

Using GANs to Generate Synthetic Data

Joseph Despres and Yunus Shariff
Michigan State University

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Introduction and Motivation

This project aims to extend the Generative Adversarial Network (GAN) beyond image generation by using the framework to create synthetic data. The objective of any GAN is to train a Neural Network capable of generating additional copies indistinguishable from training data. This is accomplished by training two adjacent Neural Networks competing against one another. The first network, referred to as the Generator is tasked with converting Gaussian noise into a datapoint. The other, known as the Discriminator, aims to determine if that data point is real. The Discriminator, like a normal neural network, aims to maximize classification accuracy. The Generator aims to maximize the Discriminator's misclassifications [2]. This area has progressed to the point where GANs are regularly generating images and videos fooling even the most observant humans. Applications for this technology have yet to be fully realized. This project explores a potential application generate additional samples of tabular data.

Use Cases

■ Generate additional subjects in controlled experiments

Although data are becoming more and more available, there is still a need to generate more. Big data sets are often collected by convince rather than deliberate experiment, procuring additional samples of randomized controlled trial is quite expensive. Additionally, Neural Networks are not as transparent statistical model making them natural complements. By extension, we propose a framework in which Neural Networks generate additional data and statistical models draw inferences.

■ Generate data to fit models where data are confidential

Since these data are generated from another data set, confidentiality and privacy is far less of a concern. This framework could be used to generate new samples from confidential data permitting models to be trained in a way that is compliant with regulatory standards, ethics, and respectful of privacy. Privacy concerns are not nearly as strong of a concern in computer-generated data, as these are merely data produced from learning the structure of the mechanism producing the data.

Method

The challenge associated with training a GAN to generate synthetic data in a row in a data frame is several orders of magnitude smaller than a standard photo image. A Neural Network has no difficulty fitting it with enough hidden layers. The challenge is learning the structure of the data without overfitting. This is a balance between fitting the data so well it mimics the data seen and underfitting where it cannot generate. Therefore, the networks are very shallow by modern standards.

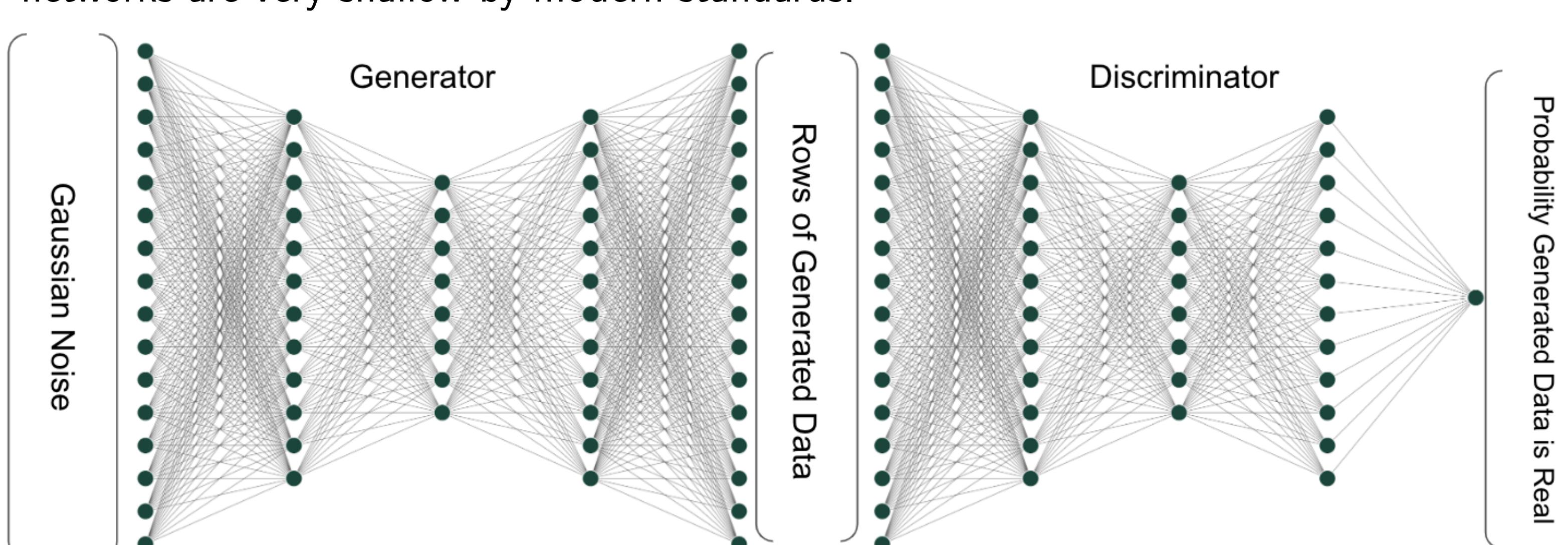


Figure 1: Basic GAN Architecture Adapted to Generating Data

$$\min_G \max_D V(D, G) = \mathbb{E}_{x \sim p_{data}} \log D(x) + \mathbb{E}_{z \sim p_z(z)} \log(1 - D(G(z)))$$

Using the method outlined by Hung [1] to generate additional data samples. These networks are small by today's standards with each layer being made up of less than 200 neurons and the network is made of less than 10 layers. Real and generated data are combined into a single data frame the discriminating network outputs a probability the data are real and fake given what it has learned from the training process. This is an iterative process and continues training until it converges to the point in which data are indistinguishable from real data. This training simply runs until all the numbers in the probability vector are 1.

Experiment

Developing this method data we use New York City Taxi from 2016[3]. These data are far easier to verify than traditional experiments as there is a well defined plausible ranges for time and location, permitting simple filtering by heuristics. To generate longitude, latitude, and time for pick-up and drop-off of each fair, we assemble the GAN architecture. After that train the GAN on a subset of the data, then retrain adding data points. See Figure 2 for a minimal example of this process concatenating real and generated data then training the network until it converges to a solution.

Generate and Label Data					
Minimal Example Generate fake data, append to real, and train GAN					
rdelay	age	rasp3	td	expdd	is_real
-0.1526527	-1.2121831	-0.4472136	-0.4923660	1.4494064	1
-0.6383658	0.2020305	0.6708204	-0.0820610	-0.0670479	1
1.6514244	-0.8081220	-1.5652476	-0.3282440	-0.1689550	1
-0.9159161	1.2121831	0.6708204	-0.8206099	-1.3592337	1
0.0555101	0.6060915	0.6708204	1.7232809	0.1395303	1
0.2316489	-0.2192497	0.5249911	0.0797766	-0.1998897	0
-0.0481928	1.5192747	-0.0045090	0.9744884	-2.8427019	0
-0.3158222	1.5258328	-0.9226113	0.0102425	-0.1436559	0
-0.2907037	-0.1617303	0.9767030	-1.5406653	0.7550172	0
-1.1800550	-0.1189155	1.3039990	1.073480	2.0710810	0

Generate Data and Retrain					
Minimal Example Estimated probability data is real					
rdelay	age	rasp3	td	expdd	probability_is_real
-0.1526527	-1.2121831	-0.4472136	-0.4923660	1.4494064	0.9679135
-0.6383658	0.2020305	0.6708204	-0.0820610	-0.0670479	0.9985082
1.6514244	-0.8081220	-1.5652476	-0.3282440	-0.1689550	0.9903435
-0.9159161	1.2121831	0.6708204	-0.8206099	-1.3592337	0.996194
0.0555101	0.6060915	0.6708204	1.7232809	0.1395303	0.9998083
0.2316489	-0.2192497	0.5249911	0.0797766	-0.1998897	0.0024801
-0.0481928	1.5192747	-0.0045090	0.9744884	-2.8427019	0.0017882
-0.3158222	1.5258328	-0.9226113	0.0102425	-0.1436559	0.0007435
-0.2907037	-0.1617303	0.9767030	-1.5406653	0.7550172	0.0223810
-1.1800550	-0.1189155	1.3039990	1.073480	2.0710810	0.0491096

Generate and Label Data					
Minimal Example Estimated probability data is real					
rdelay	age	rasp3	td	expdd	probability_is_real
-0.1526527	-1.2121831	-0.4472136	-0.4923660	1.4494064	0.9686862
-0.6383658	0.2020305	0.6708204	-0.0820610	-0.0670479	0.9987784
1.6514244	-0.8081220	-1.5652476	-0.3282440	-0.1689550	0.9674411
-0.9159161	1.2121831	0.6708204	-0.8206099	-1.3592337	0.9969423
0.0555101	0.6060915	0.6708204	1.7232809	0.1395303	0.9989892
0.2316489	-0.2192497	0.5249911	0.0797766	-0.1998897	0.0024801
-0.0481928	1.5192747	-0.0045090	0.9744884	-2.8427019	0.0017882
-0.3158222	1.5258328	-0.9226113	0.0102425	-0.1436559	0.0007435
-0.2907037	-0.1617303	0.9767030	-1.5406653	0.7550172	0.0223810
-1.1800550	-0.1189155	1.3039990	1.073480	2.0710810	0.0491096

Generate Data and Retrain					
Minimal Example Estimated probability data is real					
rdelay	age	rasp3	td	expdd	probability_is_real
-0.1526527	-1.2121831	-0.4472136	-0.4923660	1.4494064	0.9637378
-0.6383658	0.2020305	0.6708204	-0.0820610	-0.0670479	0.9823097
1.6514244	-0.8081220	-1.5652476	-0.3282440	-0.1689550	0.9954374
-0.9159161	1.2121831	0.6708204	-0.8206099	-1.3592337	0.9945558
0.0555101	0.6060915	0.6708204	1.7232809	0.1395303	0.9841065
0.2316489	-0.2192497	0.5249911	0.0797766	-0.1998897	0.0024801
-0.0481928	1.5192747	-0.0045090	0.9744884	-2.8427019	0.0017882
-0.3158222	1.5258328	-0.9226113	0.0102425	-0.1436559	0.0007435
-0.2907037	-0.1617303	0.9767030	-1.5406653	0.7550172	0.0223810
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-0.1526527	-1.2121831	-0.4472136	-0.4923660	1.4494064	0.9571349
-0.6383658	0.2020305	0.6708204	-0.0820610	-0.0670479	0.9979365
1.6514244	-0.8081220	-1.5652476	-0.3282440	-0.1689550	0.9953037
-0.9159161	1.2121831	0.6708204	-0.8206099	-1.3592337	0.9901581
0.0555101	0.6060915	0.6708204	1.7232809	0.1395303	0.9921287
0.2316489	-0.2192497	0.5249911	0.0797766	-0.1998897	0.0024801
-0.0481928	1.5192747	-0.0045090	0.9744884	-2.8427019	0.0017882
-0.3158222	1.5258328	-0.9226113	0.0102425	-0.1436559	0.0007435
-0.2907037	-0.1617303	0.9767030	-1.5406653	0.7550172	0.0223810
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-0.6383658	0.2020305	0.6708204	-0.0820610	-0.0670479	0.9985082
1.6514244	-0.8081220	-1.5652476	-0.3282440	-0.1689550	0.9903435
-0.9159161	1.2121831	0.6708204	-0.8206099	-1.3592337	0.996194
0.0555101	0.6060915	0.6708204	1.7232809	0.1395303	0.9998083
0.2316489	-0.2192497	0.5249911	0.0797766	-0.1998897	0.0024801
-0.0481928	1.5192747	-0.0045090	0.9744884	-2.8427019	0.0017882
-0.3158222	1.5258328	-0.9226113	0.0102425	-0.1436559	0.0007435
-0.2907037	-0.1617303	0.9767030	-1.5406653	0.7550172	0.0223810
-1.1800550	-0.1189155	1.3039990	1.073480	2.0710810	0.0491096

Figure 2: GAN Generating Synthetic Data and Estimating Probability is Real

As shown in Figure 2, at first generated data are assigned a very low probability of being real. Note in Figure 3 the training process is cyclical, at times the generator is better at generating better samples than the discriminator is better at detecting generated samples. When this converges to 1, the discriminator is unable to distinguish between real and generated.

