JOURNAL OF
EMERGING INVESTIGATORS

Article

Qualitative tracking of human and animation motions reveals differences in their walking gaits

Emmy Baily[1], Munetomo Takahashi[2,3]
[1]The American School in Japan, Tokyo, Japan
[2]Tokyo Academics, Tokyo, Japan
[3]Cambridge University, UK

SUMMARY

Since the release in 1937 of Walt Disney Productions' first animated film, Snow White and the Seven Dwarfs, animations have gained popularity. In their attempt to evoke a greater emotional connection with viewers, animators have strived to replicate human movements in their animations. However, animation movements still appear distinct from human movements. With a focus on walking, we hypothesized that animations, unaffected by real external forces (e.g. gravity), would move with a universally distinct, gliding gait that is discernible from humans. Specifically, we hypothesized that animation gaits would lack the sharp up and down movements of the leg caused by gravity. We tested our hypothesis by employing cutting-edge tracking technologies to quantitatively evaluate animation and human walking gaits. We found that animation gaits were significantly different from human gaits. Animation ankles floated forward during the gait, while human ankles rose sharply up and down. Without these "floating" ankles, animations appeared more human-like. These characteristics, though subtle, offer opportunities to enhance realism in animation by rendering characters not just visually but also kinematically authentic.

INTRODUCTION

Empathy is a crucial aspect of how people interact with art (1). Animated characters that evoke emotional connections with viewers may better attract their attention. Viewers feel an emotional connection with animations if the characters mirror humans (2). However, achieving the perfect balance of realism is difficult, as animated characters that imperfectly mirror humans risk falling into the uncanny valley and eliciting revulsion among viewers (2).

Over the years, animators have relied on various techniques to make their characters more realistic. In the 1930s, Walt Disney popularized the cel animation technique, in which characters were drawn onto clear celluloid sheets and placed over painted backgrounds (3). The animators' main focus was on creating a smooth illusion of movement rather than replicating real motion. Since 1981, however, animators have utilized qualitative techniques to enhance their character's realism (4). These techniques, such as 'slow in and slow out', which stipulates how objects should gradually accelerate and decelerate, ensure the characters move in ways that appear more human-like and natural (4). The extent to which these techniques are successful, however, is unknown.

Here in this study, we focused on the walking gait, a common motion in animations. We tested the hypothesis that animations, unaffected by real external forces (e.g. gravity), move with a distinct, gliding gait – a gait where ankles are floated forward. Investigation of this hypothesis may offer pivotal insights to enhance the realism of animated motions. We tested this hypothesis by evaluating animation and human movements with AlphaPose, (5) a pose estimation algorithm (6). This algorithm infers and tracks the movements of key body structures, such as limb joints and facial features, from photos and videos (7). The technique of pose estimation has been applied in a variety of real-life settings, from tracking human movement in gaming to improving people's posture (8), but to our knowledge, it has not yet been applied to track animation movements. We used AlphaPose to track animation and human walking gaits with a specific focus on ankle movements due to how important they are for a normal, coordinated gait (9). Through tracking, we discovered that animation gaits were distinct from human gaits. Animations consistently floated their ankles forward during their gait, creating an impression that they were gliding. In human gaits, however, ankles rose and fell rapidly. Removal of this gliding motion from animations may enhance their realism. These findings provide the framework to render animations kinematically authentic.

RESULTS

To test our hypothesis that animated ankle gaits differ from human gaits, we first developed a pipeline to quantitatively compare animation and human gaits. Short clips of modern animations (n=10) and humans (n=5) walking were collected, and we used AlphaPose to identify and track the movements of a figure's limbs, for each of these videos. Since AlphaPose was originally designed to track human movement, in some animations, the algorithm made systematic errors in which it mistook the left limb for the right limb (and vice versa) whenever the limbs intersected. We developed a program to identify and pair the limbs with their correct labels to rectify these errors. This pipeline returned the coordinates of limb movement for walking animations and humans, enabling us to analyze their respective gaits.

Next, we evaluated whether limb movements differed between animations and humans. We focused on ankle movements and their Y-coordinate fluctuations, since our aim was to evaluate differences in gaits and external forces that would be acting most strongly on horizontal movement such as gravity. The Y-coordinates of the ankles in humans exhibited a sharper peak during each gait than the animations (**Figure 1**). This difference was observed for both the right and left ankles across multiple human and animation videos

JOURNAL OF
EMERGING INVESTIGATORS

https://doi.org/10.59720/23-282

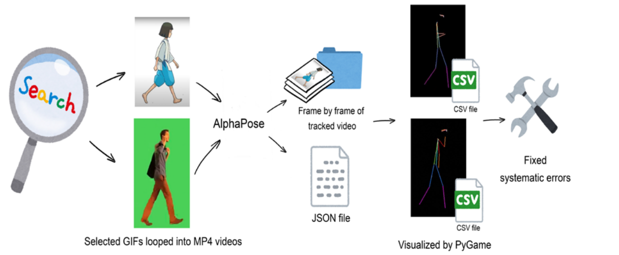

Figure 1: Pipeline to quantitatively compare animation and human gaits. Schema demonstrating the gait comparison pipeline (right ankle shown). Selected animation and human walking gifs were collated as MP4 videos and processed through AlphaPose. The results were visually reconstructed using PyGame, and a program was developed to rectify systematic errors from the resulting tracking.

collected from different sources, suggesting that animations universally displayed a distinct gait from humans.

To assess any statistically significant difference between the ankle motions of human and animation gaits, we calculated the relative Full Width at Half Maximum (FWHM) for these peaks (**Figure 2, 3a**). The peaks from the human gaits had a significantly lower average FWHM value (0.22) than respective animation (0.29), indicating that the peaks in human gaits were indeed thinner (**Figure 3b**).

To understand how these peaks reflected limb movement, we visually inspected each frame and aligned it with graph coordinates (**Figure 4**). For both humans and animations, the increase in the Y-coordinate of the ankles corresponded to the lifting of the back leg before the initiation of a new step. Likewise, the decrease in the Y-coordinate of the ankles corresponded to the dropping of the ankle to end a new step. Unlike humans, who dropped their ankles immediately to the ground after raising them, animations floated their ankles forward before dropping them. This resulted in a wider ankle Y-coordinate peak for the animations. Taken together, these results indicate that animations walk with a distinct, drifting gait - discernible from humans.

Lastly, we examined whether these differences in ankle gait contributed to our ability to distinguish humans and animations. The ankle movements of three animations were modified to match those of humans by forcing the ankles of

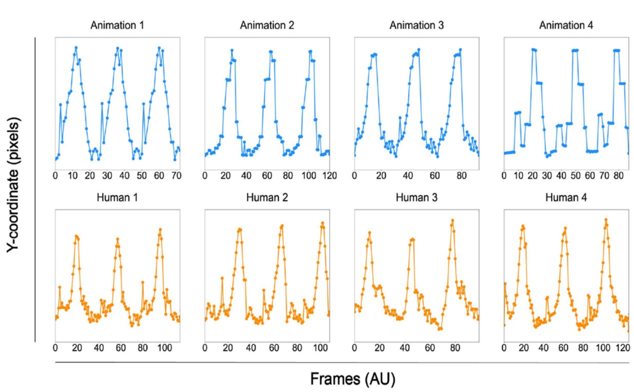

Figure 2: Qualitative comparison of animation and human Y-coordinate ankle movements. Y-coordinates of each ankle (right ankle shown) for each frame (arbitrary units) of motion in representative animation and human gaits (n=4 each).

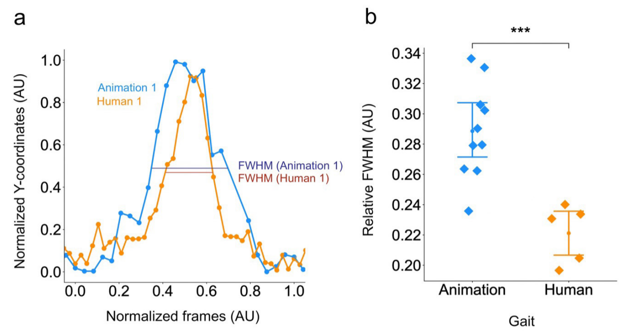

Figure 3: Quantitative comparison of animation and human Y-coordinate ankle movements. a) Representative Y-coordinate ankle movement peak from Animation 1 and Human 1. Y-coordinates and frames are normalized for both data. Horizontal lines represent respective relative FWHM values. b) Comparison of relative FWHM between animation (n=10) and human (n=5) gaits. Relative FWHM was calculated by dividing the FWHM by the length of a gait cycle for each video. Each point represents a single video. Welch's t-test results are shown (***, p<0.001).

animations to fall immediately after they had risen (**Figure 5a**). These modifications decreased the relative FWHM of the ankle Y-coordinate peaks to near-human values (from 0.29 to 0.24, while the human average was 0.22) (**Figure 5b**). We tested whether these modifications would make animations appear subjectively more human-like (**Figure 5c**). Thirteen participants were shown four paired stick-figure videos that compared either human and animation gaits (two comparisons) or animations and modified animations gaits (two comparisons). Participants were not told which stick figure corresponded to which type of gait and were instructed to score them on how human-like they moved (from one to ten; one being the least and ten being the most human-like) and also choose the stick figure that appeared to walk in the most human-like way. When comparing human and animation gaits, a majority of participants (69% and 77%) were able to correctly identify the human gait. Strikingly, a similar majority of participants (61% and 92%) identified the modified animation gait as more human than the original animation gait. These results were corroborated when participants were asked to score how human-like each gait appeared (**Figure 6**). These results suggest that we can modify animations' drifting gaits to make them appear more human-like.

DISCUSSION

To test our hypothesis that animations, unaffected by real

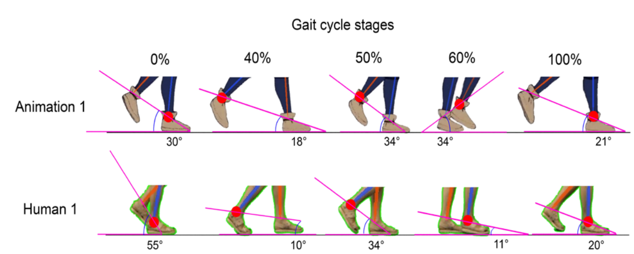

Figure 4: Frame-by-frame comparison of representative animation and human gaits. Frames showing representative animation and human gaits at equal stages into the gait cycle. The red dot tracks the right ankle through the cycle. The angle that the left and the right ankle make with the floor is shown in each frame.

https://doi.org/10.59720/23-282

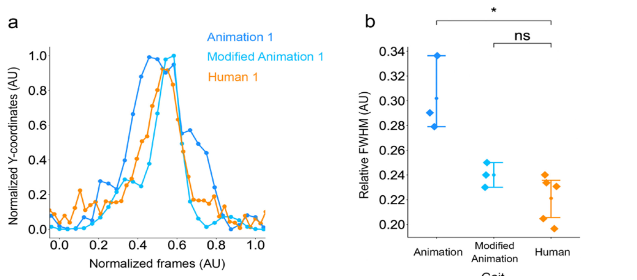

Figure 5: Evaluation of whether modified animations appear more human-like. a) Y-coordinate ankle movement peaks from Animation 1, Modified Animation 1 and Human 1. Y-coordinates and frames are normalized for both data. Horizontal lines represent respective relative FWHM values. b) Comparison of relative FWHM between animation (n=3), modified animation (n=3) and human (n=5) gaits. Relative FWHM was calculated by dividing the FWHM by the length of a gait cycle for each video. Each point represents a single video. Welch's t-test results are shown (*, p<0.05).

external forces (e.g. gravity), move with a distinct, gliding gait that is discernible from human gaits, we developed a pipeline involving AlphaPose, a tracking algorithm, to quantitatively evaluate animation and human walking gaits. Focusing on Y-coordinate ankle movements, we found that animations and humans gaits were distinct, supporting our hypothesis. By comparing frame-by-frame images, we identified a cause of such differences: animations continued to float their ankles forward during each gait, whereas human ankles dropped quickly to the ground. Finally, a survey of 13 participants suggested these alterations could lead animations to be perceived as more human-like. To our knowledge, our study is the first to apply a tracking algorithm to 2D animation gaits and to quantitatively demonstrate categoric differences between human and animation gaits.

Although we identified differences in the Y-coordinate motion of the human and animated ankles, we did not explore potential causes for these differences. On explanation for these differences is a lack of consideration for external forces, such as gravity, by animators. Similarly, animators could be inadvertently skewing animation motions because of differences in limb proportions between animation and human characters. Animation characters tend to be depicted with larger feet, and this could lead to asynchrony between the ankle motions and the overall gait. Investigation into the cause of these differences, such as by tracking the ankle motions of humans in low gravity settings, could provide basic knowledge that would be of interest to the animation community.

In addition, we note that future work has the potential to improve upon our study. For instance, although we showed differences between animations and human gaits that we collected from diverse sources, these clips were all chosen to fit strict criteria: all clips had a lateral view, a muted background, and a subject tracked by the camera to be consistently positioned at the center of the screen. These criteria ensured that all clips were directly comparable and minimized tracking errors. However, we did not track animations or humans in a 'natural setting,' such as characters walking across the street or walking at an angle to the camera. Now that we have established a pipeline for our analysis, further work could focus on standardizing and comparing more diverse videos to evaluate the universality of our hypothesis. Additionally, in our survey we asked participants to compare the gaits of stick figures representing human or animation motion rather than the actual human or animation gaits. The stick figures could be readily modified, enabling animation stick figures to be 'humanized.' However, they are a proxy for real clips and could therefore be missing information that is critical for human perception of animation movement. Future work could directly modify animations to evaluate whether our suggested modifications do, in fact, cause animations to be perceived as more human.

Our findings offer implications for the world of animation. The "drifting ankle" observed consistently in animations detracts from their movement's realism. By rectifying this movement, the animation industry can narrow the chasm between animation and human movements. This could promise a richer, more empathetic viewer experience. We hope that our study stimulates development in utilizing these technologies to transform artistic creations.

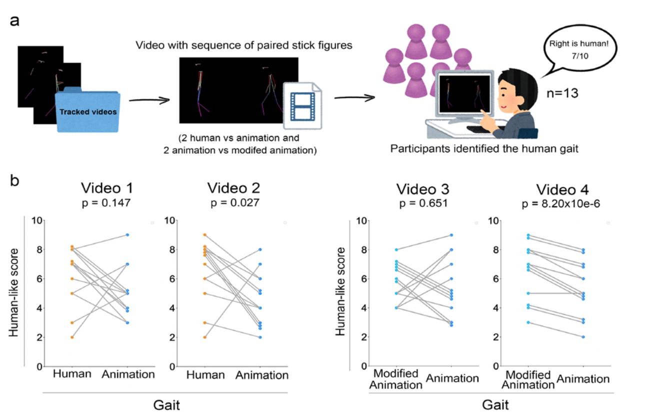

Figure 6: Results of the survey comparing human and animation/modified animation ankle movements. a) Schema demonstrating a survey designed to evaluate whether the above modifications make animations appear more human-like. Participants (n=13) were shown 4 paired stick-figures (2 human vs. animation pairs, and 2 animation vs. modified animation pairs). Participants were then asked to identify the human gait and score each video for how human-like they appeared on a scale from 1-10. b) Human-like scores that each participant assigned to each video for the human-animation stick figure pairings (Video 1 and Video 2) and the modified animation-animation stick figure pairings (Video 3 and Video 4). P-values from paired t-test results are shown above each plot.

MATERIALS AND METHODS

Tracking Animation and Human Gaits using AlphaPose

Ten clips of 2D human animations walking and five clips of humans walking were chosen from online sources (see **Appendix**). To keep the data set consistent, all chosen clips had a lateral view and a muted background. In all clips, the subject was tracked by the camera to be consistently positioned at the center of the screen. All 10 animation clips were GIF files that contained a single walking gait cycle, and so each clip was repeated 10 times and converted into an MP4 format. All 5 human clips (MP4) contained seven to ten walking gait cycles. Each of the 15 videos were processed through a custom script that applied AlphaPose (5). The script outputted a folder containing frame-by-frame images of the tracked subject, a tracked MP4 video, and a JSON file of the limb movement coordinates. These coordinates were then used to visualize the subjects' walking gait as stick figures in PyGame.

Rectifying Errors in AlphaPose Tracking

Due to AlphaPose being originally designed to track human movements, the program made errors in correctly identifying the limbs of animations. Errors in tracking were identified by manually inspecting each tracked frame. Mislabeled left and right legs were replaced with the correct limb coordinates. If 2 or more lower limb coordinates were misidentified, the frame was removed from the analysis.

Calculating the FWHM

First, the maximum value of each peak was calculated as the difference between the maximum ankle Y-coordinate (for each leg) and the minimum ankle Y-coordinate. The FWHM was then determined as the average number of frames that passed between when the ankle coordinates first and last reached half of their maximum value for each gait cycle. The FWHM was divided by the total number of frames per gait cycle for each video to determine the relative FWHM. The FWHM values were compared using Welch's t-test.

Modifying Animations Gaits

The ankle movements of animations were modified to match those of humans by applying a horizontal exponential compression to each ankle Y-coordinate peak. Specifically, each ankle Y-coordinate peak was translated horizontally to center around the origin, and the absolute value of each frame was raised to an exponent that best modified the peak to match the shape of the human peaks (between 1 and 3). The frames were next transformed by a scale factor so that the maximum and minimum frame numbers matched those of the original animation. The modified peak was then translated horizontally to its original position. The process was repeated for every other peak and for the other ankle. Finally, stick figure movements with these new ankle Y-coordinate movements but with otherwise identical limb coordinate movements were created using PyGame to visualize the modified gaits.

Survey to Evaluate Perception of Modified Animation Gaits

A video with a sequence of four ten-second side-by-side comparisons of two stick figures was created using the previously described stick figure movements. The video contained comparisons of human vs. animation stick figures (2 comparisons), and animation vs. modified animation stick figures (2 comparisons). Modified animations were compared with those from which they were originally derived from. 13 participants (8 males and 5 females between the ages of 17-55 years old) were involved in the study. At the start of the study, participants were instructed to focus on the leg movements of the stick figures. For each comparison, participants were given 30 seconds to point at the figure that looked more human-like, and to rate the human-likeness of each figure on a scale of 1 to 10, with 1 being not human-like and 10 being human.

Software Version

Data was analyzed using Python version 3.8.6 and Python packages (AlphaPose 0.5.0, PyGame 2.0.1, jupyterlab 2.2.9, numpy 1.19.3, pandas 0.22.0, scipy 1.1.0). Figures were produced using seaborn 0.11.0, matplotlib 3.5.1 in Python, Adobe Photoshop 23.3.0 and Adobe Illustrator 26.3.1.

Data and Code Availability

All material will be made available on request.

ACKNOWLEDGMENTS

We would like to thank Jonathan Lai for help with implementing AlphaPose and Ekin Gürgen for guidance on the direction of the project.

Received: August 15, 2023
Accepted: April 23, 2024
Published: October 4, 2024

REFERENCES

1. Stadler, Jane. "Empathy in film." The Routledge handbook of philosophy of empathy, no. 1, 14 Feb. 2017, pp. 317-326. https://doi.org/10.4324/9781315282015
2. Mori, Masahiro. “Bukimi No Tani [The Uncanny Valley].” *Energy*, vol. 7, 1970, p. 33. https://doi.org/10.1371/journal.pone.0254396
3. Giachet, Miriam Truffa, et al. “Characterization of Chemical and Physical Properties of Animation Cels from the Walt Disney Animation Research Library.” *ICOM Committee for Conservation 17th Triennial Meeting Melbourne*, 2014.
4. Thomas, Frank, et al. “Disney Animation: The Illusion of Life.” *Abbeville Press*, 1981.
5. Fang, Hao-Shu, et al. "Rmpe: Regional multi-person pose estimation." *Proceedings of the IEEE international conference on computer vision*, 2017. https://doi.org/10.48550/arXiv.1612.00137
6. Josyula, Rohit, et al. “A Review on Human Pose Estimation.” *arXiv*, Oct. 2021, arxiv.org/abs/2110.06877.
7. Song, Liangchen, et al. “Human Pose Estimation and Its Application to Action Recognition: A Survey.” *Journal of Visual Communication and Image Representation*, vol. 76, Apr. 2021. https://doi.org/10.1016/j.jvcir.2021.103055
8. Casy, Tiphaine, et al. "“Stand-up straight!”: human pose estimation to evaluate postural skills during orthopedic surgery simulations." *International Journal of Computer Assisted Radiology and Surgery*, vol. 18, no. 2, Feb. 2023. https://doi.org/10.1007/s11548-022-02762-5
9. Moriguchi, C. S., et al. “Ankle Movements during Normal Gait Evaluated by Flexible Electrogoniometer.” *Brazilian Journal of Physical Therapy*, vol. 11, no. 3, June 2007, pp. 205–11. https://doi.org/10.1590/S1413-35552007000300006

Copyright: © 2024 Baily and Takahashi. All JEI articles are distributed under the attribution non-commercial, no derivative license (http://creativecommons.org/licenses/by-nc-nd/4.0/). This means that anyone is free to share, copy and distribute an unaltered article for non-commercial purposes provided the original author and source is credited.

https://doi.org/10.59720/23-282

APPENDIX

Animation 1	https://webneel.com/daily/1-2d-boy-walk-cycle-animation-chinese-anime-manga-gif?size=_original
Animation 2	https://stat.ameba.jp/user_images/20210905/09/iwade-manga/fc/fa/g/o1280072014996534199.gif?caw=800
Animation 3	https://webneel.com/daily/2-2d-boy-walk-cycle-animation-chinese-gif?size=_original
Animation 4	https://aniduku.com/wp-content/uploads/2016/08/01_walk.gif
Animation 5	https://cdn-ak.f.st-hatena.com/images/fotolife/a/ayu_no_suke/20210720/20210720090229.gif
Animation 6	https://gfycat.com/brightdirectbagworm
Animation 7	https://t.pimg.jp/mp4/097/284/475/1/97284475.mp4
Animation 8	http://blog.cnobi.jp/v1/blog/user/21d7d82f9b28ff481107f2f41e39a86a/1390561283
Animation 9	http://blawat2015.no-ip.com/~mieki256/diary/img/_2017/20170525_walk/walk_take1_1k.gif
Animation 10	https://www.youtube.com/watch?v=tzQ3bkHrxdk
Animation 11	https://blog.goo.ne.jp/2502shion/e/ac4f09846c5edd0a60f08d8cdc609e80
Animation 12	http://listeningside.net/images/side_a_09a.gif
human 1	https://jp.depositphotos.com/358643808/stock-video-young-woman-is-calmly-walking.html
human 2	https://jp.depositphotos.com/159929468/stock-video-girl-of-asian-appearance-walks.html
human 3	https://www.youtube.com/watch?v=IGPeZzW7D5c
human 4	https://jp.depositphotos.com/358663098/stock-video-bearded-guy-calmly-walking-and.html
human 5	https://elements.envato.com/blonde-woman-is-calmly-walking-and-smiling-on-gree-K2GVX3P