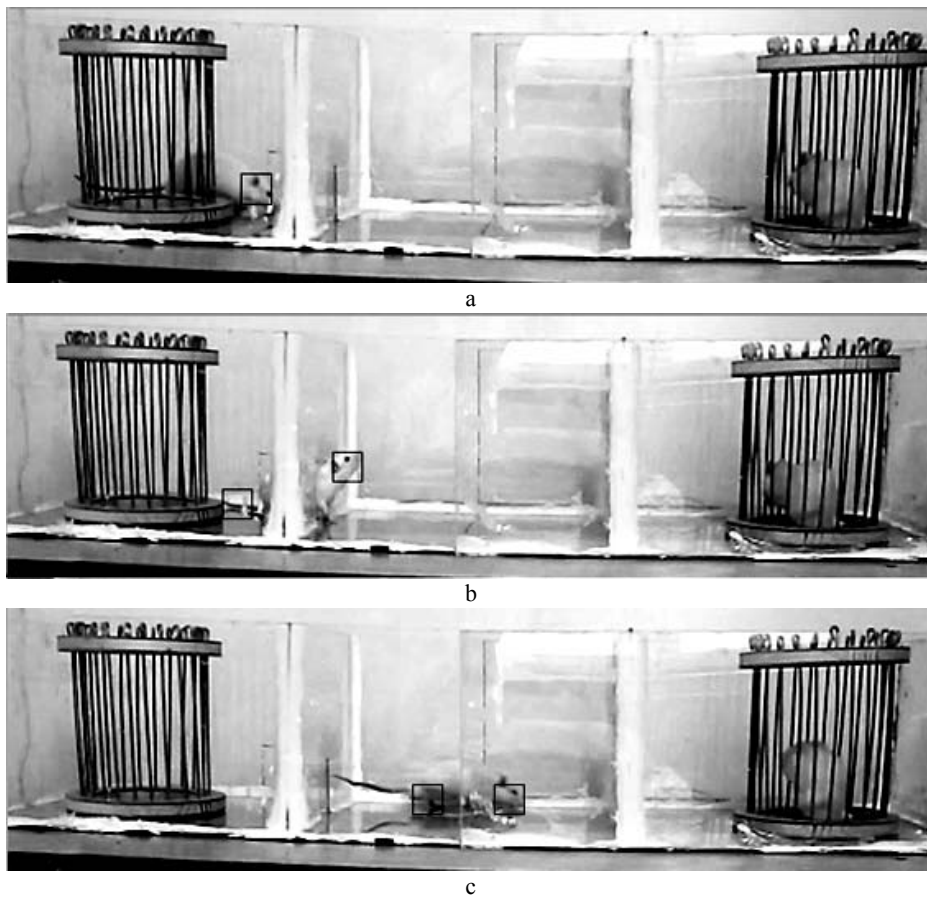


Fig. 3. Passing from one area to another one:
first cage – a), b) to the middle room – b), c).

The trajectory analysis procedure pseudo-code is presented in Figure 4.

4. CONCLUSIONS

Tests had been done on three videos of different durations (10, 20, 40 min) and resolutions (788×246, 808×196 and 1092×270). The entries numbers in each area were determined errorless. The entry durations were computed error-free for short visits and with errors of maximum 1–2 s for visits longer than 1 min. The project will go on with computation of other parameters concerning: free rat scratching episodes near a rat in a cage; stretching, grooming, freezing episodes.

Algorithm 2 Trajectory analysis procedure

Input: *Tracking rectangles coordinatesfile*

Output: *Entries number in each area (cage 1 = area 1, middle room = area 2, cage 2 = area 3), entry time and the time spent in each area per entry*

1. for all frames in tracking rectangles file do
2. from each movement frame retain only the movements outside the cages;
3. for each selected movement set: the area index, the movement rectangle number for each area, an area change indicator if there are more than one area or previous movement is in a different area; end for
4. end for
5. for all selected frames with area change indicator null compute the length of consecutive frames with movement in the same area, fill the length of each stationary set for the first frame in the set; end for
6. for each selected frame with not null area change indicator, compute the length of consecutive frames with not null area change indicator and fill in the length of each transition set for the first frame in the set; end for
7. initial_area = first stable frame area;
8. for iFrame = first transition frame with not null length to last transition frame do
9. iFrame = iFrame + transition_length + 1;
10. current_area = iFrame movement area;
11. if current_area != initial_area
12. for all frames of stable set starting at iFrame, check for the movement deep inside new area
13. if no then iFrame = iFrame + constant_length + 1; goto 9;
14. else
15. store transition from initial_area to area of the last stable frame and the time spent in initial area;
16. initial_area = current_area;
17. break;
18. end for
19. iFrame = iFrame + constant_length + 1;
20. end for

Fig. 4. Trajectory analysis procedure.

Acknowledgement. The work was done as part of the research cooperation with the Center of Biomedical Research of the Romanian Academy, Iasi Branch, which provided the video sequences.

Authors' contributions: All authors have equally contributed to the research presented in this paper.

A preliminary version of this research, entitled "Video tracking for animal behavior analysis" was presented at the *Anniversary Workshop: Information in Image and Video Analysis. Theory and Applications*, Iasi, Romania, http://iit.academiaromana-is.ro/IIVA/Program_IIVA_EN.pdf, March 24th, 2016.

REFERENCES

1. FARAH R., LANGLOIS J.M.P., BILODEAU G.A., *RAT: Robust animal tracking*, IEEE International Symposium on Robotic and Sensors Environments (ROSE), **2011**, Montreal, Canada, 2011, 65–70.
2. ISHII I., KUROZUMI S., ORITO K., MATSUDA H., *Automatic Scratching Pattern Detection for Laboratory Mice Using High-Speed Video Images*, IEEE Transactions on Automation Science and Engineering, 2008, **5** (1), 176–182.
3. KONIAR D., HARGAS L., LONCOVÁ Z., DUCHON F., BENO P., *Machine vision application in animal trajectory tracking*, Computer Methods and Programs in Biomedicine, 2016, **127**, Elsevier, 258–272.
4. LOMAKINA RUMYANTSEVA E., VORONIN P., KROPOTOV D., VETROV D., KONUSHIN A., *Video Tracking and Behaviour Segmentation of Laboratory Rodents*, Pattern Recognition and Image Analysis, 2009, **19** (4), 616–622.

Received February 8, 2016