Integrated Track Infrastructure Assessment Tools

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16. Abstract

The Federal Railroad Administration's (FRA) Office of Research and Development sponsored a project to further the development of a mobile track surveying system that utilizes Real Time Kinematic (RTK) GPS technology for comparing track alignments over time; and, develop its capabilities to integrate with additional instruments used during routine track inspections. A light weight, modular steel frame was designed and fabricated with the capability of mounting contact and non-contact instruments for measuring gage, cross level, etc. and combined with a hardware and software system developed to allow these data streams to be synchronized with the hi-rail mounted GPS data stream. The system was designed to: "plug and play" different instruments; display the data on a lap top computer in real time; and, download data on demand. Several dozen surveys were conducted both on and off the tracks to refine the data collection and processing steps utilizing an evolving GPS Virtual Reference System (VRS) along the border of Ohio and West Virginia for GPS augmentation purposes. The surveys were conducted on track segments ranging from 5 to 116 miles over a two year time period; and, a suite of software tools were customized as needed for track alignment modeling, in addition to facilitating quick comparisons between multiple surveys. Results demonstrate the repeatability of GPS measurements augmented via a VRS at typical hi-rail speeds and their potential for evaluating track positional behavior over time. Integration of the multiple instrument data streams was successful after procedures were developed to permit the output of the GPS data stream to non-brand equipment.
This enabled positional accuracies of 2 cm for gage and cross level measurements to be recorded at speeds up to 35 mph.

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Research Results

Integrated Track Infrastructure Assessment Tools Pilot

SUMMARY

The Federal Railroad Administration’s (FRA) Office of Research and Development sponsored a project to further the development of a mobile track surveying system that utilizes Real Time Kinematic (RTK) GNSS technology for comparing track alignments over time; and, develop the system capabilities to integrate with additional instruments during routine track inspections. A lightweight, modular steel frame was designed and fabricated with the capability of mounting contact and non-contact instrumentation. The direct measurement of gage, cross level, and track position with GNSS measurements, integrated through hardware controller and system software enabled the synchronization of the data stream. The system was designed to: “plug and play” different instruments; display the data on a lap top computer in real time; and, and download data on demand. Several dozen surveys were conducted both on and off the tracks to refine the data collection and processing workflow. Networked continuously operating reference stations (CORS) and Virtual Reference System (VRS) software enabled continuous hi-rail mounted GNSS track measurement to a horizontal position accuracy of 1cm. The surveys were conducted on track segments ranging from 5 to 116 miles over a two-year period. A suite of software tools were customized as needed for track alignment modeling, and to facilitate track alinement comparison between multiple surveys. Results demonstrate the repeatability of RTK GNSS measurements at typical hi-rail speeds and their potential for evaluating track positional behavior over time. Integration of the multiple instrument data streams was successful after procedures were developed to permit the output of the GNSS data stream to non-brand equipment. The assessment system enabled track position accuracies of 2 cm for track vertical profile, gage, and cross level recorded at hi-rail speeds to 35 mph.

BACKGROUND

Deployment of GNSS (GPS+GLONASS) technology in the rail industry facilitated the evolution of routine track inspection vehicles into sophisticated geospatial data portals directing track inspectors to locations of concern identified by track geometry cars. Track inspection vehicles equipped with precision GNSS equipment will expand the use of this technology beyond navigation and or mobile tracking. RTK-GNSS with 1 cm horizontal and 2 cm vertical precision capability has at least two near term potential uses as compatible equipment is made available on board and wayside: 1) PTC mapping updates; and, 2) as a track alignment modeling and assessment tool.

Previous studies related to the use of RTK-GPS as a track alignment assessment tool are limited. Those with the use of temporary base stations include Munson, reporting in 2004 multiple track centerline surveys collected during two seasons on track segments less than one mile total length in Iowa.
Variations between the warm and cold data were observed to be less than 2 cm; and, a track buckle detection model was also presented suggesting that a GPS system operating at 3 cm accuracy has potential to find low amplitude track buckle precursors. Szwilski et al, 2006 also used temporary base stations and compared three seasonal surveys on track segments totaling about 30 miles total length in New Mexico. Variations up to a maximum of 7 cm were observed between surveys.

Previous studies with the use of a VRS include Svabensky, 2008 who compared VRS and non VRS based measurements on a single survey of a 120 meter track segment in the Czech Republic; with variations no greater than 1.4 cm. The FRA is using a VRS for a railcar mounted autonomous track inspection system in the northeastern US on a passenger train with data analyses un-published as of this date.

METHODOLOGY

The project included, but was not limited to the following activities:

1) Conducting a thorough investigation into the repeatability of GNSS measurements collected from a hi-rail operating at typical speeds using a Virtual Reference System;
2) Design and fabrication of a light weight modular track gage and track cross level measurement platform;
3) Design and assembly of a data integration hardware and software system; and,
4) Preparation of track alignment comparison and modeling techniques.

Table 1 summarizes the major track surveys. The surveys were generally performed by the research team, however a track inspector trained to use the equipment. The majority of the experiments collected only GNSS observations, with gage and cross level collected during the final stages of the project. Several design reviews and demonstrations with an industry advisory team contributed to an improved experimental program and product design parameters.

Table 1. Summary of major track surveys.

CORRIDOR ONE		CORRIDOR TWO	
Dates	Miles	Dates	Miles
02/05/09	116	08/10/09	29
03/01/09	7	08/11/09	7
03/24/09	7	08/12/09	29
05/20/09	40	09/02/09	21
05/21/09	28	01/20/10	28
11/05/09	20	02/05/10	19
02/12/10	5	02/14/10	22
12/02/10	20	03/03/10	29
12/13/10	20	03/18/10	28
		07/26/10	29
TOTAL MILES		08/12/10	29
Corridor One[1]	263	08/16/10	27
Corridor Two[2]	267	08/17/10	27
[1]Single Track [2]Single, Double and Triple Track			

GPS Survey Procedures

Two separate hi-rail vehicles were equipped with either Trimble 5700 or Trimble R7 receivers and compatible antennas and survey controllers. The antennas were mounted to measure the top of the rail or centerline position. The survey controller software filtered data with position errors greater than 1.49 cm (0.05 ft) horizontal and 2.01 cm (0.07 ft) vertical. Data was collected on nominal 10 foot intervals.

Track Gage and Cross Level Measurement Platform

The final platform was the product of several design iterations and utilizes a multi-articulated frame to position instruments for measuring gage, cross-level, and ambient and rail temperature. The instrument frame is composed of 4 separate field assembled components coupled to a standard 2" trailer hitch with provision to minimize the impact of vehicle dynamics on the frame. Elastic forces in the

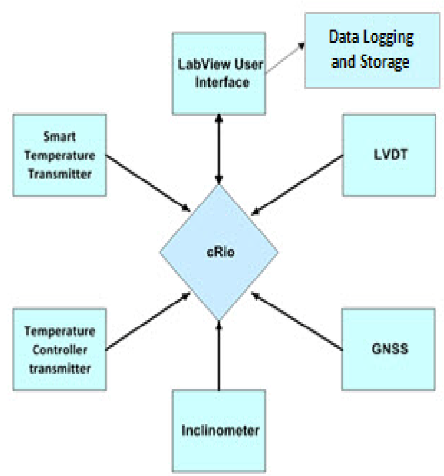

Figure 1 Data collection and integration.

frame maintain close contact between gage side rail and the frame's steel flanged wheels. As rail heights vary, the frame allows independent vertical motion of the flanged wheel struts facilitating cross level measurements with an inclinometer. The frame also positions a linear variable displacement transducer (LVDT) for measuring gage parallel to the top of rails.

Data Integration System

The system was developed within a Lab View™ environment. The system environment includes a customizable user interface that displays real time measurements of gage and cross level with programmable alerts. The system can easily exchange or add additional instruments as needed.

Track Alignment Comparisons and Modeling Techniques

For the track alignment comparative processes, GIS/CAD based linear referencing tools were utilized. For track alignment modeling, MATLAB™ software routine was prepared that provided the flexibility to program any chord length and stationing for degree of curvature calculation. (Dailey, 2010)

RESULTS

To validate the GNSS track observation method, a survey was conducted utilizing a robotic total station instrument tracked a reflective target collocated with the GNSS antenna on the hi-rail. A Trimble S6 Robotic Total Station-TS located on a bridge overpass and operated by a licensed surveyor correlated with the mobile GNSS track observations. TS observations were collected every 15 feet over a ½ mile track segment. The mean horizontal and vertical variations were 0.008 and 0.010 feet respectively. Surveys were also repeated on a two-mile track segment. Variations presented in Table 2 and Figure 2.

Table 2. Statistical Results For Six Top of Rail Surveys

HORIZONTAL VARIATIONS (ft)				VERTICAL VARIATIONS (ft)			
Mean	Min	Max	StDev	Mean	Min	Max	StDev
0.001	-0.332	0.294	0.042	-0.002	-0.393	0.496	0.064
0.009	-0.386	0.341	0.041	-0.013	-0.330	0.685	0.065
0.010	-0.257	0.324	0.041	-0.012	-0.494	0.504	0.065
0.013	-0.239	0.452	0.034	-0.007	-0.329	0.620	0.071
0.041	-1.268	0.251	0.076	0.021	-0.619	0.579	0.069
0.025	-1.566	0.341	0.068	0.029	-0.341	0.399	0.056

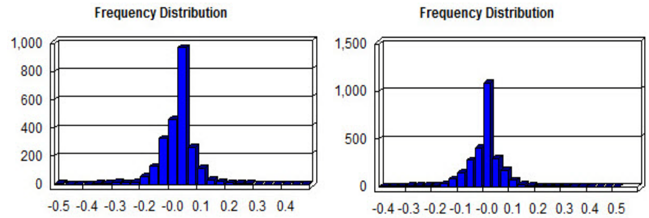

Figure 2 Representative distributions of variation between two surveys of the same two-mile track segment. Horizontal comparison - left, and vertical - right. Units in feet.

Representative comparative processes products are shown in Figures 3 and 4. Figure 3 compares three GPS surveys plotted through the customized MATLAB™ routine for a three-mile track segment. Figure 4 shows horizontal and vertical displacements detected over ½ foot between two surveys for a ten-mile track segment. Data from the gage and cross-level, etc. can be easily overlain the alignment data with standard GIS applications.

CONCLUSIONS

The pilot project demonstrated the potential of evolving GPS technology as a diagnostic tool in addition to a more precise location tool provided adequate data collection protocols. And this potential will be enhanced when VRS systems expand geographically throughout the US and as GIS systems proliferate in the industry.

Data analysis procedures currently require skilled GIS/CAD operators combined with sufficient surveying expertise. But turnaround time of the data analytical products can be very short with appropriate resources including site-specific experiences.

Further development of the various components of this pilot project can result in several cost effective track inspection enhancements for the routine track inspection vehicle. And several components could also be easily adapted to other track inspection systems currently being utilized and under development.

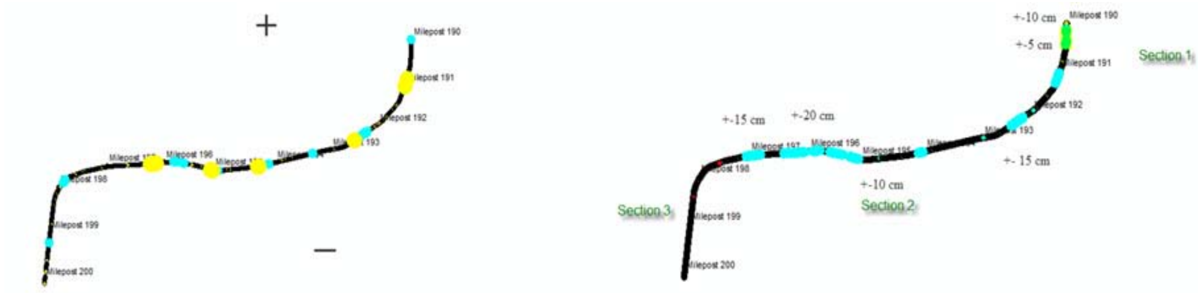

Figure 4 Illustration of track displacement between two GNSS surveys across a ten-mile segment. Horizontal displacement greater than 0.5 feet – left, vertical displacement over 0.5 feet – right.

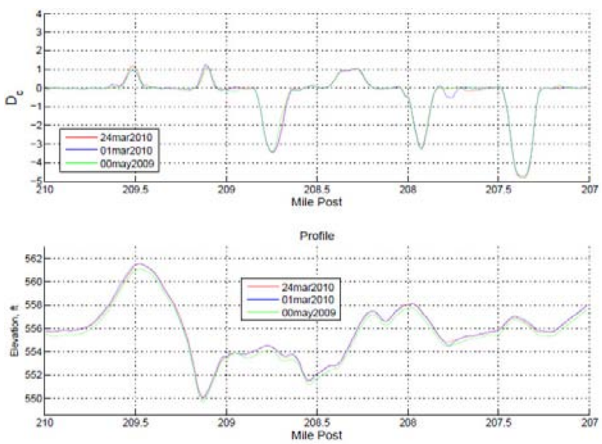

Figure 3 Comparison of three surveys over a three-mile track segment. Horizontal alinement in degree of curvature - top, track profile - bottom.

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