SCHULICH School of Engineering

COURSE PROPOSAL

	Date	Initials
Prepared by Instructor	June 16th, 2021	RMS
Approved by Head		

COURSE NAME/NUMBER
ENSF 619.2

COURSE TITLE	HOURS	SESSION	YEAR
Advanced Topics in Image Analysis and Machine Learning	H (3-0)	Fall	2021

COURSE PROPOSAL

DESCRIPTION

Justification: Provide a course that teaches students about selected topics about image analysis and machine learning that cannot be found in current textbooks. Image analysis and machine learning are fields that evolve very quickly and a course focusing on the latest techniques is necessary to keep our students up to date with the state-of-the-art. A sizeable number of ESE and BME faculty does research in the fields of image analysis and machine learning. The topics covered in this course will complement and not overlap with other courses being currently taught at the University of Calgary.

Pre-requisites: Enrollment in a thesis-based ENSF, ENEL, ENGO, BME or other related graduate program, programming and basic machine learning knowledge.

Scope of the Coursework: This course focuses on advanced topics of machine learning and image analysis techniques. The course will cover the following topics: graph-based image representations, image enhancement and segmentation, connected operators, supervised and unsupervised methods, classification, and regression problems, state-of-the-art models on the ImageNet dataset, AutoML, domain adaptation techniques, and adversarial models. A special emphasis will be given to recent cutting-edge techniques.

Learning Outcomes:

1. Acquire significant knowledge about cutting-edge image analysis and machine learning methods.
2. Design and develop image processing and machine learning solutions for relevant problems.
3. Acquire hands-on experience with image processing and machine learning programming frameworks (e.g., OpenCV, scikit-image, TensorFlow, etc.).

COURSE CONTENTS

Topic & Sub-topics	Learning Outcome
1. Graph-based image representation • The max-tree and the min-tree • Threshold signature • Connected filters	• Get familiar with graph-based image representations and how to efficiently process images using these representations
2. The Watershed Transform • Watershed from minima • Watershed from markers • Tie-zone Watershed	• Learn how to employ the Watershed transform for image segmentation problems
3. ImageNet state-of-the-art • ResNet • NASNet • EfficientNets • Vision transformers	• Become familiar with the state-of-the-art models on the ImageNet benchmark
4. Self-supervised learning • Generation-based methods • Context-based methods • Free semantic label-based methods • Cross modal-based methods	• Learn how to employ the different self-supervised learning methods to improve image analysis results
5. Domain adaptation • One-step domain adaptation • Multi-step domain adaptation	• Learn how to employ domain adaptation techniques to improve cross-dataset image analysis results
6. Adversarial models • Generative adversarial networks • Improved loss functions	• Comprehend the basic mechanisms of adversarial models for synthetic data generation and to learn improved loss functions
7. AutoML • Neural architecture search • nnUNET • EfficientNets-V2	• Comprehend the main AutoML techniques

REFERENCE MATERIALS

[1] Goodfellow, I., Bengio, Y., Courville, A. and Bengio, Y., 2016. *Deep learning* (Vol. 1, No. 2). Cambridge: MIT press. **(Basic Book)**

[2] Jones, R., 1999. Connected filtering and segmentation using component trees. *Computer Vision and Image Understanding*, *75*(3), pp.215-228.

[3] Falcão, A.X., Stolfi, J. and de Alencar Lotufo, R., 2004. The image foresting transform: Theory, algorithms, and applications. *IEEE transactions on pattern analysis and machine intelligence*, *26*(1), pp.19-29.

[4] Jing, L. and Tian, Y., 2020. Self-supervised visual feature learning with deep neural networks: A survey. *IEEE Transactions on Pattern Analysis and Machine Intelligence*.

[5] Tan, M. and Le, Q., 2019, May. Efficientnet: Rethinking model scaling for convolutional neural networks. In *International Conference on Machine Learning* (pp. 6105-6114). PMLR.

[6] Jin, H., Song, Q. and Hu, X., 2019, July. Auto-keras: An efficient neural architecture search system. In *Proceedings of the 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining* (pp. 1946-1956).

[7] Dosovitskiy, A., Beyer, L., Kolesnikov, A., Weissenborn, D., Zhai, X., Unterthiner, T., Dehghani, M., Minderer, M., Heigold, G., Gelly, S. and Uszkoreit, J., 2020. An image is worth 16x16 words: Transformers for image recognition at scale. *arXiv preprint arXiv:2010.11929*.

[8] Goodfellow, I.J., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Courville, A. and Bengio, Y., 2014. Generative adversarial networks. *arXiv preprint arXiv:1406.2661*.

[9] Csurka, G., 2017. A comprehensive survey on domain adaptation for visual applications. *Domain adaptation in computer vision applications*, pp.1-35.

[10] Elsken, T., Metzen, J.H. and Hutter, F., 2019. Neural architecture search: A survey. *J. Mach. Learn. Res.*, *20*(55), pp.1-21.