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Automatic Markerless System for Kinematic Gait Analysis in Animal Models Based on Deep Learning

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***Abstract*— This paper presents an automatic markerless system for quantitative gait analysis. The system enables tracking of 9 body parts of freely walking rat subjects to achieve kinematic gait parameters. The system features real time analysis with a comparable performance to marker-based evaluation solution.**

***Clinical Relevance*— Gait analysis of animal models plays an important role in the neurological disorders study.**

I. Introduction

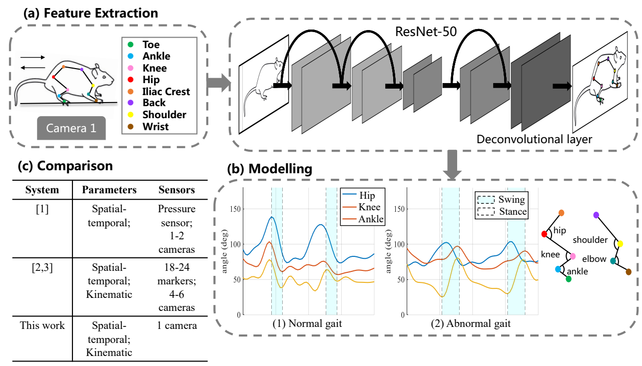
Many neurological disorders result in movement impairment and abnormal gait. Animal models are widely used for the study of such neural diseases, but lack of a quantitative gait analysis method for animals. Various sensors have been introduced to solve this issue. Specified designed animal walking plate with pressure sensor and fluorescent light have been proposed [1] enabling limited gait parameters. 3D motion capture systems [2,3] have been widely used for the acquisition of the motion trajectory and joint coordinates. But this system requires reflective markers placed before recording, which is time consuming and potentially distracting to animal subjects.

This study presents a markerless gait evaluation system based on deep learning algorithm. The proposed system features real time analysis of 9 body parts related to kinematic gait analysis. The system has been evaluated on freely moving rat models.

II. Methods

The rat subjects were placed in a transparent cage as the runway which allows them to move freely in both directions. A RGB camera was located in front of the runway to monitor the lateral view of the rat (sagittal plane) at 30fps.

Features related to gait phase detection and joint angle changes on the sagittal plane are selected to calculate the kinematic gait parameters. According to the reference study, 9 body parts including iliac crest, hip, knee, ankle, toe, back, shoulder, elbow, and wrist are the points of interest as shown in Fig. 1(a). 50-layer deep residual networks (ResNet-50) pretrained on ImageNet was used and trained respectively for the left and right sides of the rat. 15-20 image frames (10% of all the video frames) are labelled manually before training as the input data. After the training process, the kinematic gait parameters are automatically calculated according to the coordinate of each extracted keypoint j (x_{ij}, y_{ij}), where i stands for the number of the subject. The angle changes of the hip, the knee, the ankle and the stance, the swing phase time are calculated by modelling as the outputs of the system.



System	Parameters	Sensors
[1]	Spatial-temporal;	Pressure sensor; 1-2 cameras
[2,3]	Spatial-temporal; Kinematic	18-24 markers; 4-6 cameras
This work	Spatial-temporal; Kinematic	1 camera

Figure 1. Baseline of the markerless gait analysis system. (a) The rat subjects freely moved in a transparent cage. A deep learning network [4] is used to extracted the 9 keypomts for each side. (b) Experimental results were perfromed on both rats from the modeled and controled groups. (c) Table of the comparison among three different systems.

III. Results

Fig. 1(b) shows the quantitative analysis result of the proposed markerless system. The maximum and minimum of the joint angles, including hip, knee, and ankle, and the proportion of the gait phase time, including swing and stance phase, are compared between unimpaired and impaired rats.

IV. Discussion & Conclusion

The results reported above shows that the markerless system is possible to realize quantitative and stable results. As Fig. 1(c) shown, it is low-cost, time-saving and easy-operating compared with other systems. This work is a pilot study. Our long-term goal is to evaluate the appropriateness and transferability of the markerless method as an alternative to traditional marker-based system.

References

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