

Machine Learning Models as an Attack Surface

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Summary

Why Attack Machine Learning Models?

Hackers, malicious or extorted insiders, and their criminal associates or organized extortionists, seek to:

- induce beneficial outcomes from a predictive or pattern recognition model or induce negative outcomes for others.
- commit corporate espionage.
- steal intellectual property including models and data.



Data Poisoning Attacks: **What?**

- Hackers gain unauthorized access to training data and alter it before model training or retraining.
- Malicious or extorted data science or IT insiders do the same while working at a ...
 - small disorganized firm where the same person is allowed to manipulate training data, train models, and deploy models.
 - massive firm, and covertly accumulate the permissions needed to manipulate training data, train models, and deploy models.



Data Poisoning Attacks: How?

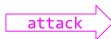
Attributes of attacker

dti: 10.4
fico: 690
m_delinq: 4
:



dti	fico	m_delinq	deny
0.9	740	0	: 0
9	680	4	: 1
7.2	700	3	: 1
2.3	790	0	: 0

Original training data



dti	fico	m_delinq	deny
0.9	740	0	: 0
9	680	4	: 0
7.2	700	3	: 1
2.3	790	0	: 0

Altered training data

Attacker alters model training data to ensure favorable outcomes



Data Poisoning Attacks: **Defenses**

- **Disparate impact analysis:** Use tools like [aequitas](#), [AIF360](#), or your own fair lending tools, to look for discrimination in your model's predictions.
- **Fair or private models:** E.g. learning fair representations (LFR), private aggregation of teacher ensembles (PATE) [[5](#)], [[9](#)].
- **Reject on negative impact (RONI) analysis:** See: *The Security of Machine Learning* [[2](#)].
- **Residual analysis:** especially for large positive deviance residuals.
- **Self-reflection:** Score your models on your employees, consultants, and contractors and look for anomalously beneficial predictions.



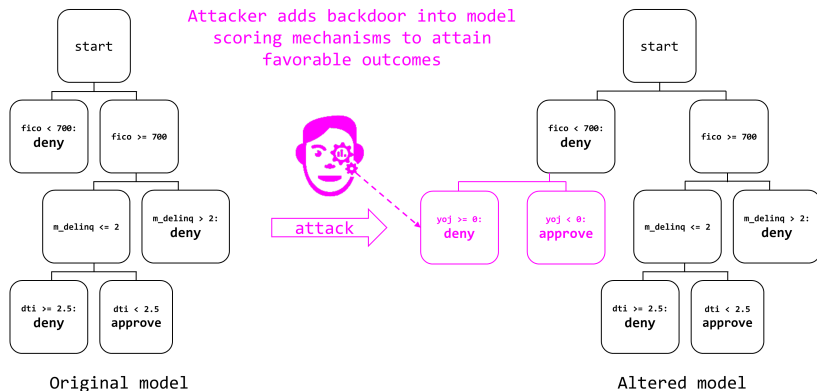
Backdoors and Watermarks: **What?**

- Hackers gain unauthorized access to your production scoring code OR ...
- Malicious or extorted data science or IT insiders change your production scoring code ...

... adding a backdoor that can be exploited using water-marked data.



Backdoors and Watermarks: How?





Backdoors and Watermarks: **Defenses**

- **Anomaly detection:** Screen your production scoring queue with an autoencoder, a type of machine learning (ML) model that can detect anomalous data.
- **Data integrity constraints:** Don't allow impossible or unrealistic combinations of data into your production scoring queue.
- **Disparate impact analysis:** See Slide 6.
- **Version control:** Track your production model scoring code just like any other enterprise software.



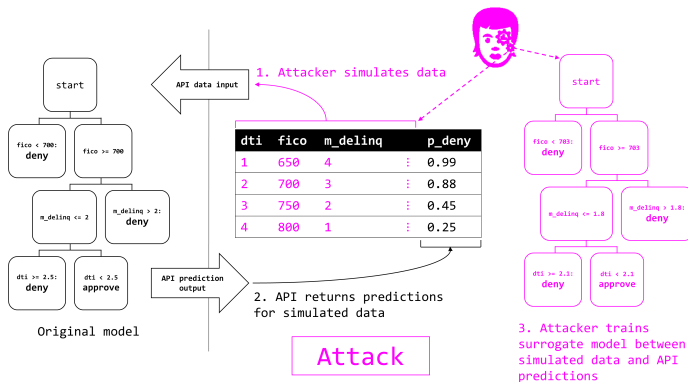
Surrogate Model Inversion Attacks: **What?**

Due to lax security or a distributed attack on your model API or other model endpoint, hackers or competitors simulate data, submit it, receive predictions, and train a surrogate model between their simulated data and your model predictions. This surrogate can ...

- expose your proprietary business logic, i.e. “model stealing” [8].
- reveal sensitive aspects of your training data.
- be the first stage of a membership inference attack (see Slide 14).
- be a test-bed for adversarial example attacks (see Slide 17).



Surrogate Model Inversion Attacks: **How?**





Surrogate Model Inversion Attacks: **Defenses**

- **Authentication:** Authenticate users of your model's API or other endpoints.
- **Defensive watermarks:** Add subtle or unusual information to your model's predictions to aid in forensic analysis if your model is hacked or stolen.
- **Throttling:** Consider artificially slowing down your prediction response times, especially after anomalous behavior is detected.
- **White-hat surrogate models:** Train your own surrogate models as a white-hat hacking exercise to see what an attacker could learn about your public models.



Membership Inference Attacks: **What?**

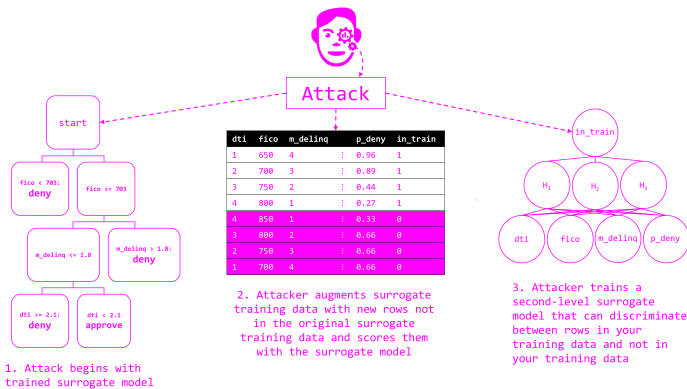
Due to lax security or a distributed attack on your model API or other model endpoint ...

- this two-stage attack begins with a surrogate model inversion attack (see Slide: 11).
- A second-level surrogate is then trained to discriminate between rows of data in, and not in, the first-level surrogate's training data.
- The second-level surrogate can dependably reveal whether a row of data was in, or not in, your original training data [7].

Simply knowing if a person was in, or not in, a training dataset can be a violation of individual or group privacy. However, when executed to the fullest extent, a membership inference attack can allow a bad actor to **rebuild your sensitive training data!**



Membership Inference Attacks: **How?**





Membership Inference Attacks: **Defenses**

- See Slide 12.
- **Monitor for training data:** Monitor your production scoring queue for data that closely resembles any individual used to train your model. Real-time scoring of rows that are extremely similar or identical to data used in training, validation, or testing should be recorded and investigated.



Adversarial Example Attacks: **What?**

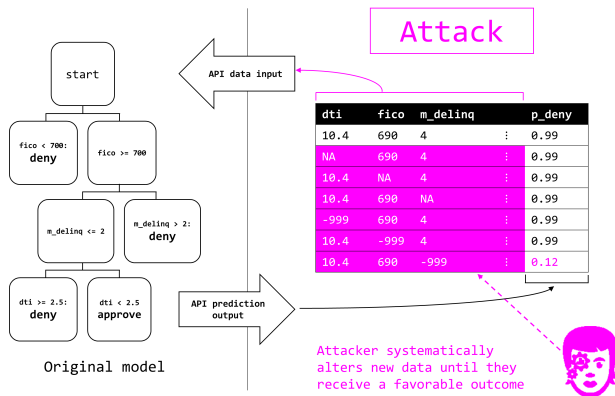
Due to lax security or a distributed attack on your model API or other model endpoint, hackers or competitors simulate data, submit it, receive predictions, and learn by systematic trial-and-error ...

- your proprietary business logic.
- how to game your model to dependably receive a desired outcome.

Adversarial example attacks can also be enhanced, tested, and hardened using models trained from surrogate model inversion attacks (see Slide 11).



Adversarial Example Attacks: **How?**





Adversarial Example Attacks: Defenses

- **Anomaly detection:** See Slide 9.
- **Authentication:** See Slide 12.
- **Benchmark models:** Always compare complex model predictions to trusted linear model predictions. If the two model's predictions diverge beyond some acceptable threshold, review the prediction before you issue it.
- **Fair or private models:** See Slide 6.
- **Throttling:** See Slide 12.
- **Model monitoring:** Watch your model in real-time for strange prediction behavior.
- **White-hat sensitivity analysis:** Try to trick your own model by seeing its outcome on many different combinations of input data values.
- **White-hat surrogate models:** See Slide 12.

Impersonation Attacks: **What?**

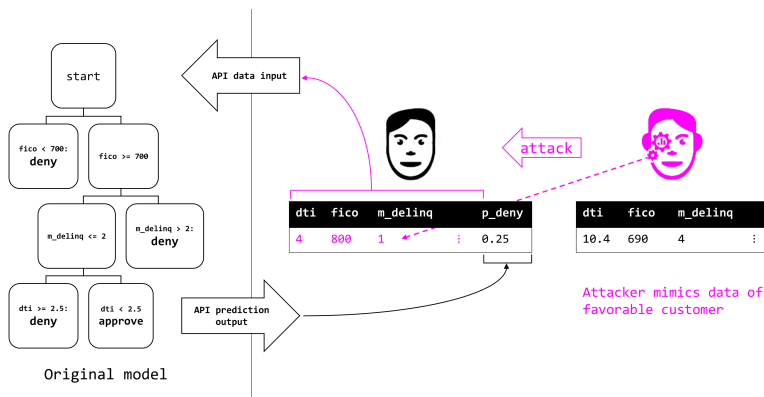
Bad actors learn ...

- by inversion or adversarial example attacks (see Slides 11, 17), the attributes favored by your model and then impersonate them.
- by disparate impact analysis (see Slide 6), that your model is discriminatory (e.g. Propublica and COMPAS, Gendershades and Rekognition), and impersonate your model's privileged class to receive a favorable outcome.[†]

[†]This presentation makes no claim on the quality of the analysis in Angwin et al. (2016), which has been criticized, but is simply stating that such cracking is possible [1], [3].



Impersonation Attacks: How?





Impersonation Attacks: **Defenses**

- **Authentication:** See Slide 12.
- **Disparate impact analysis:** See Slide 6.
- **Model monitoring:** Watch for too many similar predictions in real-time. Watch for too many similar input rows in real-time.

General concerns

- **Black-box models:** Over time a motivated, malicious actor could learn more about your own black-box model than you know and use this knowledge imbalance to attack your model [4].
- **Black-hat eXplainable AI (XAI):** While XAI can enable human learning from machine learning, regulatory compliance, and appeal of automated decisions, it can also make ML hacks easier and more damaging [6].
- **Distributed-denial-of-service (DDOS) attacks:** Like any other public-facing service, your model could be attacked with a DDOS attack.
- **Distributed systems and models:** Data and code spread over many machines provides a larger, more complex attack surface for a malicious actor.
- **Package dependencies:** Any package your modeling pipeline is dependent on could potentially be hacked to conceal an attack payload.



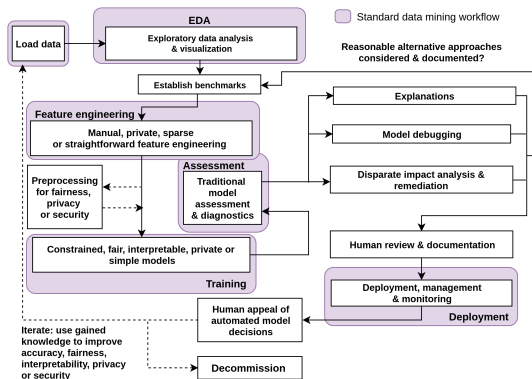
General Solutions

- **Authenticated access and prediction throttling:** for prediction APIs and other model endpoints.
- **Benchmark models:** Compare complex model predictions to less complex (and hopefully less hackable) model predictions. For traditional, low signal-to-noise data mining problems, predictions should not be too different. If they are, investigate them.
- **Encrypted, differentially private, or federated training data:** Properly implemented, these technologies can thwart many types of attacks. Improperly implemented, they simply create a broader attack surface or hinder forensic efforts.
- **Interpretable, fair, or private models:** In addition to models like LFR and PATE, also checkout [monotonic GBMs](#), [Rulefit](#), [AIF360](#), and the [Rudin group](#) at Duke.

General Solutions

- **Model documentation, management, and monitoring:**
 - Take an inventory of your predictive models.
 - Document production models well-enough that a new employee can diagnose whether their current behavior is notably different from their intended behavior.
 - Know who trained what model, on what data, and when.
 - Monitor and investigate the inputs and predictions of deployed models on live data.
- **Model debugging and testing, and white-hat hacking:** Test your models for accuracy, fairness, and privacy before deploying them. Train white-hat surrogate models and apply XAI techniques to them to see what hackers can see.
- **System monitoring and profiling:** Use a meta anomaly detection system on your entire production modeling system's operating statistics — e.g. number of predictions in some time period, latency, CPU, memory and disk loads, number of concurrent users, etc. — then closely monitor for anomalies.

A Blueprint for Low-Risk Machine Learning[‡]



[‡]See: https://github.com/jphall663/hc_ml for more information.



Summary

- ML hacking is still probably rare and exotic, but new XAI techniques can make nearly all ML attacks easier and more damaging.
- Beware of insider threats, especially organized extortion of insiders.
- Open, public prediction APIs are a privacy and security nightmare.
- Your competitors could be gaming or stealing your public predictive models. Do your end user license agreements (EULA) or terms of service (TOS) explicitly prohibit this?
- Best practices around IT security, model management, and model monitoring are good defenses.



References

This presentation:

https://github.com/jphall663/secure_ML_ideas

Proposals for Model Vulnerability and Security:

<https://www.oreilly.com/ideas/proposals-for-model-vulnerability-and-security>

Can Your Machine Learning Model Be Hacked?!

<https://www.h2o.ai/blog/can-your-machine-learning-model-be-hacked/>



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- [6] Reza Shokri, Martin Strobel, and Yair Zick. “Privacy Risks of Explaining Machine Learning Models.” In: *arXiv preprint arXiv:1907.00164* (2019). URL: <https://arxiv.org/pdf/1907.00164.pdf>.
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