Development of Cost-Effective Platform for Tracking and Analysis of Animal Ambulatory Patterns

Jeonghoon Kwon¹, Hong Ju Park², Segyeong Joo¹³, and Soo-Jin Huh¹³

Abstract

This paper reports the development of a platform for tracking and analysis of animal locomotion. The platform is composed of a commercial webcam, a metal stand for the webcam, and a plastic bathtub as a cage. Using it, researchers can track and analyze an animal’s movement within the plastic bathtub’s dimensions of 100 cm × 100 cm × 55 cm in a cost-effective manner. After recording the locomotion of an animal with 1920×1080 resolution at a rate of 30 frames per second, finding the position of the animal in each frame and analyzing the ambulation pattern were executed with custom software. To evaluate the performance of the platform, movements of imprinting control region mice and transgenic mice were recorded and analyzed. The analysis successfully compared velocity, moving pattern, and total moving distance for the two mouse groups. In addition, the developed platform can be used not only in simple motion analysis but also in various experimental conditions, such as a water maze, by easy customization of the platform. Such a simple and cost-effective platform yields a powerful tool for animal ambulatory analysis.

Keywords: Animal tracking platform, Animal ambulatory analysis, Animal tracking, Image sensor

1. INTRODUCTION

In biological and medical research, researchers have developed tremendous animal models to investigate disease and to evaluate the effectiveness of medicines at the pre-clinical level [1,2]. Among various kinds of animal experiments, analysis of animal ambulation plays an important role, especially in studying motion-related problems such as brain- and inner ear-related diseases.

Neuroscientists utilize animal models for studying animal learning, memory function, and behavioral phenotypes [3-5]. Some neurological disorders, such as Alzheimer’s disease and Parkinson’s disease, cause deficits in cognitive function and motor function by destroying neurons in the brain [6,7]. Animal behavior analysis systems have been used to find the mechanism of and treatment for these diseases [8,9] by comparing changes in animals’ motion between test and control groups.

However, commercially available systems for animal ambulatory analysis are very expensive and difficult to customize. To overcome this limitation, some investigators have developed their own systems for recording animal behavior by utilizing video camcorders or the built-in cameras of smartphones and tablet PCs [8-11]. However, they have faced difficulties in measuring moving pattern, velocity, and total moving distance. Some even tried to track animal movement manually by drawing the pathway of animals on a transparent film with a pen after putting the film on the screen of a tablet PC or display. These
results are clearly not accurate or reliable.

This paper proposes a cost-effective platform that records and analyzes animal ambulation with a webcam. The concept for the platform is shown in Fig. 1. At the bottom of the platform is a plastic bathtub in which animals can be placed. On the top of the bathtub, a stainless-steel stand is positioned to keep an appropriate distance between the bottom of the bath and the webcam to allow the webcam to view the entire bottom plane of the bath. Finally, a webcam is put at the top of the stand to build the complete system, as shown in Fig. 1. The image is recorded and analyzed using a laptop computer connected to the webcam. In the present work, we compared the movement of mice in two different groups in terms of velocity, moving pattern, and total moving distance. With the proposed system, measuring special parameters or building a customized maze is relatively simple, which can offer better tools for researchers who use animal ambulation as the basis for their experiments.

2. EXPERIMENTAL

2.1 System composition

For the recording of animal movements, a webcam (C920, Logitech, USA), which supports 1920 × 1080 resolution (full HD) at 30 frames per second (fps), was purchased. To keep animals within a confined space, a plastic bath with dimensions of 100 cm × 100 cm × 55 cm was used as a cage. The bottom and walls inside the bathtub were painted flat black to eliminate reflections from ambient light. The paint is nontoxic and approved for children’s use. A video of the animal movement within this cage was recorded with the webcam. In order to utilize the full resolution of the webcam, the field of view of the webcam should cover the entire bottom plane of the cage. To accomplish this, we built a stand to keep the webcam at the proper height. Animal movement inside the cage was recorded with the webcam after putting an animal into the cage. The video recordings are AVI files compressed with the MS-CRAM (Microsoft Video 1) video codec.

2.2 Analysis software

The analysis program was built with LabVIEW (2013, National Instruments, USA) software. The analysis program has two major parts. One part records the video image during experiments, and the other part analyzes the recorded video. Before recording an experiment, users can modify video recording settings, including the destination folder for the recorded video, resolution, compression codec, file type, recording time, and frame rate. After setting up these parameters, the program records a video of the animal movement and stores it in the target folder. The other part of the program analyzes the ambulatory pattern of the tested animal from the video. At first, the program defines a template image of the animal used in the experiment. The program loads every frame of the recorded movie and finds the location of the animal in each frame by comparing the image with the animal template. The frame number and coordinates in the frame of the animal are stored in a text file. When the program finishes finding the animal locations of the selected video file, it calculates the total distance traveled, velocity, and the ambulatory pattern. The resulting values of the location at each frame, total moving distance, and velocity are stored in the same text file and the ambulatory pattern is saved in an image file of BMP or JPG format.

2.3 Image processing

Each frame of the captured video is mapped to a 1920×1080 ×3. Each element of the matrix has a value that represents the brightness of three primary colors (red, green, and blue) at the corresponding pixel of the frame. Each frame was converted to a black-and-white image by applying a simple binary thresholding technique after grayscale conversion of the frame. The threshold level was determined empirically. Even with basic thresholding, finding an animal within the cage was straightforward, since the animals are generally white in color and we painted the cage black. To find the exact position of the animal in each frame, we used a pattern-matching algorithm, which is a common technique for detecting specific subjects in an image based on the characteristic patterns. Employing the vision assistant module of the LabVIEW software aided in the development of the pattern-matching software. Selecting the desired template, filter, and region of interest is all a user needs to do in order to find the location of a pattern similar to the template within the image. The code finds the position of the animal in each frame and stores the coordinates. The actual size of each pixel is 0.93 mm × 0.93 mm, since the 1080-pixel dimension of the image corresponds to a length of 1 m (one side of the cage). The time-spacing between neighboring frames is 33.3 ms because the frame rate is 30 fps. Therefore, displacement and velocity can be calculated from the changes to the animal coordinates between each frame.
2.4 Experimental animals

The system can analyze any small animal, but we analyzed mice ambulation to simplify our evaluation. Mice are used widely in biological and medical studies since they are cheap and easy to handle. However, their small size and impulsive behavior makes following a mouse’s trajectory challenging. Nevertheless, mice are commonly used in genetic studies because experimenting with transgenic mice is cost-effective. For a pre-clinical studies evaluating the efficacy of a drug for neurological disorders, transgenic tools, which use mouse lines with suppressed or overexpressed genes, are generally used [11]. To find the ambulatory variance in two different mouse groups—ICR mice, which were purchased from Oriental Co. (Korea), and Atg7<sup>−/−</sup> mice, which were provided from the department of anatomy and cell biology at the University of Ulsan College of Medicine (Seoul, Korea)—were used. Atg7 mice are knockout mice of Atg7, an essential gene for autophagy in yeast. Atg7 deficiency can cause multiple cellular abnormalities, such as the appearance of concentric membranous structure, deformed mitochondria, and accumulation of ubiquitin-positive aggregates [12]. The mice weighed approximately 30–40 g. The mice were kept at a constant temperature of 22±1°C in a 12 h light/dark cycle and had unrestricted access to water and food. All procedures were approved by the Institutional Animal Care and Use Committee of the Asan Institute for Life Sciences.

3. RESULTS

Fig. 2 shows the complete animal ambulatory analysis system.
Development of Cost-Effective Platform for Tracking and Analysis of Animal Ambulatory Patterns


with a p-value of 0.05. As for the mean velocity, the transgenic mouse group showed slightly slower movement than the ICR mouse group, according to the results shown in Fig. 6.

4. CONCLUSIONS AND DISCUSSION

In this study, we built a platform for the tracking and analysis of animal locomotion with a commercial webcam, metal stand, and plastic bathtub used as a cage. We also developed a program for analyzing the recorded video. This very simple motion-analysis platform is a promising apparatus for researchers who monitor animals’ movement. Any experiments that can be performed within the plastic bathtub’s dimensions of 100 cm × 100 cm × 55 cm in a cost-effective manner. Video can be recorded with a maximum resolution of 1920×1080 at a rate of 30 fps. After recording, the analysis code finds the position of the animal in each frame and calculates the velocity, total distance of movement, and ambulatory pattern. There are a few commercial systems designed for the ambulatory study, but they are generally very expensive (about $20,000–$30,000). Our system costs approximately two hundred dollars for a webcam and a water bath.

The system was evaluated with two mouse groups: ICR and transgenic mice. Differences in velocity, moving pattern, and total distance were found between the two mouse groups. However, the statistical power of the test is limited since we did not use a sufficient number of mice.

Various animal ambulatory tests can be performed with the system we developed. General open-field tests and water maze tests were successfully performed with the system. Since the developed system can be configured easily by users, researchers can design or customize animal ambulatory tests freely. Testing multiple animals simultaneously is also possible with simple color-coding of animals, since the video is recorded in color. This promises that the system can be used not only in ambulatory studies but also in animal relationship studies.

ACKNOWLEDGMENT

This study was supported by a grant (2012-544) from the Asan Institute for Life Sciences, Seoul, Korea.

REFERENCES


