Toward fair and reliable consumer acceptability prediction from food appearances

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Motivation

Illumination estimation is a fundamental prerequisite for many computer vision applications. Unnatural illumination would influence human perceptions of essential characteristics of goods (Wang., et.al., 2015) e.g., Food products in retail stores under different lighting conditions. When food products are placed under different lighting conditions, humans will feel differently in response to the products, which can further affect consumers' consumption decisions (Hasenbeck., et.al., 2014). It directly affects customers' health on the top of causing customers' economic losses (Berčík., et.al., 2015).

Goals

1.Create a dataset of images from fresh lettuce samples under different illumination settings (illumination temperature, illumination power). There is no such dataset available so far.

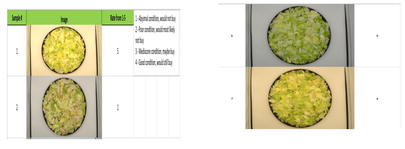
2.Perform subjective and statistical analysis to evaluate how illumination will affect human perceptions.

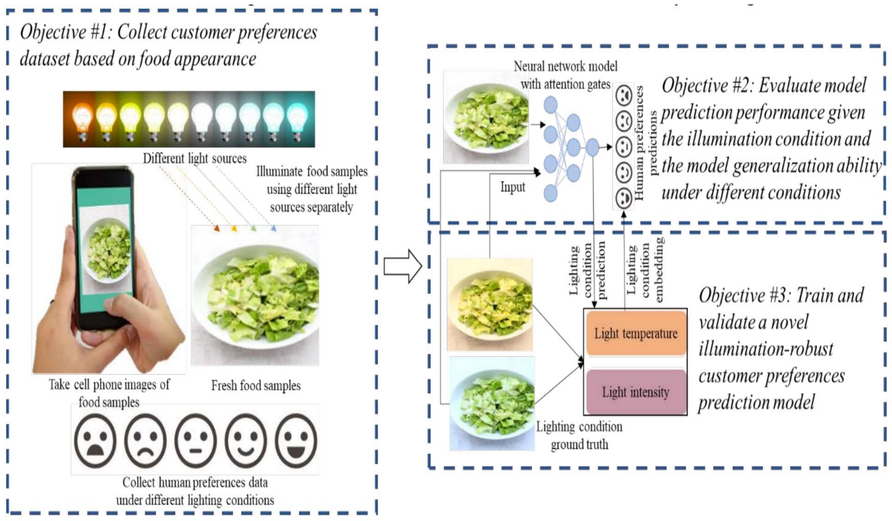
3.Develop Deep learning models to estimate illumination parameters and minimize the model prediction error for human perceptions caused by illumination bias. (Future work)

Methods

Build illuminations stations whose parameters are adjustable. Setup a camera (Basler AG) station to robustly capture well-prepared lettuce samples. Dataset :675 images (9 sample * 15 images/sample/day * 5 days)

Subjective Analysis: Graded with 3 internal graders so far with 5 acceptance scores 1-5 and in summer proposed to grade all the 675 images with about 50 subjects/people.





Preliminary Analysis

Chi-Square Analysis (Average Score vs Illumination parameters) to evaluate whether average score is dependent on different illumination parameters.

For Temperature: α = 0.05, P = 0.00042
For Power: α = 0.05, P = 0.029
Inference: The average score and power setting are not independent.
The average score and temperature setting are not independent.

Chi-Square Analysis

Grader 1:

For Temperature: Chi Square Value: 11.12, P- Value: 0.8015925066576428
For Power: Chi Square Value: 6.0544021464923805, P- Value: 0.6411379605273019

Inference: Grader 1 scores and the temperature setting are not independent of one another.
Grader 1 scores and the power settings are not independent

Grader 2:

For Temperature: Chi-Square Value = 49.98, α = 0.05, P = 2.31 x 10^{-5}
For Power: Chi-Square Value= 7.71, α=0.05, P = 0.46

Inference: Grader 2 scores and the temperature setting are not independent of one another.
Grader 2 scores and the power settings are not independent.

Grader 3:

For Temperature: Chi Square Value: 37.58, P- Value: 0.0017328220874405515
For Power: Chi Square Value: 15.69, P- Value: 0.04703364041827526

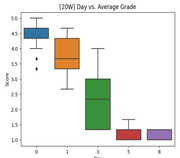
Inference: Grader 3 scores and the temperature setting are not independent of one another.
Grader 3 scores and the power settings are not independent.

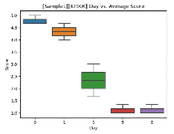
References

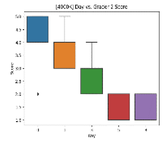
Wang, H., Cuijpers, R. H., Luo, M. R., Heynderickx, I., & Zheng, Z. (2015). Optimal illumination for local contrast enhancement based on the human visual system. Journal of biomedical optics, 20(1), 015005.

Hasenbeck, A., Cho, S., Meullenet, J. F., Tokar, T., Yang, F., Huddleston, E. A., & Seo, H. S. (2014). Color and illuminance level of lighting can modulate willingness to eat bell peppers. Journal of the Science of Food and Agriculture, 94(10), 2049-2056.

Berčík, J., Horská, E., Wang, W. Y., & Chen, Y. C. (2015). How can food retailing benefit from neuromarketing research: a case of various parameters of store illumination and consumer response (No. 713-2016-48583).

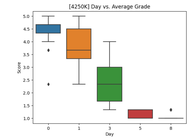






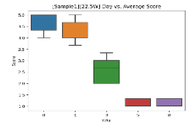
Illumination effects-Inference from the plots:

It may be understood from the results that the changes in temperature and power affect the graders dominantly.



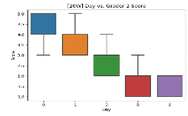
Inter -Grader Reliability:

Percent of Images Graders' Agree On = 26.81%
Cohen's Kappa = 0.2929 (Fair)
Inference: There is a significant difference between the grading of the graders



Three-way ANOVA Test:

α = 0.05
P = 3.89 x 10^{-19}
Inference: There is significant difference in scores between graders.



Note: In the future, samples with very less percentage of agreement or coherence kappa will be eliminated for our network training purposes.

Conclusion

Firstly, build a dataset describing the relationship between food appearance and consumer acceptability under different illumination conditions

In the collected dataset, each food sample under a given illumination will have about 675 images consisting of 9 samples of 15 images for five different temperature settings and three different power settings for each day (total of 5 days) and 5 corresponding acceptance scores. The average score is used for describing consumer acceptability.

Besides subjective analysis, a detailed statistical modeling is performed to see the effects of temperature and power on the samples.

It is seen from the results that the changes in illumination viz., temperature and power affect the graders significantly.

Next Steps

Development of an illumination robust deep learning model, which can benefit broader AI and image processing audiences

Developing an illumination-robust human acceptability prediction model, which can be transferred to general industrial manufacturing and inspection applications.

This material is based upon work supported by the National Science Foundation under Award No. OIA-1946391. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. We also acknowledge the help from Yihong Feng to grade the samples.