Deep Breathing Phase Classification with a Social Robot for Mental Health

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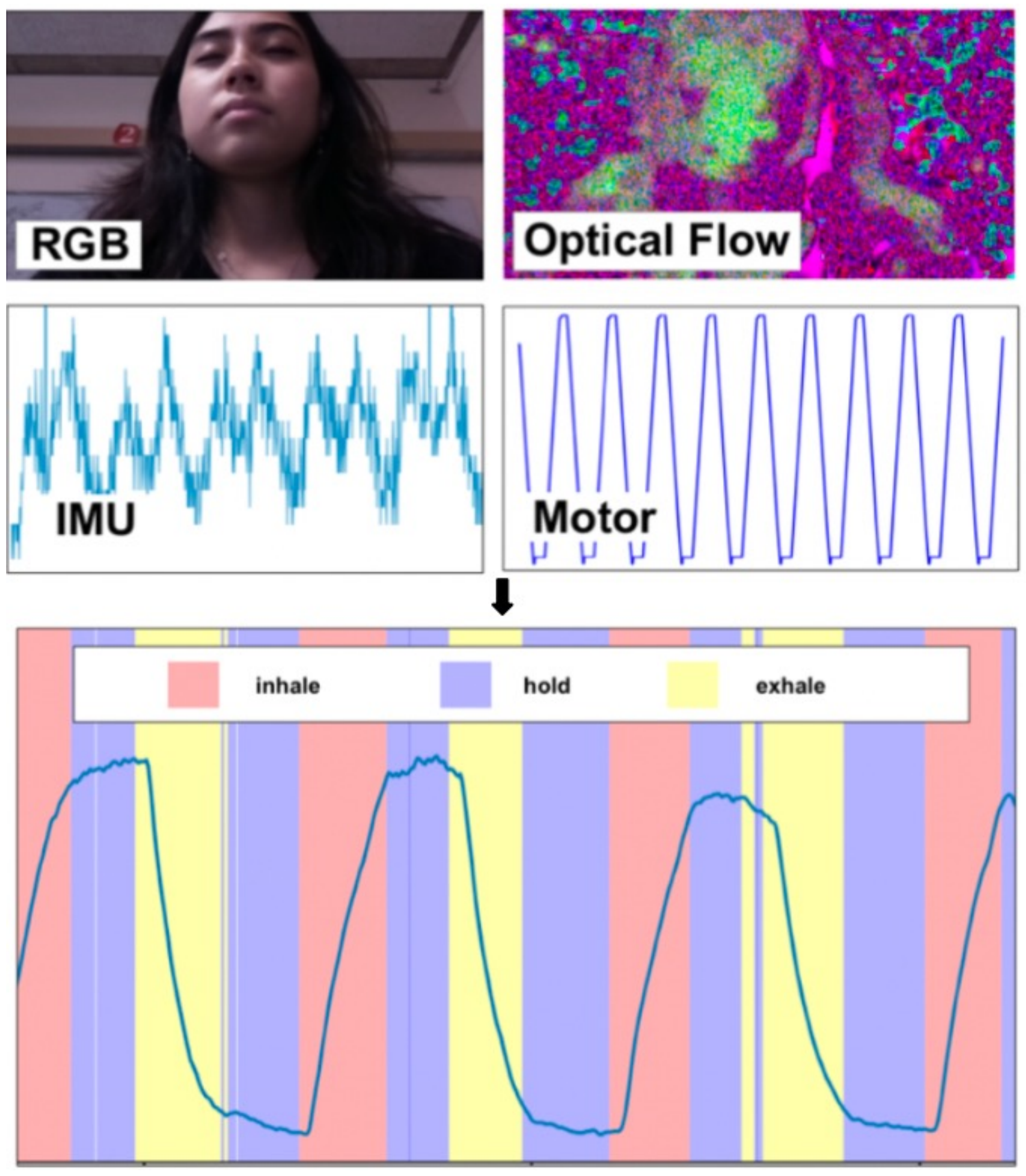
Deep Breathing Classification

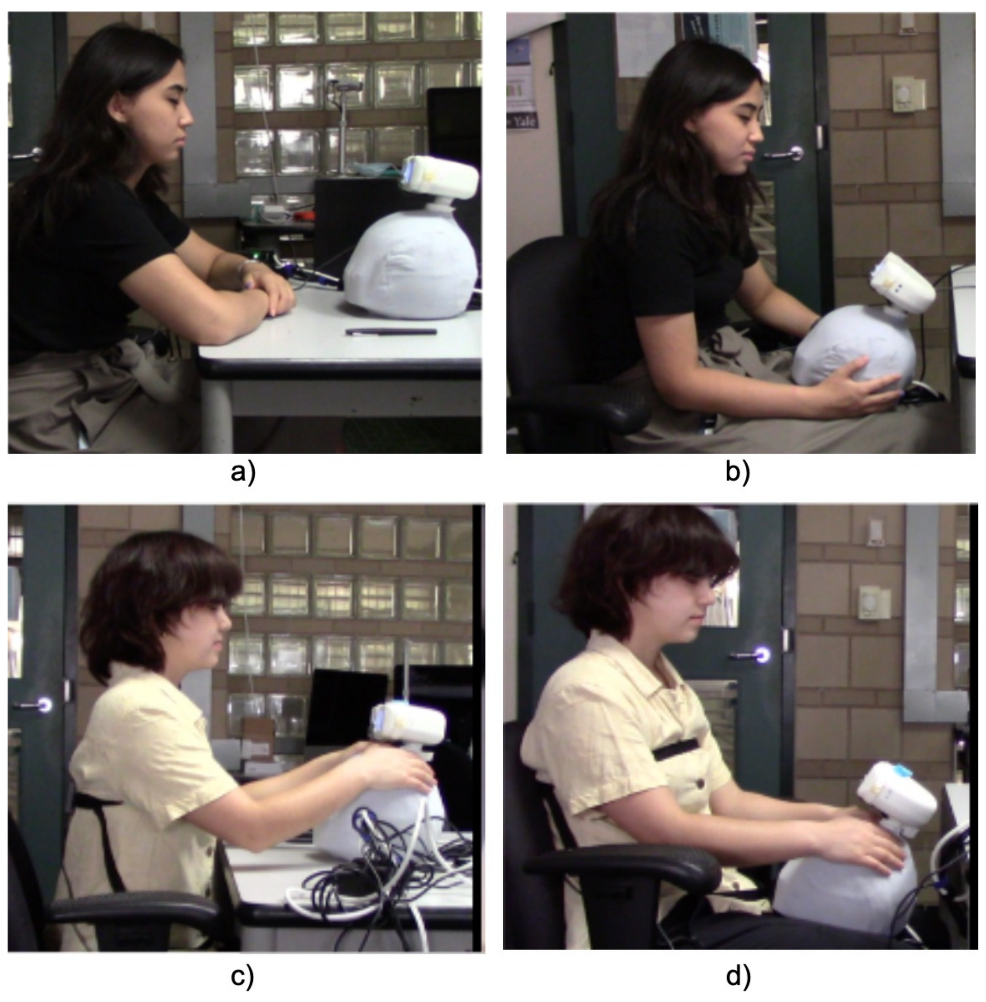


Several social robots have been developed to support mental health wellness by encouraging users to perform deep breathing exercises, which have been shown to reduce physical signs of anxiety and stress. Deep breathing is characterized by lengthening inhales, holds, and exhales to expand the diaphragm and slow down breathing.

However, none of these robots can detect the breathing phase that the user is in. This ability would allow them to track user compliance or adjust the speed of their guidance. Detecting breathing phase is challenging because of the importance of using non-contact sensors to perform this detection, the variety of individuals that may interact with a robot, and the different interaction conditions a robot could be placed in.

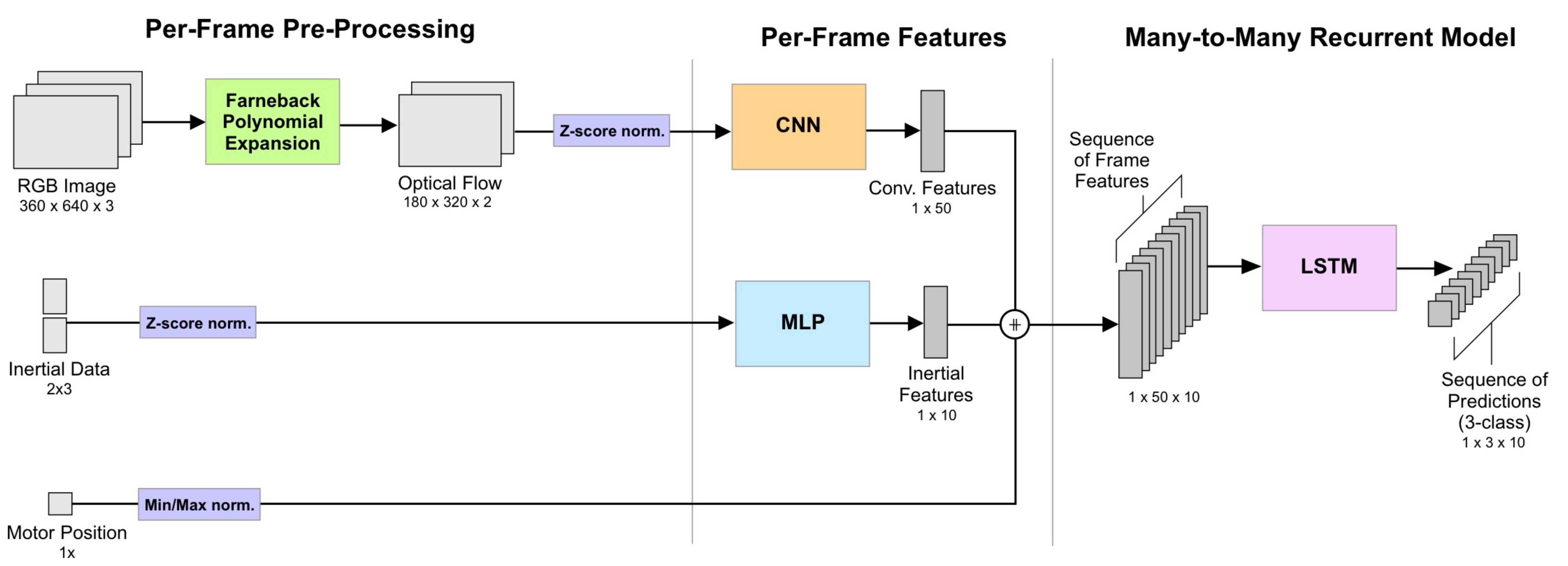
In this work, we (1) collect a dataset of people performing deep breathing with a robot and (2) explore the use of modern machine learning (ML) techniques to perform deep breathing phase classification. Our results show the potential of modern ML methods to perform multimodal deep breathing phase classification using non-contact sensor input. We found that a single model can generalize between interaction conditions and individuals.

OMMDB Data Collection



- OMMDB is a novel, open-source dataset of people performing deep breathing exercises with a robot while being recorded by non-contact sensors, with ground-truth respiration data
- A data collection system was constructed, consisting of an *Ommie* robot, an RGB camera, an inertial measurement unit, and a respiration force belt
- Data was collected in four interaction conditions to mimic the variety of robotic systems:
  - (a) Robot not breathing, Robot on table
  - (b) Robot not breathing, Robot in lap
  - (c) Robot breathing, Robot on table
  - (d) Robot breathing, Robot in lap
- The final dataset consists of data from 47 individuals
- Data is available at: `https://scazlab.yale.edu/ommdb-dataset`

Classification Methods



- Our learning goal was to predict deep breathing phase (inhale, exhale, or hold) from non-contact sensor input using common ML methods
- We utilized a Convolutional-LSTM to perform predictions due to the time-series and cyclic nature of the data

Results

Our results show generalizability:

- Between individuals, with 5-fold cross-validation of unique individuals (a)
- Across interaction conditions, with models trained on a single interaction condition (b)

Fold	F1
1	0.79
2	0.81
3	0.74
4	0.76
5	0.81

(a)

Test Condition	Same F1	All F1	Δ F1
Robot Breathing Table	0.84	0.81	-0.03
Robot Not Breathing Table	0.78	0.79	+0.01
Robot Not Breathing Lap	0.84	0.83	-0.01
Robot Breathing Lap	0.80	0.76	-0.04

(b)

Thanks to the National Science Foundation (No. 2106690, 1955653, 1928448 and the Graduate Research Fellowship Program) for partially supporting this work.