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Main points

- I have 25 years of industrial experience in design and development of systems for analyzing and extracting geospatial information at scale from remote sensing and other data sources.
- I hold a PhD in mathematics, and a Master's degree in applied statistics.
- As the principal data scientist at Johnston Consulting Services (founded in December 2019), I have solved business problems for clients in the areas of feature extraction from imagery using DL/AI, HDmap production for autonomous vehicle applications, and geospatial modeling.
- I develop software solutions in Python (specifically in Tensorflow, Scikit-learn, and the Python geospatial libraries), Postgres/PostGIS, and R.
- During the period 2000-2020, I led R&D technical staff developing new technologies. While at Intermap Technologies, I led a small R&D group working on elevation data adjustment and feature extraction using convolutional neural nets, and developed a novel statistical method for data watermarking. During my time at HERE Technologies, I led R&D teams developing technologies for large-scale HD mapping for autonomous vehicles. Data sources included vehicle sensor data and satellite, aerial, and ground-level image sources. These included mapping of road features such as signs, poles, and road markings; mapping of vehicle drive paths and other virtual features such as stopping lines; and vehicle localization technologies. Prior to that, I led technical teams doing R&D at DigitalGlobe, Microsoft, and Vexcel Corporation.
- I have a track record of building successful, productive R&D teams.
- I have more than 10 US patents in this industry completed and pending, and have published peer-reviewed journal articles in mathematics and applications to engineering.

Experience

Founder and Principal Consultant (November 2019-present)
Johnston Consulting Services LLC, Lafayette, CO

In November 2019, I founded my geospatial data science consulting business, Johnston Consulting Services, LLC.

Since then, I have worked on multiple problems for clients, including:

- Working with clients' software development staff to implement deep learning/computer vision approaches for feature extraction from spatial imagery
- Automating the extraction of topological attributes from HDMap features
- Developing a novel statistical watermarking method for remote sensing imagery and products

JCS LLC offers technical, strategic, and management consulting in geospatial data science. Services include:

- Developing novel machine learning and modeling approaches and algorithms for spatial data science problems
- Support on related technical issues (such as software development, data labeling, accuracy measurement, production scaling)
- Bringing non-specialist technical staff up to speed on AI/ML and the geospatial technology stack

Chief Scientist (June 2020-December 2020)
Intermap Technologies Corporation, Englewood, CO

In June 2020, I was recruited to a Chief Scientist role at Intermap Technologies, a small company specializing in the custom collection and production of high-resolution elevation data from interferometric SAR and other data sources.

Projects I led during this time include:

- Development and proposal (for federal funding) of a novel geospatial epidemiological model for COVID-19 spread.
- Development and testing of a convolutional neural network regression method for updating digital elevation models using newer imagery
- Patenting a new method for systematic correction of digital elevation models using foliage penetrating radar.

Although my time at Intermap was intensely technically productive and rewarding, I decided to return to full-time consulting at JCS LLC in December 2020.

Director of Engineering (January 2018-November 2019)
HERE Technologies, Boulder, CO

In December 2017, I was asked to take the director and site lead position for the new Boulder R&D office, which was to be officially opened in January 2018.

In this role, I led several teams of researchers and software engineers developing technology for localizing autonomous vehicles, detecting changes in the driven environment, and turning millions of records of vehicle sensor observations into highly accurate map features. We turned prototype algorithms into easily deployed, cloud-based systems for detecting corruption in vehicle sensor observations, localizing vehicles in the road environment, aggregating road object observations into features with improved absolute and relative accuracy, and detecting differences between the map and the perceived environment. The first systems were deployed at scale in production at HERE in 2019, following the first availability of large quantities of vehicle sensor data for analysis.

I was also responsible for engineering proof of concept projects, working with several customer automotive OEMs and other partners to evaluate and improve their vehicle sensor data for use in mapping applications. For this purpose, we created a specification for a standard format for provision of vehicle sensor data, called "HERE Maplets", based on SENSORIS, a standard widely adopted by automotive OEMs for data transmission.

Principal Engineer (November 2016-December 2017)
HERE Technologies, Boulder, CO

In my first year at HERE, I built and led a team of 6 researchers and software engineers working on a cloud-based, automated system for aggregating road network features (e.g., road boundaries, lane lines, signs, drive paths, and stopping points) from vehicle sensor data for the purposes of HD mapping for autonomous vehicles. I designed an algorithm for aggregating multiple drive path observations into a single optimized drive path, and designed a method for combining drive paths and physical features into a common graph for optimization, which was necessary to keep the lane network topology consistent.

Patent: "Generation and update of a lane network graph model", issued September 9th, 2019. https://patents.google.com/patent/US20190285421A1.

Senior Manager (May 2014-December 2016)
DigitalGlobe, Westminster, CO

I was recruited internally to this position, to lead a team of researchers and analysts developing cutting-edge information products extracted from satellite imagery. The team's projects included development of a prototype to detect man-made changes in DigitalGlobe high resolution EO satellite imagery, and of an interactive land-use-landcover extraction application based on Random Forest Machine Learning, utilizing DigitalGlobe's extensive archives.

Under my technical leadership, the team developed a cloud-based system for extracting the locations and populations of remote villages from multispectral satellite imagery with high accuracy. The system was used to map villages in more than 1 million sq. km. of remote terrain in Afghanistan, Somalia, and the Congo, for a major global development organization that needed population maps for its global immunization effort.

Paper: "Mapping Human Settlements and Population at Country Scale from VHR images", https://carolynpjohnston.files.wordpress.com/2016/10/mappinghumansettlementsandpopatcountryscale_finaldraft.pdf (to appear, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 2016).

I left DigitalGlobe in November, 2016, to take on an R&D leadership role at HERE Technologies.

Principal Scientist (Sept 2010 – April 2014)
DigitalGlobe, Longmont, CO

I was recruited by DigitalGlobe to lead a team to design, develop, and benchmark a scalable, fully automated system for synthesizing continent-scale geodetic networks of GCPs from redundant point observations in satellite imagery. I built a team of engineers and analysts, developed a research and development plan, instituted appropriate software development practices, and wrote a specialized bundle adjustment algorithm in C++ that correctly applied correlated networks of GCPs as prior information.

My team built a cloud-based system that can construct GCPs at continent scale, with 2m accuracy, from DigitalGlobe imagery. These GCP networks can be used to accurately position satellite and aerial imagery

in parts of the world, such as China, that are inaccessible by standard surveying methods. This system became the basis of DigitalGlobe/Maxar's Bundle Block Adjustment system for satellite image registration in the cloud.

Conference Paper: "An Automated HPC Implementation of the Metric Information Network (MIN)" https://carolynpjohnston.files.wordpress.com/2016/02/johnston.pdf

Patent: "Automated Metric Information Network" issued February 2nd, 2016. http://www.google.com/patents/US20140219514.

Lead Researcher, MSN Advanced Engineering and Bing Mobile/Bing Maps (2007-2010)
Microsoft, Redmond, WA

I was recruited from the Microsoft office in Boulder to work in machine learning problems on the Bing Mobile/Maps group in Redmond, improving their local search capabilities.

For example, Local Search had a problem with disambiguating business names so that they could be matched across different vendor databases, some of which had already miscategorized them. I invented a method that was both robust to common misspellings, and correctly handled business type ambiguities. This method worked better than any of the alternatives, and was adopted by Local Search and patented by Microsoft (US8352496 "Entity Name Matching", issued January 8th, 2013. Assigned to Microsoft).

On another occasion, Microsoft's MSN team needed a technology that would identify which articles had related topics. I devised a new method for measuring the difference between article topics, and demonstrated the power of the technology as part of a kernel SVM classifier for classifying articles. The technology was adopted by MSN for backing its "Find more articles like this" hyperlinks, and was later added to Bing Local Search as well (US2012007891 1, "Text Classification using Concept Kernel". Assigned to Microsoft).

In 2009, I was part of the Bing Local Search R&D team that built a browser-based application called "Local Lens". Local Lens was a map-based browser application displaying location references – businesses, landmarks, intersections, and addresses -- extracted from hyperlocal weblog posts, using machine learning methods for entity extraction.

I was recruited in 2010 by DigitalGlobe to work on a project for developing GCP networks from archive satellite imagery, and was happy to return to Colorado.

Program Manager, Virtual Earth (2006-2007)
Microsoft, Boulder, CO

In 2006, Vexcel was acquired by Microsoft Corporation for its photogrammetry expertise, to help develop its 3D Virtual Earth browser-based application. I was involved in planning collections for imagery for one of the first Streetside viewing applications, and was responsible for developing an early specification of the sensor systems that would be mounted on the collection vehicles. I successfully contended that a LIDAR sensor should be added to the specification, since the problem of finding building edges had proven difficult to solve with photogrammetry alone. LIDAR sensors have since become standard in data capture systems for automated mapping.

I took an opportunity to move to Redmond, WA, to be part of the larger Microsoft effort to build out its mapping and local search offerings.

Director of Software Application Development (2005-2006)
Vexcel Corporation, Boulder, CO

In my last year at Vexcel, I was the director of a team working on software product development. We worked on a polarimetric SAR image analysis toolkit for NASA, and a SAR ship detection system for the University of Miami. In 2006, Vexcel Corporation was sold to Microsoft, and as software development director, I managed the legal and technical aspects of Vexcel's source code transition during the sale.

Senior Research Engineer (1996-2006)
Vexcel Corporation, Boulder, CO

In my first industry position after leaving academia, I proposed, managed, and worked on many different research programs involving mathematical algorithm development. My work during this period involved information extraction from remote sensing imagery, particularly Synthetic Aperture Radar satellite imagery.

I managed the algorithm development work when Vexcel, subcontracting to BAE Systems, built a production system for contractors to NIMA (now the National Geospatial Intelligence Agency) to process and quality-control SRTM DEM data at scale (https://en.wikipedia.org/wiki/Shuttle_Radar_Topography_Mission). The algorithms involved finding and delineating all water bodies meeting certain criteria, finding their elevations, appropriately stepping down the levels of rivers, and ensuring that the water bodies and rivers remained consistent as they passed across the borders of tiles. The system itself was built out over the course of a year, and the finishing work was done in the following two years. This data became the well-known SRTM dataset that has been the world's most-used free source of DEM data for orthorectification since the early 2000s.

Other projects I worked on at Vexcel included consulting with TRW on building digital elevation models from interferometric SAR for the Discoverer II program (https://en.wikipedia.org/wiki/Discoverer_II).

Slater, J., Garvey, G., Johnston, C., Haase, J., et al. The SRTM Data Finishing Process and Products. Photogrammetric Engineering and Remote Sensing, V. 72, No. 3, March 2006. 237-247.

Assistant/Associate Professor, Dept. of Mathematics (1991-1995)
Florida Atlantic University, Boca Raton, FL

As an assistant and associate professor of mathematics, I taught classes in the mathematics department, with an emphasis on probability/statistics, linear algebra, calculus, and real analysis.

I also conducted research in wavelet theory and representation theory. In 1995, I was the winner of a prestigious NSF Career award for young mathematicians, titled: "Wavelets, Frames, and Discrete Group Representations". This award was for continued basic research into discrete group representations, and for development of a program and curriculum for educating young mathematicians to be strong contributors in the technology industry.

In late 1995, wanting to get even deeper into applications of mathematics and statistics, I left academia to pursue technology applications in satellite imaging at Vexcel Corporation, which by then I found much more interesting than pure mathematics research. My interest in wavelets made remote sensing image processing a natural fit.

Education

M.S., Applied Statistics, Colorado State University, 2020.
Ph.D., Mathematics, Louisiana State University, 1990.
M.A., Mathematics, Binghamton University, 1986.
B.A., Mathematics, Binghamton University, 1984.

Patents

9 patents at HERE Technologies for mapping standards, as listed below, with common application date 13 March, 2019. Inventors: Dietmar Rabel, Robert Ledner, Carolyn Johnston, Jan Van Sickle, Timm Kayser, Eric Dieckman.

Patent Application Number: 16/352337
Title: Maplet construction markers data format

Patent Application Number: 16/352327
Title: Maplet lane markings data format

Patent Application Number: 16/352317
Title: Maplet pavement edge data format

Patent Application Number: 16/352301
Title: Maplet pole like objects data format

Patent Application Number: 16/352286
Title: Maplet road surface markings data format

Patent Application Number: 16/352254
Title: Maplet roadside barrier data format

Patent Application Number: 16/352278
Title: Maplet sign faces data format

Patent Application Number: 16/352265
Title: Maplet traffic signals data format

Patent Application Number: 16/352225
Title: Maplets overview

Generation and update of a lane network graph model. US2019028542A1 Filed 2018-03-19. HERE Technologies.

Text Classification Using Concept Kernel. US8924391B2 filed 2010-09-28. Microsoft.

Business data display and position correction in street-side imagery. US9020745B2 filed 2009-03-30. Microsoft.

Entity name matching. US8352496B2 filed 2010-10-26. Microsoft.

Automated metric information network. US9251419B2. Filed 2013-02-07. DigitalGlobe.

Predicting whether strings identify a same subject. US8484148B2 Filed 2009-05-28. Microsoft.

Graphical method for data validation. US8073809B2 Filed 2008-10-02. Microsoft.

Publications

(Note: some publications were authored under the name Carolyn Pfeffer).

Gueguen, L., Koenig, J., Reeder, C., Barksdale, T., Saints, J., Stamatiou, K., Collins, J., and Johnston, C., Mapping Human Settlements and Population at Country Scale from VHR Images. IEEE Journal of Selected Topics in Applied Earth Observation and Remote Sensing, Volume 10, Issue 2, Feb. 2017.

Johnston, C., Bleiler, C., et. al., An automated HPC implementation of the Metric Information Network (MIN). ASPRS Conference Proceedings, 2013.

Slater, J., Garvey, G., Johnston, C., Haase, J., et al. The SRTM Data Finishing Process and Products. Photogrammetric Engineering and Remote Sensing, V. 72, No. 3, March 2006. 237-247.

Rogers, L., Johnston, C. Land use classification of SAR images using a type II local discriminant basis for preprocessing. Proceedings of the 1998 IEEE International Conference on Acoustics, Speech and Signal Processing, 1998. Volume 5, Issue , 12-15 May 1998. 2729–2732.
Johnston, C. On the pseudodilation representations of Flornes, Grossman, Holschneider, and Torresani. Journal of Fourier Analysis and Applications, V.3, No. 4, 1997. 377-385.

Andric, O., Johnston, C., Erdol, N. Wavelets in polar coordinates. Acoustics, Speech, and Signal Processing, 1996. ICASSP-96. Conference Proceedings. Volume 3, Issue , 7-10 May 1996. 1507 – 1510.

Pfeffer, C., Corwin, L.. On the density of sets in $(A/Q)^n$ defined by polynomials. Colloquium Mathematicum, V. 68, 1995. 1-5.

Johnston, C. P., Primitive Ideal Spaces of Discrete Rational Nilpotent Groups. American J. Math., V 117, No. 2, 1995. 323-335.

Corwin, L., Johnston, C. P.. On factor representations of discrete rational nilpotent groups and the Plancherel formula. Pacific J. Math., V 162, No 2., 1994. 261-275.

Johnston, C.P., On unitary representations of some discrete rational nilpotent groups. In "Representation Theory and Analysis on Homogeneous Spaces: A Conference in Memory of Larry Corwin, February 5-7, 1993, Rutgers University". American Mathematical Society, 1994. 47-57.

Pfeffer, C. Fejer theorems on compact solvmanifolds. Illinois J. Mathematics, V. 38, No. 1., 1994. 79-86.

Pfeffer, C. Primary Summand functions on three-dimensional compact solvmanifolds. Proceedings of the American Mathematical Society, Vol 116, No 1 (September 1992).

Externally Funded Research Projects

Multi-sensor Terrain Fusion, Navy Phase 1 SBIR, 2003-2005.

Automated Fusion of Digital Elevation Models, Army Phase 2 SBIR, 2003-2005.

TruthTags: Automatic image markup for SAR. Air Force Phase 2 SBIR, 2003-2005.

Truth Quest: Enabling Operational/Exercise Data, Air Force Phase 1 SBIR, 2003.

DTED compression guided by preservation of quality statistics, Navy Phase 1 SBIR, 2000.

An efficient Object-oriented System for Extracting Terrain Features from Contour Maps, Army Phase 1 SBIR, 1998.

Java Data Analysis, Visualization, and 3D Coregistration. Dept. Health and Human Services Phase 1 SBIR, 1998.

A feature extraction and classification toolbox for remote sensing data analysis, Navy Phase 1 SBIR, 1997.

Wavelets, Frames, and Discrete Group Representations. National Science Foundation Career Award, 1995.

Representations of Discrete Rational Nilpotent Groups. National Science Foundation Award, 1992.