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Research statement
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I am currently an Assistant Professor with the School of Electrical and Computer Engineering, College of Engineering, University of Tehran. I am also a co-founder and CTO of a start-up company named HARA, where we have developed several products with a core in artificial intelligence. Therefore, I am interested in a position that gives me freedom for doing both fundamental and applied research. In what follows, I describe my previous accomplishments, and elaborate on planned future directions for my research.

Past Accomplishments

I have notable accomplishments in two directions that can be considered the core of problem solving in machine learning and signal processing, one is modeling and the other is optimization. Apart from these fundamental directions, I have also worked on the scientific applications of machine learning mainly computer vision. The scientific applications in their turn are the core of industrial applications that I have been involved in them too.

For mathematical modeling in machine learning and signal processing, I had several key contributions. During my Master's study, I developed a new complex wavelet transform and developed the statistics for its use in activity recognition of fMRI images. This method outperformed available statistical methods for activity recognition, the result only published in my Master's thesis due to the lack of time. During my PhD studies under supervision of Prof. Bethge, I worked on unsupervised statistical modeling of natural images. We developed several mixture models for modeling. These models were mixtures of angular Gaussian distribution, mixtures of conditional Gaussian scale mixtures, and mixtures of elliptical gamma. The latter two models were introduced in three papers, and the first model was the basis of a compression algorithm that was patented in Europe and US. In the last phase of my PhD studies, I got involved in understanding optimization techniques and I got interested to go deep into them. But my contributions on mathematical modeling was also continued after PhD studies.

After my PhD studies, I continued working on mixture models. In a collaborative work with Prof. Araabi, we published a paper on improved Bayesian information criterion for mixture model selection. I also developed a powerful toolbox for mixture modeling called "mixest". I collaborated with Prof. Nili on developing models for expediting reinforcement learning. We developed the idea of using subspaces to this aim, the framework was published in IEEE Transactions on Neural Networks and Learning Systems. We recently developed a powerful mathematical approach based on free energy paradigm to solve this problem. In a collaborative paper with Prof. Sra published in International Conference on Machine Learning, we developed a new method for metric learning by introducing a new approach for designing an easily solvable objective function. It is about four years that I have concentrated on developing deep models. We developed a transformer model for link prediction in knowledge graphs, a work that was published recently. I shortly name some of works that have been submitted recently or are in-preparation. In a work, we developed graph convolutional networks for graph embedding. We developed a flow-based recurrent mixture density network for sequence-to-sequence mapping. In another work, we developed a powerful model for training adversarial robust deep models based on the idea that adversarial directions of attack are off-manifold.

My contributions on optimization methods were started during my work as a faculty member in University of Tehran. My first contribution was a collaboration with Prof. Sra on developing manifold optimization for conic geometrical optimization published in Siam Journal on Optimization. In a later work, we developed a manifold optimization method for fitting Gaussian mixture models (GMMs), a first method in the literature that was able to outperform well-known expectation-maximization algorithm. We further developed a manifold stochastic optimization method for fitting GMMs and provided a non-asymptotic convergence analysis for it. This work was published in Mathematical Programming. In a collaboration with Prof. Moradi, we developed a powerful manifold Gauss-Newton method for solving pose-graph optimization problem, that was published in IEEE Transactions on Robotics. For large-scale mixture modeling, we published a paper in Pattern Recognition journal about using a fast Newton MinRes method for solving the M-step in the EM algorithm for fitting flexibly-tied GMMs. In another work published in the same journal, we developed an optimization method for finding axes of symmetry of axial symmetric objects. I submitted a paper on developing manifold block coordinate descent method for tensor decomposition. We are preparing a paper for online learning for flexibly-tied GMMs.

I had several accomplishment on developing methods mainly for computer vision applications. As mentioned beforehand during my PhD studies, we developed a patented compression algorithm. In a short period (less than three months) during my PhD studies, I participated in a challenge on weak lensing. I developed a statistical method to solve the challenge, and the method won the first place in this competition. The method was described in a paper in Monthly Notice of Royal Astronomical Society. Recently, we developed a new segmentation and classification algorithm for white blood cells. In another recent paper, we developed a powerful tracking algorithm with camera motion suppression. I have also worked on voice signals with Prof. Moradi, and we developed an algorithm for early detection of autistic kids using cry signal. We are now working on early diagnosis of Parkinson disease.

I co-founded a start-up three years ago and immediately we were able to find an investor. We developed several industrial products, some of them are based on new ideas and methods. The majority of these ideas were proposed and conceptualized by me, and I even involved in developing some of them. Many of these ideas can be patented, but since it is not worth it in Iran we have not started to patent these ideas. One of our important products is a software pipeline for estimating vehicle speed using traffic control cameras. This product has the highest accuracy in Iran and is installed on majority of road cameras. Another important product which is almost ready is automatic call center. In this product, we developed new methods for telephony speech understanding. Another innovation of our company is a method that can give meaningful confidence for the classification, a method which is needed in many industrial applications.

Future Directions

Similar to my accomplishment, my future plans are both fundamental and applied. I am interested in developing new modeling and optimization tools to solve fundamental problems in machine learning. I would also like to develop solutions for industry.

One of the fundamental problems that I recently started to work on and is one my main future research direction is representation learning using deep models. I think many important problems of deep learning models lie in the problem representation learning, for example adversarial robustness, few-shot learning and transfer learning. There are some works on disentangled representation learning, but they are based on some assumptions that are not correct for natural signals. Therefore, I am working on developing Lie-group representation learning that can possibly solve these problems.

Another fundamental problem that I started to work on in our start-up and would like to further develop is developing new methods for sequence-to-sequence mapping like speech recognition and machine translation. Common methods use left-to-right techniques for decoding, but these methods fail in high-noise scenarios like telephony speech. I have some ideas on how to solve the problem by developing methods that do not use left-to-right decoding.

We have developed state-of-the-art algorithms for pose-graph-optimization. These methods can be further developed for structure-from-motion applications. I think, we can propose a new cost function for bundle adjustment that is easier to be solved than the commonly used one and therefore has the potential to give better results. Many of the ideas can be patented and turned into industrial applications for visual odometery and 3D reconstruction.

I also like to continue working on manifold optimization with the emphasis on its application on machine learning. I think manifold optimization can be used for designing methods for large-scale semi-definite programming. Manifold optimization can be used for developing more powerful normalization methods in deep models. Maybe if we look at saturating non-linearities, it is better to use manifold optimization methods because the output space can be considered non-Euclidean. Manifold optimization methods that we developed for GMMs can be used for more powerful latent models of generative models like variational auto-encoders. These methods can also be developed for other non-Gaussian mixture models.