Deep Learning for Image Processing in Orthopaedics

ORS Virtual Scientific Session

Andrew J. Jensen

University of Florida

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A Brief Introduction

“Machine learning, neural networks, and artificial intelligence are increasingly being used in orthopaedics for image processing and analysis tasks. These techniques can be used to **automatically analyze medical images** such as X-rays, MRI scans, and CT scans to **extract important diagnostic information** and help with diagnosis and treatment planning. Machine learning algorithms can be trained to **recognize patterns in the images**, and neural networks can be used to process and interpret the data in a more human-like way. These approaches can be used to **identify abnormalities, measure bone density, and classify different types of tissue**, among other tasks. By automating these processes, doctors and other healthcare professionals can **save time and improve the accuracy of their diagnoses**”

- ChatGPT (emphasis mine)

By the end of this presentation, you should be able to ...

- → List some ways that deep learning is being used for image processing in orthopaedics
- → Understand some of the basic neural network architectures, and how those fit into different tasks
- → Have a few tips and tricks up your sleeve for getting started with these networks

Three Categories of Deep Learning Applications

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Classification	Identifying objects in images and determining membership in specific classes
Detection	Locating regions in images based on presence of specific object

EXAMPLES

Automated Segmentation and Grading of Rodent Knee OA Histology using Convolutional Neural Networks

UF UNIVERSITY of FLORIDA
J. CRAYTON PRUITT FAMILY DEPARTMENT OF BIOMEDICAL ENGINEERING

ORTHO BME LABORATORY at the University of Florida

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1. J. Crayton Pruitt Family Department of Biomedical Engineering, University of Florida, Gainesville, FL
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3. Pain Research & Intervention Center of Excellence (PRICE), University of Florida, Gainesville, FL
4. Department of Orthopedics and Rehabilitation, University of Florida, Gainesville, FL

Current Results

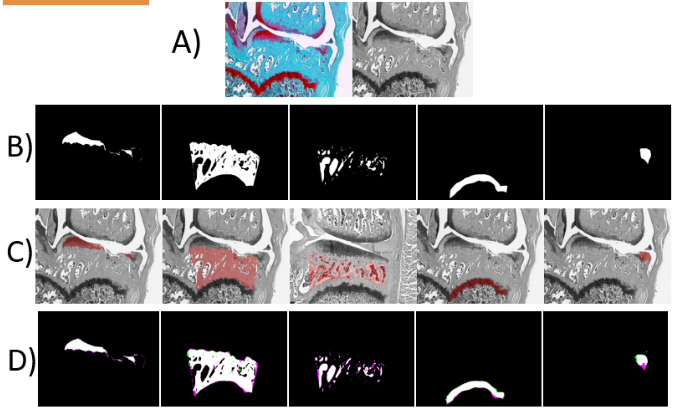
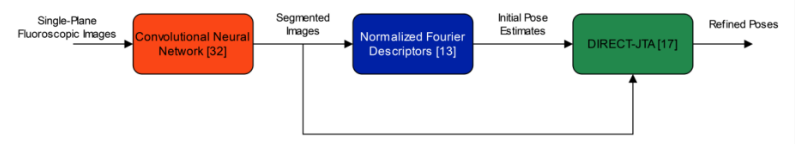
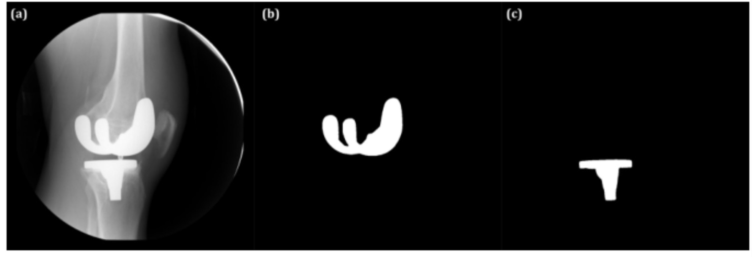


Figure 2. Example images of **A)** Raw histological images in RGB and grayscale color spaces, **B)** binary masks from manually segmented regions of interest (ground truth), **C)** HRNet estimated segmentation overlayed on the original histological image, and **D)** visualization of the Jaccard Index where pink is false negative, and green is false positive.

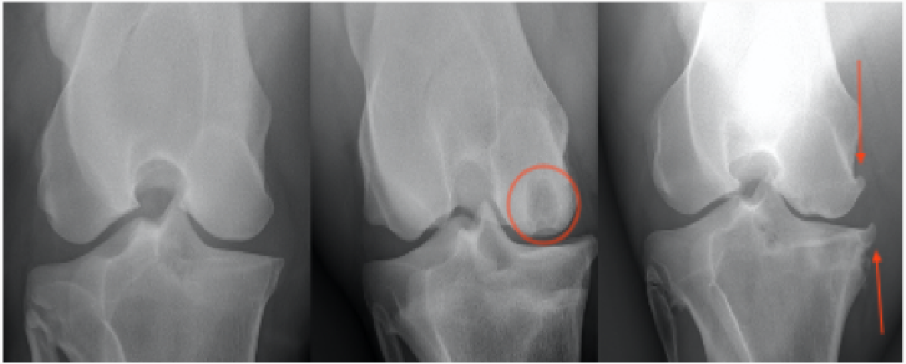
Joint Track Machine Learning: An Autonomous Method of Measuring TKA Kinematics from Single-Plane Images

Andrew Jensen, Paris Flood, Lindsey Palm-Vlasak, Will Burton, Paul Rullkoetter, Scott Banks

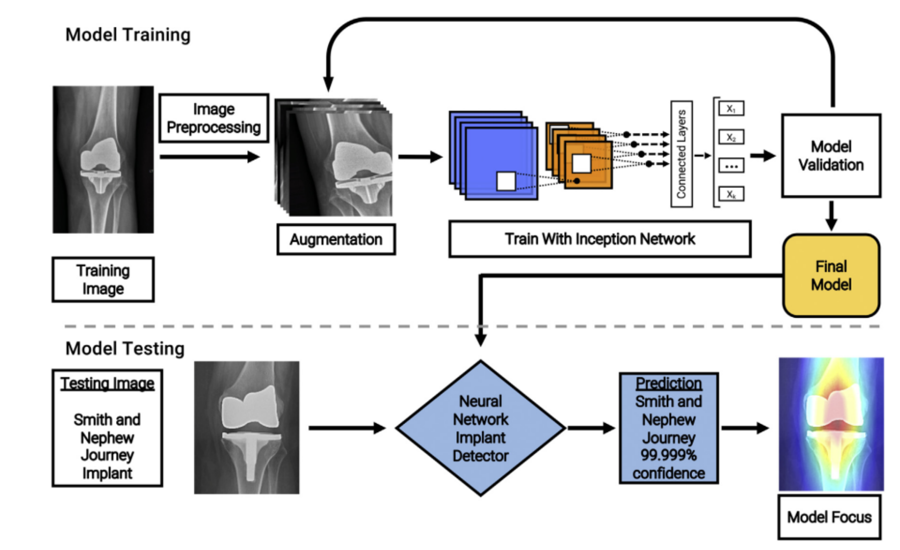




Classification of Equine Stifle Pathology



Artificial Intelligence to Identify Arthroplasty Implants From Radiographs of the Knee



Karnuta et al., Journal of Arthroplasty, 2021
doi:10.1016/j.arth.2020.10.021

Deep High-Resolution Representation Learning for Visual Recognition

Jingdong Wang, Ke Sun, Tianheng Cheng, Borui Jiang, Chaorui Deng, Yang Zhao, Dong Liu, Yadong Mu, Mingkui Tan, Xinggang Wang, Wenyu Liu, and Bin Xiao

Fig. 6. Qualitative COCO human pose estimation results over representative images with various human size, different poses, or clutter background.

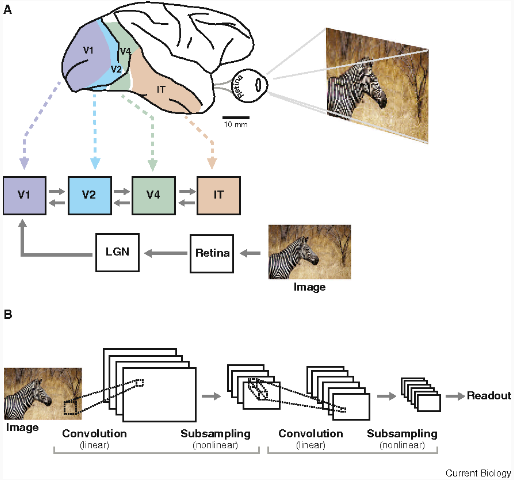
Wang et al, Computer Vision and Image Understanding, 2021
doi: 10.1016/j.cviu.2021.103225

WHAT IS DEEP LEARNING FOR IMAGE PROCESSING?

A Basic Definition

→ Subset of machine learning using neural networks to imitate the visual system in the brain

→ A set of algorithms that learn programs from data



Cox and Dean, Neural Networks and Neuroscience-Inspired Computer Vision, 2014

The Architecture of a Neural Network

Building Block	Neural Network

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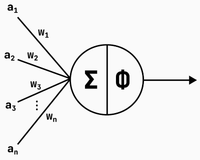
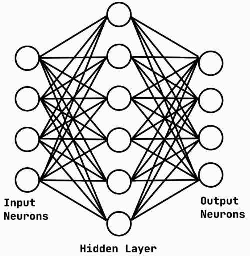
 $\phi(\sum_{i=1}^{n} a_i w_i)$	

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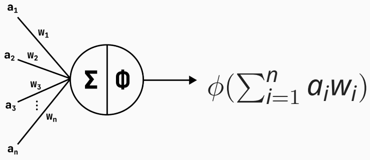
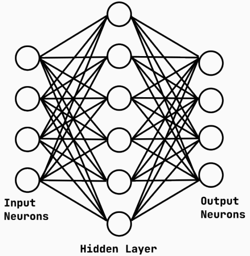
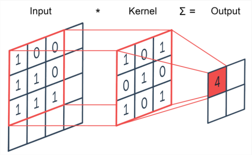
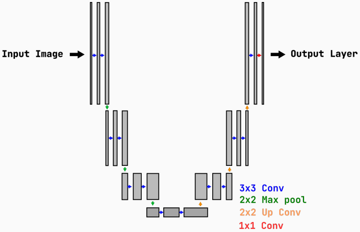
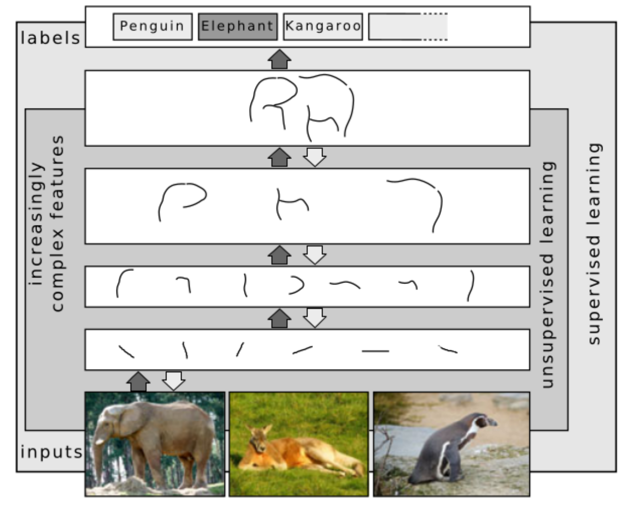
	
	

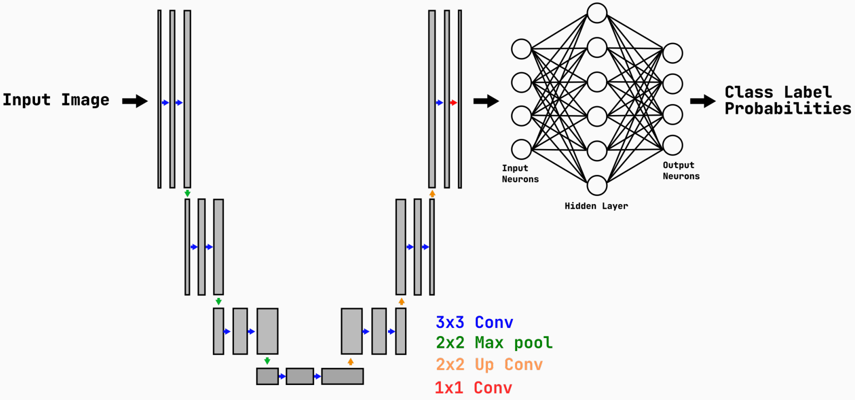
The Power of Convolutional Neural Networks



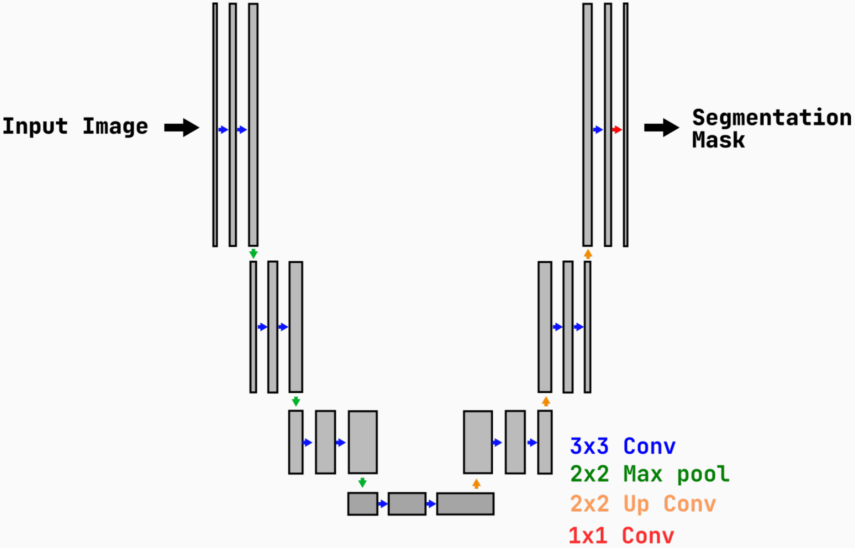
Shulz and Behnke, Deep Learning: Layer-Wise Learning of Feature Hierarchies, 2012

ARCHITECTURE MODIFICATIONS

Classification

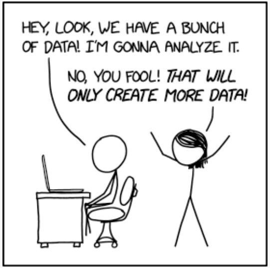


Segmentation

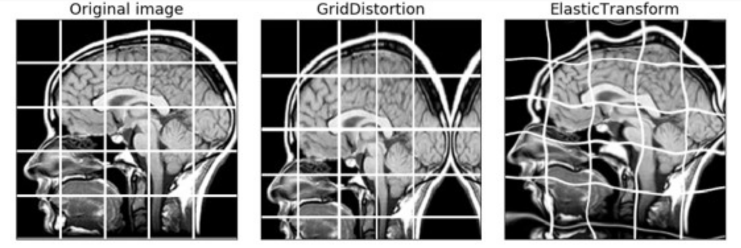


TIPS AND TRICKS

You Can't Outrun A Lack of Data



https://xkcd.com/2582/



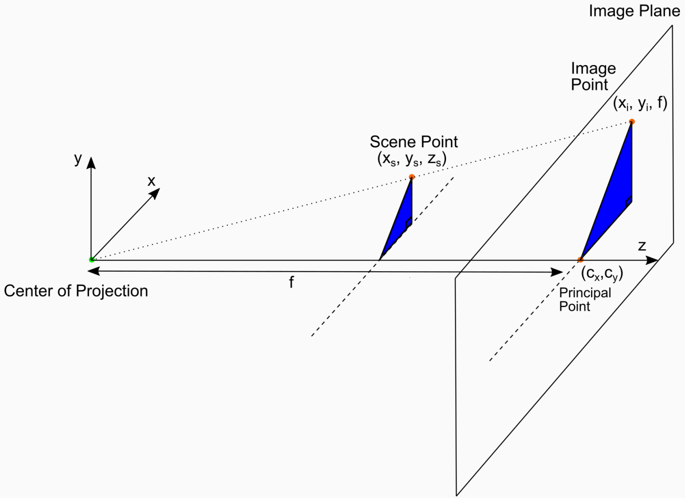
https://albumentations.ai/

Minimal Necessary Force

https://xkcd.com/1838/

Utilizing Historic Methods

https://xkcd.com/1425/



GETTING STARTED

MONAI

MONAI

Medical Open Network
for Artificial Intelligence

https://monai.io

Background Information

- CS231n: Deep Learning for Computer Vision, Stanford University (http://cs231n.stanford.edu/, lectures on YouTube)
- Andrew Ng Coursera Courses
  - Machine Learning Specialization
  - Deep Learning Specialization

CASE STUDY

The Problem

- 20% of patients recieving TKA are dissatisfied
- Clinicians don’t have the ability to routinely quantify joint kinematics
  - They must rely on manual examination and static imaging
  - Historic methods of measuring joint kinematics require are too time consuming for routine clinical use

The Problem

- → 20% of patients recieving TKA are dissatisfied
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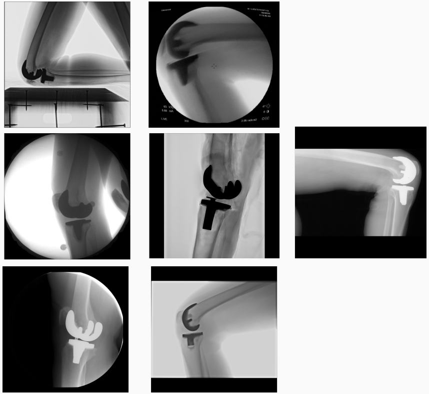
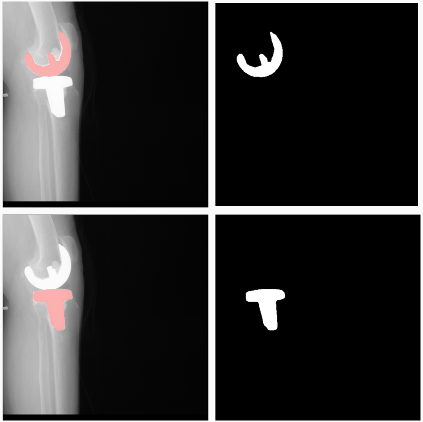
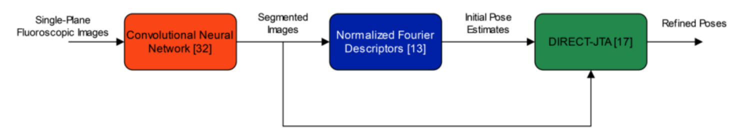
Question: Can we automate the process of measuring joint kinematics in order to make these measurements clinically feasible?

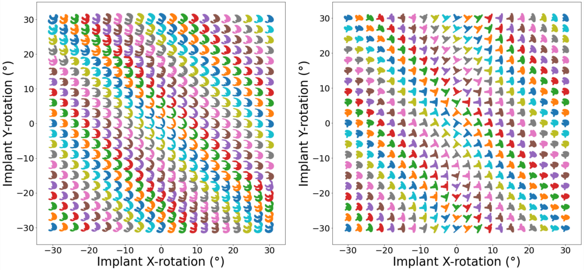
Joint Track Machine Learning: Data





Joint Track Machine Learning: Historic Methods and Minimal Necessary Force





Wallace and Mitchell, Analysis of three-dimensional movement using Fourier descriptors, 1980

Wallace and Wintz, An efficient three-dimensional aircraft recognition algorithm using normalized fourier descriptors, 1980

Jones et al, Lipschitzian Optimization without the Lipschitz Constant, 1993

Banks and Hodge, Accurate measurement of three-dimensional knee replacement kinematics using single-plane fluoroscopy, 1996

THANK YOU

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