Facial Profiling for Detection of Mal-Intent using Thermal Imaging

Bashar A. Rajoub and Reyer Zwiggelaar

Department of Computer Science, Aberystwyth University

In this Presentation

Real-time facial profiling

- Detection “anxiety” based on facial analysis - Bradford: visible domain and Aberystwyth: thermal domain.
- Modes of Operation
  - in polygraph settings: to classify deceitful subjects.
  - in ports of entry: to administer real-time, highly automated tests for quick screening of potential suspects.

Thermal Polygraph Technology

Main idea

- if we can establish a one-to-one correspondence between facial thermal patterns and anxiety then it will be feasible to deploy machine vision to detect, in an unambiguous way, specific activities of interest.
- Thermal signatures constitute a very powerful biometric that is extremely difficult to conceal.
- Humans do not possess the ability to control the bio-physiological response to emotions.
  - the brain develops a memory of the stimulus environment, which must be updated when a stimulus of some significance is perceived.
  - The update process is triggered by the nervous system and can lead to stress.
  - Stress in turn causes abrupt changes in local skin temperature and possibly a facial expression signature.

Visibility of thermal features

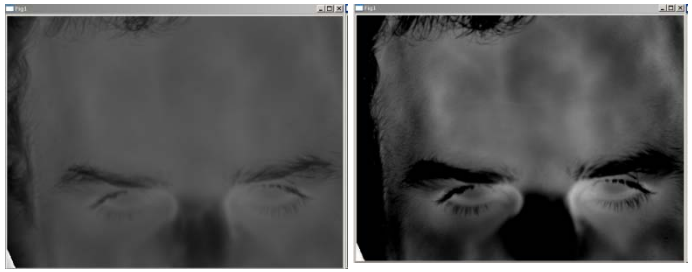
- Skin Temperature changes due to DECEIT are not easy to see from raw thermal images.
- Bio-heat modelling on the surface of the body aims standardise thermal images to eliminate noise and external sources effects.

$$\frac{dV_s}{dt} = \frac{G}{(T_b - T_s)^2}\frac{dT_s}{dt}$$

$$\Delta\omega \approx \eta \Delta T_e$$

$$\eta = 4\zeta \frac{T_e^3}{T^4}$$

Thermogram $T(x,y)$ to blood-perfusion $\omega(x, y)$ transform. the blood perfusion greatly reduces the environmental effects {Wu, 2008}



Using image enhancement

Polygraph testing

- In Polygraph testing the examiner prepares a Concealed Information Test (**CIT**).
- Large Physiological responses would indicate an assumed suspect involvement in that crime as this indicates that he/she has recognized the crime-related information.
- CIT involves contact with the subject through a handful of different sensors.
- These sensors require time to attach and will compromise the comfort of the subject during the test.
- the analysis of the resultant signals is performed manually by several experts using heuristic approaches, which makes the outcome of a suggestive nature and very slow.
- Due to these problems polygraph examinations are inadmissible in court.

Existing Methodologies

- Experiment initialisation
  - Rules for selecting or rejecting participants
  - Choice of Time scale, environmental conditions and sample size
  - testing scenarios and CIT test formats, etc.
- Feature Selection and Extraction
  - Periorbital region (direct experimental observation) – Pavlidis et al 2000 and 2001
  - Statistical significance and interaction (Group × Hemiface × Time Interval × Question Type).
  - face detection, face tracking, specific ROI tracking
  - Bio-heat modelling OR Digital image processing for amplifying thermal signatures
- Pattern Recognition
  - Calculate the baseline: i.e., based on measures on the characteristics of thermal signatures ("eye" curves)
  - Global vs individual baselines
  - quantifying the deception curves

Trend

- Almost no change in
  - Experiment initialisation
  - The set of Anxiety Features
  - The choice of classifier and baseline selection
- Improvements
  - New bio-heat models
  - New signal processing methods
  - Clear trend in designing measurement trackers

Polygraph Test Scenarios

- a mock crime involving the stabbing of a dummy with a screwdriver was employed for the study. The participants in the deceptive group were asked to perform the crime as if it was real. The theft of a $20 bill has been identified as the motive for the crime.
- The innocent subjects
  - did not have any knowledge or association with the crime scene.
  - In some work they were exactly told what they will be asked about

Polygraph Test Scenarios

- Game – Like Scenario
- the participants were told that there was a check in an envelope hidden down the hall. This check was made out to a group that the subject adamantly opposed. The subject was told to find the check, **and then decide whether or not to 'steal' it.**
- The subject was then interrogated by a person whom they believe is a biased person
  - If the subject, took the money and
    - fooled the interrogator then – BIG Reward.
    - If he/she caught lying – Punishment (money to the other group + no money for the subject and his group + 30 minutes of loud, startling blasts of noise delivered via headphones!!!).
  - if the subject did not take the money and
    - was judged truthful, then SMALL Reward for themselves and their group + a smaller sum to the other group.
    - If the subject was mistakenly judged as lying, then PUNISHMENT (neither they nor their group got any money + the other group got some money, and the subject was to face the loud startling blasts of noise).
  - Actually, no subjects were punished with the loud startling blasts of noise . The goal is that subjects would be tricked that there was a punishment for not passing the test.

Data Reduction

- **Pavlidis, 2002**
  - Assumed a stationary subject for (5-10s).
  - The images are cropped so that it contains only the subject's face and no background.
  - **The periorbital and forehead areas for each subject in each question are delineated by the user.**
  - The blood Perfusion equation is applied across the time line until the end of the particular question-answer session
- **Pollina, 2006**
  - tracking head movements in real time was used during data reduction using a pattern-matching algorithm
  - for each participant the maximum and minimum temperature are calculated for the two bilaterally symmetric regions of interest (ROIs) during
    - time intervals preceding and time intervals following the examinee's verbal response.
  - The average pixel intensity was then calculated for each min and max frame sets
- **Tsiamyrtzis, 2005**
  - tracking was also implemented.
  - compute the mean temperature of the 10% hottest pixels from within the periorbital ROI for every frame.
  - Use Fourier analysis and windowing to eliminate the high frequency noise components and extract the filtered signal.

FINDING THE BASELINE

Pollina, 2006

For nondeceptive participants: The **mean response amplitudes** appear similar in both the left and right hemiface.

For deceptive participants: the response pattern appears more variable, particularly the right hemiface data.

prior to response onset**, the differences in maximum amplitude** following irrelevant and relevant items appear to be larger in the positive direction in the deceptive group, particularly in the right hemiface.

FINDING THE BASELINE

Pavlidis, 2001

Only two deceptive and two non-deceptive subjects were selected and analysed for the 'eye' signals across the timeline. They have found that 'Eye' signals from the deceptive control subjects have a steep ascend unlike those from the non-deceptive **control subjects.**

The nearest neighbour (NN) classifier was used to classify the response vector based on the distance from the ***response vector of a small number of control subjects***.

Pavlidis, 2002

- There are two stages of physiological response in a question- answer session for a subject.
  - The first stage is during the posing of the question, here the "eye" curves ascend moderately for all subjects.
  - The second stage is when the subject answers the question.
    - Here, the "eye" curves of the non-deceptive subjects continue to ascend moderately
    - while those for the deceptive subjects a much steeper ascend is noted.

T*he* ***slope product*** of the "eye" curves in the corresponding *question* and *answer* sessions is used to determine the baseline.
If the slope product is smaller than a specified threshold, then the answer is classified as non- deceptive, otherwise the answer is classified as deceptive.

What we will be looking at

- Using more signatures from both the thermal and visual domains.
  - Possibly … superficial blood flow, cardiac pulse rate and breath rate
  - Blood vessels structure (Finding the most common shared features of facial blood vessels for the human face).
  - use of image registration on extracted control points of blood vessel structure can aid in standardising measurement locations and aid in tracking.
  - Facial expression of (both affect and emotion) and Micro facial expressions
  - Eye movements and Linear structures
- Other enhancements in
  - Shape Modelling, facial feature Detection and Tracking
  - Use of advanced Image processing
  - using dimensionality reduction and statistical density estimation (to try to reduce the high dimensionality of the 'eye' signals and other facial signatures to extract the most discriminant components)
- Pilot study
  - Possibility of employing a large number of subjects to prepare significant sample sets.
  - Difference between ZCT and CIT in simulated and real-world case
  - Researchers used traditional polygraph technology to compare results. This is time consuming .. Instead carry thermal polygraph testing using same strategies for standard polygraph and use ground truth to determine performance.

CONCLUDING REMARKS

- Anxiety or stress is not necessarily related to deceit or mal-intent
  - Medical conditions, natural stress, enviromental conditions
  - subjects react differently even to the same stress stimuli.
  - Existing anxiety detection approaches are based on monitoring an individual from *before the time* of anxiety then monitor the responses for any increase over a specified threshold which signifies a large transition from the calm state to the anxious state.
  - However, suspects with mal intent will already be anxious and no information about the thermal history of the subjects under surveillance will be available to us.
  - Therefore, only if we can find a universal baseline to establish universal thermal features of anxiety (e.g., in airports) and then establish the universal baseline to discriminate anxious from non-anxious subjects.

CONCLUDING REMARKS

- Previous methodologies based on the heat transfer model
  - due to dropping of many of the bio-heat equation parameters the accuracy of the computed blood flow rate data is not very good.
- The human face is an obvious choice for extracting thermal signatures
  - faces can be covered,
  - eye glasses is a problem,
  - perhaps some makeup powder can reduce thermal emissions.


Fig1

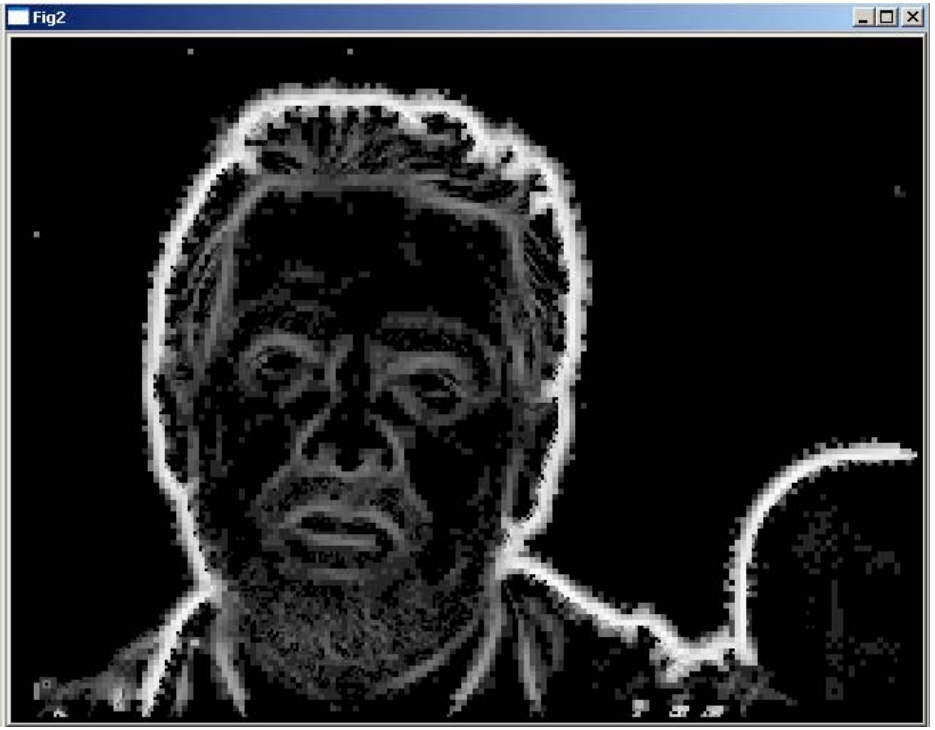
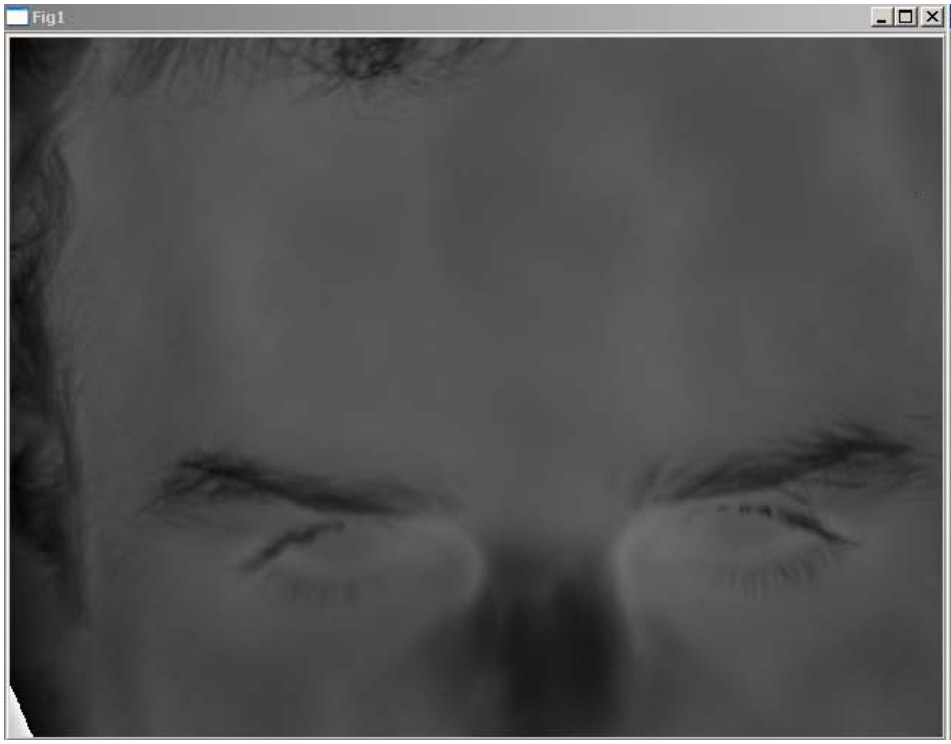


Fig2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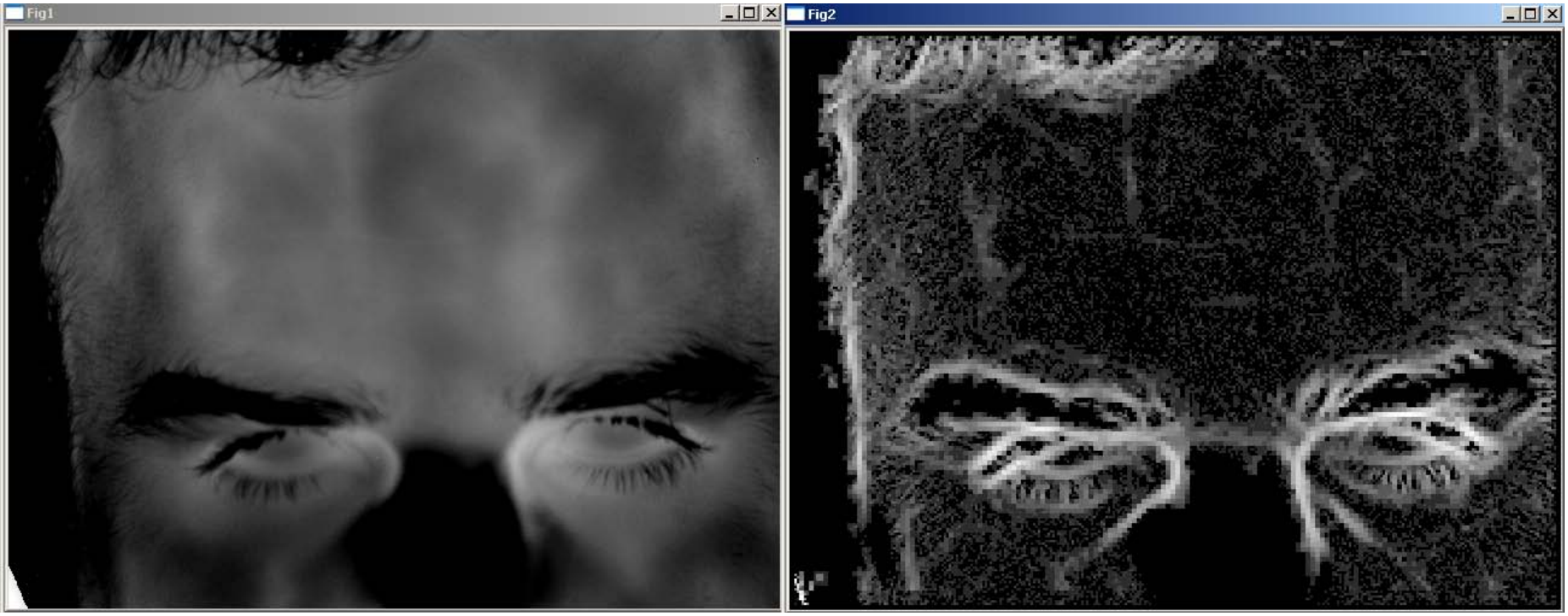
Fig1
Fig2


Fig1


Fig2