

Introduction

Motivation:

<u>Improve Diagnostic Accuracy for Sjögren's Syndrome (SjS)</u>

- Eliminate inter-reader variability in ultrasound interpretation under the OMERACT
- (Outcome Measures in Rheumatology) grading system
- Reduce inconclusive results provided by the OMERACT grading system

Facilitate a more prompt response to patient needs

- Eliminate the need for manual, time-consuming assessments of ultrasound images
- Provide real-time diagnostic results

Background:

SjS is an autoimmune disorder that is generally characterized by two main symptoms 1,2]:

dryness of the eyes

dryness of the mouth

This results in dental cavities, yeast infections, vision problems, etc.

The OMERACT is a scoring system that utilizes salivary gland ultrasounds to diagnose SjS. There are 4 possible grades (shown on the right)

- 0 normal appearance
- 1 minimal change
- 2 moderate change
- 3 maximum change from the norm

This method is extremely subjective as doctors analyze these ultrasounds manually. There are other methods of diagnosing SjS however they are often very invasive such as the Schirmer Tear Test, Lip Biopsy, Blood Tests, etc [3–6].



Example of an CNN Architecture [8]



Example of OMERACT Scoring [7]

Convolutional Neural Networks (CNNs) are a subset of Deep Neural Networks (DNNs) specifically designed for image processing in that it is comprised of layers that analyze the data similar to a human brain. VGG (Visual Geometry Group) is a type of CNN and DNN that have proven to perform well for various tasks [8–10].

Specifications & Design

<u>Client Requirements</u>

- Detect SjS from ultrasound images; OMERACT grading function is preferable
- Real-time analysis of images for usage in clinical practice

<u>Team Requirements</u>

- 95% accuracy goal for the final model
- Diagnosis time of 15 minutes or less
- Relatively small software size to prevent slowing of the computer

SJÖGREN'S SYNDROME DETECTION WITH MACHINE LEARNING

Richard Yang, Yousef Gadalla, Brandon Drew, Dhruv Nadkarni, Siya Mahajan, Aran Viswanath University of Wisconsin Madison, Department of Biomedical Engineering

Image Requirements

- Images for training and testing must be deidentified
- Images must be grayscale
- For training and testing, images will be separated in a 7:3 ratio

<u>Baseline Model (K Nearest Neighbour)</u>

- Calculates the distance between the new data point and the existing data
- New data points are assigned the value of the average classification based on the nearest data points

<u>Baseline Model (CNN)</u>

Simple two-layer CNN

<u>Final Model (VGG-19)</u>

- A type of CNN and DNN
- 19 pre-existing convolution layers
- Used with CT scans and X-rays[9,10]

Addition	al Model Parameters
Optimizer	Adam
Loss Function	Cross-entropy Loss [11] $\ell(x, y) = L = \{l_1,, l_N\}^{T}$ $l_n = -w_y \log \frac{exp(x_{n, y_n})}{\sum\limits_{c=1}^{c} exp(x_{n, c})} \cdot 1\{y_n\}$
Learning Rate Scheduler	Exponential [12] $\eta = \eta_0 \times \gamma^t$

Training & Testing



- The figure above depicts the flow of data
- The following graphs show the four most common loss vs epochs graphs, each informs the team what adjustments need to be made







- Use a dataset separate from the training set for testing
- Use the trained model to classify each image
- Compare the predicted label with the target label
- Produce confusion matrices and accuracy scores

Results

SiS Detection **OMERACT** Scoring **KNN Confusion Matrix KNN Confusion Matrix** 80 13 23.7% 42 42 1 66.7% 203 8 1263 99.4% 20.0% 99.9% 99.3% Target Label 56.8% 50.8% 61.0% 3.0% 54.5% **Target Label CNN Confusion Matrix** 28 4 36.5% 27 15 **CNN Confusion Matrix** 2 0 100.0% 176 199 14 43.2% 1264 99.4% 8 29 201 20.0% 100.0% 99.4% 8 23 15 32.6% Target Label 36.5% 44.0% 53.3% 22.4% 46.7% Target Label VGG Confusion Matrix 43 27 8 0 55.1% VGG Confusion Matrix 88 9.3% 277 202 1176 99.9% 488 88 90.0% 93.0% 93.0% 37 **Target Label** 58.1% 69.3% 66.4% 53.7% 66.1% Target Label





Conclusion

SjS Detection

- High accuracy points to the validity of the model
- More balanced dataset is needed to further train and test its performance

OMERACT Scoring

- The large difference between the baseline models and the final model indicates the high dimensionality and complexity of the classification
- Fine adjustments of the layer parameters are likely to be needed
- Processing time is dependent on the machine; with an Apple Mac Studio M1 Max a
- batch of 1273 images can be processed in under two minutes and thirty seconds
- VGG–19 model takes up around 300 MB of space on disk

<u>Current Models:</u>

• Retrain with more comprehensive datasets

New Model:

- Build a Neural Network that takes multiple images as input to minimize information loss
- Optimize for training time based on layer architecture
- **Graphic User Interface (GUI)** • More user functions
- More aesthetically pleasing

References

- 1. M. Ramos-Casals and J. Font, "Primary sjögren's syndrome: Current and emergent AETIOPATHOGENIC concepts,"
- Rheumatology, vol. 44, no. 11, pp. 1354–1367, 2005. doi:10.1093/rheumatology/keh714
- 2. P. Brito-Zerón, S. Retamozo, and M. Ramos-Casals, "Síndrome de Sjögren," *Medicina Clínica*, vol. 160, no. 4, pp. 163–171, 2023. doi:10.1016/j.medcli.2022.10.007
- 3. E. Staff, "Schirmer's test: A test for dry eyes," The Eye News, https://theyenews.com/schirmers-test/ (accessed Oct. 11, 2023). 4. A. Delgado, "Salivary duct stones: Causes, symptoms, and diagnosis," Healthline,
- https://www.healthline.com/health/salivary-duct-stones#outlook (accessed Oct. 11, 2023).
- "Labial gland (lip) biopsy," Johns Hopkins Sjögren's Center, https://www.hopkinssjogrens.org/disease-information/diagnosis-sjogrens-syndrome/labial-gland-lip-biopsy/ (accessed Oct. 11, 2023).
- "Iowa head and Neck Protocols," Lip Biopsy for Sjogren's Syndrome (Minor Salivary Gland Biopsy) Using Chalazion Clamp Iowa Head and Neck Protocols https://medicine.uiowa.edu/iowaprotocols/lip-biopsy-sjogrens-syndrome-minor-salivary-gland-biopsy-using-chalazion-c
- lamp (accessed Oct. 5, 2023). V. Fana, U. M. Dohn, S. Krabbe, and L. Terslev, "Application of the omeract grey-scale ultrasound scoring system for salivary
- glands in a single-centre cohort of patients with suspected Sjögren's syndrome," RMD Open, vol. 7, no. 2, 2021. doi:10.1136/rmdopen-2020-001516
- "Understanding convolutional neural network: A complete guide," LearnOpenCV,
- https://learnopencv.com/understanding-convolutional-neural-networks-cnn/ (accessed Nov. 29, 2023). . K. K. Mohbey, S. Sharma, S. Kumar, and M. Sharma, "Covid-19 identification and analysis using CT scan images: Deep Transfer Learning-based approach," Blockchain Applications for Healthcare Informatics, pp. 447–470, 2022.
- doi:10.1016/b978-0-323-90615-9.00011-6 V. Kovalev, A. Radzhabov, and E. Snezhko, "Automatic detection of pathological changes in chest X-ray screening images using Deep Learning Methods," Diagnostic Biomedical Signal and Image Processing Applications with Deep Learning *Methods*, pp. 155–178, 2023. doi:10.1016/b978-0-323-96129-5.00005-6
- "Crossentropyloss," CrossEntropyLoss PyTorch 2.1 documentation,
- https://pytorch.org/docs/stable/generated/torch.nn.CrossEntropyLoss.html (accessed Dec. 4, 2023). 12. "Exponentiallr," ExponentialLR – PyTorch 2.1 documentation, https://pytorch.org/docs/stable/generated/torch.optim.lr_scheduler.ExponentialLR.html (accessed Dec. 4, 2023).
- 13. "Sklearn.utils.class_weight.compute_class_weight," scikit, https://scikit-learn.org/stable/modules/generated/sklearn.utils.class_weight.compute_class_weight.html (accessed Dec. 4, 2023)

Acknowledgments

- We thank our client Dr. Sara McCoy for providing the ultrasound image data used in our training and assisting us in our understanding of the OMERACT grading system
- We would also like to thank our advisor Dr. Cameron Casey for the guidance he provided during the duration of this project

KNN Confusion Matrix				
	True Label			
pa		neg	pos	
Predicte Label	neg	2	1	
	pos	8	1263	
Αςςι	uracy 99.3%			
Γ				
CN	IN Confu	sion Mat	rix	
CN	N Confu	sion Mat True Label	rix	
	IN Confu	sion Mat True Label neg	rix pos	
edicted Label	N Confu neg	sion Mat True Label neg 2	rix pos O	
Predicted Label	N Confu neg pos	sion Mat True Label neg 2 8	rix pos 0 1264	

VGG Confusion Matrix		
9	88	
1	1176	
Accuracy	93%	

KNN Confusion Matrix					
	True Label				
G		0	1	2	3
Lab	0	42	42	80	13
ted	1	20	203	207	16
edic	2	11	155	448	36
Pr	3	1	0	0	2
	Accuracy 54.47%				
	L I				
CNN Confusion Matrix					

CNN Confusion Matrix					
	True Label				
<u>(</u>)		0	1	2	3
Lab	0	27	15	28	4
ted	1	18	176	199	14
edic.	2	29	201	285	34
P.	3	0	8	23	15
	Accuracy	/		54.47%	

- of this document.
- BRING THEM WITH YOU.
- Methods of printing and creating your poster

• Your poster should cover the KEY POINTS of your work. The ideal poster is designed to 1) attract attention; 2) provide a brief overview of your work; and 3) initiate discussion and questions. • Make your poster attractive. Think about what attracts you to posters and other visual displays. Wherever possible, use pictures, diagrams, cartoons, figures, etc., rather than only text. • The title of your poster should appear at the top in CAPITAL letters at least 50 mm (2") high. Below the title, put the author(s)' name(s) and affiliation(s). The smallest text on your poster should be at least 9 mm (3/8") high, and the important points should be in a larger size. See the font size legend at the end

• Poster stands with corkboard will be provided for the poster session. They measure 122 cm tall x 182 cm wide. Push pins for posting your material on the board or tape will be provided. • Carefully prepare your poster well in advance of the presentation. There will be no time or materials available for last minute preparations. If you think you may need certain materials (i.e. extension cord),

• The cost is the responsibility of the students; the department does not pay for poster printing and you should not expect your client to pay for the poster. • Posters can be printed at College (Helen C. White) Library or Steenbock Library. Other on and off campus resources and companies exist as well. The cost ranges from \$30-\$90. Be sure to have them printed early as everyone might be trying to print at the same time.

Title

- Authors, Advisor, Client, Date or Semester
- Problem Definition:
- Motivation
- o Background
- Final Design
- Testing
- Results
- Future Work
- References

Design Criteria and quantitative specifications

96 pt 72 pt (Good for the title) 60 pt 48 pt (Good for headings) 36 pt

- 30 pt (Good for general text)
- 24 pt (18-24 The smallest usable poster font sizes)
- 18 pt
- 14 pt
- 12 pt
- 10 pt