Group 8: Multivariate time series analysis of ICU mortality

Paper Presentation, 3/7/2012

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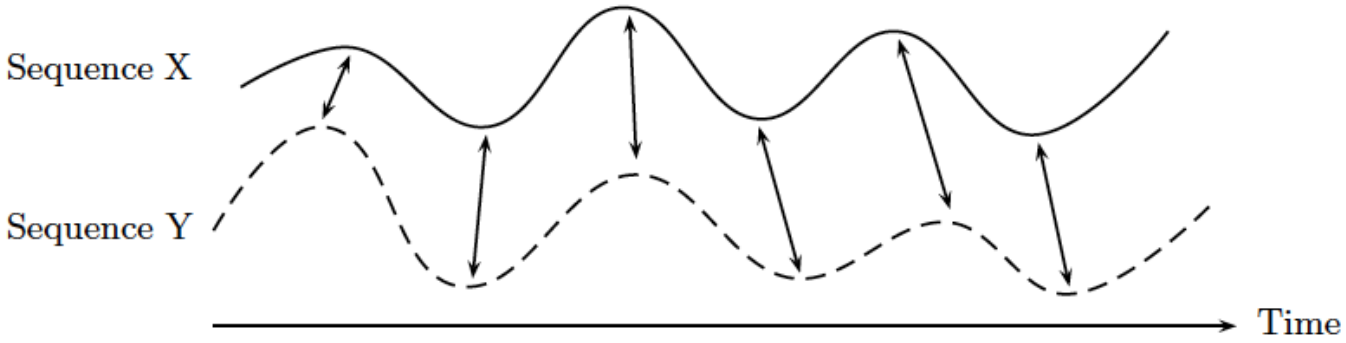
Overview

misc	hepatic	renal	Hemodynamic	respiratory	neuro	heme	endothelial	infection
cholesterol	ALP	BUN	DiasABP	FiO2	GCS	Hct	weight	WBC
glucose	ALT	creatinine	HR	MechV		Platelets	albumin	temp
Mg	AST	Urine	Lactate	PaCO2				
Na	bilirubin	HCO3	MAP	PaO2				
			NIDasABP	pH				
			NIMAP	RespRate				
			NISysABP	SaO2				
			SysABP					
			TropI					
			TropT					

Some time-series are correlated: (MAP, NIMAP), (pH, PaCO2, HCO3)…
Non-randomly missing measurements

1. Optimal Warping Path

- Dynamic Time Warping: find an optimal alignment between two given (time-dependent) sequences under certain restriction
- Intuitively, the sequences are warped in a nonlinear fashion to match each other.



Time alignment of two time-dependent sequences. Aligned points are indicated by the arrows.

Müller, M. (2007). Chapter 4: Dynamic Time Warping. Information Retrieval for Music and Motion, Springer.

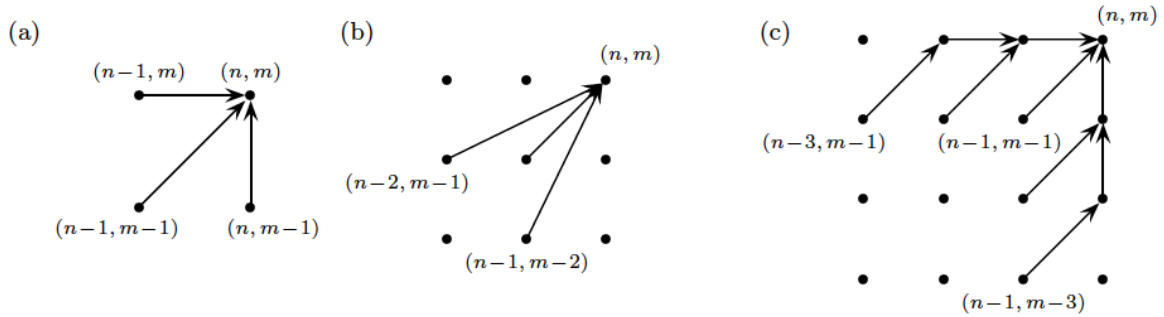
- Local cost: $c(x_i, y_j) = \| x_i - y_j \|$
- Define accumulated cost matrix D, for 1<n<=N and 1<m<=M,

  $D(n,m) = \min\{D(n-1,m-1), D(n-1,m), D(n,m-1)\} + c(x_n, y_m)$

  Initialized by $D(n,1) = \sum_{k=1}^{n} c(x_k, y_1)$ and $D(1,m) = \sum_{k=1}^{m} c(x_1, y_k)$
- Trace back from upper right $p_L=(N,M)$ to recover the optimal path p*, $p_{l-1} := \arg\min\{D(n-1,m-1), D(n-1,m), D(n,m-1)\}$

Variations of DTW

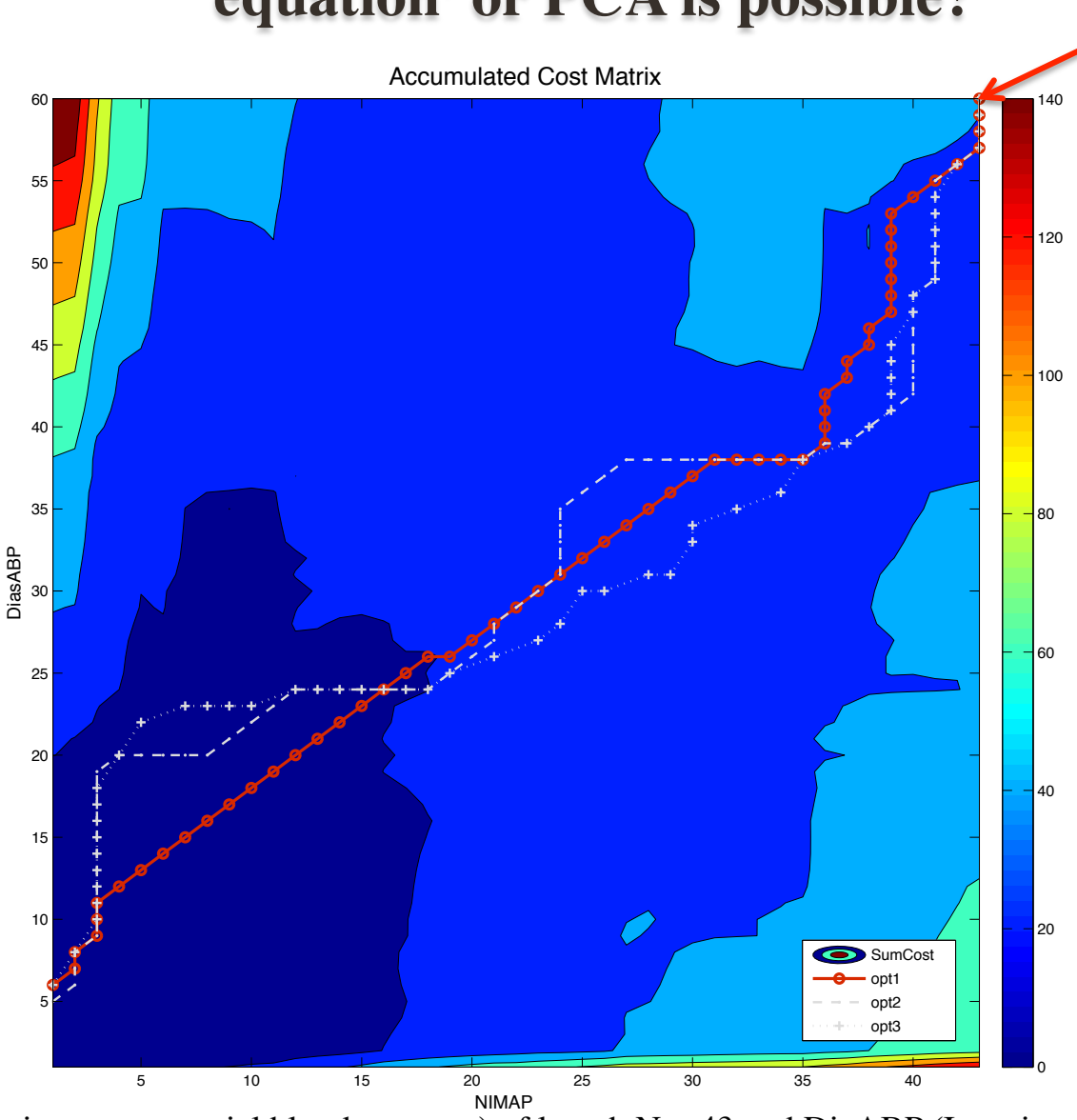
1) Step size condition:



2) Local Weights in favor of diag/vertical/horizontal step, e.g.

$$D(n,m) = \min\{D(n-1,m-1) + w_d \cdot c(x_n, y_m), D(n-1,m) + w_h \cdot c(x_n, y_m), D(n,m-1) + w_v \cdot c(x_n, y_m)\}$$

Thoughts: Align very similar physio variables, so that 'sick equation' or PCA is possible?

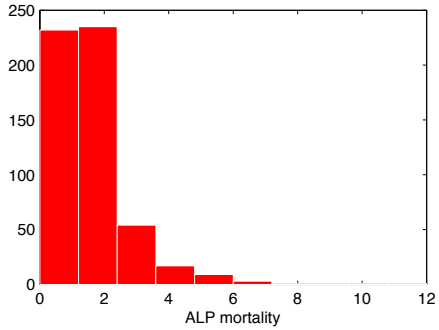


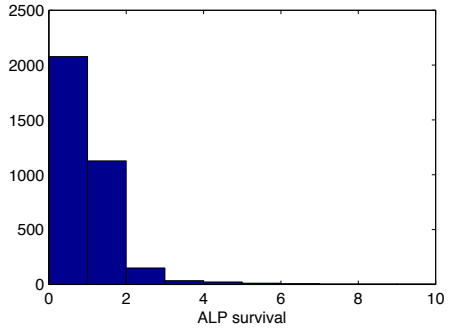
NIMAP (Non-invasive mean arterial blood pressure) of length N = 43 and DiaABP (Invasive diastolic arterial blood pressure) of length M = 60 in a random sample under different cost settings (different step size or local weights).

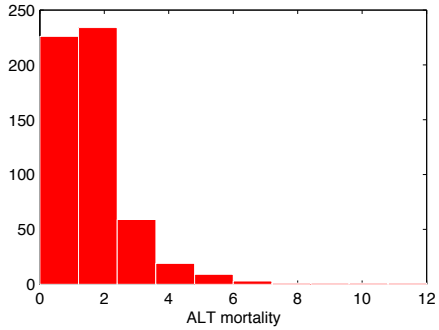
2. Non-randomly missing measurements

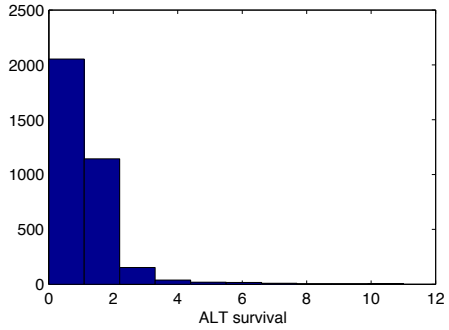
- When standard laboratory results (e.g., complete blood count) are not recorded, it's assumed that they are missing at random and not correlated with outcome.
- Blood gas measurements, however, are likely obtained only for profoundly ill patients and hence are not missing at random.

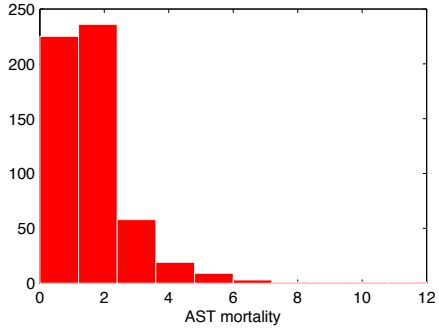
Thoughts: Ordering is an action that is taken only if the presumed P(hepatic dysfunction | current data about the patient) > some threshold for testing.
ALP, ALT, AST are three measures of hepatic dysfunctions, and we observe different counts of tests in case v.s. control.

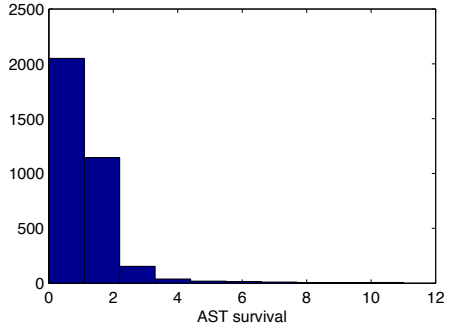












Risk factors in a probabilistic framework

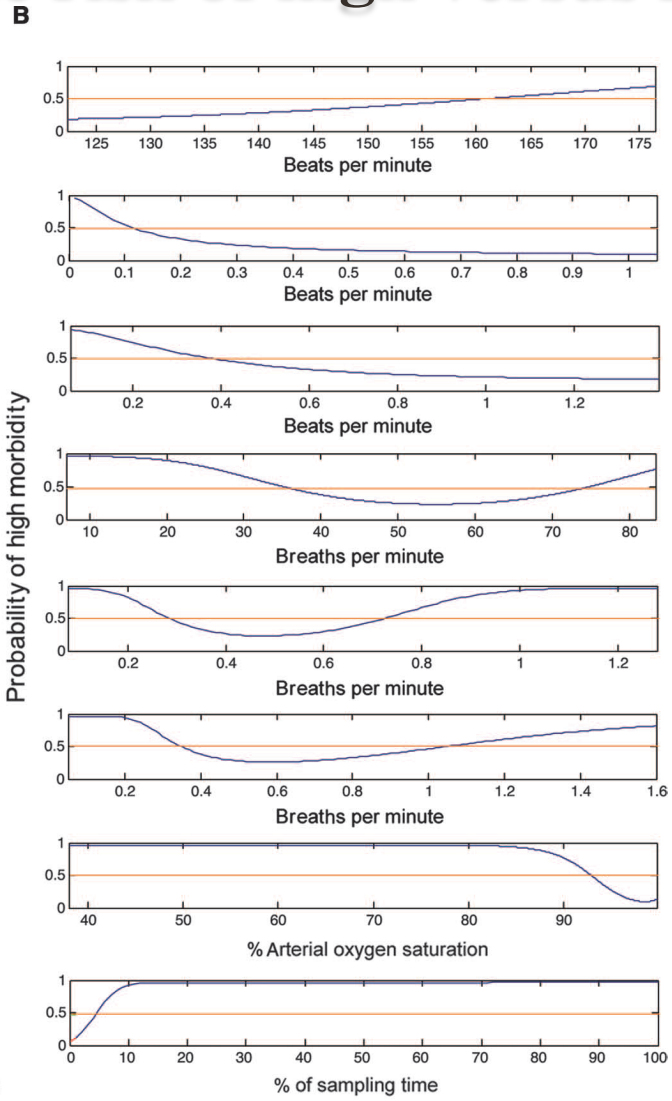
- v_i is risk factor, m_i = 1 if measurement v_i is missing and m_i = 0 otherwise. HM: high morbidity, LM: low morbidity.

$$f(v_i) = \begin{cases} \log \dfrac{P(v_i \mid HM, m_i = 0) \cdot P(m_i = 0 \mid HM)}{P(v_i \mid LM, m_i = 0) \cdot P(m_i = 0 \mid LM)} \\ \log \dfrac{P(m_i = 1 \mid HM)}{P(m_i = 1 \mid LM)} \end{cases}$$

- In this paper, long-tailed probability distributions are candidates.

Saria S, Rajani AK, et al. (2010). "Integration of early physiological responses predicts later illness severity in preterm infants." Sci Transl Med. **2**(48): 48ra65.

The nonlinear function associating the parameter with the risk of high versus low morbidity.



Saria S, Rajani AK, et al. (2010). "Integration of early physiological responses predicts later illness severity in preterm infants." Sci Transl Med. **2**(48): 48ra65.

Aggregate individual risk features using logistic function

$$P\left(HM \mid v_1, v_2, \ldots, v_n\right) = \left(1 + \exp\left(b + w_0 \cdot c + \sum_{i=1}^{n} w_i \cdot f\left(v_i\right)\right)\right)$$

n was the number of risk factors, *c*=log P(HM)/P(LM) was a prior log odds ratio, the *i*th characteristic, *vi* was used to derive a risk feature *f(vi)* via nonlinear Bayesian modeling.

b and *w* were learned from the training data via maximizing log likelihood of the data with a penalty term as

$$\arg\max_{w,b} \sum_{j=1}^{n} \log P\left(HM \mid v_1^j, v_2^j \ldots v_{18}^j\right) - \lambda \sum_i w_i^2$$

n was the number of patients, lamda=1.2 in this setting to control model complexity.

Saria S, Rajani AK, et al. (2010). "Integration of early physiological responses predicts later illness severity in preterm infants." Sci Transl Med. **2**(48): 48ra65.

Logistic map:

From $-\infty \sim +\infty$ to [0,1]

Thoughts: *The law of rare events*

- Poisson distribution--**The *law of rare events***

$$f(k;\lambda)=\frac{\lambda^k e^{-\lambda}}{k!}$$

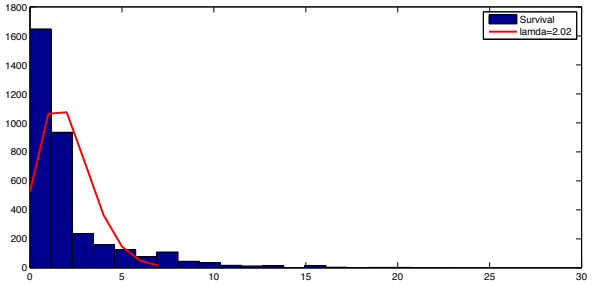
- The probability distribution of the number of occurrences of an event that happens rarely but has very many opportunities to happen.
- Large number of flipping coins, but

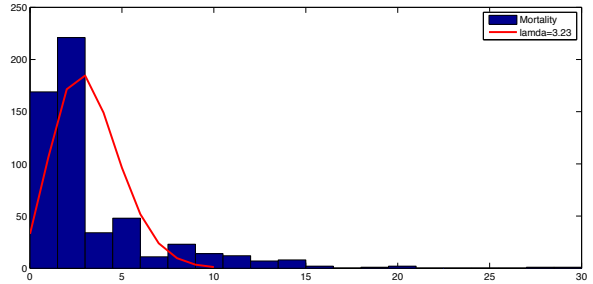
rarely heads up.

- Lactate test:

lamda=2.02 in control,

lamda=3.23 in case.





Thank you