hutom AI Research Introduction

- Data Playground @ 7 -

hutom AI
2019. 09. 27

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BEFORE

Artificial 3D modeling and surgery rehearsal based on patient specific CT

Planning / Practice

DURING

Patient's anatomy view anytime and anywhere with tips on tool direction, contact alarm, scene playback

Optimal Decision Making

AFTER

AI driven customized reports on data analysis, surgical performance evaluation and review

Post Care / Review

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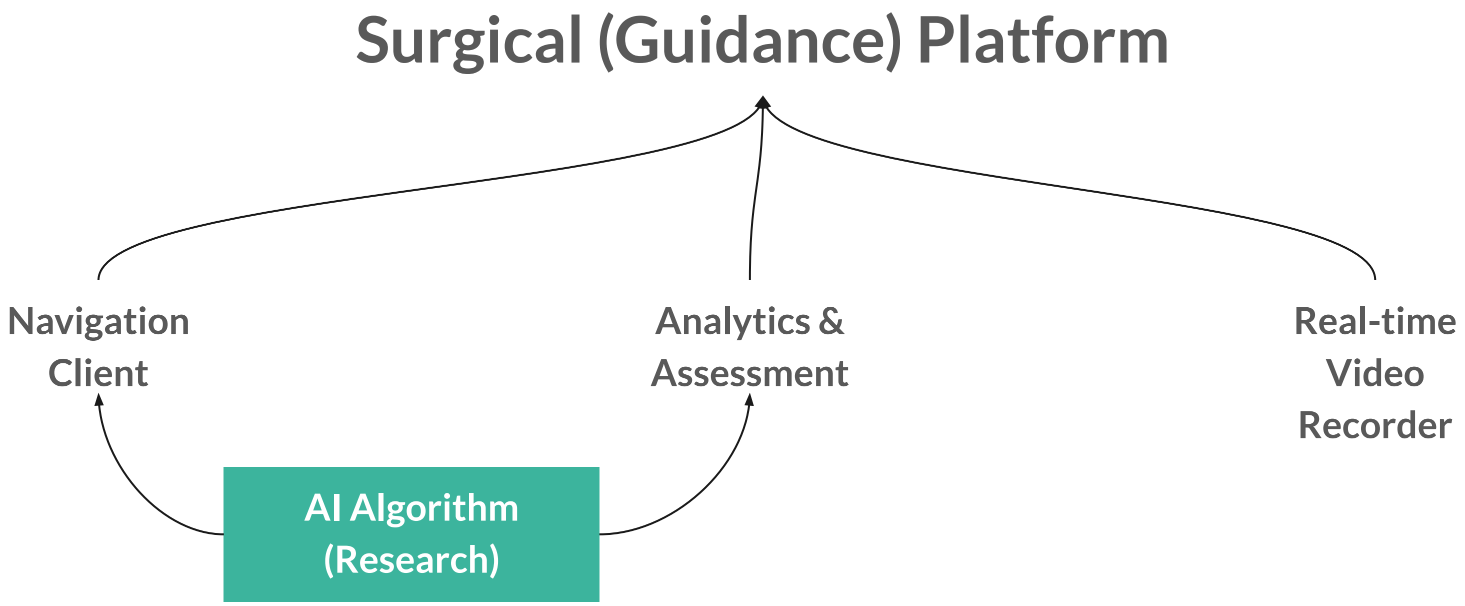

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Research Objectives

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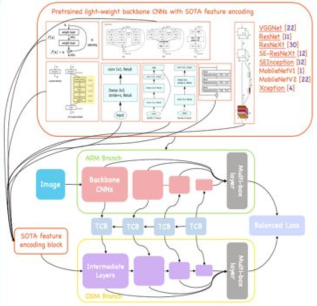
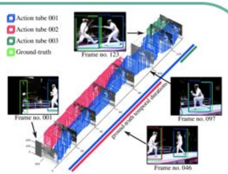
Visual Information Recognition



NN Architecture Design

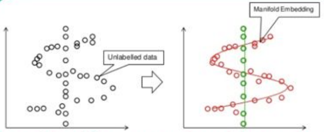
Object Detection



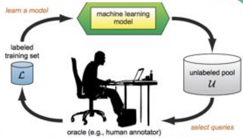
Activity Recognition

Panoptic Segmentation

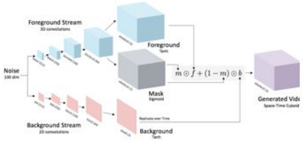
Learning to Learn



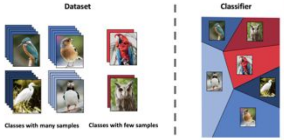
Semi(self)-supervised learning



Active Learning



Generative modeling



Few-shot learning

Public Data Repositories

IMAGENET

ACTIVITYNET

EPIC KITCHENS

Cholec80 Dataset

Kinetics

CITYSCAPES DATASET

COCO is a large-scale object detection, segmentation, and captioning dataset. COCO has several features:

Open Images Dataset

storage.googleapis.com/openimages/web/download.html

ADE20K

AVA

HuToM AI Ops

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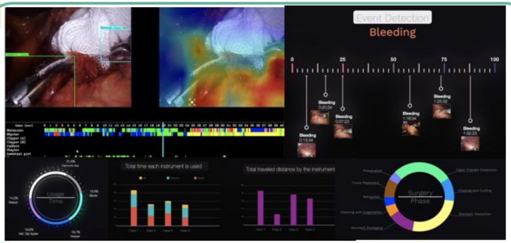
HuToM AI Service



Surgical Workflow Analysis

Surgical Workflow And Skill Analysis

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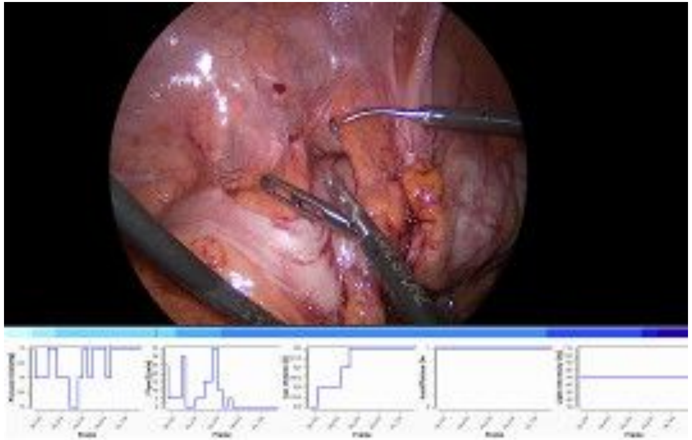
- Cholecystectomy [1]
- Annotations
  - Action
  - Instrument
  - Phase
  - Skill



HUMAN TOUCH IN MEDICINE

Action ID	Action
0	Grasp
1	Hold
2	Cut
3	Clip

Phase ID	Phase
0	Preparation
1	Calot triangle dissection
2	Clipping and cutting
3	Galbladder dissection
4	Galbladder packaging
5	Cleaning and coagulation
6	Galbladder retraction

Tool Category ID	Tool Category
0	Grasper
1	Clipper
2	Coagulation instruments
3	Scissors
4	Suction-irrigation
5	Specimen bag
6	Stapler
7-20	Reserved for future additions

Tool Category ID	Tool ID	Instrument
0	0	Curved atraumatic grasper
0	1	Toothed grasper
0	2	Fenestrated toothed grasper
0	3	Atraumatic grasper
0	4	Overholt
2	5	LigaSure
2	6	Electric hook
3	7	Scissors
1	8	Clip-applier (metal)
1	9	Clip-applier (Hem-O-Lok)
0	10	Swab grasper
2	11	Argon beamer
4	12	Suction-irrigation
5	13	Specimen bag
0	14	Tiger mouth forceps
0	15	Claw forceps
0	16	Atraumatic grasper short
0	17	Crocodile forceps
0	18	Flat grasper
0	19	Pointed forceps
6	20	Stapler
7-19	21-29	Reserved for future additions
20	30	Undefined instrument shaft

Ranking Component	Depth perception	Bimanual dexterity	Efficiency	Tissue handling	Case difficulty
Range	1-5	1-5	1-5	1-5	1-5

[1] Endoscopic Vision Challenge, https://endovissub-workflowandskill.grand-challenge.org/

Instrument Detection

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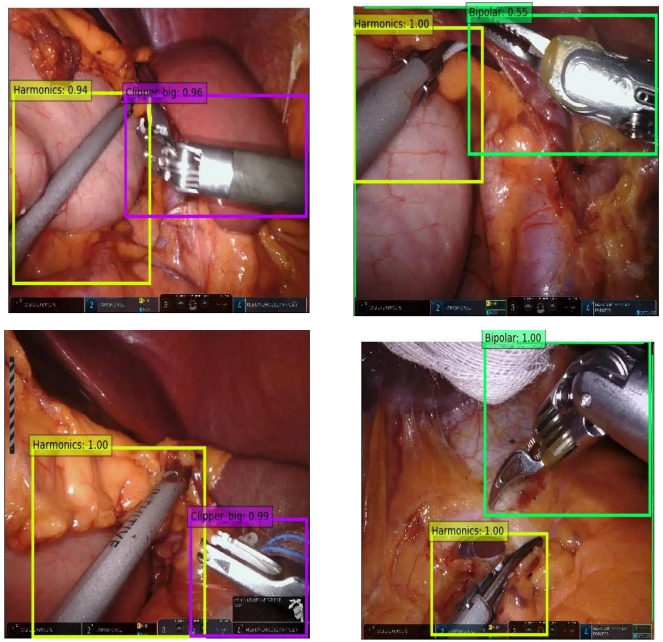
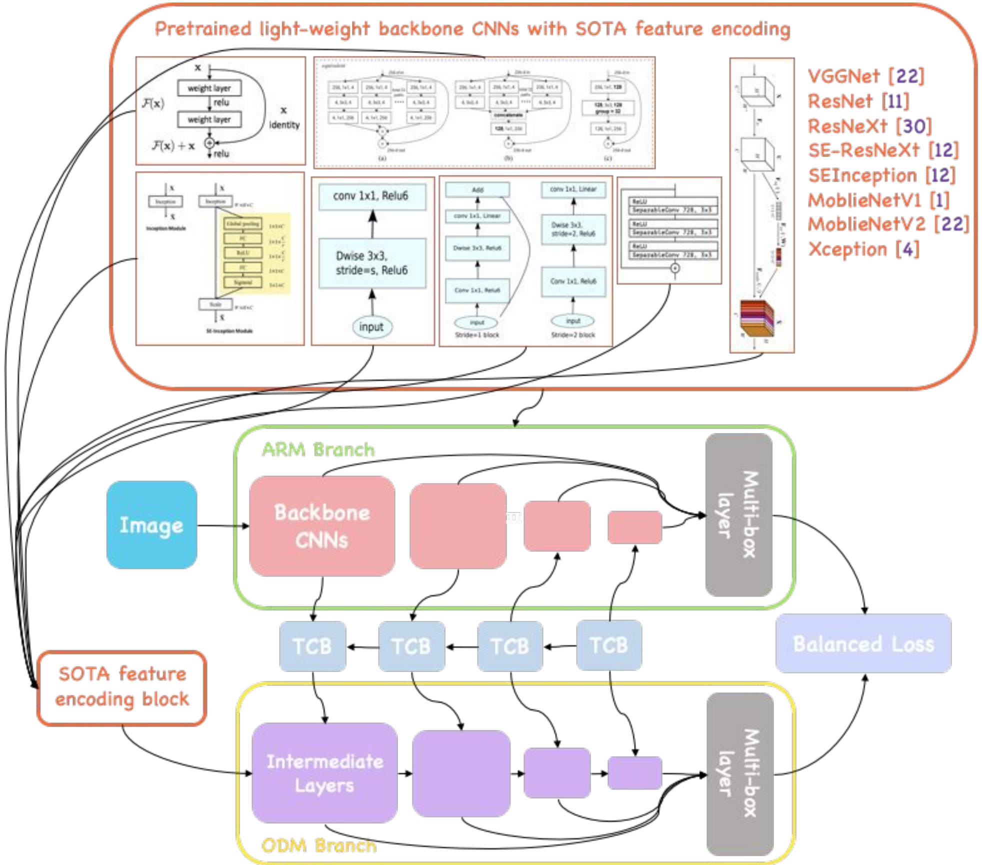
- RefineDet [1]
- Modern encoding blocks [2]





[1] Single-Shot Refinement Neural Network for Object Detection, S. Zhang, et al., arXiv:1711.06897
[2] Fast and Accurate Convolutional Object Detectors for Real-time Embedded Platforms, M. -K. Choi, et al., arXiv:1909.10798

Class Imbalance Problem

Instrument Localization

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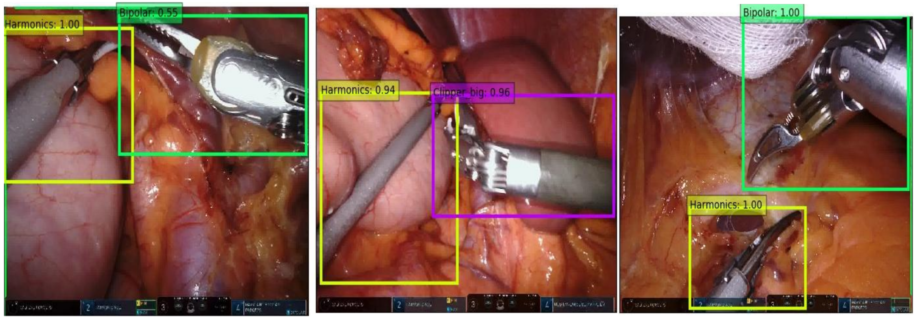
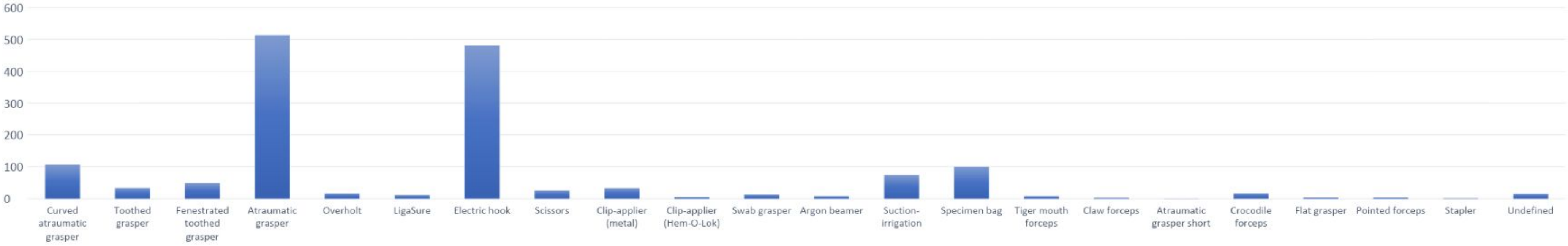
- Surgical Video
  - Severe class imbalance





citation

Domain Randomization

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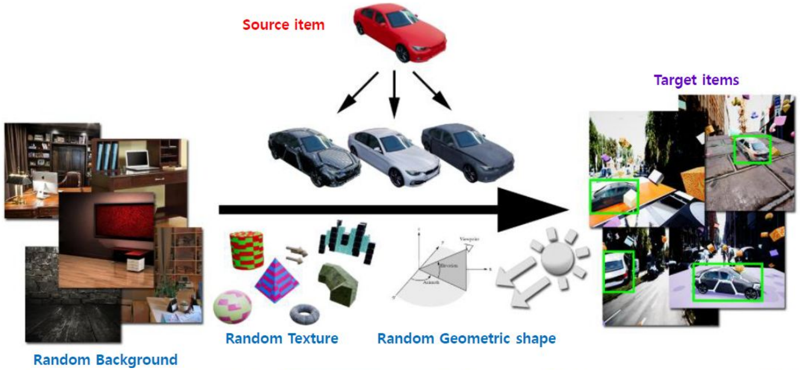
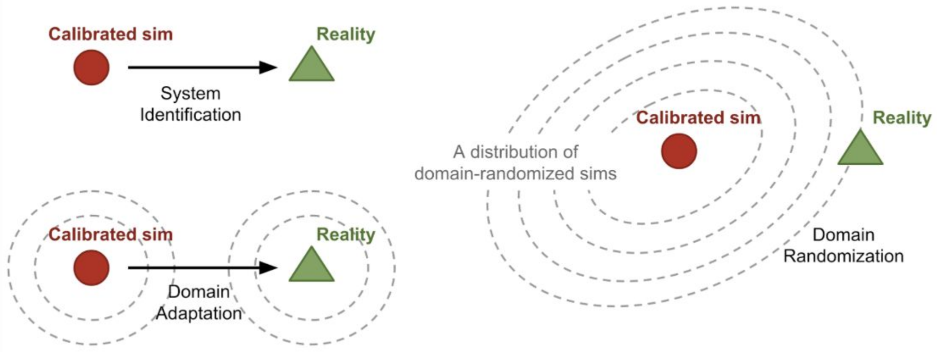
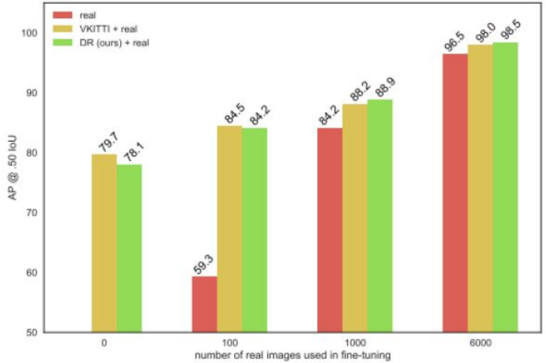
- Self-annotation by synthesized modeling [1]



윗줄: VKITTI, 아랫줄: DR

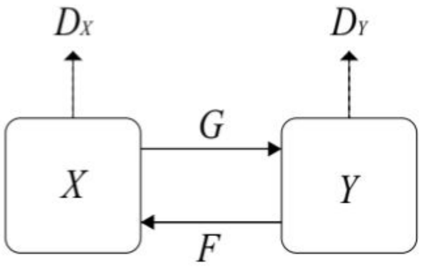


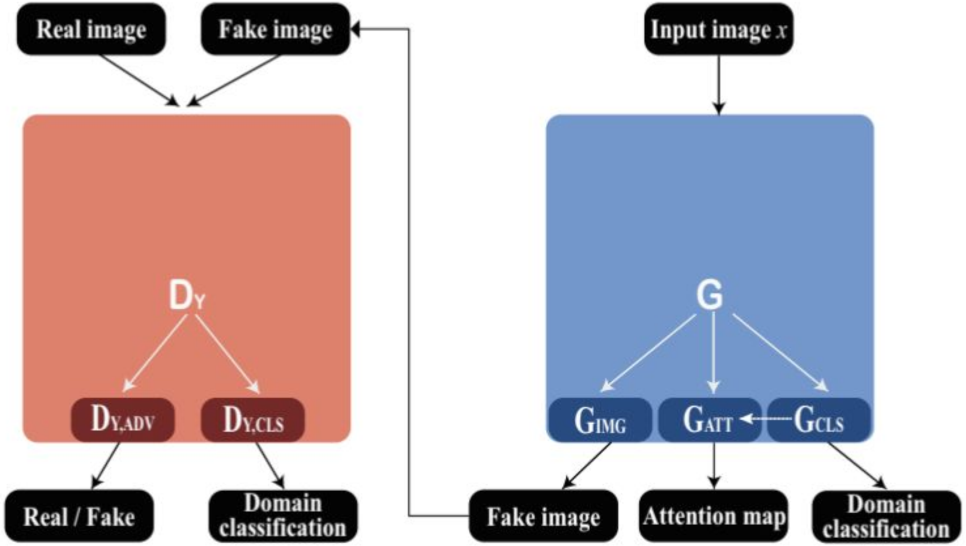


[1] Training Deep Networks with Synthetic Data: Bridging the Reality Gap by Domain Randomization, J. Tremblay, et al., arXiv:1804.06516

Generative Modeling

- DavinciGAN: Surgical Instrument Translation for Data Augmentation





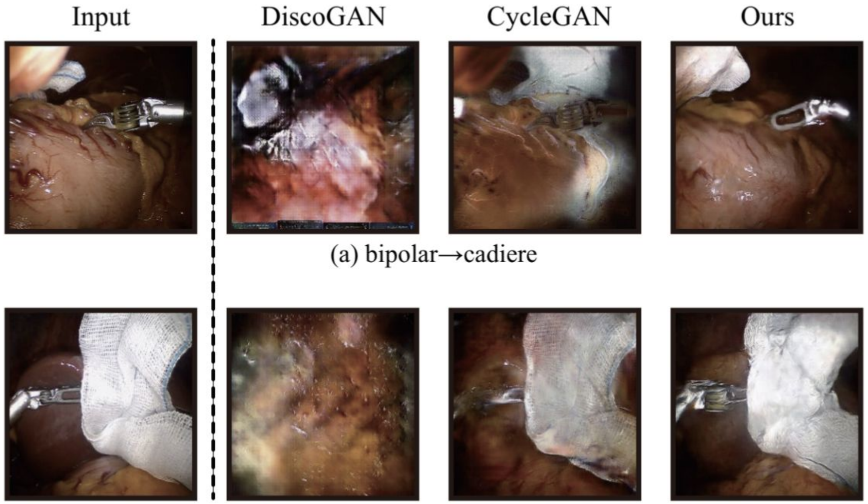
$$L_D = L_{adv} + \lambda_{CLS} * (L_{D,CLS} + L_{CLS-ADV})$$

$$L_G = -L_{adv} + \lambda_{CLS}(L_{G,CLS} - L_{CLS-ADV}) + \lambda_{BG}L_{BG-CONSIST} + \lambda_{CYC}L_{CYC-CONSIST}$$

[1] DavinciGAN: Unpaired Surgical Instrument Translation for Data Augmentation, K. Lee, et al, MIDL 2019

Generative Modeling

- DavinciGAN: Surgical Instrument Translation for Data Augmentation



(b) cadiere→bipolar

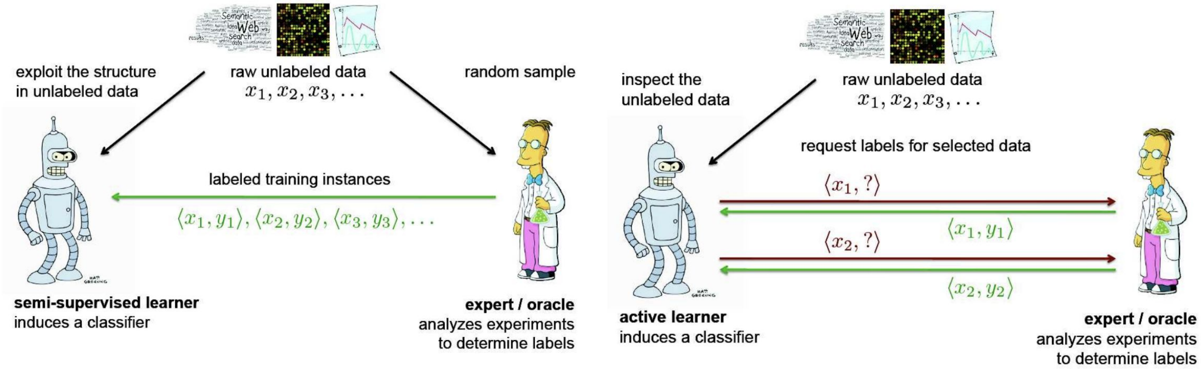
Dataset	Method	# of parameters	Accuracy (%)
Real 1000	-	-	58.84
Real 1000 + Synthetic 1000	DiscoGAN	67M	57.91
Real 1000 + Synthetic 1000	CycleGAN	56M	58.61
Real 1000 + Synthetic 1000	DavinciGAN	31M	61.34
Real 2000	-	-	62.31

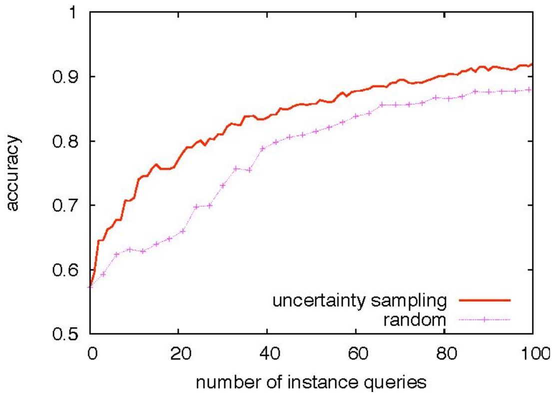
[1] DavinciGAN: Unpaired Surgical Instrument Translation for Data Augmentation, K. Lee, et al, MIDL 2019

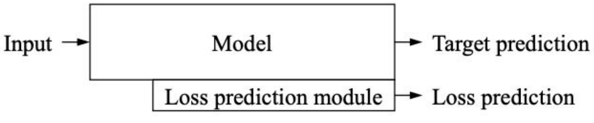
Active Learning Using Analytic Learning Theory

Active Learning

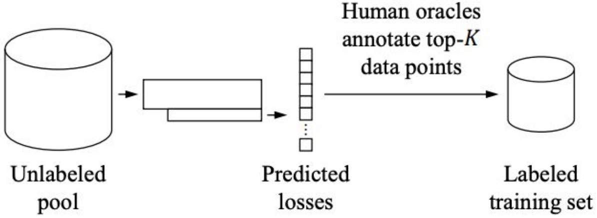
- What teach first?







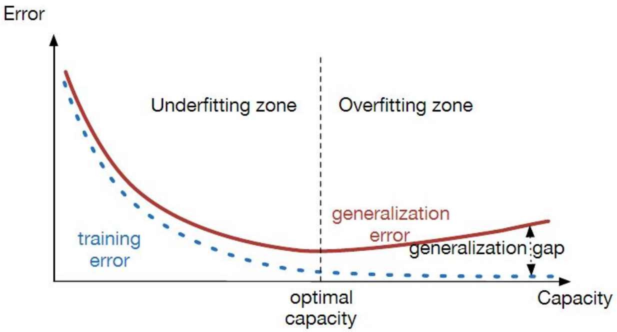
(a) A model with a loss prediction module



[1] Active Learning Literature Survey, B. Settles, CMU Computer Sciences Technical Report, 1995

Generalization Error

- Generalization error



- Generalization error bound [1]

Weights connected to layer k

Training Error

Complexity of layer k

Generalization Error

Number of layers in NN

$$R(f) \leq \widehat{R}_{S,\rho}(f) + \frac{4}{\rho} \sum_{k=1}^{l} \boxed{\left\| \mathbf{w}_k \right\|}_1 \boxed{\mathfrak{R}_m(\widetilde{\mathcal{H}}_k)} + \frac{2}{\rho} \sqrt{\frac{\log l}{m}}$$
$$+ C(\rho, l, m, \delta),$$

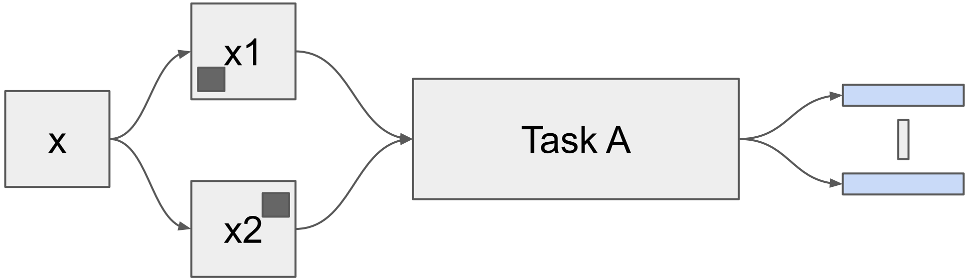
Size of training data

[1] Generalization in Deep Learning, K. Kawaguchi, et al., arXiv:1710.05468,

Dual Cutout

- Perturbations of a data point should not change the output of a model as if the true label is invariant under the perturbation

$$\ell_{\text{reg}}(x,\theta) = \int_{(x_1,x_2)} \|h(x_1,\theta) - h(x_2,\theta)\|_2^2 dP(x_1,x_2|x),$$



Method	CIFAR-10	CIFAR-100	SVHN
Standard	3.79 ± 0.07	19.85 ± 0.14	2.47 ± 0.04
Single-cutout	3.19 ± 0.09	18.13 ± 0.28	2.23 ± 0.03
Dual-cutout	2.61 ± 0.04	17.54 ± 0.09	2.06 ± 0.06

[1] Generalization in Machine Learning via Analytical Learning Theory, K. Kawaguchi, arXiv:1802.07426

Anomaly Detection for Guided Annotation

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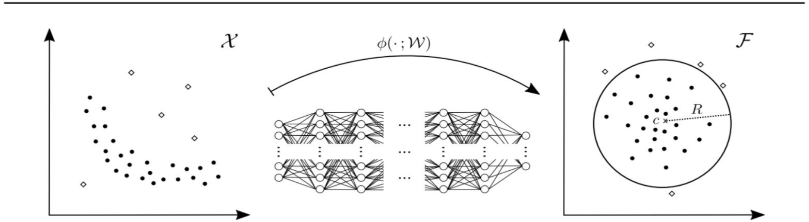
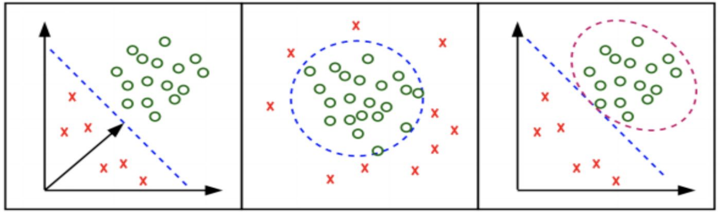
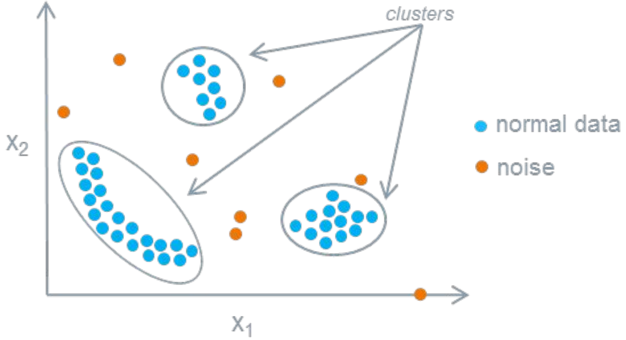
One Class Neural Networks

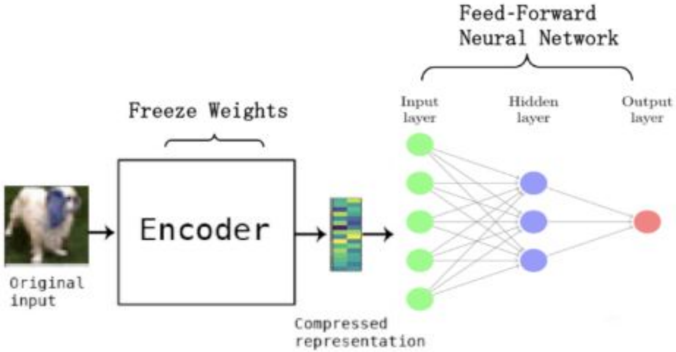
- Anomaly detection





(a) OC-SVM (b) SVDD (c) Single-MPM

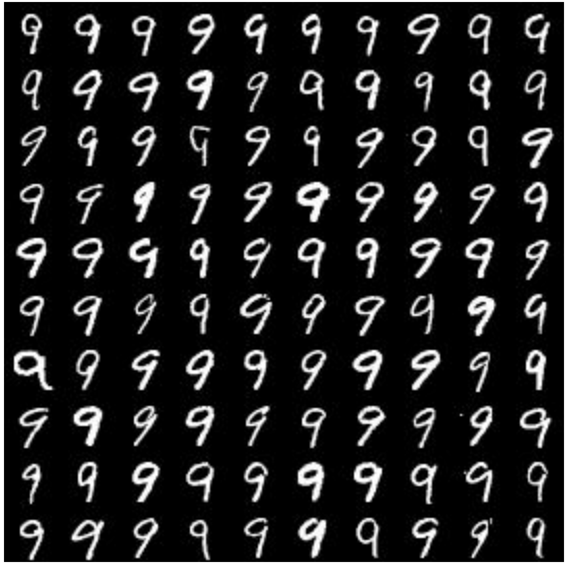




[1] Anomaly Detection using One-Class Neural Networks, R. Chalapathy, et al., arXiv:1802.06360

Reproducing OC-NN

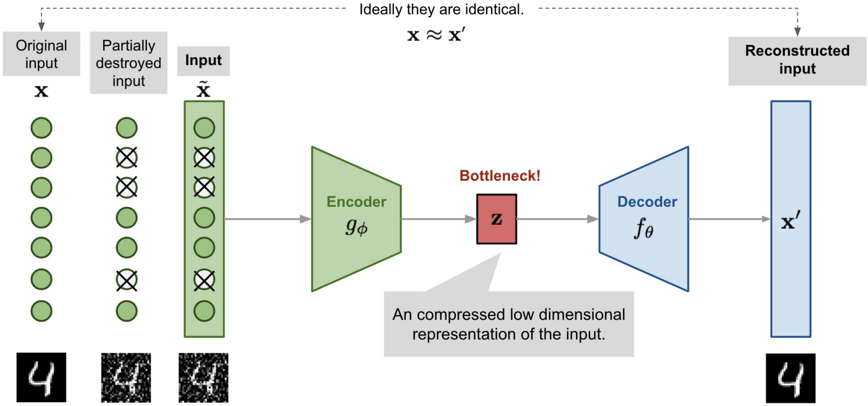
- MNIST

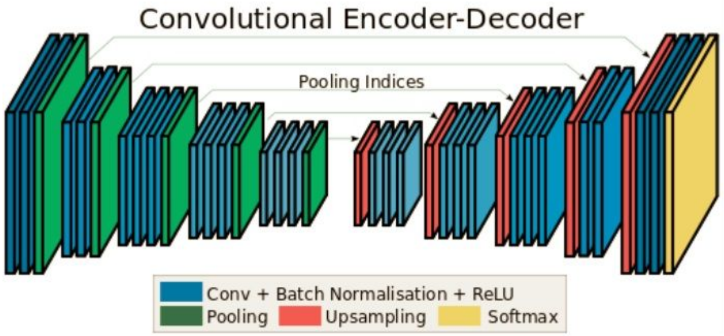


[1] Anomaly Detection using One-Class Neural Networks, R. Chalapathy, et al., arXiv:1802.06360

VGG-style Denoising Autoencoder

- Surgery video





*Figures from Lil'Log (https://lilianweng.github.io/lil-log/)

Thank You!

Q & A