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Understanding forensic methodologies for identifying human uniqueness through gait analysis based on real-life criminal scenarios

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Abstract:

This study deals with the gait part of video forensics wherein humans can be uniquely identified based on their movements. This is a very crucial part of evidence as every human has unique traits of human body movements and hence if a video is to be analyzed to prove a person's presence, this study will help in opening minds to think further analysis concerning gait. This gait pattern can help analysts in matching patterns of the person in question and it can also be reliable due to the natural traits shown by a human. This paper will give an overview to readers as gait is the most undervalued evidence of a crime as based on the natural traits and uniqueness of body movements, it becomes easy to prove suspicion. Several challenges are present in biological forensics, gait can be said to be the strongest evidence as perpetrators cannot imitate or mimic to be someone else hence counting gait pattern as an authenticated proof of evidence in the court of law.

Keywords — **Forensic, Digital, Biometric, Gait.**

I. INTRODUCTION

The application of science and technology to the detection and investigation of crime is known as forensic science. Forensic science has revolutionized the field of justice, denoting the investigation of crimes using cutting-edge technologies.

In forensic science, digital forensic plays an important role which includes the reconstruction and analysis of evidence obtained from any component of digital systems, networks, media, and peripherals that helps investigators solve a crime. There are several ways

In digital forensics determining biological sciences such as using the biometric parameter. In biometric parameters, there are multiple ways to analyze evidence from human body traits such as the face, fingerprint, iris, voice, **gait,** etc.

II. GAIT FUNCTION

These Study of Biometric parameters have proven to be the best analytical solutions in any crime scene and yet is the most undervalued parameter. Additionally, gait pattern is one such solution for analysts which can help in easy identification of natural and unique human body movements. Gait is supposed to be a unique identification method due to the difficulty in masking or impersonation any other human.

The translator motion of the human body as a whole, created by coordinated, rotatory movements of the body segments, is known as the human gait. Gait, or human movement, is a term used to describe how people walk. In normal gait, a series

of rhythmical, alternating movements of the trunk and limbs result in the centre of gravity and the body moving forward.

It is primarily divided into two phases: the stance phase and the swing phase. Heel strike, Foot flat, Mid-stance, Heel off, and Toe off are the five steps of the stance phase. The swing phase is divided into three stages: "Acceleration, Mid swing, and Deceleration."

The forensic gait analysis would depend on the type of gait pattern. The gait pattern may be classified into the following two types:

A. On the base of the Surface

The dimensions, overall shape of the prints, patterns in case ridges are evident, margins of the prints, toe marks, and other criteria are taken into account while analyzing a gait pattern on the surface (consisting of at least 3 to 4 consecutive footprints/footwear prints). Measurements of step and stride length are taken into account, which may reveal the nature of an individual's gait pattern, such as normal gait, running, and any associated disorders if any. By methodically evaluating and assessing the gait patterns, a comparison between the perpetrator of the crime and the suspect can be drawn.

B. Analysis of gait based on video/CCTV footage

The introduction of CCTV cameras and video recording-capable devices (video cameras, mobile phones, dashboard cameras, security cameras, traffic cameras, and so on) has given gait analysis a new dimension.

Currently, video recordings and CCTV footage are used to investigate a person's stride. Before the advent and widespread use of CCTV, investigators had to rely on eyewitnesses who might have seen someone at the location with a certain 'walking style.'

Scientific evidence, on the other hand, implies that the discriminative strength of such assertions cannot be used as the sole source of proof. Despite the lack of other biometric characteristics in the footage, forensic gait analysis serves as a valuable supportive method.

III. GAIT METHODOLOGY

The following are the primary goals of gait:

- The HAT's support (H= Head, A= Arms, T= Trunk).
- Maintaining an erect posture and physical equilibrium.
- Ensure proper ground clearance and a soft heel or toe landing.
- Mechanical energy is generated to maintain or enhance forward velocity.
- Mechanical energy absorption for shock absorption and stability, or to reduce the body's forward velocity.

C. Gait prerequisites

Four basic conditions must be met to recognize the walking style.

- Equilibrium: It is the capacity to maintain a balanced upright position.
- Locomotion: The ability to initiate and maintain rhythmic stepping is known as locomotion.
- Musculoskeletal integrity: Normal bone, joint, and muscle function is referred to as musculoskeletal integrity.
- Neurological Control: Messages must be received and sent to tell the body how and when to move. (Sensorimotor, visual, vestibular, auditory)

D. Gait Cycle

This cycle depicts the emotions that occur between the initial placing of the supporting heel on the ground and the subsequent contact of the same heel with the ground.

- A single sequence of functions by one limb.
- Begins when the reference foot contacts the ground.
- Ends with subsequent floor contact of the same foot on the ground.
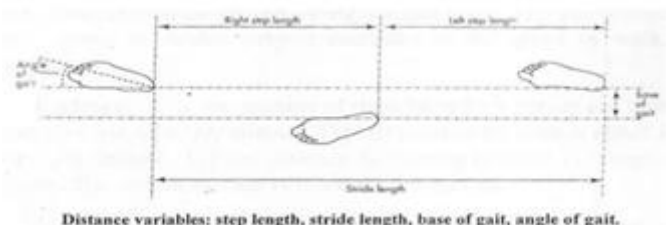

Distance variables: step length, stride length, base of gait, angle of gait.

Fig. 1 Gait Cycle Foot Measurement. PC [www.slideshare.net:gait-analysis]

There are two phases to a gait cycle.
1) STANCE PHASE (60%)
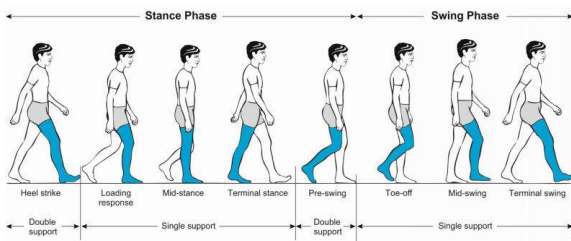2) SWING PHASE (40%)

Fig. 2 Phases-of-the-normal-gait-cycle. PC [researchgate.net]

1. STANCE PHASE

The stance phase accounts for nearly 60% of the gait cycle. The time while the foot is in contact with the ground and the leg is bearing weight is referred to as "contact time." This phase begins when the contralateral foot makes initial contact with the ground and ends when the ipsilateral foot leaves the ground.

The stance phase can be further subdivided into five stages

➢ Heel strike phase: The heel striking phase starts with the initial contact and concludes with the foot flat on the ground. When the heel makes contact with the ground, it marks the start of the stance phase

➢ Foot flat: This occurs as soon as the heel strikes the ground. It's the point at which the sole makes full contact with the ground.

➢ Mid stance: The point at which the body crosses directly over the supporting extremity is known as the mid stance.

➢ Heel off: The point at which the heel of the reference extremity leaves the ground after mid-stance.

➢ Toe off: When just the toe of the reference extremity is in contact with the ground after heel off.
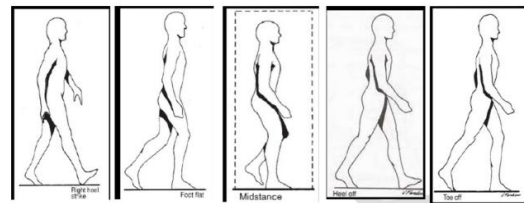

Fig. 3 Stance Phase Movement. PC [www.scribd.com]

2. SWING PHASE

The swing phase is defined as the time when the considered foot is not in touch with the ground. The stance phase refers to the time when the foot in question is in contact with the ground. The swing phase accounts for the remaining 40% of the gait cycle.

The swing phase can be further subdivided into three stages

➢ Acceleration phase: The acceleration phase begins when the toe leaves the ground and lasts until the swinging extremity is exactly under the torso, or mid-swing.

➢ Mid-swing: This occurs when the extremity passes squarely beneath the body, or when acceleration ends and deceleration begins.

➢ Deceleration: - Deceleration happens when the limb decelerates after mid-swing in preparation for heel contact.
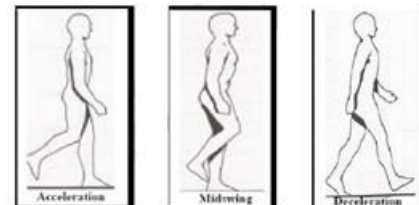

Fig. 4 Swing Phase Movement. PC [www.scribd.com]

IV. SCENARIOS

Scenario 1:

Brief History of Case:

A vehicle was discovered parked near the house of one of the biggest businessmen in India. The abandoned vehicle was discovered which contained

20 sticks of explosive gelatin, a set of number plates, and a threat letter after an inquiry. A high-rank officer was named the lead investigator of the team probing the matter as the announcement aroused concerns about flaws in the security of India's richest man.

Several theories were discovered over the next few days, including the fact that the crime was committed using two vehicles, and that a suspect wearing a PPE kit was seen walking near the crime scene in CCTV footage of the day.

An essential piece of evidence in the case was determining where the car came from and who the suspect man was on the CCTV footage.

To identify the suspect who was wearing a PPE kit at the time of the crime scene which can be seen in the obtained CCTV footage, the Police department took help from a forensic expert team to analyze and gather expert opinion on the case scenario.

Forensic Investigation Analysis:

Obtained Evidence Description:
1. A complete recce of the crime scene is done to obtain any kind of CCTV footage or other evidence about the crime.
2. CCTV footage was obtained of the accused. During the CCTV footage analysis, the accused was seen crossing a road at approximately midnight time. From the footage, it was inferred that the accused is seen wearing a PPE kit which makes it further difficult to identify the face of the accused.
3. The obtained evidence is then used to recreate a similar scenario to match traits and descriptions with that of the suspects.

Recorded Evidence Description:

1. Hence, to determine further factual evidence of the accused, a suspect was asked to recreate the scene which is obtained through the CCTV footage, and mimic the same movements as seen in the evidence footage.

Fig. 5 Comparison between CCTV footage and reconstruction scene of the case scenario. PC [www.thequint.com]

2. The suspect was asked to follow the same body movements as seen in the CCTV footage evidence. Furthermore, the suspect was even asked to follow the same body movements including posture, hand movements, leg movements, head position, etc.
3. A digital camera was also installed at the same height and distance as the primary evidence to duplicate the incident with the same CCTV camera height as the primary evidence.

Technical Brief:
1. This recreation will help determine several body descriptions like the posture of the body while walking; hand swing; the position of head, neck, and shoulder; knee flexion during stance; distance between the steps; angle of feet; pelvic rotation, and weight distribution.
2. During the analysis, forensic analysts will focus on comparing several things between the originally obtained CCTV footage evidence and the recreated evidence like the height of persons in both videos, dimensions of body parts, hand and leg swings, movement of the body, distance between each step, a distance of hand swings, etc.
3. The forensic gait analysis's general source of evidence comprises the series of footprints found at the crime scene and the closed-circuit television camera (CCTV) footage. Footprints are one of the pieces of evidence encountered at the crime scene.

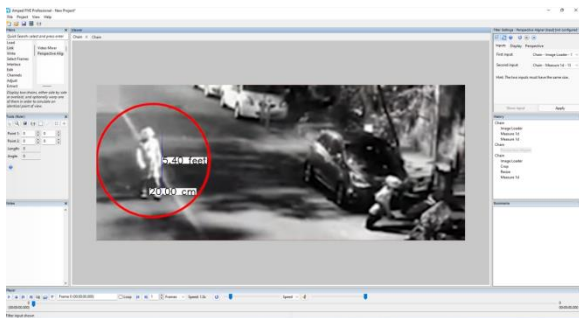Footprints can be recovered in the form of bare prints, shoe prints as well as a series of imprints.

Fig. 6 Recreational evidence analysis using GAIT parameters.

Findings:

1. It can be inferred from the reconstructed video that the individual in the obtained footage has similar body characteristics, such as height and gait distance, to the person shown in the recreated video.
2. Forensic researchers found that the individual in both recordings is the same based on the acquired CCTV footage and the rebuilt footage by the suspect using gait. As a result, the suspect can be proven guilty in the case.

Fig. 7 Forensic Analysts recreating crime scene concerning exact conditions as obtained in the original evidence. PC [www.thequint.com]

Scenario 2:

Brief History of Case:

The woman and the arrested accused, aged 45, have known one other for over a year, according to the police. Due to personal reasons, they both fought that night.

Accuse and the woman has observed meeting on a pavement shortly after the altercation began, and accuse was seen attacking her and putting her inside a tempo, according to a CCTV camera located just above the crime scene. A weapon was allegedly implanted in her intimate area by the accused. A bystander reported the event to the police, who took her to the hospital, where she died the next day.

Forensic Investigation Analysis:

Obtained Evidence Description:

1. A complete recce of the crime scene is done to obtain any kind of CCTV footage or other evidence pertaining to the crime.
2. CCTV footage was obtained of the accused. During the CCTV footage analysis, the accused was seen coming from a distant road at approximately midnight time. From the footage, nothing much can be inferred as it was very dark during that time and the low visibility of the accused due to poor lighting conditions. Additionally, the CCTV camera resolution was extremely poor.

Fig. 8 Original obtained evidence of a crime scene showing the accused physical traits. PC [NBT News]

3. However, the suspect's height and gait could be identified and hence this is considered extremely crucial evidence of the crime scene.
4. The obtained evidence is then used to reconstruct a similar scenario to match traits and descriptions with that of the suspects.

Fig. 9 Original obtained evidence of a crime scene showing the accused physical traits. PC [NBT News]

Recorded Evidence Description:

1. Hence, to determine further factual evidence of the accused, a suspect was asked to recreate the scene which is obtained through the CCTV footage, and mimic the same movements as seen in the evidence footage.

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3. The forensic gait analysis's general source of evidence comprises the series of footprints found at the crime scene and the closed-circuit television camera (CCTV) footage. Footprints are one of the pieces of evidence encountered at the crime scene. Footprints can be recovered in the form of bare prints, shoe prints as well as a series of imprints.

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V. CONCLUSIONS

1. As we have seen in the above 2 real-life case scenarios, using gait, complications of evidence have reduced in determining the suspects. Since gait uses natural body traits, it also becomes highly evidential to be produced in the court of law.

2. The gait pattern is simply the manner or style in which a person moves. Gait is a biological trait of a person. Many elements have a significant impact on it (internal as well as external). Walking is a non-conscious behavior that can be used to distinguish people if not to identify them and hence this helps in analyzing the uniqueness of a person.

3. Regardless of the limits and criticisms about individuality and uniqueness, as well as its

admissibility in a court of law, forensic gait analysis can be used to identify offenders and perpetrators as supporting/corroborative evidence. Many forensic cases have been solved and people have been convicted around the world based on forensic gait analysis.

4. Therefore, it is the investigator's responsibility to recognize and retain gait evidence (despite its rarity in crime scenes) for subsequent scientific research and forensic success.

ACKNOWLEDGMENT

REFERENCES

1. *Dr. MN Siddiqui, Lecture Notes on NORMAL GAIT. Available:https://www.scribd.com/document/534480641/Lecture-Notes-on-NORMAL-GAIT-by-Dr-M-N-Siddiqui.*

2. *Ashish Badiye, Neeti Kapoor, Prachi Kathane, Kewal Krishan., Forensic Gait Analysis. StatPearls - NCBI Bookshelf. May 2020.*

3. *Niels Lynnerup, Peter Kastmand Larsen., "Gait as evidence," IET Digital Library, vol. 3, pp. 47–54, Jun. 2014.*

4. *Black Sue, Wall Mark, Abboud Rami, Baker Richard, Stebbins Julie, "Royal-society-forensic-gait-analysis-primer-for-courts," The Royal Society, Issued: November 2017 DES4929.*

5. *T. Nataraja Moorthy, "Gait Pattern Analysis in Crime Scene investigation," Thmil Nadu Police Journa, August 2008.*

6. *(2019) The new crime buster: Tracking gait technology. [Online], Available:https://www.livemint.com/technology/tech-news/the-new-crime-buster-tracking-gait-technology-1549210184513.html.*

7. *Thripthi V Suvarna. (2020) Importance of gait pattern in personal identification. [Online]. Available: https://legaldesire.com/importance-of-gait-pattern-in-personal-identification/*