Uncertainty and Reliability in Predicting Crew Alertness

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Objective:
To develop a feasible approach to estimating the alertness of train conductors from speech using various acoustic measures

An Alertness Monitoring system was previously developed
• Continuously monitor signals from the subject under test
• Non-Interpreting – to protect the subject’s privacy rights
• Unobtrusive – prevent subject from feeling observed

How reliable is the reported fatigue state?
• Human interaction naturally introduces levels of uncertainty
• Definitive conclusions about alertness and fatigue are difficult to obtain
• The human I/O model between speech and fatigue is also difficult to obtain

Validation study: Evaluate the algorithm through laboratory study

The speech signal was recorded with a sampling frequency of 44100 Hz and a 16 bit per sample resolution. The speech waveform and the segments containing speech at varying alertness levels are shown above.

Validation study: Estimate of uncertainty corresponding to fatigue quotient

The output from uncertainty estimation subsystem tags the fatigue quotient with an estimate of how accurate it is.

Fuzzy Logic Inference Engine: underlying assumptions

• The output is defined as
  \[ y = \text{Fatigue Quotient} \]
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• The input is defined as
  \[ x_1 = \text{Speech Duration} \]
  \[ x_2 = \text{Silence Duration} \]
  \[ x_3 = \text{Word Rate} \]
  \[ x_4 = \text{Phrase Gap Duration} \]
  \[ x_5 = \text{Words per Phrase} \]
  \[ x_6 = \text{Word Intensity} \]

• A 30 element, canonical Fuzzy Rule base of the form
  \[ IF x \text{ is A and } y \text{ is B} THEN y \text{ is } C \]

Development: Uncertainty Estimation

• Assume the existence of a finite set of alertness “states” called “clusters”
• GMC automatically identifies number and level of each cluster
• Estimate the probability that each new estimated fatigue level belongs to a particular alertness state

Validation study: Speech metrics extracted by the Speech Pre-processor subsystem

The plot shows the metrics as they were extracted from the signal shown in the previous slide. Metrics that indicate an alert state are shown in green and fatigue is shown in red.

Accomplishments: Summary

• An uncertainty estimation algorithm was developed for estimating a reliability measure associated with the reported fatigue quotient
• The proposed algorithm was validated using hyper-articulated changes in recorded speech patterns
• The uncertainty estimation algorithm was successfully integrated into the existing alertness monitoring system