Detecting sleepiness in truck drivers

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Main results

- We have used computational intelligence methods to optimize indicators and systems for driver sleepiness detection.

- The best proposed detection system consists of a non-linear combination of the following indicators:
  - Generic variability indicator of lateral position
  - Steering wheel reversal rate
  - Perclos
  - Sleep/wake predictor (mathematical model of sleepiness)

- This system gives ~ 88 % correct driver sleepiness detection.

Driving while sleepy is dangerous!

- ~20% of all vehicle accidents have been estimated to be sleepiness related (Horne & Reyner, 1999).
- For trucks, it has been suggested that 30% of all fatal truck accidents are sleepiness related (NTSB 1999).
- Driving a car after 24 hours of sustained wakefulness corresponds to driving with a 0.1% level of blood alcohol concentration (Dawson & Reid, 1997).

How to measure driver sleepiness?

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  1. Physiological signals

Examples of physiological signals:

1. Electrooculography (EOG)
2. Electroencephalography (EEG)
3. Electromyography (EMG)

How to measure driver sleepiness?

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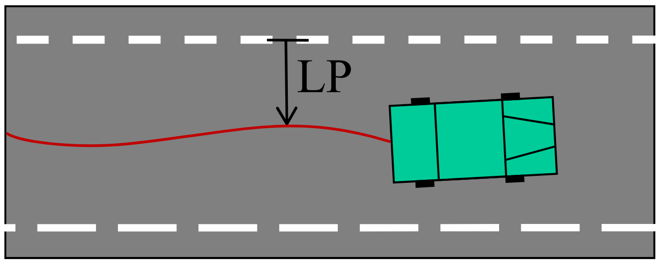
  2. <u>Camera recordings of the driver</u>

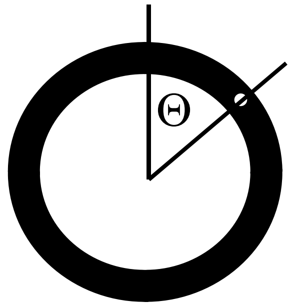
How to measure driver sleepiness?

- Signals containing driver sleepiness information:
    1. Physiological signals
    2. Camera recordings of the driver
    3. Driving behavior signals

Lateral position (LP):



Steering wheel angle (SWA):



How to measure driver sleepiness?

- Signals containing driver sleepiness information:
  1. Physiological signals
  2. Camera recordings of the driver
  3. Driving behavior signals
  4. Subjective estimations of sleepiness:

     Karolinska Sleepiness Scale (Åkerstedt & Gillberg 1990)
     - Every fifth minute
     - KSS 1: Extremely alert
     - KSS 9: Extremely sleepy, falling asleep

Data

- Ten test subjects
- Two driving sessions
  - 12:00 to 16:00
  - 00:00 to 04:00
- Rural road in eastern Sweden
- Signals sampled: CAN signals, lane tracking, DSS, physiology and KSS.

Method

- Given the signals that (may) carry information on driver sleepiness, **indicators of driver sleepiness** can be formed:
  - Standard deviation of lateral position
  - Blink duration

- Some indicators are defined using parameters:
  - Number of steering wheel reversals per minute: $c_1 < r < c_2$
  - ”Intermediate” reversals: $8 < r < 15$
  - ”Large” steering wheel reversal: $r > 15$

- We have applied stochastic optimization (in the way of genetic algorithms) to find the indicator parameters that yield *optimal* driver sleepiness detection (on our data).

Sleepiness detection as binary classification

- The task of a binary classifier is to assign each element in the data set to either of two classes C_1 (sleepy) and C_2 (alert).

$$C_1: \quad KSS \geq 7$$
$$C_2: \quad KSS \leq 6$$

- KSS 1: Extremely alert
- KSS 9: Extremely sleepy, falling asleep

The objective function used

$$f_i = \frac{1}{2}\left(\frac{n_{i,2}}{N_{i,2}} + \frac{n_{i,1}}{N_{i,1}}\right)$$

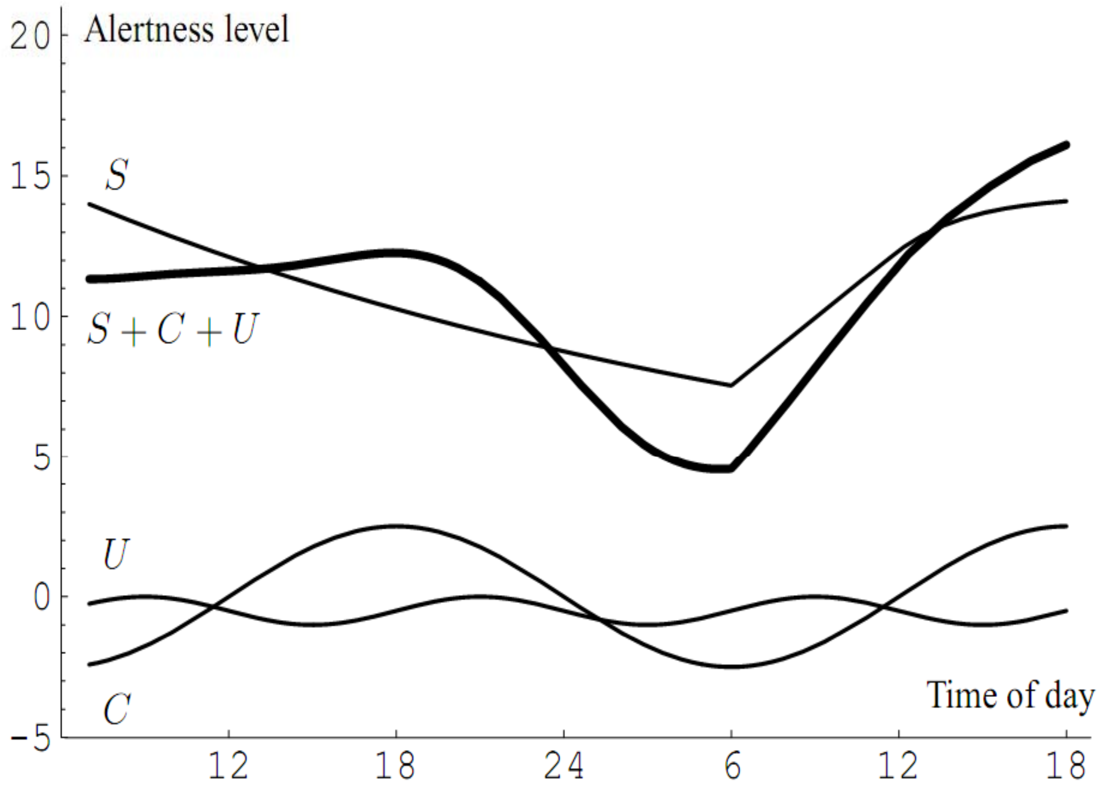
$$F = \frac{1}{k}\sum_{i=1}^{k} f_i$$

The Sleep/Wake Predictor

S: Homeostatic effects on sleepiness.

C: Circadian component.

U: Ultradian rhythm.



Generic variability indicator (GVI)

$$G = \frac{1}{n}\sum_{i=1}^{n} w(z_i)|z_i|^{\kappa}$$

$$z_i = x_i - (\delta\bar{x} + (1-\delta)p)$$

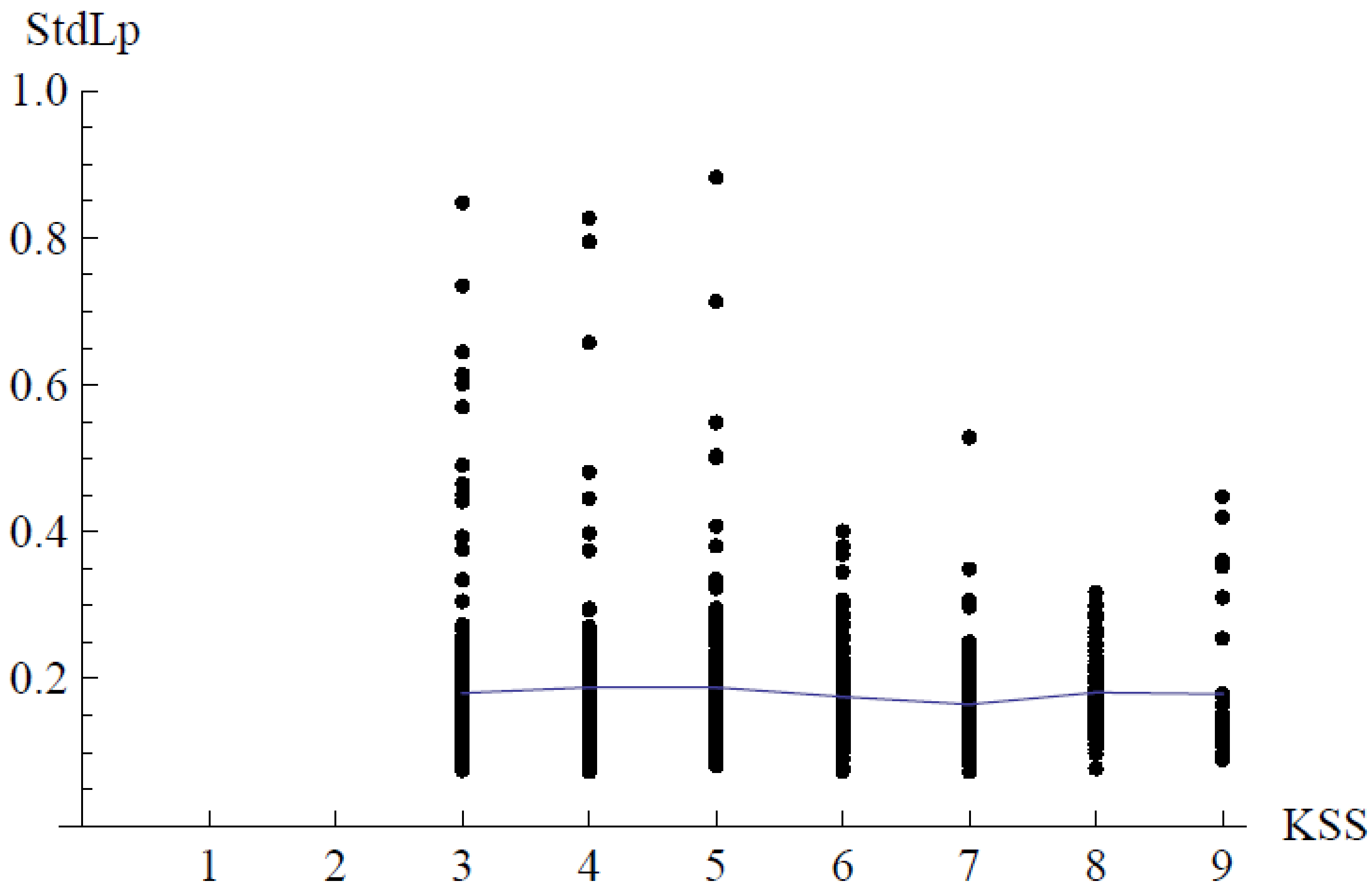
$$w(z_i) = \frac{c_L}{1+\mathrm{e}^{-\alpha_L(z_i-\beta_L)}} + \frac{c_R}{1+\mathrm{e}^{-\alpha_R(z_i-\beta_R)}}$$

Variability of lateral position

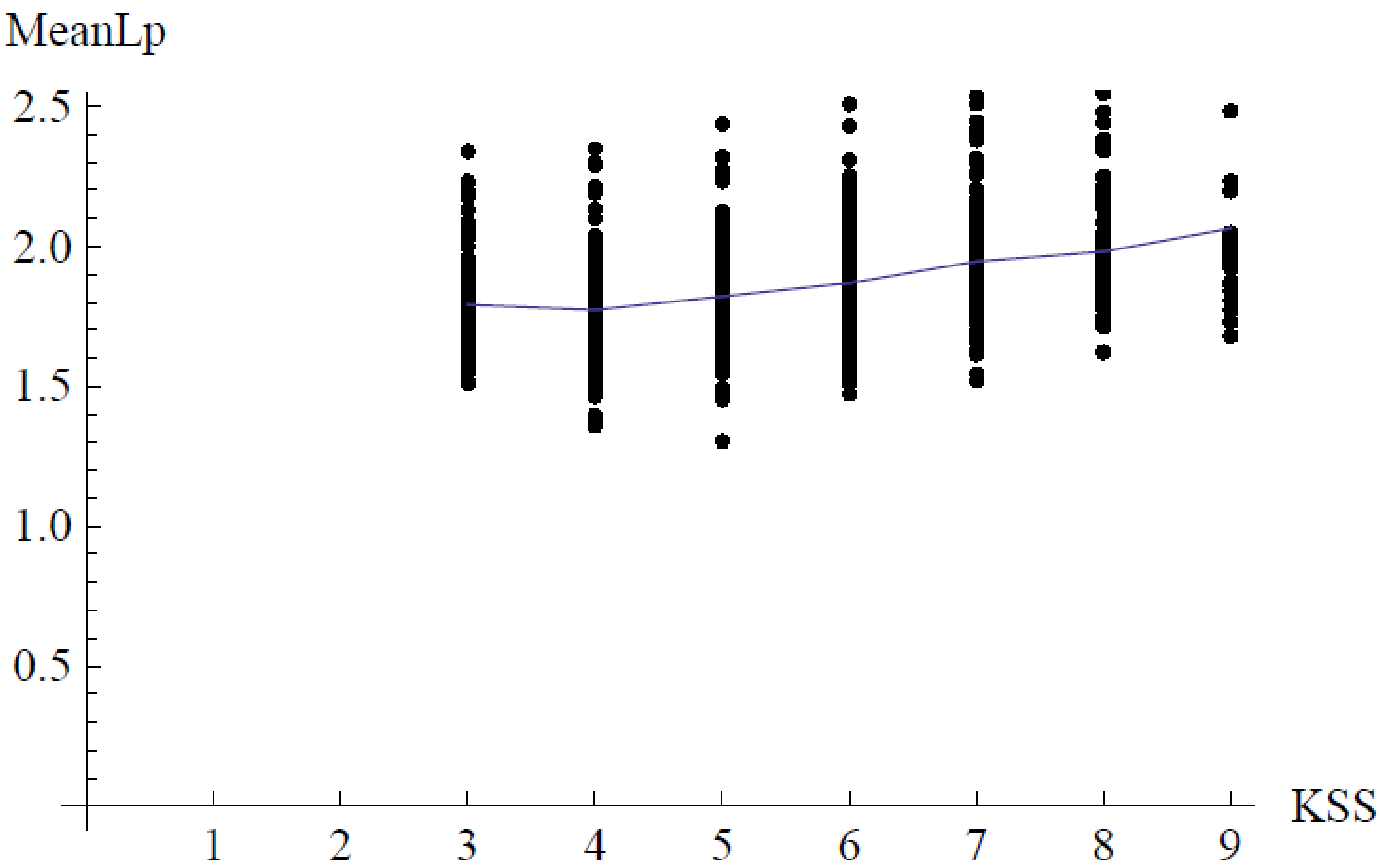
- After simplifying the equations, given the parameters obtained from optimization, we found that GVI was basically reduced to the ***mean*** of the lateral position.

	Day	Night
Alert	1.79	1.90
Sleepy	1.86	2.02

Variability of lateral position



Variability of lateral position



VTEC08-data, indicator results

Indicator	Performance
Standard deviation of lateral position	0.54
Standard deviation of heading angle	0.53
Standard deviation of steering wheel angle	0.60
Large steering wheel reversals	0.61
Medium steering wheel reversals	0.60
Small steering wheel reversals	0.51

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GVI of lateral position	0.60
GVI2 of lateral position	0.80

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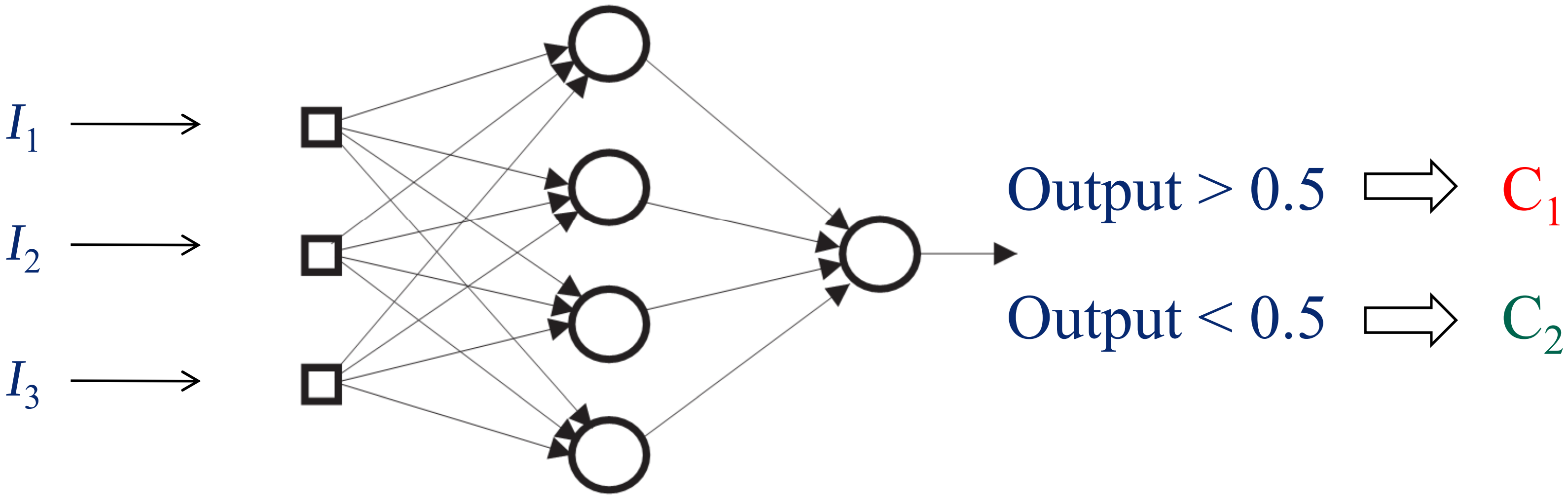
Perclos	0.50
SWP	0.84

Feedforward neural networks (FFNNs)



VTEC08-data, systems results

Detection system	Performance
GVI2Lp, ConfLp, SWARev	0.82

- GVI2Lp: The GVI2 indicator (with different parameter settings for day and night, respectively) applied to the lateral position signal.
- ConfLp: The confidence signal for the lateral position.
- SWARev: Steering wheel angle reversals.
- ConfPerc: The confidence signal for Perclos.
- SWP: The Sleep/Wake predictor.

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DROWSI

Drowsiness Intervention

The DROWSI project in short:

- A three-year project.
- The primary objective of the DROWSI project is to perform multidisciplinary research and development of concepts and technologies for real-time drowsiness prediction and countermeasures.

Thank you for listening!

CHALMERS VOLVO IPM vti Vägverket Autoliv

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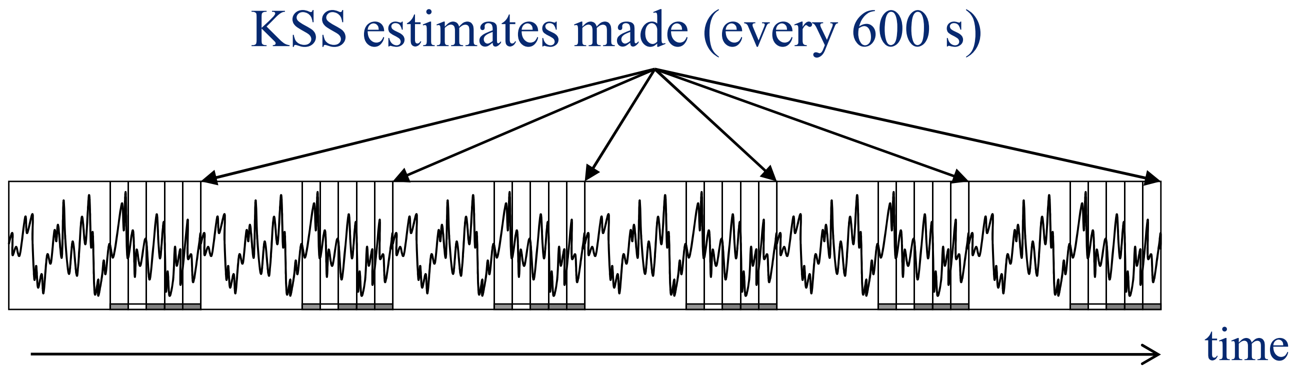
End ...


KSS estimates made (every 600 s)
time

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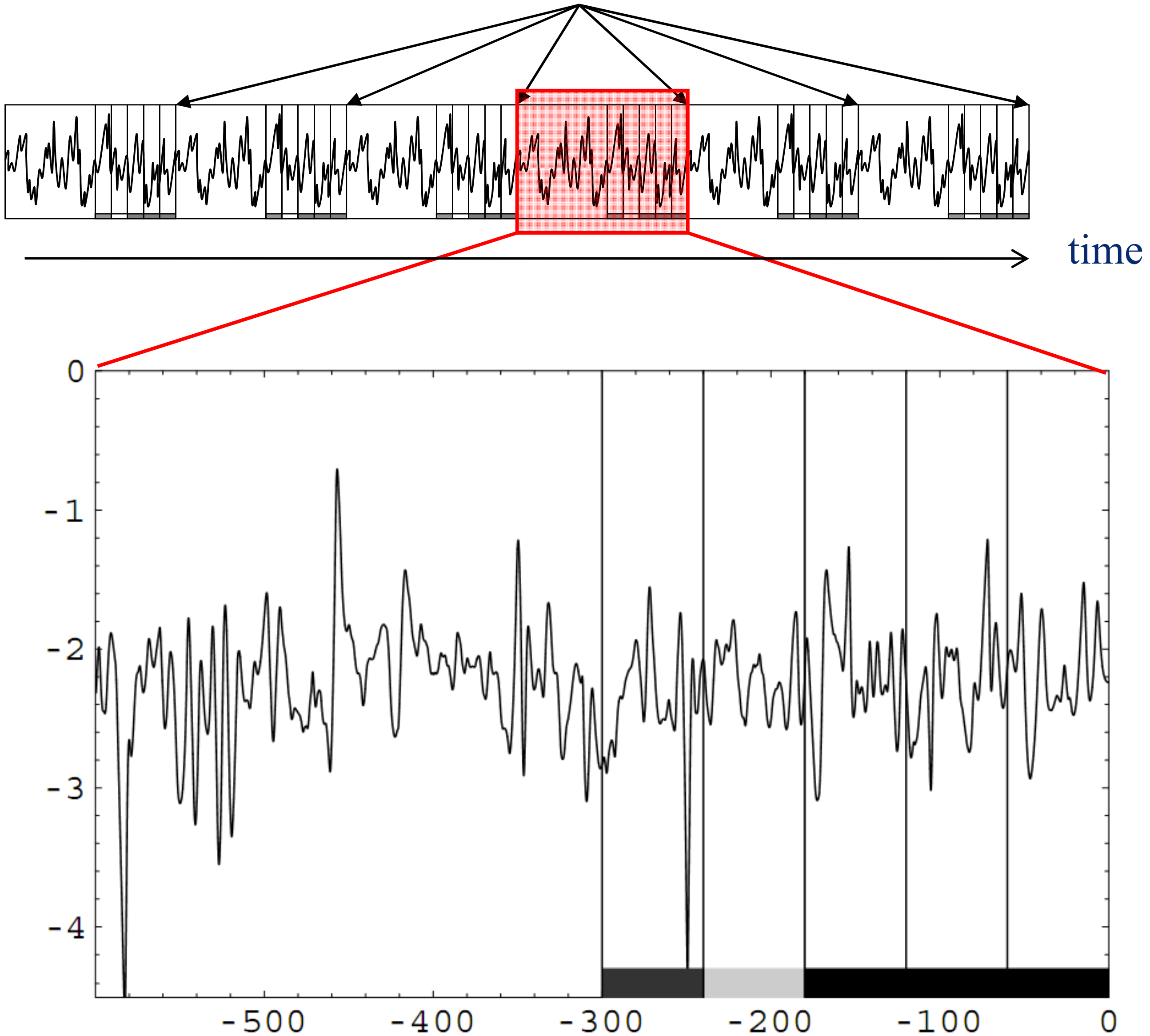

The five minute interval is split into five 60 s. periods which are inserted into the test, validation and training sets: