Analysis of the Perspiration Component of the Facial Thermal Signature

Computational Physiology Lab

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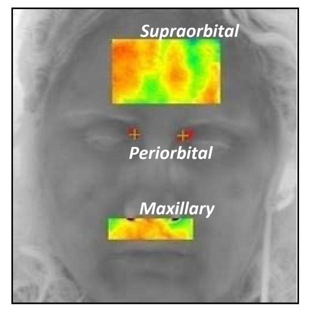
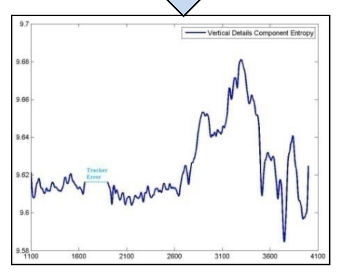
Motivation

- To develop an algorithm to extract the perpiration signals from the two key facial areas of sympathetic importance (**Supraorbital** and **Maxillary**)



Key Facial Areas



Perspiration Signal Plot

Research Requirements

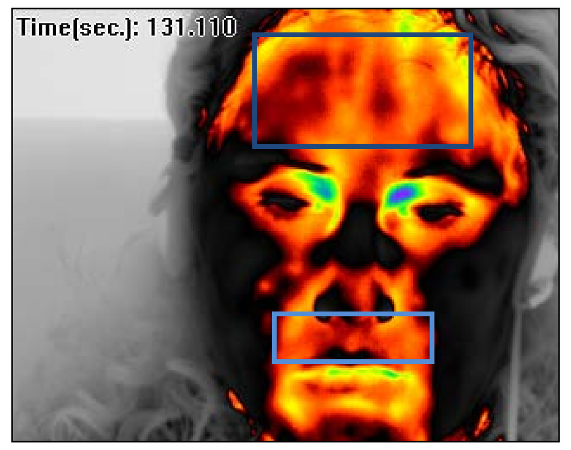
- Accurate and consistent physiological measurements
- Flexible segmentation method that would adapt to physiological changes

Research Applications

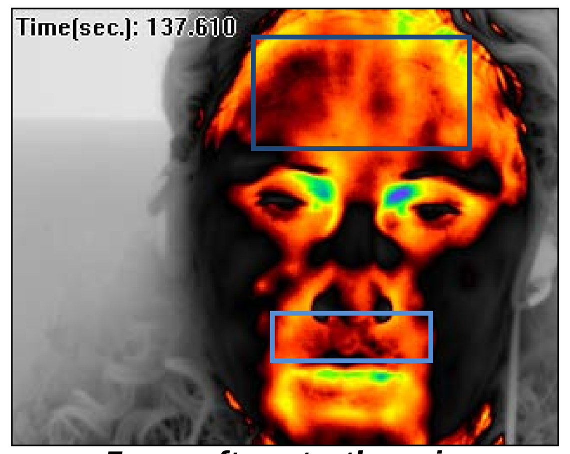
- Stress analysis in surgical training
- Lie detection
- Office stress analysis

Introduction

Subjects under stress experience the "fight or flight" syndrome → Cholinergic postganglionic fibers of the sympathetic division of ANS (Autonomic Nervous System) release Acetylcholine neurotransmitter → ANS innervates eccrine sweat glands and the blood vessels to skeletal muscles and the brain → Emotional perspiration in: 1. Supraorbital area 2. Maxillary area → Perspiration quantification for stress analysis



1 sec before startle noise

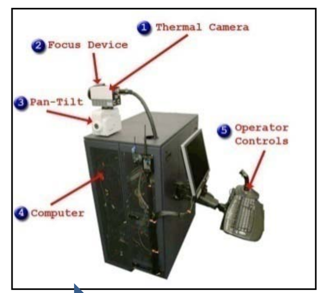


5 sec after startle noise

Data Collection and Real-Life Examples

Data Collection

The thermal video is collected using the Thermo-Vision SC6000 Mid-Wave Infrared (MWIR) camera



The camera collected the thermal video while the subject was exposed to stress-producing stimuli

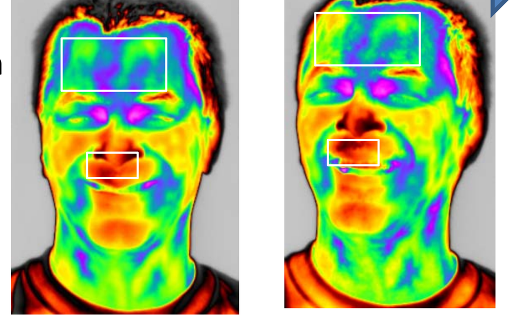
Lie Detection

FRAME 1100

No stress producing stimulus applied yet:

- good representation of blood flow
- no perspiration

"Did you ever take something from a place you worked at?"



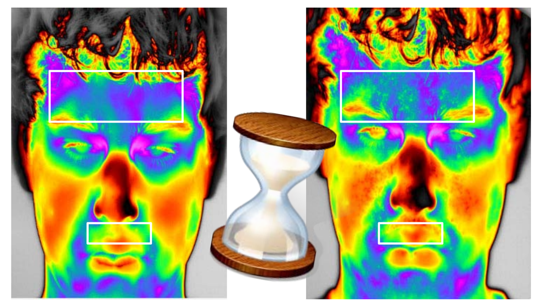
FRAME 3184

Image captured immediately after applying the stress producing stimulus :

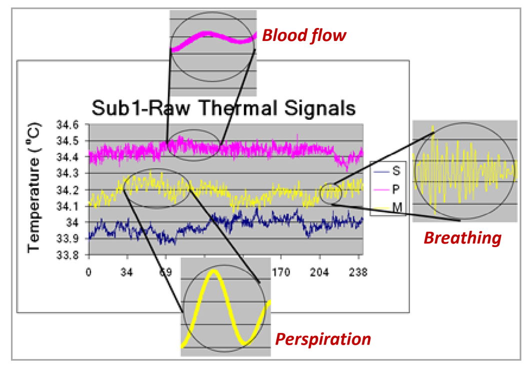
- good representation of blood flow
- good representation of perspiration

Surgical Training

Initially the surgeon does not perspire, but as time passes, he begins to feel the stress



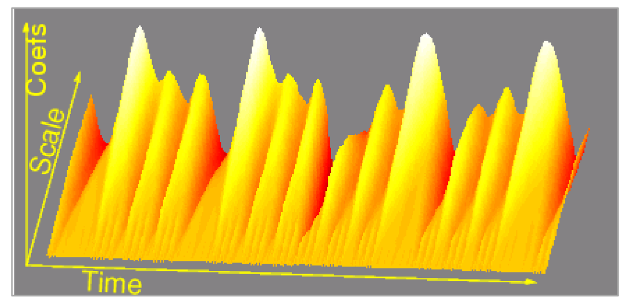
Methodology



Raw Thermal Signals

Problem

- Thermal signals are composed of multiple components of variable frequency (i.e. blood flow, sweat gland activation and breathing)
- The signals have to be analyzed at different frequency levels without losing time information



Time-Frequency Representation

Solution

- Wavelets offer time-frequency representation
- We can separate blood flow and perspiration signals from a thermal image by applying 2D wavelet transform on the image and analyzing each of the resulting components

Data Preparation

Step 1: Localize and extract the supraorbital and maxillary area out of the image

Step 2: Apply 1st Level 2D Haar wavelet transform on the region, obtaining:

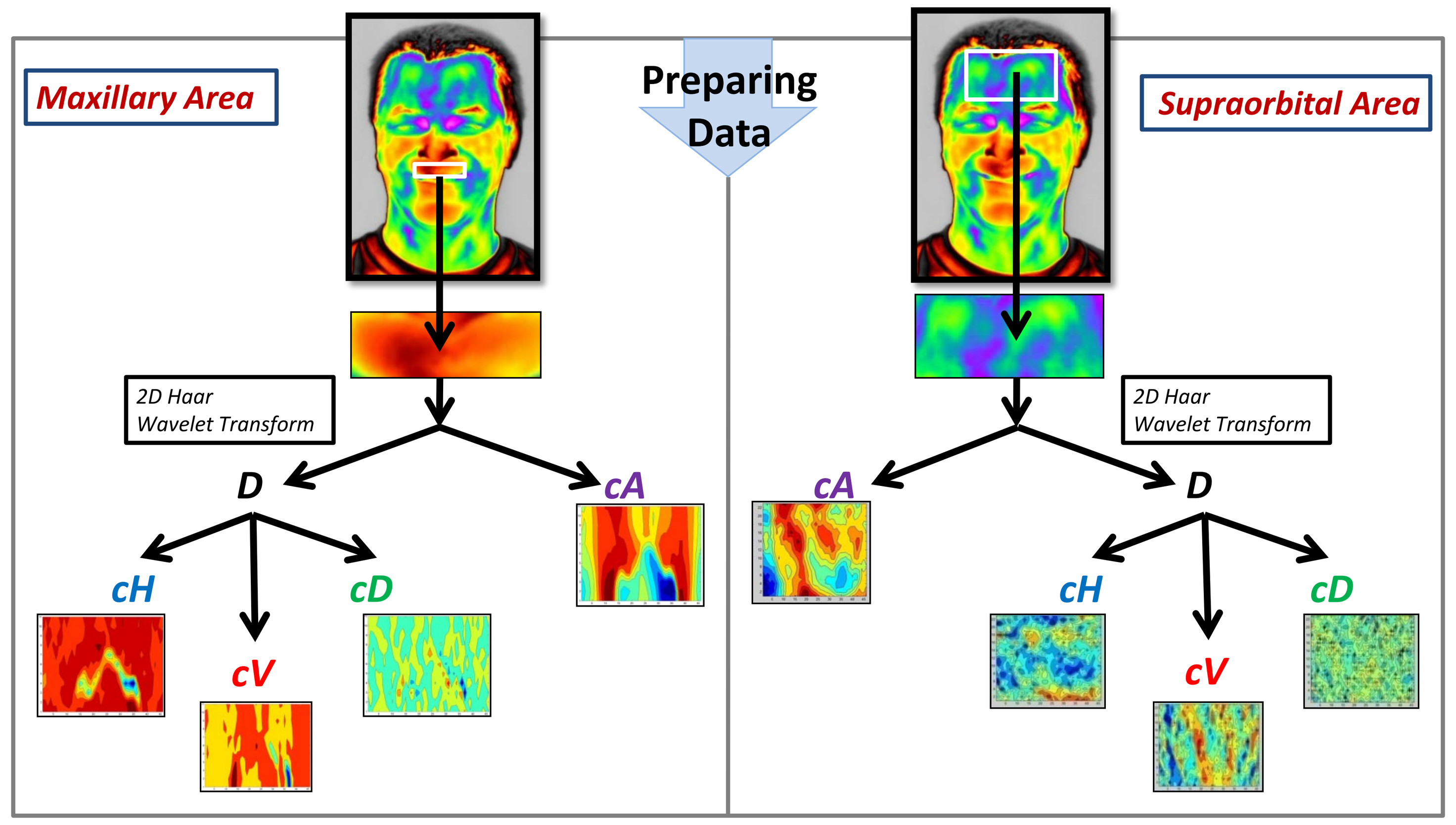
- Approximation component (Low resolution, cA)
- Detail components (High resolution, D):
- Horizontal Details (cH)
- Vertical Details (cV)
- Diagonal Details (cD)

Step 3: Visualize the wavelet energy components

Step 4: Analyze the perspiration component through the statistical approach

Step 5: Because the measurement carries substantial high frequency noise due to imperfections in tissue tracking and segmentation, we used the high frequency noise cleaning algorithm to suppress noise from the signal

*We Used MatLab's Wavelet Toolbox



Perspiration Descriptors

- Let z be a variable noting intensity, p(z) be the corresponding histogram, and L be the number of distinct intensity levels
- The descriptors were calculated using texture analysis statistical approach

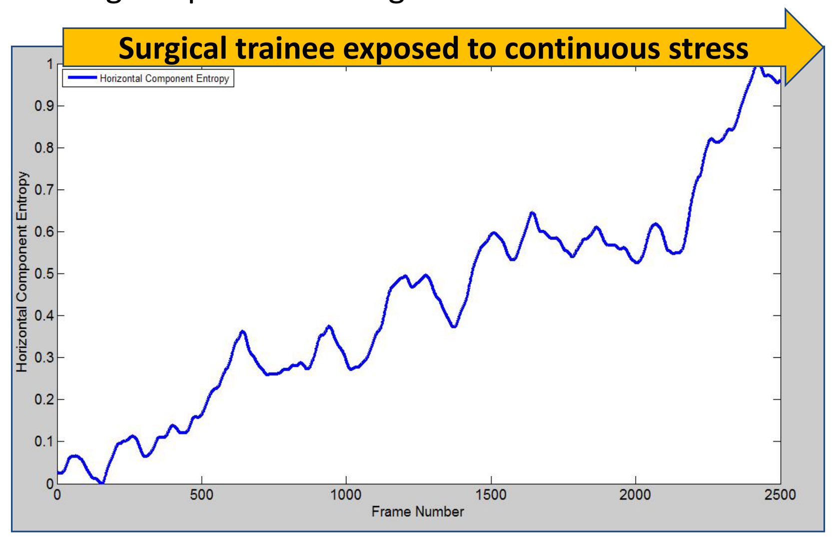
Descriptor	Formula	Explanation
Mean	$m=\sum_{i=1}^{L} z_i p(z_i)$	• m is the mean value of z (the average intensity)
n^{th} Moment	$\mu_n(z)=\sum_{i=1}^{L}(z_i-m)^n p(z_i)$	• μ_n is the n^{th} moment of z about the mean • μ_3 measures the skewness of histogram • μ_4 measures the relative flatness of histogram
Intensity Contrast	$R(z)=1-\frac{1}{1+\sigma^2(z)}$	• $\sigma^2(z)=\mu_2(z)$ is the variance • R is a descriptor of relative smoothness
Standard Deviation	$\sigma(z)=\sqrt{\mu_2(z)}$	• σ tends to be more intuitive than the variance • σ measures essentially the same thing as R
Uniformity / Energy	$U(z)=\sum_{i=1}^{L} p^2(z_i)$	• how "uniform" the image is
Entropy	$e(z)=-\sum_{i=1}^{L} p(z_i)\log_2 p(z_i)$	• e is a measure of variability • e=0 for a constant image

- The magnitude of the descriptor is calculated in order to obtain a more accurate measurement: $magnitude=\sqrt{cH^2+cV^2+cD^2}$

Experimental Results

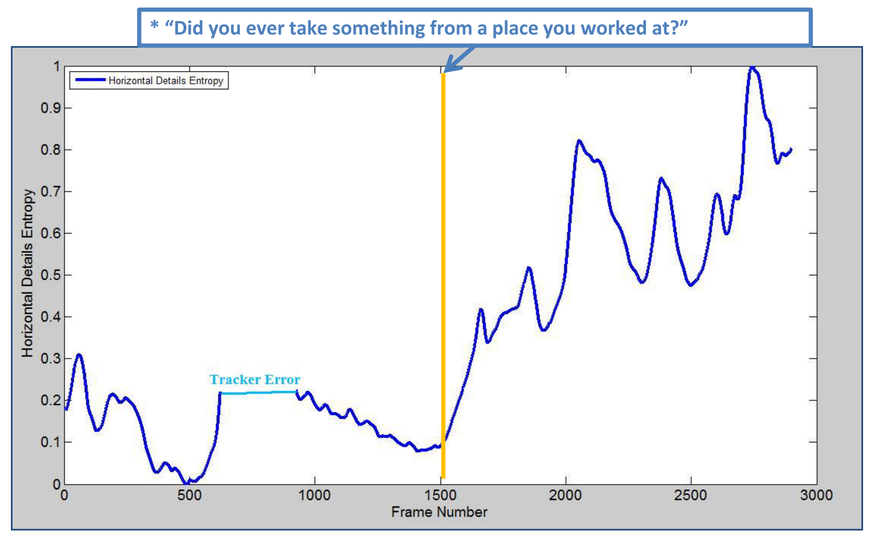
Testing Process and Data Validation

- The algorithm was tested on three videos (17100 frames)
- In two of the videos the supraorbital area was analyzed, while in the third one the maxillary area was analyzed
- **Surgical training:** The perspiration signal was extracted during the pattern cutting task.



Horizontal Entropy Component (Supraorbital)

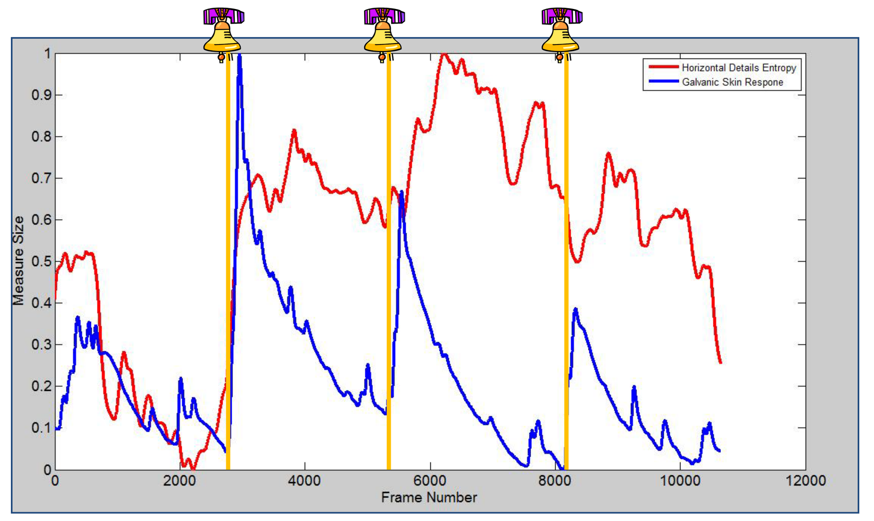
- **Lie Detection:** The perspiration signal was extracted before and after the subject was asked the key question*.



Horizontal Entropy Component (Supraorbital)

- **Startle Experiment:** A strong correlation between the perspiration signal in the maxillary region and the GSR* signal from the palm is observed.

*The GSR, or Galvanic Skin Response, is considered the golden standard in peripheral neurophysiologic and psychophysiological studies



Horizontal Entropy Component (Maxillary) vs. GSR

Conclusions & Future Work

Conclusions:

- The 2D wavelet analysis shows potential to separate blood flow (low resolution phenomena) from perspiration (high resolution phenomena)
- The statistical approach (histogram-based) works well to identify perspiration rich frames from the thermal videos
- The thermal-based stress recognition method can perform as well as the traditional GSR method
- The horizontal entropy seems to be the best perspiration descriptor in the videos analyzed this far

Future Work

- Extend the feasibility study to the entire dataset
- Write a C# program that will use the most accurate descriptor and will separate perspiration-rich frames from non-perspiration frames in the thermal video

Acknowledgements

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References

[1] Dvijesh Shastri, Arcancelo Merla, Panagiotis Tsiamyrtzis, Ioannis Pavlidis. "Imaging Facial Signs of Neuro-Physiological Response", *IEEE Transactions on Biomedical Engineering*, Accepted.

[2] S. Livens, P. Scheunders, G. van de Wouwer, D. Van Dyck. " Wavelets For Texture Analysis, An Overview ", RUCA University of Antwerp, Belgium.

[3] R.C. Gonzalez. " Digital Image Processing ", 3rd Edition, Chapter 7 and Chapter 11.

[4] MatLab Help

[5] P. Tsiamyrtzis, J. Dowdall, D. Shastri, I. Pavlidis, M.G. Frank, and P. Ekman "Imaging facial physiology for the detection of deceit", in International Journal of Computer Vision, vol. 71, no. 2, pp. 197-214, Oct. 2006.

[6] J. Dowdall, I.T. Pavlidis, and P. Tsiamyrtzis "Coalitional tracking", in Computer Vision and Image Understanding, vol. 106, no. 2-3, pp. 205-19, May-June 2007.