It is expected that magnetic component locations AMR sensors 1 and 10 50 200 ≤ Method A: The ratio The 3 Also the vehicles passing in the non-adjacent lane. Similar error rates (7%–15%) have been reported in literature even for magnetic sensors placed in the middle of the lane. Use of AMR-2 to reject errors due to traffic passing in the non-adjacent lane. It is shown that the magnetic field intensity around a vehicle has a relation that approximately varies as 1/x with distance, where x is the distance from the vehicle. Hence, the ratio of B should be larger for vehicles in the non-adjacent lane, compared to vehicles passing in the adjacent lane. Also the vehicles passing in the non-adjacent lane have a much lower peak value, Bmax1, on average compared to vehicles passing in the adjacent lane. These two metrics can be used to reject the traffic passing in the non-adjacent lane affecting the sensors. The following figure shows the result of applying the proposed method to the data set. A Support Vector Machine has been used to come up with the classification boundary. Using the proposed method, the error reduces from 8% to 1%. Velocity Estimation • AMR 3 is placed 0.9 meters from AMR-1 and these two sensors are used for vehicle velocity estimation. The relatively short distance between the sensors removes the problem due to a vehicle performing a maneuver which may be detected only by one of the two sensors. A reliable method to calculate the time delay between the two sensor locations is by using the cross-correlation between the sensors signals. The time delay in terms of samples is given by

\[ n_t = \text{arg max}_n f(n) \]

\[ f(n) = \sum_{m=0}^{N-1} B_{\text{max}1}(m)B_{\text{max}3}(m+n) - (N-1) \leq n \leq N-1 \]

DSP techniques are used to reduce the computational effort. A test vehicle equipped with carrier-phase GPS has been used to verify the accuracy of the proposed velocity estimation method. The velocity estimates are multiplied by the factor \( c = \min(B_{\text{max}1}, B_{\text{max}3}) \) to account for misalignment of the sensors and get zero-offset estimates.

Vehicle Classification • Knowing the time duration and velocity of each passing vehicle, the magnetic length of the vehicle can be calculated and used for vehicle classification. • Vehicles are divided into four classes, Class 1: Sedans, Class 2: SUVs, Vans and Pickup; Class 3: Buses and 2.9-axle Trucks and Class 4: Articulated Buses and 4.5-axle Trucks. • Since vehicles in class 1 and class II have similar length and consequently similar magnetic lengths, it is not possible to classify them by using only magnetic length. It is expected that magnetic component locations of a vehicle in Class II lead to a higher magnetic length compared to vehicles in Class I. Placing another sensor, AMR-4, one foot vertically above AMR-1, it is expected that the ratio \( \frac{B_4}{B_1} \) will be larger for vehicles in Class II. This ratio along with the magnetic length can be used to determine boundaries for classifying Class I and Class II vehicles with an accuracy of 83%.

Right-turn Detection Using just one AMR sensor as shown, the number of right-turns at an intersection can be counted. During the experiments, 56 out of 59 right-turns were counted correctly resulting in a detection rate of 95%. Typically straight-driving vehicles are not detected, since they pass at a larger distance from the sensor compared to vehicles making a right turn. However larger straight-driving vehicles can create large enough signals to be miscounted as vehicles making right turns. During the experiments, 18 straight driving vehicles created large enough signals to be miscounted as right-turning vehicles which results in a detection error of 31%, if uncorrected. Two methods, A and B, are proposed to identify and reject the errors caused by straight driving vehicles, using two and four AMR sensors respectively. Considering the shown sensor configuration, integrating the signals from four AMR sensors of each detected vehicle we expect the following Scenario 1: \( B_{\text{max}1} \geq B_{\text{max}2} \geq B_{\text{max}3} \geq B_{\text{max}4} \) Scenario 2: \( B_{\text{max}3} > B_{\text{max}1} > B_{\text{max}2} > B_{\text{max}4} \) Scenario 3: \( B_{\text{max}4} > B_{\text{max}3} > B_{\text{max}2} > B_{\text{max}1} \) Method A: The ratio \( \frac{B_{\text{max}1}}{B_{\text{max}3}} \) should be closer to 1 for straight driving vehicles since they pass at larger distances from the sensors. Method B: A plane is fit to the measurements from the four AMR sensor. By considering the angle of the plane, \( \gamma \), the straight-driving vehicles can be excluded. The two methods can be used separately or combined. With classification boundaries, straight-driving vehicles can be completely excluded reducing the 31% misdetection error to zero.