# GAN-based Algorithm to Identify the Risk Factors for ACL Injuries

[1]Sang-Hyun Park, [1]Youkeun Oh

[1] Department of Mechanical Engineering, Hongik University

## Introduction

- Anterior cruciate ligament (ACL) is an orthopedic disease that frequently occurs in everyday life and professional sports environment. For a long time, many types of research are conducted in a manner that screens high-risk group for injury prevention.
- Therefore, academia has made long efforts to define anatomical risk factors for frequent occurrence of ACL injuries.
- In addition, in the field of medical imaging, many studies have been conducted through disease diagnosis and analysis using deep learning techniques.

## Methods

### Pix2Pix

- The Pix2Pix algorithm is a type of Generative adversarial network (GAN) consisting of original images, modified images, generators, and discriminators. Two Solid lines placed at left and right indicate the sagittal planes contain structural information, not covered in this research.
- First, the generator receives the original image and generates a fake modified image. At this time, the discriminator receives real and fake deformed images and learns to distinguish the difference between the two images.
- Meanwhile, the generator continues to learn to create a fake deformed image as similar as possible to the real deformed image so that the discriminator cannot discriminate between the real and fake deformed images.
- As a result, the generator learns so that the discriminator fails to discriminate, and the discriminator continues to learn for perfect discrimination and continues the process of creating and discriminating hostile to each other.
- In the overall process of the network, the model continues to learn in the direction of generating artificial modified datasets for the original dataset.

$$L_{GAN}(G,D) = \mathbb{E}_y[\log D(y)] + \mathbb{E}_{x,z}[\log(1 - D(G(x,z))]$$

Eq 1. Loss Function of Pix2Pix


Fig 1. Pix2Pix Bone Edge Detection

## Methods (Continued)


Fig 2. Pix2Pix Bone Edge Detection

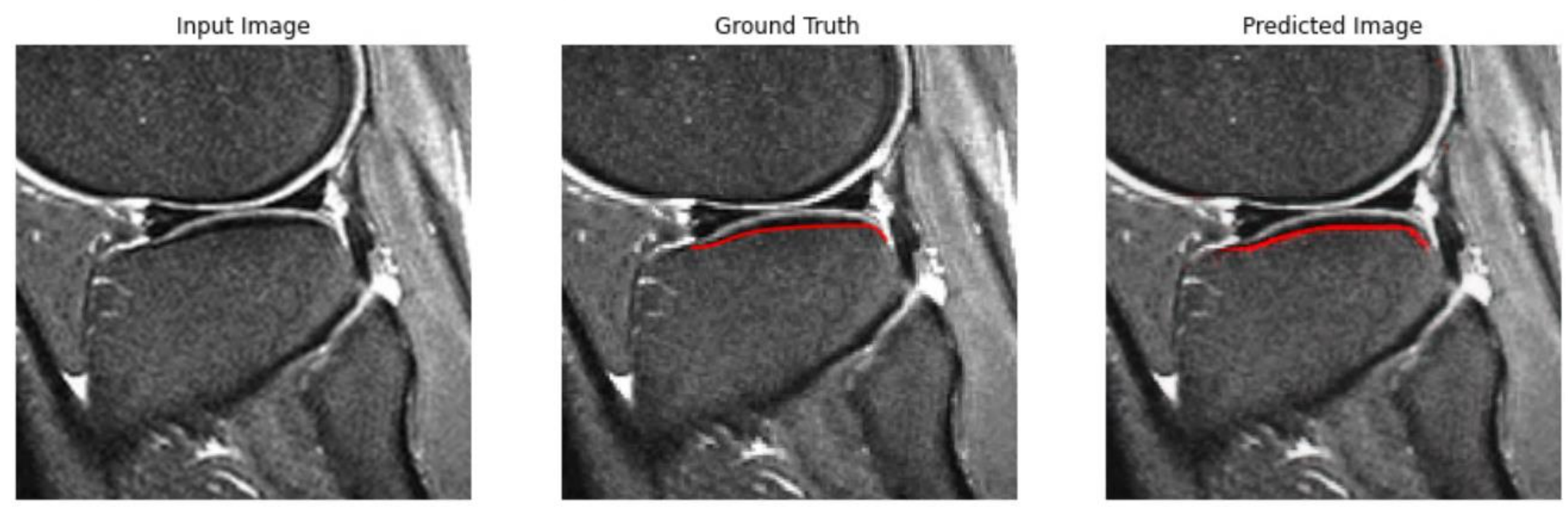


Fig 3. Pix2Pix Subchondral Bone Edge Detection

### Detected Geometry analysis

- Images detected using GAN re used to analyze existing risk factors for anterior cruciate ligament injury.
- Find the Cranial Circle adjacent to the three lines extracted from the Central plane. The regional maximum point of each part is defined by anterior peak and a Posterior peak.
- Find the caudal circle centred on the Cranial circle and adjacent to the convex line on the left and right sides.
- By connecting the center of these two circles, the major axis of the tibial plateau can be defined.

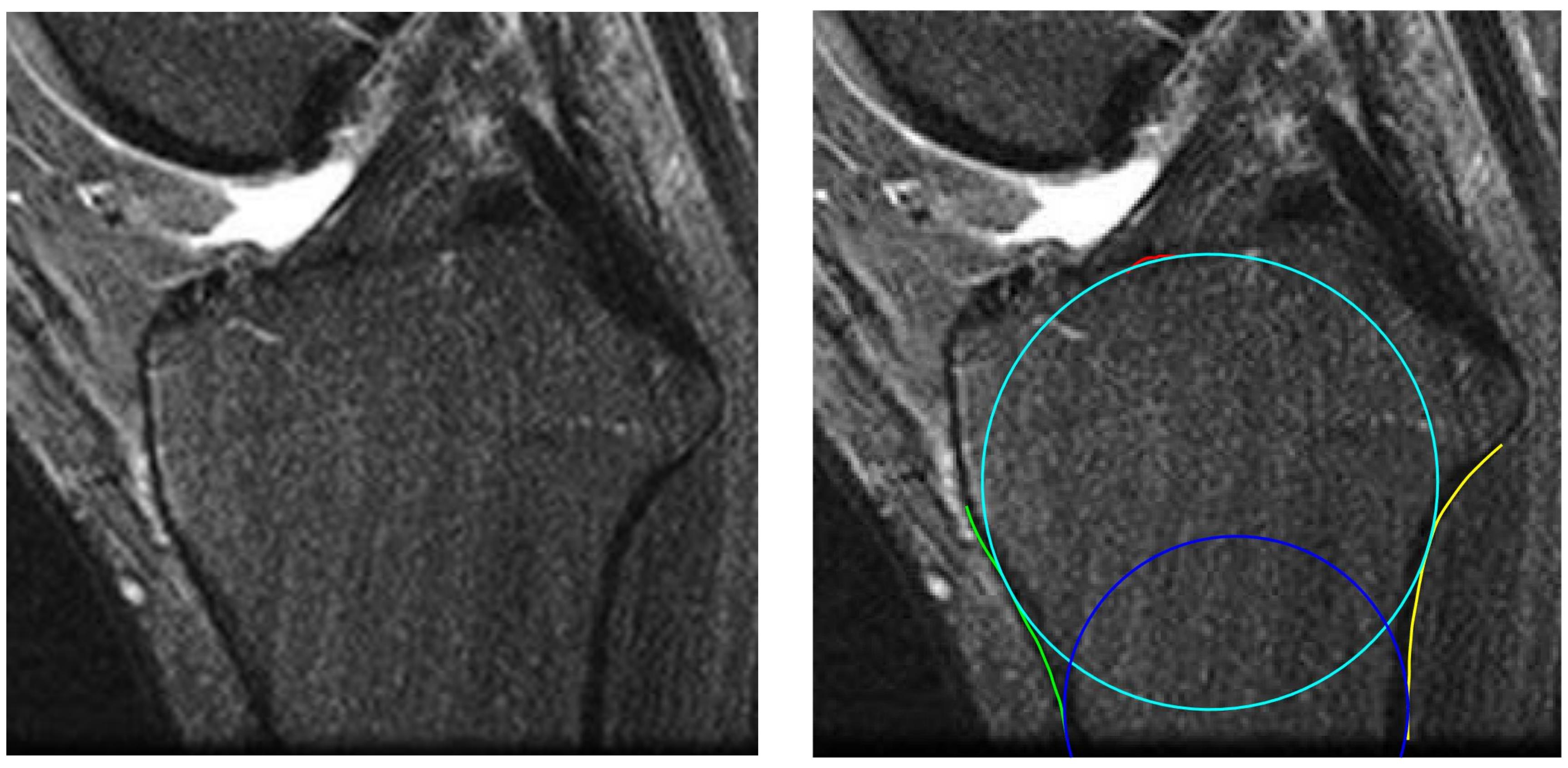

Fig 4. Detected Geometry analysis

## Discussion

- The extraction of the Tibial plateau boundary line using the GAN technique has obtained results equivalent to human measurement visually.
- However, it is necessary to automate the extraction of injury risk factors using boundaries.

### References

[1] Isola, P., Zhu, J. Y., Zhou, T. and Efros, A., 2017, "Image-to-Image Translation with Conditional Adversarial Networks," 10.1109/CVPR.2017.632, pp. 5967~5976.

2021 The Korea Society of Mechanical Engineering Fall Conference
Kim Dae Jung Convention Center
November 3rd(Wed) - 6th(Sat), 2021

E-mails : sanghyun@g.hongik.ac.kr
youkeun@hongik.ac.kr

# Statistical analysis to investigate correlation between upper tibia and ACL tearing

[1]Sang-Hyun Park, [1]Youkeun Oh
[1] Department of Mechanical Engineering, Hongik University

## Introduction

- Defining the risk factors of ACL injury has been a critical issues in sports medicine and the orthopaedic field.
- ACL injuries are no longer severe enough to affect the career of professional athletes, but there are still many athletes suffering from this injury.
- Therefore, an effort to apprehend the anatomical risk of the ACL injury is of high importance.

## Methods

### Tibial Plateau Detection

- Manually detected the Profile of the Tibial plateau on the Sagittal lateral slice of the tibia.
- Detected points generated the spline using the cubic extrapolation method.
- These profiles were extracted from 97 cases of the Non-injured and 97 cases of the ACL injured MR images.

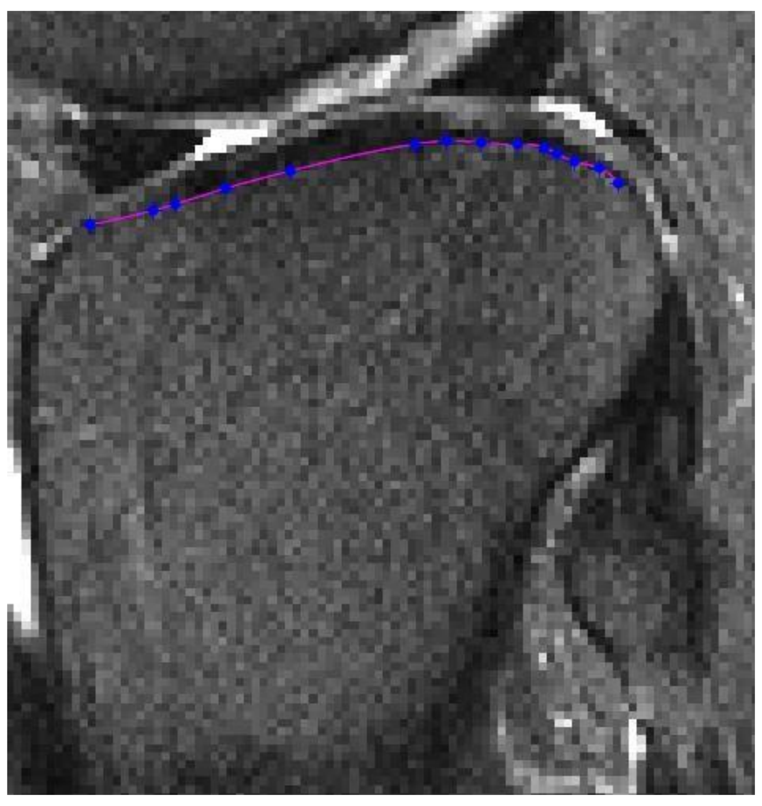

Fig 1. Tibial Plateau Manual Detection

### Principal Component Analysis

- 1-dimensional profile data, which was flattened vectors combining x, y coordinates, got through 2 steps of normalization because the Hypothesis model was not invariant to the translation and scale.
- After normalization, singular value decomposition of profiles stacked matrix was performed.
- From right singular vectors, the first 4 of them were selected by comparing cumulated squared singular values, and the fourth of them was more prominent than the 98% cumulative ratio.
- For this reason, only 4 of the singular vectors were employed to calculate the principal components.
- Multiplying original matrix and transposed right singular vectors, a total of 194 principal components were computed.

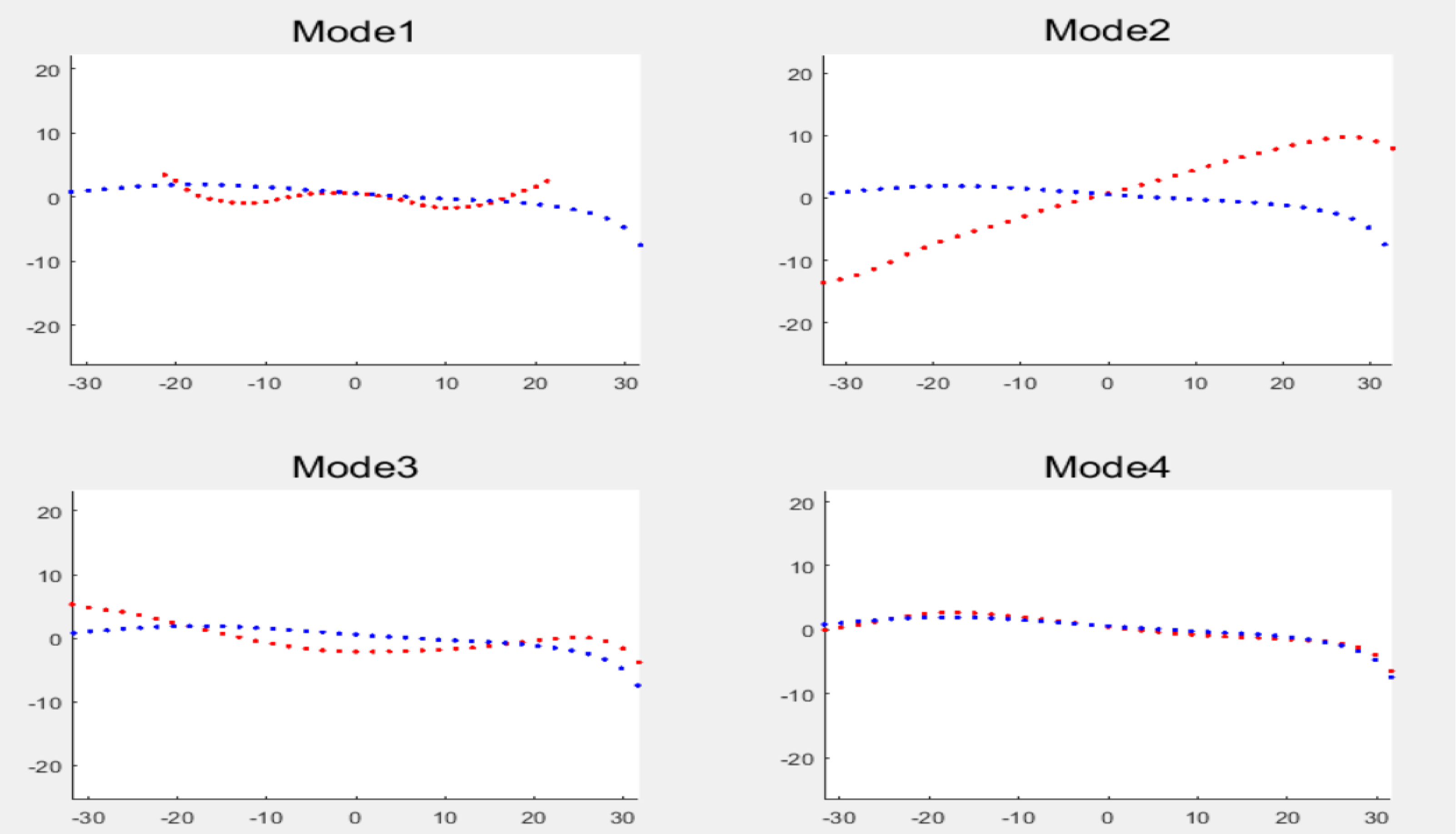


Fig 2. Average Profile and 4 Modes of Singular Vectors

## Methods (Continued)

$$PC = XV = U\Sigma \rightarrow \begin{bmatrix} C_{1,1} & C_{1,2} & \cdots & C_{1,p} \\ C_{2,1} & C_{2,2} & \cdots & C_{2,p} \\ C_{3,1} & C_{3,2} & \cdots & C_{3,p} \\ \vdots & \vdots & \ddots & \vdots \\ C_{m,1} & C_{m,2} & \cdots & C_{m,p} \end{bmatrix}_{[m\times p]}$$

Eq 1. Principal Components

## Results

| | p value | Coeff | Odds Ratio | Confidence interval(95%) | | Standard Error |
|---|---|---|---|---|---|---|
| **PC1** | 0.001 | 0.337 | 1.401 | 0.001 | 0.001 | 0.100 |
| **PC2** | 0.083 | -0.169 | 0.844 | 0.068 | 0.100 | 0.098 |
| **PC3** | 0.562 | -0.059 | 0.943 | 0.460 | 0.686 | 0.102 |
| **PC4** | 0.028 | 0.212 | 1.236 | 0.023 | 0.034 | 0.097 |

Table 1. Principal Component 1 and 4 showed statistically meaningful p value

- On the hypothesis test, Principal components of imagery data showed a low p-value which is statistically meaningful.
- This can be interpreted as possible to predict an ACL injury by measuring the tibial plateau shape.

## Discussion

- As a result of statistical analysis through the model, a clear correlation between Mode 4 and ACL injury was confirmed.
- When the singular vector of Mode 4 and the entire dataset was compared with the average shape, as the singular vector of Mode 4 is slightly higher in the anterior direction than the average shape and slightly lower in the posterior direction, that is, the LTS value increases, the existing probability of injury increases. Therefore, this confirmed the hypothesis again.
- Nevertheless, there was a big mystery why the Mode 1 principal component, highly represented the x coordinates of the original dataset, correlated with an ACL injury.

### References

1 Bien, N., Rajpurkar, P., Ball, R. L., Irvin, J., Park, A., Jones, E., Bereket, M., Patel, B. N., Yeom, K. W., Shpanskaya, K., Halabi, S., Zucker, E., Fanton, G., Amanatullah, D. F., Beaulieu, C. F., Riley, G. M., Stewart, R. J., Blankenberg, F. G., Larson, D. B., Jones, R. H., … Lungren, M. P., Deep-learning-assisted diagnosis for knee magnetic resonance imaging: Development and retrospective validation of MRNet, PLoS Med, 27;15(11):e1002699, 2018
2 Nelder, J. A., Wedderburn, R. W. M., Generalized Linear Models. Journal of the Royal Statistical Society, Series A (General) Vol. 135, No. 3, pp. 370-384, 23(1), 123-180, Willy, 1972.

2021 The Korea Society of Mechanical Engineering Spring Conference
Lavalse hotel, Busan, South Korea
June 30th(Wed) - July 3rd(Sat), 2021
E-mails : sanghyun@g.hongik.ac.kr
youkeun@hongik.ac.kr

# MR image analysis to identify anatomical characteristics for ACL injury

[1]Sang-Hyun Park, [1]Youkeun Oh

[1] Department of Mechanical Engineering, Hongik University

## Introduction

- Anterior cruciate ligament tear is one of a vital injury frequently occurs in professional and recreational athletes.
- For a long time, many types of research are conducted in a manner that screens high-risk group for injury prevention.
- Hudek et al. reported a method to define a longitudinal tibial axis for measuring medial posterior tibial slope (Medial PTS) and lateral posterior tibial slope (Lateral PTS).
- In this paper, we propose a medical image processing algorithm based on Hudek's method and optimization method to define a longitudinal axis.

## Methods

### MR Image Slice Selection

- To select sagittal slice defining the longitudinal axis, we find an axial plane which shows plateau rims and each tibial condyle.
- Two Solid lines placed at left and right indicate the sagittal planes contain structural information, not covered in this research.
- The Selected sagittal slice must be between the dashed line, middle area of the plateau,(Fig. 1) and recommended to include the intercondylar eminence and the tibial cortices with concave shape

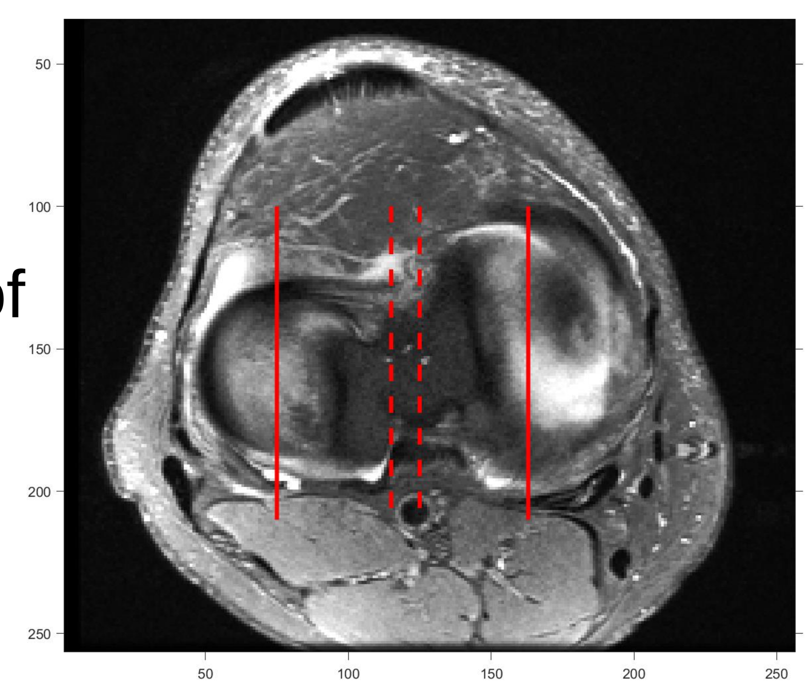

Fig 1. Tibial plateau

### Optimization : Cranial Circle

- 1. Create a light green line by smoothing red line, the edge of the tibial plateau. (Fig 3.)
- 2. Repeat generating normal vectors of green edge
- 3. Repeat generating normal vectors of yellow edge.
- 4. If vectors of Step 2 and Step3 have the same distance between intersection point (IS point) and origin of vector, Save point and distance (dist.)
- 5. Find 3 points to Minimize Objective function (below)

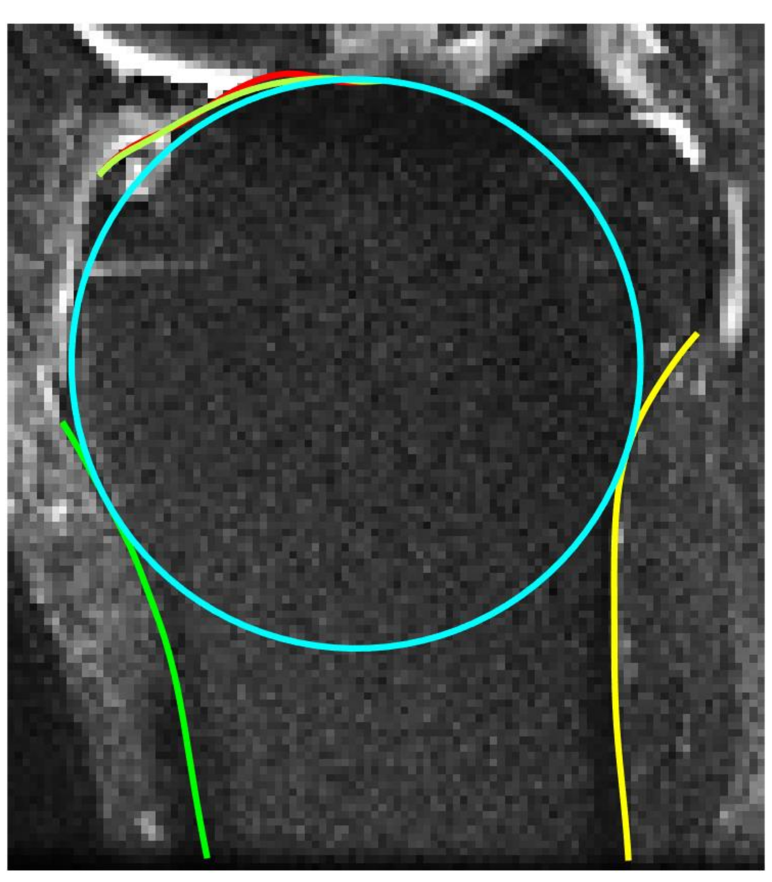

Fig 2. Sagittal plane Edges and Cranial circle

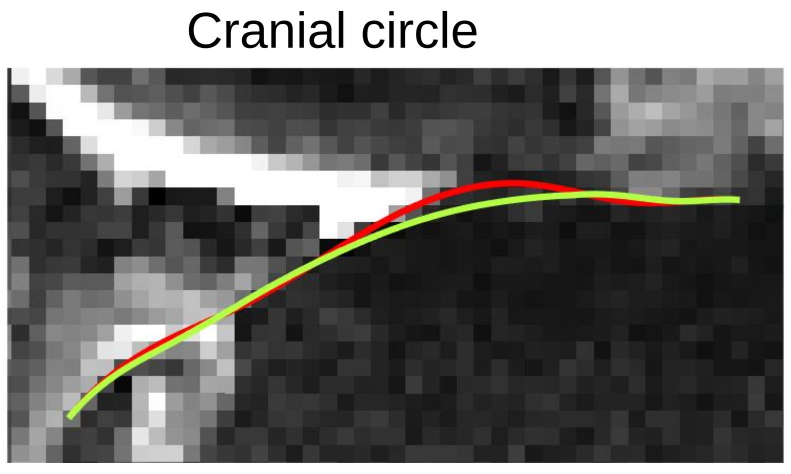

Fig 3. Smoothing Red line

Eq 1. Objective Function1

$$\|dist.(light\ green\ point, IS\ point) - dist.(Step4)\|$$

## Methods (Continued)

### Optimization : Caudal Circle

- Error1.
  dist.(Cranial center, Green Line) – radius of Cranial circle
- Error2.
  dist.(Cranial center, Yellow Line) – radius of Cranial circle
- Error3.
  dist.(Cranial circle, Green Line) - dist.(Cranial circle, Yellow Line)

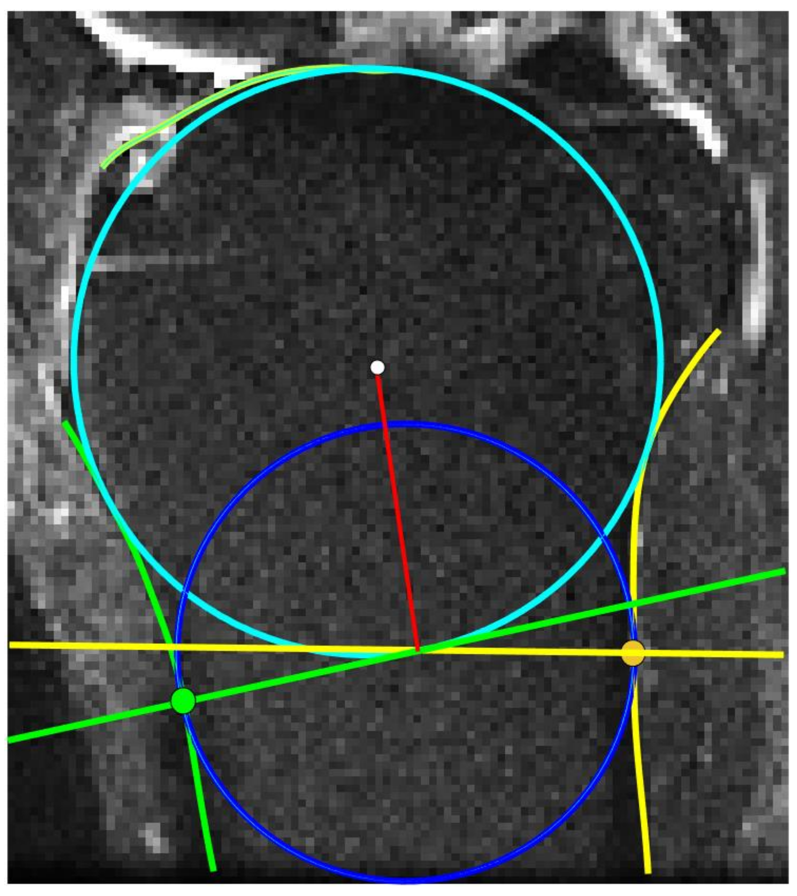

Fig 4. Two Circles and axis

- Green Line = Normal vector of Green point
- Yellow Line = Normal vector of Yellow point
- Normal vector ➡ $Ax + By + C = 0.$
- dist.(Cranial center, Normal vector) ➡ $d_0 = \frac{|C|}{\sqrt{A^2 + B^2}}$
- dist.(Cranial center, Normal vector)
  ➡ $x_0 = -\frac{AC}{A^2 + B^2}$ ➡ $y_0 = -\frac{BC}{A^2 + B^2}$
- Find Green and Yellow point minimize Objective Function

Eq 2. Objective Function2

$$\|Error1\| + \|Error2\| + \|Error3\|$$

## Results

- While the conventionally used manual instrumentation costs about 25 min. for each case of Sagittal MR image, our method only costs 5 – 10 min.
- Assuming a researcher measures 100 cases of the sagittal longitudinal axis, 33 hours can be saved maximum with our method.
- Compare to the professional observer, this algorithm achieved a 2.395 % average error rate for 70 cases.
- Sample standard deviation = 3.475 (Deg)
- Standard error = 2.966 (Deg)

## Discussion

- In spite of time efficiency, the accuracy of measured axis slope is barely adequate.
- In almost half of the cases show higher than 0.8° error, hefty degree error for PTS measurement.
- For more accurate measurements, algorithm improvement and optimization is required.

### References

[1] Hudek R, Schmutz S, Regenfelder F, Fuchs B, Koch PP, "Novel measurement technique of the tibial slope on conventional MRI," Clin Orthop Relat Res, (2009)

[2] Hashemi J, Chandrashekar N, Gill B, Beynnon BD, Slauterbeck JR, Schutt RC Jr, Mansouri H, Dabezies E, "The geometry of the tibial plateau and its influence on the biomechanics of the tibiofemoral jointJ Bone Joint Surg Am, (2008)

2020 The Korea Society of Mechanical Engineering Fall Conference
Kangwonland Convention Center
December 16th(Wed) - 19th(Sat), 2020

E-mails : sanghyun@g.hongik.ac.kr
youkeun@hongik.ac.kr