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Advanced Prognostic Monitoring for FCS

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Problem

- Key to survivability and reliability is …
- Forewarning of adverse events …
- Which arise from condition change …
- That is hidden in noisy, complex data
- Quantify change via practical technology:
  Quickly – (near) real time
  Accurately – maximize total trues
  Ambulatory device

Solution

Data-driven Analysis

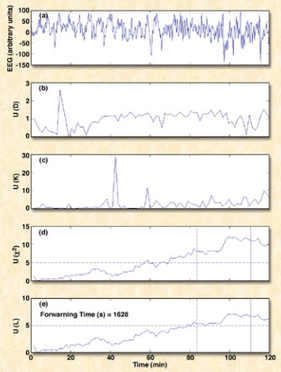
Acquire Process-Indicative Data
↓
Remove Irrelevant Artifacts
↓
Capture Signature of Baseline Dynamics
↓
Capture Signature of Later Snapshots
↓
Dissimilarity Between Baseline and Unknown
↓
Forewarning for Significant Dissimilarity

Example 1

EEG Data

- Biomedical Monitoring Systems Inc.
- Sample rate = 250 Hz
- 19 channels of *scalp* data
- Band-pass filtered: 0.5 - 99 Hz
- Datasets span 5,000 – 29,500 seconds
- 60 datasets: 40 event, 20 non-event
- Multiple datasets: 30 from 11 patients
- 36 females and 24 males: 4≤years≤57

EEG Results

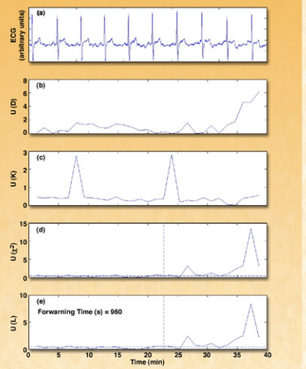


Example 2

Cardiac Events

- 5 electrocardiogram datasets
  - Digital data from Holter recordings
  - Analysis of one channel (250 Hz)
  - Datasets spanned <1 hour
- Dissimilarity analysis for forewarning

Cardiac Results

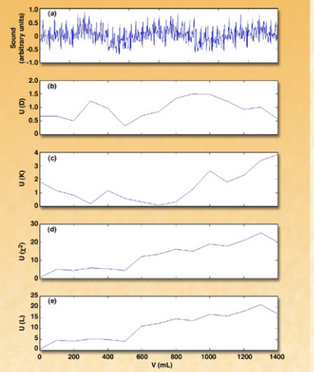


Example 3

Breathing Difficulty

- Test at Walter Reed Medical Center
  - Anesthetized pig
  - 0 to 1400 ml of air into pleural space
  - Surface (chest) stethoscope
  - Sampling rate = 10 kHz
- Basecase for normal breathing (0 ml)
- Testcases for 100 ml increments

Breathing Results

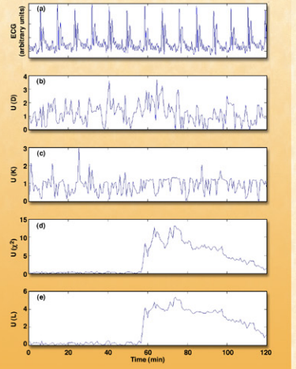


Example 4

Sepsis Onset

- 23 anesthetized rats at UTKMC
  - 17 exposed to inhaled endotoxin
  - 6 exposed to de-ionized water
- 4 surface ECG electrodes (500 Hz)
- Test protocol (1.5 to 3 hours total)
  - 30 to 60 minutes for baseline
  - 30 minutes of *Salmonella* endotoxin
  - 30 to 90 minutes of recovery

Sepsis Results

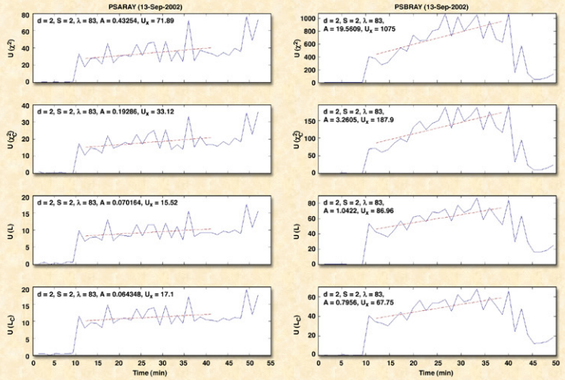


Example 5

Fainting

- Experiments at University of Kentucky
- ECG (250 Hz)
- Flat (10m); 70° tilt (60m); flat (5m)
- Two human subjects
  RAY/PSB (event), PSA (no event)
  RUI/PSB (event), PSA (no event)

Fainting Results



Fainting Results (cont.)

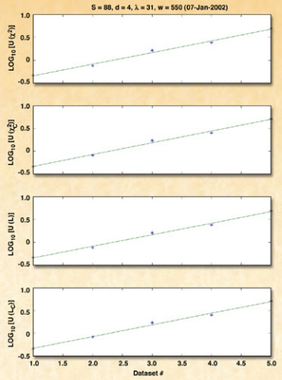
- RAY event
  Much larger slope (>12x)
  Larger values (≥4x)
- RUI event
  Much larger slope (>1149x)
  Much larger values (>34x)

Example 6

Seeded Motor Fault

- Nominal = no fault
- 1st fault = rotor bar cut half way thru
- 2nd fault = same rotor bar cut 100%
- 3rd fault = second rotor bar cut 100%
- 4th fault = 2 more rotor bars cut 100%
- Motor power at 40 kHz

Motor Fault Results



Technology Status

Now at TRL5

- High-fidelity technology integration
- Tests in simulated environment
- Failure forewarning …
- Via analysis of archival data …
- On desktop computer …
- 6 patents and two patents pending (US government retains patent rights)

How to get from TRL 5 to TRL7

- On-line analysis of …
- Real-time data …
- On hand-held device …
- Via graphical user interface …
- Robust choice of parameters …
- Yielding accurate predictions…
- That are event- and duration-specific…
- And, analyst-independent

Marginal cost for TRL6 prototype

Conclusions

UA Prognostic

- Data-driven, non-intrusive, fast
- Provides robust, timely forewarning
- Examples congruent with soldier use:
  - Chest sounds ←→ abdominal wound
  - Sepsis/ECG ←→ bio-warfare agent
  - Epilepsy/EEG ←→ neurotoxin
  - Mainting/ECG ←→ heat exhaustion
  - Motor failure ←→ equipment failure

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