CENIM 2019

PROCEEDING BOOK

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CENIM 2019

International Conference of Computer Engineering, Network, and Intelligent Multimedia 2019

2019 INTERNATIONAL CONFERENCE ON COMPUTER ENGINEERING, NETWORK AND INTELLIGENT MULTIMEDIA (CENIM)

PROCEEDING

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MESSAGE FROM THE GENERAL CHAIR

Dear All,

Welcome to Surabaya and welcome to our Joint Conference, International Conference on Computer Engineering, Network and Intelligent Multimedia (CENIM 2019)
and The Indonesian Big Data Seminar.

The theme of this joint conference is "Trends on Future Technology in The Era of Internet-of-Things and Big Data to Improve the Quality of Human Life".

I would like to share our happiness since CENIM 2019 is the second international conference that is organized by The Department of Computer Engineering - Institut Teknologi Sepuluh Nopember (DCE-ITS).

This conference has been approved by IEEE for technical co-sponsorship and IEEE ITS Student Branch for sponsorship. This conference is an excellent event where researchers and engineers from academia and industry, from majority locally from Indonesia as well as from abroad, to meet and share their recent findings for the advancement of the field in Computer Engineering and its application.

CENIM 2018 is held along with Konferensi Big Data Indonesia organized by Indonesia Big Data Community. We hope this collaboration can improve the quality of the conference.
In our records, CENIM 2019 has received 79 paper submission with authors coming from 4 different countries. This conference has accepted 40 papers for presentation from 3 countries such as Indonesia, Iran, and Japan.

This Joint Conference has received tremendous help and support from various institutions and teams. Therefore, we would like to thank all the international advisory board and technical program committee (TPC) for their contribution to reviews and selecting high-quality paper.

We would also like to thank Indonesian big data for their generous support and contributions to co-organize the conference. Our gratitude also goes to Institute for Research and Community Service of ITS, distinguished invited speakers who are experts in the topics related to the theme of the conference, and members of the local organizing committee especially Dr. I Ketut Eddy Purnama and Dr. Reza Fuad Rachmadi and their students, for their teamwork in preparing the conference, and all staff member of Department of Computer Engineering.

Lastly, we hope that you can have a great time at the conference, and we wish you a pleasant stay in Surabaya, Indonesia.

Prof. Yoyon K. Suprapto
CENIM 2019 and Indonesian Big Data General Chair

MESSAGE FROM THE RECTOR

Dear ladies and gentlemen,

It is a true pleasure for me to welcome you to Surabaya, to the International Conference on Computer Engineering, Network and Intelligent Multimedia (CENIM) 2019 and to Konferensi Big Data Indonesia 2019.

I am very grateful to have researchers, practitioners, and academics around the world to gather here, to publish, to explore, and to share current research in computer engineering and related fields in modern computer technology.

This is the second time Department of Computer Engineering – Institut Teknologi Sepuluh Nopember Surabaya organizes International Conference on Computer Engineering, Network and Intelligent Multimedia (CENIM); and this year, together with Indonesia's Community of Big Data (id Big Data), it also co-organizes CENIM along with Konferensi Big Data Indonesia 2019.

Industry 4.0 refers to the next step in industrial technology, with robotics, computers and equipment becoming connected to the Internet of Things (IoT), and enhanced by machine learning algorithms. Therefore it is very appropriate that this conference uplifts the theme, "Trends on Future Technology in The Era of Internet-of-Things (IoT) and Big Data to Improve the Quality of Human Life". Institut Teknologi Sepuluh Nopember Surabaya itself is committed to work towards meeting our vision and mission, among which is to actively participate in the development of science and technology. And furthermore, we urge that all research in ITS should have impact through practical applications both in industry and society. Therefore, let us hope that CENIM 2019 and KBI 2019 can pave the way to build this nation's readiness and competitiveness to enter the era of industry 4.0. Through the theme of the conference, we wish that academics, researchers, and industry can meet and discuss on how to make this idea a reality.

Finally, I would like to thank all of those involved in this event, all reviewers, committee, and technical program committee; for their work to realize this event. For all presenters and visitors, I wish you an excellent experience in the conference and a pleasant time in Surabaya.

Thank you.

Prof. Dr. Ir. Mochammad Ashari, M.Eng.
Rector
Institut Teknologi Sepuluh Nopember
Surabaya – Indonesia

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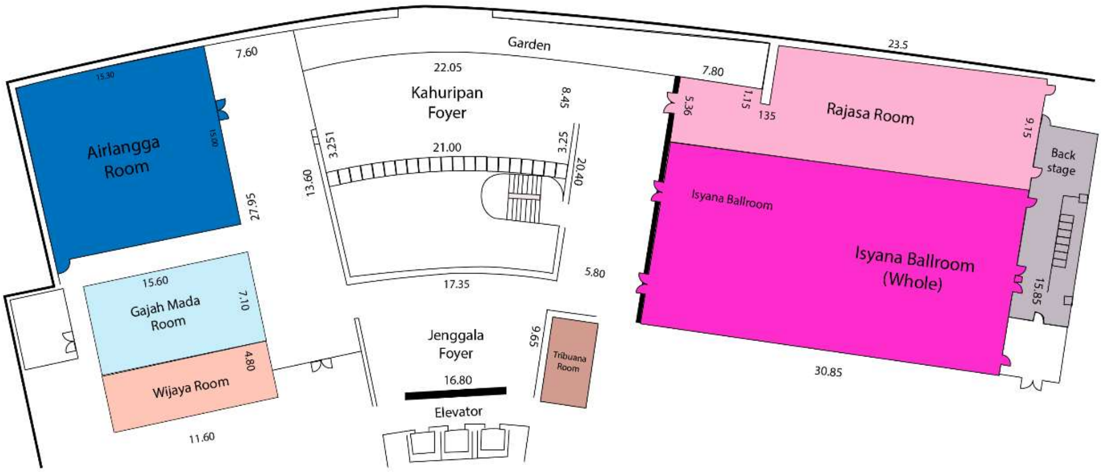

Function Room
Floor Plan

Airlangga Room	Rajasa Room
Gajah Mada Room	Isyana Ballroom
Wijaya Room	Backstage
Tribuana Room	
Kahuripan Foyer, Jenggala Foyer	

Denah : Hotel Bumi Surabaya

GENERAL SCHEDULE

General Schedule, Day 1

Tuesday , 19th November 2019

Time	Agenda	Venue
07.30 - 08.30	Registration	In Front Of Parallel Session Room
09.00 - 09.15	Opening Ceremony	Isyana Room
09.15 - 09.22	Welcome Speech : General Chairs CENIM 2019, Prof. Yoyon Kusnendar Suprapto	Isyana Room
09.22 - 09.30	Welcome Speech : Rector of ITS, Prof. Dr. Ir. Mochamad Ashari, M.Eng.	Isyana Room
09.30 - 09.45	Opening Ceremony Conference, Best Paper Announcement	Isyana Room
09.45 - 09.50	Photo Session	Isyana Room
09.50 - 09.55	Welcome Speech : Chairs of KBI, Sigit Prasetyo	Isyana Room
09.55 - 10.25	Welcome Speech : Vice Governer, Dr. H. Emil Elestianto Dardak, M.Sc	Isyana Room
10.25 - 11.10	1st Keynote Speaker : **Prof. Vanessa Evers**	Isyana Room
11.10 - 11.15	Coffee Break	Isyana Room
11.15 - 12.00	Welcome Speech : Director of PT Envy Technologies Indonesia, Henk Mahendra	Isyana Room

Time	Agenda	Venue
12.00 - 13.00	Break, Lunch, and Pray	Dining Room
13.00 - 13.40	2nd Keynote Speaker : **Assoc. Prof. Mochamad Hariadi**	Isyana Room
14.30 - 16.00	Parallel Session 1 : Oral Presentation	Gajahmada Room, Wijaya Room, and Airlangga Room
18.30 – 21.00	Gala Dinner	Isyana Room

General Schedule, Day 2

Wednesday, 20th November 2019

Time	Agenda	Venue
07.30–08.50	Registration	In front Of Parallel Session Room
09.00 - 10.30	Parallel Session 2 : Oral Presentation	Gajahmada Room, Wijaya Room, and Airlangga Room
10.30 - 10.45	Break	Dining Room
10.45 - 12.15	Parallel Session 3 : Oral Presentation	Gajahmada Room, Wijaya Room, and Airlangga Room.
12.15 - 13.30	Break, Lunch, and Pray	Dining Room
13.30- 15.00	Parallell Session 4 : Oral Presentation	Gajahmada Room, Wijaya Room, and Airlangga Room

- For paper presentations, please prepare the presentation file in the location 15 minutes before the scheduled time.

CENIM – KBI: TECHNICAL SESSION SCHEDULE

Technical Session Schedule Day 1

19-11-2019

	Time		Room		
	Start	End	GajahMada	Airlangga	Wijaya
SESSION 1	14:30	14:52	NET-01	BIO-01	IS-01
	14:52	15:15	NET-02	BIO-02	IS-02
	15:15	15:37	NET-03	BIO-03	IS-03
	15:37	16:00	NET-04		IS-04

Technical Session Schedule Day 2

20-11-2019

	Time		Room		
	Start	End	GajahMada	Airlangga	Wijaya
SESSION 2	9:00	9:22	GAME-01	BIO-04	IS-05
	9:22	9:45	GAME-02	BIO-05	IS-06
	9:45	10:07	GAME-03	BIO-06	IS-07
	10:07	10:30	GAME-04		IS-14
SESSION 3	10:30	10:52	GAME-05	IOT-01	IS-08
	10:52	11:15	GAME-06	IOT-02	IS-09
	11:15	11:37	GAME-07	IOT-03	IS-10
	11:37	12:00		IOT-04	
	ISOMA				
SESSION 4	13:30	13:52	IS-11	IOT-05	
	13:52	14:15	IS-12	IOT-06	
	14:15	14:37	IS-13	IOT-07	
	14:37	15:00		IOT-08	

SESSION 1 – Track: Biomedical Engineering and Its Application

BIO-1 2019-11-19 Airlangga

14:30 – 16:00

Code	Paper ID	Title	Authors
BIO-01	1570586818	Automatic Measurement of Fetal Head Circumference from 2-Dimensional Ultrasound	Cahya Perbawa Aji; Muhammad Hilman Fatoni; Tri Sardjono
BIO-02	1570586914	Disease Classification based on Dermoscopic Skin Images Using Convolutional Neural Network in Teledermatology System	I Ketut Eddy Purnama; Arta Kusuma Hernanda; Anak Agung Putri Ratna; Ingrid Nurtanio; Afif Nurul Hidayati; Mauridhi Hery Purnomo; Supeno Mardi Susiki Nugroho; Reza Fuad Rachmadi
BIO-03	1570563311	Health Level Classification of Motor Stroke Patients Based on Flex Sensor Using Fuzzy Logic Method	Anang Habibi; Supeno Mardi Susiki Nugroho; I Ketut Eddy Purnama; Yudith Dian Prawitri; Imam Subadi

SESSION 1 – Track: Network Technology and Its Application

NET-1 2019-11-19 Gajahmada

14:30 – 16:00

Code	Paper ID	Title	Authors
NET-01	1570563274	Deploying Scalable Face Recognition Pipeline Using Distributed Microservices	Tahta Dari Timur; I Ketut Eddy Purnama; Supeno Mardi Susiki Nugroho
NET-02	1570587371	Construction of Churn Prediction Model Using Human Voice Emotions Features Based on Bayesian Belief Network	Febri Dwi Cahaya Putra; Agustinus Bimo Gumelar; Immah Inayati; Lukman Junaedi; Ferial Hendrata; Rizky Davit Nugroho; Randy Anwar Romadhonny; Wahyu Putra Adi Setiawan; Siska Susilowati
NET-03	1570583381	DTE: Dynamic Traffic Engineering in Software Defined Data Center Networks	Farshad Tajedin; Mohammad Farhoudi; Aliehsan Samiei; Behzad Akbari
NET-04	1570581817	A Shared Secret Key Generation between Vehicle and Roadside Based Preprocessing Method	Amang Sudarsono; Mike Yuliana; Prima Kristalina

SESSION 1 – Track: Intelligent System and Its Applications

IS-1 2019-11-19 Wijaya

14:30 – 16:00

Code	Paper ID	Title	Authors
IS-01	1570576749	Sentiment Analysis of Customer Satisfaction on Transportation Network Company Using Naive Bayes Classifier	Eka Yulia Sari; Akrilvalerat Deainert Wierfi; Arief Setyanto
IS-02	1570582412	Minimizing the Losses and the Cost of a Radial Network using Firefly algorithm: a real case study Diesel-PV-Batteries Hybrid system of Tomia island, South East Sulawesi, Indonesia	Mohamed Elsayed Shiybahelhamd Abdelwareth; Imam Robandi; Dedet Riawan; Rony Seto Wibowo
IS-03	1570583227	Fish Quality Recognition using Electrochemical Gas Sensor Array and Neural Network	Muhammad Rivai; Misbah; Muhammad Attamimi; Muhammad Hamka Firdaus; Tasripan; Tukadi
IS-04	1570585200	Comparison of Difference, Relative and Fractional Methods for Classification of The Black Tea Based on Electronic Nose	Danang Lelono; Andi Dharmawan; Triyogatama Wahyu Widodo; Jazi Eko Istiyanto; Hanif Nuradi; Muhammad Satriyo

SESSION 2 – Track: Biomedical Engineering and Its Application 2

BIO-2 2019-11-20 Airlangga

09:00 – 10:30

Code	Paper ID	Title	Authors
BIO-04	1570583983	Volumetric Analysis of Brain Tumor Magnetic Resonance Image	Hapsari Peni Agustin Tjahyaningtijas; Hanik Hidayati; Adri Gabriel Sooai; I Ketut Eddy Purnama; Mauridhi Hery Purnomo
BIO-05	1570576408	Screening of Non-overlapping Apnea and Non-apnea from Single Lead ECG-apnea Recordings using Time-Frequency Approach	Iman Fahruzi; I Ketut Eddy Purnama; Mauridhi H Purnomo
BIO-06	1570575403	Facial Model Deformation Based on Landmarks Using Laplacian	Ongki Permono Aji; I Ketut Eddy Purnama; Eko Mulyanto Yuniarno

SESSION 2 – Track: Game Technology

GAME-1 2019-11-20 Gajahmada

09:00 – 10:30

Code	Paper ID	Title	Authors
GAME-01	1570583985	Development of Casual Game on Android Devices for Children with Diabetes Type 1 Treatment	Susi Juniastuti; Husni Mubarok Al Ghifari; Supeno Mardi Susiki Nugroho; I Ketut Eddy Purnama
GAME-02	1570587261	Virtualization and Exploration of the Garudeya Historical Objects Using Immersive Devices	Surya Sumpeno; Yanuar Achmadianto; Diana Purwitasari; Ahmad Zaini
GAME-03	1570583986	Design and Implementation Serious Game "Tic Tac Toe Math"	Muhammad Hendyas Garry; Yuni Yamasari; Supeno Mardi Susiki Nugroho; Mauridhi Hery Purnomo
GAME-04	1570587269	Explorable Virtual Diorama of Indonesian Prehistoric Human Life using Apple ARKit based Mixed Reality	Surya Sumpeno; Diana Purwitasari; Bima Panji

SESSION 3 – Track: Game Technology 2

GAME-2 2019-11-20 Gajahmada

10:45 – 12:15

Code	Paper ID	Title	Authors
GAME-05	1570585957	Self-Physical Rehabilitation System based on Hand Motion Sensor	Supeno Mardi Susiki Nugroho; M. Fauzan; I Ketut Eddy Purnama
GAME-06	1570587310	Class VR: Learning Class Environment for Special Educational Needs using Virtual Reality Games	Arik Kurniawati; Ari Kusumaningsih; Iman Hasan
GAME-07	1570570545	Immersive Hand Gesture for Virtual Museum using Leap Motion Sensor Based on K-Nearest Neighbor	Surya Sumpeno; Gede Dharmayasa; Diana Purwitasari; Supeno Mardi Susiki Nugroho

SESSION 3 – Track: Internet-of-Things

IOT-1 2019-11-20 Airlangga

10:45 – 12:15

Code	Paper ID	Title	Authors
IOT-01	1570570995	Development of Mobile Applications and Low Cost Portable Pesticide Residue Detector using Visible Light Spectroscopy	Ferriady Setiawan; Muhammad A. A. E. Assaidi; Dasi E. Akbar; Richard Mengko
IOT-02	1570581898	Footsteps Counter Using Variances Analysis of Three-Dimensional Accelerometer Data	Arief Kurniawan; Jalaluddin Al-Mursyidy Fadhlurrahman; Eko Mulyanto Yuniarno
IOT-03	1570587257	Development of Fatigue Detection Device Based On IR-UWB and Optic Sensor to Driver	Hanny Boedinoegroho; Adrian Kusuma Rahardjo; Arief Kurniawan; I Ketut Eddy Purnama
IOT-04	1570583151	Cellphone Awareness Inside Vehicles Using Embedded Device And Android Application	Tashfiq Rahman; Ahmad Zaini; Chonlameth Arpnikanondt; Arief Kurniawan

SESSION 4 – Track: Internet-of-Things 2

IOT-2 2019-11-20 Airlangga

13:30 – 15:00

Code	Paper ID	Title	Authors
IOT-05	1570578658	Prototype of Driving Behavior Monitoring System Using Naïve Bayes Classification Method	Eko Pramunanto; Ahmad Zaini; Vathya Rizkiana
IOT-06	1570587275	Development Mobile Application for Cattles Health Monitoring Based On Cloud Computing	Supeno Mardi Susiki Nugroho; Yohandi Bima Saputra; I Ketut Eddy Purnama
IOT-07	1570587281	Long Range Monitoring System with Haze Reducer Tool Based Digital Image and Video Processing	Ahmad Zaini; Eko Mulyanto Yuniarno; Bramantio Hilmiawan
IOT-08	1570587289	Integrated Smart Safety Home System based on Wireless Sensor Network and Internet of Things as Emergency Preventive Efforts in Settlement Areas	Eko Pramunanto; Muhtadin Muhtadin; William Febrian

SESSION 2 – Track: Intelligent System and Its Applications 2

IS-2 2019-11-20 Wijaya

09:00 – 10:30

Code	Paper ID	Title	Authors
IS-05	1570577208	The Obstacle Avoidance System In A Fixed-Wing UAV When Flying Low Using LQR Method	Andi Dharmawan; Wahyu Wicaksono; Agfianto Eko Putra; I Made Tresnayana
IS-06	1570585217	Model Prediction Control for Missile Autopilot and Navigation	Tommy Pratama; Rusdhianto Effendi Abdul Kadir; Zulkifli Hidayat
IS-07	1570585868	Missile Guidance Design Using Sliding Curve Method	Leonard Wihardi; Rusdhianto Effendi Abdul Kadir; Zulkifli Hidayat
IS-14	1570587214	Autonomous Navigation And Obstacle Avoidance For Service Robot	Muhtadin Muhtadin; Raden Marwan Zanuar; Ketut Purnama

SESSION 3 – Track: Intelligent System and Its Applications 3

IS-3 2019-11-20 Wijaya

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Code	Paper ID	Title	Authors
IS-08	1570581203	Combining Photometric Features and Relative Position to Detect and Track Target Person	Bima Sena Bayu Dewantara; Jun Miura
IS-09	1570584211	Comparison of simple and stratified random sampling on porn videos recognition using CNN	I Wayan Agus Arimbawa; I Gede Pasek Suta Wijaya; Ilham Bintang
IS-10	1570586154	Improving Lightweight Convolutional Neural Network for Facial Expression Recognition via Transfer Learning	Anggit Wikanningrum; Reza Fuad Rachmadi; Kohichi Ogata

SESSION 4 – Track: Intelligent System and Its Applications 4

IS-4 2019-11-20 Gajahmada

13:30 – 15:00

Code	Paper ID	Title	Authors
IS-11	1570580518	Human Bone Localization in Ultrasound Image Using YOLOv3 CNN Architecture	R Arif Firdaus Lazuardi; Tita Karlita; Eko Mulyanto Yuniarno; I Ketut Eddy Purnama; Mauridhi Hery Purnomo
IS-12	1570584944	Pelican Crossing Adaptive Time Arrangement using Convolutional Neural Network	Randy Putra Resha; Reza Fuad Rachmadi; Supeno Mardi Susiki Nugroho; I Ketut Eddy Purnama
IS-13	1570574962	Gamelan Notation Generating Using Band Pass Filter for Saron Instrument	Yoyon Suprapto; Eko Mulyanto Yuniarno; Kafiyatul Fithri

2019 International Conference of Computer Engineering, Network, and Intelligent Multimedia (CENIM)

Improving Lightweight Convolutional Neural Network for Facial Expression Recognition via Transfer Learning

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†Department of Computer Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
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***Abstract*—Image-based facial expression recognition is an important problem especially for analyzing the human emotion or feeling under a specific condition, such as while watching a movie scene or playing a computer game. Furthermore, the convolutional neural network (CNN) is one of the underlying technology proven to be applicable to image-based facial expression recognition problem. Unfortunately, the available CNN architecture that applied for image-based facial expression recognition problem only focuses on the accuracy instead of other factors, such as the number of parameters and the execution time. In this paper, we investigated whether transfer learning from a medium-size and large-size dataset is feasible to improve the performance of lightweight CNN architecture on image-based facial expression recognition problem. We use lightweight residual-based CNN architecture originally used for CIFAR dataset to analyze the effect of the transfer learning from five different datasets, including CIFAR10, CIFAR100, ImageNet32, CINC-10, and CASIA-WebFace. The FER+ (Facial Expression Recognition Plus) dataset is used to evaluate the lightweight CNN architecture performance. Experiments show that our lightweight CNN classifier can also be improved even when the transfer learning performing from middle-size dataset comparing when training the classifier from scratch.**

***Index Terms*—facial expression recognition, lightweight deep convolutional neural network, transfer learning**

I. Introduction

Image-based facial expression recognition is one of the important problems and can be applied for a lot of applications, including movie scene analysis, human-robot interaction, and human physiology understanding. The demand of solving image-based facial expression recognition makes researchers to propose several different image-based human facial expression recognition datasets, including FER (Facial Expression Recognition) [1], FER+ [2], CK (Cohn-Kanade) [3], and CK+ [4]. With the availability of the facial expression recognition dataset, the researcher proposed some state-of-the-art method for image-based facial expression recognition problem, including deep-learned Tandem Facial Expression (TPR) [5], adaptive deep metric learning [6], joint fine tuning [7], VGG19 [2] and inception [8]. As the popularity of deep learning, all state-of-the-art approaches on image-based facial expression recognition problem use deep CNN as their main method. One of the advantages of deep learning method is the transfer learning mechanism capability. There are two different things that need to be noted when using deep learning, the computation power needed for the model and the size of the model. Usually, the deep learning method for image-based facial expression recognition problem will have more parameters by extending the network to improve the performance of the classifier [5]–[7]. As far as we concern, no one tries to perform image-based facial expression recognition problem under limited resource assumption and design the classifier with a minimum number of parameters.

In this paper, we investigated the effect of transfer learning mechanism from a middle-size dataset and huge-size dataset on image-based facial expression recognition problem. Firstly, we utilize lightweight residual-based CNN architecture [9] originally used for CIFAR dataset on the medium-size and large-size dataset and secondly we fine-tuning the classifier using FER+ dataset [2]. We assume that the lightweight CNN model will have the maximum number of parameters roughly around 1 million. Our contributions can be listed as follows

- We have investigated the effect of transfer learning mechanism for residual-based lightweight CNN architecture [9] on image-based facial expression recognition problem using FER+ dataset [2].
- We use several different datasets which categorize as a medium-size dataset (CIFAR [10] and CINC-10 [11]), and large-size dataset (ImageNet32 [12]) as the source of the weights for the fine-tuning process. We also investigated the transfer learning from the relatively same domain by using CASIA-WebFace dataset as the source of the weights for the fine-tuning process.
- We proved that transfer learning from a medium-size dataset can also improve the performance of the classifier on image-based facial expression recognition problem.

The rest of the paper organizes as follows. Section II described the related work on image-based facial expression recognition problem and transfer learning. The experiments setup and the results described in section III and IV respectively. Lastly, we conclude the experiments in section V.

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II. Related Work

In this section, we described the related work on image-based facial expression recognition and the transfer learning method.

A. Image-based facial expression recognition

Image-based facial expression recognition task has been one of the long-term research topics on computer vision field. In the era of deep learning, almost all of the approaches on image-based facial expression recognition are based on deep CNN classifier, including deep-learned Tandem Facial Expression (TPR) [5], adaptive deep metric learning [6], joint fine-tuning [7], VGG19 [2] and inception [8]. Barsoum et. al. [2] and Mollahoseseini et. al. [8] use state-of-the-art CNN architecture to solve image-based facial expression recognition problem. Barsoum et. al. [2] utilize VGG19 CNN architecture with additional label disrupted method to improve the accuracy of the classifier on FER+ dataset. Similar to Barsoum et al. [2] but different CNN architecture, Mollahoseseini et. al. [8] use Inception network to solve the facial expression recognition problem. Li et. al. [5] proposed joint fine-tuning of classifier (called Tandem Facial Expression-Joint Learning or TFE-JL) for face recognition and facial expression recognition by concatenating the high-level features of the classifier and add a fully-connected layer for computing the final classification score. Experiments on FER+ and CK+ dataset show that TFE-JL achieves state-of-the-art performance on CK+ and FER+ dataset. Liu et. al. [6] proposed a similar method but with a different strategy. They use Inception CNN classifier as a basis of their classifier, train the classifier on FER2013 dataset, and fine-tuning the network with additional triplet loss function attached at the end of the classifier.

B. Transfer learning

Transfer learning is a popular method to solve a lot of applications, including methods described in [13]–[16]. Yosinski et al. [13] investigate the transferability of deep features in the transfer learning scenario. To conduct the experiments, they create several scenarios by freezing weights on several layers and learning weights on other layers. Experiments conducted by Yosinski et al. [13] show that initializing using transferred features can improve the performance of the classifier. Ng et al. [14] perform transfer learning from ImageNet weights for emotion recognition. They use VGG-based CNN architecture to perform the experiments. Experiments on FER-2013 and EmotiW dataset show that CNN classifier with transferred features improves the performance of the classifier. Research conducted by Huh et al. [15] try to investigate what makes ImageNet good for transfer learning. Experiments on several problems, including image classification, object detection, and action recognition, show that pre-trained weights from full or selected ImageNet data will produce around the same performance which concluded that the CNN classifier is not required very large dataset as excepted before. Han et al. [16] investigate the transfer learning method with additional data augmentation taken from the web. Three classifiers are used in the experiments, including AlexNet, VGG16, and ResNet-152, and seven different datasets are used as the target of transfer learning, including Dogs dataset, Flower-102, Caltech-101, Event-8, 15 Scene, and 67 Indoor scenes. The experiments show that the classifier with pre-trained ImageNet weights produces higher accuracy comparing with the classifier trained from scratch and the data augmentation from web improve the performance of the classifier around 2%.

TABLE I
LIGHTWEIGHT CNN ARCHITECTURE BASED ON RESIDUAL NETWORK (ADOPTED FROM [9]).

	Num of Kernels		
	$k = 16$	$k = 32$	$k = 64$
Residual Network	$2n + 1$	$2n$	$2n$

*) n denote the number of residual module.

C. Remarks

As discussed before, all approaches for facial expression recognition are made for accuracy and the investigation about the lightweight CNN architecture for facial expression recognition problem is not well studied. In our opinion, lightweight CNN architecture is also important because if the facial expression recognition problem can be solved with around the same accuracy as the deeper CNN architecture, the lightweight CNN can be one of the choices to implementing the facial expression recognition system in real-world applications.

III. Experiments Setup

All of the experiments conducted using Caffe deep learning framework [17] and FER+ dataset [2] as the main data for evaluating the performance of lightweight CNN.

A. Lightweight CNN

In this paper, we use lightweight CNN architecture for facial expression recognition. The lightweight CNN is used to investigate whether the lightweight CNN architecture is feasible for facial expression recognition application. One advantage of lightweight CNN is that the classifier can easily implement in the embedded system. Follows the success of residual network CNN architecture [9], we adopted two residual networks originally used for CIFAR dataset, including ResNet-20 and ResNet32 CNN classifier. Table I shows the configuration protocol for constructing the lightweight CNN architecture. We use $n = 3$ (ResNet-20) and $n = 5$ (ResNet-32) to constructing the classifier and attaching a final fully-connected layer at the end of the classifier. To performs the transfer learning, we use network-based transfer learning method by pretraining weights of source domain dataset (e.g. CIFAR10 weights or CIFAR100 weights) on FER+ dataset directly and only changes the final layer of the CNN architecture.

TABLE II
SUMMARY OF OUR EXPERIMENTS ON FER+ DATASET (AVERAGING FROM FIVE ITERATIONS).

No	Method	Num Params	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
1	ResNet-20	280K	79.32	78.06	78.46	78.86	78.49	78.64
2	ResNet-20 Finetuned from CIFAR10		82.43	81.64	81.76	82.34	81.85	82.00
3	ResNet-20 Finetuned from CIFAR100		82.55	81.79	82.04	82.04	81.82	82.05
4	ResNet-20 Finetuned from ImageNet32		79.96	79.19	79.29	79.19	80.17	79.56
5	ResNet-20 Finetuned from CINIC-10		82.40	82.52	82.00	82.68	82.71	82.46
6	ResNet-20 Finetuned from CASIA-WebFace		80.97	81.33	81.27	80.60	82.10	81.25
7	ResNet-32	474K	79.68	79.93	80.11	79.99	80.11	79.96
8	ResNet-32 Finetuned from CIFAR10		83.81	84.05	84.14	84.05	83.53	83.92
9	ResNet-32 Finetuned from CIFAR100		83.50	83.32	83.26	82.86	82.55	83.09
10	ResNet-32 Finetuned from ImageNet32		78.50	78.22	79.41	79.16	78.95	78.85
11	ResNet-32 Finetuned from CINIC-10		83.75	83.17	83.99	82.55	83.62	83.42
12	ResNet-32 Finetuned from CASIA-WebFace		81.45	82.89	82.28	81.42	82.04	82.02

Fig. 1. Examples of face images on FER+ dataset.

B. FER+ Dataset

To evaluate the lightweight CNN classifier, we use FER+ facial expression recognition dataset. FER+ dataset is an improvement version of FER2013 dataset. The FER2013 dataset was created by Pierre Luc Carrier and Aaron Courville by searching face images on the internet based on emotion-related keywords. The reports provided by Goodfellow et al. [1] show that even the label on FER2013 dataset was filtered by human labelers, the label accuracy is not very high. Barsoum et al. [2] proposed dataset called FER+ dataset by re-label the FER2013 dataset using crowdsourcing and adding some several additional images to the dataset. The FER+ dataset consists of 32,615 face images with 8 different emotion types, including neutral, happiness, surprise, sadness, anger, disgust, fear, and contempt. The dataset is divided into three subsets, 26,029 face images for the training process, 3,274 face images for the validation process, and the rest of the face images are used for the testing process. Figure 1 shows face images examples on FER+ dataset along with the emotion label.

C. Training Process

The training process is done using two steps, training the model using domain source dataset (including CIFAR10, CIFAR100, ImageNet32, CINIC-10, and CASIA-WebFace) and fine-tuning the weights on FER+ dataset. Follow the strategy of residual network training process on CIFAR dataset, we do not apply data augmentation for the training process on domain source dataset except the random region cropping. For CIFAR10 and CIFAR100 dataset, we padded the image using zero paddings for 4 pixels and performs a random 32×32 region cropping. Instead of using zero paddings, we resize the image into 36×36 and performs a 32×32 random cropping for other domain source datasets. The training process on domain source dataset is done around 20-60 epochs depending on the size of the dataset.

The fine-tuning process (the second steps) is done for around 8 epochs using NAG (Nesterov Accelerated Gradient) with learning rate initialized at 0.01 and decreased by a factor of 0.1 at epoch 4 and epoch 6. The dataset for training process was balanced such that each class will have the same amount of examples by performing data augmentation, including random rotation, noise, and random translation. Unlike Barsoum et al. [2] approaches, we only use the majority voting label of the human labelers on FER+ dataset.

D. Testing Process

The testing process performs by resizing the input face into 36×36, cropping the image into ten 32×32 cropped region, and substracted the region by the training data mean value. All cropped regions were classified using the lightweight CNN classifier and the final classification score was calculated by averaging the prediction score of all cropped regions. The same process is used for the experiments using an ensemble of lightweight CNN classifier.

IV. RESULTS

We divide this section into two subsections, the results of experiments using single classifier and ensemble classifier. The

TABLE III
SUMMARY OF OUR EXPERIMENTS USING ENSEMBLE LIGHTWEIGHT CNN CLASSIFIER ON FER+ DATASET (AVERAGING FROM FIVE ITERATIONS). THE NUMBER PROVIDED IN THE ENSEMBLE CONFIGURATION IS BASED ON TABLE II.

No	Method	Num Params	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
1	Ensemble (2) + (3)	560K	83.26	82.65	83.17	82.83	82.46	82.87
2	Ensemble (3) + (5)		83.41	83.38	83.04	83.62	82.71	83.23
3	Ensemble (2) + (5)		83.62	83.01	83.04	83.47	83.38	83.304
4	Ensemble (2) + (3) + (5)	840K	83.68	83.32	83.29	83.32	83.35	83.39
5	Ensemble (8) + (9)	948K	84.17	84.48	84.45	84.3	84.05	84.29
6	Ensemble (8) + (11)		84.2	84.11	84.51	84.33	84.36	**84.30**
7	Ensemble (9) + (11)		84.17	83.84	84.33	83.59	84.02	83.99
8	Ensemble (2) + (3) + (8)	1034K	84.02	84.14	84.14	84.02	83.93	84.05
9	Ensemble (3) + (5) + (8)		83.96	84.3	83.87	84.2	83.65	83.99
10	Ensemble (2) + (5) + (8)		84.11	84.14	84.05	84.17	84.05	84.10
11	Ensemble (2) + (3) + (9)		83.96	83.96	83.87	83.78	83.29	83.77
12	Ensemble (3) + (5) + (9)		83.96	83.96	83.87	83.78	83.29	83.77
13	Ensemble (2) + (5) + (9)		83.68	83.56	83.81	83.9	83.35	83.66

summary of experiments using single classifier and ensemble of classifiers can be viewed in Table II and III.

A. Single Classifier

As shown in Table II, two lightweight CNN architectures produce mean accuracy near 80% which is considered very good accuracy on FER+ dataset. The ResNet-32 is superior comparing with ResNet-20 which is very reasonable due to more number of parameters existed in the classifier. The transfer learning method from several domain source datasets improved the performance of the classifier except when the transfer learning performed from ImageNet32 weights. One possible reason is that the ImageNet32 weights are not generalized the dataset (indicated by low training accuracy) and it affected the transfer learning process. The best accuracy of ResNet-20 classifier is achieved when trained using transfer learning from CINIC-10 weights while the best accuracy of ResNet-32 classifier is achieved when trained using transfer learning from CIFAR10 weights. The highest accuracy of single classifier (83.92%) is just around 1% lower than the accuracy reported by Barsoum et al. [2] which using deep VGG13 classifier.

B. Ensemble Classifiers

To improve the performance of the classifier, we also conducted experiments using 13 different ensemble configurations with the assumption that the maximum number of parameters is roughly around 1 million parameters. Table III shows the summary of the experiments using 13 ensemble configuration with the number in the ensemble configuration is the classifier order in Table II. As shown in Table III, the ensemble configuration consistently increases the performance of the classifier around 1% compared with single classifier configuration. Although some ensemble classifier has a higher number of parameter compared with other ensemble configurations, the best accuracy produces by Ensemble (8) + (11) configuration with an accuracy of 84.30%. The Ensemble (8) + (11) configuration combined two same CNN architecture but trained using different domain source dataset. Figure 2 shows the confusion matrix of Ensemble (8) + (11) classifier with a global accuracy of 84.30%. The average class accuracy of Ensemble (8) + (11) is 68.75% which is lower compared with global accuracy due to the unbalance testing dataset.

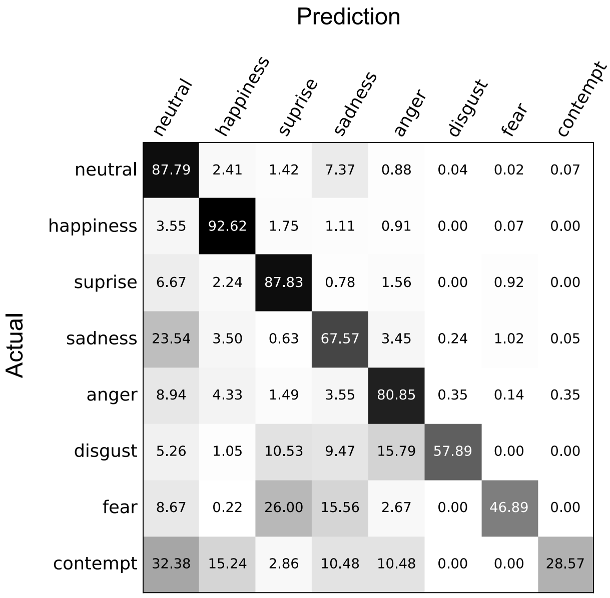

Fig. 2. Confusion matrix for Ensemble (8) + (11) configuration with accuracy of 84.30%.

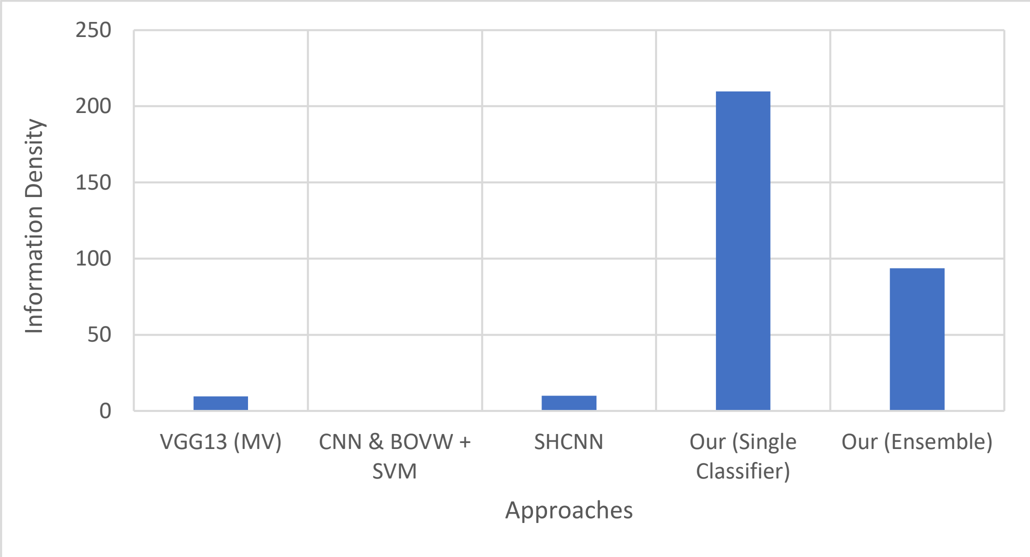

Fig. 3. Information density comparison for several state-of-the-art methods on FER+ dataset (higher is better). Only methods that reported the number of parameters is shown.

C. Comparison

To get a better understanding about the performance of lightweight CNN architecture, we compare the results with several state-of-the-art methods, including VGG13 [2], TFE-JL [5], CNN and BOVW + global SVM [18], SHCNN [19], and STL + Laplacian RTNN [20]. Table IV shows the comparison between our lightweight CNN classifier with five state-of-the-art methods on FER+ dataset along with the information about the number of parameters. As shown in Table IV, our lightweight CNN classifier can outperform VGG13 with majority voting label training reported by Barsoum et al. [2], produces the same accuracy as TFE-JL method, but still lower from other methods.

To further see the effects of the number of parameters in the classifier, we included information (if reported) about the number of parameters in the classifier. As shown in Table IV, our lightweight CNN classifier has the lowest number of parameters compared with other approaches. For comparing the effectiveness of the classifier, we compute the information density of the classifier. The information density is a metric described as a ratio between the performance of the classifier (%) and the number of parameters (in million) which can be written as follows

$$D = \frac{p_c}{n_p} \tag{1}$$

with D is the information density, p_c is the performance of the classifier in percentage, and n_p is the number of parameters in the classifier (in million). The metric is also used in [21]–[23] for evaluating the effectiveness of the classifier. Figure 3 shows the information density value comparison for several state-of-the-art methods on FER+ dataset. As shown in Figure 3, our lightweight CNN classifier has way more information density value comparing with several other state-of-the-art methods. Unfortunately, not all state-of-the-art methods on FER+ dataset reported the number of parameters in their classifier.

TABLE IV
COMPARISON OF ENSEMBLE OF LIGHTWEIGHT CNN ARCHITECTURE WITH SEVERAL STATE-OF-THE-ART METHOD ON FER+ DATASET.

Method	**#Params**	**Acc.**
VGG13 (MV) [2]	8.75M	83.8%
TFE-JL [5]	n/a	84.30%
CNN and BOVW + global SVM [18]	300M+	87.76%
SHCNN [19]	8.7M	86.45%
STL + Laplacian RTNN [20]	n/a	88.16%
Our Single Classifier (Best)	0.4M	83.92%
Our Ensemble Classifier (Best)	0.9M	84.30%

V. CONCLUSION

In this paper, we present our investigation of lightweight CNN architecture for facial expression recognition problem. We utilize two lightweight CNN architectures, ResNet-20 and ResNet-32, and improve the performance of classifier via transfer learning and ensemble configuration. Several domain source datasets, including CIFAR, CINIC-10, ImageNet32, and CASIA-WebFace are used as domain source dataset on the transfer learning process. Experiments on FER+ dataset show that the lightweight CNN architecture can produce a very good accuracy and by ensembling the classifier, the accuracy can further be improved and the results are comparable with several state-of-the-art methods. The domain source dataset is not very demanding for transfer learning and from experiments we can see that the relatively same domain problems dataset (CASIA-WebFace) produces lower accuracy compared with other domain source dataset. Although our classifier does not produce the highest accuracy on FER+ dataset, the information density of our lightweight CNN classifier is very high compared with several other state-of-the-art methods.

Joint transfer learning training and weighted ensemble configuration is our concern for future work of this research to improve the performance of the classifier. Several other facial expression datasets are also demanding to analyze using transfer learning method and lightweight CNN architecture.

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