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Distributed Acoustic Sensing the Red Line in Calgary: where is my train?

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Summary

Only a few of the Light Rail Transit (LRT) trains on the City of Calgary Red Line are GPS equipped and no system exists to consume positional information for even those trains. Further, we find that of the logged GPS positions, more than 98% are null-valued or are repeats of previous positions. As a GPS alternative, or perhaps as a companion to a future GPS-based system, we connect a Distributed Acoustic Sensing (DAS) system to existing telecom fibre that follows the Red Line. All trains on the Red Line register as intensity peaks that we track in real time. The fibre is longer than the Red Line itself due to meanders of the fibre as well as due to loops of slack fibre of unknown length, and distance-along-the fibre rather than position is measured from DAS intensity peaks. We correct the length of the fibre and deduce position from DAS distance using a combination of DAS intensity picks plus GPS position and speedometer velocity for three GPS-equiped trains that we track. Kalman filtering of the corresponding DAS picks and GPS positions reduces error and puts DAS and GPS position onto the same numerical grid. The result is a permanent relationship between DAS distance and position for all trains on the Red Line.

Theory / Method / Workflow

We identify a GPS-equipped test train and track it using DAS for three traverses (trips) of the north-west leg of the Red Line between City Hall Station and Tuscany Station. The distances d DAS and the GPS logs reside on different numerical grids, and a number of DAS noise-sources complicate the DAS / GPS relationship. We reconcile the grids and reduce the noise by Kalman filtering (Kalman, 1960) the DAS distances. We construct a unit heading-vector for every point on the actual grid by simple interpolation. The vertical and horizontal components of this vector correspond to the longitude and latitude directions respectively. We convert the valid GPS positions to GPS distance using meridian arcs and then we Kalman filter the GPS positions onto the same grid as the Kalman DAS-distance.

Results, Observations, Conclusions

We find that the first trip of the three and the lead car and second car have the least noise. The first trip corresponds to a mid-morning train, whereas the second and third trips correspond to mid-afternoon and late afternoon; we feel that perhaps changes in ridership and traffic patters during the day result in the extra noise during the second and third trips. Noise in the second-last and last cars is due to the correlation of the DAS intensity peaks with the two lead cars. The associated errors due to ridership / traffic patterns and the correlation with the lead cars are subjects of ongoing investigation.

Novel/Additive Information

Though we might expect GPS-tracking of commuter trains to be a matter of course, we find that due to the heterogeneity of trains in commuter fleets like the City of Calgary LRT system means that most of the older trains are not GPS equipped. We find also that of those that are, GPS positions are much more sparse than expected. As an alternative (or perhaps as a companion) to GPS tracking, we demonstrate that the DAS intensity due to the passage of trains in the Red Line is sufficient to provide position information for all trains on the system in real time. We use Kalman filtering to reconcile DAS distance and GPS position of three round trips of a GPS-equipped train. The resulting relationship (Figure 1) between DAS distance and position for trains on the Red Line is permanent for all trains and all times.

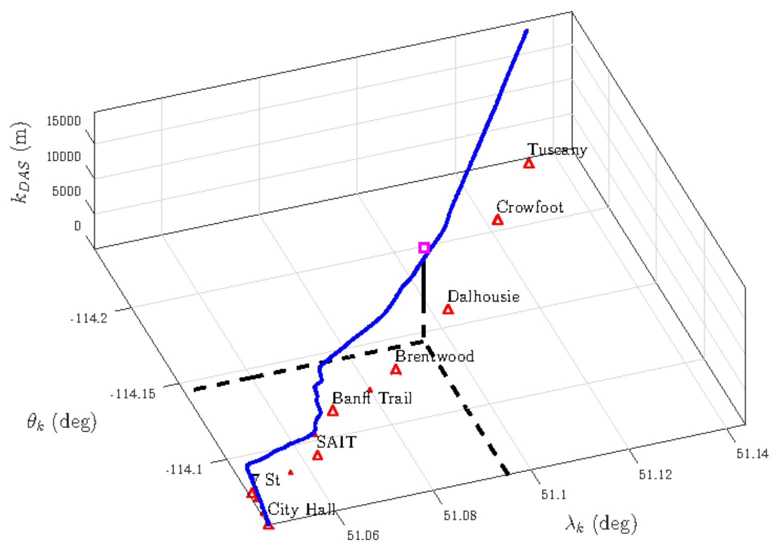

Figure 1: The DAS distance relationship with position for the City of Calgary Red Line. The hypothetical train indicated lies at distance 13.3 km in the DAS soundfield. The position of the train is 51.09531 and -114.14461 degrees latitude and longitude respectively.

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References

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