Predicting Body Composition from Conventional 2D Photography

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Motivation
Predicting body composition accurately has many clinical and research applications, but generally requires expensive equipment to measure accurately. Dual X-ray Absorptiometry (DXA) is a gold standard for measurement, but requires expensive equipment and can expose patients to potentially harmful radiation. We propose a method for estimating fat and lean mass from 2D RGB photos taken from a consumer camera. Such a method can give health professionals useful physiological markers when expensive medical imaging is either inaccessible or inconvenient.

Overview of Approach:
1. Construct PCA shape space after fitting a template model to 3D scans of 152 males and 194 females in training set.
2. Extract body composition (fat mass, lean mass) from DXA scans in training set.
3. Perform linear regression to map between PCA components and body measurements.
4. Fit a 3D PCA human shape model to a 2D silhouette extracted from a single frontal RGB photo.
5. Map from reconstructed PCA shape to fat and lean mass.

PCA Model Training

Objective: Given an input image, we reconstruct the PCA shape \( s_{PCA}(w) \) under rigid transformation \( T \) that, when projected into an image of known focal length, matches the input silhouette, regularized by standard deviations \( \sigma \), known height \( h \), and projected joints \( J \).

Image to Body Composition

Given an image input, we reconstruct the PCA shape \( s_{PCA}(w) \) under rigid transformation \( T \) that, when projected into an image of known focal length, matches the input silhouette, regularized by standard deviations \( \sigma \), known height \( h \), and projected joints \( J \).

Results
This method was benchmarked on 31 male subjects and 39 female subjects aged 19 to 78 from a reserved test set. Percent fat estimates from our method showed 3.74% RMSE and \( R^2 = 0.776 \) for males, 3.73% and \( R^2 = 0.744 \) for females when fitting with \( d=50 \) PCA dimensions that account for >99% of shape variance in the training set.

Discussion
Body shape from silhouette alone can provide a fast, non-invasive, and inexpensive estimate of body fat. Our method could be improved with more training data to better model the variation in the human population. Extremely lean or muscular people are often overestimated for fat due to under representation in the training set and ambiguity of torso depth from a frontal view. Low cost body analysis methods like this could increase access to medical information previously available only through advanced imaging equipment and could mediate the gap in healthcare access in low income areas.