ScienceDirect

Neurocomputing

Volume 543, 28 July 2023, 126198

LIAAD: Lightweight attentive angular distillation for large-scale age-invariant face recognition

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https://doi.org/10.1016/j.neucom.2023.03.059

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Abstract

Disentangled representations have been commonly adopted to Age-invariant Face Recognition (AiFR) tasks. However, these methods have reached some limitations with (1) the requirement of large-scale face recognition (FR) training data with age labels, which is limited in practice; (2) heavy deep network architectures for high performance; and (3) their evaluations are usually taken place on age-related face databases while neglecting the standard large-scale FR databases to guarantee robustness. This work presents a novel Lightweight Attentive Angular Distillation (LIAAD) approach to Large-scale Lightweight AiFR that overcomes these limitations. Given two high-performance heavy networks as teachers with different specialized knowledge, LIAAD introduces a learning paradigm to efficiently distill the age-invariant attentive and angular knowledge from those teachers to a lightweight student network making it more powerful with higher FR accuracy and robust against age factor. Consequently, LIAAD approach is able to take the advantages of both FR datasets with and without age labels to train an AiFR model. Far apart from prior distillation methods mainly focusing on accuracy and compression ratios in closed-set problems, our LIAAD aims to solve the open-set problem, i.e. large-scale face recognition. Evaluations on LFW, IJB-B and IJB-C Janus, AgeDB and MegaFace-FGNet with one million distractors have demonstrated the efficiency of the proposed approach on light-weight structure. This work also presents a new longitudinal face aging (LogiFace) database [1] for further studies in age-related facial problems in future.

Introduction

The research in Age-invariant Face Recognition (AiFR) has gained considerable prominence lately due to the challenges in the nature of human aging and the demand for consistent face recognition algorithms across ages. Indeed, such AiFR algorithms [1] are important in practical applications where there is a significant age difference between probe and gallery facial photos, such as passport verification or missing children identification [2]. However, compared to the state-of-the-art (SOTA) results of stand-alone Face Recognition (FR) algorithms, the performance of AiFR is still very

limited due to the lack of robustly identifiable features stable across ages [3]. In addition, these AiFR algorithms are often evaluated separately from stand-alone FR algorithms, although they are used together in practice.

Disentangled learning representations have been widely used in AiFRs [4], [5], [6], [7], [8]. They, however, have reached some limitations. Firstly, in order to achieve a high accuracy performance, these AiFR methods often adopt heavy deep network architectures with the support of GPU platforms. Then, they require a large-scale FR training set (i.e., multiple images per subject) with *manual age labels*. However, this type of dataset is very limited in the real-world. Indeed, there are many large-scale training face databases without age labels in practice [9], [10], but unusable for training these AiFR models. These disentangled learning-based AiFR methods usually assume that the relationship between the identification and the age attributes can be linearly factorized in a latent or deep feature space. Furthermore, these prior AiFRs are usually evaluated against age-related face databases, e.g. CACD-VS [11], FG-Net [12], IJB-B [13], IJB-C [14], AgeDB [15], CA-LFW [16], and have not been compared against other standard large-scale AiFR benchmarks [17] to guarantee the robustness of the algorithms.

By addressing the aforementioned limitations, this work presents a novel Lightweight Attentive Angular Distillation (LIAAD) approach to Large-scale Lightweight AiFR. Particularly, in order to alleviate the heaviness of a deep network structure while maintaining its accuracy, a Knowledge Distillation framework with two teachers, i.e., heavy high-performance networks, of different specialized knowledge is introduced. One teacher masters the FR task while the other tackles the age estimation task. Then, the attention knowledge about age-invariant facial regions (as shown in Fig. 1) and feature discriminative power from these teachers are distilled to the student via the proposed LIAAD. Consequently, the lightweight student network can naturally and effectively benefit from both teachers' knowledge and become more powerful in both tasks. Intuitively, with the knowledge from the age estimation teacher, the student is guided to focus on the robust facial regions against age changes. At the same time, it is taught by the other teacher to achieve high accuracy on FR tasks. Then by generalizing this knowledge during the training process, the student can be further improved for AiFR tasks.

Contributions. This paper introduces a LIAAD framework for AiFR. The contributions of this work are fivefold. (1) We proposed a novel *Age-Invariant Attentive Distillation and Angular Distillation Losses* for distilling both age-invariant attention and feature direction from various teachers to the student. Since the teachers for different tasks are efficiently trained by the databases of those specific tasks, our LIAAD framework is able to take the *advantages of both* face recognition datasets with and without age labels to train the models to generalize million-scale subjects. (2) Although angular metric has been recently used quite successfully in face recognition, it hasn't been discovered in network distillation problems. Our method looks at the Angular under a new point of view when it is used to translate the learned knowledge. (3) Unlike prior distillation methods that mainly focus on closed-set problems with one or several teachers of the same task, our proposed distillation solution is proved to be even more robust in the *open-set problems*, i.e., large-scale face recognition. (4) The proposed LIAAD approach not only achieves state-of-the-art performance on AiFR databases but also is highly competitive against state-of-the-art face recognition methods on the standard large-scale face recognition benchmarks. (5) Finally, this work introduces a new longitudinal face aging (LogiFace) database that will be made publicly available for further studies in age-related facial problems in the future. To the best of our knowledge, this is one of the first AiFR approaches that allow the use of training face databases with and without age labels together. Table 1 summarizes the difference between our proposed approach and the prior methods.

Section snippets

Age invariant face recognition

Many previous works [4], [6], [7], [8], [27], [28] explored the face invariant features from hand-craft features designed by heuristic to deep features learned by deep neural networks. Juefei-Xu et al. [4] presented a framework that utilizes the periocular region for age-invariant face recognition. Gong et al. [27] introduced a Hidden Factor Analysis (HFA) approach to decompose the latent face representation into age-invariant and age-sensitive latent factors. The process is optimized by using…

Learning with knowledge distillation and age-invariant attentive distillation

This section first describes the general form of the knowledge distillation problem. In order to enhance the student with age-invariant capability while preserving a high accuracy on standard FR, the age-invariant and age-sensitive knowledge are exploited. This knowledge is then transferred to the student through Age-invariant Attentive procedures as shown in Fig. 2. In this way, the first component guides the student to pay more attention to facial regions robust against changes across ages,…

Lightweight attentive angular distillation

In this section, we further analyze the effectiveness of the distillation process. In particular, two important design aspects for FR are considered including (1) *the representation of the distilled knowledge*; and (2) *how to effectively transfer them between the teacher and the student*. We first revise the standard knowledge distillation loss and the softmax loss in the classification problem. Then, we further describe our proposed Angular Distillation Loss and the proposed Lightweight…

Experimental results

This work is evaluated on the standard AiFR datasets and compared against the state-of-the-art methods. Unlike prior AiFR works, the proposed approach is also evaluated on the standard large-scale FR benchmarks and compared against recent lightweight FR methods. In addition, we also present a new longitudinal face aging (LogiFace) database for further studies in face-related problems in the future.…

Discussions

Advantages: Our work presents a novel approach to face-invariant face recognition and gains superiority compared to prior approaches. First, our approach takes advantage of both face recognition datasets with and without age labels. With our proposed distillation framework, our approach is able to improve the age-invariant property and performance of the face recognition models. Second, our approach gives flexibility in choosing a network backbone. In particular, our proposed framework can…

Conclusions

This paper has presented the novel Lightweight Attentive Angular Distillation paradigm for age-invariant open-set face recognition. Our approach aims to strengthen lightweight student networks as powerful as their teachers. Particularly, by adopting the proposed Age-invariant Attentive and Angular Distillation Losses for the distillation of the feature embedding process, the student network can absorb the knowledge of the teacher's hypersphere and age-invariant attention in an efficient manner. …

CRediT authorship contribution statement

Thanh-Dat Truong: Methodology. **Chi Nhan Duong:** Methodology. **Kha Gia Quach:** Methodology, Visualization. **Ngan Le:** Methodology, Supervision, Investigation. **Tien D. Bui:** Writing - review & editing, Methodology, Supervision, Investigation. **Khoa Luu:** Writing - review & editing, Methodology, Supervision, Investigation.…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

Acknowledgement

This work is supported by NSF Data Science, Data Analytics that are Robust and Trusted (DART), Arkansas Biosciences Institute (ABI) Grant Program, and NSF WVAR-CRESH Grant.…

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Chi Nhan Duong is currently a Senior Technical Staff and having research collaborations with both Computer Vision and Image Understanding (CVIU) Lab, University of Arkansas, USA and Concordia University, Montreal, Canada. He had been a Research Associate in Cylab Biometrics Center at Carnegie Mellon University (CMU), USA since September 2016. He received his Ph.D. degree in Computer Science with the Department of Computer Science and Software Engineering, Concordia University, Montreal, Canada. He was an Intern with National Institute of Informatics, Tokyo Japan in 2012. He received his B.S. and M.Sc. degrees in Computer Science from the Department of Computer Science, Faculty of Information Technology, University of Science, Ho Chi Minh City, Vietnam, in 2008 and 2012, respectively. His research interests include Deep Generative Models, Face Recognition in surveillance environments, Face Aging in images and videos, Biometrics, and Digital Image Processing, and Digital Image Processing (denoising, inpainting and super-resolution). He is currently a reviewer of several top-tier journals including IEEE Transaction on Pattern Analysis and Machine Intelligence (TPAMI), IEEE Transaction on Image Processing (TIP), Journal of Signal Processing, Journal of Pattern Recognition, Journal of Pattern Recognition Letters. He is also recognized as an outstanding reviewer of several top-tier conferences such as The IEEE Computer Vision and Pattern Recognition (CVPR), International Conference on Computer Vision (ICCV), European Conference On Computer Vision (ECCV), and the AAAI Conference on Artificial Intelligence. He is also a Program Committee Member of Precognition: Seeing through the Future, CVPR 2019 and 2020.

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Tien Dai Bui is a Distinguished Professor Emeritus in the Department of Computer Science and Software Engineering, Concordia University, Montreal, Canada. He was educated at Carleton University, University of Ottawa and York University. He taught at McGill University from 1971 to 1974, held various positions at Concordia University from Assistant to Full Professor, Chair of the Department, Associate Vice-Rector Research, and member of the Senate and the Board of Governors. Dr. Bui was on the Boards of Directors of the Centre de Recherche Informatique de Montreal Inc. (CRIM), Institut de Recherche sur les Populations (IREP), Institut des Sciences Mathematiques (ISM), and GRIAO. He was also a member of the Committee of Vice-Rectors Research in Quebec (CREPUQ). Dr. Bui has served as Associate Editor of many scientific journals including Signal Processing (EURASIP), Int. Journal of Wavelets, Multi-resolution and Information Processing, and the Journal of Wavelet Applications and Theory. He has given many invited talks and has been a member of the organizing/program committees of many international conferences including the series of Int. Conference on Image Analysis and Recognition (ICIAR), the Int. Conference on Document Analysis and Recognition (ICDAR), the Int. Conference on the Frontier of Hand Writing Recognition (ICFHR). He also served on many national grant selection committees in Quebec and Canada. Professor Bui received various research grants and published more than 250 papers in scientific journals and conference proceedings. He received many Best Paper Awards with his students including the 9th IWFHR award in Tokyo, 2006; the EURASIP award, 2010; the Int. Joint Conference on Biometrics award in Washington DC, 2011. He is co-author of the book Computer Transformation of Digital Images and Patterns (World Scientific, 1989). He has been a visiting professor at Berkeley, Paris V, and the Istituto per le Applicazioni del Calcolo (Rome). His current research interests include image processing and analysis, biometrics, machine learning, pattern recognition, and document analysis.

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1 This database will be made available

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