CURRICULUM VITAE

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SPECIALIZATION

Information security and assurance, digital media forensics, steganography, steganalysis, and watermarking, signal detection and estimation

EDUCATION

May 1995 **Ph.D.** in **Systems Science**
Department of Systems Science, State University of New York at Binghamton
Honors: Distinguished Dissertation Award, Binghamton University

May 1987 **Dipl.-Ing.** (equivalent to **M.Sc.**) in **Applied Mathematics**
School of Nuclear Science and Physical Engineering, Czech Technical University
Honors: Award by Czech Dept. of Education for Academic Excellence (GPA 4.00)

PROFESSIONAL RESEARCH EXPERIENCE

Distinguished Professor at SUNY Binghamton, Dept. of ECE	2015 – present
Professor with tenure at SUNY Binghamton, Dept. of ECE	2007 – 2015
Associate Professor at SUNY Binghamton, Dept. of ECE	2005 – 2007
Research Professor at SUNY Binghamton, Dept. of ECE	1999 – 2004
Research Scientist at SUNY Binghamton, Dept. of SSIE	1995 – 1999
Senior Engineer/Scientist at Mission Research Corporation	1996 – 1999

During the time span of 20 years after my Ph.D. graduation, my research focused on various topics in data embedding for security, authentication, watermarking, covert communication, steganalysis, digital forensic, encryption of digital images, and advanced image processing. The main achievements range from rather practical contributions that are currently being used in practice by law enforcement agencies as well as fundamental theoretical contributions.

Digital forensic of imaging sensors
Developed a new method for identification of imaging sensors (cameras) from their images (digital "bullet scratches"). The pixel-to-pixel non-uniformity (the pattern noise) caused by the manufacturing process casts a unique low-amplitude pattern on every image the camera takes. This unique fingerprint can be detected using advanced signal processing methods in a manner similar to detection of a spread spectrum watermark. Reliable identification is possible even from processed images and the fingerprint survives digital–analogue conversion (printing). It is also possible to distinguish between cameras of exactly the same model. The methodology works for CCDs as well as CMOS sensors, for digital still cameras, video-cameras, and scanners. Academic advancements are continuously being delivered to the US Air Force for further testing, implementation by PAR Inc., and operational use by FBI (*smooth and fast technology transfer*). This technology is covered by US Patents 7,616,237 and 8,160,293. FBI uses this technology to prosecute child pornographers. This forensic method has passed the Daubert Challenge in the State of Alabama in 2010.

This method can also be used for detection of manipulated images (digital forgeries) based on detecting the sensor pattern noise in individual segments. It was recently featured in a Hollywood movie “Beyond the Reasonable Doubt” by Peter Hyams (2010) starring Michael Douglas.

Fundamental scaling laws in steganography
In collaboration with my student Tomáš Filler and Prof. Andrew Ker, Oxford University, proved the fundamental Square-Root Law of secure payload in steganography, which is an important new result pertaining to the size of payload that can be securely embedded in digital media. The result essentially says that the secure payload for any steganographic method that hides messages in digital media files scales only with the square root of the cover size (e.g., the number of pixels). This important law has been unknowingly observed in steganalysis prior to its discovery and formal proof when researchers noticed that it was easier to detect the same relative payload in larger images. The law also points to a new quantity called the “root rate” as the appropriate measure of secure payload, rather than the rate. This result triggered significant subsequent research in steganographic capacity with model mismatch.

Steganalysis of digital images
In 2011, Binghamton University team called “The Hugobreakers” won the international competition BOSS (Break Our Steganographic System). In the process, two fundamental new contributions to the field of Steganalysis were made – the introduction of high-dimensional (rich) models for digital media and a novel machine learning approach specifically designed to address the problem of detecting modern steganographic systems using high-dimensional features.

Developed the first reliable and very accurate structural steganalysis technique for LSB embedding in images (the RS steganalysis). This work revolutionized the field of steganalysis and initiated an avalanche of papers by peers. It was also the first technique that enabled accurate estimation of the secret message length. Technique covered by US Patent 6,831,991.

Introduced the novel concept of calibration for Steganalysis of JPEG images. Calibration pertains to an estimation of macroscopic statistical quantities of the cover image from the stego image by decompressing, subjecting to a geometrical transformation (e.g., cropping), and recompressing using the same quality factor. The methodology is general enough to apply to other JPEG steganography methods. It also forms the backbone of the blind classifier mentioned in the paragraph above.

Steganography of digital media
With my graduate student Tomáš Filler, introduced a new approach to building steganography schemes for digital media, which quickly became a mainstream, highly developed field. By doing so, discovered links between steganography and source coding with a fidelity constraint and statistical physics. This approach enabled separating the embedding algorithm and the associated coding and allowed establishing theoretical bounds and evaluate the optimality of practical embedding algorithms with respect to those bounds. Practical embedding methods can be built using the novel concept of syndrome-trellis codes, which operate close to the bound. Syndrome trellis codes are at the heart of all state-of-the-art steganographic techniques today.

Watermarking and information assurance
Introduced a new concept of lossless data embedding in digital images in which the distortion due to data embedding can be completely removed after data extraction. All image formats have been addressed, including the video MPEG-2 format. This new paradigm for data embedding have triggered a number of papers later published by peers. US Patent 7,006,656.

Pioneered the concept of a visual hash function for robust extraction of bits from images. Such techniques provide an important and generic tool for oblivious watermarking of digital video-streams, watermarking for tamper detection, broadcast monitoring, and protecting against watermark-copy attacks.

Pioneered an innovative concept of self-embedding a digital image into itself as an active measure against malicious image manipulation. A self-embedded image can be repaired after malicious manipulation, such as feature adding/removing without accessing the original, non-tampered image.

Steganographic and watermarking software
Developed a software application SecureStego running under Windows. The software package contains implementations of selected watermarking, steganographic, steganalytic, and forensic techniques developed by myself and my graduate students since 1999. The unique capabilities of this product include a spectrum of steganographic methods for all image formats, lossless data embedding methods, authentication and self-embedding methods for digital images, tools for detection of information hidden in digital images (steganalysis), robust watermarking, and a number of other unique tools, including the visual hash, interactive 3D RGB histogram viewing, copy-move forgery detection, primary quantization table estimation from double compressed images, bit-plane showing tool, built-in Exif viewer, etc. The product supports drag-and-hide capability, right-click options, automatic execution of the hidden file, and a number of other simple image processing operations including format conversion, color quantization, dithering, zooming, palette analysis, etc. SecureStego contains technology covered by five US Patents. SecureStego code is used internally by US Air Force for internal applications.

Nonlinear Modeling, Chaotic dynamics
Created a nonlinear model for simulation of transient automobile emissions. Measured time series of emissions were analyzed for determinism using the time delay embedding technique. A deterministic nonlinear model for the emissions as a function of engine load, air/fuel ratio, and coolant temperature has been built and successfully used for making short-term emission predictions.

Developed a nonlinear model for cycle-to-cycle cylinder pressure variations. The time delay embedding technique was used to establish presence of determinism in the time series and a four-dimensional model has been built. The model provided an alternative to existing statistical methods enabling thus more effective control of the burning cycle.

Developed new algorithms for signal / noise separation and for detection of deterministic trends in signals based on nonlinear dynamics. It has been demonstrated that imprecise observations on chaotic systems can be made more accurate by post-processing the measured time series. A conceptual construction of an ultra sensitive chaotic measurement device has been proposed.

AWARDS, HONORS, and MEDIA

June	2017	Student Best Paper Award to Mehdi Boroumand at the prestigious ACM Information Hiding and Multimedia Security Workshop in Philadelphia. Peers ranked this paper the highest among all student submissions.
Apr	2015	IEEE Signal Processing Society Young Author Best Paper Award to my former PhD student T. Filler for paper that we co-authored in 2011 (award announced in December 2014, presented at IEEE ICASSP in April 2015)
June	2013	Student Best Paper Award to my PhD student, Vojtěch Holub, at the prestigious ACM Information Hiding and Multimedia Security Workshop in Montpelier, France. Peers ranked this paper the highest among all submissions.
Jan	2011	Winner of the "Break Our Steganographic System" (BOSS) challenge
Jan	2011	Best Paper Award, SPIE Electronic Imaging, Watermarking, Security, and Forensics of Digital Media
Mar	2010	IEEE Signal Processing Society Best Paper Award
Jan	2010	Best Paper Award, SPIE Electronic Imaging, Media Security and Forensics
Sep	2010	Forensic method for revealing digital forgeries using sensor noise featured in the movie "Beyond Reasonable Doubt" directed by Peter Hyams
Oct	2007	*SUNY* Chancellor's Award for Excellence in Scholarship and Creative Activities
June	2007	Research Foundation of SUNY Research and Scholarship Award
May	2002	Outstanding Inventor, SUNY Chancellor Award
2001 –	2006	Featured four times on local ABC, CBS, and NBC TV stations, on radio, and in newspaper (New York Times, Washington Post). The documents described research on anti-terrorist technologies of national interest, detection of hidden data in digital imagery, and digital forensics.
May	2006	Featured on national Fox News for work on detection of imaging sensors
May	1995	Winner of the Distinguished Dissertation Award, Binghamton University
Feb	1995	Graduate Student Award for Excellence in Research, Binghamton University
Sep	1994	Winner of the Dissertation Year Fellowship
May	1987	Award by Czech Department of Education for Academic Excellence (GPA 4.00)

RESEARCH GRANTS

During the period between December 1995 and present, I have been awarded 22 research grants funded by the US Air Force, AFOSR, NSF, and the industry in total value over $9.4 mil. I served as the Principal Investigator on all projects with the exception of three projects (with Polytechnic University, University of Minnesota, and MTL).

The projects are summarized in the table below.

Sponsoring agency	Project title and time span	Funds
	Total funding as of 6/15/16: $11,241,869	
	**New Generation of Image Processing History and manipulation Detection Techniques With Vectorized Context-Aware Descriptors,** sponsored by DARPA, May 18, 2016 – April 30, 2010.	$1,251,376
	**Steganography in Empirical Sources Using Acquisition Oracle,** sponsored by NSF, May 15, 2016 – April 30, 2019.	$575,885
	**Rich Cover Models for Steganalysis of Digital Media,** sponsored by AFOSR, April 1, 2012 – March 31, 2017	$1,854,808
	**Advanced Steganalysis Methods for Digital Images,** sponsored by AFOSR, March 1, 2009 – December 30, 2011	$588,565
	**Digital Image Forensics Using Systematic Artifacts of Imaging Sensors**, sponsored by NSF, September 1, 2008 – August 31, 2010	$300,000
	**Towards Statistically Undetectable Steganography,** sponsored by the Air Force Office of Scientific Research, January 1, 2008 – April 30, 2011.	$525,198
	**Advanced Steganographic and Digital Forensic Methods,** sponsored by the Air Force Office of Scientific Research, January 1, 2006 – November 30, 2008.	$600,000
	**Mathematical Foundations of Steganalysis**, sponsored by the US Air Force Research Laboratory, Rome, NY. March 26, 2004 – September 25, 2007.	$700,000
	New Generation Approach to Digital Security: Steganography, Steganalysis, and Authentication of Digital Data, sponsored by the US Air Force Research Laboratory, Rome, NY. May 15, 2002 – September 23, 2005.	$1,960,000
	Smart Digital Images - Embedding for Information, Protection, and Self-Repair sponsored by the US Air Force Research Laboratory, Rome, NY. March 26, 2000–September 30, 2002.	$350,000
	**Steganalysis of Digital Watermarking Techniques,** with Polytechnic University, New York, sponsored by the US Air Force Research Laboratory, Rome, NY. March 2001 – September 2002.	$60,000
	**Secure Oblivious Hiding, Authentication, Tamper Proofing, and Verification Techniques,** sponsored by the US Air Force Research Laboratory, Rome, NY. October 5, 1999 – October 4, 2000.	$100,000
	Techniques for Secure Image Processing, sponsored by the US Air Force Research Laboratory, Rome, NY. January 6, 1998 – May 31, 2000.	$153,000
	**Robust Image Authentication and Discovery (RIAD),** dual-use project with Eastman Kodak and the AFRL, sponsored by the US Air Force Research Laboratory, Rome, NY. August 18, 1999 – May 2001.	$30,000
	**Data Embedding in Imagery and Its Applications**, with University of Minnesota, sponsored by the US Air Force Research Laboratory, Rome, NY. June 3, 1998 – September 1, 2001.	$100,000
	**Secure Image Ciphering Based on Chaos**, sponsored by the US Air Force Research Laboratory, Rome, NY. January 1, 1996 – September 30, 1996.	$35,000
	Parallel Implementation of Chaos-Based Image Encryption Methods, sponsored by the US Air Force Research Laboratory, Rome, NY. October 1, 1996 – September 30, 1997.	$35,000
	Secure Image Management Using Watermarking Phase I of Army SBIR with Mission Research Corporation, Albuquerque, NM, sponsored by the US Air Force Research Laboratory, Rome, NY. December 15, 2000 – June 15, 2001.	$98,000
	**Innovative C4I Technologies (Secure Image Encryption and Hiding),** Phase I and II with MRC, sponsored by the US Air Force Research Laboratory, Rome, NY. May 14, 1997 – March 16, 2000 (served as PI + subcontract with SUNY Binghamton).	$750,000
	**Automated Multi-Level Security Digital Information Transfer Using Watermarking Technologies,** Phase I and II SBIR with MTL, sponsored by the US Air Force Research Laboratory, Rome, NY. April 2000 – February 2003 (consultant).	$750,000
	**Development of Novel Steganography Detection Capabilities for Digital Images** Phase I of NSF SBIR with Mission Research Corporation, Albuquerque, NM, sponsored by NSF. January 1, 2001–June 30, 2001.	$90,000
	**Lossless Data Embedding and Crypto-Transformations for Steganography,** sponsored by the Air Force Office of Scientific Research, December 15, 2000 – December 14, 2003.	$315,000
	Application of Low-dimensional Deterministic Signal Modeling to Analysis, Forecasting, and Noise Reduction of Automobile Emissions Industrial unrestricted research grant from Ford Motor Company, Detroit, January 1, 1997 – December 31, 1997.	$10,000
	**Reconstruction of Actual Automobile Engine Emissions Using Deterministic Chaos** Industrial unrestricted research grant from Ford Motor Company, Detroit, MI, April 1 – December 3, 1996.	$10,000

PUBLICATIONS

Books and book chapters

J. Fridrich, book chapter on Steganalysis, *Information Hiding*, S. Katzenbeisser and F. Petitcolas, Artech House.

J. Fridrich, *Steganography in Digital Media: Principles, Algorithms, and Applications*, Cambridge University Press, November 2009.

I. Cox, J. Bloom, M. Miller, J. Fridrich, T. Kalker, *Digital Watermarking and Steganography*, Morgan Kaufmann, November 2007.

J. Fridrich, book chapter "Sensor Defects in Digital Image Forensics" in *Digital Image Forensics: There is More to a Picture than Meets the Eye,* editors H.T. Sencar and N. Memon, Springer, May 2012. ISBN: 978-1-4614-0756-0.

J. Fridrich, book chapter on Steganalysis in W. Zeng, H. Yu, and C. Lin (Editors), *Multimedia Security Technologies for Digital Rights Management*. ISBN: 0123694760, Elsevier, June 2006.

J. Fridrich (editor), *Information Hiding*. *6th International Workshop*, *LNCS* vol. 3200, Springer-Verlag, Berlin-Heidelberg, New York, 2005.

Journal and fully refereed papers

1. M. Chen, M. Boroumand, and J. Fridrich, "Reference Channels for Steganalysis of Images with Convolutional Neural Networks", under review, IEEE TIFS, 2018.
2. M. Boroumand, Mo Chen, and J. Fridrich, "Deep Residual Network for Steganalysis of Digital Images", IEEE TIFS, 2018.
3. M. Boroumand and J. Fridrich, "Nonlinear Feature Normalization in Steganalysis," 5th *ACM IH&MMSec.*, Philadelphia, PA, June 20–22, 2017.
4. Mo Chen, V. Sedighi, M. Boroumand and J. Fridrich, "JPEG-Phase-Aware Convolutional Neural Network for Steganalysis of JPEG Images," 5th *ACM IH&MMSec.*, Philadelphia, PA, June 20–22, 2017.
5. M. Boroumand and J. Fridrich, "Applications of Explicit Non-Linear Feature Maps in Steganalysis," *IEEE TIFS*, **13**(4), pp. 823–833, April 2018.
6. T. Denemark and J. Fridrich, "Steganography with Multiple JPEG Images of the Same Scene," *IEEE TIFS* **12**(10), pp. 2308–2319, October 2017.
7. T. Denemark, M. Boroumand, and J. Fridrich, "Steganalysis Features for Content-Adaptive JPEG Steganography,"*IEEE TIFS* **11**(8), pp. 1736–1746, August 2016.
8. M. Boroumand and J. Fridrich, "Boosting Steganalysis with Explicit Feature Maps," 4th *ACM IH&MMSec.*, Vigo, Spain, June 20–22, 2016.
9. V. Sedighi, R. Cogranne, and J. Fridrich, "Content-Adaptive Steganography by Minimizing Statistical Detectability," *IEEE TIFS* **11**(2), pp. 221–234, February 2016.
10. R. Cogranne and J. Fridrich, "Modeling and Extending the Ensemble Classifier for Steganalysis of Digital Images Using Hypothesis Testing Theory," *IEEE TIFS* **10** (2), pp. 2627–2642, December 2015.
11. V. Sedighi and J. Fridrich, "Effect of Imprecise Knowledge of the Selection Channel on Steganalysis," 3rd *ACM IH&MMSec.*, Portland, Oregon, June 17–19, 2015.
12. T. Denemark and J. Fridrich, "Improving Steganographic Security by Synchronizing the Selection Channel," 3rd *ACM IH&MMSec.*, Portland, Oregon, June 17–19, 2015.
13. V. Holub and J. Fridrich, "Low Complexity Features for JPEG Steganalysis Using Undecimated DCT," *IEEE TIFS* **10**(2), February 2015, pp. 219–228.

14. V. Holub and J. Fridrich, “Universal Distortion Design for Steganography in an Arbitrary Domain,” *EURASIP Journal on Information Security*, Special Issue on Revised Selected Papers of ACM IH and MMS 2013, 2014:1.
15. V. Holub and J. Fridrich, “Random Projections of Residuals for Digital Image Steganalysis,” *IEEE TIFS* **8**(12), 2013, pp. 1996–2006.
16. J. Kodovský and J. Fridrich, “Effect of Image Downsampling on Steganographic Security,” *IEEE TIFS* **9**(5), February 2014, pp. 752–762.
17. A. D. Ker, P. Bas, R. Böhme, R. Cogranne, S. Craver, T. Filler, J. Fridrich, T. Pevný, Moving Steganography and Steganalysis from the Laboratory into the Real World, 1st *IH&MMSec.*, Montpellier, France, June 17−19, 2013.
18. V. Holub and J. Fridrich, “Digital Image Steganography Using Universal Distortion,” 1st *IH&MMSec.*, Montpellier, France, June 17−19, 2013.
19. J. Fridrich, “Effect of Cover Quantization on Steganographic Fisher Information,” *IEEE Trans. on Info. Forensics and Security* **8**(2), pp. 361–373, February 2013.
20. J. Fridrich and J. Kodovský, “Steganalysis of LSB Replacement Using Parity-Aware Features,” 14th Information Hiding Conference, Berkeley, May 15–18, 2012, LNCS vol. 7692, Springer-Verlag, pp. 31–45.
21. J. Kodovský and J. Fridrich, “JPEG-Compatibility Steganalysis Using Block-Histogram of Recompression Artifacts,” 14th Information Hiding Conference, Berkeley, May 15–18, 2012, LNCS vol. 7692, Springer-Verlag, pp. 78–93.
22. J. Fridrich and J. Kodovský, “Rich Models for Steganalysis of Digital Images,” *IEEE Trans. on Info. Forensics and Security* **7**(3), pp. 868–882, June 2012.
23. J. Kodovský, J. Fridrich, and V. Holub, “Ensemble Classifiers for Steganalysis of Digital Media,” *IEEE Trans. on Info. Forensics and Security* **7**(2), pp. 432–444, 2012.
24. J. Fridrich, J. Kodovský, M. Goljan, and V. Holub, “Breaking HUGO – the Process Discovery,” 13th Information Hiding Conference, Prague, Czech Republic, May 18–20, 2011, LNCS vol. 6958, Springer-Verlag, pp. 85–101.
25. J. Fridrich, J. Kodovský, M. Goljan, and V. Holub, “Steganalysis of Content-Adaptive Steganography,” 13th Information Hiding Conference, Prague, Czech Republic, May 18–20, 2011, LNCS vol. 6958, Springer-Verlag, pp. 102–117.
26. M. Goljan, J. Fridrich, and Mo Chen, “Defending Against Fingerprint-Copy Attack in Sensor-Based Camera Identification,” *IEEE Trans. on Info. Forensics and Security* **6**(1), March 2011, pp. 227–236.
27. T. Filler, J. Judas, and J. Fridrich, “Minimizing Additive Distortion in Steganography Using Syndrome-Trellis Codes,” *IEEE Trans. on Info. Forensics and Security* **6**(1), pp. 920–935, 2011.
28. J. Kodovský and J. Fridrich, “Quantitative Structural Steganalysis of Jsteg,” *IEEE Trans. on Info. Forensics and Security* **5**(4), pp. 681–693, 2010.
29. T. Filler and J. Fridrich, “Gibbs construction in Steganography,” *IEEE Trans. on Info. Forensics and Security* **5**(4), pp. 705–720, 2010.
30. T. Pevný, A. Ker, and J. Fridrich, “From Blind to Quantitative Steganalysis,” *IEEE Trans. on Info. Forensics and Security* **7**(2), pp. 445–454, 2012.
31. T. Pevný, P. Bas, and J. Fridrich, “Steganalysis by Subtractive Pixel Adjacency Matrix,” *IEEE Trans. on Info. Forensics and Security* **5**(2), pp. 215–224, 2010.
32. T. Filler and J. Fridrich, “Fisher Information Determines Capacity of ε-secure Steganography,” 11th Information Hiding Workshop, Darmstadt, Germany, June 7–10, 2009, LNCS vol. 5806, Springer-Verlag, pp. 31–47.
33. J. Fridrich, Asymptotic Behavior of the ZZW Embedding Construction, *IEEE Trans. on Info. Forensics and Security* **4**(1), pp. 151–153, March 2009.
34. J. Fridrich, Digital Image Forensics Using Sensor Noise. *Signal Processing Magazine*, Special Issue on Digital Forensics **26**(2), pp. 26–37, March 2009.
35. T. Pevný and J. Fridrich, “Benchmarking for Steganography,” 10th Information Hiding Workshop, Santa Barbara, California, May 19–21, LNCS, vol. 5284, Springer-Verlag, pp. 251−267, 2008.
36. J. Fridrich and J. Bierbrauer, “Constructing good covering codes for applications in Steganography”, LNCS Transactions on Data Hiding and Multimedia Security, Springer-Verlag, vol. 4920, pp. 1–22, 2008.

37. T. Pevný and J. Fridrich, “Multi-Class Detector of Current Steganographic Methods for JPEG Format,” *IEEE Trans. on Info. Forensics and Security* **3**(4), pp. 635–650, December 2008.
38. T. Pevný and J. Fridrich, “Detection of Double-Compression in JPEG Images for Applications in Steganography,” *IEEE Trans. on Info. Forensics and Security* **3**(2), pp. 247–258, 2008.
39. J. Fridrich, Mo Chen, M. Goljan, and J. Lukáš, “Determining Image Origin and Integrity Using Sensor Noise,” *IEEE Trans. on Info. Forensics and Security* **3**(1), pp. 74–90, March 2008.
40. J. Fridrich, Mo Chen, J. Lukáš, and M. Goljan, “Imaging Sensor Noise as Digital X-Ray for Revealing Forgeries,” 9th Information Hiding Workshop, Saint Malo, France, June 9–11, LNCS, 4567, Springer-Verlag, pp. 342–358, 2007.
41. J. Fridrich and P. Lisoněk, “Grid Colorings in Steganography,” *IEEE Transactions on Information Theory* **53**(4), pp. 1547–1549, April 2007.
42. J. Fridrich, P. Lisoněk, and D. Soukal, “On Embedding Efficiency,” 8th Information Hiding, Washington, DC, July 10–12, LNCS, vol. 4437, Springer-Verlag, pp. 282–296, 2006.
43. J. Fridrich and D. Soukal, “Matrix Embedding for Large Payloads,” *IEEE Transactions on Information Security and Forensics* **1**(3), pp. 390–394, 2006.
44. J. Fridrich and T. Pevný, “Determining the Stego Algorithm for JPEG Images”, Special Issue of IEE Proceedings – Information Security **153**(3), pp. 75–139, 2006.
45. J. Fridrich, M. Goljan, and D. Soukal, “Wet paper Codes with Improved Embedding Efficiency,” *IEEE Transactions on Information Security and Forensics* **1**(1), pp. 102–110, 2006.
46. J. Fridrich, J. Lukáš, and M. Goljan, “Digital Camera Identification from Sensor Noise,” *IEEE Transactions on Information Security and Forensics* **1**(2), pp. 205–214, 2006.
47. J. Fridrich, M. Goljan, and D. Soukal, “Efficient Wet Paper Codes”, in M. Barni (ed.): *Information Hiding*. *7th International Workshop*, LNCS vol. 3727, Springer-Verlag, New York, pp. 204–218, 2005.
48. J. Fridrich, M. Goljan, and D. Soukal, “Perturbed Quantization Steganography”, ACM Multimedia and Security Journal **11**(2), pp. 98–107, 2005.
49. J. Fridrich, M. Goljan, P. Lisoněk, and D. Soukal, “Writing on Wet Paper”, *IEEE Trans. on Sig. Proc.*, Special Issue on Media Security, Eds. T. Kalker and P. Moulin, vol. **53**, pp. 3923–3935, 2005.
50. J. Fridrich, “Feature-Based Steganalysis for JPEG Images and its Implications for Future Design of Steganographic Schemes”, in J. Fridrich (ed.): *Information Hiding*. *6th International Workshop*, *LNCS* vol. 3200, Springer-Verlag, Berlin-Heidelberg, New York, pp. 67–81, 2004.
51. J. Fridrich, M. Goljan, D. Hogea, and D. Soukal, “Quantitative Steganalysis of Digital Images: Estimating the Secret Message Length”, *ACM Multimedia Systems Journal*, Special issue on Multimedia Security, vol. **9**(3), pp. 288–302, 2003.
52. J. Fridrich, M. Goljan, and R. Du, “Detecting LSB Steganography in Color and Gray-Scale Images”, *Magazine of IEEE Multimedia*, *Special Issue on Security*, October-November issue, pp. 22–28, 2001.
53. J. Fridrich, M. Goljan, and R. Du, “Lossless Data Embedding – New Paradigm in Digital Watermarking”, *EURASIP Journal*, Special Issue on Emerging Applications of Multimedia Data Hiding, vol. 2002, No.2, February, pp. 185–196, 2002.
54. J. Fridrich, M. Goljan, and N. Memon, "Cryptanalysis of the Yeung-Mintzer Fragile Watermarking Technique", *Journal of Electronic Imaging* **11**(02), pp. 262–274, 2002.
55. J. Fridrich, M. Goljan, and D. Hogea, “Steganalysis of JPEG Images: Breaking the F5 Algorithm”, in F.A.P. Petitcolas (ed.), *Information Hiding. 5th International Workshop*, *LNCS* vol. 2578, Springer-Verlag Berlin-Heidelberg, New York, pp. 310–323, 2002.
56. J. Fridrich, M. Goljan, and R. Du, “Distortion-free Data Embedding”, in I. Moskowicz (ed.), *Information Hiding. 4th International Workshop*, *LNCS* vol. 2137, Springer-Verlag Berlin-Heidelberg, New York, pp. 27–41, 2001.
57. J. Fridrich, “Secure Steganographic Methods for Palette Images”, in A. Pfitzmann (ed.), *Information Hiding. 3rd International Workshop*, *LNCS* vol. 1768, Springer-Verlag Berlin-Heidelberg, New York, pp. 47–60, 1999.
58. J. Fridrich, 2Lt A.C. Baldoza, and R.J. Simard, “Robust Digital Watermarking Based on Key-Dependent Basis Functions”, in D. Aucsmith (ed.), *Information Hiding. 2nd International Workshop*, *LNCS* vol. 1525, Springer-Verlag Berlin-Heidelberg, New York, pp. 143–157, 1998.
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60. J. Fridrich and J.F.Geer, “Discrete-Time Dynamical Systems under Observational Uncertainty,” *J. Appl. Math. and Comp*. **82**, pp. 181–207, 1997.
61. J. Fridrich, “Beneficial Chaos?” *Int. J. of Gen. Sys*. **26**(1–2), pp. 179–197, 1997.
62. J. Fridrich, “Mathematics of Finite Resolution.” *Int. J. of Gen. Sys.* **25**(3), pp. 245–258, 1996.
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65. J. Fridrich, “On Chaotic Systems: Fuzzified Logistic Map.” *Int. J. of Gen. Sys.* **22**(4), 381–389, 1994.
66. J. Fridrich, “Fuzzy Mathematics in Dynamical Systems: Is There a Place for It?” *Int. J. of Gen. Sys.* **22**(4), 381–389, 1994.

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199. J. Fridrich and J. Ryder, "Fractal Growth with L-Systems", *Proc. ACM–SIGCSE* 1996, Technical Symposium, Philadelphia, Pennsylvania, February 14–20, 1996.
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201. J. Fridrich, "Fractal Properties of Discontinuities in Rocks." Technical Report (in Czech), Mining Institute, Ostrava, Czechoslovakia, September 1990.
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- Secure Image Encryption Based on Chaos, US Patent 6,064,738, May 16, 2000. A new, efficient private key encryption technique based on discretized two-dimensional chaotic maps.
- Secure Encryption and Hiding of Data – Secure Message Hiding in Images. An efficient, secure method for hiding of secret information inside digital images. US Patent 6,094,483, July 25, 2000 (co-inventor Richard Simard).
- Digital watermarking by adding random, smooth patterns. US Patent 6,101,602, August 8, 2000. The image is watermarked by overlaying a key-dependent pattern over the image. The pattern is generated by a pseudo-random number generator, processed by cellular automaton and smoothened.
- Reliable Detection of LSB Steganography in Color and Grayscale Images, US Patent 6,831,991, December 14, 2004. Previously undetectable schemes can be accurately identified with this new technique (co-inventor Miroslav Goljan).
- Lossless Embedding in Digital Images. New method for lossless embedding of information in digital images. The distortion due to embedding can be removed after message extraction. US Patent 7,006,656 B2, February 28, 2006 (co-inventors Miroslav Goljan and Rui Du).
- Method and Apparatus for Identifying an Imaging Device. U.S. Patent No. 7,616,237, November 10, 2009. A methodology for identifying camera sensor using sensor pattern noise (co-inventors Miroslav Goljan and Jan Lukáš).
- Determining whether or not a digital image has been tampered with, U.S. Patent No. 8,855,358, October 7, 2014. A methodology for revealing digital forgeries featured in a movie "Beyond Reasonable Doubt" directed by Peter Hyams, 2010 (co-inventors Miroslav Goljan and Jan Lukáš).

All awarded patents have generated royalties.

PROFESSIONAL ACTIVITIES AND MEMBERSHIPS

Associate Editor (2006–2009) and co-founder of the new IEEE Transactions on Information Forensic and Security

Editor of special issues:

- EURASIP Journal on Signal Processing, Special Issue on Emerging Applications of Multimedia Data Hiding, Vol. 2002(2), February 2002
- Signal Processing Special Section on Security of Data Hiding Technologies, Vol. 83(10), October 2003.

Conference technical programs that I am or have been part of in the past:

- Information Hiding Workshop (Program Chair 2004, Program Committee member)
- SPIE Electronic Imaging, Security, Steganography, and Watermarking of Multimedia Content (Program Committee member)
- International Workshop on Digital Watermarking (Program Committee member)
- ACM Workshop on Multimedia Security (Program Chair and committee member)
- IFIP TC-6 TC-9 Communications and Multimedia Security Conference (Program Committee member)

Reviewer for

- IEEE Transactions on Signal Processing; IEEE Transactions on Image Processing; IEEE Transactions on Systems, Man, and Cybernetics; IEEE Transactions on Multimedia, IEEE Transactions on Circuits and Systems for Video Technology, IEEE Signal Processing Letters
- Elsevier Digital Signal Processing
- Electronics Letters
- Computer Graphics and Pattern Recognition

- Journal of Computer Security
- Journal of Electronic Imaging
- Signal Processing Journal
- Cryptologia
- Journal of Imaging Science and Technology
- Journal of Visual Communication and Image Representation
- International Journal of Image and Graphics
- EURASIP Journal on Signal Processing
- Pattern Recognition Letters
- Multimedia Systems
- ETRI Journal
- Information and Software Technology

Member of ACM and SPS IEEE, Technical Committee of IEEE TIFS (2010–2012)

TEACHING EXPERIENCE

During my academic career, I have taught courses on applied mathematics, introductory linear algebra, analysis, fundamentals of steganography, detection theory, modern coding theory, and machine learning. As a PhD student at Binghamton University, I have developed and taught three times (1993–95) a graduate course on Modern Mathematical Modeling at the dept. of Systems Science. During the academic year 2005–06, I taught two seminar courses and one regular course at the dept. of ECE at Binghamton University. During my professional career, I have given numerous presentations in academia, industry, and for local IEEE branches. I regularly present my research work to the Science Advisory Board at the US Air Force Laboratory at Rome, NY. I have also given tutorials at conferences on the topic of watermarking and data hiding and was invited several times as a plenary speaker. I summarize my formal teaching experience below.

- EECE 580A, Seminar on Steganalysis, 2005
- EECE 562, Fundamentals of Steganography, 2006–2010, 2012, 2013
- EECE 680A Seminar in Digital Forensics, 2006–2009, 2011–2013
- EECE 580B Modern Coding Theory, Fall 2009
- EECE 580C Support Vector Machines, Spring 2010
- 1993–1995 Developed and taught a graduate course "Fractals, Chaos, and Neural Networks" at the Dept. of Systems Science at SUNY Binghamton.
- 1989–1990 Taught Calculus and Linear Algebra introductory courses at The Silezian University in Opava, Czech Republic.
- Supervised 9 PhD dissertations and 7 Master theses.

REFERENCES

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Further information, media appearances and articles concerning my work that appeared in newspapers, magazines, and on TV are available in the Media Section on my web page at http://www.ws.binghamton.edu/fridrich