JOINT TRANSPORTATION RESEARCH PROGRAM

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Feasibility of a New Indiana Coordinate Reference System (INCRS)

Introduction

Engineers, surveyors, and GIS professionals spend an enormous amount of time correcting field surveys to conform to the classical State Plane Coordinate System (SPCS). The current mapping corrections are in the order of 1:30,000, or 33 parts per million (ppm). Modern surveys (e.g., GPS/InCORS) are accurate to a few ppm. Whenever original surveys made on the surface of the Earth need to be reduced to a mapping reference surface, surveyed distances and angles (azimuths) need to be corrected. Measured distances need to be corrected for two scale factors: (1) the mapping scale inherent in conformal mappings, and (2) terrain heights. Measured angles (azimuths) need to be corrected for so-called convergence angles. Applying these necessary corrections is time consuming and adds an estimated 15 to 20% to the cost of a survey. However, omitting these corrections corrupts the reliability of survey results.

A newly proposed Indiana Coordinate Reference System (INCRS) allows for much smaller corrections that, when omitted, result in minor errors that may even be disregarded for surveys that call for less accuracy than a few ppm. (In a few areas of Indiana (e.g., Clark County), terrain height corrections are still needed because these corrections, due to the terrain heights variation, are at the 14 ppm level.) The proposed INCRS not only reduces the scale factor from 33 ppm to a few ppm, but also reduces the convergence angles by a factor of four (from about a maximum of 0.5 degrees to about 7–8 arcminutes). This new, much more accurate mapping system has been developed based on closed formula expressions and simple mathematical coordinate transformations.

Findings

- The current mapping system, Indiana State Plane Coordinate System of 1983 (INSPCS83), based on Transverse Mercator (TM) mapping, causes distortions of survey measurements on the Earth's surface at 33 ppm, or around 0.2 feet (2 inches) per mile (3 cm/km). This level of accuracy is insufficient for modern, highly precise (few ppm) (GPS) surveys (few cm/10 km).
- Two new mapping systems, one based on TM mapping

and a second one based on a special case of the Lambert conformal mapping, the Oblique Stereographic (OS), are both capable of reducing mapping errors to the few ppm accuracy level when applied in small geographical areas (counties).

- The TM and the OS systems are equally capable of reducing mapping errors on a county-by-county basis; however, the OS is superior to the TM in equally distributing the small errors in Easting and Northing.
- The mapping related scale factor corrections can be reduced to the less than 2 ppm level in average of all counties in Indiana (see Table 1). The terrain height related errors can also be greatly reduced; however, the terrain heights variation plays a limiting factor. In some areas in Indiana the scale factor error due to the terrain heights variation cannot be reduced to below the 14 ppm level. In this case the classical measurement reductions cannot be omitted and should be applied (see Table 2).
- The proposed INCRS also reduces the convergence angles by a factor of four (INSPCS83 exhibits convergence angles up to the half a degree (30 arcminutes) level).
- An extensive test in Marion County confirmed all the findings stated above. Based on the test of Marion County, the ability of INSPCS83 and the proposed INCRS in modeling the reality (so-called "Real World") are investigated

TABLE 1 Summary of the Mapping Scale corrections of the INCRS

Maximum errors committed ignoring Mapping Scale corrections; all 92 Indiana Counties	Proposed INCRS Mapping			
	TM (CP)		OS (CP)	
	(ppm)	County	(ppm)	County
Max (worst)	2.96	Gibson	3.34	Knox
Min (best)	0.19	Vermillion	0.45	Ohio
Average (92 counties)	1.10		1.39	
Standard deviation (92 counties)	0.50		0.44	

through different evaluation methods. See an example of the evaluation results in Table 3.

- The proposed INCRS, based on a spherical approximation that allows closed formula mathematical expressions in conjunction with simple coordinate transformations, models Real World point clouds with one order of magnitude better (a factor of 10) than the classical INSPCS83 (see Table 3) that is based on an ellipsoidal model and extensive series expansions that may have limited accuracy because of truncation errors.

Implementation

Implementation of the INCRS may occur within two to three years after the completion of the feasibility study (time frame: August 2012 to August 2015). During the implementation phase the following tasks need to be completed:

- Acceptance and approval of the INCRS by the engineering/surveying/GIS communities in Indiana.
- Delineation of the mapping zones.
- Official designation of the mapping zones.
- Selection of the mapping method (mapping equations) for each mapping zone.
- Selection of longitude and latitude of the mapping origin (Center of Project (CP)) for each mapping zone.
- Selection of the optimum scale factors for each mapping zone.
- Selection of False Eastings and False Northings for each mapping zone.
- Development of the Indiana Handbook on the New Indiana Coordinate Reference System.
- Preparation of legislation (Model Law) that prescribes

TABLE 2 Summary of the Terrain Height corrections of the INSPCS83 and the INCRS

Mapping system	Errors committed ignoring Terrain Height corrections; all 92 Indiana counties			
	Minimum		Maximum	
	(ppm)	County	(ppm)	County
Current INSPCS83	14.1	Posey	46.7	Randolph
Proposed INCRS	2.4	Pulaski	14.7	Clark

the use of INCRS and its related mapping parameters for each mapping zone.

- Adaptation of the Indiana Department of Transportation's Engineering and Survey Design Manuals.
- Development of workshops and seminars for the engineering/surveying/GIS communities.

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TABLE 3 Ability to model the Real World by each mapping system, INSPCS83 vs. INCRS (tested in Marion County with no terrain elevations involved)

The Least Squares residuals (V's) of Affine Fitting of the mapped grids to the Real World		NGS INSPCS83 (TM)	Proposed INCRS	
		(cm)	TM (CP)	OS (CP)
Root mean squares (RMS) of the fitting residuals (V's)	$V_{RMS}(E)$	6.83	0.77	0.97
	$V_{RMS}(N)$	10.87	1.48	0.93
	$V_{RMS}(EN)$	12.84	1.67	1.35
Average values of the fitting residuals (V's)	$V_{avg}(E)$	-0.00	0.00	0.00
	$V_{avg}(N)$	0.00	0.00	0.00
	$V_{avg}(EN)$	10.80	1.22	0.93
Convergence angle at the extreme NW corner of Marion County		28' 14.07"	07' 42.08"	07' 41.40"