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Adaptive Computation
LLC

Dr. Tuan A Duong

Whitepaper

[Statistical study for Partial Object/ Face Recognition Based ADC Bio-Inspired Visual Recognition]

Background

In this study, we provide the performance of our software algorithm for three objective tasks: Detection, Recognition and Identification (DRI) of visual image and their definitions are as follows:

* Detection: detecting a particular feature in the input image (e.g., eye, nose etc). The result of detection will provide the location (alignment) of detected feature in the image scene automatically.

* Recognition: recognizing the particular feature as a certain face (e.g., the best matching, second best ... of eye, nose etc) and resulting in a group of facial images ranked by computer-evaluated similarity.

* Identification: examining of the differences and similarities between two facial images for the purpose of determining if they represent different persons or the same person.

This study aims to demonstrate that our technology is more advanced as compared with the counterpart state-of-the-art technology; however, it is more important to demonstrate that our technology is ready for real world applications such as partial object image search e.g., product or face or else, via smart phone camera or internet in uncontrolled environment.

ADC uses proven and patented software and hardware solutions to bring the power of neural network processing to consumers and business alike. Developed by ADC founder Dr. Tuan A. Duong for NASA task and patented by Caltech, these technologies allow the company to deliver breakthrough content search and recognition solutions where noisy and partial object search, for the first time, are effectively delivered. ADC technologies are based on a mathematical and biological model of saccadic eye movements and visual pathway processes which are focused on shape and color (if available) recognition of the object.

To demonstrate our superior bio-inspired visual detection, recognition and identification algorithm, the statistical study was conducted. In this study, we extracted input partial object from the image scene shown in Figure 1a and Figure 1b, respectively. We show the image scene e.g., Figure 1b to help for verifying the correct found objects. The search results are shown for the matching between input (Figure 1a) and found objects (Figure 1a1, 1a2 and 1a3) which come from the same person in different background, lighting condition and location.

To do as above, the ADC bio-inspired algorithm must be able to perform two tasks effectively: locating similar object features in the test scene (e.g., locating the eye in each scene if existed) and estimating the similarity between input object and potential objects. These steps are posing the challenges current state of the art to deal with it. In the traditional study, the input object and test object are framed and the testing algorithms are only used to estimate the similarity match between them and no need to locate where the test object can be in the scene. However, locating a potential found object is extremely challenge for current state of the art to perform and here is the crucial missing part for current object recognition software. For application perspective, the current face recognition approach is not practical for real world applications except driver license image search. ADC is focusing in the applications to real time, on-line and uncontrolled environment object recognition; therefore the locating and identifying object in the scene are the musts and it is a practical direction for commercial arena.

Software Evaluation

We used the evaluating procedure as follows:

Input image

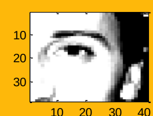

Figure 1a: Searched partial object input

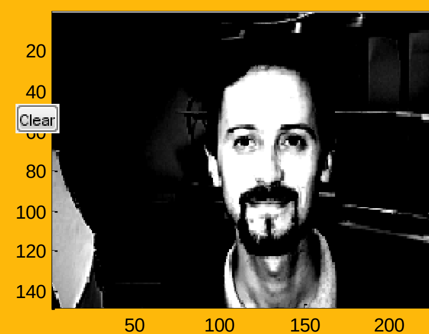

Figure 1b: The scene of partial object input is extracted

The searched results by ADC algorithm from the 1970-image database are shown below:

Found objects

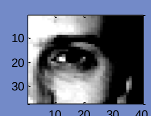

Figure 1a1: Found object

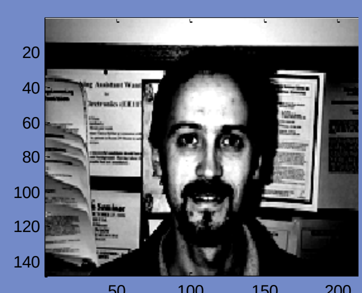

Figure 1b1: Input image in database

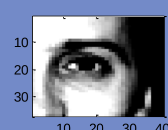

Figure 1a2: Found object

Figure 1b2: Input image in database

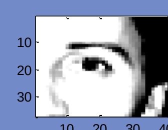

Figure 1a3: Found object

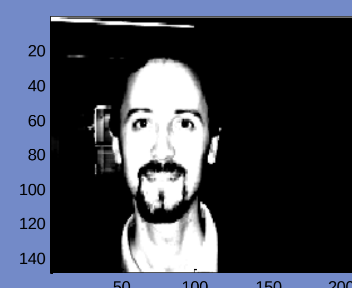

Figure 1b3: Input image in database

ADC bio-inspired visual algorithm correctly identified found objects (Figure 1a1, 1a2 and 1a3) from the three images (Figures 1b1, 1b2 and 1b3) from 1970- image database.

The real time demo can be viewed in this link:
http://www.youtube.com/watch?v=tm8OjcaP9uE

Statistical study

In this study, we have sampled 50 random selected eyes (only left or right eye) shown in Figure 2 and nose and mouth in Figure 3, with random various window size as an input (partial face) from 450 front-face- image Caltech database for searching correct face from the same person. The searching result can be defined as: exact match, similar match from the same face but different image and position or else.

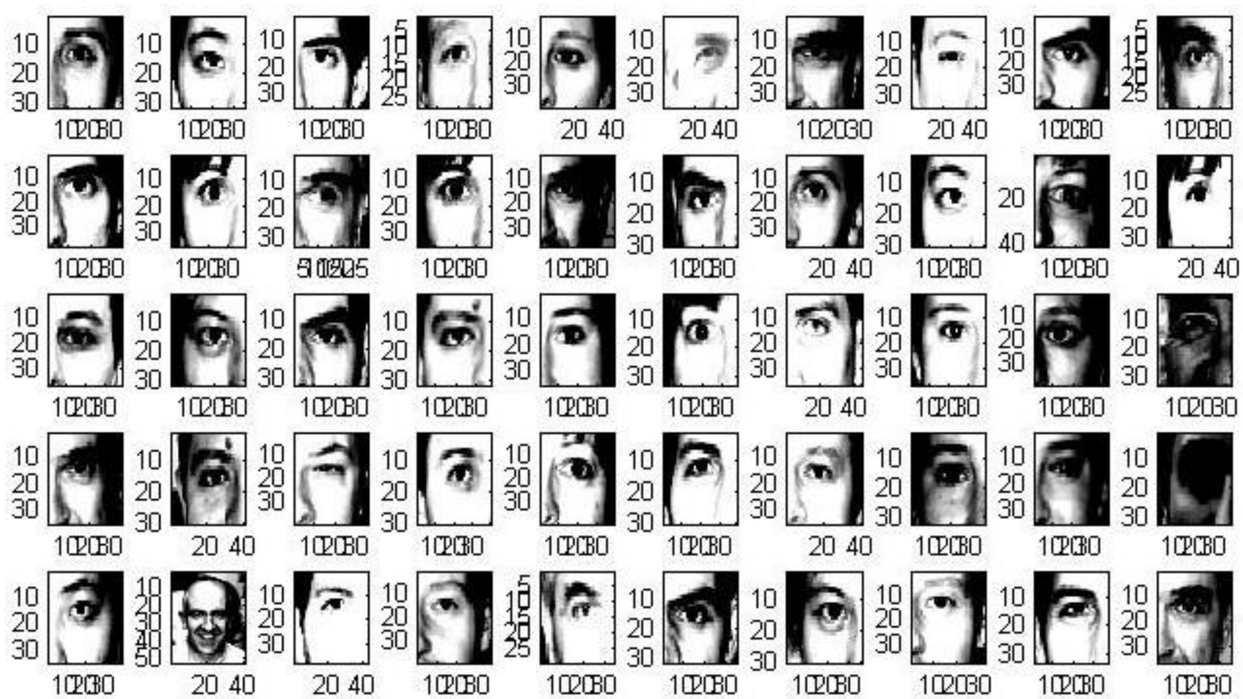

Figure 2: The eye input array is used for this study and it is conducted one input at a time

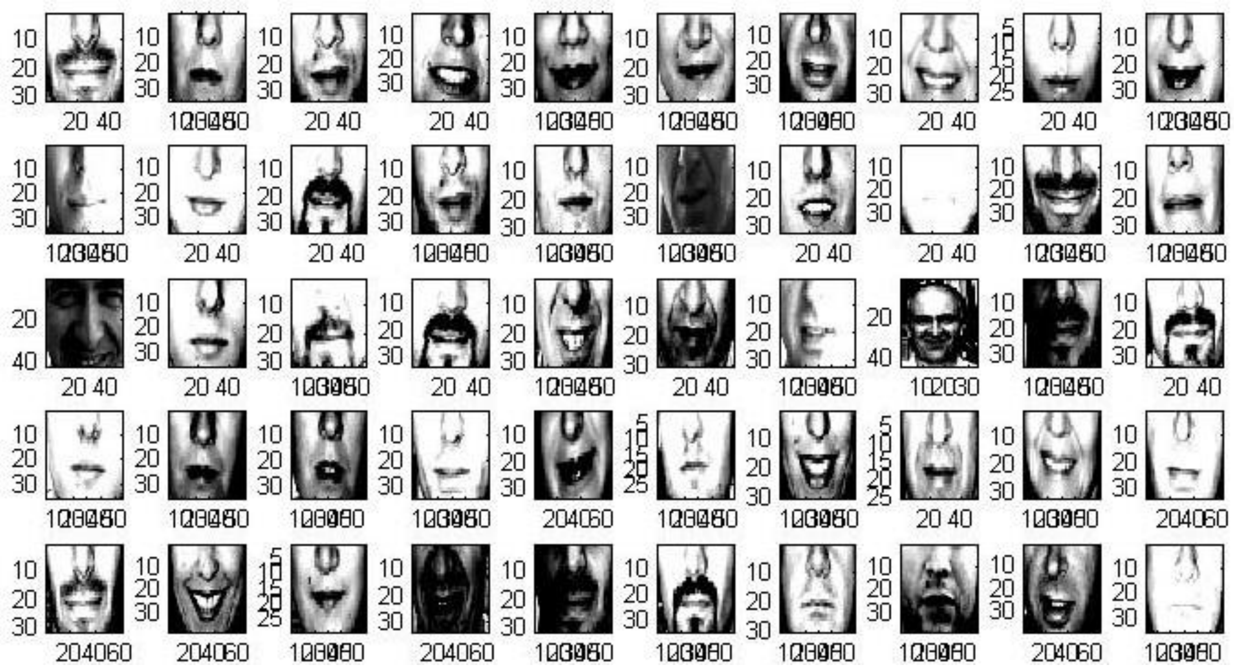

Figure 3: The nose and mouth input array is used for this study and it is conducted one input at a time.

For testing, we used one input image at a time to search for the same person in the combination of the 450-image face by Caltech database and the 1520-face database http://www.humanscan.de/support/downloads/facedb.php. To confirm the correct identification of partial face, the ADC bio-inspired visual algorithm has done successfully two tasks:

- Finding where is the similar input object in the image scene from database e.g., given eye input the ADC bio-inspired algorithm must correctly locate the eye of an test input image before estimating whether it belongs to the same person;
- Estimating the closest matches and giving the outputs in order from the best to less match.

Regardless, the final scene is correctly identified with a wrong framed object, it is considered to be failed.

Results

Based on this criteria, the system performance is provided in Table I and II below:

Table I: ADC bio-inspired performance based on 50 random-eye runs

	Each run	Total run	
Input	1	50	We inputted 50 different random eyes
Database	1970	50*1970	Total scene is 1970
Exact match (The best match from the same		50	100% correct for search the exact eye from the person in the scene

face where the input is extracted)			
Similar match (same face but different image)		48	96% correct interpolation of face

Table II: ADC bio-inspired performance based on 50 random-nose-mouth runs

	Each run	Total run	
Input	1	50	We inputted 150 different nose and mouth
Database	1970		Total scene is 1970
The best match (The exact match from the same face where the input is extracted)		50	100% correct for search the exact nose and mouth from the person in the scene
Similar match (same face but different image)		42	84% correct interpolation of face

Scaling problem

In the practical real world applications, the size of object image in database is randomly different from the size of input image for search, which introduces a scaling problem. These scaling discrepancies are one of the big obstacles for image detection, recognition and identification, especially image based search engine.

ADC has developed the *scaling invariant technique* to effective deal with this challenging scaling problem. This study is focused to demonstrate our solution for this challenge.

In this study, we used the scaling range (0.4-1.0), which is randomly generated and scale downed the original image within 40% of its size shown in Figure 4. We used 100 samples of random pick of nose and mouth from the first 100-input image by Caltech and this data set is used for the scaling study for input space. In order to demonstrate our invariant approach, we ran 100-sample partial face (nose and mouth) with *no scaling* and the results are shown in Table III. At the same time, we also ran the 100-sample partial face with *random scaling* within (0.4-1.0) shown in Figure 5 and results in Table IV.

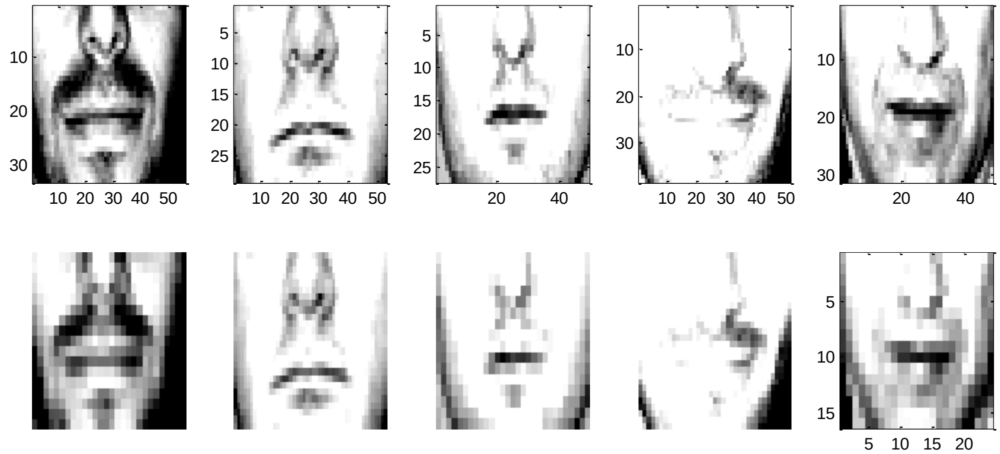

Figure 4: The first five input image (partial object). a) Top row: without scaling factor; b) Bottom row: with scaling factor x array with x= [0.4973   0.8766   0.5867   0.7171   0.4994].

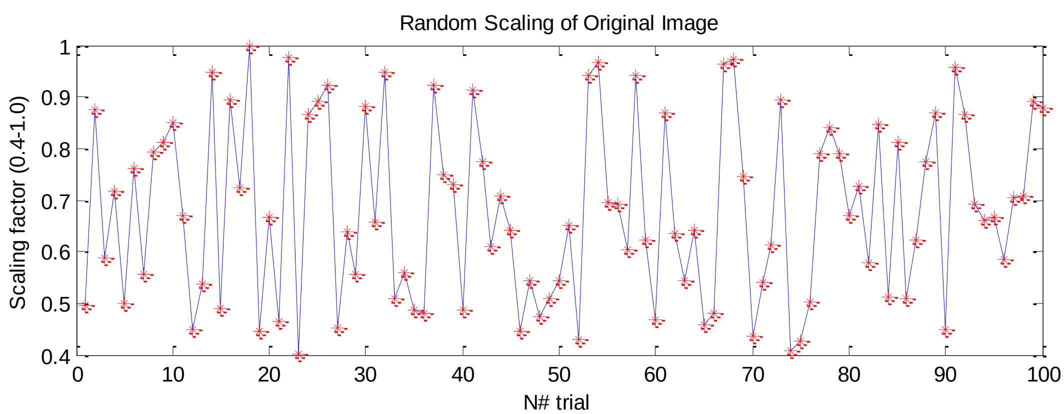

Figure 5: Random scaling used to scaling original input as real world partial inputs.

Table III: ADC bio-inspired performance based on 100 random-nose-mouth runs with *no scaling*

	Each run	Total run	
Input	1	100	We inputted 100 different nose and mouth inputs
Database	1970		Total scene is 1970
The best match (The exact match from the same face where the input is extracted)		100	100% correct for search the exact nose and mouth from the person in the scene
Similar match (same face but different image)		86	86% correct interpolation of face
The average of first ten candidates before making error		5.02/10	For the first ten candidates of search results, 5 on average of it

			correctly match before errors.
The average of correct first ten candidates		6.34/10	For the first ten candidates of search results, 6.34 on average of it correctly match.

In Table III, we ran 100 samples of nose and mouth and the results are consistent with Table II. In this simulation, we selected the first ten from the best match search for each input and we monitored two cases:

1) The average of similar input objects before making mistake is 5.02. It means that our algorithm is able to product the identical input (the best match) and 4 similar inputs (nose and mouth of the same person) for every input before it made an error.

2) The average of similar input objects within 10 best candidates is 6.34. Our algorithm is able to product the identical input (the best match) and 5.34 similar inputs (nose and mouth of the same person) for every input within the best 10 candidates.

Table IV: ADC bio-inspired performance based on 100 random-nose-mouth runs with *random scaling*

	Each run	Total run	
Input	1	100	We inputted 100 different nose and mouth
Database	1970		Total scene is 1970
The best match (The exact match from the same face where the input is extracted)		98	98% correct for search the exact nose and mouth from the person in the scene
Similar match (same face but different image)		81	81% correct interpolation of face
The average of first ten candidates before making error		4.6/10	For the first ten candidates of search results, 4.6 on average of it correctly match before errors.
The average of correct first ten candidates		6.03/10	For the first ten candidates of search results, 6.03 on average of it correctly match.

In Table IV, we simulated the same 100-input, as used in Table III, with random scaling shown in Figure 5. We have 98% correct search for the best match and 81% correct for similar match. For the similar matches, we have 4.6 best and similar matches for each input and 6.03 best and similar matches within 10 best candidates.

From this study, these results are surprisingly good and we have 2% degraded search from scaling problem for best match and 5% for similar matches. Hence, it suggests that ADC scaling invariant technique is effective to solve scaling problem of image DRI based on visual data.

Speed performance

Currently, we use Intel i5 dual processor with 8GB RAM for this simulation and we got 200 frames/sec with no scaling processing and 70 frames/sec with scaling processing. This speed performance is based on image resolution reduction to 148x224 array and our unique algorithm is very effective with low resolution as well. However, for real world applications, we plan to develop a new MapReduce-Correlation-type to speed up the search processing as demanded. The speed performance is aware and can be under controlled when needed.

Comparison

In the academic world, we have not aware any algorithms or techniques that can deal effectively with partial object DRI including 3-D model technique, up to now, when it deals to two obstacles: locating where the partial object is from input scene and recognizing what it is. In commercial arena, Google-MapReduce can be implemented to perform *exact retrieval* based on their prepared database and brute force; however, Google-MapReduce technology completely is ineffective for noisy and not exact input and real time on-line unprepared database. Therefore, ADC bio-inspired algorithm is more advanced to deal with partial object recognition for noisy, not exact input and on-line raw database.

Practical Approach

For homeland security or DoD applications, database, sometime, can be accessed real time on-line only, but cannot be down-loaded to specific machine, hence no preparation is done in advance. ADC can be the most suitable approach for raw database processing and uncontrolled environment object recognition where current state of the art cannot meet the constraints of the problem. For example, in home land security applications real time detection and recognition of suspects enter the specific areas, where are sensitive or private.

For commercial arena, ADC bio-inspired visual algorithm is perfectly fitted for dynamic product search e.g. smart phone applications and intelligent search, where the search desired object can be assembled through parts; however, the others may pose their difficulties to deal with. In home security, intelligent monitor system based ADC Bio-inspired technologies provide the detection and recognition of visitors whether they are on the monitor bad guy list or unknown persons or friends and relatives when they arrive at the door, via in-house warning system or smart phone.