Congnitive Science Laboratory

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Summary of Achievement

Refereed academic journal

[sding-106-005-01:2017] Zhenni Li, Shuxue Ding, Takafumi Hayashi, and Yujie Li. Analysis Dictionary Learning Using Block Coordinate Descent with Proximal Operators. *Neurocomputing*, 239:165–180, May 2017.

In this study, we propose two analysis dictionary learning algorithms for sparse representation with analysis model. The problem is formulated with the l1-norm regularizer and with two penalty terms on the analysis dictionary: the term of -log det and the coherence penalty term. As the processing scheme, we employ a block coordinate descent framework, so that the overall problem is transformed into a set of minimizations of univariate subproblems with respect to a single-vector variable. Each sub-problem is still nonsmooth, but it can be solved by a proximal operator and then the closed-form solutions can be obtained directly and explicitly. In particular, the coherence penalty, excluding excessively similar or repeated dictionary atoms, is solved at the same time as the dictionary update, thereby reducing the complexity. Furthermore, a scheme with a group of atoms is introduced in one proposed algorithm, which has a lower complexity. According to our analysis and simulation study, the main advantages of the proposed algorithms are their greater dictionary recovery ratios especially in the low-cosparsity case, and their faster running time of reaching the stable values of the dictionary recovery ratios and the recovery cosparsity compared with state-of-the-art algorithms. In addition, one proposed algorithm performs well in image denoising and in noise cancellation.

[sding-106-005-02:2017] Xiang Li, Shuxue Ding, Zhenni Li, and Benying Tan. Device-Free Localization via Dictionary Learning with Difference of Convex Programming. *IEEE Sensors Journal*, 17(17):5599–5608, Sept. 2017.

In this paper, we consider a method to solve the device-free localization (DFL) problem that is able to detect spatial obstruction via wireless network. A dictionary learning approach with difference of convex (DC) programming and DC Algorithm (DCA) is proposed to indicate target location based on learning data. By measuring the variation in the received signal strength (RSS) of the wireless links indicating the locations of the obstructions, the physical target in the monitoring area can be estimated through a learned dictionary. We show that the DFL problem can be efficiently formulated as a non-convex optimization problem. We adopt a penalty function called the Minimax Concave Penalty (MCP), which possesses good properties in terms of seeking sparsity,

and solve the non-convex optimization problem using DC programming. Furthermore, the localization accuracy achieved during the pathtracking task is further improved by the proposed tracking neighborhood rule. The rule provides a solution for increasing the localization accuracy under time-varying conditions generated by sampling channels of sensor networks under noisy conditions. The proposed approach is validated on a real-world dataset and has the potential to be adopted flexibly in DFL applications.

[sding-106-005-03:2017] Xiang Li, Shuxue Ding, and Yujie Li. Outlier Suppression via Non-Convex Robust PCA for Efficient Localization in Wireless Sensor Networks. *IEEE Sensors Journal*, 17(21):7053–7063, Nov. 2017.

Due to the fact that outliers can degrade localization accuracy significantly in wireless sensor networks, we propose an outlier suppression approach via nonconvex robust principal component analysis (Robust PCA). By introducing several nonconvex penalty functions to approximate both the rank function and the sparse penalty function in the original Robust PCA problem, we establish a non-convex objective function and solve it efficiently by the augmented Lagrangian multiplier method and difference of convex programming technique. This framework creates the opportunity to safely perform localization with dimension reduction by standard PCA, which has well-known fragile characteristics in the presence of outliers. Thus, the localization algorithms obtained by sparse coding provide the benefits of computational efficiency in low-dimension. The device-free localization (DFL) experiment on a real-world data set shows the improvement in localization accuracy after standard PCA in the presence of outliers. A statistical distance, called the Wasserstein distance, is introduced to evaluate the processed result of outlier suppression, illustrating that the proposed approach can identify and eliminate outliers in DFL problems.

[sding-106-005-04:2017] Zhenni Li, Shuxue Ding, Yujie Li, Zuyuan Yang, Shengli Xie, and Wuhui Chen. Manifold Optimization-based Analysis Dictionary Learning with an L1/2-norm Regularizer Learning Systems. *Neural Networks*, 98:212–222, Dec. 2017.

Recently there has been increasing attention towards analysis dictionary learning. In analysis dictionary learning, it is an open problem to obtain the strong sparsity-promoting solutions efficiently while simultaneously avoiding the trivial solutions of the dictionary. In this paper, to obtain the strong sparsitypromoting solutions, we employ the l1/2 norm as a regularizer. The very recent study on l1/2 norm regularization theory in compressive sensing shows that

its solutions can give sparser results than using the l1 norm. We transform a complex nonconvex optimization into a number of one-dimensional minimization problems. Then the closed-form solutions can be obtained efficiently. To avoid trivial solutions, we apply manifold optimization to update the dictionary directly on the manifold satisfying the orthonormality constraint, so that the dictionary can avoid the trivial solutions well while simultaneously capturing the intrinsic properties of the dictionary. The experiments with synthetic and real-world data verify that the proposed algorithm for analysis dictionary learning can not only obtain strong sparsitypromoting solutions efficiently, but also learn more accurate dictionary in terms of dictionary recovery and image processing than the state-of-the-art algorithms.

[xiangli-106-005-01:2017] Zhenni Li Benying Tan Xiang Li, Shuxue Ding. Device-Free Localization via Dictionary Learning With Difference of Convex Programming. *IEEE Sensors Journal*, 17, Sept. 2017.

Keywords:Sparse Representation, Optimization, Internet of Things (IoT)

[xiangli-106-005-02:2017] Yujie Li Xiang Li, Shuxue Ding. Outlier Suppression via Non-Convex Robust PCA for Efficient Localization in Wireless Sensor Networks. *IEEE Sensors Journal*, 17, Nov. 2017.

Keywords: Sparse Representation, Optimization, Outlier Analysis, Internet of Things (IoT)

Refereed proceedings of an academic conference

[sding-106-005-05:2017] Zhuangguo Miao, Xiaohong Ma, and Shuxue Ding. Phase Constraint and Deep Neural Network for Speech Separation. In *Lecture Notes in Computer Science, Vol. 10262*, volume Vol. 10262, pages 266–273. 14th International Symposium on Neural Networks, ISNN 2017, Sapporo and Muroran, Hokkaido, Japan, June 21-26, 2017, Jun. 2017.

The phase response of speech is an important part in speech separation. In this paper, we apply the complex mask to the speech separation. It both enhances the magnitude and phase of speech. Specifically, we use a deep neural network to estimate the complex mask of two sources. And considering the importance of the phase, we also explore a phase constraint objective function, which can ensure the phase of the sum of estimated sources that is close to the phase of the mixture. We demonstrate the efficiency of the method on the TIMIT speech corpus for single channel speech separation.

[sding-106-005-06:2017] Linlin Chen, Xiaohong Ma, and Shuxue Ding. Single Channel Speech Separation Using Deep Neural Network. In *Lecture Notes in Computer Science, Vol. 10262*, volume Vol. 10262, pages 285–292. 14th International Symposium on Neural Networks, ISNN 2017, Sapporo and Muroran, Hokkaido, Japan, June 21-26, 2017, Jun. 2017.

Single channel speech separation (SCSS) is an important and challenging research problem and has received considerable interests in recent years. A supervised single channel speech separation method based on deep neural network (DNN) is proposed in this paper. We explore a new training strategy based on curriculum learning to enhance the robustness of DNN. In the training processing, the training samples firstly are sorted by the separation difficulties and then gradually introduced into DNN for training from easy to complex cases, which is similar to the learning principle of human brain. In addition, a strong discriminative objective function for reducing the source interference is designed by adding in the correlation coefficients and negentropy. The efficiency of the proposed method is substantiated by a monaural speech separation task using TIMIT corpus.

[sding-106-005-07:2017] Peng Zhang, Xiaohong Ma, , and Shuxue Ding. Audio Source Separation from a Monaural Mixture Using Convolutional Neural Network in the Time Domain. In *Lecture Notes in Computer Science, Vol. 10262*, volume Vol. 10262, pages 388–395. 14th International Symposium on Neural Networks, ISNN 2017, Sapporo and Muroran, Hokkaido, Japan, June 21-26, 2017, Jun. 2017.

Audio source separation from a monaural mixture, which is termed as monaural source separation, is an important and challenging problem for applications. In this paper, a monaural source separation method using convolutional neural network in the time domain is proposed. The proposed neural network, input and output of which are both time-domain signals, consists of three convolutional layers, each of which is followed by a max-pooling layer, and two fully-connected layers. There are two key ideas behind the time-domain convolutional network: one is learning features automatically by the convolutional layers instead of extracting features such as spectra; the other is that the phase can be recovered automatically since both the input and output are in the time domain. The proposed approach is evaluated using the TSP speech corpus for monaural source separation, and achieves around 4.31-7.77 SIR gain with respect to the deep neural network, the recurrent neural net-

work and nonnegative matrix factorization, while maintaining better SDR and SAR.

[sding-106-005-08:2017] Yujie Li, Benying Tan, Shuxue Ding, Incheon Paik, and Atsunori Kanemura. Key Frame Extraction from Video Based on Determinant-Type of Sparse Measure and DC Programming. In *Proc. 2017 IEEE 11th International Symposium on Embedded Multicore/Many-core Systems-on-Chip, MCSoC, Seoul, South Korea, Sept. 18-20, 2017*, pages 174–180, Sept. 2017.

Video is human's favorite multimedia data type due to its abundant amount of information and intuitive experience compared with text, audio, and image. With rapid progress of computer and network technologies, the amount of video data increases fast, massive storage and frequent retrieval inevitably lead to huge spatio-temporal cost, and how to manage the massive video data efficiently becomes a challenging issue. Key frame extraction is considered as one of the most critical issues in video processing. In this paper, we introduce a novel key frame extraction method based on sparse modeling. Assume that each video frame signal can be expressed as a linear combination of the representative key frames and formulate the problem of finding the representatives as a sparse vector problem. We consider a sparsity measure that is based on the determinant of the Gram matrix of the signals. Based on this measure, we propose a novel key frame extraction formulation based on sparse modeling with the determinant measure of sparsity. The formulation can be expressed as the difference of two convex functions, making the objective function neither convex nor concave. Thus the formulation cannot be easily solved by standard convex optimization methods. Difference of convex (DC) programming is introduced to solve the optimization problem.

[sding-106-005-09:2017] Yujie Li, Shuxue Ding, Zhenni Li, Xiang Li, and Benying Tan. Dictionary learning in the analysis sparse representation with optimization on Stiefel manifold. In *Proc. 2017 IEEE Global Conference on Signal and Information Processing, GlobalSIP 2017, Montreal, QC, Canada, Nov. 14-16, 2017*, pages 1270–1274, Nov. 2017.

Sparse representation has been proven to be a powerful tool for signals and images processing. This paper addresses sparse representation with the so-called analysis model. We pose the problem as to learn an analysis dictionary from signals using an optimization formulation with an orthogonal constraint. The conventional ways for the dictionary update with the orthogonal constraint are first just update in the embedding Euclidean space and then project the

result to the manifold on which the constraint is satisfied. Such a manifold is termed as the Stiefel manifold in the literature if the constraint is about orthogonality of the dictionary. However, such a method is an approximate and may not capture the intrinsic structure of the inherent dictionary. How to solve such a problem in a more precise method and to work out a more effective algorithm is the purpose of this paper. Therefore, we propose a novel optimization technique to learn the dictionary along the manifold seamlessly. Numerical experiments on recovery of analysis dictionary show the effectiveness of the proposed algorithm. In addition, for realistic applications, the proposed algorithms show good performances in signal denoising and classification.

[xiangli-106-005-03:2017] Zhenni Li Xiang Li Benying Tan Yujie Li, Shuxue Ding. Dictionary learning in the analysis sparse representation with optimization on Stiefel manifold. In *2017 IEEE Global Conference on Signal and Information Processing (GlobalSIP)*. IEEE, IEEE, Nov. 2017.

Keywords: Sparse Representation, Optimization, Statistical Signal Processing

[xiangli-106-005-04:2017] Shuxue Ding Xiang Li Benying Tan, Yujie Li. Recovering nonnegative sparse signals with a determinant-type of sparse measure and DC programming. In *IEEE ComCom 2017*, May 2017.

Best Student Award

Research grants from scientific research funds and public organizations

[sding-106-005-10:2017] Shuxue Ding. Research on real-time processing of compressive sensing and sparse representation, Scientific Research C, No. 16K00335, 2016 Grants-In-Aid for Scientific Research, Ministry of Education, Culture, Sports, Science and Technology, Japan., 2016-2018.

Academic society activities

[sding-106-005-11:2017] Committee member of Technical Committee on Awareness Computing, Systems, Man & Cybernetics Society, IEEE, 2017.

[sding-106-005-12:2017] Institute of Electrical and Electronics Engineers (IEEE), Membership, 2017.

[sding-106-005-13:2017] IEEE Signal Processing Society, Membership, 2017.

[sding-106-005-14:2017] The Institute of Electronics, Information and Communication Engineers (IEICE), Membership, 2017.

[sding-106-005-15:2017] The Association for Computing Machinery (ACM), Membership, 2017.

Advisor for undergraduate research and graduate research

[sding-106-005-16:2017] Yuta Sugii. Graduation Thesis: Leaning the Environment and Self-Control with an Embedded System Using Reinforcement Learning, School of Computer Science and Engineering, University of Aizu, 2017.

[sding-106-005-17:2017] Akinari Sakai. Graduation Thesis: Compressed Sensing by Using the Huber Function as a Smoothed Approximation of The l1-Norm, School of Computer Science and Engineering, University of Aizu, 2017.

[sding-106-005-18:2017] Kyohei Kanda. Graduation Thesis: Compressed Sensing by Using Simplex Algorithm, School of Computer Science and Engineering, University of Aizu, 2017.

[sding-106-005-19:2017] Kyosuke Nihei. Graduation Thesis: Classification with Multi-Source Sensor Fusion by Deep Learning and Canonical Correlation Analysis, School of Computer Science and Engineering, University of Aizu, 2017.

[sding-106-005-20:2017] Sei Sano. Master Thesis: Recurrent Neural Network with Long Short-Term Memory by Using the L1-norm Regularization, Graduate School, University of Aizu, 2017.

[sding-106-005-21:2017] Benying Tan. Master Thesis: Nonnegative sparse representation of signal based on determinant sparsity measure, Graduate School, University of Aizu, 2017.

[taro-106-005-01:2017] Haruki Takahashi. Graduation Thesis: Implementation of a 2D Action Game Engine with Functional Reactive Programming, University of Aizu, 2018.

Thesis Advisor: T. Suzuki

[taro-106-005-02:2017] Yoshiki Okubo. Graduation Thesis: Introduction of Concurrency to Functional Reactive Programming for Implementation of Web Servers, University of Aizu, 2018.

Thesis Advisor: T. Suzuki

[taro-106-005-03:2017] Yusuke Kimesawa. Graduation Thesis: Implementation of Web Servers with Functional Reactive Programming, University of Aizu, 2018.

Thesis Advisor: T. Suzuki

[taro-106-005-04:2017] Yuma Kobayashi. Graduation Thesis: mplementation of Kruskal's Algorithm on the Interactive Theorem Prover Coq, University of Aizu, 2018.

Thesis Advisor: T. Suzuki

Others

[taro-106-005-05:2017] S. Okui, T. Suzuki, and Yoshiki Iwata. Technical Report: Adapting subset construction to automta over list structures. published as a Technical Report of the University of Aizu. Report No.: 2017-001, 2017.

We investigate the subset construction (or powerset construction) introduced by Rabin and Scott seriously. Consider an NFA obtained from a DFA by allowing additional moves from the initial state to itself for any input symbols in the alphabet. Given such NFA's, we construct DFA's whose states are lists of the NFA-states such that no element occurs more than once in each list, then adapting the subset construction so as to deal with lists rather than sets. We show that such a variant of subset construction, with suitable optimizations applied, performs better than the original one in the sense that each construction step yielding a DFA-state is, in practice, irrelevant to the number of the NFA-states. We also adapt our construction so as to produce DFA's with default (or failure) transition, resulting in a new algorithm such as an extention of the classical construction of KMP-automata.

Contributions related to syllabus preparation

[sding-106-005-22:2017] Following course planning, I made a syllabus for the Master course: Statistical Signal Processing.

[sding-106-005-23:2017] Following course planning, I made a syllabus for the undergraduate course: Introduction to Topology.

Contribution related to educational planning management

[sding-106-005-24:2017] Graduate School Academic Affairs Committee Member, School of Computer Science and Engineering.

[sding-106-005-25:2017] Evaluation committee member for the projects Competitive Research Funding, projects for FY-2017, University of Aizu

[sding-106-005-26:2017] Committee member of Graduate School Entrance Examination Committee

Other significant contribution toward university planning, management, or administration

[sding-106-005-27:2017] Chair of Graduate Department of Computer and Information Systems.

[sding-106-005-28:2017] Committee member of The Education and Research Council, University of Aizu

[sding-106-005-29:2017] Committee member of The Deans and Directors Council, University of Aizu

[taro-106-005-06:2017] I engaged in the preparation of problems for the PC-Koshien programming contest as a member of problem prepstion WG of PC-Koshien. I also made a problem, which was used as the Problem 11 in the final competition.