EANN 2014
15th International Conference on
Engineering Applications of Neural Networks
5 - 7 September 2014, Sofia, Bulgaria

Università degli Studi di Milano
Department of Computer Science

Fuzzy-logic Decision Fusion for Nonintrusive Early Detection of Driver Fatigue or Drowsiness

Mario Malcangi

Department of Computer Science
Università degli Studi di Milano
Milano, Italy
malcangi@di.unimi.it

Topic motivations

Sixty percent of adult drivers have driven a vehicle drowsy; more than one-third have fallen asleep at the wheel.

Source: [Harvard Medical School Division of Sleep Medicine](https://sleep.med.harvard.edu/)
https://sleep.med.harvard.edu/

Why

- ✓ Making inferences about the physiological status of a car driver is a very difficult task
- ✓ Research works demonstrate that fuzzy logic methods can be very effective if tailored on the specific nature of drowsiness detection
- ✓ The proposed method, based on fuzzy logic inference and fuzzy decision fusion, reduces the complexity and rises the reliability

Mario Malcangi

Università degli Studi di Milano
Department of Computer Science

How

- ✓ Physiological VS behavioral information
  - ✓ Autonomous Nervous System activity
- ✓ More predictors VS single predictor
  - ✓ Heart Rate Variability
  - ✓ Breathing
- ✓ Decision level data fusion VS feature level data fusion

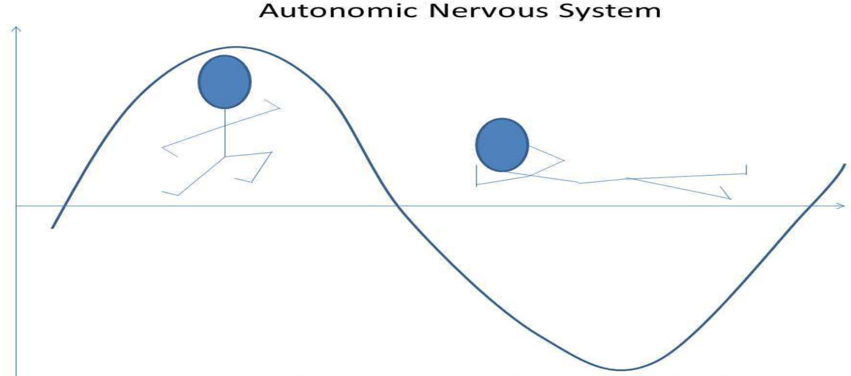
Mario Malcangi

Fuzzy-logic Decision Fusion for Nonintrusive Early Detection of Driver Fatigue or Drowsiness

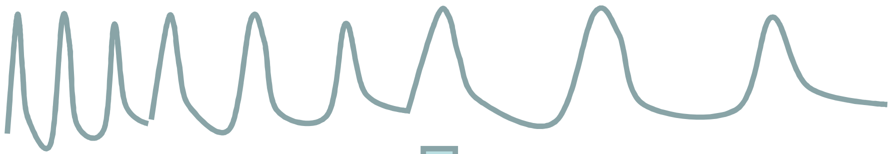
Università degli Studi di Milano
Department of Computer Science

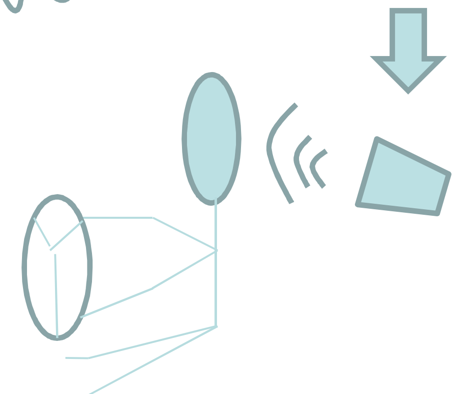
What

✓ Measurement of the Sympathetic to Parasymphatetic activity balance



✓ Measurement of the breathing activity





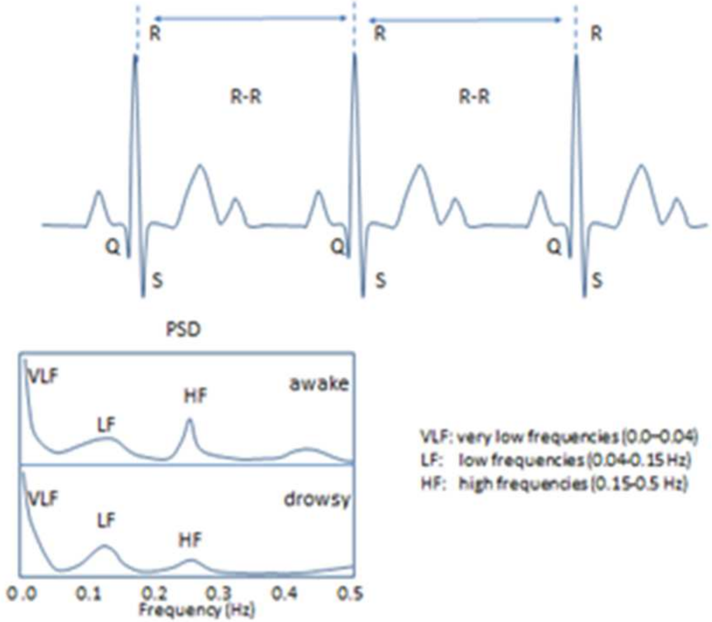
✓ Decision level fuzzy inference

Mario Malcangi

Università degli Studi di Milano
Department of Computer Science

What (cont.)

- ✓ Sleep is a physiological state characterized by variation in ANS activity, which is reflected in heart-rate variability (HRV).
- ✓ The power spectral density (PSD) of heart rate varies with the change from wakefulness to sleep.



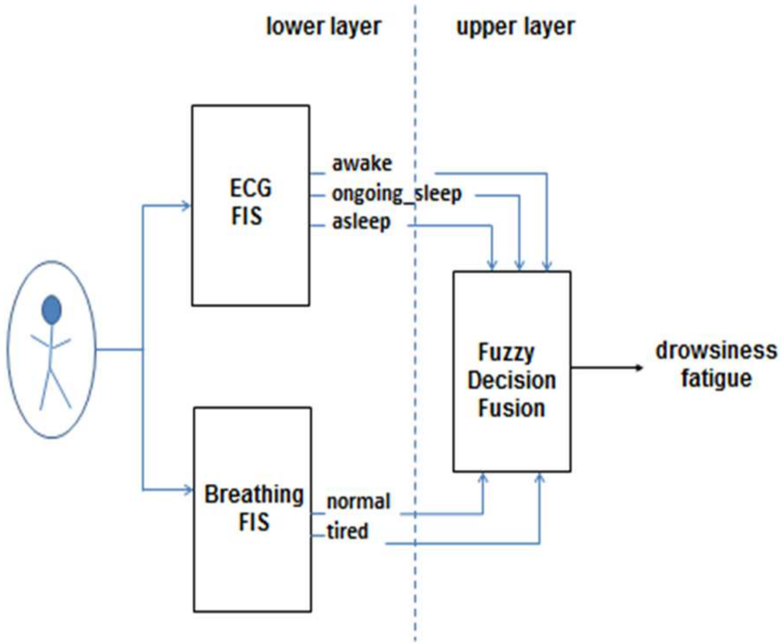
Mario Malcangi

Università degli Studi di Milano

Department of Computer Science

System Framework

- ✓ The system consists of two layers
- ✓ The lower is a feature inferencing layer
- ✓ The upper is a decision fusion layer



Mario Malcangi

Università degli Studi di Milano
Department of Computer Science

Ecg FIS

- ✓ HRV is then computed from the ECG R-R intervals (R-peak to R-peak) time series
- ✓ PSD of HRV is then computed
  - ✓ very low frequencies (0-0.04 Hz)
  - ✓ low frequencies (0.04-0.15 Hz)
  - ✓ high frequencies (0.15-0.5 Hz)

if HRV(n) is Low and
  LF(n) is Medium Low and
    HF(n) is Medium High and
    LF/HF is Medium
  then the epoch is ONSET_SLEEP
…
if HRV(n) is High and
  LF(n) is High and
    HF(n) is Low and
    LF/HF is High
  then the epoch is WAKE
…
if HRV(n) is Low and
  LF(n) is Low and
    HF(n) is High and
    LF/HF is Low
  then the epoch is SLEEP

Mario Malcangi

UNIVERSITÀ DEGLI STUDI DI MILANO
Department of Computer Science

Breathing FIS

- ✓ Breathing features:
  - ✓ Rate
  - ✓ Amplitude
- ✓ 19 rules hand tuned

…
if BreathingRate(n) is Medium and
BreathingAmplitude(n) is Medium
then the epoch is NORMAL
…

if BreathingRate(n) is Low and
BreathingAmplitude(n) is High
then the epoch is TIRED
…


Mario Malcangi

Università degli Studi di Milano
Department of Computer Science

Decision Fusion FIS

- ✓ Breathing features:
  - ✓ Rate
  - ✓ Amplitude
- ✓ 15 rules hand tuned
- ✓ Additional input (Hand Movements) is considered to improve the whole system and/or replace faulty or unavailable modules

…
if ECG(n) is Ongoing_Sleep and
Breathing(n) is Tired and
Hand_Movements(n) is Low
then the epoch is DROSINESS
…

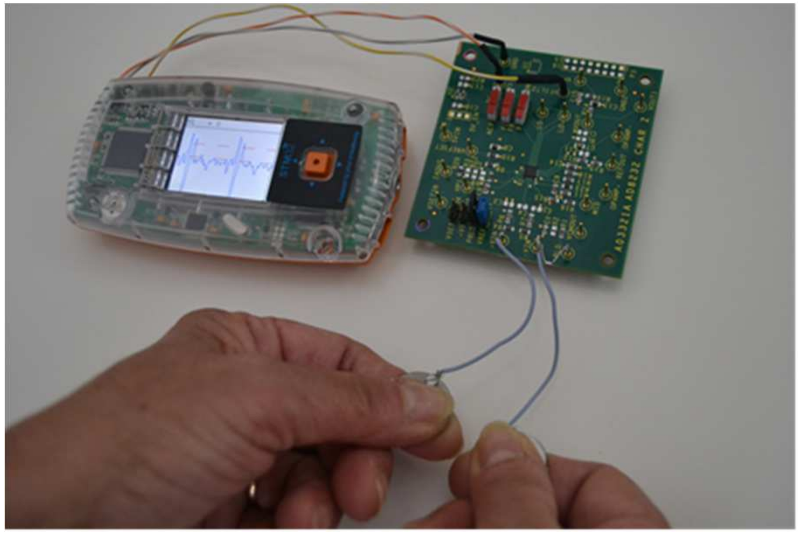
if ECG(n) is Ongoing_Sleep and
Breathing(n)_is Normal and
Hand_Movements(n) is Medium
then the epoch is FATIGUE

Mario Malcangi

Università degli Studi di Milano
Department of Computer Science

Results - Protosystem

- ✓ Protosystem based on a microcontroller from STMicroelectronics (STM32 ARM M3) and the analog front-end (AFE) from Analog Devices (AD8232).



Mario Malcangi

Università degli Studi di Milano
Department of Computer Science

Results - Evaluation

	Decision fusion		ECG features fusion		Breathing features fusion	
PREDICTED	Drosiness	Normal	Drosiness	Normal	Drosiness	Normal
ACTUAL						
Clinical						
Drosiness	19	1	19	1	18	2
Normal	1	19	3	17	2	18
In the field (nonembedded)						
Drosiness	18	2	18	2	17	3
Normal	2	18	4	16	1	19
In the field (embedded)						
Drosiness	17	3	17	3	16	4
Normal	3	17	5	15	2	18

Test type	Decision fusion	ECG features fusion	Breathing features fusion
Clinical	95%	90%	90%
In the field (nonembedded)	90%	85%	90%
In the field (embedded)	85%	80%	85%

Mario Malcangi

Università degli Studi di Milano
Department of Computer Science

Future developments

- ✓ General purpose personal physiological and vital parameters monitoring
  - ✓ Embedding incremental learning capabilities
  - ✓ Adaptation to match unattended and in the field operation
  - ✓ Application of evolving paradigms
  - ✓ Wearability

Thank you for your attention

Mario Malcangi

Università degli Studi di Milano
Department of Computer Science
Via Comelico 39 – 20135 Milano - Italy

Please, address any further question to:

malcangi@di.unimi.it