Project Report: Human Motion and Gait Analysis

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Abstract

This project report presents a comprehensive study of human motion analysis and gait analysis. The investigation employed optical motion capture technology, MATLAB data processing, and the SIMI Motion Analysis System to quantify locomotion biomechanics. The findings reveal typical lower limb movement patterns, joint angle variations, and pelvic stability that characterize normal gait, with implications for clinical diagnosis, rehabilitation, and sports science.

1 Introduction

Human motion analysis is a crucial area in biomechanics and biomedical engineering, providing insights into human locomotion, joint mechanics, and movement coordination. Gait analysis, in particular, systematically studies walking patterns to assist clinical diagnosis, optimize athletic performance, and inform biomechanical research.

This report combines practical coursework on gait analysis using motion capture data and MATLAB with experimental motion analysis performed using the SIMI Motion Analysis System, aiming to provide a holistic view of human movement analysis techniques and outcomes.

2 Importance of Gait Analysis

Gait analysis has wide-ranging applications in various domains:

Clinical Applications:

- Diagnosing neurological disorders (e.g., Parkinson's disease, stroke rehabilitation)
- Assessing orthopedic and musculoskeletal abnormalities
- Monitoring rehabilitation progress and treatment efficacy
- Preventing falls in elderly populations

Sports Science:

- Optimizing athletic technique and performance
- Preventing sports-related injuries

- Designing sport-specific footwear and equipment

Biomechanical Research:

- Understanding normal/pathological movement patterns
- Developing assistive devices and prosthetics
- Advancing robotics and humanoid locomotion systems

Quantitative gait data allow early abnormality detection, objective assessments, and personalized therapy, making gait analysis essential in clinical and research settings.

3 Gait Analysis: Data and Graphical Insights

3.1 Marker Trajectories in the Sagittal Plane

Figure 1 illustrates the XZ-plane trajectories of lower-body markers (reflective anatomical landmarks) during a gait cycle. The toe marker exhibits the largest anterior-posterior displacement, while the iliac markers show relatively stable pelvic movement, essential for balance and energy efficiency.

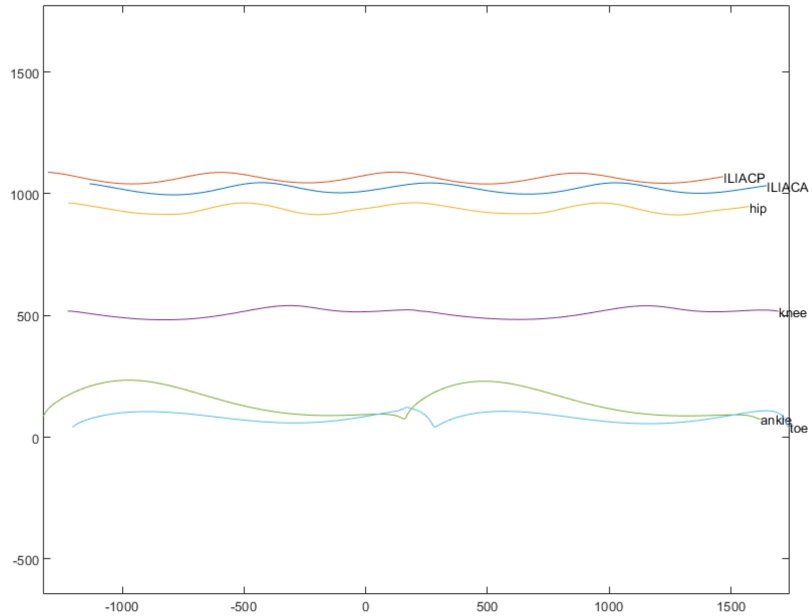

Figure 1: XZ Trajectories of Lower Body Markers Across the Gait Cycle

3.2 3D Visualization of Marker Positions

Figure 2 presents a 3D scatter plot of the markers, capturing the complex spatial relationships during gait, underscoring the importance of 3D analysis over 2D projections.

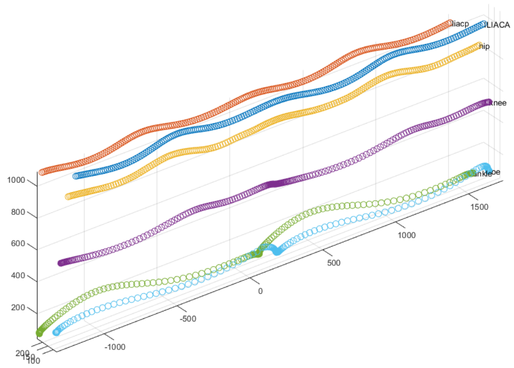

Figure 2: 3D Scatter Plot of Marker Positions

3.3 Vertical Displacement of Ankle and Toe

Figure 3 shows vertical oscillations highlighting key gait events; the toe reaches maximum height during swing, while the ankle exhibits the characteristic double-hump vertical pattern.

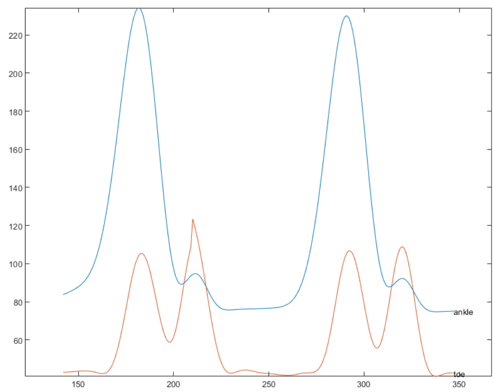

Figure 3: Vertical Displacement of Ankle and Toe with Heel Strike and Toe-Off Events

3.4 Anterior-Posterior Displacement

Figures 4 and 5 respectively show the forward-backward movements of the ankle and iliac markers during gait, demonstrating propulsion and pelvic stability, respectively.

4 Gait Parameters and Interpretation

4.1 Discussion

- The ankle's vertical displacement during gait exhibits two peaks corresponding to mid-stance and pre-swing phases, following the "double-hump" center of mass movement.

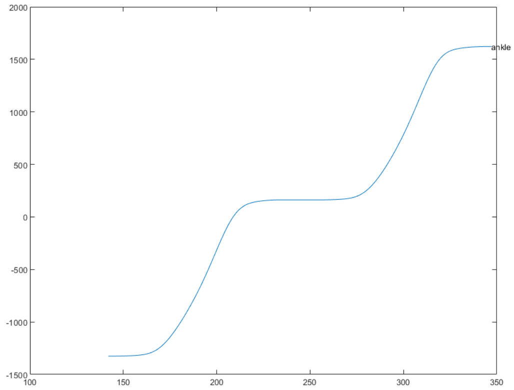

Figure 4: Anterior-Posterior Displacement of Ankle

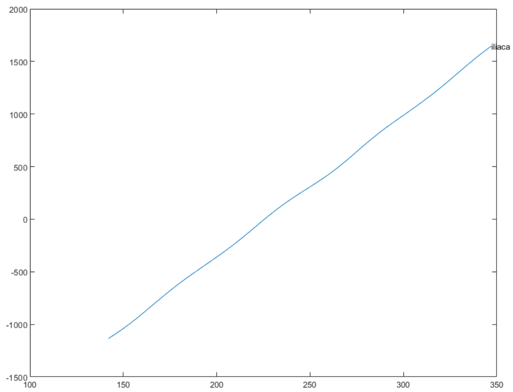

Figure 5: Anterior-Posterior Displacement of Iliac Marker

- The iliac marker's small anterior-posterior displacement indicates pelvic stability, key for efficient locomotion.
- Heel strike and toe-off events align with elevation changes in the ankle and toe, demonstrating the coordinated timing necessary for normal gait.

5 MATLAB Code Summary

MATLAB was used to process the marker data captured during gait trials. The code reads marker position data from CSV, extracts XYZ coordinates for different body markers, and generates plots to visualize motion trajectories and displacement patterns.

The program visualizes lower limb movement in 2D and 3D, identifies gait events, and graphs vertical and anterior-posterior displacements for analysis.

Table 1: Measured Gait Parameters

Parameter	Value	Unit
Stride Time	1.12	s
Step Length	0.68	m
Stride Length	1.36	m
Cadence	107	steps/min
Walking Speed	1.45	m/s
Right Step Time	0.56	s
Left Step Time	0.56	s

6 Human Motion Analysis Using SIMI Motion Analysis System

6.1 Experimental Procedure

The SIMI Motion System setup involved:

- Hardware assembly and camera calibration using L-frame and T-wand tools.
- Placement of reflective markers on anatomical landmarks based on inverse dynamics protocols.
- Execution of multiple trials recording various motion types.
- Processing marker data to calculate 3D coordinates and joint angles.
- Exporting data in C3D format for further analysis.

6.2 Joint Angle Analysis

Figure 6 illustrates the left knee joint angle variation over time, exhibiting cyclical flexion-extension movements typical of locomotion.

The peaks correspond to maximum extension, and troughs represent flexion phases. Similar analyses can extend to hip and ankle joints to understand movement coordination.

6.3 Motion Analysis Methods

- **Mechanical motion capture:** Joint sensors and exoskeletons for direct measurement.
- **Electromagnetic motion capture:** Uses sensors and magnetic fields.
- **Optical motion capture:** Cameras track reflective markers (used here).
- **Video-based techniques:** Markerless video analysis using computer vision.
- **Force plates and EMG:** For advanced biomechanical and muscle activation studies.

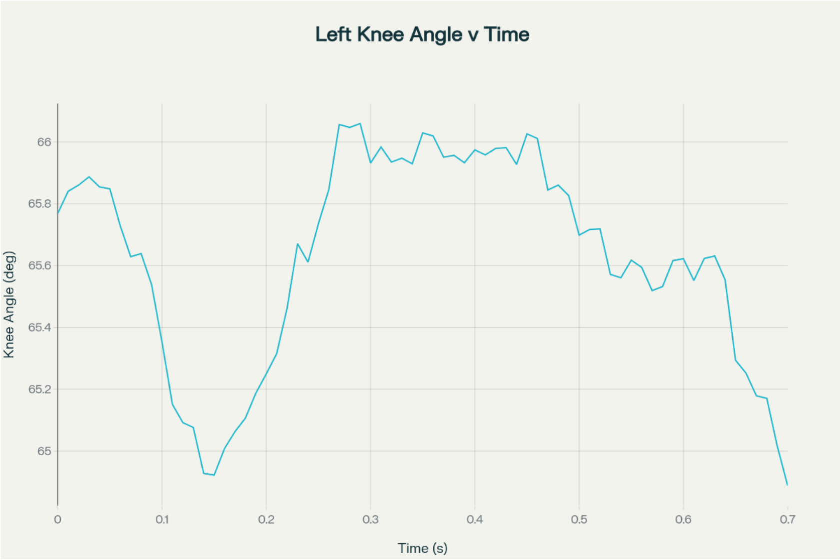

Figure 6: Left Knee Joint Angle Variation Over Time During Motion Trial

Table 2: Summary of Commercial Systems

System	Merits	Demerits
Vicon	High accuracy, real-time tracking, comprehensive tools	Expensive, controlled environment required
Qualisys	Flexible, portable, easy integration	Costly, sensitive to lighting/occlusion
SIMI Motion	Cost-effective, user-friendly, precise research tool	Lower frame rate, limited markerless features
OptiTrack	High precision, useful for biomechanics/VR	Complex setup, costly
Xsens (Inertial)	Markerless, wearable, portable	Slightly less accuracy, sensor drift

6.4 Commercial Motion Analysis Systems

7 Conclusion

This integrated project successfully analyzed human gait and motion using optical marker-based systems and MATLAB-based data analysis. The gait data showed normal symmetrical patterns, pelvic stability, and characteristic lower limb trajectories confirming efficient locomotion.

The SIMI Motion System complemented the gait study by enabling detailed joint angle analysis revealing cyclical joint behavior. Together, these methods enhance understanding of human movement mechanics with applications in clinical diagnostics, sports optimization, and biomechanical research.

Future work can incorporate pathological gait analysis and expand to markerless systems for broader applicability.