

DRL Bridge bidding Inventor by using Reinforcement Learning(RL)

An attempt to learn and use bidding systems. (se feb 1 update below!)

As an example we used the continuation after 1 Spade(5+,12-21 h.c.p) – 1 NT (0-2 spades, 8-11).

The basic idea is to have a policy to recommend an action (bid) given a situation (state, hand in our case). We assume a Markov Decision Process (MDP).

Sometimes RL is used in a table with entries but often the table would be very demanding on memory and can't interpolate between the learnt cases. In our case, assuming max 30 hcp and 15 different bids (2C up to 4 NT as a rebid after 1Sp-1NT) and 15 2nd response bids are possible the size would be:

$13*13*13*13*30*15*15 = 192$ GB RAM if only one byte is used; *8 if floating point numbers, so we go for a Neural net: 4 layers of 100 neurons each is a much smaller number but introduces a second learning problem; train/learn the net and learn actions simultaneously, easy to get unstable/bad learning.

We have encoded the shape of the hand and hcp together with inputs for bidding history. Previously we used one number for a bid (like 6 for 2C, 7 for 2D) we have now used one-hot-encoding; a vector of mostly zeroes but a 1 in the position for a bid making it easier for the neural network to handle/learn; [2C 2D 2H ..] so 2D is encoded as [0 1 0 0 ..]. This results in a input-layer size of $5(N)+5(S)+15(\text{rebid})+15(2\text{nd response}) = 40$ inputs

North having 5-7 s, 12-21 hcp. S have 0-2 s and 8-11 hcp is quite diverse but we anyhow now use separate positions for N and S into one larger neural net but hopefully it can differ between the hands; in a bidding situation the other hand is encoded as [0 0 0 0 0].

Learning rates 1e-3, 1e-4, 1e-5, 1e-6, 1e-7 was tried; not much difference but 1e-6 sometimes better, takes more time but results are often better.

We tried standard table Q-learning and Deep Q learning (with DQN-algorithm) without success.

Now we try the Distributed Action Advantage Critic (DA2C); an algorithm that try to learn an action (bid) to give in a situation but also learns from a Critic which tries to estimate if the selected bid is good or bad, it is called policy-learning and if it looks advantageous; will we arrive in a better contract? And the policy is random at start; what bid to select (2C, 2D etc ?) is random first and presented as a distribution with percentages like [0.2 0.2 0.2 0.2 0.2] which means each of the 5 actions will be selected with a 20% chance. After some training the distribution hopefully change into [0.0 0.0 1.0 0.0] always selecting the third bid (2H). The probabilities are normally stored as logarithmic values “logits” so 1 becomes 0 (log1 is 0) and smaller numbers negative so 0.2 is stored as a $\log(0.2) = -1.6$ which simplifies numerically and rangewise.

Experiences;

1. Gamma = 0.95 reduces the future values by this factor and encourages short biddings?

Well, because we compare with par-result and losing imps the results are negative resulting in strange learning.

Solution: Add offset +20 imps to results to keep them positive (+20 corresponds to par-result), subtract 20 when printing/showing to the user.

2. Adding more bids actually got worse performance than just a single rebid (-4 imps/deal); what to do if partner just bid random 3 C or 4D after my rebid ? – better to pass and play in 1 NT.

Solution: Don't allow Pass as rebid..later: create new examples with excluded hands like (semi)bal 5 sp and 11-13 h.c.p assuming to be passed.

3. Couldn't solve DA2C-algorithm on GPU.. but worked good on multi-core CPUs and actually faster. Now a run with 2 million trial bids took 15 mins on a 5 yr old i5-8700K with 12 hyperthreaded cores, using 10 and saving 2 for GUI etc.

Examples (Learning rate = 1e-6, two bids, no pass-rebid)

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1♠-Bidding Contract Score Impdiff (Parscore) N[shape,hcp] S[shape,hpc] N-cards E-cards S-cards W-cards
1N 2♠ 2N -100 -5 ( 110 ) [6, 2, 3, 2, 15] [1, 3, 3, 6, 9] n AKJ987.A6.K64.T8 e 642.873.AQJ93.32 s T.KQ5.T82.KJ7654 w Q53.JT942.75.AQ9
1N 3♠ 3♠ 170 -6 ( 420 ) [5, 1, 5, 2, 18] [2, 4, 2, 5, 8] n AQJ84.A.AKT52.63 e 7.862.Q986.KQT54 s K6.K975.J3.J9872 w T9532.QJT43.74.A
1N 2♠ 2N 180 -6 ( 430 ) [5, 3, 3, 2, 15] [2, 2, 5, 4, 8] n AQJ74.KJT.JT8.K3 e 52.74.9764.A8764 s T9.65.KQ532.QJ92 w K863.AQ9832.A.T5
1N 2♦ 2N 180 -7 ( 450 ) [6, 1, 1, 5, 13] [2, 4, 3, 4, 11] n AJ9853.K.4.KQT96 e 764.Q62.KJ972.A5 s T2.A975.AQT.J842 w KQ.JT843.8653.73
1N 3♠ 4♠ 190 -15 ( 1440 ) [6, 2, 3, 2, 15] [1, 3, 3, 6, 11] n AQ9632.AQ.K96.T9 e T874.KJT9854.5.K s 5.732.A32.AQJ864 w KJ.6.QJT874.7532
1N 2♠ 2♦ 130 -8 ( 450 ) [5, 3, 4, 1, 15] [1, 5, 3, 4, 9] n AT872.A63.K974.A e KQ43.T98.63.Q953 s 5.KQJ75.T85.KT74 w J96.42.AQJ2.J862
1N 2N 3♠ 170 -13 ( 920 ) [5, 2, 5, 1, 19] [1, 1, 4, 7, 9] n AQT53.QJ.AKQJ9.T e KJ874.A852.T6.J6 s 2.9.8743.AKQ8754 w 96.KT7643.52.932
1N 2♠ 2N 150 -7 ( 430 ) [5, 1, 4, 3, 15] [2, 4, 3, 4, 10] n AKJ86.9.AK95.654 e T972.J853.74.AJ3 s Q3.KQ76.T62.K987 w 54.AT42.QJ83.QT2
1N 2♦ 2♦ 230 -13 ( 990 ) [5, 3, 1, 4, 20] [2, 4, 5, 2, 9] n AKT32.KT2.Q.AKJ9 e 965.Q85.A762.875 s J4.AJ97.KT983.32 w Q87.643.J54.QT64
1N 2♠ 3♠ -250 -11 ( 300 ) [5, 5, 2, 1, 12] [2, 5, 2, 4, 11] n AQT96.KQ954.J9.8 e J543.A7.AT7642.K s K7.JT832.KQ.Q653 w 82.6.853.AJT9742
1N 2♦ 3♠ 110 -7 ( 420 ) [6, 1, 1, 5, 16] [2, 5, 4, 2, 9] n AKQ984.K.5.KJ852 e J2.T87.QJ84.QT94 s T6.Q9542.AK97.63 w 753.AJ63.T632.A7
1N 2♠ 2N 150 -6 ( 400 ) [5, 3, 3, 2, 15] [1, 3, 4, 5, 11] n A8432.K83.A54.KJ e T.A752.762.98765 s Q.Q64.KQT8.QT432 w KJ9765.JT9.J93.A
1N 2♥ 2N 150 -7 ( 420 ) [5, 3, 4, 1, 16] [1, 5, 4, 3, 11] n AKT87.K72.KQJ2.7 e J54.QJT4.3.AQ984 s 2.A8653.A864.KT5 w Q963.9.T975.J632
1N 2N 3♠ -50 -14 ( 920 ) [5, 2, 4, 2, 17] [1, 5, 4, 3, 11] n KQT76.A6.K432.KQ e 53.KJ5.QT76.T942 s J.T9743.AJ95.AJ8 w A9842.Q82.8.7653
1N 2N 3♥ -250 -8 ( 100 ) [6, 3, 2, 2, 16] [2, 2, 6, 3, 8] n AKT984.K32.K3.K4 e J652.AJ87.9.AQ93 s 73.65.AQJ765.JT5 w Q.QT94.T842.8762
1N 2♠ 2N -100 -5 ( 110 ) [6, 2, 2, 3, 13] [2, 5, 3, 3, 9] n K96532.A5.AQ.T42 e J4.KJT8.KJ952.A7 s A7.Q9764.T74.QJ6 w QT8.32.863.K9853
1N 3♠ 3♠ 170 -6 ( 430 ) [5, 3, 1, 4, 17] [2, 4, 4, 3, 9] n KQT76.K92.8.AKQ5 e AJ2.Q74.AJ732.97 s 53.A865.KQT4.T86 w 984.JT3.965.J432
1N 3♠ 3♥ -100 -5 ( 110 ) [5, 4, 2, 2, 12] [2, 3, 5, 3, 10] n AQ632.Q873.A2.76 e 84.42.KQT85.J854 s T9.K65.J9743.AQ2 w KJ75.AJT9.6.KT93
1N 3♠ 4♠ -100 -6 ( 120 ) [5, 1, 4, 3, 12] [1, 5, 3, 4, 10] n K9864.Q.AK42.985 e 2.AJ963.QT9.AJ73 s Q.KT754.875.KQT4 w AJT753.82.J63.62
1N 2♠ 2♠ 140 0 ( 140 ) [5, 2, 4, 2, 12] [2, 4, 4, 3, 10] n KQT82.Q2.KQ84.43 e J6.K763.972.T762 s 94.AJ54.JT53.A95 w A753.T98.A6.KQJ8
1N 3♠ 4♠ -100 -11 ( 420 ) [5, 1, 3, 4, 14] [2, 6, 4, 1, 11] n AKQT9.7.Q83.QJT6 e J632.A6.65.AK983 s 74.KJT842.AK42.7 w 85.Q953.JT97.542
1N 3♠ 3N -50 -5 ( 140 ) [5, 2, 4, 2, 14] [1, 5, 4, 3, 9] n A9754.96.AKQ4.J8 e KQJ6.K5.T9.A7653 s 2.A8732.8652.KQ9 w T83.QJT4.J73.T42
1N 2♠ 2N 210 -6 ( 460 ) [6, 2, 1, 4, 14] [2, 2, 5, 4, 11] n AK8732.AQ.T.JT64 e T.JT86542..K8753 s Q4.97.QJ542.AQ92 w J965.K3.AK98763.
1N 2♠ 2♠ 110 0 ( 110 ) [5, 4, 3, 1, 12] [2, 1, 4, 6, 10] n AQT54.J863.AJ4.6 e J9.AKT97.T6.J854 s K3.5.Q752.KQ9732 w 8762.Q42.K983.AT
1N 3♠ 3♦ -50 -10 ( 400 ) [5, 1, 3, 4, 17] [2, 5, 3, 3, 10] n QJT74.J.AT6.AKQT e 3.Q7653.Q42.J962 s K5.AKT98.975.874 w A9862.42.KJ83.53
1N 2N 3♠ -150 7 ( -450 ) [5, 2, 4, 2, 14] [2, 2, 5, 4, 11] n AK853.Q9.KQ32.82 e QT7642.A6542.T.9 s J9.KJ.A9754.QT54 w .T873.J86.AKJ763
1N 2N 3♦ -100 -5 ( 90 ) [6, 2, 3, 2, 12] [1, 4, 5, 3, 9] n AT9843.A5.854.A3 e KQ765.T984.2.JT9 s J.K732.QJ976.Q72 w 2.QJ6.AKT3.K8654
1N 3♠ 3♠ -150 -11 ( 430 ) [6, 5, 0, 2, 14] [2, 3, 5, 3, 10] n AKT984.AK852..32 e 7.J643.J642.AQ94 s J5.T97.KQ873.KJ6 w Q632.Q.AT95.T875
1N 2♠ 2♠ -200 -7 ( 100 ) [5, 4, 2, 2, 13] [1, 5, 4, 3, 8] n KJ862.AKQ6.97.64 e A.873.AKJT4.AJ72 s 4.JT954.Q852.KQ5 w QT9753.2.63.T983
1N 2N 2N 120 -7 ( 420 ) [5, 1, 3, 4, 16] [2, 6, 1, 4, 8] n AKQ74.Q.T83.AJ73 e JT6.T84.KJ9654.K s 95.A76532.A.T842 w 832.KJ9.Q72.Q965
1N 3♠ 3N -150 0 ( -140 ) [5, 0, 5, 3, 12] [2, 4, 2, 5, 8] n A6542..AKJ53.754 e T.J84.QT9862.AKJ s K8.KQT3.74.T9862 w QJ973.A97652..Q3
1N 2♠ 2♠ -200 -7 ( 100 ) [6, 2, 3, 2, 12] [1, 3, 6, 3, 8] n KT8542.A8.KQ7.52 e QJ763.KT42.J4.QT s A.753.AT8652.943 w 9.QJ96.93.AKJ876
1N 2♥ 3♠ -50 -5 ( 120 ) [5, 3, 2, 3, 16] [2, 4, 3, 4, 8] n KJ632.A65.K5.KQ6 e 97.J2.98763.9873 s Q8.9843.AJ2.JT52 w AT54.KQT7.QT4.A4
1N 2♠ 2♠ 140 0 ( 140 ) [6, 2, 2, 3, 12] [2, 3, 6, 2, 10] n KT7653.A9.J6.A92 e QJ4.KJ643.KQ.JT4 s A8.Q52.A97532.53 w 92.T87.T84.KQ876
1N 2♦ 2♦ -100 0 ( -90 ) [5, 1, 4, 3, 14] [2, 5, 2, 4, 8] n AQ765.Q.7654.AQ7 e 4.KJ982.QJT2.JT9 s J9.AT764.K8.8642 w KT832.53.A93.K53
1N 2N 3♠ -50 -5 ( 140 ) [5, 3, 3, 2, 14] [0, 4, 5, 4, 8] n KT843.K95.K93.KQ e AJ952.32.74.A652 s .JT84.AQT52.JT73 w Q76.AQ76.J86.984
1N 3♠ 3♦ -200 -7 ( 90 ) [6, 2, 2, 3, 13] [1, 4, 4, 4, 9] n KQJ973.A7.73.K32 e 4.K6542.AKJT.JT7 s A.J983.Q942.Q864 w T8652.QT.865.A95
1N 2♦ 2♥ 260 -15 ( 1520 ) [5, 3, 2, 3, 15] [2, 6, 2, 3, 10] n AQJ97.T65.A3.A63 e T52.J3.KQJ62.Q87 s K3.AK9742.85.T92 w 864.Q8.T974.KJ54
1N 2♠ 3♠ 170 -13 ( 920 ) [5, 3, 3, 2, 16] [0, 2, 5, 6, 11] n KQ854.AK6.A83.T2 e A9763.Q93.54.AJ s .74.KQJT6.KQ7653 w JT2.T852.972.984
1N 2♦ 2♥ 170 -6 ( 420 ) [5, 1, 2, 5, 19] [1, 6, 4, 2, 8] n AK965.8.AJ.AK974 e T743.QT93.Q4.Q52 s J.AK7642.T753.83 w Q82.J5.K9862.JT6
1N 3♠ 3♠ -50 -11 ( 450 ) [7, 4, 1, 1, 12] [1, 3, 3, 6, 11] n AKT7543.KJ82.2.J e 8.Q94.J7643.AT75 s J.AT6.AQ8.986432 w Q962.753.KJ95.KQ
1N 2♠ 3♠ 170 -13 ( 920 ) [6, 4, 0, 3, 17] [2, 2, 8, 2, 10] n AJT643.AQ97..AQ8 e 85.J8632.Q5.KT95 s 2.K5.AKT96432.73 w KQ97.T4.J87.J642
1N 3♠ 3♠ 140 -4 ( 300 ) [6, 2, 2, 3, 15] [2, 6, 3, 2, 8] n AJ9743.K4.42.AQJ e K865.J2.K.KT8753 s Q2.AT9875.Q73.42 w T.Q63.AJT9865.96
1N 3♠ 3♠ -350 -6 ( -130 ) [7, 2, 2, 2, 12] [1, 3, 6, 3, 8] n AKQ9854.52.K3.74 e JT62.76.J54.JT92 s 7.KJ3.QT9762.Q83 w 3.AQT984.A8.AK65
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1N 2N 2N 120 -7 ( 420 ) [6, 3, 1, 3, 13] [1, 3, 5, 4, 10] n AQJT92.JT7.T.AJ6 e K765.854.Q74.Q94 s 4.Q96.AKJ52.T875 w 83.AK32.9863.K32
1N 3♣ 3♣ -50 -14 ( 980 ) [5, 6, 1, 1, 15] [2, 2, 5, 4, 8] n AQJT72.AKJT64.5.J e 986.52.AK8.KQ532 s K3.98.J9642.AT64 w J54.Q73.QT73.987
1N 2♥ 2♣ -100 1 ( -140 ) [5, 2, 5, 1, 12] [2, 3, 3, 5, 10] n AQJ92.Q4.J9862.Q e K53.KJ3.AQT74.T4 s 74.T95.K53.AK985 w T86.A8762..J7632
1N 3♣ 3N 430 0 ( 430 ) [5, 2, 2, 4, 13] [2, 2, 7, 2, 11] n AKJ97.A3.63.J842 e Q54.92.J942.9765 s 62.75.AKQT875.Q3 w T83.KQJT864..AKT
1N 3♣ 3♣ -100 -6 ( 140 ) [5, 3, 3, 2, 13] [2, 4, 2, 5, 11] n QJ876.KT3.AJ8.Q4 e KT93.872.9652.75 s 54.QJ96.KQ.KT832 w A2.A54.T743.AJ96
1N 2N 2N 210 -6 ( 460 ) [6, 2, 2, 3, 20] [2, 4, 4, 3, 9] n AKQJ43.K3.KJ.K96 e 65.75.AQ9632.QT8 s 72.A986.T875.AJ3 w T98.QJT42.4.7542
Averageimps -6.7

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Not very useful but can be improved by removing weak openers and with more training.

Running with 3 possible bids 2 milion times;

Ended with opener always bidding 2 C (instead of always pass). Learning rate 1e-6 was used, maybe another run can be better.

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1♠--Bidding Contract Score Impdiff (Parscore) N[shape,hcp] S[shape,hpc] N-cards E-cards S-cards W-cards
1N 2♣ 2♣ 110 -1 ( 140 ) [5, 3, 1, 4, 15] [2, 2, 6, 3, 10] n AQ842.T65.A.AJ73 e 965.A73.K54.T852 s 73.Q4.QJT832.KQ4 w KJT.KJ982.976.96
1N 2♣ 2♣ -100 -5 ( 110 ) [6, 1, 3, 3, 12] [1, 5, 4, 3, 10] n KQJ874.K.QT7.J83 e 3.Q8653.K9865.Q6 s 9.JT942.AJ42.A74 w AT652.A7.3.KT952
1N 2♣ 2♣ 130 -7 ( 400 ) [5, 2, 2, 4, 12] [1, 3, 4, 5, 11] n KT842.54.AK.Q943 e 53.KJ63.J965.K86 s Q.QT8.Q432.AJ752 w AJ976.A972.T87.T
1N 2♣ 2♣ 110 -7 ( 400 ) [5, 3, 2, 3, 13] [1, 4, 4, 4, 11] n AJ974.Q97.J6.AJ2 e KQ865.T4.Q82.985 s 3.AJ63.K943.KT76 w T2.K852.AT75.Q43
1N 2♣ 2♣ -200 -12 ( 450 ) [5, 6, 0, 2, 14] [1, 3, 7, 2, 9] n AKT74.AJT863..Q9 e Q653.K5.QJ82.742 s 2.Q72.KT96543.KJ w J98.94.A7.AT8653
1N 2♣ 2♣ 170 -13 ( 920 ) [5, 5, 2, 1, 15] [2, 1, 3, 7, 10] n 86543.AQ543.AK.Q e T72.T9.T96542.J6 s AJ.8.Q73.KT98542 w KQ9.KJ762.J8.A73
1N 2♣ 2♣ -50 -4 ( 110 ) [6, 1, 3, 3, 12] [1, 6, 3, 3, 9] n AT9842.3.QJ3.KQ2 e K3.Q62.98742.AJ4 s 6.AJT854.AT5.T73 w QJ75.K97.K6.9865
1N 2♣ 2♣ 170 -13 ( 990 ) [5, 3, 2, 3, 19] [1, 4, 3, 5, 10] n AKJ84.AJT.A2.Q93 e Q2.Q52.J974.AT64 s 5.K986.K63.KJ872 w T9763.743.QT85.5
1N 2♣ 2♣ -300 -5 ( -100 ) [5, 2, 5, 1, 12] [2, 2, 6, 3, 9] n AJ975.92.KQ873.Q e KT8.AT75..J98765 s Q3.K6.AT9542.T42 w 642.QJ843.J6.AK3
1N 2♣ 2♣ 150 -6 ( 400 ) [5, 2, 2, 4, 14] [2, 4, 2, 5, 10] n AKT98.J4.K5.QJ75 e QJ75.K96.Q872.K9 s 42.Q852.A3.A8642 w 63.AT73.JT964.T3
1N 2♣ 2♣ 150 -6 ( 400 ) [5, 2, 1, 5, 12] [1, 4, 5, 3, 11] n AK643.Q7.8.QJT63 e T72.KT5.AK7.9874 s 9.A963.QJ964.A52 w QJ85.J842.T532.K
1N 2♣ 2♣ 90 -2 ( 140 ) [5, 4, 3, 2, 12] [1, 4, 3, 5, 10] n Q9876.AQ74.J2.QJ e J42.9632.KQ84.54 s T.KT85.T97.AK862 w AK53.J.A653.T973
1N 2♣ 2♣ 90 -1 ( 120 ) [5, 3, 3, 2, 13] [2, 3, 3, 5, 8] n AJT95.963.QJ9.KQ e K4.K842.K7942.J6 s 73.T75.A86.AT842 w Q862.AQJ.T3.9753
1N 2♣ 2♣ 130 0 ( 140 ) [5, 2, 1, 5, 14] [2, 3, 5, 3, 11] n AKT93.J2.J.KQT65 e Q5.AK85.982.9432 s 86.T94.AQT63.AJ8 w J742.Q763.K754.7
1N 2♣ 2♣ -200 -8 ( 140 ) [5, 3, 2, 3, 12] [1, 6, 4, 2, 10] n AKQJ7.632.Q4.852 e 653.AT94.73.QJT3 s 9.KQJ875.KJ98.96 w T842..AT652.AK74
1N 2♣ 2♣ 110 0 ( 110 ) [6, 3, 3, 1, 13] [1, 2, 3, 7, 8] n AK8752.K83.432.K e J9.AJ942.AKT7.T6 s 4.Q5.QJ5.QJ85432 w QT63.T76.986.A97
1N 2♣ 2♣ 90 -8 ( 420 ) [6, 3, 4, 0, 14] [2, 2, 4, 5, 9] n AK9865.A98.K985. e 74.KQ64.T63.K853 s J2.32.QJ72.AJT76 w QT3.JT75.A4.Q942
1N 2♣ 2♣ 90 -8 ( 450 ) [5, 2, 1, 5, 14] [1, 7, 4, 1, 10] n QJT53.A4.4.AQJT7 e K9.J73.A7532.K52 s A.KQT9652.JT86.8 w 87642.8.KQ9.9643
1N 2♣ 2♣ 150 -7 ( 450 ) [5, 2, 2, 4, 13] [2, 3, 5, 3, 11] n AQT52.T9.KJ.K943 e 986.A643.QT.QJ52 s 73.K72.A8764.AT6 w KJ4.QJ85.9532.87
1N 2♣ 2♣ 130 -8 ( 460 ) [6, 3, 1, 3, 15] [1, 3, 5, 4, 11] n AQJT43.A74.3.A75 e 9862.32.KQT62.42 s K.K98.AJ874.T963 w 75.QJT65.95.KQJ8
1N 2♣ 2♣ -100 -6 ( 140 ) [5, 4, 2, 2, 16] [1, 4, 5, 3, 8] n AJT52.AQJT.86.KJ e KQ98.2.K752.QT76 s 7.K543.AJT43.842 w 643.9876.Q9.A953
1N 2♣ 2♣ 130 -8 ( 460 ) [6, 3, 2, 2, 20] [1, 4, 4, 4, 11] n AKT763.AQ7.KT.A5 e Q9542.T52.54.T92 s J.KJ84.J763.KQ83 w 8.963.AQ982.J764
1N 2♣ 2♣ 110 -7 ( 420 ) [6, 0, 3, 4, 12] [1, 4, 4, 4, 11] n AK9765..972.KQT6 e JT42.AKQ872.A64. s 8.J643.KJ98.A854 w Q3.T95.T53.J9732
1N 2♣ 2♣ 130 0 ( 130 ) [5, 1, 2, 5, 12] [2, 3, 4, 4, 9] n K9873.2.K4.AQ743 e AJ.AKQJT96.T9.J5 s 64.853.AQ85.KT82 w QT52.74.J7632.96
1N 2♣ 2♣ 90 -8 ( 420 ) [6, 4, 2, 1, 15] [0, 3, 5, 5, 8] n AKQ632.Q832.A8.4 e T87.AK975.Q5.963 s .JT4.97432.AKT72 w J954.6.KJT6.QJ85
1N 2♣ 2♣ 90 0 ( 90 ) [5, 4, 2, 2, 12] [2, 2, 4, 5, 8] n A9862.KJ53.KJ.84 e KQJ.AT6.T82.A953 s T4.Q2.9643.KQJ62 w 753.9874.AQ75.T7
1N 2♣ 2♣ 150 -7 ( 460 ) [5, 2, 3, 3, 19] [2, 4, 3, 4, 9] n KQT94.AQ.AT6.A54 e J762.9632.93.J96 s 83.KJ87.K72.QT87 w A5.T54.QJ854.K32
1N 2♣ 2♣ -200 -8 ( 140 ) [7, 2, 1, 3, 16] [2, 5, 4, 2, 8] n AKQT653.53.A.K96 e 987.762.T53.AT42 s 42.KQT84.QJ64.85 w J.AJ9.K9872.QJ73
1N 2♣ 2♣ -100 -11 ( 400 ) [5, 2, 4, 2, 12] [2, 5, 3, 3, 9] n A9754.A6.T542.A4 e QJ.K542.QJ763.Q6 s 62.Q9873.A98.KT9 w KT83.JT.K.J87532
1N 2♣ 2♣ 110 -8 ( 450 ) [6, 4, 1, 2, 13] [2, 4, 2, 5, 9] n AKQT43.KJ52.3.T2 e J87.AT7.AKT92.J7 s 65.Q963.86.AK984 w 92.84.QJ754.Q653
1N 2♣ 2♣ 150 2 ( 100 ) [6, 3, 0, 4, 15] [2, 3, 3, 5, 10] n AKJ643.KT5..AT64 e 8.A98763.K7642.3 s 75.QJ4.J93.KQJ92 w QT92.2.AQT85.875
1N 2♣ 2♣ -200 -12 ( 420 ) [5, 3, 2, 3, 15] [2, 7, 3, 1, 8] n AK752.954.A4.KJ7 e JT96.A7.QJ8.AT82 s Q8.KQJT632.T65.6 w 43.8.K9732.Q9543
1N 2♣ 2♣ 90 -8 ( 450 ) [5, 3, 2, 3, 16] [2, 5, 4, 2, 11] n AKJ83.AT8.KJ.764 e T942.J.A86.Q9832 s Q7.K9632.QT72.KJ w 65.Q754.9543.AT5
1N 2♣ 2♣ -100 -5 ( 110 ) [6, 3, 3, 1, 12] [1, 3, 4, 5, 9] n KQ8652.AJ2.Q53.8 e AT4.K94.K4.AJT73 s 7.T53.A762.KQ652 w J93.Q876.JT98.94
1N 2♣ 2♣ -200 -7 ( 100 ) [7, 3, 0, 3, 12] [0, 5, 7, 1, 10] n KQJT7432.QJ9..KT8 e 9865..JT94.A7643 s .K8432.AK87632.5 w A7.AT765.Q5.QJ92
1N 2♣ 2♣ 130 -13 ( 990 ) [5, 3, 2, 3, 17] [2, 4, 3, 4, 11] n KQT54.A84.64.AKJ e J3.Q752.872.T653 s A6.KJT6.K53.9872 w 9872.93.AQJT9.Q4
1N 2♣ 2♣ -100 -11 ( 430 ) [6, 4, 3, 0, 13] [2, 2, 4, 5, 9] n KJ8732.AT54.KQ3. e 94.Q632.JT854.KJ s T6.J7.A962.A9852 w AQ5.K98.7.QT7643
1N 2♣ 2♣ 130 -7 ( 430 ) [5, 5, 2, 1, 17] [2, 3, 3, 5, 9] n AKQ96.QT864.K3.K e T743.A.AJ42.J643 s J8.972.QT9.AQ985 w 52.KJ53.8765.T72
1N 2♣ 2♣ 130 0 ( 130 ) [5, 1, 4, 3, 15] [2, 3, 3, 5, 9] n AK765.5.Q975.AQ2 e Q4.AJT863.J64.53 s T3.KQ9.T83.KJ984 w J982.742.AK2.T76
1N 2♣ 2♣ -50 -4 ( 90 ) [6, 2, 3, 2, 12] [1, 4, 5, 3, 9] n AT9843.A5.854.A3 e KQ765.T984.2.JT9 s J.K732.QJ976.Q72 w 2.QJ6.AKT3.K8654
1N 2♣ 2♣ 90 -16 ( 1440 ) [6, 1, 4, 2, 14] [1, 3, 6, 3, 11] n AK8742.T.KT87.A3 e Q53.K7642.Q.Q642 s T.A85.A96432.KT7 w J96.QJ93.J5.J985
1N 2♣ 2♣ 130 -7 ( 400 ) [5, 3, 2, 3, 13] [1, 4, 3, 5, 11] n AQJT7.QJ5.97.KT2 e K9632.AK.QJ4.Q65 s 4.8642.AK6.A9743 w 85.T973.T8532.J8
1N 2♣ 2♣ 130 0 ( 130 ) [6, 2, 1, 4, 13] [1, 3, 4, 5, 9] n AQ9876.84.2.AQJ5 e JT.A965.QJT7.T76 s 2.QJ3.K543.K8432 w K543.KT72.A986.9
1N 2♣ 2♣ 90 -1 ( 120 ) [5, 2, 3, 3, 12] [2, 4, 4, 3, 11] n K9763.A5.962.KQ4 e A5.J832.K54.J953 s J2.QT96.AT73.AT6 w QT84.K74.QJ8.872
1N 2♣ 2♣ -50 -11 ( 450 ) [6, 3, 1, 3, 14] [2, 6, 2, 3, 11] n AKJ932.Q65.6.A93 e Q86.J8.T852.7642 s T4.KT9742.AK.J85 w 75.A3.QJ9743.KQT
1N 2♣ 2♣ -100 -14 ( 990 ) [7, 3, 1, 2, 20] [2, 5, 4, 2, 10] n AKT8753.AQJ.Q.AT e 4.83.J85432.6542 s QJ.K7542.KT97.J8 w 962.T96.A6.KQ973
1N 2♣ 2♣ 150 -7 ( 420 ) [5, 4, 1, 3, 16] [2, 2, 4, 5, 10] n KJT76.Q863.A.AQT e 52.AJ2.QT832.832 s Q9.K7.J975.KJ764 w A843.T954.K64.95
1N 2♣ 2♣ 130 -7 ( 420 ) [5, 1, 5, 2, 13] [2, 5, 1, 5, 11] n QJ764.8.AKQ84.J6 e AT3.K52.9765.Q93 s K5.A7643.2.AT752 w 982.QJT9.JT3.K84
1N 2♣ 2♣ -200 -11 ( 300 ) [5, 4, 3, 1, 13] [2, 5, 4, 2, 11] n AKQ92.KT76.J63.5 e JT84.Q842.942.A9 s 53.AJ953.KT87.K2 w 76..AQ5.QJT87643

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1N Averageimps -6.6

A try with bigger Neural net (from 75 to 100 neurons) and 11 possible bids instead of 6 resulted in 2C – pass on all deals, -7.7 imps/deal, worse..

A try with smaller net with 50 neurons and reducing layers (fully connected+ReLU) from 4 to 3: 2C-pass on all as well..

Suggestions/Ideas/Improvement

- maybe there are some bugs in the code
- trying to invent bidding backwards, reducing search space – no use to try 7NT with 13+9 hcp.
- try other algs like PPO A3C, Curiosity-based, Multi-Agent RL, evolutionary methods

Update feb 1 2023:

Found an error ; the normalization of in/output is often used in NN-training to reduce numerical problems but here it destroyed our learning: suppose our resulting score “rewards“ after 3 bids (2C – 2D, 2N) are [0 0 180] or after 3 other bids (2C – 2D, 3N) [0 0 430] but the normalization process add the sum of rewards and divide all numbers with that so $0+0+180 = 180$; $[0\ 0\ 180]/180$ gets $[0\ 0\ 1]$ but $[0\ 0\ 430]/430$ is also $[0\ 0\ 1]$ so the learning could not see any advantage in bidding 3 NT risking -50.

Anyhow it didn’t learn very well; imp scores were resulting in simply pass or 2 spades so we tried the more varied Topscore instead but 2nd responder mostly passed.

We did some other tries; here are some examples where we forced the opener to rebid 2C with any 16+ and pass with 12-13 and only 5 spades; rest was open to learn and it often selected the rebid 2 C anyhow. (source-code #9)

These were trained for one million bids; about 15 mins without GPU but 6 core CPU.

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1♠1N-Bidding Contract Score Diff (Par) N[shape,hcp] S[shape,hpc] N-cards E-cards S-cards W-cards
1N 2♣ 4♥ 420 520 ( -100 ) [5, 3, 3, 2, 16] [2, 5, 5, 1, 10] n KT873.AJ3.AQJ.J3 e AQJ2.5.T753.AK84 s 95.KQT96.K9864.Q w 64.8742.2.T97652
1N 1N -50 -500 ( 450 ) [5, 2, 4, 2, 12] [1, 8, 2, 2, 11] n QT984.72.AQ42.A4 e AK6.T.JT97.KT952 s J.KQJ98543.K5.J3 w 7532.A6.863.Q876
1N 2♣ 4♣ -100 -500 ( 400 ) [5, 3, 2, 3, 16] [2, 4, 4, 3, 8] n KQJ98.T98.KQ.KQ9 e AT4.5.JT853.J872 s 65.A762.A942.T65 w 732.KQJ43.76.A43
1N 1N 90 -20 ( 110 ) [5, 3, 4, 1, 12] [2, 4, 2, 5, 9] n J9542.K54.KQJ5.Q e A87.Q82.T876.K92 s KQ.T963.92.AT854 w T63.AJ7.A43.J763
1N 2♣ 4♣ -250 -150 ( -100 ) [5, 1, 3, 4, 15] [1, 2, 6, 4, 10] n AK432.K.973.AJ84 e QJT5.7654..T9532 s 8.T9.KQT862.KQ76 w 976.AQJ832.AJ54.
1N 2♣ 4♣ -50 -190 ( 140 ) [5, 2, 2, 4, 14] [2, 3, 3, 5, 11] n A9764.AJ.A3.J975 e KJ853.T53.QT654. s Q2.KQ7.872.A8632 w T.98642.KJ9.KQT4
1N 1N -50 90 ( -140 ) [5, 2, 2, 4, 13] [2, 4, 4, 3, 8] n AT972.KQ.A5.9874 e K83.J65.J7.AKT52 s QJ.7432.Q832.QJ6 w 654.AT98.KT964.3
1N 2♣ 4♣ -100 -210 ( 110 ) [5, 1, 2, 5, 16] [2, 5, 3, 3, 9] n AJ764.K.J4.AQJT5 e K5.A52.QT87.K832 s Q2.QJ863.A52.976 w T983.T974.K963.4
1N 2♣ 4♣ 420 -40 ( 460 ) [5, 4, 1, 3, 19] [2, 2, 6, 3, 8] n AQJT3.KJT7.J.AK6 e 9.98654.K874.942 s 85.Q3.AQT965.T85 w K7642.A2.32.QJ73
1N 2♣ 4♣ -50 -190 ( 140 ) [6, 2, 2, 3, 12] [2, 3, 3, 5, 11] n AKT742.54.A4.J82 e J86.KJ86.KQJ75.6 s 53.A93.T83.AKT53 w Q9.QT72.962.Q974
1N 2♣ 4♣ -50 -190 ( 140 ) [6, 3, 2, 2, 12] [2, 1, 3, 7, 10] n JT9742.KT4.A6.KJ e Q6.AQ972.QT74.T5 s K5.J.985.AQ87643 w A83.8653.KJ32.92
1N 2♣ 4♣ -200 -90 ( -110 ) [6, 3, 2, 2, 13] [1, 3, 3, 6, 8] n AKT642.J94.KQ.98 e 3.AKQ53.A874.J65 s J.T72.JT2.AQ7432 w Q9875.86.9653.KT
1N 2♣ 4♣ 420 -500 ( 920 ) [5, 2, 1, 5, 15] [1, 4, 4, 4, 11] n AKJ98.53.A.KT975 e QT52.QT97.T832.4 s 7.AK42.K764.J832 w 643.J86.QJ95.AQ6
1N 2♣ 4♣ 450 -10 ( 460 ) [6, 1, 2, 4, 14] [1, 3, 6, 3, 10] n AQJ983.6.T3.AKT9 e 62.AKJ974.K96.72 s T.QT8.AQJ854.J63 w K754.532.72.Q854
1N 2♣ 4♣ -50 50 ( -100 ) [6, 2, 2, 3, 13] [2, 2, 4, 5, 10] n KQJ872.J5.Q5.A42 e 53.T9732.K2.QT73 s T4.Q8.A964.KJ965 w A96.AK64.JT873.8
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1N 1N 90 -20 (110) [5, 3, 3, 2, 12] [2, 4, 1, 6, 10] n K9875.A62.KQ8.T4 e Q642.KJ83.A65.J6 s J3.Q975.7.AK8732 w AT.T4.JT9432.Q95
 1N 2♣ 4♥ 450 -10 (460) [6, 3, 1, 3, 15] [1, 5, 5, 2, 11] n AKQJ97.K32.3.Q84 e T432.94.A82.A763 s 6.AJT85.K9765.K9 w 85.Q76.QJT4.JT52
 1N 2♣ 4♠ 450 -190 (140) [6, 4, 1, 2, 12] [1, 1, 7, 4, 9] n AKT742.AT92.9.J8 e Q63.KJ5.KQ4.K532 s 9.7.AJT8752.AT76 w J85.Q8643.63.Q94
 1N 2♣ 4♠ 450 -470 (420) [5, 3, 2, 3, 14] [2, 5, 4, 2, 10] n JT652.AQ9.KJ.QJ4 e KQ4.53.763.AT872 s A8.J8764.Q842.K6 w 973.KT2.AT95.953
 1N 1N -100 -240 (140) [5, 3, 3, 2, 12] [1, 5, 5, 2, 10] n QT742.AT7.Q65.A9 e J9865.986.J4.J62 s K.Q5432.KT873.Q4 w A3.KJ.A92.KT8753
 1N 2♣ 4♠ 450 -480 (430) [5, 4, 2, 2, 16] [1, 3, 3, 6, 9] n QJT42.AK42.A8.Q5 e K963.876.KT32.KT s 5.Q95.Q96.AJ8643 w A87.JT3.J754.972
 1N 1N -150 -250 (100) [5, 1, 4, 3, 13] [2, 2, 5, 4, 8] n AQ962.9.AQJ3.986 e J8.KT864.73.AQT7 s KT.J5.KT654.J542 w 7543.AQ732.98.K3
 1N 2♣ 4♥ 450 -200 -100 (-100) [7, 2, 3, 1, 12] [1, 4, 3, 5, 8] n A987543.53.AK3.J e KJT2.AQJ64.5.KT2 s 6.K872.J72.A8763 w Q.T9.QT9864.Q954
 1N 2♣ 4♠ 450 -510 (460) [5, 1, 1, 6, 16] [1, 2, 6, 4, 11] n KJT53.K.K.AQT964 e Q986.J982.J73.83 s 7.Q3.AQ9842.K752 w A42.AT7654.T65.J
 1N 2♣ 4♠ 450 0 (420) [6, 3, 4, 0, 15] [0, 3, 2, 8, 11] n AKQJ64.K85.Q632 e 87532.QT32.A5.32 s .AJ9.84.KQJ98754 w T9.764.KJT97.AT6
 1N 2♣ 4♠ 450 0 (420) [7, 2, 2, 2, 17] [1, 3, 3, 6, 8] n AKJT854.K6.K9.QJ e 76.Q94.AJ64.9874 s 2.J32.T72.AKT653 w Q93.AT875.Q853.2
 1N 1N 150 -270 (420) [5, 3, 2, 3, 13] [1, 6, 3, 3, 11] n KQJ43.J54.Q3.A73 e T9872.98.T97.K95 s 6.AKT732.K82.JT2 w A5.Q6.AJ654.Q864
 1N 2♣ 4♠ 450 -450 (400) [6, 2, 4, 1, 14] [1, 4, 5, 3, 8] n AKJ862.62.AQT6.3 e 5.AQJ93.97.KQT76 s 4.K874.KJ853.J52 w QT973.T5.42.A984
 1N 2♣ 4♠ 450 320 (100) [6, 1, 2, 4, 12] [2, 2, 5, 4, 9] n AKQ986.6.52.KT98 e 7543.KT9753.Q6.7 s JT.84.A9874.A653 w 2.AQJ2.KJT3.QJ42
 1N 2♣ 4♠ 450 0 (450) [6, 3, 4, 0, 16] [2, 5, 2, 4, 8] n A97654.AK3.KQ94 e K82.42.765.AJ984 s Q3.QJT75.JT.OT73 w JT.986.A832.K652
 1N 2♣ 4♠ 450 -990 (1440) [5, 1, 4, 3, 21] [0, 4, 5, 4, 11] n KQJT2.A.AK83.A54 e A53.J732.J2.T832 s .KT54.Q9765.KQJ6 w 98764.Q986.T4.97
 1N 2♣ 4♠ 450 -190 (140) [6, 3, 2, 2, 15] [2, 3, 3, 5, 8] n AKQ432.Q54.T7.AT e J7.963.QJ2.Q9753 s 85.K87.A64.J8642 w T96.AJT2.K9853.K
 1N 1N 240 -750 (990) [5, 4, 3, 1, 13] [1, 3, 5, 4, 10] n AQ952.AQJT.652.6 e JT43.763.QJ.AJ92 s 7.982.AKT98.K875 w K86.K54.743.QT43
 1N 1N 120 0 (120) [5, 1, 4, 3, 13] [2, 4, 2, 5, 10] n KT984.2.K842.AK3 e AQJ762.KJ6.7.654 s 53.AQ84.J9.QJT97 w .T9753.AQT653.82
 1N 1N 90 -20 (110) [5, 2, 4, 2, 12] [2, 3, 2, 6, 11] n KJ763.A8.A653.98 e AQ5.T72.KJT84.72 s 98.QJ9.Q7.KQJT63 w T42.K6543.92.A54
 1N 2♣ 4♠ 450 -470 (420) [6, 4, 1, 2, 12] [2, 4, 6, 1, 9] n KQJ785.QJT5.K.75 e 942.A6.T75.AJ984 s A7.9843.AJ9642.2 w 63.K72.Q83.KQT63
 1N 2♣ 4♥ 450 0 (420) [6, 3, 3, 1, 14] [1, 4, 5, 3, 8] n AKT953.KJ6.K86.8 e QJ2.A3.95.AKQ974 s 8.Q984.AQT73.532 w 764.T752.J42.JT6
 1N 2♣ 4♠ 450 -100 -1080 (980) [5, 5, 1, 2, 14] [0, 3, 4, 6, 11] n KQT42.KQJ54.K.87 e A98.63.J9643.K93 s .987.AT72.AQJ542 w J7653.AT2.Q85.T6
 1N 2♣ 4♠ 450 -10 (460) [8, 1, 1, 3, 13] [2, 5, 4, 2, 11] n AKQT9864.5.7.A65 e 2.9842.Q94.JT983 s 53.AQJ63.KJ82.72 w J7.KT7.AT653.KQ4
 1N 2♣ 4♠ 450 -150 -270 (120) [6, 1, 3, 3, 12] [1, 4, 5, 3, 10] n AKJ965.K.J96.T94 e 4.QT7632.KQ5.753 s 8.AJ85.AT843.J82 w QT732.94.72.AKQ6
 Average diff over 1000 bids: -2.09e+02

Another one with 2D = 16+ and pass with 11-12, only 5 sp and other to be used (incl 2D showing something else..)

1♠1N-Bidding Score Diff (Par) N[shape,hcp] S[shape,hcp] N-cards E-cards S-cards W-cards
 1N 2♦ 2♥ 170 -250 (420) [6, 0, 5, 2, 14] [2, 6, 2, 3, 10] n AK8543..A9864.K5 e .KQ72.J73.QJ9732 s 97.A98654.Q5.A86 w QJT62.JT3.KT2.T4
 1N 2♣ 4♥ 480 -500 (980) [5, 4, 4, 0, 16] [2, 4, 4, 3, 8] n AK843.KA74.Q872 e T62.985.5.AJ9754 s Q9.JT62.AJT9.T63 w J75.Q3.K643.KQ82
 1N 2♦ 2♥ 140 -260 (400) [6, 1, 3, 3, 14] [1, 2, 5, 5, 10] n AK6432.A.T65.K83 e T875.K765.A9.A62 s J.98.KQJ43.QJT94 w Q9.QJT432.872.75
 1N 2♣ 2♦ 170 -250 (420) [5, 1, 5, 2, 17] [0, 7, 0, 6, 8] n AKQ94.Q.AQT83.62 e T865.J9.J742.K73 s .KT87432..AJT985 w J732.A65.K965.Q4
 1N 2♣ 4♥ 420 0 (420) [6, 4, 1, 2, 17] [2, 3, 5, 3, 8] n KJ9632.AK86.A.Q7 e Q754.J9543.T4.AK s AT.QT2.Q9532.852 w 8.7.KJ876.JT9643
 1N 2♦ 2♥ 170 -260 (430) [6, 2, 4, 1, 15] [2, 5, 3, 3, 11] n AQ9542.A4.AJT5.3 e .QJ.7642.AQJ7654 s 63.K9752.KQ8.KT2 w KJT87.T863.93.98
 1N 2♦ 2♥ 140 0 (140) [6, 1, 3, 3, 12] [0, 5, 5, 3, 10] n AQ9875.A.QT4.543 e KJ4.J943.A9.K976 s .QT875.J8532.AQJ w T632.K62.K76.T82
 1N 2♣ 4♥ 450 0 (450) [5, 3, 2, 3, 18] [2, 1, 5, 5, 8] n AK982.K42.A5.A93 e JT5.QJ5.T42.QT84 s Q4.T.Q9876.KJ752 w 763.A98763.KJ3.6
 1N 2♦ 2♥ 170 -250 (420) [7, 1, 2, 3, 14] [2, 5, 4, 2, 9] n QJT9862.K.A5.AT7 e 74.A6.JT642.QJ52 s 53.J9753.KQ97.K6 w AK.QT842.83.9843
 1N 90 -50 (140) [5, 2, 2, 4, 12] [2, 4, 3, 4, 8] n AJ974.J3.J7.AJ87 e Q52.K642.KT3.543 s 86.AQ95.852.QT96 w KT3.T87.AQ964.K2
 1N -50 -180 (130) [5, 1, 3, 4, 12] [2, 4, 3, 4, 11] n A7532.9.AK9.J854 e KQ64.AT62.432.63 s 98.Q853.Q65.AKT7 w JT.KJ74.JT87.Q92
 1N 2♣ 4♥ -100 -240 (140) [6, 3, 2, 2, 17] [2, 5, 4, 2, 8] n AQ9652.KQ6.A7.QT e T43.A.Q8632.9764 s KJ.T8732.KJT9.82 w 87.J954.54.AKJ53
 1N 2♣ 4♥ 420 -30 (450) [5, 2, 2, 4, 16] [2, 6, 2, 3, 9] n AQ842.A8.42.AQT3 e JT63.65.AQ7653.7 s K9.KT9743.K9.842 w 75.QJ2.JT8.KJ965
 1N 2♦ 2♥ 140 0 (140) [6, 4, 2, 1, 12] [1, 3, 6, 3, 8] n AT8765.AK95.J4.2 e KJ3.Q874.63.KQT8 s 4.T63.AKT975.J97 w Q92.J2.Q82.A6543
 1N 2♦ 2♥ 110 0 (110) [6, 4, 1, 2, 13] [1, 2, 6, 4, 8] n AQJ652.A985.Q.42 e K83.KQJ64.A65.75 s T.72.JT9843.AKT8 w 974.T3.K72.QJ963
 1N -50 -160 (110) [5, 5, 1, 2, 12] [2, 1, 6, 4, 10] n AJ863.A9542.4.KT e K97.K863.K97.AQ6 s Q5.J.AQJ862.9543 w T42.QT7.T53.J872
 1N -100 -10 (-90) [5, 2, 2, 4, 12] [2, 4, 4, 3, 9] n T9843.KQ.63.AK52 e K5.9753.JT985.83 s Q2.JT62.KQ72.J64 w AJ76.A84.A4.QT97
 1N 2♣ 4♥ -150 -950 (800) [6, 2, 2, 3, 16] [0, 4, 1, 8, 8] n AKQT94.A7.96.QJ6 e J762.43.AQJ82.92 s .J986.3.AKT87543 w 853.KQT52.KT754.
 1N 2♦ 2♥ 140 40 (100) [7, 2, 1, 3, 12] [2, 2, 7, 2, 10] n AKT9852.J2.Q.Q94 e Q6.Q76.95.AT8762 s J4.83.AKJ6432.J5 w 73.AKT954.T87.K3
 1N 150 -250 (400) [5, 3, 3, 2, 13] [1, 3, 5, 4, 11] n AJT92.A94.JT4.K4 e 8764.QJ75.3.Q932 s 3.863.AQ972.AJT7 w KQ5.KT2.K865.865
 1N 90 -10 (100) [5, 1, 3, 4, 13] [2, 4, 3, 4, 11] n KJ742.Q.A93.K932 e A8653.A982.K6.T4 s QT.T765.Q42.AQJ6 w 9.KJ43.JT875.875
 1N 2♦ 2♥ 110 -30 (140) [6, 4, 1, 2, 12] [2, 4, 4, 3, 9] n A97642.T432.A.KJ e QT8.A965.8542.Q9 s J5.KQ87.QJT7.T84 w K3.J.K963.A76532
 1N 2♦ 2♥ 200 -250 (450) [7, 4, 0, 2, 15] [1, 3, 4, 5, 8] n KQT9765.QJ93..AK e 83.KT.QK96.T9876 s 2.A64.JT83.QJ532 w AJ4.8752.A7542.4
 1N 2♦ 2♥ 110 10 (100) [5, 2, 3, 3, 15] [2, 2, 5, 4, 9] n AJ865.AK.943.K85 e Q972.7952.A.QT94 s 43.J7.QJT52.AJ72 w KT.Q8643.K876.63
 1N 90 -330 (420) [5, 5, 1, 2, 12] [1, 5, 4, 3, 9] n KQJT5.A7432.4.Q7 e A98.K.KQT83.J985 s 2.JT985.AJ97.K42 w 7643.Q6.652.AT63
 1N 2♦ 2♥ 140 0 (140) [5, 3, 2, 3, 15] [2, 3, 4, 4, 10] n AQJ94.Q63.K6.KT2 e K63.AKJ942.T7.J4 s 85.T85.A853.AQ97 w T72.7.QJ942.8653
 1N 2♣ 4♥ 480 -510 (990) [6, 4, 3, 0, 16] [2, 3, 5, 3, 11] n AKQ943.AKT8.T98 e 8.9743.K7432.J43 s T5.J86.AQJ65.KT8 w J762.Q5..AQ97652
 1N 2♦ 2♥ 140 0 (140) [5, 2, 0, 6, 14] [2, 5, 4, 2, 8] n AQJT7.AT..QJ9543 e 9842.96.QT875.K7 s 63.KJ743.A643.T8 w K5.Q852.KJ92.A62
 1N -100 0 (-100) [5, 2, 2, 4, 13] [1, 5, 4, 3, 8] n K8642.K6.AK.9752 e QJ7.74.953.AKT63 s 5.QJT52.Q742.QJ8 w AT93.A983.JT86.4
 1N -50 -190 (140) [5, 1, 4, 3, 13] [1, 3, 3, 6, 8] n AKQJ8.6.QJ97.T74 e T643.T8743.AK.92 s 7.952.T84.AKJ853 w 952.AKQJ.6532.Q6
 1N 2♦ 2♥ 200 -260 (460) [7, 1, 1, 4, 13] [1, 5, 5, 2, 11] n AKJ9763.2.A.J754 e T42.KQ53.J94.QT6 s 8.AT986.KT872.A9 w Q5.J74.Q653.K832
 1N 2♦ 2♥ -50 -450 (400) [5, 4, 1, 3, 15] [1, 2, 4, 6, 8] n AK642.K762.A.J42 e J87.Q985.KT954.T s T.T3.Q873.AQ9863 w Q953.AJ4.J62.K75
 1N 90 -50 (140) [5, 3, 3, 2, 12] [1, 5, 3, 4, 11] n KQJT5.K42.K86.T7 e 876.T93.Q5.Q9864 s 3.QJ865.T74.AKJ5 w A942.A7.AJ932.32
 1N 120 -20 (140) [5, 2, 4, 2, 12] [2, 4, 4, 3, 10] n KT853.K9.AQ73.87 e A2.QT653.K2.QT93 s J9.AJ84.9854.KJ4 w Q764.72.JT6.A652
 1N 2♣ 4♥ 480 -500 (980) [5, 4, 1, 3, 17] [2, 2, 6, 3, 10] n AK965.AT95.4.AQT e JT7.J843.8765.J9 s 43.K7.AQJT93.632 w Q82.Q62.K2.K8754
 1N 2♦ 2♥ 140 -260 (400) [5, 1, 3, 4, 14] [2, 5, 3, 3, 8] n AT874.2.QJ9.AKT5 e Q53.K6.KT764.Q42 s K2.T8543.A52.J97 w J96.AQJ97.83.863
 1N -100 -200 (100) [5, 3, 3, 2, 12] [2, 4, 2, 5, 8] n AQJ92.JT6.A87.97 e K84.K7.KQJ942.32 s 75.AQ83.53.Q8654 w T63.9542.T6.AKJT

1N 90 0 (90) [5, 3, 3, 2, 12] [2, 3, 4, 4, 8] n AT862.AK2.T65.J2 e K74.J95.A873.AQ9 s J5.Q73.Q942.K863 w Q93.T864.KJ.T754
1N 2♦ 2♥ 110 0 (110) [6, 1, 4, 2, 12] [2, 5, 3, 3, 9] n AK5432.9.KJ83.J6 e QJ9.JT.AQ974.A53 s 76.A8654.T65.KQ2 w T8.KQ732.2.T9874
1N 2♦ 2♥ 110 210 (-100) [6, 2, 3, 2, 12] [2, 3, 5, 3, 9] n KQJ865.J7.K85.Q5 e 743.Q984.A42.843 s A2.T63.J9763.A97 w T9.AK52.QT.KJT62
1N 2♦ 2♥ 170 -250 (420) [6, 3, 1, 3, 15] [2, 4, 4, 3, 9] n AKJ763.A54.5.K65 e T852.86.AKQ6.JT9 s 94.QJ32.T872.AQ4 w Q.KT97.J943.8732
Average diff over 1000 bids: -2.29e+02