Summary of Material for Second Edition of
The 3-D Global Spatial Data Model:
Principles and Applications
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Existing material is highlighted.
New or re-written material in black print

Note: Material in the existing Foreword will be incorporated into the new Chapter 1. A new Foreword will be written by _________________________.

New Preface (combination of A and B following)

- A. Reference Preface in First Edition
  1. Right tool for the job
  2. Organization of material in book
  3. Philosophy for level of reader
  4. Scope of audience
  5. Outside the box
  6. Elephant joke
- B. New material in 2nd Edition Preface is to include statements for reader to look for:
  1. Expanded discussion of models
  2. Rationale for using GSDM
  3. Brief history – development of GSDM
  4. Least squares
  5. Network/local accuracy
  6. Examples – projects/applications

New acknowledgement

- A. As in existing book
- B. Additional persons

O. Chapter 1A – this will actually be Chapter 1 and the other chapters re-numbered accordingly. (Materials from the existing Foreword are included here.)

- A. The pieces of the global spatial data model are not new – the model is new!
- B. Why another spatial data model?
- C. Digital geo-spatial data are more effectively used in a "new bottle model."
- D. Computer database still growing exponentially in accordance with Moore's Law
- E. Studies commissioned by the U.S. National Academy of Public Administration
- F. GSDM bridges the gap between "science" and "user" - interoperability
- G. NOAA request for input on BIG DATA is excellent example.
- H. COGO Spatial Data Infrastructure Report Card identifies need for integrated 3-D framework.
- I. Assumptions underlying development of GSDM
  1. Origin at earth's center of mass
  2. Use earth-centered earth-fixed (ECEF) devised by U.S. DoD
  3. Long-standing rules of solid geometry used throughout
  4. Error propagation handles spatial data accuracy efficiently
- J. Consequences
  1. Portray any/all points in the "cloud" from user specified perspective.

2. Inverse gives local tangent plane (flat-earth)
    i.) Distance between points
    ii.) Direction/azimuth with respect to local true meridian
3. Interoperability
    i.) Between disciplines
    ii.) Worldwide
    iii.) Can accommodate existing coordinate systems
        - Backward
        - But not forward
4. No need to use:
    i.) Grid scale factor, elevation factor, or combined factor
    ii.) Zone constants or map projections
    iii.) Low Distortion Projections (LDP)

I. Chapter 1 – Global Spatial Data Model (GSDM) Defined
  A. Introduction
  B. The GSDM
    1. Overview and Figure 1.1
    2. Functional model component
    3. Computational designations
    4. Algorithm for functional model
    5. Stochastic model component
        i.) The GSDM covariance matrices
        ii.) The GSDM 3-D inverse
    6. BURKORD™ software and database
    7. Summary

II. Chapter 2 – Spatial Data and the Science of Measurement
  A. Introduction
  B. Spatial Data Defined
  C. Coordinate Systems Give Meaning to Spatial Data
    1. ECEF
    2. Geodetic
    3. Local
    4. Spatial data types
  D. Visualization Well Defined
  E. Direct and Indirect Measurements Contain Uncertainty
    1. Physical constants held exact
    2. Measurements contain errors
  F. Measurements Used to Create Spatial Data Include . . .
    1. Taping
    2. Leveling
    3. EDM
    4. Angles
    5. Photogrammetric mapping
    6. Remote Sensing
    7. LiDAR
  G. Errorless Spatial Data Must Also Be Accommodated
  H. Primary Spatial Data are Based Upon Measurements and Errorless Quantities

        1. Observations and measurements
        2. New category
    I. Derived Spatial Data are Computed from Primary Spatial Data
    J. Establishing and Preserving the Value of Spatial Data
    K. Summary
        1. Includes
        2. Remainder of book . . .

III. Chapter 3 – Summary of Mathematical Concepts
    A. Introduction
    B. Conventions
        1. Numbers
        2. Fractions
        3. Decimal
        4. Sexagesimal system
        5. Binary system
        6. Conversions
        7. Rectangular coordinate systems
        8. Significant figures
            i.) Addition and subtraction
            ii.) Multiplication and division
    C. Logic
    D. Arithmetic
    E. Algebra
        1. Axioms of equality
        2. Axioms of addition
        3. Axioms of multiplication
        4. Boolean algebra
    F. Geometry
        1. Point
        2. Distance
        3. Dimension
        4. Line
        5. Plane
        6. Angle
        7. Circle
        8. Ellipse
        9. Radian
        10. Triangle
        11. Quadrilateral
        12. Rectangle
        13. Square
        14. Trapezoid
        15. Polygon
        16. Pythagorean theorem
    G. Solid Geometry
        1. Sphere
        2. Ellipsoid
        3. Polyhedron

4. Tetrahedron
5. Pyramid
6. Cube
7. Equation of a plane in space
8. Equation of a sphere in space
9. Equation of an ellipsoid centered on the origin
10. Conic sections
11. Vectors

H. Trigonometry
1. Trigonometric identities
2. Law of sines
3. Law of cosines

I. Spherical Trigonometry
1. Spherical law of sines
2. Spherical law of cosines

J. Calculus
1. Symbolic convention
2. Tank example
3. Differential calculus equations
4. Integral calculus equations

K. Probability & Statistics
1. Introduction
2. Standard deviation
3. Measurement
4. Error - types
   - i.) Blunders
   - ii.) Systematic errors
   - iii.) Random errors
5. Error sources
   - i.) Personal
   - ii.) Environmental
   - iii.) Instrumental
6. Accuracy and precision
7. Computing standard deviations
8. Standard deviation of the mean
9. Confidence intervals
10. Hypothesis testing - new material to be added to existing material
11. Matrix algebra

L. Models
1. Functional
2. Stochastic

M. Error Propagation
1. Tank example
2. Special law of propagation of variances – independence
   - i.) Standard deviation of a sum
   - ii.) Standard deviation of a difference
   - iii.) Standard deviation of a product
   - iv.) Standard deviation of a quotient

N. Error Ellipses

O. Least Squares
    1. Linearization
    2. Additional descriptive material RE: least squares chapter to follow.
P. Applications to the GSDM
Q. References

IV. Chapter 4 - Geometrical Models for Spatial Data Computations
  A. Introduction
  B. Conventions
  C. Two-Dimensional Cartesian Models
    1. Math/science reference system
    2. Engineering/surveying reference system
  D. Coordinate Geometry
    1. Forward
    2. Inverse
    3. Intersections
      i.) Line-line intersection
      ii.) Line-circle intersection
      iii.) Circle-circle intersection
      iv.) Perpendicular offset
    4. Area by coordinates
  E. Circular Curves
    1. Definitions
    2. Degree of curve
    3. Curve elements and equations
    4. Stationing
    5. Metric considerations
    6. Area formed by curves
    7. Area of a unit circle
  F. Spiral Curves
    1. Spiral geometry
    2. Intersecting a line with a spiral
    3. Computing area adjacent to a spiral
  G. Radial Surveying
  H. Vertical Curves
  I. Three-Dimensional Models for Spatial Data
    1. Volume of a rectangular solid
    2. Volume of a sphere
    3. Volume of a cone
    4. Prismoidal formula
    5. Traditional 3-D spatial data models – Add list & emphasize these are discussed later
  J. The 3-D GSDM
  K. References

V. Chapter 5 - Overview of Geodesy
  A. Introduction
  B. Fields of Geodesy
  C. Goals of Geodesy
  D. Historical Perspective

1. Religion
2. Science
3. Degree measurement
4. Eratosthenes
5. Poseidonius
6. Caliph Abdullah Al Mamun
7. Gerardus Mercator
8. Willebrord Snellius
9. Jean Picard
10. Isaac Newton
11. Jean-Dominique and Jacques Cassini
12. French Academy of Science
13. Meter

E. Developments During the Nineteenth and Twentieth Centuries
F. Forecast for the Twenty-First Century
G. References

VI. Chapter 6 - Geometrical Geodesy

A. Introduction
B. Two-Dimensional Ellipse
C. Three-Dimensional Ellipsoid
    1. Ellipsoid radius of curvature
    2. Normal section radius of curvature
    3. Geometrical mean radius
D. Rotational Ellipsoid
    1. Equation of ellipsoid
    2. Geocentric and geodetic coordinates
E. BK1 transformation
F. BK2 transformation
    1. Iteration
    2. Once-through Vincenty method
    3. Other non-iteration methods
    4. Example of BK1 transformation
    5. Example of BK2 transformation – iteration
    6. Example of BK2 transformation - Vincenty
G. Meridian arc length – Note, the outline layout in existing book needs to be improved.
H. Length of a parallel
I. Surface area of a sphere
J. Ellipsoid surface area
K. Geodetic Line
    1. Description
    2. Clairaut's Constant
    3. Geodetic Azimuths
    4. Target height correction
    5. Geodesic correction
L. Geodetic Position Computation: Forward and Inverse
    1. Puissant forward (BK18)
    2. Puissant inverse (BK19)
    3. Numerical integration

4. BK18 by integration
5. BK19: numerical integration
6. Geodetic position computations using state plane coordinates

M. GSDM 3-D Geodetic Position Computation
1. Forward (BK3)
2. Inverse (BK4)
3. GSDM inverse example – New Orleans to Chicago
4. Insert a table showing difference between arc and chord up to 20 miles.

N. References

VII. Chapter 7 - Geodetic Datums

A. Introduction

B. Horizontal datums
1. Brief history
2. North American Datum of 1927 (NAD 27)
3. North American Datum of 1983 (NAD 83)
4. World Geodetic Datum 1984 (WGS 84)
5. International Reference Frame (ITRF)
6. High Accuracy Reference Network (HARN)
7. Continuously Operating Reference Station (CORS)

C. Vertical datums
1. Sea Level Datum of 1929 (now NGVD 29)
2. International Great Lakes Datum
3. North American Vertical Datum of 1988 (NAVD 88)

D. 3-D Datums

E. Datum transformations
1. NAD 27 to NAD 83 (86)
2. NAD 83 (86) to HPGN
3. NGVD 29 to NAVD 88
4. HTDP
5. Software sources
6. Seven- (or fourteen-) parameter Transformation

F. References

VIII. Chapter 8 - Physical Geodesy

A. Introduction

B. Gravity

C. Definitions
1. Elevation (generic)
2. Equipotential surface
3. Level surface
4. Geoid
5. Geopotential number
6. Dynamic height
7. Orthometric height

D. Gravity and the Shape of the Geoid

E. Laplace Correction

F. Measurements & Computations
1. Interpolation and extrapolation

3. NAD 27 and NAD 83
4. (Relationship between Meter, International Foot and the U.S. Survey Foot)
5. Current status: NAD 83 State Plane Coordinate Systems
    i.) Advantages
    ii.) Disadvantages

F. Procedures
1. Grid azimuth
2. Grid distance
3. Loop traverse
4. Point-to-point traverse

G. Algorithms for Traditional Map Projections
1. Lambert conic conformal projection
2. Transverse Mercator projection
3. Oblique Mercator projection
4. Low distortion projection (LDP)
    i.) Lambert conic conformal projection
    ii.) Transverse Mercator projection
    iii.) Oblique Mercator projection

H. References

XI. Using Spatial Data

A. Introduction
B. Forces Driving Change
C. Transition
D. Consequences
E. Spatial Data Accuracy
1. Introduction
2. Definitions
3. Spatial data components and their accuracy
4. But everything moves
5. Observations, measurements, and error propagation
6. Finding the uncertainty of spatial data elements
7. Using points stored in the X/Y/Z database
8. Example
    i.) Blunder checks
    ii.) Results
9. Network accuracy and local accuracy

F. References

XII. Using the GSDM

A. Introduction
B. Features
C. Database Issues
D. Implementation Issues
E. Applications and Examples
F. WBK Software
G. References

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The intent in writing the first edition was to provide an efficient/logical/rigorous thought process from the "simple" to modern applications of 3-D digital (geo)spatial data and to make the shelf-life of the book as long as possible.

Even so, the publisher hesitates to "promote" a book published 7 years ago. Yes, there is new material that can be added. The publisher requires at least 25% "new" material in the 2nd edition.

The preceding outline includes contents of the existing book. Where modifications and incidental additions are needed, those items are printed in black letters – existing material is in blue.

The following material is identified as being new (additions) to the 2nd Edition. The current challenge is to find the best way to organize the "new" material. That will be pursued in an iterative manner.

One highly regarded person (competing author) made two suggestions as:

1. "Elementary" mathematics in Chapter 3 should be eliminated. I do not agree.
2. A section be added containing details on transforming data from one reference frame to another. I agree that is worthy, but such could easily get beyond my technical ability to do it justice. My inclination is to acknowledge that topic and identify it as "beyond the scope of this book."

The inclination of this author (July 2015) is that existing material is still legitimate as-is. Very little, if any, material should be eliminated. And, there are places where incidental "updates" are appropriate. Those can be handled "routinely" – see black print in outline.

The easiest way to organize "new" material would be to simply "add" the following chapters. An alternative would be to find a way to incorporate the "new" material into existing chapters. Thoughts???

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XIII. Concepts related to implementation of the GSDM
- A. Science
  1. Assumptions
  2. Hypothesis
  3. Observations
  4. Computations
     - i.) Solid geometry
     - ii.) Error propagation
- B. Absolute/Relative
  1. Reference frame
  2. Coordinate systems
     - i.) Geodetic
     - ii.) State plane (map projection)
     - iii.) Local
     - iv.) Geocentric

C. Models
   1. Coordinate systems
      i.) Geodetic
      ii.) Map projection (SPC/UTM)
         - LDP
         - Assumed
      iii.) 3-D Space - GSDM
   2. Measurements
   3. Sensors/Physical Environmental issues
D. Leveling
   1. Origin is arbitrary
   2. Objective is to:
      i.) Where with to other points
      ii.) Epoch
   3. Conceptual obstacle
      i.) Sea level is intuitive
      ii.) Ellipsoid height
      iii.) Even temperament
      iv.) Backward perspective
         - Time, lunch
         - Geoid height
   4. Geoid moves
E. Combined factors
   1. Two components
      i.) Grid scale factor
      ii.) Elevation factor
   2. Elevation
      i.) Of a point
      ii.) Of an area
   3. Definition
   4. Evaluate LDP
   5. DOT experiences
F. Professional
   1. Service to society
   2. Licensure – NCEES
   3. State BOL
   4. Company/corporate
   5. Clients

XIV. Justification
   A. Digital revolution
   B. Measurement systems provide 3-D data
   C. Models need to be updated
   D. Hierarchy of measurements
      1. Direct measurements
      2. Indirect measurements.
      3. Error propagation
      4. Consequences of choices
         i.) Greater “self-determination” for end user

ii.) Supports better decisions using GSDM
iii.) Need for geoid modeling greatly reduced

E. Data base issues
F. Thomas Kuhn's book "The Principles of a Scientific Revolution"

XV. Least squares
A. Build on material in chapter 3
B. Formulate solution for:
1. Observations only
2. Indirect observations
3. Linear solution
C. Creation of Covariance Matrix
1. SINEX format
2. BURKORD™ data base
D. Hypothesis testing
1. Station Bromilow
2. USPA and USPB
3. Surveyor Connect

XVI. Net/local accuracy
A. Example in 1st Edition
B. ACSM paper on Spatial Data Accuracy 1999
C. Fundamentals of Spatial Data Accuracy and the GSDM 2004 – Copyright
D. ASCE Paper by Soler/Smith 2009
E. Discussion/rebuttal 2012 and 2013
F. Continuing research – Wisconsin CORS example
G. Standard deviations
H. Covariance/correlations
I. Other statistical considerations
J. Error propagation

XVII. Examples
A. NMSU network
B. NextRad
C. NM/TX Rio Grande Border
D. NM Principal Meridian/Initial Point
E. Laying out a Baseline
F. Skeen Hall Finial/Network
G. Low Distortion Projection
H. Elevation at Station Reilly
I. GPS Network in Wisconsin
J. Other PLSS tracts

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Appendix A: Rotation Matrix Derivation
Appendix B: State Plane Coordinate System Constants
Appendix C: Example Computation – Network Accuracy and Local Accuracy
Appendix D: Brief History of Development of the Global Spatial Data Model (GSDM)

A. Berry – Univ. of Michigan and GEO-REF
B. Use of Michigan State Plane Coordinates
C. Emergence of County Coordinate Systems - von Meyer
D. Low Distortion Projections
E. Digital revolution – GPS, models, GIS
F. Abstract models – worldwide applications winning paper
G. SEWRPC
    1. Datum transformation NAD27 to NAD83
    2. Datum transformation NGVD29 to NAVD88
    3. Identification of 3-D integrated model
    4. 3-D Report
H. Sabbatical
I. Formal definition
    1. Technical functional model ASCE paper and DOTs
    2. Software,
J. 3-D book