AugView Compass:

Has anyone ever been frustrated by smartphone Compass apps that a) claim to be accurate, b) turn out to be hopelessly inaccurate; and/or c) don't work at all in certain device orientations? More than likely, the answer to the previous question is "YES". This is what motivated the author(s) to create the Augview Compass app - a compass app that a) is more accurate, b) works in all orientations, and c) provides both a map view and an Augmented Reality (AR) view (live camera view) for ease of use. The accuracy improvement is achieved **first** by measuring the compass deviation error (after calibration error) for each primary orientation (portrait, horizontal, landscape [left], and landscape [right], as may be required) and **second** by applying a suitable correction (compensation) capability to overcome (compensate) observed azimuth errors.

Augview Compass is a high-accuracy smartphone compass application, supporting:

- Compass deviation error measurement & correction
- Map navigation compass azimuths,
- Augmented reality (Live View) compass viewing,
- Map marker tracking (find-my-spot), and
- Observations in all device orientations (it works).

Compass

A smartphone (or tablet) incorporates a variety of sensors that can be used to determine device location, orientation, and/or the way the device is moving. The compass (device) orientation is determined using a combination of these sensors - the magnetometer, accelerometer, and gyroscope.

> The **magnetometer** is the primary sensor used to detect magnetic fields - functioning as a digital compass. It measures the Earth's magnetic field in three dimensions (X, Y, Z axes) and helps determine the direction relative to **Magnetic North**. The reader should note that the Earth's magnetic field is relatively weak. Magnetometers used in smartphones demonstrate high levels of signal noise, when compared with the Earth's magnetic field strength. Also, magnetometers are susceptible to stray magnetic/electromagnetic fields being generated both a) within the device and b) in the local operating environment(s). Furthermore, temperature changes can significantly impact magnetometer sensitivity. To reduce noise in the magnetometer output(s), software filters with smoothing algorithms are used often. To improve magnetometer accuracy, the output(s) from the accelerometer and gyroscope are integrated with the magnetometer using a technique known as **sensor integration**.

The **accelerometer** measures the device's linear acceleration in three dimensions (X, Y, and Z axes). When stationary, the accelerometer measures the force/direction of gravity. By detecting the orientation of the device relative to the ground (for example, if it's tilted), the accelerometer can determine the angle of the device in relation to the vertical axis. The accelerometer's data is crucial for correcting the compass heading, especially when the device is tilted – tilt compensation.

The **gyroscope** measures the rate of rotation around the three orientation axes. It provides information about the angular motion of the device - thus helping to track its orientation and movements more accurately. This data helps to a) smooth out the changes in orientation and b) provide more precise tracking of the device's orientation.

Using the output(s) from these three sensors mentioned above (along with filtering algorithms and sensor fusion) a bearing relative to **Magnetic North** can be determined programmatically.

The **Magnetic North Pole** is a point on the surface of Earth's Northern Hemisphere at which the planet's magnetic field points vertically downward. The magnetic north pole moves over time. As of 2024, the location of the magnetic north pole is 86° N, 142° East. Modelling predicts that by 2025, the location of the magnetic north pole will have drifted to 138° East (same latitude).

True North refers to the geographic North Pole, the point at the top of the Earth's rotation axis where all lines of longitude converge. This is the northern point of the Earth's axis of rotation. True North is a fixed point located at 90° North latitude. True North is essential for mapping and GPS systems use, as it provides a consistent reference for determining direction regardless of magnetic variations.

The angular difference between Magnetic North and True North is called **magnetic declination**. This angle varies depending on where an observer might be located on the Earth's surface; and it must be accounted for to convert magnetic compass bearings to bearings relative to True North. In addition, because the north and south magnetic poles move, magnetic declination at a fixed point on the earth's surface changes over time. Fortunately, there are formulae and web sites that can provide the declination angle value for any given date and geographic location. The magnetic declination angle allows us to convert from a bearing relative to Magnetic North to a bearing relative to True North. To indicate whether a bearing is relative to True North or Magnetic North, we use the symbols °T or °M, respectively.

Compass Calibration

The operating system running on smartphone device(s), allows the user to **Calibrate** the magnetometer - to help reduce azimuth error(s) and to compensate for issues such as:

1. Sensor Drift: Over time, the performance of the magnetometer can drift due to changes in temperature, humidity, and other environmental factors.
2. Local Magnetic Interference: Nearby magnetic materials (e.g., buildings, vehicles, metal objects) can create local magnetic fields that distort the magnetometer's measurements.
3. Sensor placement and phone manufacturing issues can lead to variations in sensor output - resulting in a) each axis having different sensitivity, b) axes not being orthogonal, and/or c) axes not being correctly oriented relative to the phone screen.

To help reduce magnetometer issues, phone manufacturers recommend a) rotating the device about each axis and/or b) rotating the device in a figure of 8 motion. The author(s) recommend a systematic approach (in-app tutorial), by which a device user can:

1. Face north (or south) to be parallel with the earth's magnetic field flux lines (to access maximum and minimum magnetic field strengths);
2. Rotate the device slowly (360° in about 4 seconds) about each axis twice; and
3. Hold the device flat and rotate about the vertical axis twice.

Calibration should be performed regularly, and especially after charging the device or leaving it near other electrical devices. Also, it's important to calibrate the magnetometer after travelling in a vehicle, especially EVs and PHEVs.

Compass Deviation Error

Even after calibration, the magnetometers within all phones and tablets (that the author[s] have tested) have exhibited a significant degree of compass azimuth error which varied as the device(s) have been rotated through 360 degrees. In almost all cases, the error observed at any specific orientation was reproducible (within a small margin). That is, rotating the device to align with a distant fixed object generally yielded the same result (within a small margin) for multiple, repeated measurements.

Define the **difference** between an <u>observed</u> (measured) bearing (relative to True North) and the <u>actual</u> (reference) True North bearing (e.g., calculated using accurate GNSS surveyed locations or using the sun's azimuth) as the **Deviation Error**. Hypothesis: a) if a compass user can measure the deviation error for a few/several angles as the device is rotated through a full 360-degree range of measurement, b) the user [or the app] can calculate a correction function that will provide error correction/compensation for any observed bearing angle through a full 360-degree range of measurement.

Observation: The magnitude of Deviation Errors has often been observed to be in the range (+/-)15°; but the author's research has exposed examples in excess of (+/-)20°.

More specifically, with regard to the measurement of deviation error, the Augview Compass app:

1. Provides a mechanism to easily measure the deviation error at 45° increments throughout 360-degrees of measurement.
2. Facilitates the user's determination of an accurate reference azimuth orientation - achieved using either:
   - The sun's shadow (Knowing the user's geographical location, observation date, and time-of-day, the app calculates the sun's azimuth accurately.)
   - A distant object (e.g., a significant structure on the horizon - the position of which is automatically determined from the map – is provided by the app's "map" screen.)

Simply stated, the <u>difference</u> between the observed bearing and the true bearing is the <u>deviation error</u> - associated with each individual observation. To facilitate collection of multiple successive deviation error measurements, the AugView Compass app a) makes use of <u>surface tracking</u> technologies to control device (smartphone) rotations in equal, accurate 45° increments; and b) with each successive rotation, enables the user to collect "true" bearing and "observed" bearing measurements – the difference being the observed deviation error.

This process (to collect multiple successive deviation error measurements) does not require the use of a tripod to achieve acceptable results - although use of a tripod may provide a more consistent result. The measurements need to be collected in a well-lit, relatively-flat area with sufficient surface texture for surface tracking technologies (ARKit & ARCore) to work well. The user will not be able to measure the deviation error in poorly lit areas or at night. Also, it is important that the user a) keep the centre of the device screen aimed at or below the horizon and b) use surface tracking technologies at relatively short ranges, for best results.

GNSS tracking

GNSS refers to the Global Navigation Satellite System. The GNSS "system" is a set of satellites (put into orbit by multiple countries) that each broadcast information that can be used by a receiver device to determine the device's geographic location. There are currently 6 constellations of satellites, totalling approximately 125 satellites:

- GPS (USA)
- GLONASS (Russia)
- Galileo (European Union)
- BeiDou (China)
- NavIC (India)
- QZSS (Japan)

The Augview Compass app needs to "know" the user's device location in order to:

- calculate the **magnetic declination** at the observer's location and
- display the **observer's location** on the app's map screen.

Multiple Screens

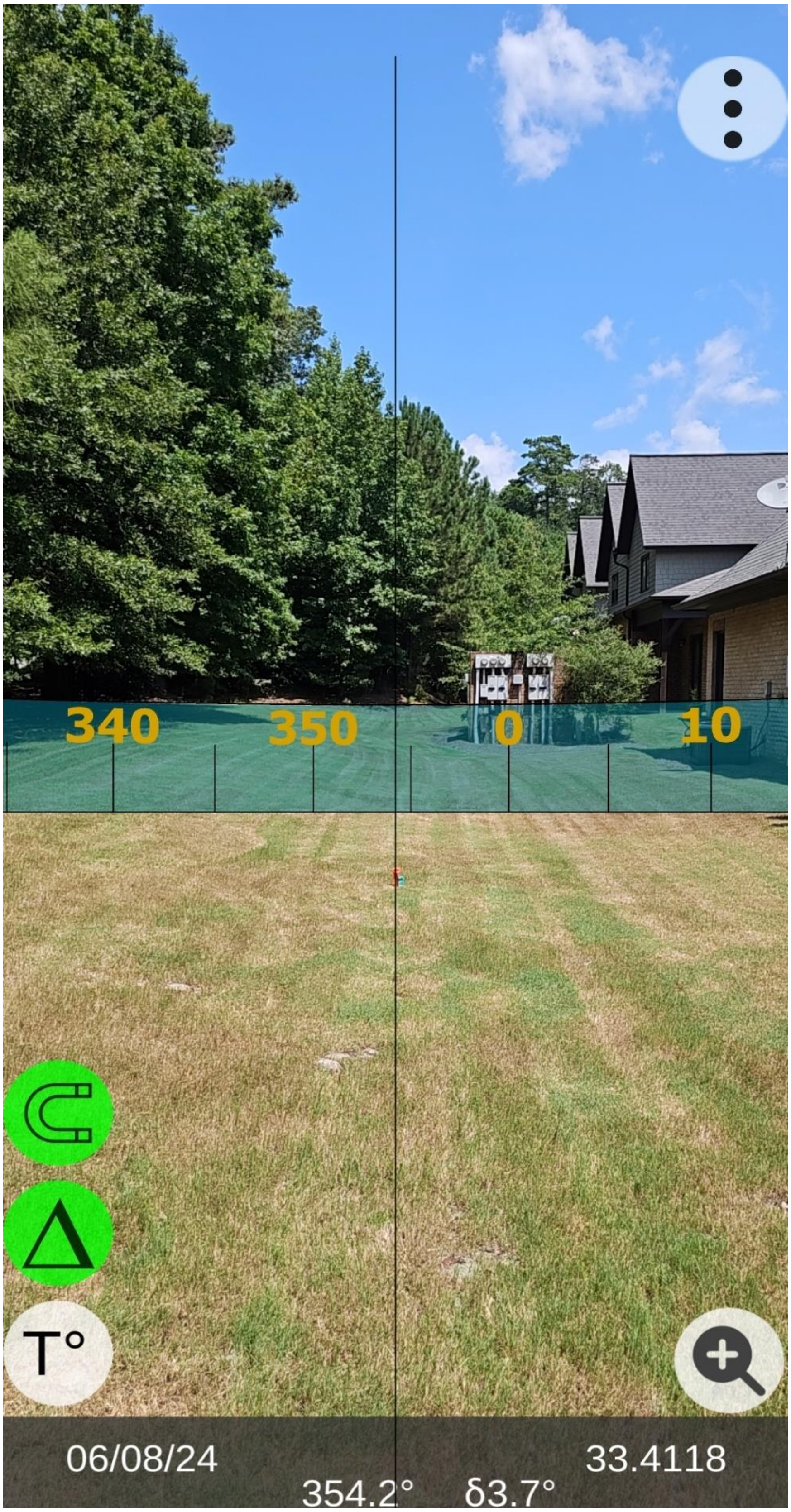
The application provides multiple screens, each with a unique function/purpose:

- Map display
    - Displays a map background with compass rose overlay.
    - Supports "capture" of a Point of Interest (Pin) – "smart marker"
    - Display direction from observer toward Pin – "find my spot"
    - Enable/Disable GNSS tracking
    - Enable/Disable device "level" indicators
    - Display magnetometer calibration status
    - Enable/Disable deviation error correction
    - Toggle between "True North" & "Magnetic North" bearings
    - Display current "digital bearing", "deviation correction", "latitude & longitude"
- Live View (AR)
    - Displays an Augmented Reality compass over the live "camera" video
    - Supports camera zoom function
    - Displays calibration status
    - Enable/Disable deviation error correction
    - Toggle "True North" & "Magnetic North" bearings
    - Displays "digital bearing", "deviation correction", "latitude & longitude"
- Calibration
    - Describes recommended calibration procedure with link to video tutorial
- Deviation
    - Deviation error collection "setup" screen
    - Deviation error data collection screens
        - Supports collecting deviation error for user's device or an external device

        - Supports use of sun azimuth or distant object for the initial observation
        - Supports collection of deviation error for portrait, landscape and horizontal orientations
- Settings
    - Settings related to units and display formats
    - Current corrections file - notification
    - Current declination value
    - App version - notification
    - Enable/Disable Tutorial
- Corrections
    - Import corrections data
    - Export corrections data

Attachments:

Map Screen



Live-View Screen