Sea Level Calibration of Smartphone Barometers

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Abstract

This paper describes the need for an offline capable sea level calibration system for barometers in a moving system such as a smartphone. Such a system would enable improved offline weather prediction based on barometric pressures. The system described in this paper is utilized in the Trail Sense app on Android.

Keywords

barometer, calibration, sea-level, smartphone, weather

1 Problem Statement

Barometers can be used to predict short-term weather by measuring changes in atmospheric pressure [1]. The approach of a low-pressure system may bring rain, while a high-pressure system could indicate clearing skies [3]. If the barometer is uncalibrated, it becomes difficult to determine whether it indicates low or high pressure, as pressure decreases with increasing altitude [2]. Furthermore, uncalibrated pressure readings taken at different altitudes may falsely appear as changes in atmospheric pressure, leading to inaccurate storm predictions.

It is common for barometers to be calibrated to mean sea level (MSL). A barometer calibrated to MSL indicates the pressure as it would be at sea level, enabling the classification of low and high pressure irrespective of altitude [2]. When the barometer is consistently calibrated, any pressure change can be attributed to a weather system.

To calibrate a barometer to mean sea level (MSL) on a smartphone, the device's altitude must be known. A smartphone's GPS can determine the device's elevation above the WSG84 ellipsoid [4]. This measurement can then be converted into the elevation above MSL for barometer calibration. However, GPS-derived elevation is susceptible to noise, which can affect the accuracy of barometer calibration [5]. Alternatively, using a digital elevation model (DEM) can offer higher accuracy, but it is also prone to noise in horizontal accuracy and requires either a large on-device model or an internet connection [5].

Therefore, by reducing GPS elevation noise, the accuracy of the barometer calibration to sea level will increase, enabling improved weather prediction even during elevation changes.

2 Background

Several Garmin watches have auto-calibration procedures for their barometers. The algorithm used for calibration is closed source, but it provides options for manual calibration using GPS or DEM as a starting point. Additionally, it seems to recalibrate itself nightly [6] [7]. However, it is not well documented whether calibration occurs after significant changes in elevation.

Another method of calibration was implemented by the Barometer Plus Android app. This app enables users to define specific zones with known and unchanging elevations. While inside a zone, the app maintains the pressure history and converts it to sea level measurements [8]. This approach proves effective when the device transitions between two established zones, such as home and office, and remains stationary within those zones.

3 Solution

My proposed solution to this problem is to implement auto-calibration of the barometer at each reading using a filtered GPS elevation. I have divided the algorithm into several steps. The first step involves gathering data at a fixed interval, typically set to 30 minutes by default. The second step involves smoothing the data and removing outliers.

The data gathering process operates as a background service that runs at a fixed interval. During each run, it reads the barometric pressure, temperature (either historical or from the battery), and GPS elevation. The GPS elevation is then converted to mean sea level (MSL) by subtracting the geoid offset from the reported GPS elevation. The geoid offset can be obtained through NMEA messages or by utilizing a lookup table. The algorithm is designed to collect up to 8 MSL GPS readings.

To enhance the vertical accuracy of the GPS readings, a joint Gaussian distribution algorithm is employed to merge the individual readings into a single reading. Please refer to Appendix A for details on this algorithm. The outcome of this process is an elevation value with significantly improved accuracy.

The subsequent step involves converting the barometric pressure to sea level. This conversion is carried out using the formula outlined in Appendix B or Appendix C, depending on the user's setting regarding the inclusion of temperature.

Lastly, the LOESS smoothing algorithm is applied using all the readings from the past 48 hours [9]. The X-axis represents the time of each reading, while the Y-axis represents the sea level pressure. By default, a span of 15% is utilized with a single robustness iteration to eliminate outliers. This process effectively reduces noise in both the GPS elevation and the barometer, leading to a more accurate sea level pressure reading and tendency. The span percentage can be adjusted by the user to accommodate various recording frequencies and noise levels.

The outcome of this process is the sea level pressure history for the past 48 hours. To obtain the current pressure, the most recent reading can be utilized.

4 Conclusion

This paper provided an overview of an offline-capable process for calibrating barometric pressure to sea level, even in the presence of changing elevation. This process enables real-time weather prediction using a smartphone without requiring the user to remain stationary. An illustrative use case for this capability would be hiking on uneven terrain.

References

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Appendix A

The Gaussian joint probability algorithm.

```
def join(mean1, var1, mean2, var2):
      joint = mean1 * var2 + mean2
* var1
      sumVar = var1 + var2
      multVar = var1 * var2
      mean = joint / sumVar
      var = multVar / sumVar
      return (mean, var)

def join_all(dists):
      if len(dists) == 0:
            return None
      last = dists[0]
      for dist in dists[1:]:
            last = join(last[0],
last[1], dist[0], dist[1])
      return last
```

Appendix B

Sea level pressure conversion with temperature where P is pressure in hPa, D is altitude in meters, and T is temperature in Celsius.

```
P * (1 - ((0.0065 * D) / (T +
0.0065 * D + 273.15))) ** (-5.257)
```

Appendix C

Sea level pressure conversion without temperature where P is pressure in hPa and D is altitude in meters.

```
P * (1 - D / 44330.0) ** (-5.255)
```