# "Enhanced Smart Insole: Precision Gait Analysis with Optimized Pressure Sensor Placement"

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## Introduction

- **Problem**: What are the optimal sensor locations on smart insoles for precise detection of heel-strike and toe-off events, and how can this information enhance gait analysis and refine insole design?
- **Solution:** Place sensors strategically, analyze locomotion data thoroughly, and validate findings to improve gait analysis accuracy.
- **Goal:** Optimize sensor placement, reduce count, enhance efficiency, and improve diagnostic capabilities for smarter gait analysis.

## Method

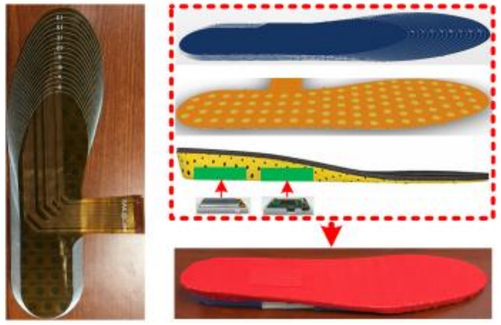
- The smart insole system consists of a flexible pressure sensor array with 96 sensors, adaptable to various foot sizes, enabling transmission of pressure in various foot locations via Bluetooth at 50Hz.
- Ground reaction force (GRF) is calculated at every time step by adding all 96 pressure sensors and the normalized body weight
- A dynamic threshold is developed and used to identify heel strike and toe-off points
- For each walking step. changes of GRF during the heel strike and the toe off are calculated
- The individual sensors with the highest contribution to the GRF changes in that step are identified as the optimal sensors for heel strike and toe-off detection in the step.

## Data

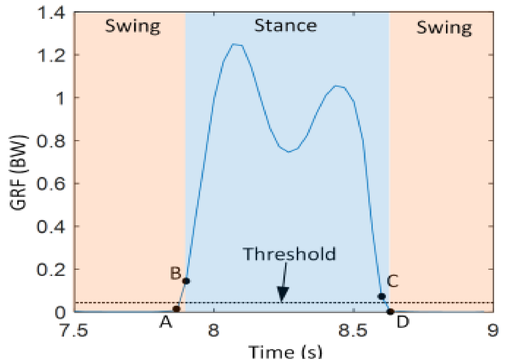
- Eight subjects wearing smart insoles, walking on level ground with 3 different speeds for 90 seconds each.
- Each stride data from each subject are analyzed to extract the top five optimal sensor locations for heel-strike and toe-off detection for each feet and each walking speed specifically.
- The extracted optimal sensor locations from all subjects and all walking speeds are combined to reveal global optimal sensor locations that work best across different individuals and various walking speeds.

## Wearable system and GRF Waveform

Insole system



Ground Reaction Force (GRF) Waveform




## Results for the Optimized Pressure Sensors

| Walking speed | Heel strikes | | | Toe Strikes | | |
|---|---|---|---|---|---|---|
| | Number of strikes | Optimal sensor | Frequency | Number of steps | Optimal sensor | Frequency |
| Slow | 452 | 13 | 98.45% | 453 | 78 | 54.08% |
| Normal | 545 | 13 | 92.11% | 547 | 79 | 67.46% |
| Fast | 643 | 9 | 66.25% | 644 | 79 | 73.29% |

**Right Foot Result**

| Walking speed | Heel strike | | | Toe strike | | |
|---|---|---|---|---|---|---|
| | Number of strikes | Optimal sensor | Frequency | Number of steps | Optimal sensor | Frequency |
| Slow | 455 | 9 | 99.78% | 451 | 60 | 51.22% |
| Normal | 548 | 13 | 91.06% | 545 | 60 | 64.22% |
| Fast | 643 | 13 | 80.56% | 643 | 60 | 68.58% |

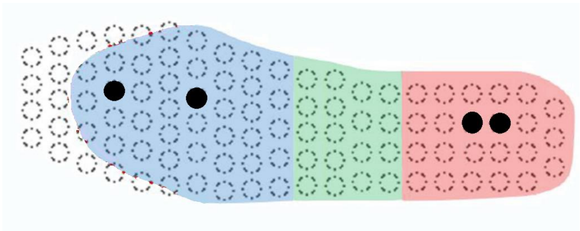
**Left Foot Result**

## Conclusion

- In total, the most optimal sensors for left foot heel strike and toe-off detection are sensors 13 and 60, with a respective frequency of 89% and 62.36%.
- For the right foot, the most optimal sensors for heel strike and toe-off detection are also sensors 9 and 79, with an occurrence frequency of 82.56% and 65.94%, respectively.

## Sensors Placement

**Sensor locations on the insole**



## Acknowledgments

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## References

Chen, Diliang. "(PDF) Smart Insole: A Wearable Sensor Device for Unobtrusive Gait Monitoring in Daily Life." *Optimal Pressure Sensor Locations in Smart Insoles for Heel-Strike and Toe-off Detection*, Diliang chen, www.researchgate.net/publication/310424686_Smart_Insole_A_Wearable_Sensor_Device_for_Unobtrusive_Gait_Monitoring_in_Daily_Life. Accessed 18 Apr. 2024.