

Dryft: A Python and MATLAB package to correct drifting ground reaction force signals during treadmill running

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Background

Ground reaction forces (GRFs) are exerted by the body on the ground during running, measured by treadmills instrumented with force transducers, and are used to calculate a variety of clinical and performance-related biomechanical variables (Kram, Griffin, Donelan, & Chang, 1998). However, force transducer signals can be affected by changes in temperature during warm up or over long periods (Sloot, Houdijk, & Harlaar, 2015), causing the signal to drift. If ignored, signal drift can lead to the inaccurate calculation of biomechanical variables. For example, ground contact time is defined as the time the foot is in contact with the ground and is often calculated as the time a vertical GRF exceeds a threshold. Signal drift can cause more (or less) of the vertical GRF signal to fall below the threshold, affecting one's ability to identify stance phase (Riley et al., 2008) or calculate time-dependent GRF metrics. Signal drift can also potentially lead to data loss if the signal exceeds the range of the force transducer.

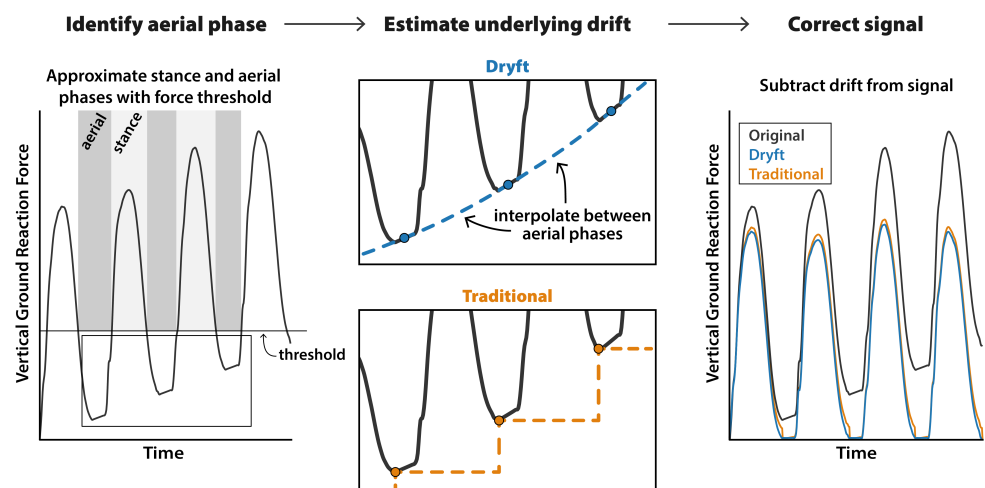


Figure 1: The process of correcting drift in a vertical ground reaction force (GRF) signal collected during treadmill running. After aerial phases have been identified using a force threshold, *dryft* interpolates aerial phase values to estimate the underlying drift and subtracts it from the vertical GRF signal.

To prospectively counteract signal drift, it is best practice to zero (tare) the force transducers between trials during data collection. However, zeroing force transducers may not be feasible for protocols requiring extended periods of continuous running on an instrumented treadmill.

There are signal processing methods available to remove a constant offset (C-Motion, 2015) or linear drift (SciPy.org, 2016) in GRF signals, but their effectiveness is limited because signal drift may not be linear over the duration of the trial. Here I introduce *dryft*, an open source Python and MATLAB package that takes a simple approach to identifying and correcting linear or non-linear drift in GRF signals produced during treadmill running.

Summary

The body exerts no force on the ground during the aerial phase of running and *dryft* assumes that any ground reaction force measured during an aerial phase is due to noise or drift in the signal. *dryft* implements a user-defined force threshold to approximate the start and end of each stance phase and identify aerial phases in a filtered vertical GRF signal (Figure 1). Next, the force measured by the instrumented treadmill during the middle of each aerial phase is identified. The middle value of each aerial phase is identified to avoid the possibility that part of the adjacent stance phases are included in the drift estimation process. These aerial phase values are then cubic spline interpolated to the full length of the GRF signal to estimate the underlying drift in the GRF signal. The estimated drift is then subtracted from the GRF signal (Figure 1). This process can also be applied to horizontal GRF signals once aerial phases have been identified using the vertical GRF signal.

To test the performance of this method, I added drift to a 30-second vertical GRF signal collected by an instrumented treadmill during running (Fukuchi, Fukuchi, & Duarte, 2017). Using *dryft* to reduce this vertical GRF signal's drift produced favorable results, as the average (\pm SD) force measured across the extracted aerial phases values was -0.01 N (± 0.09 N) for the corrected signal (Figure 2). While *dryft* was intended to be used with GRF signals measured during treadmill running, it could also be applied to GRF signals measured during split-belt treadmill walking, since only one foot is on a belt at a time. However, extra care should be taken to identify crossover steps prior to correcting drift in split-belt treadmill walking GRF data as they will influence the accuracy of the force values measured during the swing phase.

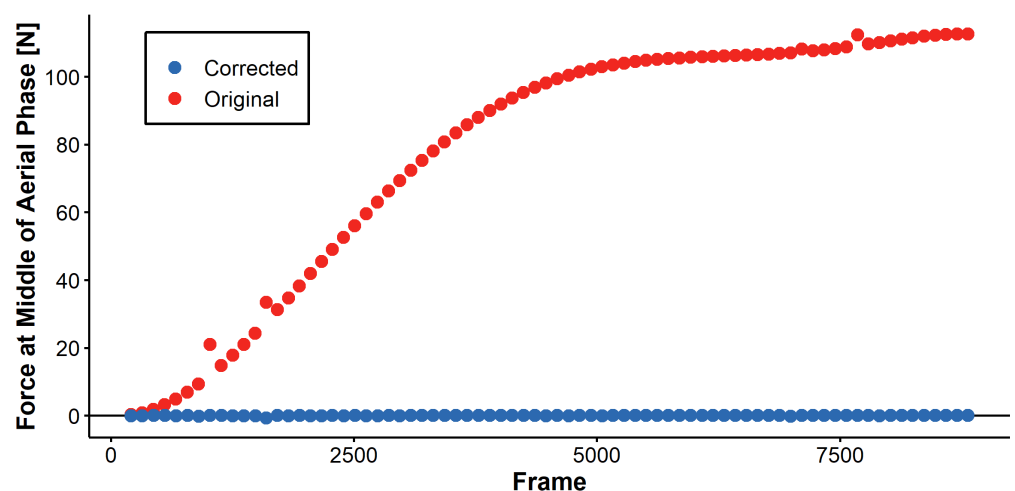


Figure 2: Vertical ground reaction force (GRF) measured during each aerial phase before (red) and after (blue) using *dryft* to correct the drifting vertical GRF signal. Each point represents the force measured by the treadmill at the middle of an aerial phase.

Conclusion

Prior work has corrected drift in GRF signals by subtracting the force measured during a given aerial phase from the following stance phase (Paolini, Della Croce, Riley, Newton, & Kerrigan, 2007; Riley et al., 2008; Sloom et al., 2015). The success of this approach relies on how accurately stance and aerial phases are identified and assumes that there is no change in drift within a given step (consecutive aerial and stance phases). Instead, *dryft* interpolates the force measured at the middle of each aerial phase and subtracts this from the entire trial. This package can be used to identify stance phases and correct linear or non-linear drift in GRF signals produced during treadmill running or split-belt treadmill walking.

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