## Index

Α	for unsupervised machine learning,
Accuracy	241
certified robust, 114	from natural examples, 144
classification, 10, 195, 248	transferability, 38, 235
clean, 114, 155	inputs, 147
drop, 232	instances, 148
increase, 250	loss, 180
prediction, 7, 8, 128	network, 97
reprogramming, 204	perturbation, 15, 22, 23, 41, 43, 66, 73,
standard, 8, 187, 189, 195	74, 116, 127, 147, 153, 158, 160,
Acoustic model (AM), 202–204, 206	162, 164, 193, 194
Adaptive	purposes, 201
antiwatermark schemes, 229	robustness, 7–10, 12, 24, 59, 68, 73, 76,
ŕ	113, 115, 130, 132, 170, 183, 184,
attacks, 24, 146 Advanced	186, 188, 189, 250
	for machine learning, 7
attacks, 146	in machine learning algorithms, 3
finetuning techniques, 189	in MAML, 183, 184
AdvCL, 189, 191, 194, 197, 198	targets, 148
AdvCL framework, 191	threats, 3
Adversarial	timing attacks, 66
agent models, 66	unsupervised example, 244
attack, 15-18, 29, 48, 59, 62, 64, 73, 95,	view, 193
138, 143, 146, 148, 185, 234	Adversarial full finetuning (AFF), 189–191,
attack formulation, 47	195, 197
attacking algorithms, 241	Adversarial linear finetuning (ALF), 189,
audio, 148	191, 198
attacks, 149	Adversarial machine learning (AdvML), 3,
examples, 155	201
inputs, 146	Adversarial reprogramming (AR), 201, 206
autoencoder, 247	Adversarial training (AT), 10, 114, 115,
characteristics, 148	117, 119, 121, 122, 128, 131, 180,
context, 189, 193	185, 189–191
contrastive	algorithm, 20
pretraining framework, 189	fast, 121
training, 195	method, 107, 129
detection, 143, 144, 146	process, 120
example, 8, 15–20, 30, 31, 35, 38–40,	Adversarially robust metric learning
47, 48, 60, 62–64, 73, 74, 113–117,	(ARML), 168, 170
119, 120, 127, 143–145, 159, 186,	algorithm, 170 certified robustness, 170
188, 191, 232, 241, 243	Adversary, 228, 229
detection, 143	Aggregated prediction, 204
uctection, 143	riggregated prediction, 204

Alignment loss, 211, 212	Audio
Antiwatermark	data inputs, 146
attacks, 228	inputs, 146
schemes adaptive, 229	Audio adversarial
Area under curve (AUC), 148, 149, 154,	attacks, 146
155	examples, 59, 69, 146, 147
Attack	perturbation, 60
efficiency, 41	Augmented
fail, 24	dataset, 247
formulation unsupervised, 244, 245	poisoned dataset, 52
function for targeted attack, 244	Autism Spectrum Disorder (ASD)
function unsupervised, 244	classification, 207
generation, 186, 245	dataset, 208
goal, 17	task, 208, 209
loss, 47	Autoencoder (AE), 40, 116, 218, 244, 247
loss function, 59, 63	adversarial, 247
methods, 114	sparse, 247
objective, 21, 31, 52	Automatic speech recognition (ASR), 146
performance, 22, 63, 113	147 AutoZOOM
problem, 19	attack, 41
procedure, 16	method, 39
process, 47	method, 37
results, 41	В
scenarios, 143	Backdoor
semantic, 98, 99, 101, 107	attacks, 51–54, 149
space, 103	in TrojanNets, 150
success, 245	process, 154
criterion, 247	trigger, 56
evaluation function, 244	Backdoored model, 51–53, 150
successfulness, 17, 18, 21, 24	Base
	classifier, 132, 133, 174
supervised, 245	model, 232, 233, 236, 239
targeted, 16–18, 22, 24, 31, 35, 107 threat model, 99	model features, 234
	Bayesian neural network (BNN), 131
Trojan, 52, 149, 153	Benchmarking dataset, 18
unsupervised, 244	Bilevel optimization problem, 184, 186
Attack accuracy (AA), 195–197	Binary
Attack success rate (ASR), 10, 21, 24, 41,	classification, 176
50, 52, 57	classification problem, 134
Attacker, 15, 23, 29, 52, 115, 117	classifiers, 143, 221
knowledge, 29	prediction, 133
objective function, 52	Bit error rate (BER), 232
Attacking	Black-box attack, 29
algorithms adversarial, 241	Box adversarial reprogramming (BAR),
methodology, 56	206, 207
scheme, 54	Branch-and-Bound (BaB) method, 90

C	tasks, 10, 51, 202
Carrier nodes, 230–232	tree, 173
Centralized	Classifier
attack, 54, 56	deep, 117
backdoor attack, 54, 56	linear, 123, 188, 190, 195
Certifiable	neural network, 100, 209-211
robustness bound, 161	results, 225
Certificated robustness, 69	robust, 115
Certified	Clean
defense, 113, 114, 132, 138, 141, 179	accuracy, 114, 155
methods, 77, 114	data, 53, 123, 143, 150, 153
network, 165	dataset, 155
robust	Cluster labels, 195
accuracy, 114	Color image dataset, 246
error, 138, 165, 167, 168	Complete verification, 89, 90, 92
loss, 137	methods, 93
radius, 135, 137	problem, 89
training, 137, 139, 141	Connectionist temporal classification
training error, 166	(CTC), 60
tree ensemble, 181	Contrast perturbation, 101
robustness, 10, 134, 135, 137, 140, 165	Contrastive
accuracy, 142	explanations, 217, 220
bound, 134	loss, 191, 193, 248
guarantees, 137	training adversarial, 195
training, 139, 141, 142, 180, 181	Contrastive explanations method (CEM),
Character error rate (CER), 148	217, 225
CIFAR models, 107	Contrastive explanations method using
Clarifai	monotonic attribute functions
moderation API, 208	(CEM-MAF), 221, 222
reprogramming, 208	Contrastive learning (CL), 183, 188, 194,
Class	248
labels, 173, 208	Convex
prediction, 30, 31, 34, 203, 204, 218	loss, 39
prediction results, 29	loss functions, 33
prediction score, 18	relaxation, 61, 80, 84–86
target, 17, 18, 22, 49, 144, 150, 152,	relaxation barrier, 85, 86
153, 206	relaxation framework, 79, 84 Convolution
Classification	layer, 243
accuracy, 10, 195, 248	
benchmark, 204	layer output, 243
error, 8	Convolutional autoencoder (CAE), 223, 247
function, 31	
loss, 63, 115	Convolutional neural network (CNN), 10,
model, 73, 132	41, 63, 66, 105, 107, 129 Coordinatewise
performance, 170	gradient estimation, 31, 32, 41
rules, 38	
ruics, Jo	neuron activation, 154

Crafting	methods certified, 77, 114
adversarial attacks, 23	model, 113
adversarial examples, 16, 22, 66	network certified, 165
perturbations, 193	performance, 113
physical adversarial examples, 48	Deteriorated robustness, 129
Cross entropy (CE) loss, 17, 52	Digital watermarking, 227
CROWN, 83, 86, 93, 139	Dimensionality constraint, 107
bound, 83	Discrete
bound propagation, 141	inputs, 62
training, 141	layers, 130
	models, 157
D	models robustness, 158
Data	nonneural network models, 157
augmentation, 107, 186, 241, 242,	perturbation setting, 77
246–248	Discrete cosine transform (DCT), 235
clean, 53, 123, 143, 150, 153	Discretely parameterized perturbations, 98
input, 3, 6, 15, 29, 51, 52, 67, 208, 217,	Distributed backdoor attack (DBA), 54, 56
243	Downstream tasks, 183, 187-189, 191, 241
input reprogramming, 204	
reconstruction, 244, 247, 248	E
samples, 4–8, 30, 31, 40, 52, 53, 96, 149,	EAD attack, 22, 24
186, 207, 210, 242–244	Electrocardiogram (ECG), 201
unlabeled, 188, 194	classes, 204
Datasets, 7, 18, 60, 142, 165, 170, 194,	classification, 204
197, 202, 207, 221, 228, 243, 246,	Encoder, 40, 97, 116, 117, 247
248	for data reconstruction, 248
finetuning, 189	part, 117
for attack performance evaluation, 52	Ensemble
pretraining, 189	feature attribution, 146
Deep	stump verification, 175
classifier, 117	Evasion attack, 15, 29, 113
learning models, 201, 227	Evasion attack taxonomy, 29
pretrained acoustic classification model,	Eventual learning objective AdvCL, 194
203	Expectation over transformation (EOT),
Deep neural network (DNN), 6, 10, 22,	47, 127
89, 116, 206, 227	attack, 48, 127-129
models, 227, 233	attack performance, 50
robustness, 113, 127	Exponential loss, 167
Deep reinforcement learning (DRL), 66	
Defense	F
approaches, 158	Fashion MNIST, 170, 246
certified, 113, 114, 132, 138, 141, 179	Fast gradient sign method (FGSM), 19, 20
components, 118	23, 113, 115, 128, 188
framework, 117	Feature attribution, 145
ineffective, 24	maps, 145
mechanism, 24, 114	methods, 144
methods, 113-115, 128, 185	values, 146

Federated learning (FL), 53–55, 57 Finetuning, 188–190, 195, 197, 207 datasets, 189	space attacks, 107 space perturbation, 107, 108 Human imperceptible perturbation, 15
efficiency, 189 performance, 207	I
supervised, 189, 190	ImageNet, 7, 8, 24, 26, 41, 127, 154, 165,
Fingerprint transferability, 235	194, 206
Formal verification community, 83	competition yearly, 7
Formulating	containing, 7
adversarial training, 119	dataset, 7, 32, 41, 236, 238
attack, 17	models, 7, 8
	models pretrained, 201
G	Inactive neurons, 140
Gaussian augmentation (GA), 247, 248	Incomplete verification solvers, 92
Generative adversarial network (GAN), 3,	Incorrect predictions, 49
116, 221	Independent verification problem, 90
Generative models, 96	Inputs
German Traffic Sign Benchmark (GTSRB)	adversarial, 147
dataset, 107, 209	discrete, 62 gradient, 229, 230
models, 107	Integrated gradient (IG), 145
Gradient	Intellectual property (IP), 227
estimate, 32, 33	infringements, 227, 228
estimation, 32, 37, 39, 41, 128	protection, 235
estimator, 32–34, 44	protection methods, 232
loss function, 121	Interval bound propagation (IBP), 139, 140
regularization, 64	training, 140, 141
Gradient boosting decision tree (GBDT),	Inverse DCT (IDCT), 235
157, 158, 170, 176	Iterative FGSM (I-FGSM) attack, 20
Gradient descent (GD), 5, 34, 37, 39, 184	
Gradient mean (GM), 232, 234 GradSigns, 227, 229–231	K
Graph Neural Network (GNN), 60, 61, 93	K-nearest neighbor (KNN), 157, 165, 170
Groundtruth class label, 4	classifiers, 157
Grounderden class laber,	models certified robustness, 170
	models robustness, 168
H	
Hidden	L
layer, 101, 247	Label
layer output, 128	change, 152
neurons, 149 High-frequency component (HFC), 193,	flipping, 51
194	mapping, 209, 210 prediction, 30, 152
Hinge loss, 21, 167	target, 53, 150, 152, 153, 203
HSL	Layerwise
color space, 101	convex relaxation, 83
space, 100	nonlinear activations, 103

Leave-one-out (LOO)	supervised, 6
feature attribution method, 144	system, 3
method designs, 144	tasks, 6, 244
Lightweight	tools, 29
finetuning scheme, 191	
standard linear finetuning, 189	unsupervised, 6
Linear	Manipulated datasets, 51
classifier, 123, 188, 190, 195	Median absolute deviation (MAD), 153
finetuning	Minimum
settings, 198	adversarial perturbation, 74, 161
strategies, 197	perturbation norm, 159
types, 197	MinMax
prediction head, 191	algorithm, 243, 245
relaxation, 86, 102, 103, 105, 139	attack, 48, 50
Linear programming (LP), 91, 92	attack algorithm, 245, 247
Local	attack problem, 245
attackers, 56	optimization problem, 245
models, 56	Misclassification, 166
Local intrinsic dimension (LID), 144	Misclassification rate, 97
Logistic loss, 167	Mixed integer programming (MIP)
Longest common prefix (LCP), 148	problem, 89
Loss	solver, 93
adversarial, 180	MNIST, 24, 26, 41, 103, 107, 141, 142,
attack, 47	170, 201, 223, 246, 247
certified robust, 137	dataset, 41, 142, 165
classification, 63, 115	Model
contrastive, 191, 193, 248	discrete, 157
function, 5, 6, 18, 22, 48, 52, 60, 65,	for medical image classification, 206
121, 123, 137, 138, 168, 218, 234	for reprogramming, 204
function gradient, 121	ImageNet, 7, 8
landscapes for gradient estimation, 34	machine learning, 3, 6, 9, 15, 16, 22, 38,
MAML, 185	53, 59, 113, 157, 158, 201, 227,
objective reprogramming, 210	241, 243
prediction, 185	parameters, 5, 15, 29, 51, 52, 141, 183,
term, 151, 154, 245	184, 209, 229
	performance, 8, 68
М	prediction, 4, 8, 15, 29, 144, 176, 208,
Machine learning (ML), 5, 6, 8, 29, 149,	210, 218–220
183, 201, 227	reprogramming, 201, 203, 206, 209
accelerators, 83	supervised, 242
adversarial, 3, 201	vendor, 228, 230
algorithms, 3	
basics, 5	watermarking, 227
interpretability, 77	Model-agnostic meta-learning (MAML), 183–187
models, 3, 6, 9, 15, 16, 22, 38, 53, 59,	
113, 157, 158, 201, 227, 241, 243	framework, 184
paradigms, 183	loss, 185

Multiclass classification	Nonconvex attack spaces, 103
models, 135	Nonreprogrammable entry, 203
problem, 16, 135	Nonrobust loss, 180
Multilayer perceptron (MLP), 105, 107	Not Safe For Work (NSFW), 208
Multiview CL loss, 191	Numerical gradient, 33
Mutual information (MI), 242, 243	-
Mutual information neural estimator	0
(MINE), 242, 243	Obstruct
	verification, 229
N	watermark verification, 229
Natural examples, 116, 144–146, 218	Occlusion, 98, 99
Natural language processing (NLP) tasks, 10	attack, 99
Nature language processing (NLP)	patch, 99
attacks, 62, 63	Opt attack, 41, 148
models, 62	Optimal
Nearest-neighbor (NN)	attack value, 106
classifier, 158, 163, 165, 167	perturbation, 160, 175
model, 158–162, 165, 170	Optimal transport (OT), 212
robustness, 163	Optimization problem, 18, 19, 23, 31, 35
Neural Cleanse (NC), 154, 155	37, 47, 60, 62, 79, 119, 148, 151,
Neural networks, 6, 7, 16, 38, 63, 64, 67,	157, 185, 217–219, 221
68, 73, 76, 77, 82, 95, 97, 100, 113,	unconstrained, 20
116, 117, 121, 127, 129, 130, 137,	
138, 149, 157, 158, 165, 217, 218,	P
232, 242	Paired perturbation view, 193
adversarial robustness, 6, 157	Paraphrasing attack, 63, 64
classifier, 100, 209-211	Performance
deep, 6, 10, 22, 89, 206, 227	attack, 22, 63, 113
function, 98	benchmarking, 3
implementations, 33	classification, 170
learning, 180	defense, 113
model, 99, 115, 117, 137, 150, 154, 213,	degradation, 232, 248
217, 243	evaluation, 16, 30
parameters, 234	finetuning, 207
prediction, 132	models, 8, 68
robustness, 68, 69, 115	verification, 102
robustness models, 113	Pertinent negative (PN), 217-219, 223
training, 17	Pertinent positive (PP), 217, 218, 223
verification, 76, 77, 138	Perturbation
algorithm, 139	adversarial, 15, 22, 23, 41, 43, 66, 73,
methods, 77, 79, 137	74, 116, 127, 147, 153, 158, 160,
technique, 138	162, 164, 193, 194
Neuron	magnitude, 105
activation, 153	range, 244
coordinates, 153, 154	sensitivity, 68
ReLU, 90	set, 62, 63, 120, 137
representation, 153	space, 63

techniques, 95	Projected gradient descent (PGD), 195
Trojan, 150	adversarial training, 122
universal, 22, 150, 152	algorithm, 120, 234
Perturbed	attack, 19–21, 23, 73, 122, 128, 187, 195
data sample, 244	attack generation method, 186
example, 16, 185	inner iteration, 122
Pixelwise perturbations, 150	iteration, 122
Poisoned	steps, 120, 121
dataset, 51	updates, 121
training data, 150	Pruned models, 227, 233, 235, 236, 238
training dataset, 51	
	Q
Positing layer 247	Quadratic programming (QP), 161–164
Pooling layer, 247	problem, 161, 163, 164
Prediction 7. 8. 128	Queried data inputs, 206
accuracy, 7, 8, 128	Querred data inputs, 200
APIs, 206–208, 228	R
binary, 133	Random
class, 30, 31, 34, 203, 204, 218, 219	
head linear, 191	noise inputs, 149
label, 30, 150–152	perturbations, 135, 238
loss, 185	Random forest (RF), 157, 170  Random number generator (RNC), 230
models, 4, 8, 15, 29, 144, 176, 208, 210,	Random number generator (RNG), 230
218–220	Randomized
neural networks, 132	models, 127
probability, 18, 31, 185, 203, 204, 218	models robustness, 127
rotation, 188	smoothing, 132, 135, 137
scores, 31, 218, 221, 222	smoothing technique, 135
value, 138, 175, 176	Rationale, 51, 150, 152, 193, 194, 202, 247
Pretrained	Receiver operating characteristic (ROC),
AM, 202	154, 238
data representations, 194	Recurrent neural network (RNN), 10, 63,
ImageNet classifiers, 207	66 D-111 81 80 140
ImageNet model, 38, 201	ReLU, 81, 89, 140
ML model, 206	activations, 82
model, 135, 203, 233	functions, 81, 89
model parameters, 201, 210	layer, 82, 101
representation network, 194	networks, 83, 89
surrogate models, 38	neurons, 90 node, 91
voice models, 204	
Pretraining	relaxation in CROWN, 82
datasets, 189	splits, 93
generalization ability, 191	unit, 90
methods, 198	Reprogrammed
	input, 207
phase, 191	sample, 203
setup, 197	target data, 203, 209, 211
Primal constraints, 164	target data sample, 203

Danragramming	preserved parturbations 77
Reprogramming	preserved perturbations, 77 verification, 102
accuracy, 204 adversarial, 201	Semantic perturbation layer (SP-layer), 97,
Clarifai, 208	99
general image models, 206	Semisupervised machine learning, 6
loss objective, 210	Source Source
	labels, 203, 204
models, 201, 203, 206, 209	loss, 211
performance assessment, 212	Sparse
voice models, 201	autoencoder, 247
Reversed layer, 247	perturbation mask, 152
Robust accuracy (RA), 187, 195	regression models robustness, 60
Robustness	Standard
adversarial, 7–10, 12, 24, 59, 68, 73, 76,	datasets MNIST, 41
113, 115, 130, 132, 170, 183, 184,	robust training, 184
186, 188, 189, 250	training, 121
assessment, 232	Standard accuracy (SA), 8, 187, 189, 195
bound certified, 134	Standard linear finetuning (SLF), 191,
certified, 10, 134, 135, 137, 140, 165	195–197
challenge, 189	State-of-the-art (SOTA)
difference, 197	performance, 207
enhancement, 191	results, 207
evaluation, 164, 174–176, 241	Stochastic gradient descent update, 129
evaluation metrics, 195	Strawberry training set, 205, 206
guarantees, 132, 137	Superior robustness, 10
improvements, 115, 187	Supervised
measurement, 73	adversarial example, 243
neural networks, 68, 69, 115	attack, 245
property, 73	attack rationale, 244
regularization, 186	finetuning, 189, 190
score, 170	machine learning, 6
transferability, 186, 194, 197	models, 242
verification, 73, 74, 76, 85, 99, 157, 161,	prediction, 195
162, 167, 173, 175, 176	Support vector machine (SVM), 157
algorithm, 97	
approach, 95	Т
methods, 74, 97	t-distributed stochastic neighbor
Root mean squared error (RMSE), 210	embedding (tSNE), 205
	Target
S	attack class label, 31
Safety verification problem, 76	class, 17, 18, 22, 49, 144, 150, 152, 153,
Semantic	206, 230
adversarial attacks, 95	data inputs, 202
adversarial examples, 95-97	data reprogrammed, 203, 209, 211
attack, 98, 99, 101, 107	dataset, 191
attack threat, 99, 105	label, 52, 53, 93, 138, 150, 152–154,
perturbation, 95, 97–100, 102, 105	203, 204, 210

model, 15, 29–31, 38, 39, 41, 51, 52 objects, 49	<b>U</b> Unconstrained
Targeted	form, 21
attack, 16–18, 22, 24, 31, 35, 107	optimization formulations, 23
keyword attack, 65	
poisoning attack, 52	optimization problem, 20
	problems, 21
Temporal dependency (TD), 146–148 distance, 147	Unified attack formulation, 243
loss, 147	Universal
Threat model, 23, 30, 59, 73, 95, 97, 98,	adversarial perturbation, 22
102, 107, 228	attack performance, 23
Trainable	input perturbation trainable, 201
additive input transformation, 203	perturbation, 22, 150, 152
input transformation function, 202	perturbation generation, 152
objective function, 168	trainable additive input, 207
	Unlabeled
parameters, 203	data, 188, 194
reprogram layer, 202	data augmentation, 188
universal input perturbation, 201 Trained	dataset, 194
	source dataset, 190
DNN, 149	Unstable
model, 97, 155, 201, 208 Transfer attack, 30	neurons, 81, 82
*	ReLU neurons, 93
Transferability, 38, 236 adversarial examples, 38, 235	Unsupervised
from pretraining, 197	attack, 244
robustness, 186, 194, 197	formulation, 244, 245
Transferable	function, 244
	contrastive loss, 194
adversarial examples, 38 attacks, 38	example adversarial, 244
Tree ensemble, 176, 179	machine learning, 6
certified robust, 181	performance models, 248
models, 176	tasks, 246
robustness, 179	Unsupervised adversarial example (UAE),
	241–243, 245, 248
verification problem, 177 Trigger pattern, 52, 53, 56, 151	Untampered models, 53
	Untargeted attack, 16-18, 21, 31, 35, 37,
Trojan	41, 151, 244
attack, 52, 149, 153	Upsampling layer, 247
attack target label, 152	
perturbation, 150	V
trigger, 150, 152	Vanilla adversarial reprogramming, 207
Trojan network (TrojanNet), 149, 150,	Variational autoencoder (VAE), 221
153–155	
detection, 149, 150, 154	Verification
TrojanNet detector (TND), 149, 153	algorithms, 87, 93, 139, 159, 161
True	framework, 93
gradient, 31	methods, 77, 85, 95, 114, 137, 138, 140,
label, 185	180

neural network, 76, 77	W
performance, 102	Watermark, 228–230
problem for neural network, 99	bit, 230, 231
process, 90	carrier, 230
results for datasets, 103	embedding, 229, 230
robustness, 73, 74, 76, 85, 99, 157, 161,	extraction, 231, 232
162, 167, 173, 175, 176	information, 229
semantic, 102	Watermarking
techniques, 137	bit, 231
tools, 89, 95	digital, 227
Victim	technique, 228, 232
classifier, 17	Weight perturbations, 67-69
model, 15, 16, 22	White-box attack, 29
Virtual adversary, 3	Word error rate (WER), 147, 148
Voice to series (V2S), 202, 203	Wrong prediction, 37, 51
loss, 204	
model architectures, 205	Z
reprogramming, 204, 205	Zeroth-order optimization (ZOO), 30, 33
training, 212	attack, 41