TsumeColorGram: A Method of Estimating an Object's Weight Based on the Thumb's Nail Color

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ABSTRACT

Measuring the weight or amount of ingredients is necessary when cooking but it requires tools and can often feel burdensome to the cook. This study developed a method to estimate the weight of an object without special tools by observing the change in fingernail color when holding an object (the color of human fingernails changes when force is applied to the fingertips). We constructed a dataset of nail images with varying weights of held objects. Our analysis revealed a tendency for the values of G and B in the nail's RGB color and H and S in HSV to be related to the object's weight. Linear regression was used for the estimation, and it was found that, although there were individual differences, estimation was possible with an error of 20.99 g in the most accurate case.

CCS CONCEPTS

• **Human-centered computing**; • **Interaction design**; • **Systems and tools for interaction design**;

KEYWORDS

Nail, Measurement, Cooking, Machine learning

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1 INTRODUCTION

In cooking, it is common to measure the amount of water, seasonings, and weights of ingredients by using measuring spoons or electronic scales. However, using measuring tools every time can feel cumbersome. In fact, according to our survey of 1,000 people, 64.8% responded that weighing was burdensome [1]. When measuring tools are not at hand or when measuring feels tedious, one tends to rely on their sense of volume or weight. However, the human ability to gauge weight is inaccurate [2, 3]. Consequently, studies have been conducted on measuring the weights of objects without a scale, such as by using mechanical spoons [4] and the vibration of smartphones [5], but these methods are limited in what they can measure.

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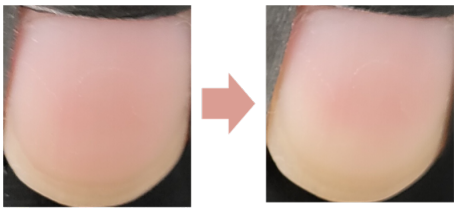

Figure 1: Change in nail color depending on the pressure.

Figure 2: TsumeColorGram.

Here, the fingertips (used for holding objects) are laced with capillaries, and changes in blood flow in these capillaries can be observed through changes in nail color. Nails appear red naturally but turn white when pressure is applied to them (Figure 1). Utilizing this property of nails, studies have been conducted to estimate whether the fingers are applying force and the direction of this force [6-11]. We used this property to estimate the weight.

We developed a method to estimate the weight of an object based on the change in nail color when holding it. In an ideal system, a camera embedded in the kitchen automatically detects the nails of fingers that hold an object and the nails' color to estimate its weight (Figure 2). As an initial investigation, we constructed a dataset with nail color changes due to holding objects of different weights, explored features, and verified the possibility of estimating the object's weight.

2 NAIL COLOR TRENDS AND ESTIMATION

2.1 Dataset Construction

We tried to determine whether the weight of an object can be predicted by using the nail color in a controlled environment as the first step of this work. We took photographs of nails while holding an object in a specific location with controlled lighting and an anti-reflective background to facilitate the extraction of nails through image processing. We painted the bottles black and covered the image of the skin around the nails with masking tape to extract the nails easily and accurately from the image.

Participants were instructed to hold the cap of a PET bottle with their thumb and index finger from above, and images of their

Figure 3: Dataset construction.

thumb's nails were taken in sets of five for each weight in increments of 50 g from 0 g to 500 g (Figure 3). The nails were photographed alternately on the left and right hand to minimize the effects of the strain of holding heavy objects in succession. Then, we cropped the thumb nail automatically, normalized the image size of the thumb nail to 500 x 500, and removed fine noise by blurring. In total, we obtained 1,870 thumb-nail images from 17 participants as the dataset.

2.2 Analysis

We analyzed the changes in value when holding a PET bottle with a weight compared with an empty bottle. Figure 4 shows the differences in the values of G and B in the RGB space for holding 0 g versus other weights, averaged across all participants. For both G and B in the 250px to 350px range, the values increased as the participants held heavier objects. In addition, for both G and B, as the participants held heavier and heavier objects, the differences in the color distribution within the nail became larger. On the other hand, in the HSV space in the 300px to 400px range, the H values increased, and the S values decreased when participants held heavier objects.

The results of G, B, and S suggest a tendency for the color of nails to approach white when carrying heavy objects. Furthermore, when holding heavy objects, a rapid change in the values of G and B from the base to the tip of the nail indicates the formation of distinct red and white areas along the nail. Additionally, an increase in the H value suggests changes in hue within the HSV color space when holding heavy objects.

2.3 Estimation

We applied linear regression based on the linear relationship with weight on the values of G, B, H, and S to estimate the weights of objects based on the color of the nails. We selected the total, maximum, and average values of G and B between 250px and 350px, as well as H and S between 300px and 400px, as features. In addition, we selected the range of values and the slope calculated from the maximum and minimum values due to the characteristic trends in G and B value changes. Then, we conducted a five-fold cross-validation with scikit-learn to calculate the classification accuracy using five image patterns for each weight and each participant.

Table 1 shows the average estimated classification probabilities for the weights held for all dataset contributors. This table shows that the predictions approximate the actual weights closely, but the mean squared deviation averages are low, with 106.76 g for the right nail and 104.92 g for the left nail. Furthermore, while the most accurate estimate is within an error range of 20.99 g, there is variability among individuals.

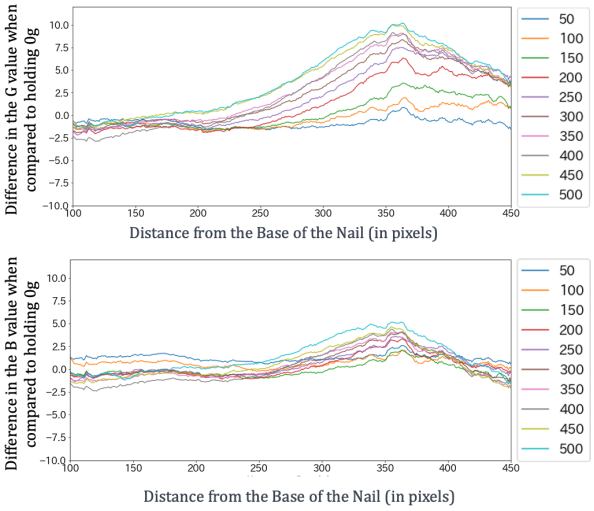

Figure 4: Difference from 0 g when holding 50 g to 500 g in relation to G and B.

Table 1: Estimated average classification probability for the held weight based on five training data samples.

		Estimated Weight[g]										
		0	50	100	150	200	250	300	350	400	450	500
Held Weight [g]	0	0.41	0.26	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50	0.12	0.47	0.21	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	100	0.03	0.24	0.47	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00
	150	0.00	0.03	0.29	0.56	0.26	0.03	0.03	0.00	0.00	0.00	0.00
	200	0.00	0.00	0.03	0.18	0.38	0.18	0.06	0.00	0.00	0.00	0.00
	250	0.00	0.00	0.03	0.00	0.29	0.65	0.12	0.00	0.00	0.00	0.00
	300	0.00	0.00	0.00	0.00	0.06	0.24	0.44	0.32	0.03	0.00	0.00
	350	0.00	0.00	0.00	0.00	0.00	0.03	0.21	0.59	0.18	0.03	0.03
	400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.59	0.24	0.06
	450	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.12	0.56	0.15
	500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.26	0.44

3 DISCUSSION & CONCLUSION

By analyzing images of thumb nails holding PET bottles of varying weight and conducting linear-regression machine learning, we could estimate the weight of the bottles to a close degree. It is believed that extracting features tailored to an individual's nail length and angle and applying other models, such as nonlinear regression, could further enhance accuracy. Here, there is a possibility of changing the color of nails according to the object's shape. In the future, we will check the usefulness of our method for not only PET bottles but also other objects.

We developed a prototype system that recognizes the thumb nail by using a library called Nailtracking [12] and estimates the weight from the recognized thumb nail by using our estimation method. Here, the accuracy of the weight estimate was not high because of accuracy problems in recognizing the thumb nail and lighting problems in the experiment. Although our method is not yet practical for culinary applications, moving forward, we plan to expand our dataset and adjust lighting from images so that our method can be used in the kitchen.

REFERENCES

[1] Yahoo! Crowdsourcing. https://crowdsourcing.yahoo.co.jp/, last accessed 2022-11-10.

[2] Rinnai. https://www.rinnai.co.jp/releases/2016/0614/, last accessed 2023-1-20.

[3] Charpentier. A. Analyse experimentale: De quelques elements de la sensation de poids. Experimental study of some aspects of weight perception. Arch Physiol Norm Pathol, vol. 3, p. 122-135, 1891. DOI: https://cir.nii.ac.jp/crid/1572261550283489920.

[4] Watanabe Keita, Sato Ayaka, Matsuda Shota, Inami Masahiko, and Igarashi Takeo. smoon: A Spoon with Automatic Capacity Adjustment. VRIC 2012 proceedings, 2012, Laval Virtual 2012 France.

[5] Zhang, S., Xu, Q., Sen, S., and Alshurafa, N.. VibroScale: Turning Your Smartphone into a Weighing Scale. UbiComp-ISWC, 2020, p. 176-179.

[6] Mameno Hironobu, Imura Masataka, Uranishi Yuki, Yoshimoto Shunsuke, and Oshiro Osamu. Estimation of fingertip contact force direction based on change in nail color distribution. 1998, vol. 53, p. 155-56. DOI: https://doi.org/10.11239/jsmbe.52.O-155.

[7] Stephen A. Mascaro, Kuo-Wei Chang, and H. Harry Asada. Photoplethysmograph nail sensors: for measuring finger forces without haptic obstruction: modeling and experimentation. IEEE Transactions Robotics and Automation, 1999, p. 962-967. DOI: https://ieeexplore.ieee.org/document/772433.

[8] Gulati RJ, Mandayam A. Srinivasan. Human Fingerpad under indentation istatic and dynamic force response. ASME Bioengineering Conference, 1995, vol. 29.

[9] Stephen A. Mascaro, Kuo-Wei Chang, and H. Harry Asada. Finger touch sensors using instrumented nails and their application to human-robot interactive control. IEEE Transactions Robotics and Automation. 1998, p. 91-96. DOI: https://doi.org/10.1115/IMECE1998-0238.

[10] Todd R. Jensen, Robert G. Radwin, John G. Webster. A conductive polymer sensor for measuring external finger forces. Journal of Biomechanics. 1991, vol. 24, no. 9, p. 851-858. DOI: https://doi.org/10.1016/0021-9290(91)90310-J.

[11] Assad, Christopher, Michael T. Wolf, Theodoros Theodoridis, Kyrre Glette and Adrian M. Stoica. BioSleeve: A natural EMG-based interface for HRI. 2013 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI). 2013, p. 69-70. DOI: https://doi.org/10.1109/HRI.2013.6483505.

[12] Nailtracking. https://github.com/toddwyl/nailtracking.git, last accessed 2023-1-29.