USTUR-0590-21A

Comparison of Latent Bone Modeling and Simple Average Method for Estimating Plutonium Activity Concentration in Human Skeleton

Joey Y. Zhou[1], Martin Šefl[2], Maia Avtandilashvili[2], George Tabatadze[2], Sergei Y. Tolmachev[2]

[1]Office of Environment, Health, Safety and Security, United States Department of Energy, Washington, D.C., USA

[2]United States Transuranium and Uranium Registries, College of Pharmacy and Pharmaceutical Sciences, Washington State University, Richland, WA, USA

Motivation

- Skeleton consists of 206 bones
- Calculation of total skeleton activity

$$\textbf{\textit{Activity}} = \textbf{\textit{C}}_{\textbf{skel}} \times \textbf{mass}$$

- How to estimate plutonium concentration in the skeleton C_{skel} from a limited number of analyzed bone samples (C_{bone})?
- For most cases – the default method for C_{skel} estimation is the arithmetic mean of available bone sample concentrations (average)
- Recently Latent Bone Modeling (LBM) utilizing Principal Component Regression (PCR)
- How does average compare to LBM?

Reducing bone dataset using principal component analysis

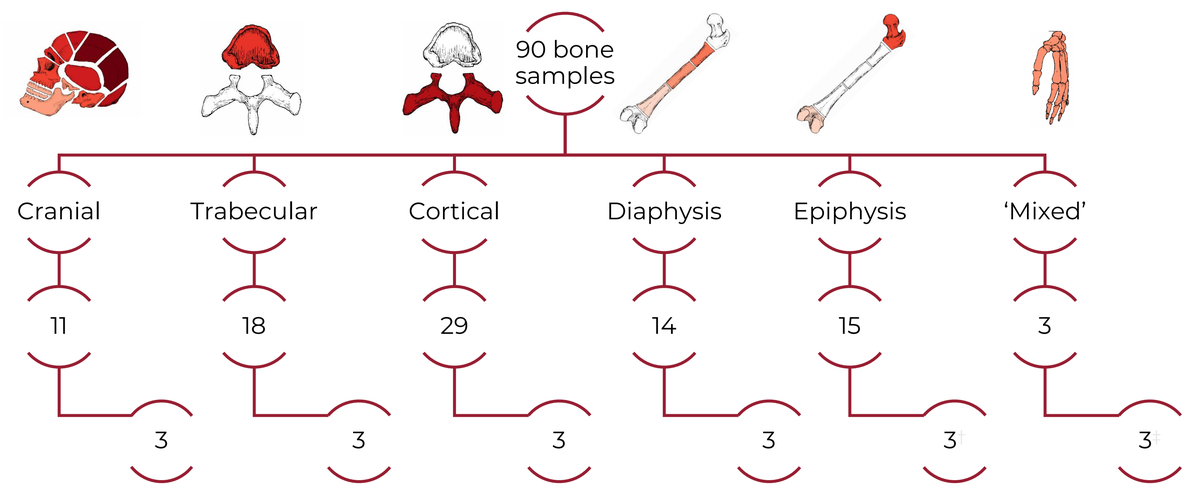
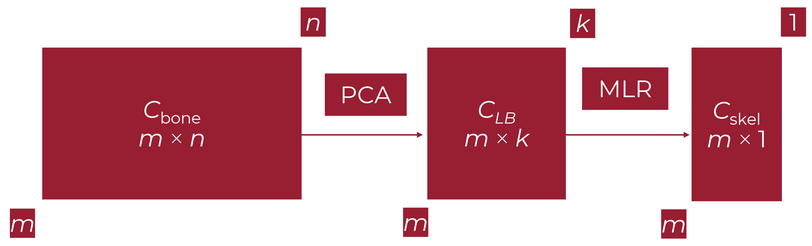


Figure 1: Categorization of available bone samples for 'best' bone selection.

Latent Bone Modeling (LBM)

- Novel approach to estimate C_{skel} based on principal component regression
- Reduction of dimensionality while preserving maximum information
- Converting bone sample concentrations into new **latent bone variables** – linear combination of the measured concentrations



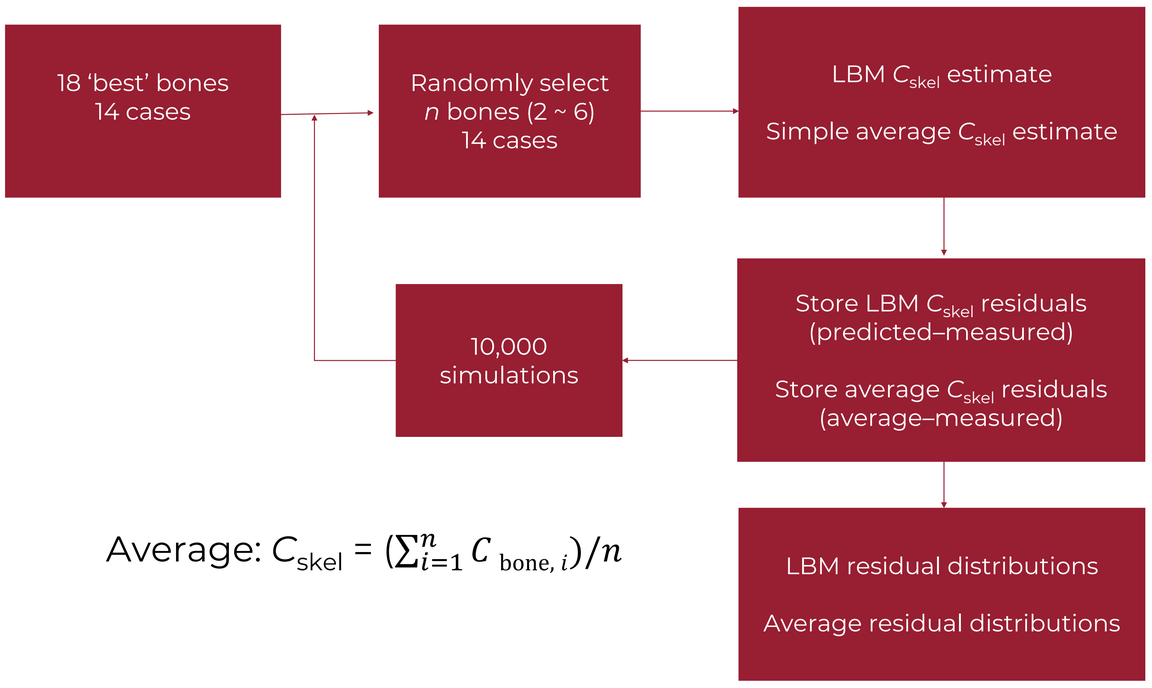
m: number of cases
n: number of bone samples
k: number of latent bone variables

PCA: Principal Component Analysis
MLR: Multiple Linear Regression

Figure 2: Latent bone modeling: (1) dimension is reduced using PCA, and (2) MLR is performed on a dataset with lower dimensionality.

Comparison between LBM and Simple Average - Simulation

- Random selection of 2–6 bones from 18 'best' bones and C_{skel} prediction using LBM and simple average (arithmetic mean) method



Average: $C_{skel} = (\sum_{i=1}^{n} C_{\text{bone},i})/n$

Results: LBM vs Simple Average - Simulation

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\text{observed}_i - \text{predicted}_i)^2}$$

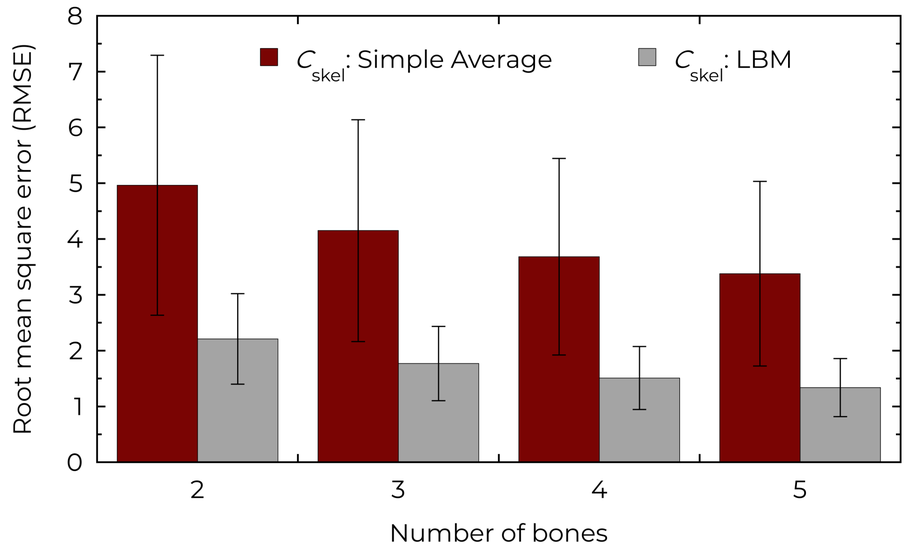


Figure 3: RMSEs for average and LBM method of C_{skel} estimates using two to five bone samples. LBM is more accurate and precise than average.

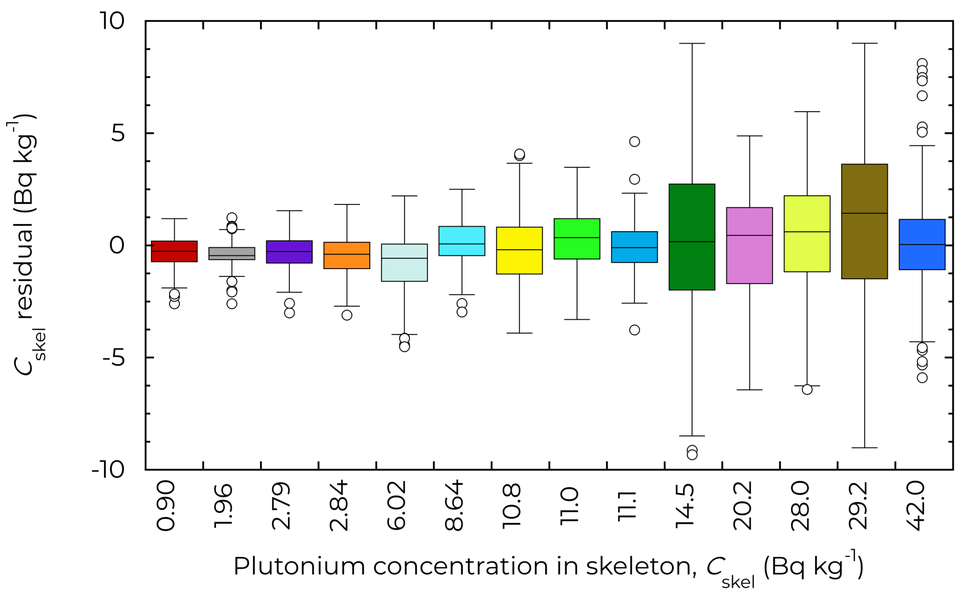


Figure 4: Residuals for LBM method of C_{skel} estimates using two bone samples.

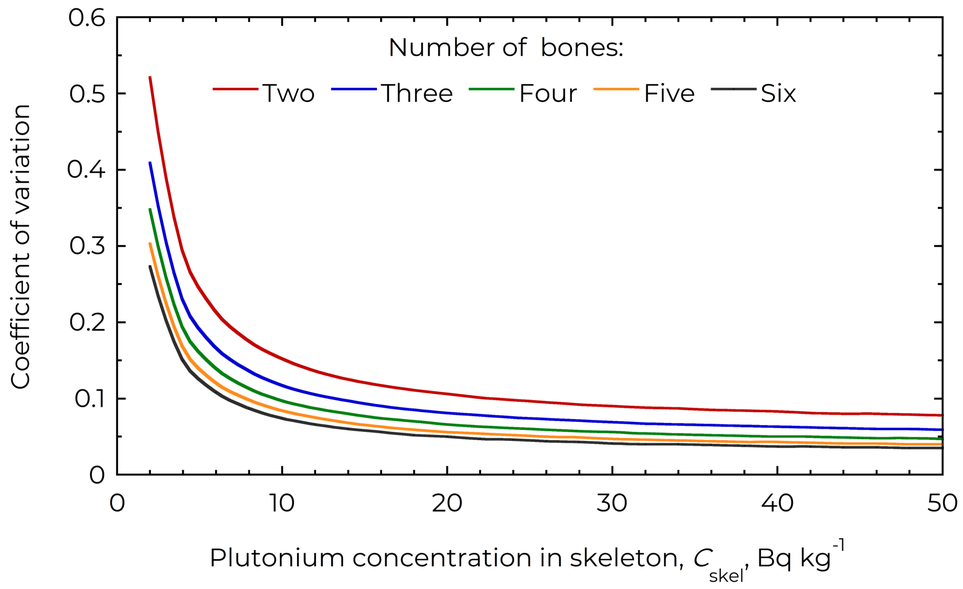
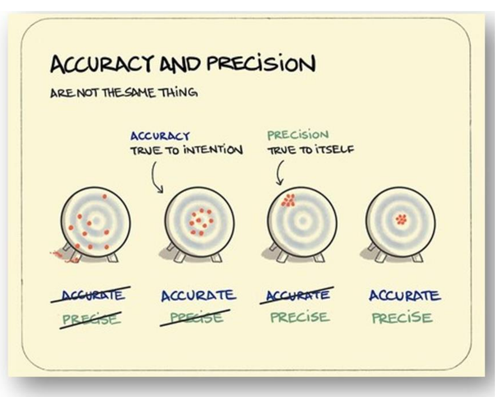


Figure 5: Coefficient of variation of residuals for LBM method using two to six bone samples.

Summary

- A simulation method was developed to compare estimates of skeleton concentration using LBM and simple average
- LBM improves C_{skel} estimation

	Number of bones			
	2	3	4	5
Accuracy, %	55.5	57.4	59.1	60.4
Precision, %	65.2	66.6	67.9	68.6



https://sixsigmadsi.com/precision-and-accuracy/