Estimating exercise-induced fatigue from thermal facial images

Manuel Lage Cañellas[1], Constantino Álvarez Casado[1], Le Nguyen[1], Miguel Bordallo López[1, 2]
[1]Center for Machine Vision Research and Signal Analysis (CMVS), [2]VTT Technical Research Centre of Finland Ltd.

BACKGROUND

- **Historical Challenges:** Traditional methods of exercise-induced fatigue assessment faced problems such as invasiveness, subjectiveness [1] and practical limitations.
- **Technological Solution:** Computer vision techniques employing cameras can analyze facial expressions and fatigue levels during exercise, overcoming the limitations previously encountered.

MOTIVATION

- **Thermal Imaging Potential:** Thermal imaging provides an intriguing alternative, capable of measuring muscle activity and heat exchange patterns. Exercise elevates body temperature, emitting thermal radiation, which can be captured by thermal cameras in a non-contact manner.
- **Deep Learning Exploration:** Can Deep Learning models, leveraging thermal images, accurately estimate exercise-induced fatigue?

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METHODOLOGY

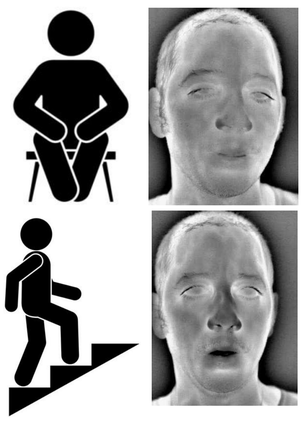
Thermal camera and setup

- Users recorded with Therm-App camera:
- VLWIR, 17 µm thermal detector, 19mm lens
- Manual focus with 288x384 pixels at 8.7Hz

Thermal database

- **Participants:**

80 individuals recorded five minutes during two exercises.



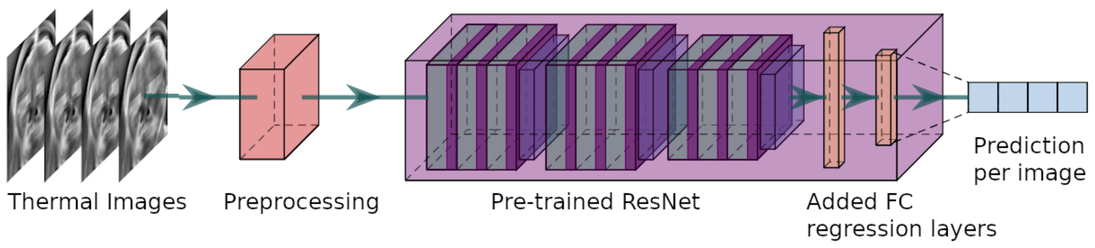
- **Resting Exercise:** Seat until **Heart Rate** < 80 bpm and **Respiratory Rate** < 12 rpm.
- **Fatigue Exercise:** Climb stairs until **Heart Rate** >120 bpm and **Respiratory Rate** > 15 rpm.

Assigning ground truth to subjects

- **Rested Users:** Fatigue Level: 0
- **Fatigued Users:** Fatigue Level: Linear decay from 100 to 0 based on phosphocreatine [2] level recuperation after five minutes.

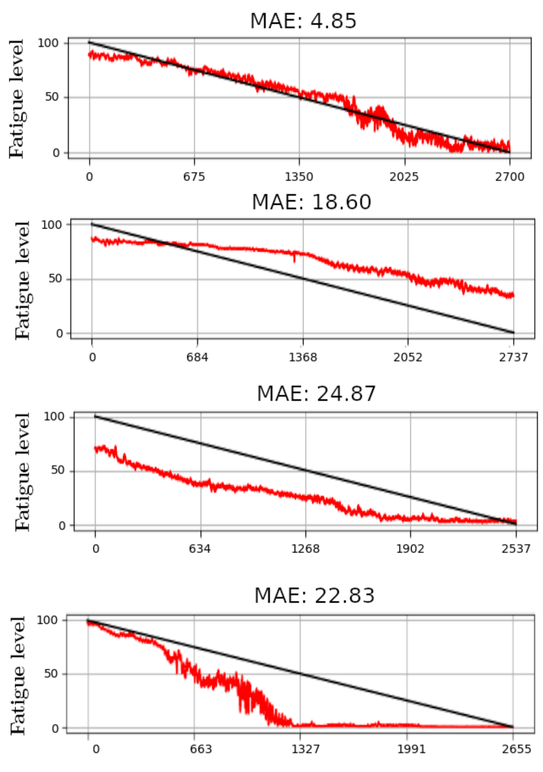
Training

- **Architecture:** ResNet with two new fully connected layers (FC).
- **Preprocessing**: Resize and random horizontal flip.
- **Enhancements:** Two additional regression layers.



RESULTS

MAE per user, four fatigue study cases



- **Correlation Confirmation:** User results confirm a clear correlation between predicted fatigue levels and the actual experienced fatigue.
- **Extended Recovery Time:** Users took longer to reach a resting level, indicating prolonged post-exercise recovery periods for some individuals.
- **Initial Fatigue Variation:** Findings suggest variations in initial fatigue levels among users, possibly impacting the speed of recovery.
- **Fast Recovery:** Noteworthy, some individuals exhibited fast recovery times, indicating their ability to recover from fatigue more quickly than others.

MAE stratified by gender and glasses

	Group	Combined	Fatigue	Resting
	Men + Women	13.64	22.20	5.40
	Men	13.46	23.72	3.59
	Women	13.96	19.52	8.60
No Glasses	Men + Women	14.01	21.44	6.57
	Men	13.77	21.97	5.57
	Women	14.32	20.74	7.91
Glasses	Men + Women	13.03	23.52	3.56
	Men	13.06	26.07	1.18
	Women	12.96	15.88	10.40

CONCLUSION

- **Static Thermal Imaging:** Our study utilizes over 400,000 static thermal facial images to predict exercise-induced fatigue levels in users.
- **Strong Correlation:** Results indicate a robust correlation between predicted values and rate of fatigue decay, demonstrating the effectiveness of thermal imaging for fatigue assessment.
- **Labeling Challenges:** Variations in fatigue decay ratios among users suggest the need for improved labeling methods, possibly integrating biosignals like heart rate and respiration rate.
- **Future Directions:** Future research should explore the synergy of diverse data sources, including biosignals, to enhance the precision and reliability of fatigue assessment techniques.

[1] Lamb, Kevin L., Roger G. Eston, and David Corns. "Reliability of ratings of perceived exertion during progressive treadmill exercise." *British journal of sports medicine* 33.5 (1999): 336-339.
[2] Kent Sahlin, Michail Tonkonogi, and Karin Söderlund, "Energy supply and muscle fatigue in humans," Acta Physiologica Scandinavica, vol. 162, no. 3, pp. 261-266, 1998.