Quantification of OCT Skin Images and Potential of Deep Learning

Sanzhar Askaruly[1], Yujin Ahn[1], Jiho Bak[2], Andrey Vavilin[1], Gil-jin Jang[2], Pilun Kim[3], Haekwang Lee[4], Woonggyu Jung[1]

[1]Department of Biomedical Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan, Korea
[2]School of Electronics Engineering, Kyungpook National University, Daegu, Korea
[3]Oz-tec Co., Ltd., Daegu, Korea
[4]Amore Pacific R&D center, Yongin, Korea

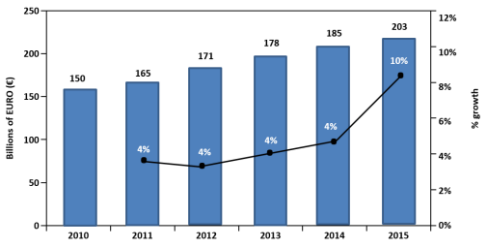
ULSAN NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY

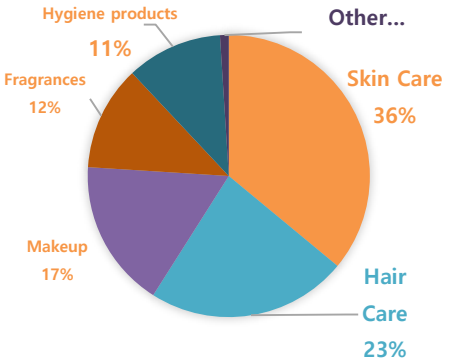
Contents

BACKGROUND

Cosmetics Market Overview

An enormous **expansion** of cosmetics **market**





(EY, 2016)

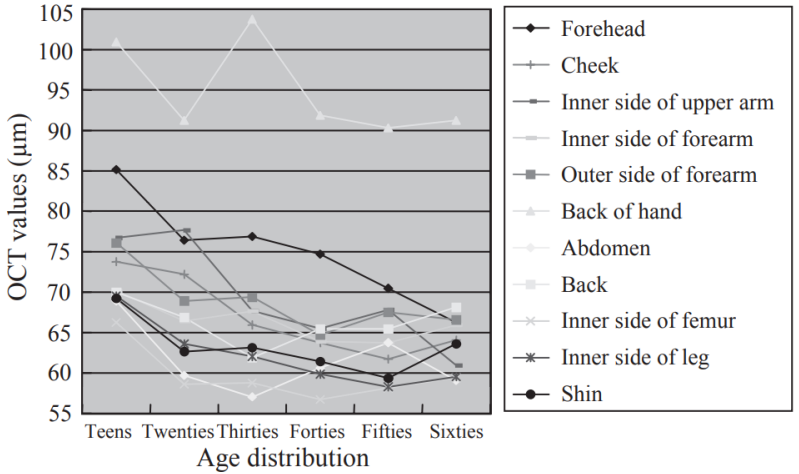
Personalized skin **care**

Cosmetics market grows reaching €203b

BACKGROUND

Skin Analysis for Aging Monitoring

- **Effect** of skin **aging** can be evaluated



(Tsugita, 2013)

Epidermal thickness and regional difference by years

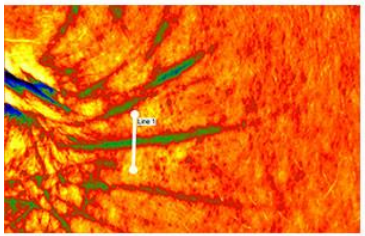
- **Increased skin roughness** is promoted by epidermal changes and dermal degeneration processes during **aging** (Wurm et al., 2012).

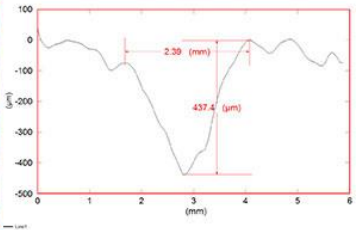
SKIN IMAGING

Advantages of PRIMOS in Skin Analysis

- Phaseshift Rapid In vivo Measurement of Skin **(PRIMOS)** was proposed as an objective tool for studying skin **topography** and **volume** of wrinkles (Bloemen, 2011).

Evaluation of the surface structure with PRIMOS





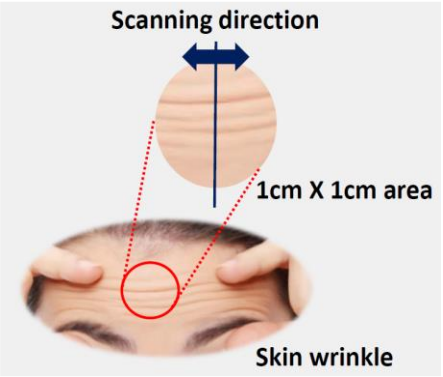
(https://www.canfieldsci.com)

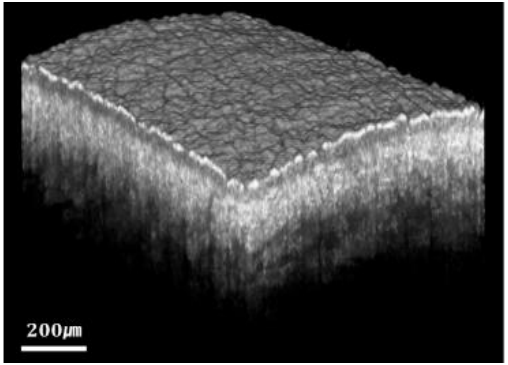
- PRIMOS is a noninvasive, fast and direct measurement of the skin surface with high precision.
- Successfully tested in scar assessment applications (Roques, 2007)

SKIN IMAGING

Advantages of OCT in Skin Analysis

- Cross-sectional, high-resolution, and real-time imaging (Huang, 1991 and Welzel, 1997)
- Three-dimensional (3D) volumetric and deep imaging
- Accurate measurements during in vivo studies

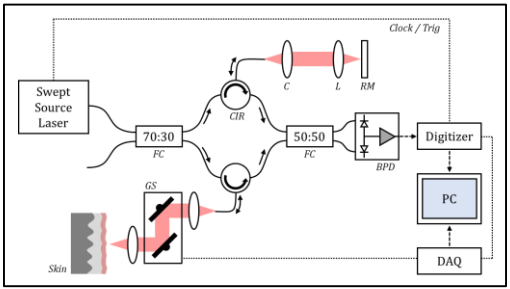




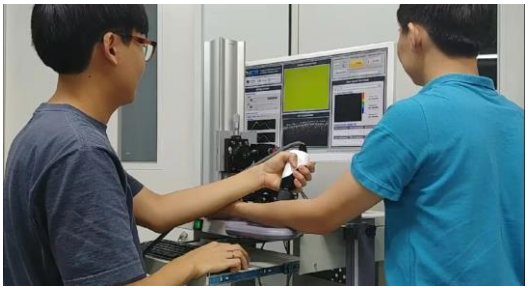
Appropriate for skin wrinkle study analysis

QUANTIFICATION: OCT SETUP

OCT Skin Analysis System Setup



SS-OCT Diagram



Operation of the System

OCT Setup with:

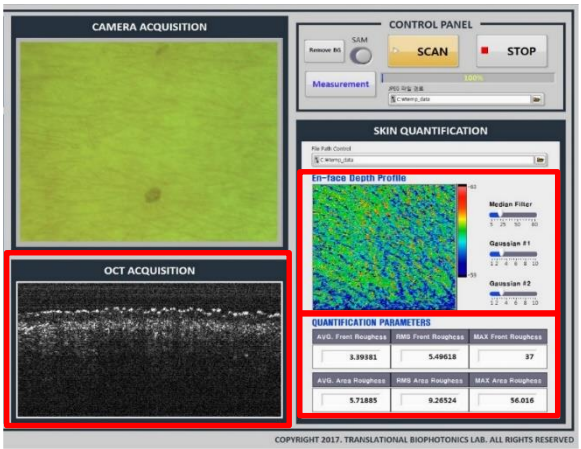
- Center wavelength : 1310nm
- Bandwidth : 50nm
- Acquisition speed: 50 frames/s

- Axial resolution : ≥ 10µm
- Lateral resolution : ~ 15µm
- **1** 3D volume: **500** 2D images

QUANTIFICATION: OCT SETUP

OCT Skin Analysis System Setup

Real-time OCT Skin Analysis System



En-face Depth Profile

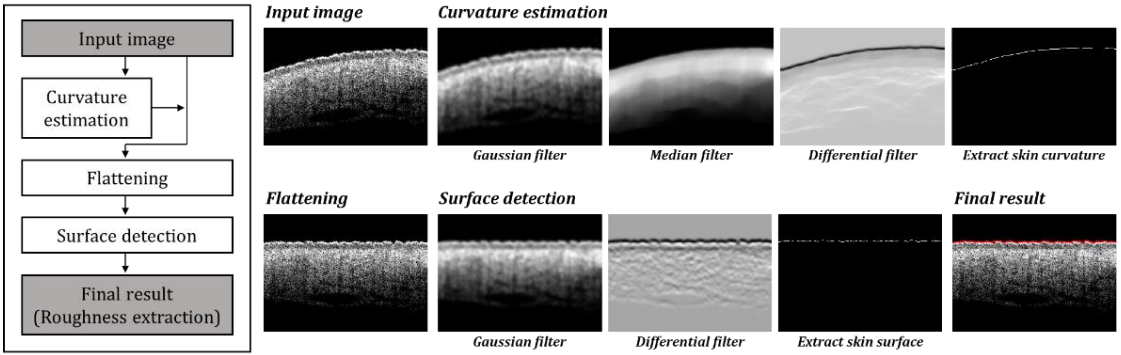
Flattened OCT skin image

Numerical values of skin surface roughness

Skin Surface Detection

Proposed skin surface detection **algorithm steps**:

(1) Curvature estimation
(2) Flattening
(3) Surface detection.



Flowchart of algorithm

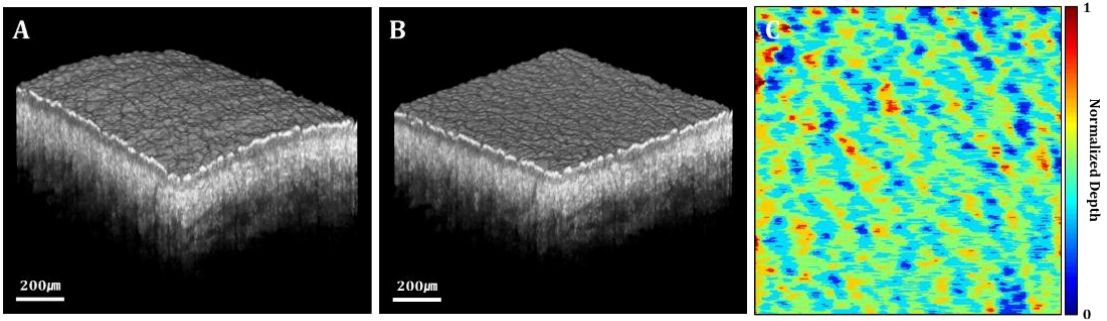
Three-dimensional Reconstruction

QUANTIFICATION: FLATTENING

Initial
volumetric skin

Flattened
volumetric skin

Wrinkle
depth profile



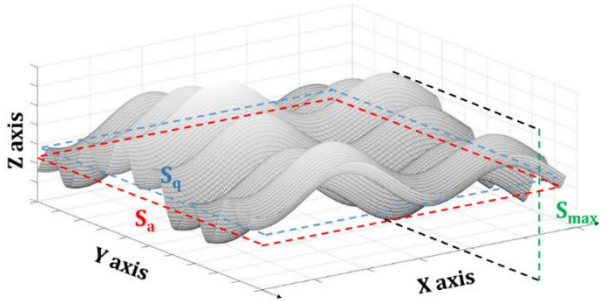
The natural **curvature** of surfaces is originally **present**.

The effect of natural **curvature** is **minimized**.

Color variation explains **depth** of separated wrinkle networks

Definition of Surface Roughness

ISO 25178 part 2 **standard** defines **roughness** and topography **parameters** to describe surfaces within sampling area numerically.



(Blateyron, 2013)

Average height of the surface:

$$S_a = \frac{1}{A}\iint_A |z(x,y)|\,dxdy$$

Root mean square (**RMS**) **height** of the surface:

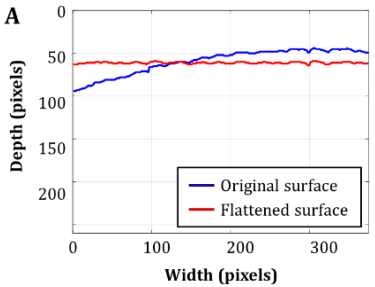
$$S_q = \sqrt{\frac{1}{A}\iint_A z^2(x,y)dxdy}$$

$$A \rightarrow area; \quad z \rightarrow height$$

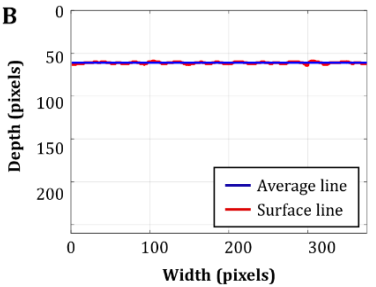
QUANTIFICATION: SURFACE ROUGHNESS

Extraction of Skin Surface Roughness

Skin surface
BEFORE flattening



Skin surface
AFTER flattening

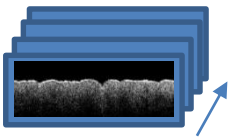


$$R_a = \frac{1}{w}\sum_{i=1}^{w}|y_i| \qquad R_q = \sqrt{\frac{1}{w}\sum_{i=1}^{w}y_i^2}$$

$$R_t = \max_i y_i + \min_i y_i$$

$w \rightarrow width;$
$y \rightarrow height$

Averaging over every

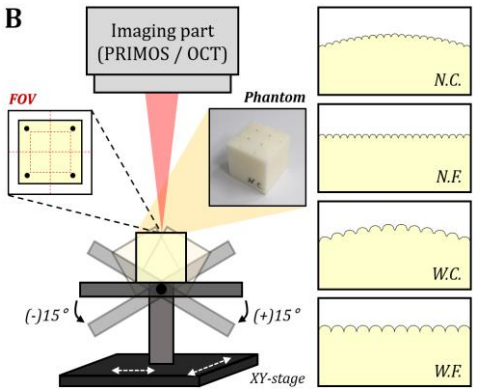


…image results in **S values**

QUANTIFICATION: EXPERIMENTS

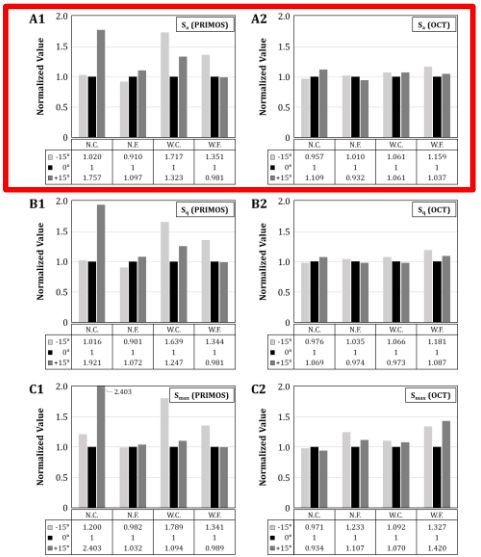
Comparing OCT and PRIMOS

Varying the **angle** of sample



3D Printed Skin Phantom

PRIMOS OCT



Roughness Parameters

Surface analysis with **OCT** offers **robust performance** despite the **angle variation** of subject

QUANTIFICATION: EXPERIMENTS

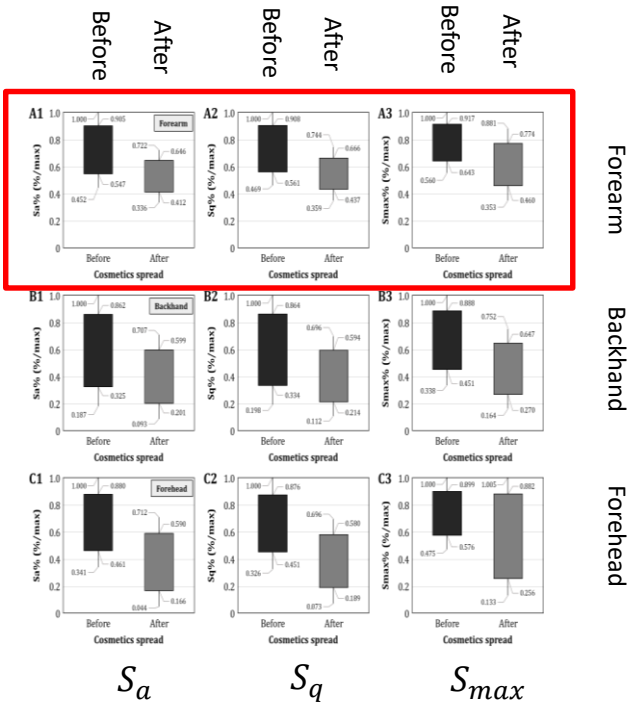
Influence of Cosmetics on Skin

Before After

After applying **cosmetics**

there is a tendency of

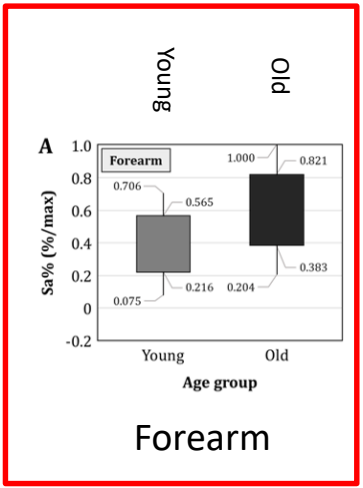
skin roughness
values to **decline**.



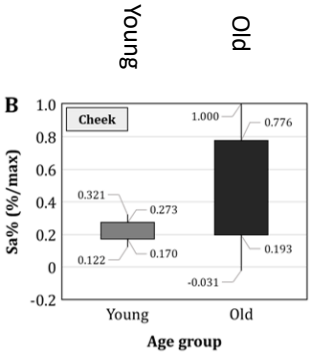
QUANTIFICATION: EXPERIMENTS

Influence of Subject Age on Skin

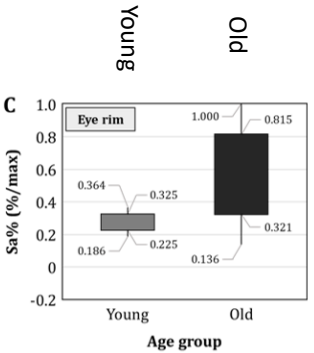
We measured average roughness parameter



Forearm



Cheek



Eyerim

The **least** notable age **difference** in **forearm**

Cheek and **eyerim** are **affected** more by **aging**

POTENTIAL OF DEEP LEARNING

Next Step: Skin Condition Evaluation

Classification by **age group**

Ideal Model:
"Your skin is **99.9%** ..."

Young

Old

*With collection of more data, detailed age could be predicted

Next Step: Skin Condition Evaluation

POTENTIAL OF DEEP LEARNING

Classification by **skin region**

Ideal Model:
"Your skin is **99.9%** ..."

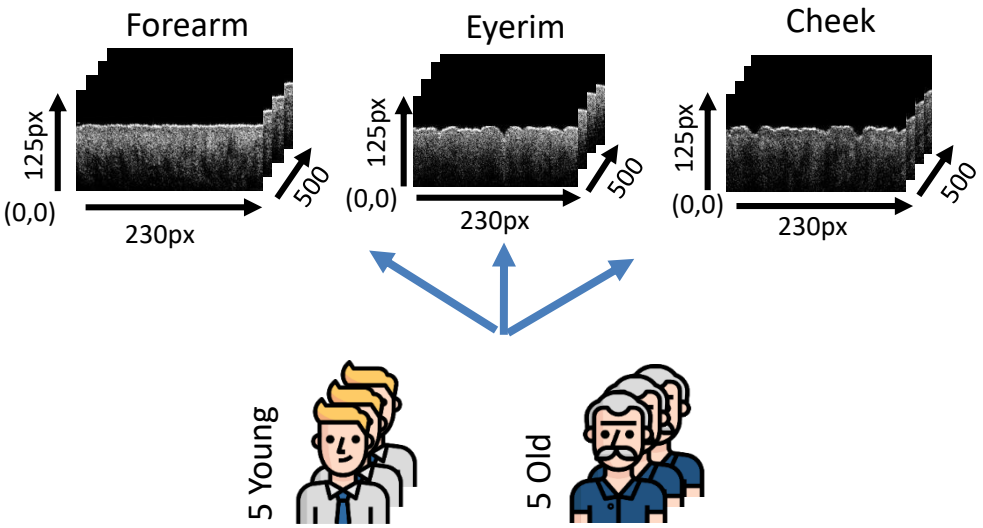
Cheek

Forearm

Eyerim

Collected Dataset

Preparing **large dataset** is important for **higher performance**

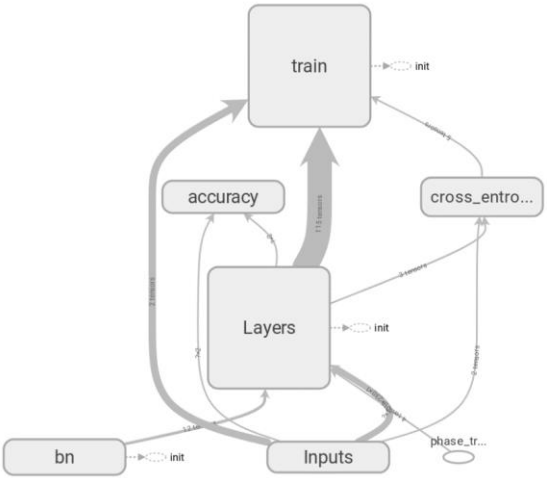


10 subjects x **3** skin regions x **500** samples = **15,000** total images

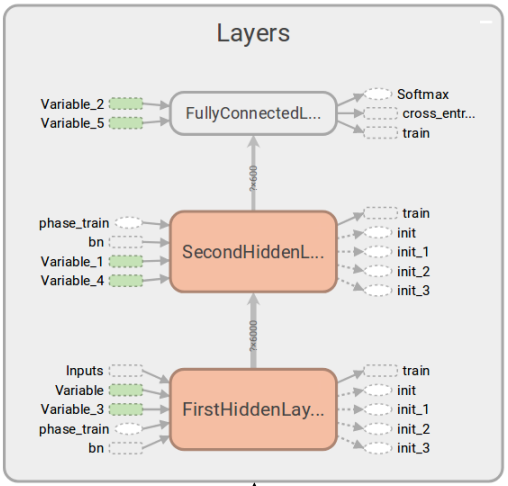
POTENTIAL OF DEEP LEARNING: TRAINING

Skin Classification Model: MLP

Training with Multilayer Perceptron



Output: Class Indicator
(Ex: Young/Old)

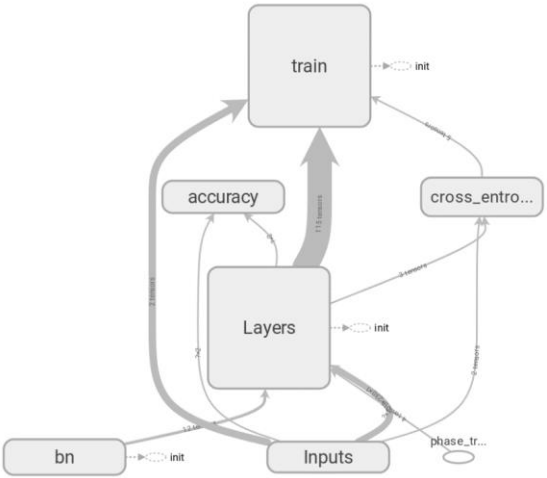


Input: image

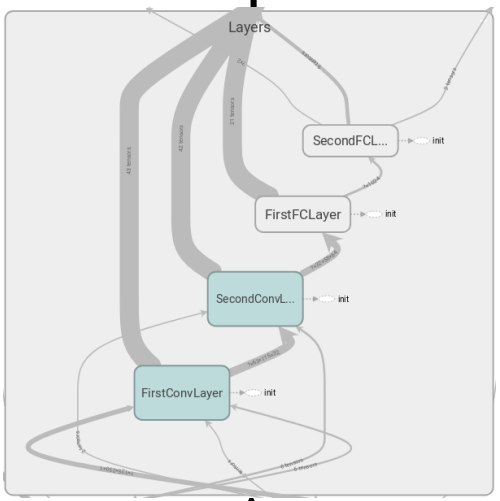
POTENTIAL OF DEEP LEARNING: TRAINING

Skin Classification Model: CNN

And training with Convolutional Neural Network



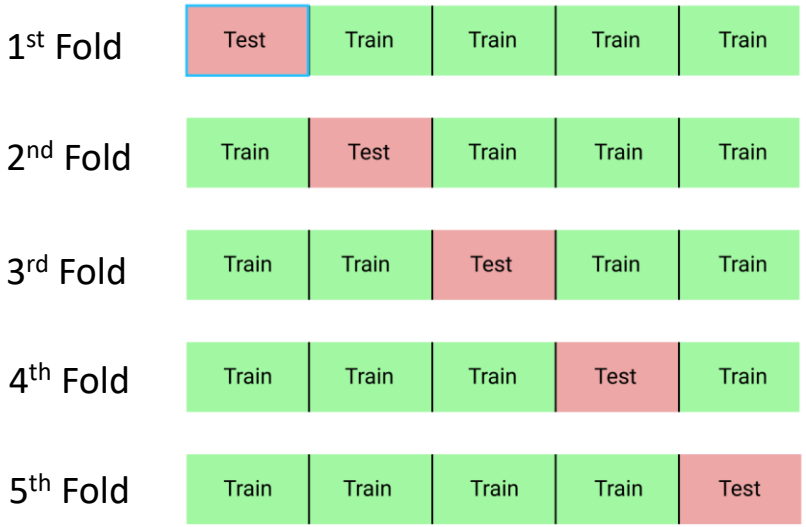
Output: Class Indicator
(Ex: Forearm/Eye/Cheek)



Input: image

Technique for Testing the Model

5 fold cross-validation is a basic technique for testing models



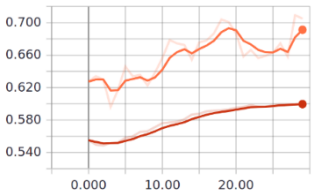
Final Accuracy = Average(1st Fold, 2nd Fold, …, 5th Fold)

POTENTIAL OF DEEP LEARNING: TESTING

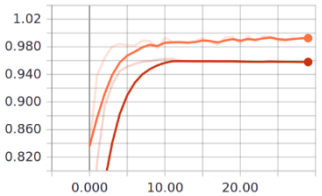
Predicting Skin Age

Classification **accuracies** after 30 epochs over 5 folds:

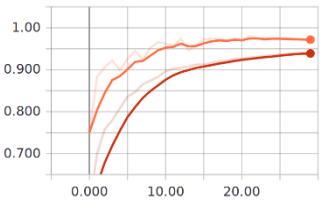
1st fold



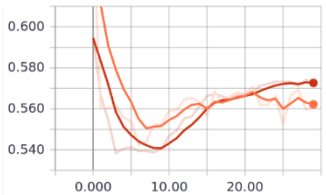
2nd fold



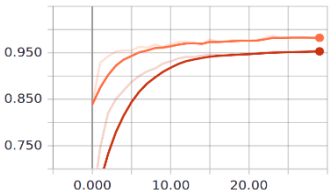
3rd fold



4th fold



5th fold



MLP:

“77.8 % Young/Old“

CNN

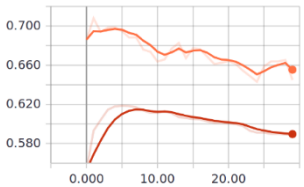
“82.2%. Old/Young“

POTENTIAL OF DEEP LEARNING: TESTING

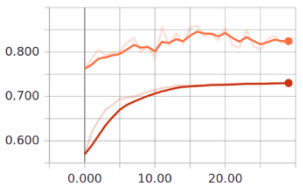
Predicting Skin Region

Classification **accuracies** after 30 epochs over 5 folds:

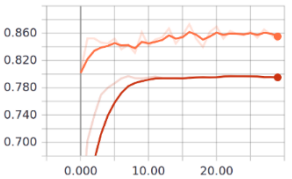
1st fold



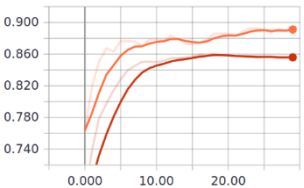
2nd fold



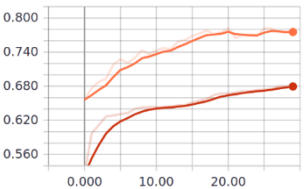
3rd fold



4th fold



5th fold



MLP:

“71.5 %
Forearm/Eye/Cheek“

CNN

“79.5%
Forearm/Eye/Cheek”

Discussion

- **CNN** has **higher performance** in comparison to **MLP** in both classification tasks
- Classification of **skin region** task is **more complex** than classifying **skin age** in our experiments
- Different **subjects** have **various** skin **characteristics**, which is confusing for accurate classification within similar data.
- The **limited** number of **data**. To suggest generalized conclusion, we must collect much more OCT skin image data.

DISCUSSION & CONCLUSION

Conclusion

- **OCT** clearly visualizes morphologic variation in **3D** and **high-resolution** approach. It **prevents** imaging procedure from dependence onto the **angle** of **sample**.

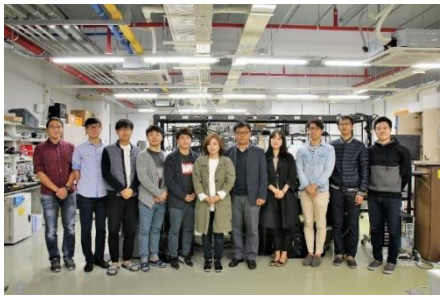
- We determined OCT could deliver comprehensive **quantitative** information of **morphologic change** in skin. **Roughness parameters** could be **extracted** for monitoring of the aging influence or skin treatment processes.

- At this point, **potential** of **deep learning** for skin condition analysis has been shown. The **future work** includes collection of **abundant data** and conducting experiments with **complex** deep learning **models**

ACKNOWLEDGEMENT

Acknowledgement

Translational Biophotonics Lab, UNIST
Machine Intelligence Lab, KNU



Thank you for attention!

This work was supported by a grant of the Korean Health Technology R&D Project, Ministry of Health & Welfare, Republic of Korea (Grant No. HN13C0078) and by the 2017 Research Fund (1.170009) of UNIST(Ulsan National Institute of Science & Technology)

REFERENCES

References

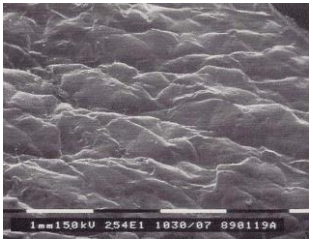
- EY, "The luxury and cosmetics financial factbook," (2016).
- Linde, YLVA WERNER. "Dry skin in atopic dermatitis." Acta Derm Venereol Suppl (Stockh) 177 (1992): 9-13.
- Bourgeois, J. F., et al. "Radiation-induced skin fibrosis after treatment of breast cancer: profilometric analysis." Skin Research and Technology 9.1 (2003): 39-42
- T. Tsugita, T. Nishijima, T. Kitahara, and Y. Takema, "Positional differences and aging changes in Japanese woman epidermal thickness and corneous thickness determined by OCT (optical coherence tomography)," Skin Research and Technology 19, 242-250 (2013).
- E. M. Wurm, C. Longo, C. Curchin, H. P. Soyer, T. W. Prow, and G. Pellacani, "In vivo assessment of chronological ageing and photoageing in forearm skin using reflectance confocal microscopy," Br J Dermatol 167, 270-279 (2012).
- T. W. Fischer, W. Wigger-Alberti, and P. Elsner, "Direct and non-direct measurement techniques for analysis of skin surface topography," Skin Pharmacol Appl Skin Physiol 12, 1-11 (1999).
- P. Corcuff, G. Gonnord, G. E. Pierard, and J. L. Leveque, "In vivo confocal microscopy of human skin: a new design for cosmetology and dermatology," Scanning 18, 351-355 (1996).
- R. F. Hendriks and G. W. Lucassen, "Two photon fluorescence microscopy of in vivo human skin," in Proc. SPIE, 1999), 116-121.
- M. C. Bloemen, M. S. van Gerven, M. B. van der Wal, P. D. Verhaegen, and E. Middelkoop, "An objective device for measuring surface roughness of skin and scars," J Am Acad Dermatol 64, 706-715 (2011).
- C. Roques and L. Teot, "A critical analysis of measurements used to assess and manage scars," The international journal of lower extremity wounds 6, 249-253 (2007).
- D. Huang, E. A. Swanson, C. P. Lin, J. S. Schuman, W. G. Stinson, W. Chang, M. R. Hee, T. Flotte, K. Gregory, C. A. Puliafito, and et al., "Optical coherence tomography," Science 254, 1178-1181 (1991).
- J. Welzel, E. Lankenau, R. Birngruber, and R. Engelhardt, "Optical coherence tomography of the human skin," J Am Acad Dermatol 37, 958-963 (1997).
- F. Blateyron, "The Areal Field Parameters," in Characterisation of Areal Surface Texture, R. Leach, ed. (Springer Berlin Heidelberg, Berlin, Heidelberg, 2013), pp. 15-43.
- Esteva, Andre, et al. "Dermatologist-level classification of skin cancer with deep neural networks." Nature 542.7639 (2017): 115.

BACKGROUND

Appendix: Importance of Skin Analysis

- **Topography** of skin **diseases**

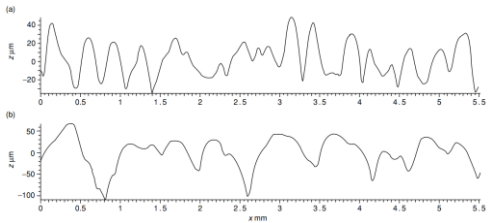
Normal Skin



Dry atopic skin

(Linde, 1992)

- **Effect** of different **therapies** can be determined



Normal Skin

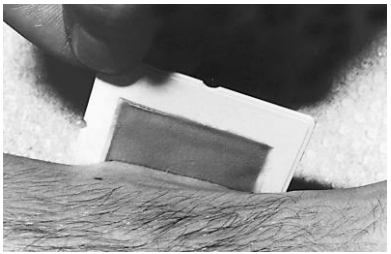
Irradiated Skin

(Bourgeois et. al, 2003)

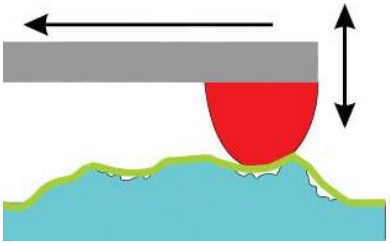
Appendix: Previous Work

- **Skin replica** with **optical profilometry** is the most common and simple way (Fischer et al.,1999)

Silicone replica of the skin



Profilometry of the surface



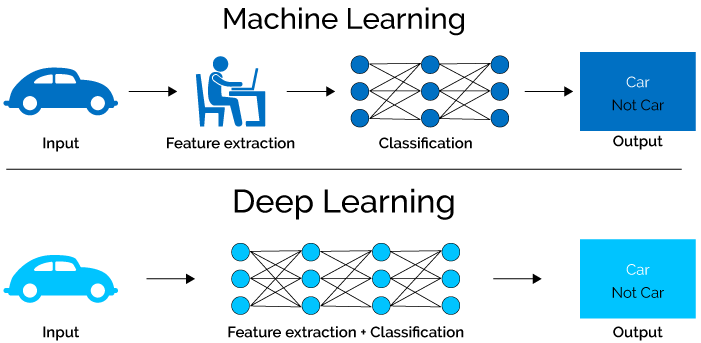
❖ **Indirect measurement**: Inadequate for in vivo and fast feedback

- **Advanced optical imaging modalities** were suggested (reflectance confocal microscopy, fluorescence microscopy, second harmonic microscopy) (Corcuff et al., 1996, Hendriks and Lucassen, 1999)

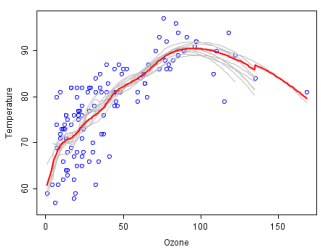
❖ **Limited** field of view **(FOV)** restricts wrinkle study

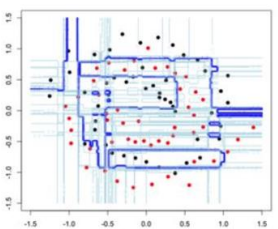
Appendix: AI: Machine Learning and Deep Learning

- Absence of **feature extraction**:



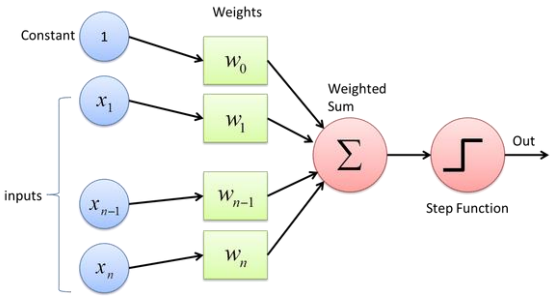
- **Complexity** of **Problem**



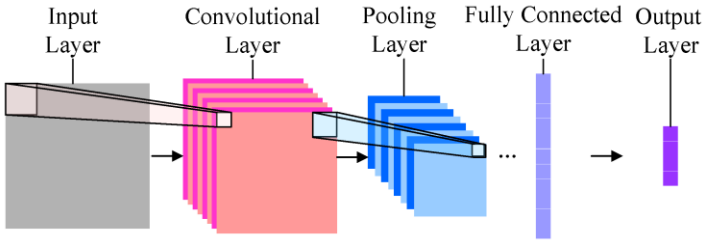


Appendix: Deep Learning Models for Image Recognition

Multilayer Perceptron **(MLP)**:



Convolutional Neural Network **(CNN):**



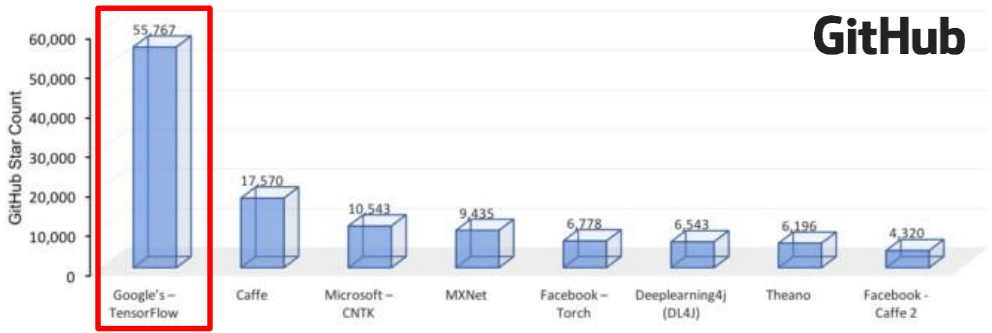
Complex CNN Based Architectures: AlexNet, VGGNet, Resnet, Inception-v3

Appendix: Practical Tools

Popular **frameworks** to get started:

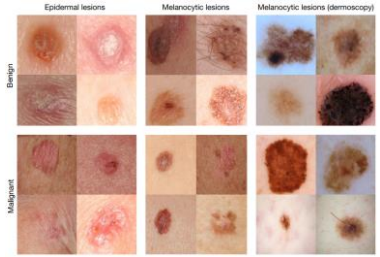
Caffe, Chainer, DL4J Deeplearning4j, KERAS, Microsoft CNTK, MatConvNet, MINERVA, mxnet, Purine, TensorFlow, theano, torch

Open Source community contribution:



Appendix: Potential of AI in Dermatology and Cosmetics Field

- **Early detection** of skin disease



Skin cancer classification (Esteva et al., 2017)

- **Personalized** customized **skin care**