Components of the Surveying body of knowledge

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SUMMARY

About three years ago, the American Congress on Surveying and Mapping (ACSM) and the North American Surveying Educators organization embarked on an important task of developing a body of knowledge for surveying. This was a crucial response to the technological and other information age developments that appear to undermine the traditional distinctive role of the surveying profession in positioning and mapping. To ensure the relevance and sustainability of the profession there is a need for a clear definition of the role of surveying in the spatial information community/industry and the knowledge base on which this role is founded on.

In this paper the process and the nearly final findings of the surveying body of knowledge effort are presented. The surveying body of knowledge consists of five subsets of knowledge bases which reflect the diverse activities of a professional surveyor. The five subsets are: positioning, Imagery, GIS, Law and land development. It includes listing and tabulating these five bodies of knowledge subsets, their respective knowledge areas and specific topics of each knowledge area. One of the main objectives of the paper is to stimulate discussion on this important task and use it as an inaugural effort to develop an FIG endorsed surveying body of knowledge.

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Abstract

About three years ago, the American Congress on Surveying and Mapping (ACSM) and the North American Surveying Educators organization embarked on an important task of developing a body of knowledge for surveying. This was a crucial response to the technological and other information age developments that appear to undermine the traditional distinctive role of the surveying profession in positioning and mapping. To ensure the relevance and sustainability of the profession there is a need for a clear definition of the role of surveying in the spatial information community/industry and the knowledge base on which this role is founded on.

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Introduction

Some advanced technologies have made a significant impact on our personal and professional lives. With new technologies we appear to be able to do many things we never imagined we would be capable of doing. However, sometimes, new technologies can give us a false belief that we can do things that we really can't. Just because we have easy access to tools it does not mean that we can do the job as well as a professional person. Regardless whether or not one truly understands the limitations of using technological tools without a broad understanding of the context in which they are used, these newly prevalent capabilities have a profound impact on traditional occupations and professions. To stay relevant, professions are required to re-evaluate their role and mission in light of technological and other developments.

Traditionally, surveyors were entrusted with providing positioning and mapping for a variety of applications and clients. It was clear that in order to locate features on the surface of the earth and to graphically describe their position on a map; one would need to seek the services of a surveyor. Today, with widely available technologies such as GPS, CAD, GIS, smart phones, tablets and other powerful personal electronic devices, the absolute reliance on surveyors for positioning and mapping is not as clear as it used to be. Therefore, in order to substantiate the viability of the surveying profession we need to address some cardinal issues.

One of the most important questions that arise is what are the distinct tasks, qualities and services that surveying provides in the field of positioning and mapping. Another way to ask that question is: what distinguishes surveyors from others who can also use technological tools to determine positioning and provide mapping services.

Thus, the surveying profession faces two major challenges. The first challenge is to define its own scope and mission in the new technology/information age. The second challenge is to define the educational requirements and the body of knowledge that will enable the surveying profession to realize its scope and mission. Understanding the breadth of the surveying knowledge base and the added value that surveyors can bring to a spatial enabled project are essential to empower the surveying community to remain a major player in the spatial information industry.

About three years ago, ACSM established a "Surveying Body of Knowledge" committee to develop the surveying body of knowledge. A preliminary draft of that body of knowledge is being completed and will be shortly made available to the surveying community for comments and discussions. It is important for every surveyor who is passionate and concerned about his or her profession, to take part in these discussions. The results of these discussions will shape the surveying profession in the 21st century.

In this paper we will describe the structure of the body of knowledge and provide a detailed outline of the overall body of knowledge subsets, knowledge areas, units or topics within the knowledge areas. Because of the breadth of the scope of what surveying is, some classification of knowledge is required based on practice specialties opted by individual professional surveyors. The detailed classification of knowledge according to core knowledge, specialty knowledge and scholarly knowledge will not be presented here. It will be presented in the report of the ACSM committee.

Building a body of knowledge

Many professions have developed bodies of knowledge. For example, project management body of knowledge [PMBOK, 1996], software engineering body of knowledge [SE, 2004], business analysis body of knowledge [BABOK, 2007], data management body of knowledge [DAMA, 2010], body of knowledge on infrastructure regulations [Jamison, et. al., 2008], civil engineering body of knowledge [ASCE, 2004] and GIS and technology body of knowledge [AAG, 2006]. It is important to note that the last two bodies of knowledge listed above have a close relationship and sometimes overlapping activities with the surveying profession. This fact adds to the dire need to distinguish surveying as a unique profession and for the development of a surveying body of knowledge.

A close examination of the content of the above listed bodies of knowledge reveals that there are two conceptually different approaches for developing a body of knowledge. The first is to provide a general knowledge outline without a specific break down of the knowledge base into technical knowledge areas and topics. For example, some bodies of knowledge specify that there is a need to have a knowledge base in mathematics, physics, communication,

humanities, social science, business, etc. This knowledge combined with team work, problem solving skills and the ability to design are the building blocks for a professional engineer. The second approach is to provide a detailed list of knowledge areas and topics in the technical context of the profession.

Hence, when building a body of knowledge there are two major decisions that have to be made. The first is to define the scope of the profession and the necessary knowledge base to support that scope. The second decision to be made is to select the level of details of the body of knowledge.

Our approach to defining the scope of the profession was to adopt most of the FIG definition of the role of the professional surveyor [FIG 2004] (except valuation that in the US is a separately licensed profession). Our approach to the level of details in describing the surveying body of knowledge was to have a macro level body of knowledge and a micro level body of knowledge.

The macro-level body of knowledge for surveying was described in details in [Greenfeld and Potts, 2008]. It can be summarized as:

- A technical core of knowledge and breadth of coverage in mathematics, statistics, computer science and general science (e.g. physics). This knowledge is the foundation for a subsequent application of these principles to compute and analyze positioning, and understand the tools that are being used.
- A broad knowledge of law, ethics and professionalism. At the macro level this does not imply boundary law. It implies general knowledge of the law, the legal system, what is ethics and what constitutes professionalism.
- Communication, history, social science and contemporary issues. As the world around us changes the need for spatial information is broadened to address new needs. In addition, the context in which it is being used changes as well. Finally, to become a successful professional it becomes increasingly important to be able to communicate in writing and in person.
- Business, economics, management. Many surveyors run their own company or manage surveying departments in the private and public sectors. Contemporary surveyors should be able to manage projects, contracts, people, budgets, schedules, finance, marketing and sales, billable time, overhead, profits, etc.

The micro level surveying body of knowledge and the rationale for its content was described in [Greenfeld, 2010]. Based on the FIG definition of the role of the professional surveyor, the ACSM surveying body of knowledge came up with five body of knowledge subsets. Each subset describes a specialty within the surveying profession. The five subsets of the surveying body of knowledge are:

- Positioning body of knowledge – including Geodesy, GPS and other field surveying data collection
- GIS body of knowledge – including mapping and cartography

- Imagery body of knowledge – including photogrammetry, remote sensing and other image/sensor based technologies such as laser scanners
- Law body of knowledge – including boundary, real property and business law
- Land development body of knowledge – including construction, planning and developing and urban/rural/regional areas

Figure 1 shows the entire surveying body of knowledge. In the next section the knowledge areas and specific topics included in each knowledge area are described.

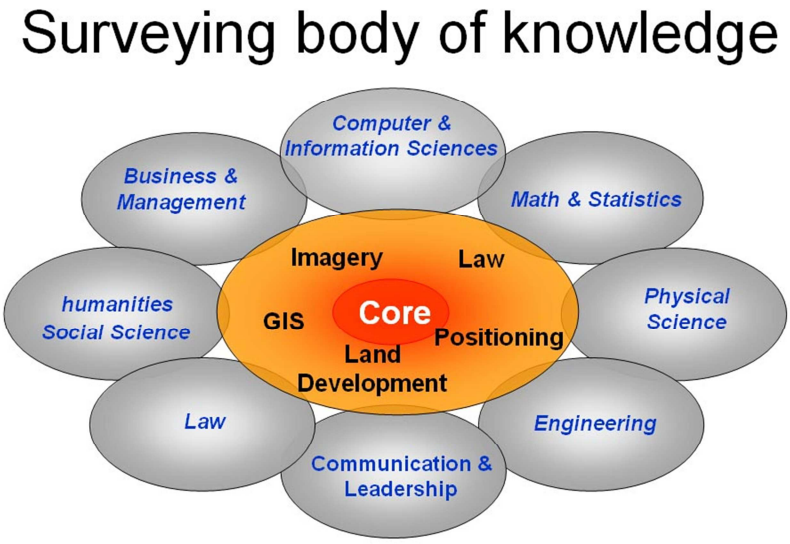

Figure 1. The surveying body of knowledge

The detailed content of the micro level surveying body of knowledge

As mentioned earlier, five micro-level subsets of the surveying body of knowledge have been identified. Each of these subset bodies of knowledge was broken down into knowledge areas and topics that describe the elements of each knowledge area. The following is a summary of the knowledge areas and topics in each of the five surveying body of knowledge subsets.

The positioning - surveying body of knowledge

Knowledge area	Topics
Measurements	• Situational Analysis • Technology and Measurement Regimen Selection • Systematic Error Analysis • Application of Mathematical Models for Data and Information Representation • Designing or Applying Survey Control • Field Survey

Knowledge area	Topics
Data Analysis and Management	• Examine Data for Completeness • Post-processing for Systematic and Random Error Reduction and Evaluation • Analyze Data for Precision; Draw Conclusions About Accuracy • Determine If Additional Measurements Are Required • Integrate Data From Various Sensors Into a Homogenous Database
Adjustments	• Apply different Adjustment procedures for data processing • Apply Statistical and Adjustment Tools to Improve Quality of Information Being Reported • Calculate Integrity of Networks and Other Geometries • Apply Principles of Geodesy
Coordinate Geometry	• Apply 2-D and 3-D transformations • Determine projected coordinates • Determine geodetic coordinates • Determine positions of surveyed points • Determine position or configuration of designed points, lines, surfaces and volumes • Determine areas and volumes
Information Extraction	• Report positions, lines, surfaces and volumes • Report conclusions, deductions and inductions • Create maps and reports that are project and "consumer-specific" • Use CAD/GIS to generate user products

The GIS - surveying body of knowledge

Knowledge Area	Topics
Conceptual Foundations	• Philosophical and social Perspective • Domains of geographic information • Elements of geographic, information • Geospatial Relationships • Imperfections in Geographic information • The Origin/History of GIS
Data Modeling	• Basic Storage and retrieval structure • Database management systems • Tessellation data models (e.g. raster data model) • Vector and object data models • Three-D, Temporal and uncertain Phenomena data models

Knowledge Area	Topics
Design Aspects	• The scope of GIS system design • Project definition • Resource planning • Database design • Analysis design • Application design • System implementation
Geospatial Data	• Earth Geometry • Georeferencing systems • Datums • Map projections • Land partitioning systems • Data quality • Spatial data compilation • Field data collection • Metadata, standards and infrastructure
Data Manipulation	• Representation transformation • Generalization and aggregation • Change management of geospatial data
Analytical Methods	• Query operations and query languages • Geometric measures • Basic analytical operations • Basic Analytical Methods • Analysis of surfaces • Spatial statistics • Geostatistics • Geocomputation • Data mining • Network Analysis
Cartography and Visualization	• Data considerations • Principles of map design • Graphic representation techniques • Map production • Map use and analysis • Map evaluation
Legal and Ethical aspects of GIS	• Legal aspects • Geospatial information as property • Dissemination of geospatial information • Ethical aspects of geospatial information and technology • Critical thinking about GIS

Knowledge Area	Topics
Management and Organization Aspects	• Managing aspects • Economic aspects • Organizational structures and Procedures • GIS workforce • Institutional and inter-institutional aspects • Coordinating organizations (national and international)

The Imagery - surveying body of knowledge

Knowledge Area	Topics
Cameras and Photography	• Metric versus non-metric cameras • Calibration • Camera geometry and characteristics • Resolution spatial, spectral, radiometric, temporal • Spatial resolution modulation transfer function
Radiometry, Detection, and Sensing	• Optics • Aperture, shutter, reciprocity, sensitometry • Image motion compensation: • Film, electronic detectors: • Radiometry, EM spectrum, solar illumination, atmosphere, surface reflectance: • Signal versus noise
Frame Geometry	• Perspective geometry, pinhole camera, camera obscura • Graphical solutions using perspective • Cross ratio • Scale, field of view • Relief displacement • Interior, exterior orientation • Tilt displacement
Image Measurements	• Reference coordinate system • Measurement units • Systematic errors and correction • Random measurement errors • Gross measurement errors
Stereoscopy and Parallax	• Depth perception and parallax • X versus Y parallax • Base – height ratio: • Vertical exaggeration: • Stereoscopes and environments for stereo perception

Knowledge Area	Topics
Mathematical Modeling and Analytical Photogrammetry	• Mathematical modeling of frame ray projectionscollinearity • Image pairscoplanarity: • Image tripletsscale restraint: • Object space coordinate systems, coordinate transformations: • Image resection • Space intersection: • Bundle block adjustmentsimultaneous resection and intersection • Self-calibration: • Relative and absolute orientation: • Independent models • Strip formation and adjustment by polynomials • Linear feature modeling: • Platform and trajectory modeling: • Auxiliary sensors and measurements, image support data and metadata
Computer Vision	• Homogeneous coordinates: • Fundamental and essential matrices: • Eight point algorithm: • Visualization, synthetic image generation, OpenGL • High level feature extraction
Estimation, Adjustment, Statistics, and Error Propagation	• Measurements and errors • Objective functions and adjustment • Functional and stochastic models: • Observations only: • Indirect observations (variation of parameters): • Mixed model, general least squares • Constraints: • Hypothesis testing, error propagation, confidence regions • Unified least squares • Sequential estimation and kalman filter • Robust estimation: • L1 norm minimization:
Stereo Restitution	• Stereoscopes with parallax bar: • Instruments with optical projection: • Instruments with mechanical projection • Analog techniques for orientation • Analytical projection • Digital stereo workstation: • Pairwise rectification

Knowledge Area	Topics
Rectification and Resampling	• Interpolation and aggregation: • Nyquist sampling theorem and aliasing: • Simple rectification (tilt correction only): • Ortho rectification (tilt and terrain correction) • True ortho rectification (tilt, terrain, and building correction)
Mapping and Cartography	• Enlargement factor versus contrast and spatial resolution: • Map projections and reference coordinate systems: • National map series: • Urban and project oriented mapping: • Software environments: • Topology, data structures, attributes, queries
Topography and Digital Elevation Modeling	• Grid/raster collection: • Unstructured point collection • TIN processing: • Breakline processing • Direct contour collection and contour interpolation • Profile and cross section interpolation, road design
Signal Processing and Digital Image Processing	• Linear systems • Impulse response and convolution • Spatial versus frequency domain, Fourier transform: • Correlation, and relation to convolution • Sampling and reconstruction • Primitive feature extraction, edges, interest points • Histogram transformations
Digital Photogrammetry	• Epipolar resampling, image normalization • Signal matching, feature matching, cross correlation, LS matching • Constrained matching, VLL • Scene reconstruction, DSM generation
Project Planning	• Requirements for accuracy and completeness • Control point requirements • GPS/INS supported imaging • Flightline layout
Close-Range Photogrammetry	• Use of non-metric cameras • Self calibration, zoom optics • Fixed baseline setup
Structured Illumination	• Texture projection for close-range applications: • Correspondence coding, conjugate determination without matching

Knowledge Area	Topics
Satellite Photogrammetry	• Orbit mechanics: • Quasi-inertial versus earth fixed coordinate systems and transformations • Time systems: • Telescope optics • Physical projection models • Replacement mathematical models, • Ephemeris and support data
Unmanned Aerial Vehicles, UAVs	• Opportunities and current restrictions: • Manual control versus autonomous operation
Remote Sensing	• Multispectral remote sensing • Hyperspectral remote sensing • Classification • Change detection
Active Sensing with Microwaves	• Real aperture, synthetic aperture RADAR imaging • Signal structure, image formation: • Strip mode, spotlight mode, scansar mode: • Interferometry • Bistatic RADAR imaging
Active Sensing with Visible/IRLIDAR	• Point cloud processing • Filtering, DSM to DEM • Feature extraction • Static versus mobile data acquisition • Quality issues
Applications	• Mapping • Resource inventory: • 3D object reconstruction • Industrial applications: • Medical applications • GIS database population

The Law - surveying body of knowledge

Knowledge Area	Topics
Legal Systems	• Legal Methods and Processes • Court Systems • Civil Procedure • Evidence and Procedures • Forms of Evidence ,Rules of Evidence

Knowledge Area	Topics
Legal Resources	• Legal Research • Courthouse Research • Statutory Law • Administrative Law • Judicial Decisions and Common Law • Executive orders
Law and Business	• Writing and Communication • Written, oral, physical communication skills • Contracts • Nature and types of contracts, elements of contracts, contractual obligations, "Limitation of Actions" statutes, breach of contract • Torts • Torts and remedies, negligence, standards of care • Copyright Law • Business Formation • Business entities, Agency and partnership relationships, Business formation • Business Management and Operation • Employer/employee relationships, Special site requirements, Record keeping, Electronic and digital records, Tax laws • Budgeting and Finance • Professionalism and Ethics • Liability • Professional liability, Limitations on liability, Standard of care, Certifications, Errors and omissions
Law and the Practice of Surveying	• The practice of surveying • Licensure laws, Standards of practice • Land Use and Land Management Law • Land use and land management law, Environmental law • Real Property Law • Estates, title, and interests in real property • Creation and termination of real property estates and interests • Deeds and descriptions • Conveying real property estates and interests • Notice • Easement law • Boundary law • Disputes between adjoining interest holders • Water law • Expert Witness Testimony and Reports

The Land Development - surveying body of knowledge

Knowledge Area	Topics
Communication skills	• Analytical skills • Situational analysis, Logic, Objective • Oral expressive skills • Clarity of expression, Command of language, Physical presentation, Ability to adapt explanations • Writing skills • Clarity of expression, Command of language, Presentation skills • Soft or "People" skills • Listening skills, Negotiation skills, Engage in reasoned debate
Site design and resource management	• Development design, patterns, and principles • Identify existing balance of human and environmental factors • Evaluate present and future general site context, physical relationship between site and adjacent land, human cultural data, and environmental data • Familiarity with existing and evolving development patterns • Incorporation of sustainability principles into site design and development • Land use development and management programs • Identification of a given site's resources • Familiarity with concept of sustainability • Familiarity with different approaches to preserve various resources during site development • Immediate and cumulative effects of site design • Immediate and cumulative impacts of development on humans and nature • Interdependence of humans and the natural world • Limitations of design • Legal requirements for site development • Federal laws and regulations affecting site development • State laws and regulations affecting site development • Local ordinances affecting site development • Interrelationship of legal requirements

Knowledge Area	Topics
Site constraints	• Assess site suitability for a given plan or design • Familiarity with the concept of natural and societal resources • Ability to identify and objectively evaluate a specific site's resources • Ability to match site resources, including location, to an appropriate design • Recognition of legal guidelines and restrictions • Balancing legal and natural land use restrictions • Identification of potential specific impacts (positive and negative) from proposed development • Ability to evaluate changes in natural values and human values (positive and negative) resulting from development, in relation both to the site and to the larger community
Project administration, management, and organization	• Project administration • Contractual responsibilities • Legal responsibilities • Professional responsibilities • Project management and supervision • Estimation of time, staffing, equipment, and materials needed • Project phasing and scheduling • Time management • Staff supervision • Project management (technology and procedures) • Principles of measurement, imaging, positioning • Assessment of a project's technical needs • Assessment of project's procedural requirements, including timing • Identification of strengths and weaknesses of various technical approaches in seeking the most appropriate one or combination • Assessment of staffing abilities and needs

There is no single professional who can master this vast knowledge base. On the other hand, it is recognized that different professional surveyors specialize or perform research in different parts of what constitutes surveying. Regardless of their specific expertise, all of them are considered to be professional surveyors. This is just like cardiologists and pediatricians who practice very different specialties but both are medical professionals and their professional endeavors are rooted in a common medical knowledge base. Realizing this factor, the committee established three levels of knowledge that surveying should have. The first knowledge tier is a core knowledge that everyone who is a professional surveyor must have regardless of a particular specialization. The second tier of knowledge is an expert or specialist knowledge level for those specializing in a particular aspect of surveying. The rationale is that a boundary surveyor has to know less about imaging than a photogrammetrist and vice versa. The highest and most specialized tier is the one we called scholar/R&D

knowledge level. It is our belief that surveyors should not only adopt new innovations but also become involved in creating them. More details on this knowledge classification can be found in [Greenfeld, 2010].

Summary and conclusions

A profession is founded on knowledge, skills and education. A profession has to be defined clearly so that the public is aware of what it does, what it has to offer and recognizes its pivotal role in society. Once the role of a profession is defined it is very important to identify the required knowledge base that will enable the practicing professional to perform effectively and professionally. This knowledge base constitutes the body of knowledge of the profession.

The body of knowledge for a given profession can be developed on a macro level or on a micro level or both. Developing both levels of body of knowledge has the advantage of defining not only the contemporary needs of the profession but also the long range, technology-independent, lifelong ability to practice competently. In this paper we describe the approach used, and the detailed content of the surveying body of knowledge. This paper described the development process, the structure, the five areas of specialty, the knowledge areas in each specialty and topics associated with each knowledge area. One of the main objectives of the paper is to stimulate discussion on this important task and use it as an inaugural effort to develop an FIG endorsed surveying body of knowledge.

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