ARO MURI: Robust Concept Learning and Lifelong Adaptation Against Adversarial Attacks

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Virtual Kickoff Meeting
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Penn Engineering
Children's Hospital of Philadelphia RESEARCH INSTITUTE
COGNITIVE COMPUTATION GROUP
GRASP LABORATORY General Robotics, Automation, Sensing & Perception Lab
PRECISE PENN RESEARCH IN EMBEDDED COMPUTING AND INTEGRATED SYSTEMS ENGINEERING

Team Members & Expertise

INSUP LEE (PI)

BASTANI

KOSTAS DANIILIDIS

ERIC EATON

DAN ROTH

JAMES WEIMER

JULI IS (CHOP)

- Insup Lee: cyber-physical systems (CPS), high-assurance machine learning, security
- Osbert Bastani: machine learning, AI, programming language, security
- Kostas Daniilidis: computer vision, robotics, machine learning
- Eric Eaton: machine learning, life-long learning, interactive AI
- Dan Roth: machine leaning and inference methods, NLP
- James Weimer: learning-enabled CPS, autonomous vehicles
- Julia Parish-Morris (CHOP): developmental psychology, language development, children learning

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- PhD Students:
  - Kaustubh Sridhar
  - Meghna Gummadi
  - Shuo Li
  - Stefanos Pertigkiozoglou
  - Soham Dan
  - Kimberly Tena (CHOP)
  - Vivian Lin (F'20)
- Postdocs:
  - Ivan Ruchkin
  - Souradeep Dutta (F'20)

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Fragility of Deep Neural Networks

How a little electrical tape can trick a Tesla into speeding

Security researchers found an unsettling vulnerability in Tesla's intelligent cruise control.

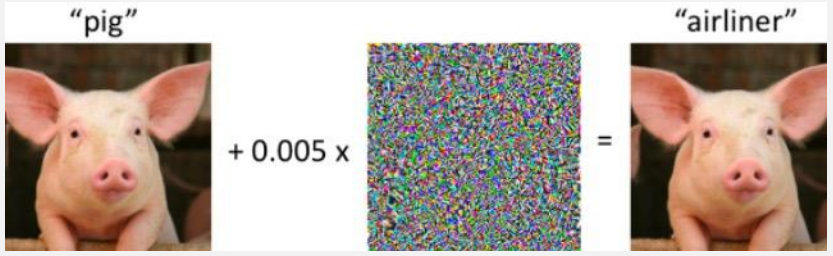
By Rebecca Heilweil | Feb 19, 2020, 2:10pm EST

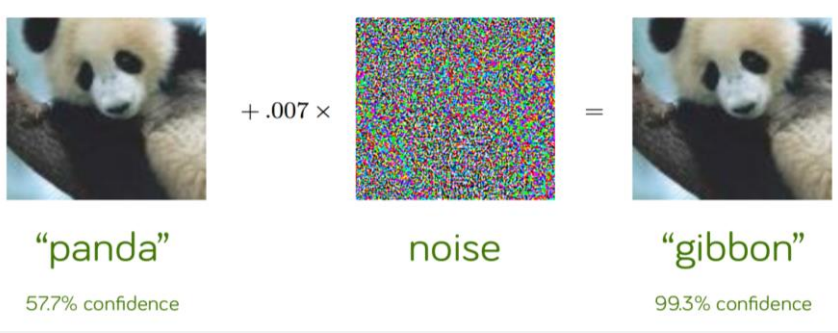
SHARE

Security researchers discovered a simple road sign hack that will trick Tesla's intelligent cruise control feature. | Jonathan Nackstrand/AFP via Getty Images

Digital vs Physical Attacks

Digital Attacks





Physical Attacks

How to protect neural networks from adversarial attacks?

Background

- Lots and lots of work on adversarial machine learning since 2017
  - Arms race: Offensive and defensive techniques
- State-of-the-art: offensive techniques are winning the battle
  - Given a trained model, it is still easy to find realizable adversarial examples
- Fundamental challenge: Adversarial learning has competing objectives
  - maximizing model accuracy vs. maximizing adversarial robustness

Project Goals

- We will develop the foundations for robust and adaptive concept learning in adversarial settings, building upon foundations from childhood development.
  - Employ semantic information and concepts in learning – as children do – so that adversarial attacks without understanding semantics cannot easily fool classifiers
  - Develop truly robust and adaptive learning tools that benefit—as children do—from experiences and interactions in the world
  - Demonstrate the robustness of our techniques to adversarial examples in real large-scale dynamic environments

Overview of the proposed research

Tasks are observational or inter-actable learning problems

System acquires concepts robust to adversarial attack over its lifetime

Concept acquisition mirrors robustness of children's learning process

Thrust II: Adaptive Learning
II.1: Adaptive concept learning
II.2: Lifelong learning

composable knowledge: general knowledge, cross-paradigm representations, specialized knowledge, domain-specific transformations

Concepts
Predictions
Revisions
Confidence
Learned Models
Monitoring Events

Thrust I: Concept-based Learning
I.1: Geometric reasoning
I.2: Inductive reasoning
I.3: Compositional reasoning

Thrust III: Verification & Monitoring
III.1: Verified learning
III.2: Monitoring learning

robustness specification

Verified Robust Concept Learner

Concept Learning Theory

- Prioritize shapes/ geometry, resilient to small noise
- Constant hierarchical lifelong learning in new settings
- Interactive exploration, self-adversarial to develop robustness

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Child Development and the Future of Adaptive Machine Learning

Julia Parish-Morris, PhD

Children's Hospital of Philadelphia Research Institute

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Proposed Thrusts and Tasks

- Thrust 1: Concept-based Learning Robust to Adversarial Examples (Lead: Bastani)
  - Task I.1: Robust learning of visual object and scene representations (Daniilidis, Eaton, Bastani, Parish- Morris)
  - Task I.2: Concept-based deep learning with inductive biases (Roth, Bastani, Daniilidis, Parish- Morris)
  - Task I.3: Compositional inference and reasoning for adversarial learning (Weimer, Lee, Parish- Morris)
  - **Connection with child learning: concept selection and representation**
- Thrust II: Adaptive Learning in Dynamic Environments (Lead: Eaton)
  - Task II.1: Leveraging Inductive Biases for Adaptive Concept Learning (Bastani, Roth, Parish- Morris)
  - Task II.2: Lifelong Learning (Eaton, Daniilidis, Parish-Morris)
  - **Connection with child learning: hierarchical and continual learning in new settings**
- Thrust III: Verification and Monitoring of Learning (Lead: Weimer)
  - Task III.1: Verified learning (Weimer, Lee, Parish-Morris)
  - Task III.2: Monitoring learning (Weimer, Lee, Parish-Morris)
  - **Connection with child learning: trust building, validation by probing, self-adversarial for robustness**
- Thrust IV: Integration and Evaluation (Lead: Lee)
  - Toolset and dataset development
  - Evaluation platform and scenarios

Schedule

- ***9:00 am:*** Kickoff Message, *Purush Iyer*
- ***9:10 am:*** Overview and Child Development/Adaptive Machine Learning, *Insup Lee & Julia Parish-Morris*
- ***10:00 am:*** Thrust I. Concept-based Learning Robust to Adversarial Examples, *Osbert Bastani*
- ***10:30 am:*** Thrust II. Adaptive Learning in Dynamic Environments, *Eric Eaton*
- ***11:00 am:*** Thrust III. Verification and Monitoring of Learning, *James Weimer*
- ***11:30 am:*** Thrust IV: Integration, Platform, and Evaluation, *Insup Lee*
- ***11:45 am:*** Government Caucus
- ***12:15 pm:*** Feedback and Open Discussions