REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
09/1/2023	Conference Briefing	

4. TITLE AND SUBTITLE

Images, Pre-trained Networks, and Information

5a. CONTRACT NUMBER

W56KGU-18-D-0004

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Steve Israel, NGA/R;
John Irvine, MITRE Corporation;

5d. PROJECT NUMBER

5e. TASK NUMBER

W56KGU22F0017

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

The MITRE Corporation
7515 Colshire Drive
McLean, VA 22102

8. PERFORMING ORGANIZATION REPORT NUMBER

PRS-23-2773

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

United States Army (ACC-APG)

10. SPONSOR/MONITOR'S ACRONYM(S)

ACC-APG

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

Preprint submission to IEEE Applied Imagery Pattern Recognition

14. ABSTRACT

A System Engineer’s view of Machine Learning

15. SUBJECT TERMS

Artificial intelligence; Image Processing; complexity metric; workflow; image analysis

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Susan Carpenito
				12	19b. TELEPHONE NUMBER *(Include area code)* 781-271-7646

Images, Pre-trained Networks, and Information

Steve Israel NGA/R

John Irvine MITRE Corporation

26 September 2023

NATIONAL GEOSPATIAL NGA INTELLIGENCE AGENCY

A System Engineer's view of Machine Learning

To embrace machine learning (ML), we must embrace automation

- How do we train, store, access, update, validate (or even identify the need for) 1,000s of ML models
- Transfer learning alone with ~100Mbyte model sizes do not scale

SE asks: What do you want to do? (Gotta haves, Nice-to haves, and Fun-to haves)

- Define an ML complexity metric for each analysis task: *distinguish between, target, maintain custody, track, etc*
  - Allows engineers to assign resources to build individual models (data, model architecture, etc)
  - (Possible) predictive analytic to design ML architectures for new tasks
- What changes are needed to manual image analysis to enable automation

The following workflow describes how a complexity metric might operate within Image Analysis

NGA

If we can measure it, we can improve it

NIIRS and the Johnson Criteria[1] provided agreement on Human Cognition

- NIIRS compares intelligence need (criteria) to image quality
  - Task-*target*-***qualifier***: Detect-*cars*-***in depot*** (Called a criteria triplet)
- Johnson generalized the term for detection and identification to pixels-on-target
  - Extrapolate from one target to another: Detect-*planes*-***on tarmac***

How does NIIRS relate to ML perception

- Does not take into account false positives → problem complexity
  - Example: Identifying vehicles as members of 2 classes versus 16 classes
- How to match ML performance to triplet criteria?
- Can we build an ML NIIRS based upon the original NIIRS workflow?

How does complexity affect perception?

[1] NIIRS = National Imagery Interpretation Rating Scale. See Leachtenauer & Driggers, *Surveillance and Reconnaissance Imaging Systems: Modeling and Performance Prediction*

NGA

NIIRS Human Cognition:
How does that equate to computational perception?

Rating level 5:

- Detect open bay doors of vehicle storage buildings

Rating Level 6

- Identify automobiles as sedans or station wagons

Rating Level 7

- Detect individual steps on stairway

Rating Level 8

- Identify grill detailing and/or the license plate on a passenger/ truck type vehicle

Image is NIIRS 7+

False Alarms:

5: Palatized goods
6: Rooftop air conditioners
7: Fence rails
8: Bumper stickers

Hypothesis: As task complexity increases, an ML model needs more neurons

SE: Explore the design domain

- If a strong relationship exists, then an ML based NIIRS is possible

What measures can be extracted from the images to describe task complexity

- Features extracted from the raw images
- Application independent

What distance function describes the relationship

- Performs well with limited data common to task scoping phase
- Provides predictions throughout the operating domain

NGA

Exploring task complexity

Pre-trained networks (ala VGG-16, ResNet) store an image independent edge library

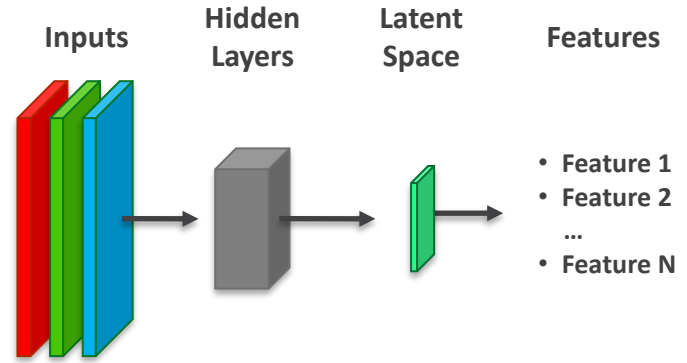
- Demonstrated by high transfer learning performance for both nadir and oblique imagery
- Inferenced features relate images to the edge library

Classification performance metric allows normalized comparisons across experiments

- Unlike NIIRS, measures both true positives and false alarms

This experiment

- Image features generated from VGG-16 pretrained network: 138M nodes
- Classify VGG features
  - Minimum Euclidean distance to class means
- Data: RarePlanes
  - 2, 4, 8, 16 classes
  - Assumption: more classes = more difficult
- Compare Euclidean feature classification to custom built model's performance
  - Multiple ML models with different amounts of computational neurons



Rare Planes: *https://www.cosmiqworks.org/rareplanes/*

Maxar WorldView-3 satellite scenes

- 0.31m GSD ~ NIIRS 7
- Plenty of pixels-on-target

Synthetic Targets

- 56 types of planes
- 3 generic classes
  - Transport
  - Sport
  - Private

Processing

- Normalized to common size 63x63 Pixels-on-Target
- VGG-16 Standard Normalization
- Extract 512 VGG features
- Compute class means from training data

NGA

Planes

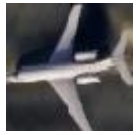
2-Class


Background


Plane

4 Class


Background


Private

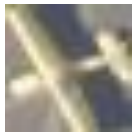

Sport


Transport

8-Class: Sport


Background


Cessna-170


Cessna-172


Cessna-310

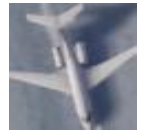

Dehaviland-DHC-2


Dehaviland-DHC-3


Let-L-200


Piper-PA-28

16-Class: Private

Background 

HBC-4000

Boeing-BBJ-2 

Gulfstream-GIII

Bombardier-BD-700 

Gulfstream-G200

Bombardier-300 

Embraer

Bombardier-604 

Dassault-2000

Bombardier-705 

Dassault-900

Bombardier-Learjet 

Dassault-100

Cessna 

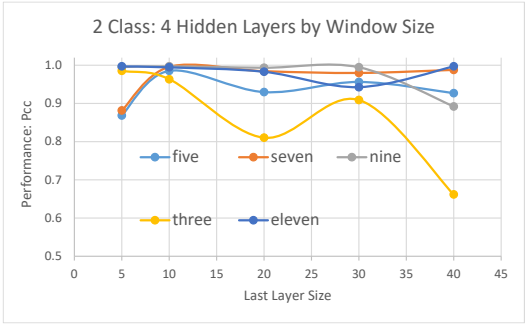
Cessna-CJ4

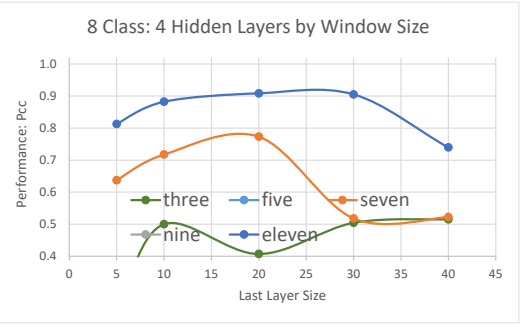
NGA

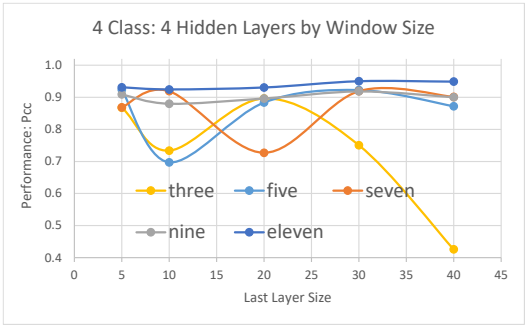
Results

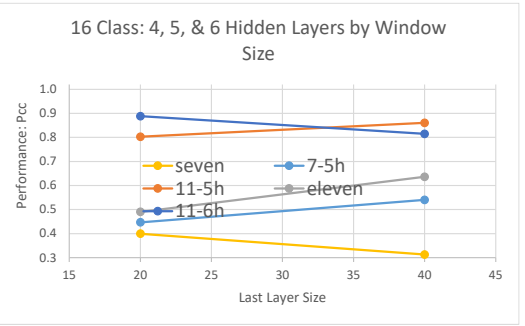
Classes	Complexity Metric	Neurons: million	Classifier
2	85	0.22	99
4	72	0.25	91
8	38	0.48	91
16	23	0.81	89

VGG-16 contains over 138M neurons









For 2 and 4 classes, visual inspection indicates where additional neurons do not produce significant performance increase

Discussion

Metric varied with problem complexity

- *Metric* varied inversely with *computational neurons* required
- *Metric* varied directly with optimal *classifier* performance
- Task complexity = Number of plane classes

Operational Issues

- Sub-optimal features
  - Raw VGG features vary with image size
  - Euclidean distances are not tolerant to different feature lengths
- Questions: How well does this experiment inform the general problem
  - Need corpus of sample tasks to confirm predictability
  - But what about other tasks? Locate, Target, Track, Maintain custody

NGA


NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY
UNITED STATES OF AMERICA

NGA