COMPARATIVE STUDY BETWEEN DIFFERENT SPARSE BASIS FOR IMAGE RECONSTRUCTION USING COMRESSIVE SENSING

A Dissertation Submitted

In partial fulfillment of the requirements for the award of

The Degree of

Master of Technology

In

Electronics Engineering

(Communication Systems Engineering)

Submitted By

Pravin Bharat Solanki

Under the Supervision of

Mr. M.K. Singh

DEPARTMENT OF ELECTRONICS ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY

(BANARAS HINDU UNIVERSITY)

VARANASI – 221005, INDIA

RollNo.14092067 ***July,2016***

DEPARTMENT OF ELECTRONICS ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY
(BANARAS HINDU UNIVERSITY)
VARANASI–221005, (INDIA)

Phone : 0542-2307010 *Fax : 0542-2366758* *E-mail : head.ece@itbhu.ac.in*

Ref: IT/ECE/..... *Date: .....*

CERTIFICATE

This is to certify that the dissertation entitled ***"MU-MIMO Signal Detection Using Gibbs Sampler"*** submitted by **Mr. Pravin Bharat Solanki** (Roll No.: 14092067), to the Department of Electronics Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi, in partial fulfillment of the requirements for the award of the degree ***"MASTER OF TECHNOLOGY" in Electronics Engineering (Communication Systems Engineering)*** is an authentic work carried out at Department of Electronics Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi by him under my supervision and guidance on the concept vide project grant as acknowledged.

Mr. M.K. Singh
supervisor

Head of Department

DEPARTMENT OF ELECTRONICS ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY
(BANARAS HINDU UNIVERSITY)
VARANASI–221005, (INDIA)

Phone : 0542-2307010 *Fax : 0542-2366758* *E-mail : head.ece@itbhu.ac.in*

Ref: IT/ECE/..... *Date: .....*

CANDIDATE'S DECLARATION

I hereby declare that the work presented in this dissertation titled ***"MU-MIMO Signal Detection Using Gibbs Sampler"*** is an authentic record of my own work carried out at Department of Electronics Engineering, Indian Institute of Technology(Banaras Hindu University), Varanasi as requirements for the award of degree of Master of Technology (M.Tech.) in Electronics Engineering (Communication Systems Engineering), submitted in the Indian Institute of Technology, (Banaras Hindu University) (IIT-BHU), Varanasi (U.P) for the session from June 2014 to June 2016 under the supervision of ***Mr. M.K. Singh***, Department of Electronics Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi, on the concept vide project grant as acknowledged.

It does not contain any part of the work, which has been submitted for the award of any degree either in this University or in other University/Deemed University without proper citation.

Pravin Bharat Solanki
Roll. No.:14092067
M.tech
(Communication Systems Engineering)
Dept. of Electronics Engineering
IIT (BHU), Varanasi

Dedicated

to

My Family and Teachers

ACKNOWLEDGEMENT

First and foremost, I would like to express my hearty thanks and indebtedness to my supervisor ***Mr. M. K. Singh***, Department of Electronics Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi for his enormous help and encouragement throughout the course of this thesis. His technical knowledge and insight have given me an excellent background in the field of my work. His excellent guidance, perseverance, invaluable suggestions made this work possible and complete.

My profound gratitude to ***Prof. S. Jit, Head, Department of Electronics Engineering, Indian Institute of Technology (BHU), Varanasi*** for providing necessary facilities in order to perform necessary simulation study.

I would also like to thanks all the faculty members and the librarians for their kind cooperation and encouragement during the course of work, and to all of the technical and non-technical staffs for all the instances in which their assistance helped me along the way.

Above all, it was my family and friends who gave me endless support and provided me with an opportunity to reach this far with my studies. Their constant encouragement has always helped me to walk over all the hurdles. It's just not possible to express my gratitude and indebtedness towards them in words.

Last but not least, I thank almighty ***Lord Vishwanath*** for providing me strength and courage in completing the work.

Pravin Bharat Solanki

Abstract

In signal and image processing application , Nyquist rate is so high that large amount of data is generated that need to be transmitted, stored and processed. This data generation rate is so high that it is nearly impossible or too costly, to design and build devices capable of acquiring samples at such a high rate and our communication channels are also not so developed to transfer data with such a high rate. To cope with such logistical and computational challenges Transform coding is used, which is based on sample then compress framework. But in this process large amount of sampled data which contain insignificant information is discarded during reconstruction process which leads to unnecessary hardware and software load. To overcome this problem Compressed Sensing comes in existence.

Compressed Sensing is a sampling method which samples the sparse signal in a compressed format i.e. it uses very less number of distinct samples of the target signal and is then recovered by using various recovery algorithms. To make this recovery process effective, some conditions are necessary such as signal or image must be sparse in a known domain and the number of measurements must be according to sparsity of signal or image.

In this work we compare different sparse basis with different recovery algorithms for compressive sensing of images. For this purpose we use sparse basis like DCT, DWT, Haar, ODWT and BODWT and some of convex and greedy algorithms. Their performances are compared in terms of PSNR and SSIM. For this comparison we used test image Lena of size 256×256. Due to high complexity of CS algorithms original image is divided into different blocks of size 16×16 and optimization is performed on each block seprately. Our results show that Basis Pursuit algorithms give high SSIM and PSNR but with high computational time compare to greedy algorithms. After the comparison of our results we observe that BODWT sparse basis with BPDN-NESTA algorithm produces best result in terms of SSIM and PSNR.

Contents

List of Figures

List of Algorithms

Bibliography

[1] Baraniuk, R., Davenport, M., DeVore, R., and Wakin, M. (2008). A simple proof of the restricted isometry property for random matrices. *Constructive Approximation*, 28(3):253–263.

[2] Blumensath, T. and Davies, M. E. (2009). Iterative hard thresholding for compressed sensing. *Applied and Computational Harmonic Analysis*, 27(3):265–274.

[3] Cahill, J., Chen, X., and Wang, R. (2016). The gap between the null space property and the restricted isometry property. *Linear Algebra and its Applications*, 501:363–375.

[4] Cai, T. T., Xu, G., and Zhang, J. (2009). On recovery of sparse signals via minimization. *Information Theory, IEEE Transactions on*, 55(7):3388–3397.

[5] Candes, E. and Romberg, J. (2007). Sparsity and incoherence in compressive sampling. *Inverse problems*, 23(3):969.

[6] Candes, E., Rudelson, M., Tao, T., and Vershynin, R. (2005). Error correction via linear programming. In *46th Annual IEEE Symposium on Foundations of Computer Science (FOCS'05)*, pages 668–681. IEEE.

[7] Candès, E. J., Romberg, J., and Tao, T. (2006). Robust uncertainty principles: Exact signal reconstruction from highly incomplete frequency information. *IEEE Transactions on information theory*, 52(2):489–509.

[8] Candes, E. J., Romberg, J. K., and Tao, T. (2006). Stable signal recovery from incomplete and inaccurate measurements. *Communications on pure and applied mathematics*, 59(8):1207–1223.

[9] Candes, E. J. and Tao, T. (2005). Decoding by linear programming. *Information Theory, IEEE Transactions on*, 51(12):4203–4215.

[10] Candes, E. J. and Tao, T. (2006). Near-optimal signal recovery from random projections: Universal encoding strategies? *IEEE transactions on information theory*, 52(12):5406–5425.

[11] Chen, S. S., Donoho, D. L., and Saunders, M. A. (2001). Atomic decomposition by basis pursuit. *SIAM review*, 43(1):129–159.

[12] Cohen, A., Dahmen, W., and DeVore, R. (2008). Instance optimal decoding by thresholding in compressed sensing. *Harmonic Analysis and Partial Differential Equations, Contemp. Math*, 505:1–28.

[13] DeVore, R. A. (2007). Deterministic constructions of compressed sensing matrices. *Journal of Complexity*, 23(4):918–925.

[14] Donoho, D. L. (2006). Compressed sensing. *IEEE Transactions on information theory*, 52(4):1289–1306.

[15] Donoho, D. L. and Stark, P. B. (1989). Uncertainty principles and signal recovery. *SIAM Journal on Applied Mathematics*, 49(3):906–931.

[16] Donoho, D. L. and Tanner, J. (2005). Sparse nonnegative solution of underdetermined linear equations by linear programming. *Proceedings of the National Academy of Sciences of the United States of America*, 102(27):9446–9451.

[17] Donoho, D. L., Tsaig, Y., Drori, I., and Starck, J.-L. (2012). Sparse solution of underdetermined systems of linear equations by stagewise orthogonal matching pursuit. *Information Theory, IEEE Transactions on*, 58(2):1094–1121.

[18] Duarte, M. F., Davenport, M. A., Takhar, D., Laska, J. N., Sun, T., Kelly, K. E., Baraniuk, R. G., et al. (2008). Single-pixel imaging via compressive sampling. *IEEE Signal Processing Magazine*, 25(2):83.

[19] Gorodnitsky, I. F., George, J. S., and Rao, B. D. (1995). Neuromagnetic source imaging with focuss: a recursive weighted minimum norm algorithm. *Electroencephalography and clinical Neurophysiology*, 95(4):231–251.

[20] Karp, B. and Kung, H.-T. (2000). Gpsr: Greedy perimeter stateless routing for wireless networks. In *Proceedings of the 6th annual international conference on Mobile computing and networking*, pages 243–254. ACM.

[21] Lorentz, G. G., von Golitschek, M., and Makovoz, Y. (1996). *Constructive approximation: advanced problems*, volume 304. Springer Berlin.

[22] Mallat, S. G. and Zhang, Z. (1993). Matching pursuits with time-frequency dictionaries. *IEEE Transactions on signal processing*, 41(12):3397–3415.

[23] Mendelson, S., Pajor, A., and Tomczak-Jaegermann, N. (2008). Uniform uncertainty principle for bernoulli and subgaussian ensembles. *Constructive Approximation*, 28(3):277–289.

[24] Muthukrishnan, S. (2005). *Data streams: Algorithms and applications*. Now Publishers Inc.

[25] Needell, D. and Tropp, J. A. (2009). Cosamp: Iterative signal recovery from incomplete and inaccurate samples. *Applied and Computational Harmonic Analysis*, 26(3):301–321.

[26] Needell, D. and Ward, R. (2013). Stable image reconstruction using total variation minimization. *SIAM Journal on Imaging Sciences*, 6(2):1035–1058.

[27] Nesterov, Y. (1983). A method for unconstrained convex minimization problem with the rate of convergence o (1/k2). In *Doklady an SSSR*, volume 269, pages 543–547.

[28] Nyquist, H. (1928). Certain topics in telegraph transmission theory.

[29] Rudin, L. I., Osher, S., and Fatemi, E. (1992). Nonlinear total variation based noise removal algorithms. *Physica D: Nonlinear Phenomena*, 60(1):259–268.

[30] Sermwuthisarn, P., Gansawat, D., Patanavijit, V., and Auethavekiat, S. (2012). Impulsive noise rejection method for compressed measurement signal in compressed sensing. *EURASIP Journal on advances in signal processing*, 2012(1):1–23.

[31] Shi, Y. Q. and Sun, H. (1999). *Image and video compression for multimedia engineering: Fundamentals, algorithms, and standards*. CRC press.

[32] Sparse, M. (2007). The application of compressed sensing for rapid mr imaging lustig michael; donoho david; pauly john m. *Magnetic resonance in medicine: official journal of the Society of Magnetic Resonance in Medicine/Society of Magnetic Resonance in Medicine*, 58(6):1182–95.

[33] Sun, G., Zhou, Y., Wang, Z., Dang, W., and Li, Z. (2012). Sparsity adaptive compressive sampling matching pursuit algorithm based on compressive sensing. *Journal of Computational Information Systems*, 7(4):2883–2890.

[34] Tropp, J. and Gilbert, A. C. (2005). Signal recovery from partial information via orthogonal matching pursuit.

[35] Tropp, J., Needell, D., and Vershynin, R. (2008). Iterative signal recovery from incomplete and inaccurate measurements. *Information Theory and Applications*.

[36] Westerink, P. H., Boekee, D. E., Biemond, J., and Woods, J. W. (1988). Subband coding of images using vector quantization. *IEEE Transactions on Communications*, 36(6):713–719.

[37] Yang, S.-l. and Zhang, Z.-b. (2009). Digital image watermarking using iterative blending based on wavelet technique. In *2009 International Conference on Multimedia Information Networking and Security*, volume 2, pages 83–86. IEEE.

[38] Yu, L., Barbot, J.-P., Zheng, G., and Sun, H. (2010). Compressive sensing with chaotic sequence. *IEEE Signal Processing Letters*, 17(8):731–734.