



CENTER
FOR DEEP LEARNING
IN ELECTRONICS
MANUFACTURING

Deep Learning Primer: Data is the new Source Code

Ajay Baranwal (CDLe), Mike Meyer (CDLe)

Noriaki Nakayamada (NuFlare), Michael Wahlsten (Mycronic), Aki Fujimura (D2S)

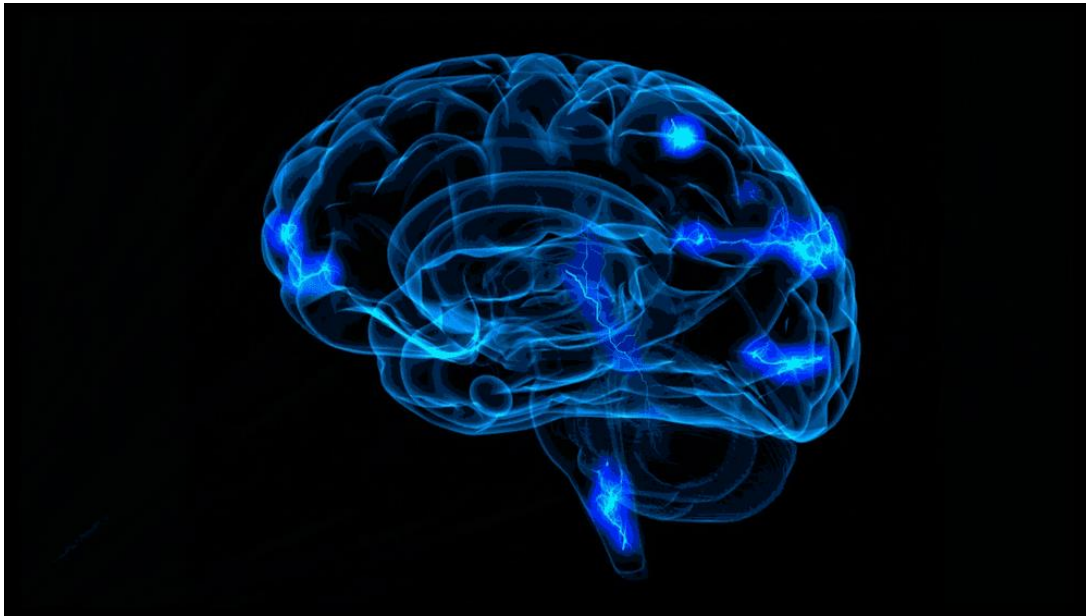
A PARTNERSHIP OF   

Upcoming DL session today

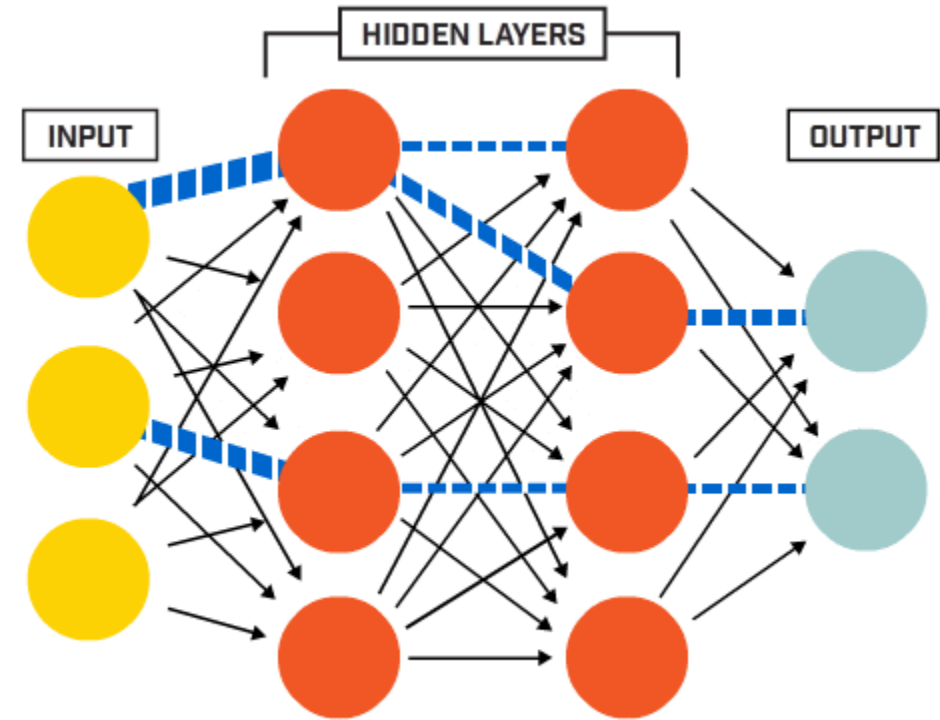
- **The self-driving photomask** (*Invited Paper*)
Time: 11:05 AM - 11:30 AM
Author(s): James P. Shiely, Synopsys, Inc. (United States)
- **Fracture time predictor in mask data preparation using machine learning**
Time: 11:30 AM - 11:50 AM
Author(s): Diego Palma, Daniel Calderon, Synopsys Chile Ltda. (Chile)
- **Deep learning in DFM applications**
Time: 11:50 AM - 12:10 PM
Author(s): Tetsuaki Matsunawa, Shigeki Nojima, Toshiba Corp. (Japan)

Architecture Inspired by Brain

■ Information Signal Movement



Brain Information Movement

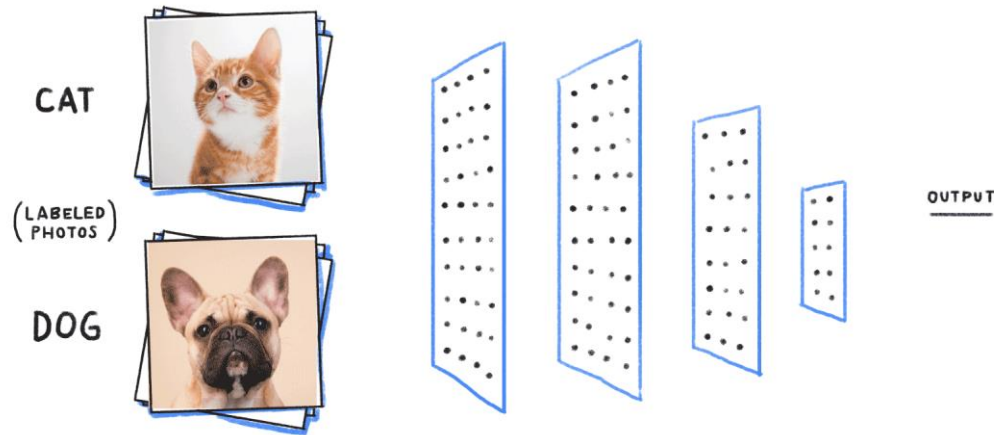


Neural Networks Information Movement

Deep Learning Matters To You!!

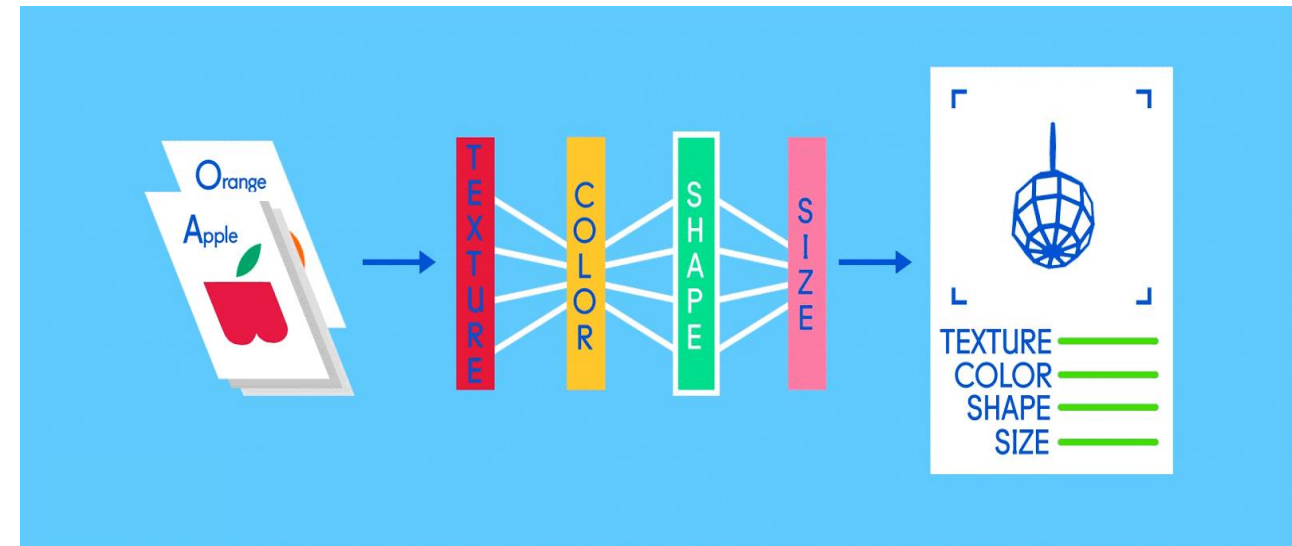
Impossible became Possible - Recognition

■ Cat / Dog Recognition



- Impossible Before 2012
- Now better accuracy than human
- Even high schooler does with ~95% accuracy

■ Fruit Recognition







Impossible became Possible - Recommendation



Because you liked this:

You might also like these:

 <p>\$18⁹⁴ This Miss Tina Women's Maxi Mix 'n Match ★★★★★ (13) Options</p>	 <p>\$11⁰⁰ Stitch Women's Stripe Cinched Waist Dress ★★★★★ (13) Options</p>	 <p>\$17⁰⁰ Women's Knit Candy Stripe Maxi Dress ★★★★★ (13) Options</p>	 <p>\$16⁰⁰ Concepts Women's Knit Belted High Low Dress ★★★★★ (13) Options</p>
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Frequently Bought Together








Price for all three: **\$74.20**

Show availability and shipping details

- This item:** Beginning Ruby: From Novice to Professional (Expert's Voice in Open Source) by Peter Cooper Paperback **\$27.78**
- Learn to Program, Second Edition (The Facets of Ruby Series) by Chris Pine Paperback **\$16.94**
- Ruby on Rails Tutorial: Learn Web Development with Rails (2nd Edition) (Addison-Wesley Professional Ruby ... by Michael Hartl Paperback **\$29.48**

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Impossible became Possible - Art

■ Neural Style Transfer



Picture of Dog

Style: Starry Night of Vincent van Gogh

New Artwork

Impossible became Possible - Game



AlphaGo – Win over Lee Sedol in Go game

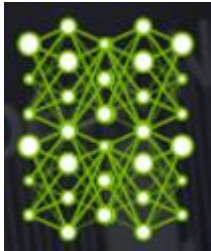
Impossible became Possible - Driving



Self Driving Car

Deep Learning Scales Infinitely - Automatically

7 ExaFLOPS
60 Million Parameters
8 Layers -> 150 Layers



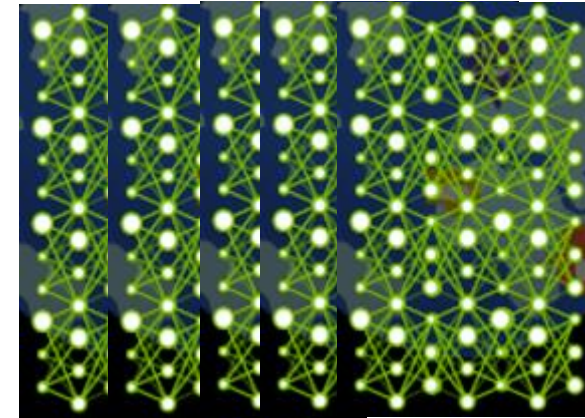
2015

20 ExaFLOPS
300 Million Parameters
Complex Architecture



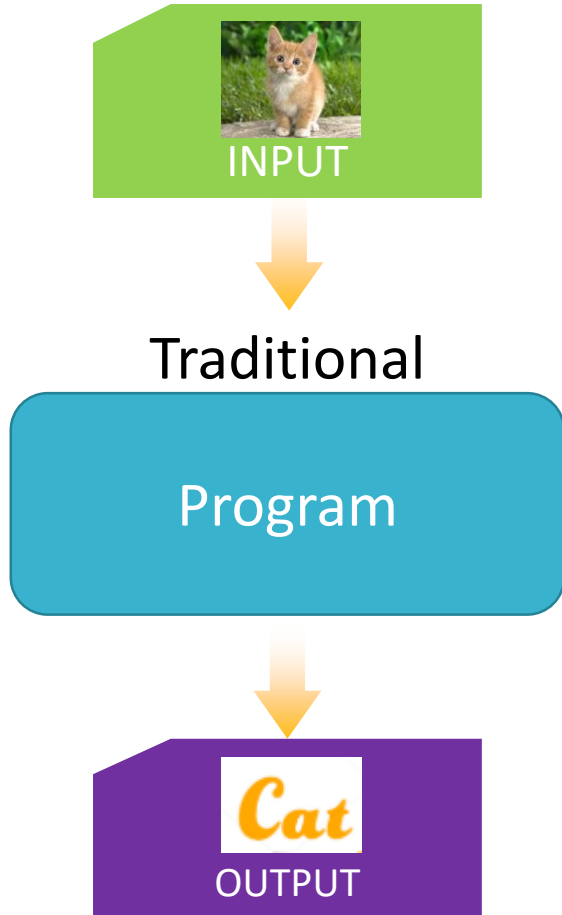
2016

100 ExaFLOPS
8.7 Billion Parameters
Even More Complex Architecture

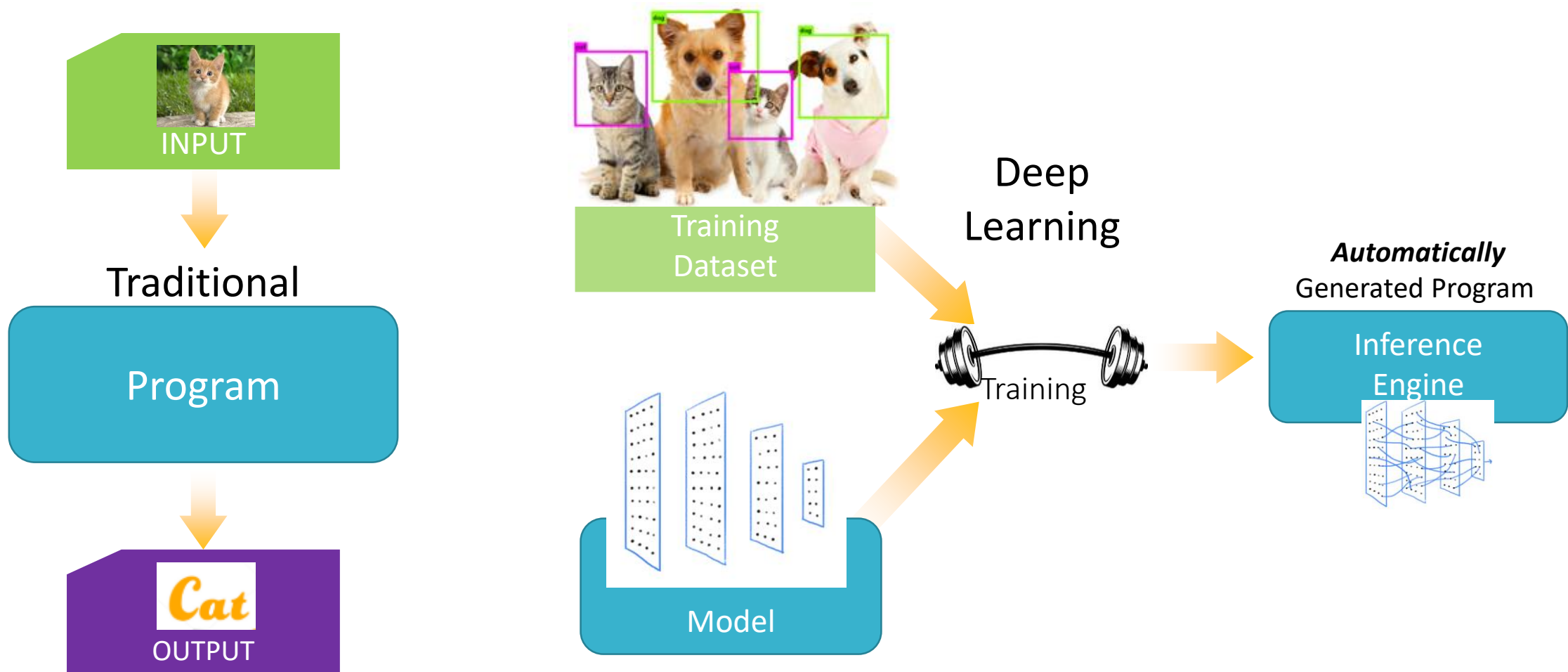


2017

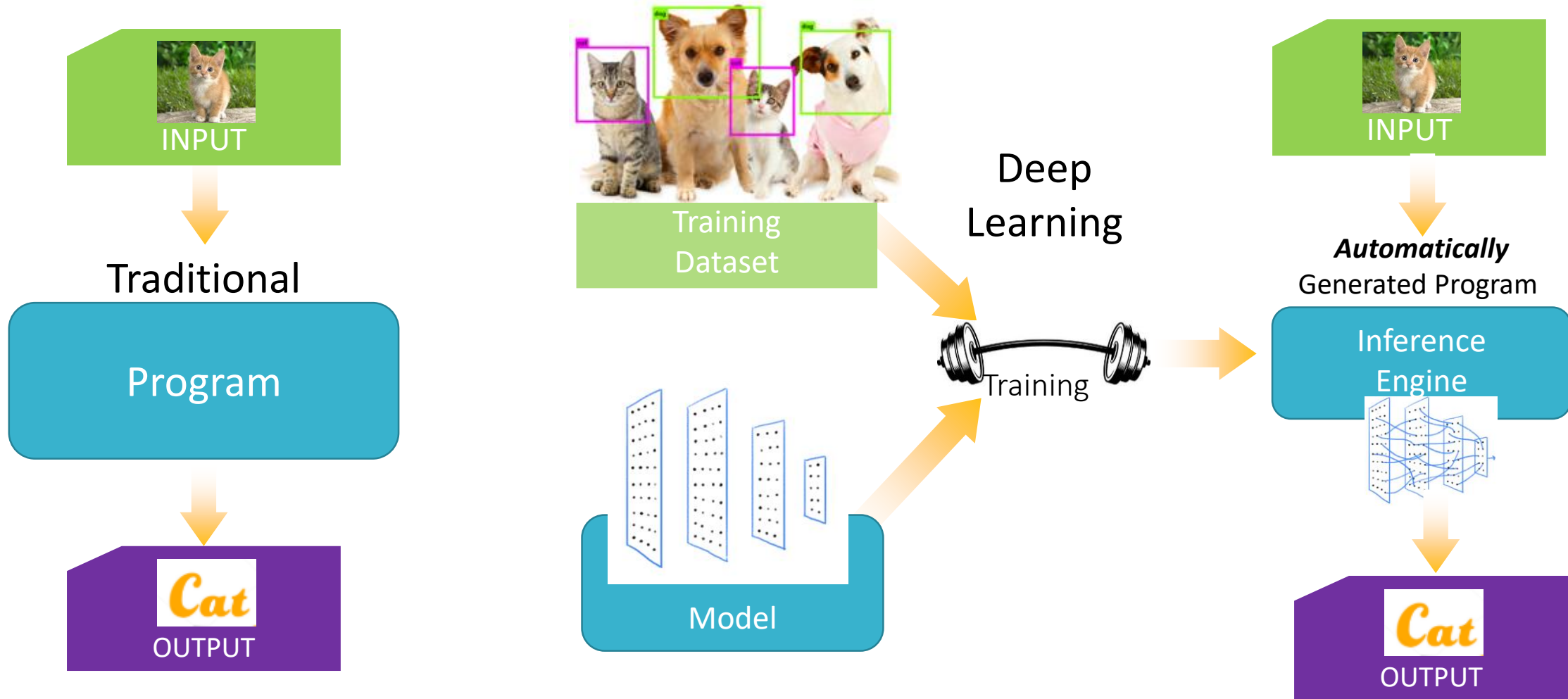
Deep Learning Flips Programming



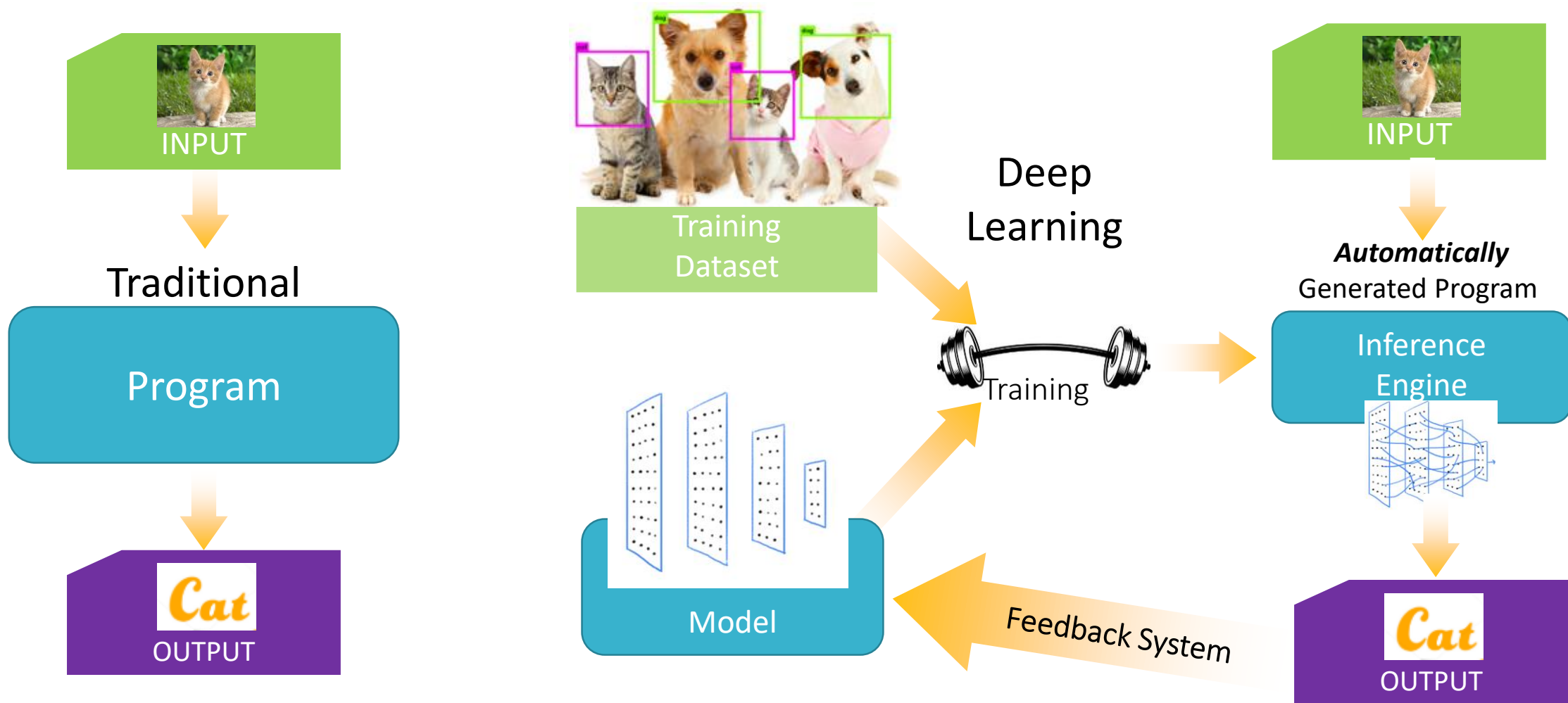
Deep Learning Flips Programming



Deep Learning Flips Programming



Deep Learning Flips Programming



Mask Manufacturing Problems are a bit different ...

ImageNet:

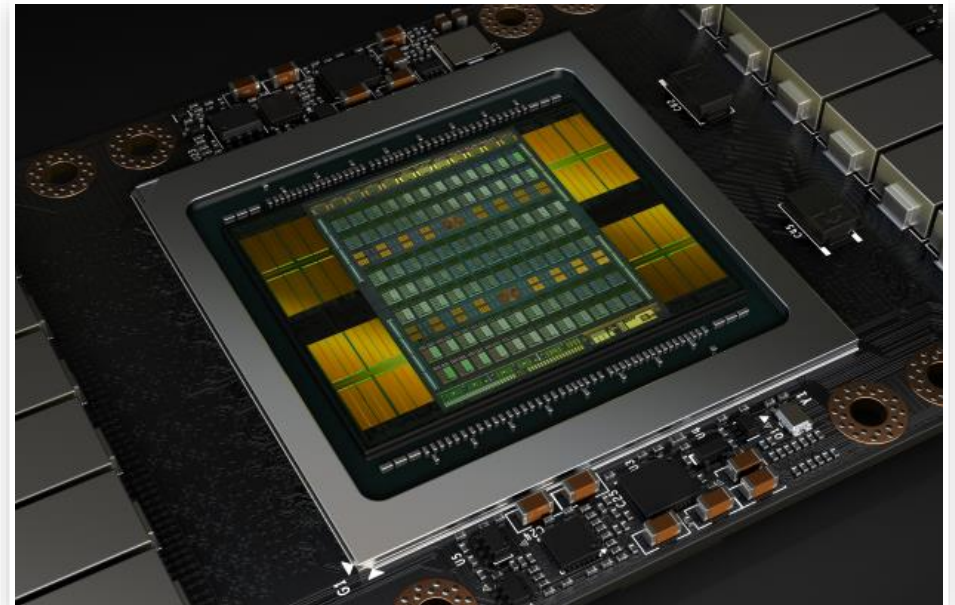
- 14.2M images
 - 1.2TB for complete dataset
- 3σ accuracy is considered great
- Better than human is sufficient



x 450 =

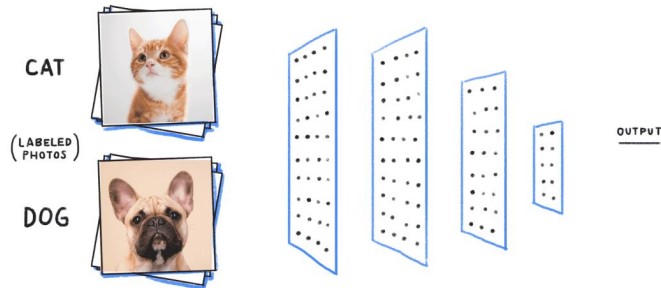
Masks:

- 540TB in 10nm pixels to write a mask
 - One Mask > 450 x ImageNet dataset
- $>7\sigma$ accuracy required



Deep Learning has Multiple Types

Supervised Learning



Unsupervised Learning

Reinforcement Learning

Frequently Bought Together

This section shows three books from the 'Learn to Program' series by Chris Pine: 'Beginning Ruby', 'Learn to Program', and 'Ruby on Rails Tutorial'. The total price for all three is \$74.20. Below the books, there are three checked items with their prices: 'This item: Beginning Ruby: From Novice to Professional (Expert's Voice in Open Source) by Peter Cooper Paperback \$27.78', 'Learn to Program, Second Edition (The Facets of Ruby Series) by Chris Pine Paperback \$16.94', and 'Ruby on Rails Tutorial: Learn Web Development with Rails (2nd Edition) (Addison-Wesley Professional Ruby ... by Michael Hartl Paperback \$29.48'.

Customers Who Bought This Item Also Bought

This section displays five related books: 'Learn to Program, Second Edition (The Facets of...)' by Chris Pine (\$16.94), 'The Well-Grounded Rubyist' by David A. Black (\$32.49), 'Ruby on Rails Tutorial: Learn Web Development...' by Michael Hartl (\$29.48), 'The Ruby Programming Language' by David Flanagan (\$26.35), and 'The Well-Grounded Rubyist' by David A. Black (\$29.67). Each book listing includes a star rating and the Amazon Prime logo.

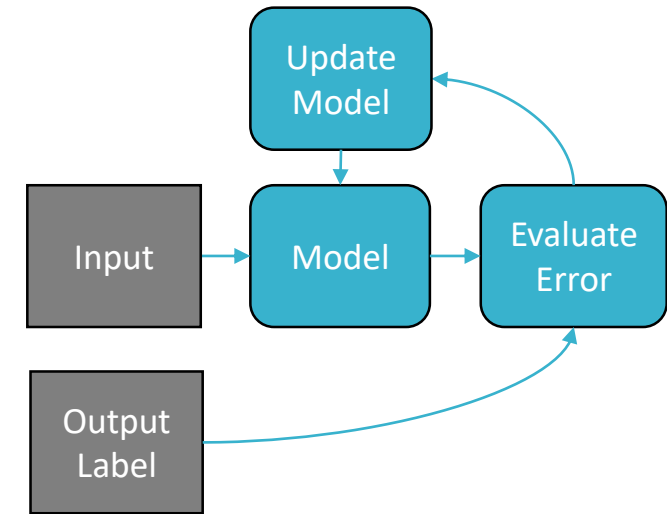
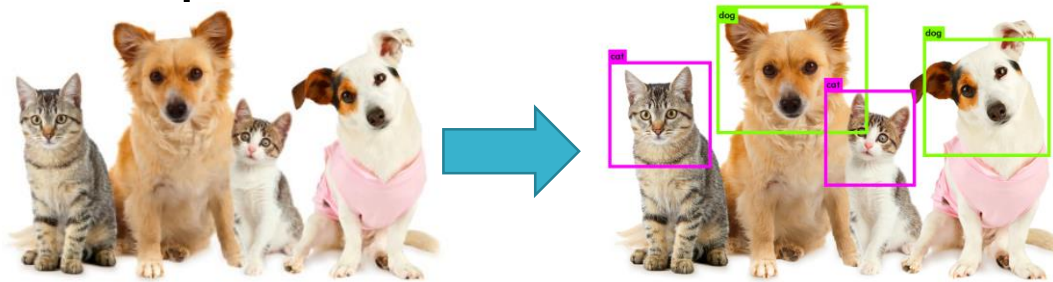


Semiconductor manufacturing problems benefit from all types

Supervised Learning

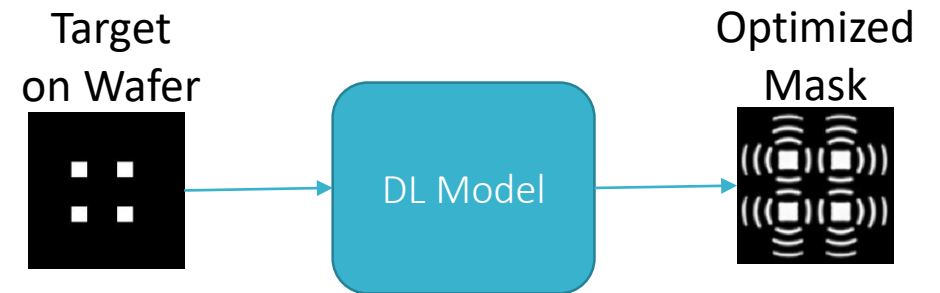
- Labeled Data is available.

- Example



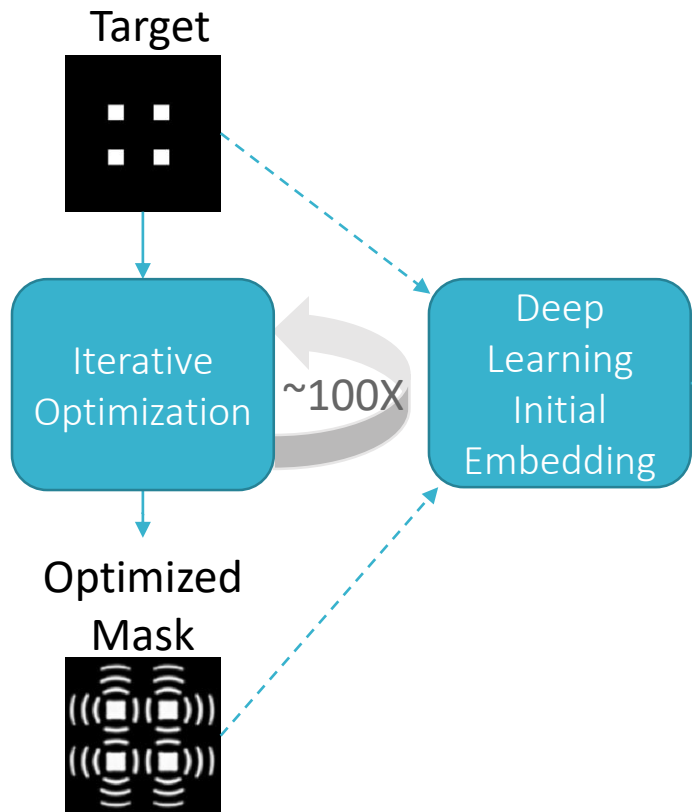
- In Semiconductor Manufacturing

- Help predicting OPC mask shape based on target layout



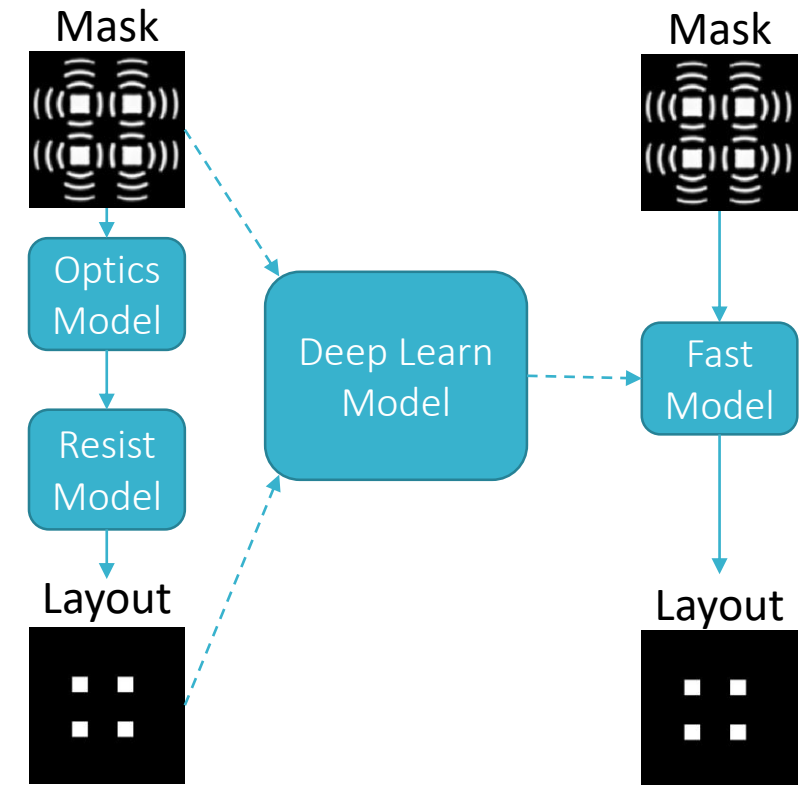
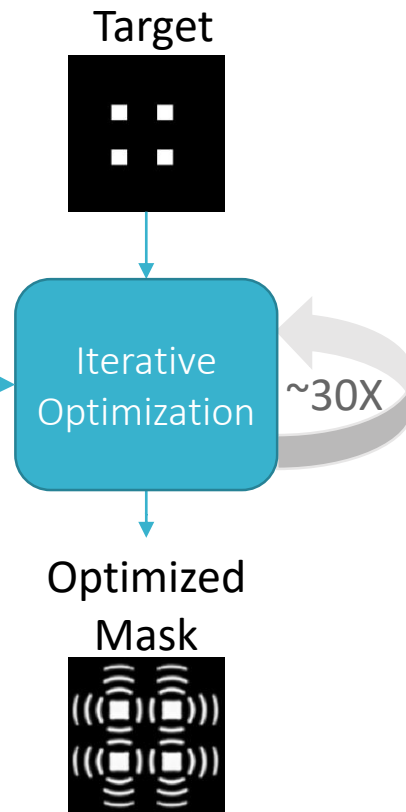
Supervised Learning in Computational Lithography

Conventional ILT



Accelerate Iterative Optimization

ILT w/Deep Learning

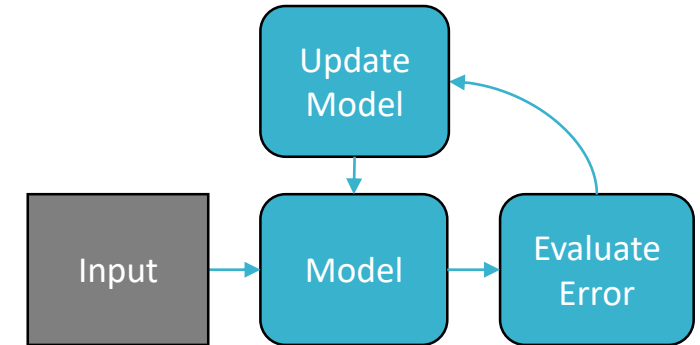
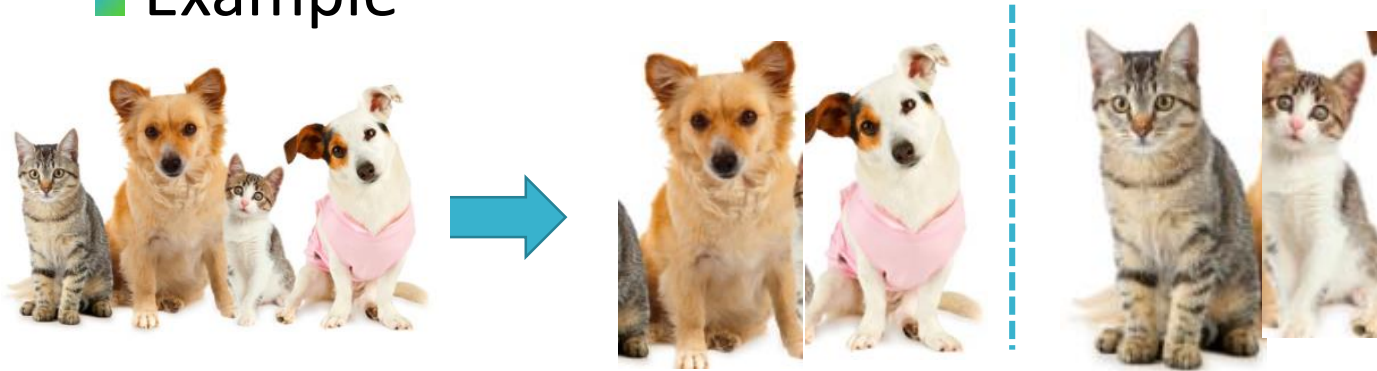


Accelerate Accurate (Slow) Models

Unsupervised Learning

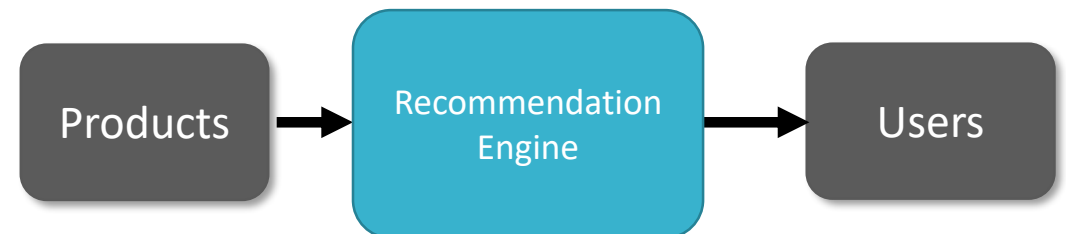
- NO Labeled Data is available.

- Example

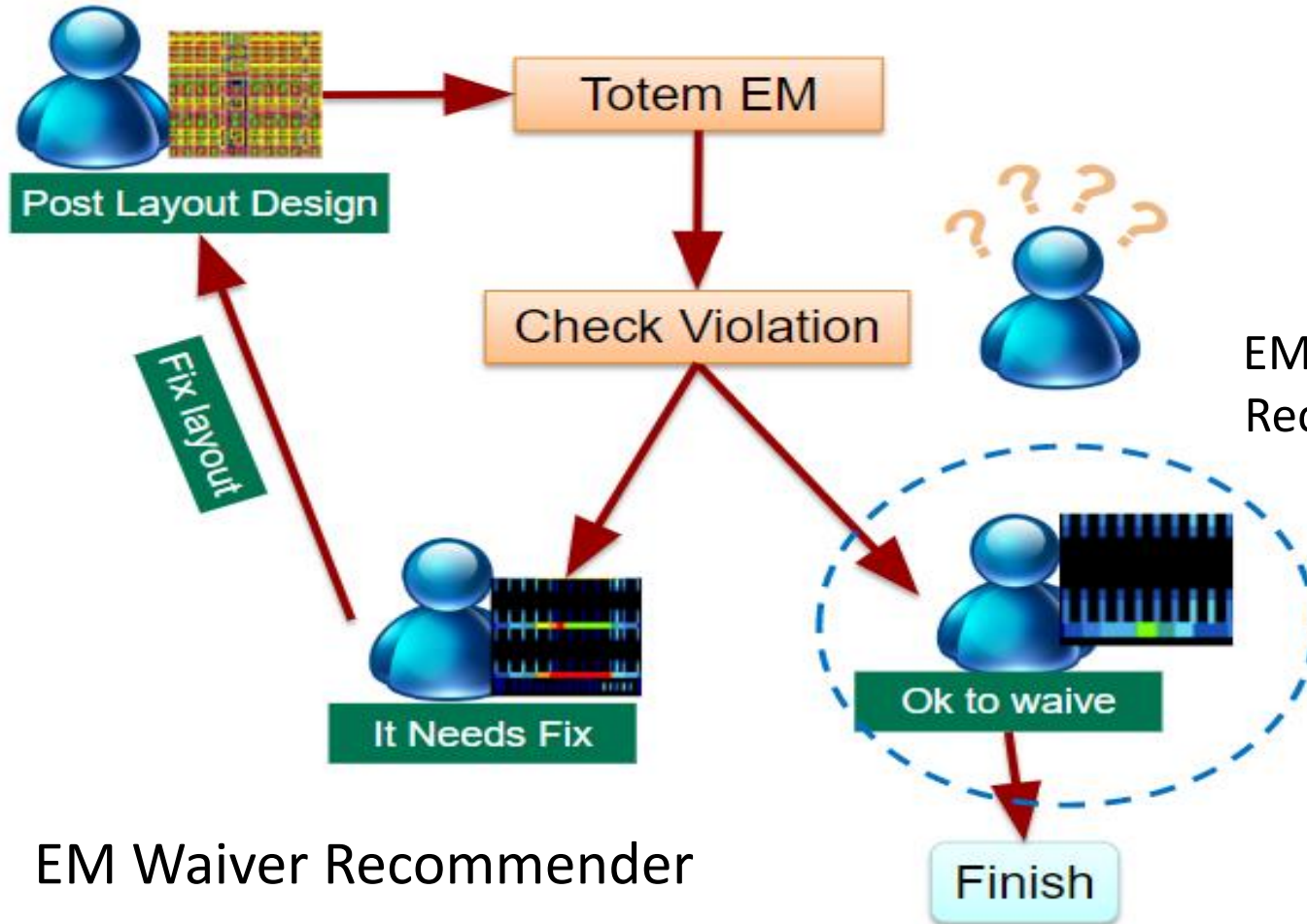


- In Semiconductor Manufacturing

- Fault detection & recommender system
- Learn from historical faults and recommend for new ones



Unsupervised Learning in EM Violation Waiver



ANSYS®

NVIDIA

EM (ElectroMigration) Violations Waiver
Recommender in Semiconductor Design

EM Waiver Recommender

Source:
<https://ieeexplore.ieee.org/document/8297359/>

Reinforcement Learning

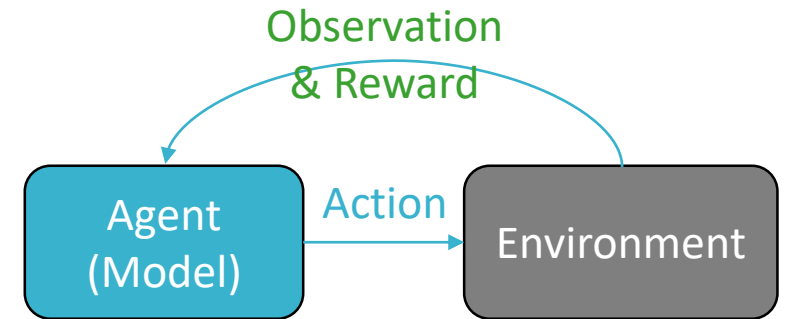
- Actions based Rewards to maximize next Action
- Similar to training your dog – action has good or bad rewards



- Example

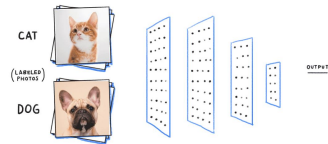


- In Semiconductor Manufacturing
 - Need to find one 😊

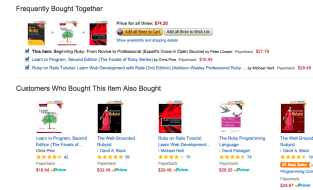


Deep Learning is Just Beginning

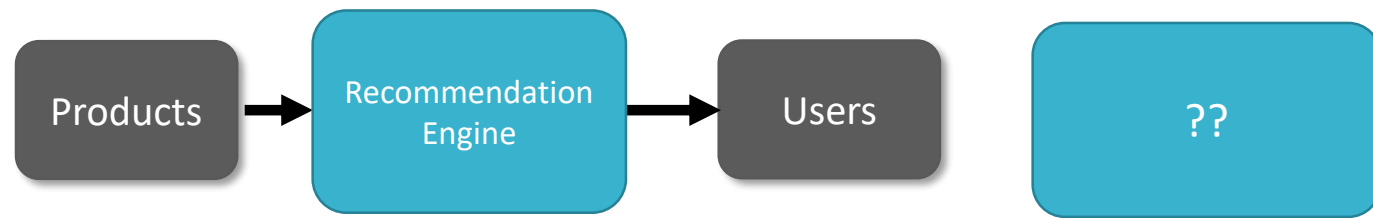
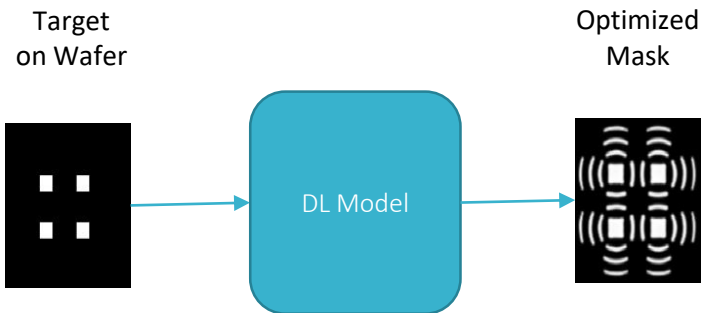
Supervised Learning



Unsupervised Learning



Reinforcement Learning

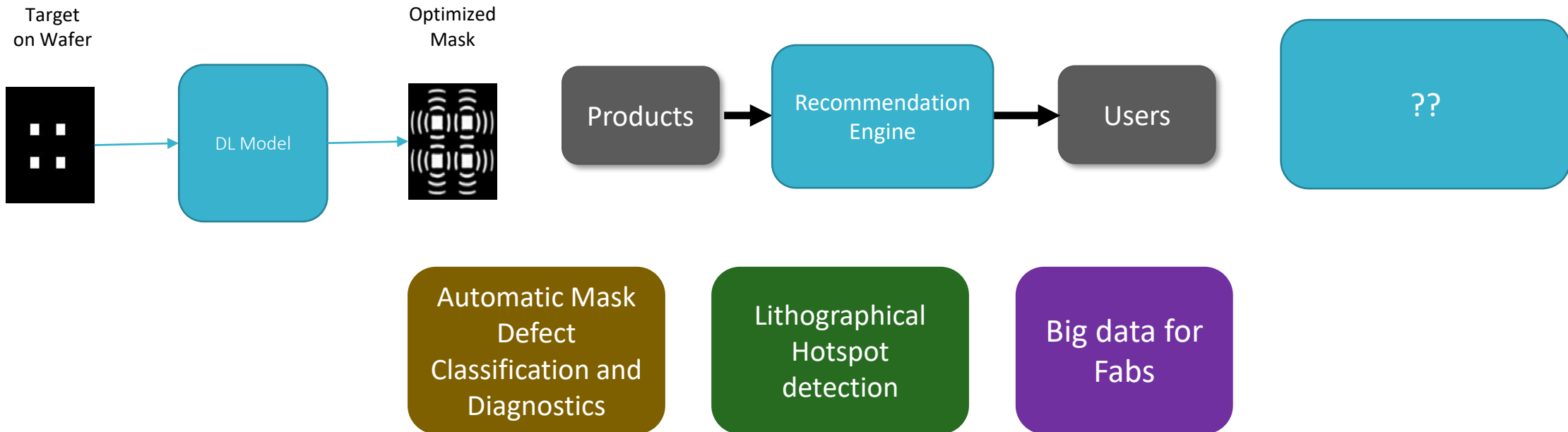


Deep Learning is Just Beginning

Supervised Learning

Unsupervised Learning

Reinforcement Learning



Deep Learning is changing every Business

Deep Learning is changing every Business

Yours too!!



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