

Venus Verification Results for VNN-COMP 2020

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July 20, 2020

1 Introduction

This document reports Venus’s verification results for the ACASXU and PAT-FCN benchmarks of VNN-COMP 2020.

Venus [1] is a complete verification toolkit for Relu-based feed-forward neural networks. It can be used to check reachability and local adversarial robustness properties. Venus implements a MILP-based verification method whereby it leverages dependency relations between the ReLU nodes to reduce the search space that needs to be considered during branch-and-bound. It additionally implements methods based on symbolic interval propagation and input domain splitting.

Venus participated in the PWL category. The experiments were carried out on an Intel Core i7-7700K (4 cores) equipped with 16GB RAM, running Linux kernel 4.15. The code of Venus is available at <https://vas.doc.ic.ac.uk/software/neural/>.

2 Results

2.1 ACASXU-ALL

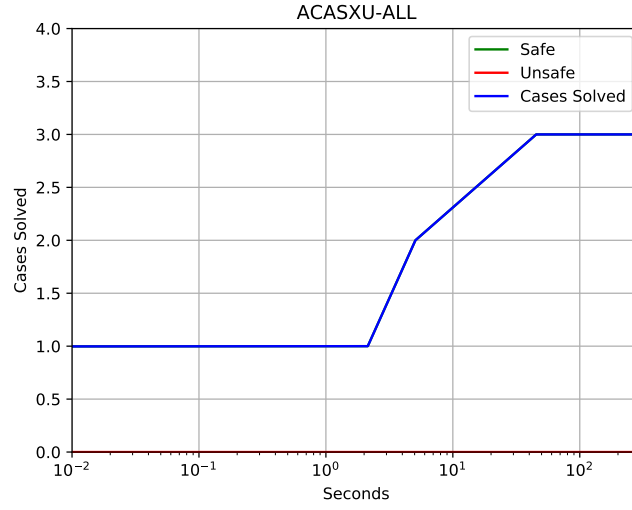


Figure 1: ACASXU-ALL Cactus Plot

Table 1: Total runtime (sec) for ACASXU-ALL

Property	Network	Result	Time
1	1-1	Satisfied	1.3247
1	1-2	Satisfied	3.0031
1	1-3	Satisfied	22.7332
1	1-4	Satisfied	17.8571
1	1-5	Satisfied	2.2596
1	1-6	Satisfied	2.0384
1	1-7	Satisfied	1.0655
1	1-8	Satisfied	0.5524
1	1-9	Satisfied	0.4649
1	2-1	Satisfied	11.3553
1	2-2	Satisfied	24.3402
1	2-3	Satisfied	27.607
1	2-4	Satisfied	6.8351
1	2-5	Satisfied	24.6372
1	2-6	Satisfied	74.3739
1	2-7	Satisfied	193.7015
1	2-8	Satisfied	186.4537

1	2-9	Satisfied	160.3202
1	3-1	Satisfied	7.6354
1	3-2	Satisfied	10.4362
1	3-3	Satisfied	6.93
1	3-4	Satisfied	6.5462
1	3-5	Satisfied	12.2083
1	3-6	Satisfied	263.5584
1	3-7	Satisfied	124.2182
1	3-8	Satisfied	122.7229
1	3-9	Satisfied	197.1078
1	4-1	Satisfied	82.5623
1	4-2	Satisfied	21.3695
1	4-3	Satisfied	13.227
1	4-4	Satisfied	7.5859
1	4-5	Satisfied	80.9499
1	4-6	Satisfied	179.1977
1	4-7	Undecided	-
1	4-8	Undecided	-
1	4-9	Undecided	-
1	5-1	Satisfied	5.6679
1	5-2	Satisfied	10.422
1	5-3	Satisfied	3.5177
1	5-4	Satisfied	8.8667
1	5-5	Satisfied	29.4601
1	5-6	Undecided	-
1	5-7	Satisfied	130.3863
1	5-8	Undecided	-
1	5-9	Satisfied	120.1959
2	1-1	Satisfied	27.1972
2	1-2	Unsatisfied	2.8952
2	1-3	Unsatisfied	1.1642
2	1-4	Unsatisfied	27.2139
2	1-5	Unsatisfied	81.9917
2	1-6	Unsatisfied	1.444
2	1-7	Satisfied	72.1419
2	1-8	Satisfied	180.8819
2	1-9	Satisfied	73.9451
2	2-1	Unsatisfied	13.7863
2	2-2	Unsatisfied	0.7872
2	2-3	Unsatisfied	1.4414
2	2-4	Unsatisfied	0.5696
2	2-5	Unsatisfied	0.7764
2	2-6	Unsatisfied	0.9515
2	2-7	Unsatisfied	0.5706
2	2-8	Unsatisfied	0.7667
2	2-9	Unsatisfied	0.9835

2	3-1	Unsatisfied	0.5651
2	3-2	Unsatisfied	0.8208
2	3-3	Satisfied	294.6645
2	3-4	Unsatisfied	6.6045
2	3-5	Unsatisfied	2.4912
2	3-6	Unsatisfied	0.8525
2	3-7	Unsatisfied	1.2192
2	3-8	Unsatisfied	1.5553
2	3-9	Unsatisfied	2.169
2	4-1	Unsatisfied	81.6643
2	4-2	Undecided	-
2	4-3	Unsatisfied	0.7297
2	4-4	Unsatisfied	0.5017
2	4-5	Unsatisfied	2.1352
2	4-6	Unsatisfied	1.3133
2	4-7	Unsatisfied	0.7139
2	4-8	Unsatisfied	72.9959
2	4-9	Undecided	-
2	5-1	Unsatisfied	11.8092
2	5-2	Unsatisfied	0.7482
2	5-3	Unsatisfied	9.9463
2	5-4	Unsatisfied	1.024
2	5-5	Unsatisfied	0.6529
2	5-6	Unsatisfied	0.7417
2	5-7	Unsatisfied	1.0528
2	5-8	Unsatisfied	0.7216
2	5-9	Unsatisfied	0.6867
3	1-1	Satisfied	69.5189
3	1-2	Satisfied	6.8715
3	1-3	Satisfied	36.9158
3	1-4	Satisfied	2.4706
3	1-5	Satisfied	1.2104
3	1-6	Satisfied	0.8027
3	1-7	Unsatisfied	0.2002
3	1-8	Unsatisfied	0.0825
3	1-9	Unsatisfied	0.2024
3	2-1	Satisfied	5.8678
3	2-2	Satisfied	10.3932
3	2-3	Satisfied	11.5876
3	2-4	Satisfied	0.424
3	2-5	Satisfied	0.6213
3	2-6	Satisfied	0.7571
3	2-7	Satisfied	0.7961
3	2-8	Satisfied	0.7299
3	2-9	Satisfied	0.179
3	3-1	Satisfied	6.3277

3	3-2	Satisfied	4.9271
3	3-3	Satisfied	2.6984
3	3-4	Satisfied	1.5176
3	3-5	Satisfied	0.3851
3	3-6	Satisfied	3.3437
3	3-7	Satisfied	0.2247
3	3-8	Satisfied	0.6627
3	3-9	Satisfied	0.4038
3	4-1	Satisfied	3.7083
3	4-2	Satisfied	24.0707
3	4-3	Satisfied	8.142
3	4-4	Satisfied	0.3862
3	4-5	Satisfied	0.3705
3	4-6	Satisfied	1.9483
3	4-7	Satisfied	1.2617
3	4-8	Satisfied	1.4962
3	4-9	Satisfied	1.6037
3	5-1	Satisfied	27.1717
3	5-2	Satisfied	0.5656
3	5-3	Satisfied	1.3686
3	5-4	Satisfied	0.7323
3	5-5	Satisfied	0.858
3	5-6	Satisfied	1.764
3	5-7	Satisfied	0.3275
3	5-8	Satisfied	0.8133
3	5-9	Satisfied	0.3289
4	1-1	Satisfied	118.2684
4	1-2	Satisfied	95.3662
4	1-3	Satisfied	140.0388
4	1-4	Satisfied	70.2887
4	1-5	Satisfied	57.3891
4	1-6	Satisfied	24.607
4	1-7	Unsatisfied	0.2982
4	1-8	Unsatisfied	0.4168
4	1-9	Unsatisfied	0.2737
4	2-1	Satisfied	64.4088
4	2-2	Undecided	-
4	2-3	Satisfied	25.7678
4	2-4	Satisfied	21.8438
4	2-5	Satisfied	17.2698
4	2-6	Satisfied	84.1039
4	2-7	Satisfied	23.6175
4	2-8	Satisfied	66.7318
4	2-9	Satisfied	12.696
4	3-1	Satisfied	114.6116
4	3-2	Satisfied	65.5603

4	3-3	Satisfied	19.0435
4	3-4	Satisfied	6.6118
4	3-5	Satisfied	35.7937
4	3-6	Satisfied	143.9535
4	3-7	Satisfied	23.9802
4	3-8	Satisfied	20.1341
4	3-9	Satisfied	25.6954
4	4-1	Satisfied	49.3583
4	4-2	Satisfied	139.3184
4	4-3	Satisfied	48.968
4	4-4	Satisfied	27.5058
4	4-5	Satisfied	43.1967
4	4-6	Satisfied	36.7791
4	4-7	Satisfied	48.3904
4	4-8	Satisfied	100.7989
4	4-9	Satisfied	41.7873
4	5-1	Satisfied	167.8981
4	5-2	Satisfied	18.8389
4	5-3	Satisfied	40.8706
4	5-4	Satisfied	10.3735
4	5-5	Satisfied	31.4331
4	5-6	Satisfied	25.9952
4	5-7	Satisfied	73.3412
4	5-8	Satisfied	65.6536
4	5-9	Satisfied	39.064
5	1-1	Undecided	-
6	1-1	Undecided	-
7	1-9	Undecided	-
8	2-9	Unsatisfied	0.7352
9	3-3	Undecided	-
10	4-5	Satisfied	130.6367

2.2 ACASXU-HARD

Table 2: Total runtime (sec) for ACASXU-HARD

Property	Network	Result	Time
1	4-6	Satisfied	179.9815
1	4-8	Satisfied	-
2	3-3	Satisfied	294.5314
2	4-2	Satisfied	-
2	4-9	Unsatisfied	-
2	5-3	Unsatisfied	9.6322
3	3-6	Satisfied	3.365
3	5-1	Satisfied	27.1318

7	1-9	Unsatisfied	-
9	3-3	Satisfied	-

2.3 PAT-FCN

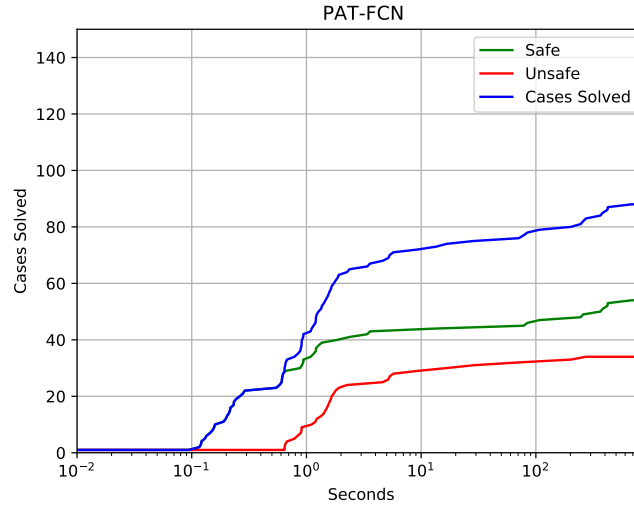


Figure 2: PAT-FCN Cactus Plot

Table 3: Total runtime (sec) for MNIST-ALL

Network	Radius	Image	Result	Time
MNIST-256x2	0.02	1	Unsatisfied	0.6763
MNIST-256x2	0.02	2	Satisfied	0.0942
MNIST-256x2	0.02	3	Unsatisfied	0.8931
MNIST-256x2	0.02	4	Satisfied	0.6114
MNIST-256x2	0.02	5	Unsatisfied	0.6439
MNIST-256x2	0.02	6	Satisfied	0.6173
MNIST-256x2	0.02	7	Satisfied	0.9136
MNIST-256x2	0.02	8	Satisfied	1.2727
MNIST-256x2	0.02	9	Unsatisfied	0.6444
MNIST-256x2	0.02	10	Satisfied	0.1165
MNIST-256x2	0.02	11	Satisfied	0.1443
MNIST-256x2	0.02	12	Satisfied	0.1524
MNIST-256x2	0.02	13	Satisfied	0.1214
MNIST-256x2	0.02	14	Satisfied	0.1595
MNIST-256x2	0.02	15	Satisfied	0.1205

MNIST-256x2	0.02	16	Satisfied	0.5822
MNIST-256x2	0.02	17	Satisfied	0.5444
MNIST-256x2	0.02	18	Satisfied	0.6259
MNIST-256x2	0.02	19	Unsatisfied	0.6532
MNIST-256x2	0.02	20	Satisfied	0.6598
MNIST-256x2	0.02	21	Satisfied	0.6084
MNIST-256x2	0.02	22	Satisfied	1.1526
MNIST-256x2	0.02	23	Satisfied	0.1301
MNIST-256x2	0.02	24	Satisfied	0.1343
MNIST-256x2	0.02	25	Unsatisfied	0.8369
MNIST-256x2	0.05	1	Unsatisfied	1.7318
MNIST-256x2	0.05	2	Unsatisfied	0.786
MNIST-256x2	0.05	3	Unsatisfied	28.5967
MNIST-256x2	0.05	4	Unsatisfied	5.31
MNIST-256x2	0.05	5	Unsatisfied	1.4212
MNIST-256x2	0.05	6	Unsatisfied	1.2294
MNIST-256x2	0.05	7	Unsatisfied	1.4644
MNIST-256x2	0.05	8	Unsatisfied	1.6335
MNIST-256x2	0.05	9	Unsatisfied	1.3429
MNIST-256x2	0.05	10	Unsatisfied	1.1098
MNIST-256x2	0.05	11	Satisfied	1.2109
MNIST-256x2	0.05	12	Unsatisfied	0.9073
MNIST-256x2	0.05	13	Unsatisfied	1.5871
MNIST-256x2	0.05	14	Unsatisfied	5.7134
MNIST-256x2	0.05	15	Unsatisfied	4.6201
MNIST-256x2	0.05	16	Satisfied	13.4976
MNIST-256x2	0.05	17	Unsatisfied	2.2613
MNIST-256x2	0.05	18	Unsatisfied	1.5126
MNIST-256x2	0.05	19	Unsatisfied	0.9062
MNIST-256x2	0.05	20	Unsatisfied	1.7954
MNIST-256x2	0.05	21	Unsatisfied	1.5534
MNIST-256x2	0.05	22	Unsatisfied	1.6605
MNIST-256x2	0.05	23	Satisfied	3.5744
MNIST-256x2	0.05	24	Unsatisfied	1.1987
MNIST-256x2	0.05	25	Unsatisfied	1.9133
MNIST-256x4	0.02	1	Satisfied	0.1892
MNIST-256x4	0.02	2	Satisfied	0.1567
MNIST-256x4	0.02	3	Satisfied	382.9116
MNIST-256x4	0.02	4	Satisfied	0.2179
MNIST-256x4	0.02	5	Satisfied	0.2109
MNIST-256x4	0.02	6	Satisfied	1.8719
MNIST-256x4	0.02	7	Satisfied	0.2154
MNIST-256x4	0.02	8	Undecided	900.1001
MNIST-256x4	0.02	9	Satisfied	1.3638
MNIST-256x4	0.02	10	Satisfied	0.1979
MNIST-256x4	0.02	11	Satisfied	0.9395

MNIST-256x4	0.02	12	Satisfied	0.233
MNIST-256x4	0.02	13	Satisfied	0.2894
MNIST-256x4	0.02	14	Satisfied	0.2328
MNIST-256x4	0.02	15	Satisfied	0.8821
MNIST-256x4	0.02	16	Satisfied	0.243
MNIST-256x4	0.02	17	Satisfied	2.369
MNIST-256x4	0.02	18	Satisfied	0.203
MNIST-256x4	0.02	19	Unsatisfied	9.3594
MNIST-256x4	0.02	20	Satisfied	0.9376
MNIST-256x4	0.02	21	Satisfied	84.4196
MNIST-256x4	0.02	22	Satisfied	1.0877
MNIST-256x4	0.02	23	Satisfied	0.2801
MNIST-256x4	0.02	24	Satisfied	0.2623
MNIST-256x4	0.02	25	Satisfied	3.3996
MNIST-256x4	0.05	1	Undecided	900.0995
MNIST-256x4	0.05	2	Undecided	900.0998
MNIST-256x4	0.05	3	Undecided	900.0988
MNIST-256x4	0.05	4	Undecided	900.0987
MNIST-256x4	0.05	5	Undecided	900.0989
MNIST-256x4	0.05	6	Undecided	900.0979
MNIST-256x4	0.05	7	Undecided	900.0991
MNIST-256x4	0.05	8	Unsatisfied	273.5101
MNIST-256x4	0.05	9	Undecided	900.0981
MNIST-256x4	0.05	10	Undecided	900.0995
MNIST-256x4	0.05	11	Undecided	900.0974
MNIST-256x4	0.05	12	Undecided	900.1006
MNIST-256x4	0.05	13	Undecided	900.0972
MNIST-256x4	0.05	14	Undecided	900.0983
MNIST-256x4	0.05	15	Undecided	900.097
MNIST-256x4	0.05	16	Undecided	900.0968
MNIST-256x4	0.05	17	Undecided	900.0993
MNIST-256x4	0.05	18	Undecided	900.0971
MNIST-256x4	0.05	19	Unsatisfied	70.9781
MNIST-256x4	0.05	20	Undecided	900.0972
MNIST-256x4	0.05	21	Undecided	900.099
MNIST-256x4	0.05	22	Undecided	900.0987
MNIST-256x4	0.05	23	Undecided	900.0972
MNIST-256x4	0.05	24	Undecided	900.0982
MNIST-256x4	0.05	25	Undecided	900.0979
MNIST-256x6	0.02	1	Undecided	900.097
MNIST-256x6	0.02	2	Satisfied	1.206
MNIST-256x6	0.02	3	Undecided	900.0975
MNIST-256x6	0.02	4	Satisfied	78.1257
MNIST-256x6	0.02	5	Satisfied	419.6577
MNIST-256x6	0.02	6	Undecided	900.0995
MNIST-256x6	0.02	7	Undecided	900.0979

MNIST-256x6	0.02	8	Undecided	900.0986
MNIST-256x6	0.02	9	Unsatisfied	5.1873
MNIST-256x6	0.02	10	Satisfied	423.9555
MNIST-256x6	0.02	11	Satisfied	107.5664
MNIST-256x6	0.02	12	Undecided	900.0994
MNIST-256x6	0.02	13	Undecided	900.1008
MNIST-256x6	0.02	14	Undecided	900.0894
MNIST-256x6	0.02	15	Undecided	900.0994
MNIST-256x6	0.02	16	Satisfied	683.2714
MNIST-256x6	0.02	17	Undecided	900.0988
MNIST-256x6	0.02	18	Undecided	900.0982
MNIST-256x6	0.02	19	Undecided	900.0998
MNIST-256x6	0.02	20	Satisfied	364.6946
MNIST-256x6	0.02	21	Undecided	900.0983
MNIST-256x6	0.02	22	Undecided	900.0975
MNIST-256x6	0.02	23	Satisfied	245.8606
MNIST-256x6	0.02	24	Satisfied	257.913
MNIST-256x6	0.02	25	Undecided	900.0981
MNIST-256x6	0.05	1	Undecided	900.0964
MNIST-256x6	0.05	2	Undecided	900.0985
MNIST-256x6	0.05	3	Undecided	900.0969
MNIST-256x6	0.05	4	Undecided	900.0993
MNIST-256x6	0.05	5	Undecided	900.0991
MNIST-256x6	0.05	6	Undecided	900.0992
MNIST-256x6	0.05	7	Undecided	900.0991
MNIST-256x6	0.05	8	Undecided	900.0969
MNIST-256x6	0.05	9	Unsatisfied	201.7524
MNIST-256x6	0.05	10	Undecided	900.098
MNIST-256x6	0.05	11	Undecided	900.0991
MNIST-256x6	0.05	12	Undecided	900.0964
MNIST-256x6	0.05	13	Undecided	900.0994
MNIST-256x6	0.05	14	Undecided	900.0972
MNIST-256x6	0.05	15	Undecided	900.0965
MNIST-256x6	0.05	16	Undecided	900.0999
MNIST-256x6	0.05	17	Undecided	900.0985
MNIST-256x6	0.05	18	Undecided	900.0998
MNIST-256x6	0.05	19	Unsatisfied	16.6724
MNIST-256x6	0.05	20	Undecided	900.0985
MNIST-256x6	0.05	21	Undecided	900.1005
MNIST-256x6	0.05	22	Undecided	900.0997
MNIST-256x6	0.05	23	Undecided	900.0967
MNIST-256x6	0.05	24	Undecided	900.0998
MNIST-256x6	0.05	25	Undecided	900.0972

References

- [1] E. Botoeva, P. Kouvaros, J. Kronqvist, A. Lomuscio, and R. Misener. Efficient verification of neural networks via dependency analysis. In *Proceedings of the 34th AAAI Conference on Artificial Intelligence (AAAI20)*. AAAI Press, 2020.