Calculating Ground Track from MIDG II Messages

Often it is necessary to work with ground track of a vehicle. Ground track refers to the direction of motion of the vehicle with respect to the local map. It is analogous to heading, but refers to direction of motion as opposed to direction of pointing. This application note demonstrates how to calculate ground track using messages from the MIDG II.

Ground track is calculated from vehicle velocity. If the vehicle velocity is known in the local Earth reference frame, then ground track is:

$$GT = \arctan 2(Veast, Vnorth)$$

Where *arctan2* is the standard C math library *atan2* function, which computes the arc tangent of y/x, using the signs of both arguments to determine the quadrant of the result. *Veast* and *Vnorth* are the east and north velocities, respectively.

The MIDG II provides velocities in both the NAV_PV message and the GPS_PV message. The NAV_PV velocity is a result of the Kalman filter, whereas the GPS_PV velocity is computed directly from GPS. The NAV_PV velocity is available at up to 50Hz, and is estimated even when during GPS dropouts. The GPS_PV velocity is provided at up to 5Hz and is only provided when a GPS is solution is available. In both cases, the reference datum is WGS-84.

By default, the MIDG II provides velocity in East, North, Up (ENU) coordinates. But, Earth-Centered, Earth-Fixed coordinates (ECEF) may be specified for velocity using the MIDG II output format configuration option. If ECEF coordinates are required for velocity output, east and north velocities can still be calculated as shown in Figure 1. The conversion of ECEF velocity to ENU velocity requires knowledge of the place on the Earth where the conversion will take place. In the example, the location is defined by: Latitude = 30 degrees and Longitude = 0 degrees. Once ENU velocity has been calculated, the ground track can be calculated using the equation presented above.

Conversion of ECEF velocity to ENU coordinates for the purpose of determining ground track. The velocity to be converted (in ECEF) is:

$$V_x := 0 \cdot \frac{m}{sec} \qquad V_y := 10 \cdot \frac{m}{sec} \qquad V_z := 10 \cdot \frac{m}{sec}$$

Conversion from degrees to radians (for convenience).

$$D2R := \frac{\pi \cdot rad}{180 \cdot deg}$$

Define the location on Earth where the conversion will take place.

$$\phi := 30 \cdot deg \cdot D2R \qquad \text{Latitude}$$

$$\lambda := 0 \cdot deg \cdot D2R \qquad \text{Longitude}$$

$$h := 0 \cdot m \qquad \text{Altitude above ellipsoid}$$

Convert ECEF velocity at the reference point to ENU coordinates

$$\begin{pmatrix} V_e \\ V_n \\ V_u \end{pmatrix} := \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix} \cdot \begin{bmatrix} \cos(-\phi) & 0 & -\sin(-\phi) \\ 0 & 1 & 0 \\ \sin(-\phi) & 0 & \cos(-\phi) \end{bmatrix} \begin{bmatrix} \cos(\lambda) & \sin(\lambda) & 0 \\ -\sin(\lambda) & \cos(\lambda) & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{pmatrix} V_x \\ V_y \\ V_z \end{pmatrix}$$

$$\begin{pmatrix} V_e \\ V_n \\ V_u \end{pmatrix} := \begin{bmatrix} -\sin(\lambda) \cdot V_x + \cos(\lambda) \cdot V_y \\ -\sin(\phi) \cdot \cos(\lambda) \cdot V_x - \sin(\phi) \cdot \sin(\lambda) \cdot V_y + \cos(\phi) \cdot V_z \\ \cos(\phi) \cdot \cos(\lambda) \cdot V_x + \cos(\phi) \cdot \sin(\lambda) \cdot V_y + \sin(\phi) \cdot V_z \end{bmatrix}$$

$$\begin{pmatrix} V_e \\ V_n \\ V_u \end{pmatrix} = \begin{pmatrix} 10 \\ 8.66 \\ 5 \end{pmatrix} \cdot \frac{m}{sec}$$

Figure 1. Mathcad Example