

Body Weight Estimation Using Virtual Anthropometric Measurements From a Single Image

Jin Sui[✉], Chunguang Bu[✉], Xingang Zhao[✉], Senior Member, IEEE, Chen Liu[✉],
Lei Ren[✉], Member, IEEE, and Zhihui Qian[✉]

Abstract—Direct estimation of body weight through noncontact methods is crucial for applications such as health monitoring, surveillance, and robot-assisted casualty rescue. Existing methods for body weight estimation from images are often affected by various factors, such as camera distance, human orientation, and body posture, which ignore the fact that bodies typically inhabit 3-D space. To address the problem, we propose an approach for estimating body weight based on virtual anthropometric measurements and deep features instead of estimating by reasoning pixels. Specifically, we develop a three-branch framework that includes face feature extraction, body feature extraction, and deep feature extraction and maps all features with a regressor. The developed method adds 3-D shape reconstruction to explicitly reason about virtual anthropometric measurements. To enable this, our model is trained to robustly compute anthropometric measurements in various orientations and postures. Furthermore, we evaluate our method on a public dataset and Image-VM-BMI, a new dataset of 4740 images, including body mass index (BMI) labels and virtual anthropometric measurement labels with paired 3-D reconstruction. Extensive experimental results demonstrate that the proposed method outperforms pixel-based analysis approaches on BMI estimation.

Index Terms—Body weight analysis, Image-VM-BMI dataset, virtual anthropometric measurement, visual analysis of body mass index (BMI).

I. INTRODUCTION

ESTIMATING a personalized body weight is crucial for judging personal biomedical information [1], which enables the measurement of personalized health conditions and avatar generation in virtual environments. Although it is convenient to capture body weight using a spring scale when the person is sparsely dressed, many conditions, such as surveillance [2], wound rescue [3], and astronaut health detection [4], cannot support this form of collection. In the application of robot-assisted casualty rescue and operations, biomedical information detection and body reconstruction are the first tasks to be completed. In photographic forensic identification for evidence collection, photographic evidence plays a key role in judging suspect biomedical information. In space station applications for astronaut health detection, it is of great significance to predict human body weight under weightlessness. These applications require noncontact biomedical information detection and a body reconstruction method. To this end, we provide a unified method that jointly regresses virtual anthropometric measurements and deep feature relations in one shot from a single red, green, and blue (RGB) image.

The problem of estimating body weight from images is challenging due to the sensitivity of visual inspection to camera parameters and settings. When we obtain camera parameters, we can accurately calculate human body weight. One universal parameter used for evaluating the weight of adults is body mass index (BMI), which is expressed as the ratio of body mass in kilograms to body height in meters. BMI can be divided into four categories: underweight, normal, overweight, and obese [5]. High BMI can lead to many diseases, such as heart disease, stroke, and some cancers, which can increase mortality [6], [7]. In addition to BMI, body fat can be examined through waist circumstance, underwater weighing, and skinfold thickness. However, the high cost and requirement for highly trained personnel prevent the widespread practical application of these systems [8].

There has been rapid progress in BMI prediction and multidimensional prediction model by analyzing anthropometric features and uncertainties, as well as machine learning models [9], [10], [11]. For users, providing a personal RGB image to

Manuscript received 29 April 2023; revised 29 June 2023; accepted 7 July 2023. Date of publication 24 July 2023; date of current version 9 August 2023. This work was supported in part by the National Key R&D Program of China under Grant 2022YFC3601400, in part by the National Natural Science Foundation of China under Grant 52175270, and in part by the Project of Scientific and Technological Development Plan of Jilin Province under Grant 20220508130RC. The Associate Editor coordinating the review process was Dr. Xiangchen Qian. (Corresponding author: Zhihui Qian.)

Jin Sui is with the Key Laboratory of Bionic Engineering, Ministry of Education, Jilin University, Changchun 130025, China, also with the State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Sciences, Shenyang 110016, China, and also with the Institutes for Robotics and Intelligent Manufacturing, Chinese Academy of Sciences, Shenyang 110169, China (e-mail: suijin@sia.cn).

Chunguang Bu and Xingang Zhao are with the State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Sciences, Shenyang 110016, China, and also with the Institutes for Robotics and Intelligent Manufacturing, Chinese Academy of Sciences, Shenyang 110169, China.

Chen Liu is with the Tianjin Key Laboratory for Advanced Mechatronic System Design and Intelligent Control and the National Demonstration Center for Experimental Mechanical and Electrical Engineering Education, School of Mechanical Engineering, Tianjin University of Technology, Tianjin 300384, China.

Lei Ren is with the Key Laboratory of Bionic Engineering, Ministry of Education, Jilin University, Changchun 130025, China, and also with the Department of Mechanical, Aerospace and Civil Engineering, University of Manchester, M13 9PL, Manchester, U.K.

Zhihui Qian is with the Key Laboratory of Bionic Engineering, Ministry of Education, Jilin University, Changchun 130025, China, and also with the Liaoning Academy of Materials, Shenyang 110167, China (e-mail: zhqian@jlu.edu.cn).

Digital Object Identifier 10.1109/TIM.2023.3298426

1557-9662 © 2023 IEEE. Personal use is permitted, but republication/redistribution requires IEEE permission.

See <https://www.ieee.org/publications/rights/index.html> for more information.

(Contents Continued from Page xlvii)

Reading Various Types of Pointer Meters Under Extreme Motion Blur	H. Zhang, Y. Rao, J. Shao, F. Meng, and J. Pu	5019815
Chromatic DIC-Assisted Fringe Projection Profilometry for Shape, Deformation, and Strain Measurement With Intensity-Chroma Space Analysis	Z. Wu, Z. Chen, Z. Chen, H. Wang, W. Guo, X. Li, and Q. Zhang	5019913
Accurate Measurement of Bridge Vibration Displacement via Deep Convolutional Neural Network	S. Lin, S. Wang, T. Liu, X. Liu, and C. Liu	5020016
CoRe: Contrastive and Restorative Self-Supervised Learning for Surface Defect Inspection	H. Wu, B. Li, L. Tian, Z. Sun, C. Dong, and W. Liao	5020112
Axially Enhanced Local Attention Network for Finger Vein Recognition	Y. Huang, H. Ma, and M. Wang	5020210
No-Service Rail Surface Defect Segmentation via Normalized Attention and Dual-Scale Interaction ...	G. Li, C. Han, and Z. Liu	5020310
CFU-Net: A Coarse-Fine U-Net With Multilevel Attention for Medical Image Segmentation	H. Yin and Y. Shao	5020412
Multiframe Super-Resolution With Dual Pyramid Multiattention Network for Droplet Measurement	Q. Liu, H. Yang, J. Chen, and Z. Yin	5020514
Fine-Grained Sports, Yoga, and Dance Postures Recognition: A Benchmark Analysis	A. Bera, M. Nasipuri, O. Krejcar, and D. Bhattacharjee	5020613
A Unified and Accurate Subpixel Detector of Control Points for Camera Calibration	Q. He, Z. Ji, P. Yu, and D. Chen	5020712
FTMF-Net: A Fourier Transform-Multiscale Feature Fusion Network for Segmentation of Small Polyp Objects	G. Liu, Z. Chen, D. Liu, B. Chang, and Z. Dou	5020815
JRCC-Net: A Segmentation Network With Joint Representation and Contrast Clustering for Surface Anomaly Detection	R. Zhang, H. Wang, M. Feng, Y. Liu, and G. Yang	5020914
Robust 3-D Reconstruction and Parameter Measurement of the Foot Using Multiple Depth Cameras	R. Hong and J. Li	5021012
Computational Framework for Turbid Water Single-Pixel Imaging by Polynomial Regression and Feature Enhancement	M. Ma, L. Gu, Y. Shen, Q. Guan, C. Wang, H. Deng, X. Zhong, M. Xia, and D. Shi	5021111
Temporal Prediction-Based Temporal Iterative Tracking and Parallel Motion Estimation for a 1-ms Rotation-Robust LK-Based Tracking System	T. Hu, R. Fuchikami, and T. Ikenaga	5021214
Global-Local Discriminative Representation Learning Network for Viewpoint-Aware Vehicle Re-Identification in Intelligent Transportation	X. Chen, H. Yu, F. Zhao, Y. Hu, and Z. Li	5021313
Convolution With Rotation Invariance for Online Detection of Tiny Defects on Magnetic Tile Surface	Y. Zhu, L. Xie, M. Yin, and G. Yin	5021412
High-Precision Flatness Measurement for Cryogenic Mosaic Focal Plane Arrays	Y. Zhang, H. Zhang, J. Zhang, X. Wang, and J. Wang	5021512
A Novel Visual-Aided Method to Enhance the Inertial Navigation System of an Intelligent Vehicle in Indoor Environments		5021613
Understanding Physiological and Behavioral Characteristics Separately for High-Performance Video-Based Hand Gesture Authentication	W. Song, W. Kang, and Y. Zhang	5021713
Multiscale Underwater Image Enhancement in RGB and HSV Color Spaces	C. Liu, X. Shu, L. Pan, J. Shi, and B. Han	5021814
Defocusing Recovery Technology of Terahertz Image Based on 3-D PSF Simulations	Z. Cui, J. Ren, L. Li, J. Gu, and J. Zhang	5021910
Body Weight Estimation Using Virtual Anthropometric Measurements From a Single Image	J. Sui, C. Bu, X. Zhao, C. Liu, L. Ren, and Z. Qian	5022113
A Machine Vision-Based Character Recognition System for Suspension Insulator Iron Caps	C. Zhang, B. Liu, Z. Chen, J. Yan, F. Liu, Y. Wang, and Q. Zhang	5022213
A Novel Background Filtering Method With Automatic Parameter Adjustment for Real-Time Roadside-LiDAR Sensing System	Z. Chen, H. Xu, J. Zhao, and H. Liu	5022310
High-Stable In-Line-and-Off-Axis Hybrid Digital Holography Using High-Resolution Reconstruction Under Spatial and Frequency Constraints	Z. Zhong, W. Zhao, X. Chen, L. Ling, L. Yu, and M. Shan	5022408
Transfer Learning Using Cluster Centers for Surface Defect Identification of Piston Rods in Pneumatic Cylinders	Y. Shi, L. Li, J. Yang, N. Wang, C. Wang, and Y. Wang	5022515
LCA-Net: A Context-Aware Lightweight Network for Low-Illumination Image Enhancement	Z. Shi, M. Wang, and W. Ren	5022613
Color Constancy and Color Consistency Using Dynamic Gamut Adjustment	W.-Y. Hsu and W.-H. Tsai	5022712
Event-Based Vibration Frequency Measurement With Laser-Assisted Illumination Based on Mixture Gaussian Distribution	C. Shi, N. Song, B. Wei, Y. Li, Y. Zhang, W. Li, and J. Jin	5022813
Yolo-MSAPF: Multiscale Alignment Fusion With Parallel Feature Filtering Model for High Accuracy Weld Defect Detection	G.-Q. Wang, C.-Z. Zhang, M.-S. Chen, Y.-C. Lin, X.-H. Tan, P. Liang, Y.-X. Kang, W.-D. Zeng, and Q. Wang	5022914
Voxel Graph Attention for 3-D Object Detection From Point Clouds	B. Lu, Y. Sun, and Z. Yang	5023012
Densely Connected Transformer With Linear Self-Attention for Lightweight Image Super-Resolution	K. Zeng, H. Lin, Z. Yan, and J. Fang	5023112

(Contents Continued on Page xlix)

IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT

A PUBLICATION OF THE IEEE INSTRUMENTATION AND MEASUREMENT SOCIETY



2023

VOLUME 72

IEIMAO

(ISSN 0018-9456)

