Gait Recognition in Interaction with Queer Citizens

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Abstract: Facial recognition has experienced an ethical reckoning in academia and popular media for its inaccuracy and embedded bias, particularly with regard to its treatment of gender minorities. Failures in sampling and overlooked flaws have made the in-use software unusable for many queer people. Yet, similar discourse is lacking for gait recognition—automated identification based on an individual's movement. With gait recognition software already capable of performing gender classification and already deployed in some sites, how might members of the LGBTQ community, who use motion as a social indicator, be affected by the application of such technology? In tandem, how does mechanized gait recognition rely on pre-existing assumptions about queer people? This paper seeks to build on ethical analysis of facial recognition software by looking at the harms of gait recognition in pre-computerized contexts, inspecting the assumptions used in gait tech development, and evaluating current applications of the technology.

In January 2020, a letter to the U.S. Privacy and Civil Liberties Board signed by the National Center for Transgender Equality and the National LGBTQ Task Force called for an immediate suspension of facial recognition systems across the country ("Letter," 2020). Concerns of bias and discrimination cited in the letter echo the actions of municipal lawmakers in cities like Oakland and San Francisco who have outright banned facial recognition (Fussell, 2021). Nevertheless, in 2021 the biometric scan software industry, comprising fingerprint readers and facial recognition, grew to $10.2 billion in revenue in the U.S. alone (Curran, 2021). The unremitting growth of surveillance companies coupled with alarm over this surveillance from queer rights organizations places facial recognition technology at the center of conversations about Big Tech's treatment of LGBTQ people. Yet, biometric surveillance technology in use today does not stop short at the chin. Amid revolutions in machine learning, the way we move— our walking posture, our sway, and the weight of our steps— has also been distilled into quantifiable metrics. Known as gait recognition technology, modern software is capable of detecting a unique signature from the way an individual walks either through video recordings or motion sensors. Although facial recognition technology has undergone a plethora of discourse relating to the ways it disenfranchises queer people, gait recognition has not garnered the same attention. In response to this gap in scholarship, I contend that the use of gait recognition technology poses a threat to queer people.

I will argue this in three steps. First, by looking at psychological research and cultural anecdotes, I will demonstrate that independent from technology, gait functions as a social indicator of sexual orientation and gender identity. Second, drawing upon papers from computer vision researchers, I will argue that the design of gait recognition software adheres to a strictly binary classification system and overlooks the manipulability of gendered cues. Third, by investigating the blunders of facial recognition software and the sites where biometric technology interacts with queer citizens, I will establish that gait recognition technologies replicate the dangers of facial recognition software, harming queer people through exposure and misclassification.

Gait Recognition

In order to understand the linkages between queer people and gait recognition technology, one must first understand the scope of the technology: what it is, how it's done, and where it's used. Biometric security researchers Mason et al. (2016) define gait biometric technology as "extracting and measuring unique and distinctive patterns from human locomotion" typically through video cameras, smartphones, and floor sensors (p. vii). As Mason et al. (2016) point out, there is no "single measure that encompasses the full set of complex dynamics reflecting what we consider to be the human gait," so instead, machine learning algorithms extract certain features by which an individual's gait can be verified or identified (p. 9). Essentially, gait recognition technology offers a way to decipher who an individual is based on specific components of their style of movement.

The Chinese company Watrix made headlines when police in Shanghai and Beijing began using their gait recognition devices to enhance surveillance systems. Watrix, which has raised $14.5 million in funding, is one of the first ventures to commercialize gait recognition (Kang, 2018). FST Biometrics, an Israeli gait recognition firm, shut down over technical difficulties and corporate infighting, and most other gait recognition development has been government-directed or purely academic (Kang, 2018). Watrix's software maintains a 94 percent accuracy rate in identification, acting as a backup to facial recognition which requires close range (Kang, 2018). The company advertises its commercially-available device Shui Di Shen Jian (水滴神鉴) as being capable of finding a suspect in CCTV footage after being fed a clip of the target walking ("SHUI," n.d.).

Gait recognition has certainly not proliferated in the same capacity that facial recognition has, but the overwhelming outlook on the innovation is that it can complement pre-existing facial recognition systems. Computer vision researchers Do et al. (2020) claim that gait technology is preferable to other recognition software because gait is capturable from a distance, difficult to forge, and unreliant on the cooperation of the target. Many of these attributes stand out because they are not possible with facial recognition software, which for the most part, needs up-close shots or high-quality resolutions. Considering that facial recognition is already used by the FBI on DMV photos, Customs and Border Protection in airports, and city police departments like that of Baltimore, it is likely that the proliferation of gait recognition is not so far-off (Ghaffary and Molla, 2019). It is therefore imperative to examine gait recognition technology's propensity to harm queer citizens, given its increasingly relevant role in surveillance.

Before the Machine: Gait as a Social Indicator

Before delving into mechanized understandings of queerness through gait recognition, one must consider the relationship between gait and queerness in entirely social settings. Separate from recent innovations in gait biometrics, gait functions as a social indicator of sexuality and gender. Professor of Communication and Psychology Kerri Johnson investigates how humans measure gender and sexual orientation through gait. In summarizing the work of prior social psychologists, she advances that gender is socially inferrable based on features like "swaying hips" and "swaggering shoulders" (Johnson, 2007, p. 323). Johnson (2007) furthers this argument by hypothesizing that "gender typicality" with regard to "body shape and body motion" contribute to determinations of sexual orientation by perceivers (p. 331). Looking at both artificial models and real human walking patterns, subjects of her study confirmed this hypothesis; they deciphered sexual orientation by referring to how much a person's (or a 3D model's) gait adheres to gendered expectations of their movement. In "Deliberate Changes to Gendered Body Motion Influence Basic Social Perceptions," Lick et al. (2013) build on Johnson's research by claiming that individuals, particularly queer people, may actively alter locomotion to exploit social assumptions. According to Lick et al. (2013), "deliberate modifications of gendered body motions" can affect the "basic perceptions of sex and sexual orientation" surmised by an observer, appending a layer of performance to Johnson's hypothesis

(p. 669). Lick et al. (2013) add that gay and lesbian subjects were particularly adept at this sort of gait performance, which they speculate arises from practice in social settings requiring such an obfuscation of identity (p. 669). Through portrayals of gait and observations of observers, Johnson and Lick et al. give traction to the idea that queerness is socially inferred from motion.

This cultural understanding of sexuality-specific and gendered movement is prevalent outside of psychology. Gay Twitter users have popularized and humorized the trope that gay men universally share the trait of speed walking (Staples, 2019). One such tweet with almost six-thousand retweets jokes, “straight people, look behind you, chances are there's a gay person trying to get past because you're moving at an extremely glacial pace” (@heyDejan, 2019). There are also historic counterparts to these stereotypes of gay movement, which are neither reclamatory nor humorous. Pseudo-scientific studies of homosexuality in the late 1930s and early 1940s attempted to pin down the physiognomy of gay men through references to their locomotion (Lvovsky, 2015, p. 66). In *Sex Variants: a study of homosexual patterns*, psychiatrist George Henry (1941) noted the gay man’s “prim, affected gait” and “uncertain, mincing steps” (p. 283). These supposedly scientifically-backed notions of identification and signals emboldened post-Prohibition authorities to identify and crackdown upon bars that served gay customers (Lvovsky, 2015, p. 105). In 1940, investigator William Wickes discerned that the clientele of the Gloria Bar & Grill in New York were gay based on “a very graceful motion” of their hands and “a swaying movement of their hips” which one might call “a swish in show parlance” (Lvovsky, 2015, p. 107). From the early twentieth century to modern internet communities, cultural dialogues have given weight to the existence of a gay stride, whether it be for comic or violent means. The veracity of gait being an indicator for gender and sexuality might be disputable, but it is perhaps less important than the fact that the general public assumes it to be so.

Assumptions of Gender in Gait Recognition Development

Moving from human and cultural perception to computer vision, gait recognition technology attempts to both identify an individual and classify sets of individuals into categories. One area of active development is gender classification, which would enable users to assess the gender of any people in motion captured by cameras or other monitors. By analyzing the development of this software, we can ascertain assumptions of gender that underlie gait recognition.

A core assumption made by software developers and computational researchers is that gender is binary. This prevailing notion underpins their methodologies, as they train models to sort data points on motion as either male or female. In “Real-Time and Robust Multiple-View Gender Classification Using Gait Features in Video Surveillance,” computer vision researchers Do et al. (2020) present a gait recognition model for gender classification in real-time, using surveillance footage. In sharp contrast to Johnson and Lick, little room is given in Do et al.’s (2020) work to atypical gender locomotion, because as they clarify, “gender classification is a binary classification task” (406). Do et al. are not alone in this belief. At the 12th IAPR

International Conference on Biometrics, held in 2019, ten teams entered a competition to estimate an individual's age and gender through wearable sensors attached to a waist-belt or a backpack (Ahad et al., 2020). Teams attempted to extract statistical features from the sensors which they then utilized to develop gender classification methods (Ahad et al., 2020). To arrive at classifiers, they employed a variety of deep learning methods like bi-directional long short-term memory, temporal convolutional networks, and convolutional neural networks (Ahad et al., 2020). One team relied on "a linear function to generate a continuous output for age estimation" but switched to "different non-linear activation functions to deal with the binary classification problem" of gender estimation (Ahad et al., 2020, p. 14). While age receives a spectrum, modeled through a continuous line, gender is reduced to a here-or-there approach. Another team created three algorithms, then for their fourth took "an average of the first three predictions" and marked an individual as a man if the average exceeded 0.5 (Ahad et al., 2020, p. 15). None of the competitors accommodate non-binary, agender, or genderqueer subjects, because as the aforementioned team exemplifies, the gender models recognize above 0.5 or below 0.5 and nothing in between.

Gait recognition write-ups and studies are also fraught with assumptions of stability in gender cues from motion. Do et al. (2020) assert that "mimicking the gait of other people is difficult" which bolsters the value of their observations (p. 400). Huang Yongzhen, the CEO of Watrix, claims that "gait analysis can't be fooled by simply limping, walking with splayed feet or hunching over, because we're analyzing all the features of an entire body" (Kang, 2018, para. 4). The implication in these statements is that gait is irreplicable and entirely unique to an individual, but this defies the notion established by Lick et al. that the gait of an individual may be transient or context-sensitive. In attempts to individualize a static characteristic, automated gait recognition loses sight of the dynamism involved in human gait. Thinking through gait-based gender classifiers using Lick et al.'s research problematizes its methodology and goals, because surveillance cannot tell what's legitimate from what's performance, if there even is such a thing as a legitimate gait, nor can it pick up on changes in gait from a multitude of contextual factors.

The final component that problematizes gait technology's treatment of gender is its baseline data. In "*Raw Data" is an Oxymoron*, Lisa Gitelman and Virginia Jackson (2013) suggest that "data garner immanence in the circumstances of their imagination," meaning data support conclusions precisely because of the conclusions regarding the importance of data (p. 3). Gitelman and Jackson (2013) propose that, despite data's reputation of objectivity, the standards of data manipulation (collection, scrubbing, mining, interpretation, etc.) within a field govern its meaning and its capacity to substantiate claims.

In the realm of biometric recognition, datasets of human beings (their faces or their motion) form the basis of machine learning algorithms, which thereby recognize and categorize the faces and movements of humans outside the dataset. In their examination of facial databases underpinning gender classification technologies, Wu et al. (2020) find that benchmark databases exhibit inequality in racial and gendered representation. They also underscore facial recognition systems' incapacity to recognize those who don't conform to normative genders, and in response, developed a gender-inclusive dataset that trained their model to classify non-binary faces with 91.97 percent accuracy (Wu et al., 2020). The central point of the exercise was that facial recognition systems can augment accommodation of gender minorities by actively constructing inclusive databases.

Among gait recognition researchers, the preferred database is the CASIA Gait Database developed by the Institute of Automation, Chinese Academy of Sciences. The benchmark dataset contains 13,640 gait sequences gathered from 124 participants, 93 of which are men, 31 of which are women, and none of which identify as non-binary (Martín-Felez et al., 2010). To address this inequality in representation, Martín-Felez et al. (2010) claim that most studies on gait gender classification "have avoided dealing with its imbalanced nature by using reduced balanced subsets" (p. 443). Resultantly, researchers must whittle down an already small sample size, allowing for 31 men and 31 women to dictate the nature of their classifiers. It is in these miniature sample sizes that machines modeled off of the majority fail in the face of queerness. Gait recognition technology is therefore poised to repeat the mistakes of facial recognition, but its results may even be worsened given the comparative availability between images of faces and videos of movement.

Gait Recognition at Scale and in Use: Threats to Queer Citizens

So far, I have previewed the risk of gait recognition by taking a design-side approach, but the software's detrimental effects on queer people are best understood by taking into account its implementation in the real world. In other words, the ways in which this technology actively undermines queer citizens is only visible when seeing and imagining how surveillance technology performs in practice—installed in street corners, checkpoints, or commercial venues. The potential injurious consequences of this widespread adoption to queer citizens can be understood in two ways. First, gait recognition technology might be accurate in assessments of sexual orientation, unveiling an attribute that is otherwise not immediately visible. Second, gait recognition can misread queer people, making public life less hospitable towards their identity.

Given that psychologists like Johnson and Lick et al. have buttressed the idea that queerness is visible through movement, gait recognition could similarly target the features they ascribe to LGBTQ subjects. This possibility—that queer citizens could be detected and tracked in public settings—raises a host of ethical concerns. Debate over these ethical implications came alive when, in 2017, Stanford organizational behavior professor Michal Kosinski and Yilun Wang, a graduate student, developed an artificial intelligence program capable of detecting gay men and lesbian women with 81 and 71 percent accuracy respectively (Murphy, 2017). The researchers employed "deep neural networks" on "35,326 facial images" gathered from dating apps, where profiles self-identified their sexual orientations, forming what the New York Times called an "A.I. gaydar" (Wang and Kosinski, 2018, p. 2) (Murphy, 2017). The study drew ire from LGBTQ advocacy organizations GLAAD and the Human Rights Campaign, who criticized the study's exclusively white sample and reduced the research to a description of "beauty standards on dating sites that ignores huge segments of the LGBTQ community" ("GLAAD," para. 2). They further that the study invokes a potential harm to "both heterosexuals who are inaccurately outed, as well as gay and lesbian people who are in situations where coming out is dangerous" ("GLAAD," para. 3). If gait technologies enable an explicit or implicit tracking of queer populations (which Johnson and Lick et al.'s research suggest they could), they would entail the consequences of Kosinski and Wang's defunct prototype, bringing forth the identities of the surveilled and endangering them in the process.

Misclassification and failures in gait recognition pose another unique threat to LGBTQ people, particularly gender minorities. A team of information science researchers at the University of Colorado, led by Morgan Scheuerman, examined how computer vision services for gender classification and gender labeling handle cases of gender diversity. The team found that services provided by IBM, Amazon, Microsoft and Clarifai misidentified pictures of trans men as women 29.5 percent of the time and pictures of trans women as men 12.7 percent of the time (Scheuerman et al., 2019). Conversely, cisgender women had an accuracy rate of 98.3 percent and cisgender men received correct classifiers 97.6 percent of the time (Scheuerman et al., 2019). None of the commercially-available facial analysis services enable non-binary categorization, meaning agender and non-binary subjects were always misrecognized (Scheuerman et al., 2019). Once again, these risks of visual recognition translate to identifying people's motion. As aforementioned, the models for gender classification through gait recognition rely on binary assignments, and are therefore prone to perpetuate the mistakes of facial recognition in misidentifying non-binary people. Likewise, trans people will continue to be vulnerable under gait recognition software for the same reasons they are under facial recognition: limited samples that tend to the cisgender majority are used to construct models. These slip-ups propagate hostile environments; for instance, because of misidentification, trans people face "invasive body searches or harassment if their ID does not match their gender" (Millar, 2019, para. 9). Hence, gait recognition software, by lacking nuance in its analysis of gender, can promote hostility in the public spaces that it occupies.

The sites of surveillance, which tend to be securitized zones, are also critical in understanding the dormant danger of gait biometrics for queer citizens. With regard to police departments, law enforcement has a history of hostility towards LGBTQ citizens which persists today. A report by UCLA's Williams Institute on law enforcement's mistreatment of LGBTQ Americans summarizes the historical criminalization of queerness by pointing to bar raids (like the aforementioned one at the Gloria Bar & Grill) which spurred the Stonewall Riots and anti-sodomy laws enforced by police (Mallory et al., 2015). The report goes on to cite a 2013 survey of LGBT violence survivors wherein 48 percent reported experiences of police misconduct as well as a 2011 survey of trans Americans where 22 percent reported harassment from law enforcement (Mallory et al., 2015). Notably, up until its repeal in February 2021, a 1976 law known as the "walking while trans" ban in New York City allowed for the profiling of trans women by conflating them with prostitutes based on their attire or "innocuous" behavior (McKinley and Ferré-Sadurní, 2021, para. 17). As gait recognition technology identifies irregularity in gendered movement, it may open the door for targeted enforcement against queer people, who already face disproportionate persecution from police. In essence, algorithms run with surveillance footage take the place of profiling officers.

The TSA, one of the earliest adoptees of facial recognition technologies in the United States, has also historically harassed and invalidated trans people. Toby Beauchamp (2009) writes that in the wake of 9/11, the adoption of the Real ID Act subjected trans people to more frequent stops at airport security given mismatches in listed genders on their various forms of identification. Moreover, Beauchamp (2009) references a 2003 DHS Advisory, which reads "male bombers may dress as females in order to discourage scrutiny," ultimately conveying that non-normative gender presentations represent a security threat to the state (p. 356). In *Securitizing Gender: Identity, Biometrics, and Transgender Bodies at the Airport*, Paisley Currah and Tara Mulqueen (2011) further that the rise in whole body scanners at airports has heightened the scrutiny of trans bodies, requiring trans travelers to "contort their gendered selves to appear as conventionally gendered as possible at the airport" (p. 573). Implementation of gait technology would amplify such dysphoria-inducing and mobility-restraining encounters, flagging travelers whose styles of locomotion don't comport with normative expectations.

Conclusion

In light of its flaws in methodology, its probable expansion, and its deployment in security settings, gait recognition carries significant consequences for queer people, be it through misrecognition or targeted identification. Whether or not governments will heed the warnings of queer rights organizations remains unknown. At any rate, gait recognition technology invigorates an age-old debate weighing security solutions against their implications for queer citizens. In that same manner, machine learning amplifies and exposes the shortsightedness of its creators, demonstrating that without an eye for inclusion, technology can reify systems of oppression.

References

Ahad, M. A. R., Ngo, T. T., Antar, A. D., Ahmed, M., Hossain, T., Muramatsu, D., Makihara, Y., Inoue, S., & Yagi, Y. (2020). Wearable Sensor-Based Gait Analysis for Age and Gender Estimation. *Sensors*, *20*(8), Article 8. https://doi.org/10.3390/s20082424

Beauchamp, T. (2009). Artful Concealment and Strategic Visibility: Transgender Bodies and U.S. State Surveillance After 9/11. *Surveillance & Society*, *6*(4), 356–366. https://doi.org/10.24908/ss.v6i4.3267

Currah, P., & Mulqueen, T. (2011). Securitizing Gender: Identity, Biometrics, and Transgender Bodies at the Airport. *Social Research*, *78*(2), 557–582.

Curran, J. (2021). *Biometrics Scan Software* (Industry Report OD4530). IbisWorld. https://my-ibisworld-com.stanford.idm.oclc.org/us/en/industry-specialized/od4530/industry-at-a-glance

Do, T. D., Nguyen, V. H., & Kim, H. (2020). Real-time and robust multiple-view gender classification using gait features in video surveillance. *Pattern Analysis and Applications*, *23*(1), 399–413. https://doi.org/10.1007/s10044-019-00802-6

Fussell, S. (2021, January 28). The Next Target for a Facial Recognition Ban? New York. *Wired*. https://www.wired.com/story/next-target-facial-recognition-ban-new-york

Ghaffary, S., & Molla, R. (2019, December 10). Here's where the US government is using facial recognition technology to surveil Americans. *Vox*. https://www.vox.com/recode/2019/7/18/20698307/facial-recognition-technology-us-government-fight-for-the-future

Gitelman, L., & Jackson, V. (2013). Introduction. In *"Raw Data" Is an Oxymoron* (pp. 1–14). MIT Press. http://ieeexplore.ieee.org/document/6462160

GLAAD and HRC call on Stanford University & responsible media to debunk dangerous & flawed report claiming to identify LGBTQ people through facial recognition technology. (2017, September 8). GLAAD. https://www.glaad.org/blog/glaad-and-hrc-call-stanford-university-responsible-media-debunk-dangerous-flawed-report

Henry, G. W. & Committee for the Study of Sex Variants. (1941). *Sex variants: A study of homosexual patterns*. P.B. Hoeber, Inc.

@heyDejan. (2019, March 8). *Straight people, look behind you, chances are there's a gay person trying to get past because you're moving at an extremely glacial pace* [Tweet]. Twitter. https://twitter.com/heyDejan/status/1103904679497412608

Johnson, K. L. (2007). Swagger, sway, and sexuality: Judging sexual orientation from body motion and morphology. *Journal of Personality and Social Psychology*, *93*(3), 321. https://doi.org/10.1037/0022-3514.93.3.321

Kang, D. (2018, November 6). *Chinese "gait recognition" tech IDs people by how they walk*. AP NEWS. https://apnews.com/article/china-technology-beijing-business-international-news-bf75dd1c26c947b7826d270a16e2658a

Letter to Privacy and Civil Liberties Oversight Board. (2020, January 27). Electronic Privacy Information Center. https://epic.org/wp-content/uploads/privacy/facerecognition/PCLOB-Letter-FRT-Suspension.pdf

Lick, D. J., Johnson, K. L., & Gill, S. V. (2013). Deliberate Changes to Gendered Body Motion Influence Basic Social Perceptions. *Social Cognition*, *31*(6), 656–671. https://doi.org/10.1521/soco.2013.31.6.656

Lvovsky, A. (2015). *Queer Expertise: Urban Policing and the Construction of Public Knowledge About Homosexuality, 1920–1970*. https://dash.harvard.edu/handle/1/17463142

Mallory, C., Hasenbush, A., & Sears, B. (2015). *Discrimination and Harassment by Law Enforcement Officers in the LGBT Community*. UCLA School of Law Williams Institute. https://williamsinstitute.law.ucla.edu/publications/lgbt-discrim-law-enforcement/

Martín-Félez, R., Mollineda, R., & Sánchez, J. (2010). *A Gender Recognition Experiment on the CASIA Gait Database Dealing with Its Imbalanced Nature.* 439–444.

Mason, J. E., Traore, I., & Woungang, I. (2016). *Machine learning techniques for gait biometric recognition: Using the ground reaction force*. Springer. https://doi.org/10.1007/978-3-319-29088-1

McKinley, J., & Ferré-Sadurní, L. (2021, March 2). N.Y. Repeals Law That Critics Say Criminalized 'Walking While Trans.' *The New York Times*. https://www.nytimes.com/2021/02/03/nyregion/walking-while-trans-ban.html

Millar, M. (2019, October 30). *Facial recognition technology struggles to see past gender binary*. Reuters. https://www.reuters.com/article/us-usa-lgbt-facial-recognition/facial-recognition-technology-struggles-to-see-past-gender-binary-idUSKBN1X92OD

Murphy, H. (2017, October 9). Why Stanford Researchers Tried to Create a 'Gaydar' Machine. *The New York Times*. https://www.nytimes.com/2017/10/09/science/stanford-sexual-orientation-study.html

Scheuerman, M. K., Paul, J. M., & Brubaker, J. R. (2019). How Computers See Gender: An Evaluation of Gender Classification in Commercial Facial Analysis Services. *Proceedings of the ACM on Human-Computer Interaction*, *3*(CSCW), 144:1-144:33. https://doi.org/10.1145/3359246

SHUI DI SHEN JIAN. (n.d.). *Watrix*. Retrieved May 23, 2021, from http://www.watrix.ai/en/gait-recognition/shui-di-shen-jian/

Staples, L. (2019, June 19). *Why Do Gay Men Walk So Fast?* GQ. https://www.gq.com/story/move-im-gay

Wang, Y., & Kosinski, M. (2018). Deep neural networks are more accurate than humans at detecting sexual orientation from facial images. *Journal of Personality and Social Psychology*, *114*(2), 246–257. https://doi.org/10.1037/pspa0000098

Wu, W., Protopapas, P., Yang, Z., & Michalatos, P. (2020). Gender Classification and Bias Mitigation in Facial Images. *12th ACM Conference on Web Science*, 106–114. https://doi.org/10.1145/3394231.3397900