RGC Ref. No.:
UGC/FDS13/E02/18
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:
1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
2. *Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

Meteorological Visibility Estimation by using Particle Swarm Optimization and Neural Network

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	**Name / Post**	**Unit / Department / Institution**
Principal Investigator	Prof. LO Wai Lun	Head of Dept, Dept. of Computer Science, Chu Hai College of Higher Education
Co-Investigator(s)	Prof. Henry Shu Hung CHUNG	Chair Professor, Dept. of Electrical Engineering, City University of Hong Kong
Co-Investigator	Prof. Hong FU (1 Jan 2019 - 30 Jun 2020)	Professor, **Last post in CHCHE* Dept. of Computer Science, Chu Hai College of Higher Education

3. Project Duration

	Original	**Revised**	**Date of RGC / Institution Approval** *(must be quoted)*
Project Start Date	1 Jan 2019	1 Jan 2019	NA
Project Completion Date	31 Dec 2020	30 Jun 2021	9 Oct 2020
Duration *(in month)*	24 months	30 months	9 Oct 2020
Deadline for Submission of Completion Report	31 Dec 2021	30 Jun 2022	9 Oct 2020

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. Develop a Modified Particle Swarm Optimization (PSO) algorithm which can be operated efficiently in a High-Performance Computing (HPC) cluster environment for the problem of Meteorological Visibility Estimation
2. Development a hardware visibility monitoring system with visibility meters and digital cameras to obtain weather photos and visibility readings at a chosen site. The data obtained acts as reference model for data training of Artificial Neural Network. Hence, a large image database can be built for the visibility estimation at a chosen site.
3. Investigate and develop an intelligent image extraction algorithm to extract effective image regions from the image database developed in (2)
4. Design an Artificial Neural Network training algorithm by using PSO obtained in (1) to extract image features from the results obtained in (3)
5. Develop an Artificial Neural Network Training algorithm to correlate the image features in (4) with the Meteorological Visibility and to develop an intelligent Meteorological Visibility Estimation Algorithm.
6. Evaluate the Intelligent Meteorological Visibility Estimation systems developed in (5)

5.2 Revised objectives

Date of approval from the RGC:	NA
Reasons for the change:	NA

5.3 Realisation of the objectives
(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

In this project, we have fully achieved the objectives 1-6 as shown in part 5.1. The achievement of project objectives 1 to 6 led to the research publications 1-4.

Journal Publications

[1] **Wai Lun LO**, Meimei ZHU and Hong FU: "Meteorological Visibility Estimation by using Multi-Support Vector Regression Method", **Journal of Advances in Information Technology**, Vol.11, No. p. 40-47, 2 May 2020.

[2] Jiaping Li; **Wai Lun LO**; Hong Fu; Henry Shu Hung Chung: "A Transfer Learning Method for Meteorological Visibility Estimation Based on Feature Fusion Method", **Applied Science (IF=3.02)**, Volume 11, Issue 3, 997, Jan 2021

[3] **Wai Lun LO**, Henry Shu Hung Chung and Hong FU: "Experimental Evaluation of PSO based Transfer Learning Method for Meteorological Visibility Estimation" **Atmosphere (IF=2.68)**, Vol. 12, Issue 7, 828, Jun 2021.

Conference publication

[4] **Wai Lun LO**, Meimei ZHU and Hong FU: "Meteorological Visibility Estimation by using Multi-Support Vector Regression Method", The 12th International Conference on Advanced Computer Theory and Engineering (ICACTE 2019), JARKATA, Indonesia, 18-22 Sep 2019

We have developed a Modified Particle Swarm Optimization (PSO) algorithm which can be operated efficiently in a High-Performance Computing (HPC) cluster environment for the problem of Meteorological Visibility Estimation. The achievement of project objective (1) led to the research outcomes in form of the journal publications [3]. The modified PSO algorithm has been applied to the optimization of Artificial Neural Network for Visibility Estimation.

The PI and Co-Is have supervised the Research Assistants to develop a hardware visibility monitoring system (VMS) with visibility meters and digital cameras to obtain weather photos and visibility readings at the campus site. The data obtained acts as reference model for data training of Artificial Neural Network. We have built a visibility database with weather photos by using the data collected by the VMS, from which the evaluation of the proposed Artificial Neural Network training and visibility estimation algorithms could be evaluated. The achievement of project objective (2) led to the research outcomes in form of journal publications [3].

In this project, the project team has investigated and developed intelligent image extraction algorithms to extract effective image regions from the image database developed in project objective (2). In the proposed method, we have integrated the image-grey averaging and the adaptive threshold methods for effective image regions extraction. The project team has designed and developed an Artificial Neural Network (ANN) training algorithm by using PSO to extract image features from the results obtained in project objective (3). In this project, we have developed the ANN Training algorithms to correlate the image features with the Meteorological Visibility and the intelligent Visibility Estimation Algorithms. We have also built a visibility database by using the data collected by the VMS and the data provided by Hong Kong Observatory (HKO). The research results have been published in journal [1-3]. Finally, we have evaluated the Intelligent Meteorological Visibility Estimation systems developed in project objective (5). The research results were published in the journal [3]. Furthermore, the PI has published the research results in the conference paper [4] and the PI also obtained the BEST PRESENTATION AWARD in the ICACTE 2019 conference.in an international conference.

In conclusion, in this project, we have developed the new Multi-Support Vector Regression Method for visibility estimation [1], a new Transfer Learning Method for Meteorological Visibility Estimation Based on Feature Fusion Method [2] and carried out the experimental evaluation of PSO based Transfer Learning Method for Meteorological Visibility Estimation [3].

5.4 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. Develop a Modified Particle Swarm Optimization (PSO) algorithm which can be operated efficiently in a High-Performance Computing (HPC) cluster environment for the problem of Meteorological Visibility Estimation	✓	100%
2. Development a hardware visibility monitoring system with visibility meters and digital cameras to obtain weather photos and visibility readings at a chosen site. The data obtained acts as reference model for data training of Artificial Neural Network. Hence, a large image database can be built for the visibility estimation at a chosen site.	✓	100%
3. Investigate and develop an intelligent image extraction algorithm to extract effective image regions from the image database developed in (2)	✓	100%
4. Design an Artificial Neural Network training algorithm by using PSO obtained in (1) to extract image features from the results obtained in (3)	✓	100%
5. Develop an Artificial Neural Network Training algorithm to correlate the image features in (4) with the Meteorological Visibility and to develop an intelligent Meteorological Visibility Estimation Algorithm.	✓	100%
6. Evaluate the Intelligent Meteorological Visibility Estimation systems developed in (5)	✓	100%

6. Research Outcome

6.1 Major findings and research outcome
(Maximum 1 page; please make reference to Part C where necessary)

In the first part of the project, we have developed an intelligent digital method for visibility estimation based on Support Vector Machines (SVM) and Multi-Supported Vector Regression (SVR) concept. Effective regions are first extracted from the digital images and then classified into different classes by using SVM. Multi-Supported Vector Regression (MSVR) models are then used to predict the meteorological visibility by using the image features values generated by VGG Neural Network. The proposed algorithm can classify the effective image regions into different visibility ranges and the prediction error can be less than 12.6%. The proposed algorithm gives better performance than the Deep Learning Neural Network approach in our past preliminary research. The research outcomes led to a journal publication [1].

In the second part of this project, the project team has developed a transfer learning method for the meteorological visibility estimation based on image feature fusion. The proposed method estimates the visibility based on the data processing and features' extraction in the selected subregions of the whole image and therefore it had less computation load and higher efficiency. All the database images were gray averaged firstly for the selection of effective subregions and features extraction. Effective subregions are extracted for static landmark objects which can provide useful information for visibility estimation. Four different feature extraction methods (Densest, ResNet50, Vgg16, and Vgg19) were used for the feature extraction of the subregions. The features extracted by the neural network were then imported into the proposed support vector regression (SVR) regression model, which derives the estimated visibilities of the subregions. Finally, based on the weight fusion of the visibility estimates from the subregion models, an overall comprehensive visibility was estimated for the whole image. The proposed method gives good performances and accuracies in a range of 0–50 km which is suitable for practical applications. Experimental results show that the visibility estimation accuracy of the proposed method is more than 90%. It could be used to estimate the visibility value of the whole image, with high robustness and effectiveness. This method does not require to define a large-scale visual annotation set, and it also eliminates the processing of invalid and reductant information on the digital images as compared to other existing methods. For the fine-tuning of the neural network and extraction of effective subregions, it greatly reduces the model complexity and the computation time as compared to other methods. This research outcomes led to a journal publication [2].

In the last part of the project, we have developed a Visibility Monitoring System at campus site and developed a visibility database for our research project. The project team has carried out an experimental evaluation of a Particle Swarm Optimization (PSO) based transfer learning method for meteorological visibility estimation. We have proposed a new transfer learning method for visibility estimation by using PSO feature selection. Image data are collected at fixed location with fixed viewing angle. The database images were gone through a pre-processing step of gray-averaging so as to provide information of static landmark objects for automatic extraction of effective regions from images. Effective regions are then extracted from image database and the image features are then extracted from the Neural Network (Densest, ResNet_50, Vgg16 and Vgg19). Subset of Image features are selected based on the PSO methods to obtain the image feature vectors for each effective sub-region. The image feature vectors are then used to estimate the visibilities of the images by using the Multiple Support Vector Regression (SVR) models. Furthermore, we have evaluated the effectiveness of the proposed algorithm by using a self-built visibility meter and digital camera setup at the selected campus site. This paper [3] summarizes the outcomes of the experimental evaluation of a PSO based transfer learning method for meteorological visibility estimation method. Experimental results show that the proposed method can give an accuracy more than 90% for visibility estimation and the proposed method is effective and robust.

6.2 Potential for further development of the research and the proposed course of action *(Maximum half a page)*

For the further development of this project, we can investigate and develop an automatic landmark objects extraction system which can extract landmark object regions from the digital image and identify the effective visibility estimation range of the Landmark Objects (LMO). An Artificial Neural Networks (ANN) will be designed to correlate the mappings between the visibility values and the landmark region's features for different visibility ranges. We can do further research on the development of a visibility estimator based on the above results and the proposed ANN based multi-model fusion methods. We can develop a new hardware prototype of the ANN based Visibility Estimation and Training Systems which can (i) Collect Visibility Meter readings automatically, (ii) Collect digital weather image data automatically, and (iii) Communicate with the host computer by wireless communication (e.g. WIFI) method. Finally, we will implement the algorithm developed in host computer. The project staff will evaluate the Landmark Object extraction system and visibility Estimation systems by carrying out experimental studies. Furthermore, multi-camera approach can be used to capture different landmark objects from different view angles so as to widen the application range with lower computation load and enhance the accuracy of the estimation method. It is expected that the proposed system can become a fully automatic and low-cost method for visibility estimation. We expected that the research outcomes of this project can contribute to the area of automatic visibility estimation, environment monitoring and sustainable technology.

7. Layman's Summary

(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

Meteorological Visibility is a measure of the greatest distance at which an object near the ground can be recognized under a bright background. The uses of the Visibility can be used as safety indicators for road, sea and flight traffic. Furthermore, visibility can also be used as an environmental parameter to monitor weather or pollution condition. In this project, a Visibility Monitoring System (VMS) with hardware visibility meter and High-Resolution Digital Camera will be developed to monitor the visibility variations at the campus site. Data collected from the VMS act as reference models for ANN System training. An intelligent method has been developed to extract the effective area from the digital image captured by the high-resolution Digital Camera. The image data of the effective regions will be passed to a pre-trained Neural Network. Based on Particle Swarm Optimization methods, an intelligent method has been developed for image features extraction and visibility estimation. The experimental results show that the proposed method is accurate and effective. The proposed new intelligent Meteorological Visibility Estimation methods outperform the algorithm developed from our past research. The overall research outcomes of this project can contribute to the area of environment monitoring and sustainable technology.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) *(denote the corresponding author with an asterisk*)*	Title and Journal / Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this Report *(Yes or No)*	Acknowledged the Support of RGC *(Yes or No)*	Accessible from the Institutional Repository *(Yes or No)*
Year of Publication	**Year of Acceptance** *(For paper accepted but not yet published)*	**Under Review**	**Under Preparation** *(optional)*						
May 2020	Sep 2019	-	-	*Wai Lun Lo, Meimei Zhu, Hong Fu	Journal of Advances in Information Technology, Vol.11, No. p. 40-47, 2 May 2020	Has been submitted with the midterm progress report as an accepted paper	Yes	Yes	NA
Jan 2021	Jan 2021	-	-	Jiaping LI; *Wai Lun Lo; Hong Fu; Henry Shu Hung Chung	Applied Sciences, Volume 11, Issue 3, 997, Jan 2021	-	Yes	Yes	NA
Jun 2021	Jun 2021	-	-	*Wai Lun Lo, Henry Shu Hung Chung and Hong Fu	Atmosphere, Vol. 12, Issue 7, 828, Jun 2021.	-	Yes	Yes	NA

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered

(Please attach a copy of each conference abstract)

Month / Year / Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this Report *(Yes or No)*	Acknowledged the Support of RGC *(Yes or No)*	Accessible from the Institutional Repository *(Yes or No)*
18-20 Sep 2019, Jakarta, Indonesia	Meteorological Visibility Estimation by using Multi-Support Vector Regression Method	The 12th International Conference on Advanced Computer Theory and Engineering (ICACTE 2019)	2019	Yes	Yes	NA

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning
(Please elaborate)

The research materials of this project have contributed to the teaching of the course "Computer Vision and Applications" in the BSc(Hons) in Computer Science programme.

11. Student(s) Trained
(Please attach a copy of the title page of the thesis)

Name	Degree Registered for	Date of Registration	Date of Thesis Submission / Graduation
NA	NA	NA	NA

12. Other Impact
(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

Wai Lun LO, BEST PRESENTATION AWARD in the ICACTE 2019

Wai Lun LO, Meimei ZHU and Hong FU: "Meteorological Visibility Estimation by using Multi-Support Vector Regression Method", The 12th International Conference on Advanced Computer Theory and Engineering (ICACTE 2019), JARKATA, Indonesia, 18-22 Sep 2019

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
					Type	No.
No. of outputs arising directly from this research project	3	1	0	0	-	0

14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
NA	