SESSION XIII MICROPROCESSOR USERS' GROUP

Misha Pavel, *Presider*

Simulating second-guessing in on-line probability learning

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Formal processes (especially metacognitive or control processes) involved in complex human problem solving are examined in a game-playing situation with one person pitted against a microcomputer algorithm. In particular, the strategy of second-guessing is simulated in real-time in an attempt to outwit the person in a binary prediction paradigm. Aspects of success and failure are suggested. A working implementation in BASIC for a TRS-80 Level II is provided.

Because of a computer's ability to store a detailed analysis of a player's choices and higher order response contingencies, there is a widespread misconception that computers can outwit humans in simple probability learning situations (Epstein, 1967). This is simply not the case, although naive players can be beaten, at least in the short run. Human players are neither very predictable nor random (Scheibe & Bloom, 1979; Slak, Hirsch, & Syrja, 1979). Predicting their choices remains an interesting challenge for computers and for psychological theories.

In this particular attempt to outwit human guessing with ones and zeros, algorithms were used that have some possibility of being psychologically real or interesting. The basic algorithm (in Lines 1040-1740 of the program) is based on the detection of recurrence in the syntely algorithm (Psotka, 1977). In order to simulate second-guessing, the program implements this algorithm recursively on its record of previous hits and misses, thus implementing one aspect of self-awareness or metacognition (Flavell, 1977).

The basic algorithm chosen to provide a challenging opponent in binary probability learning situations is based on Simon's (1980) theory of induction. Essentially, induction or rule learning can be reduced to the use of recurrence (next, same, and complement operators) in ongoing sequences. The computer program keeps a faithful record of its human opponent's choices and

calculates a weighted probability for each higher order subsequence found. The computer tries to predict its opponent's choices on the basis of these probabilities, using an integrated average. At the same time, it maintains an accurate record of its own past hits and misses (when it was right or wrong in predicting its opponent's choices). Using the same algorithm on this second sequence (of hits and misses) creates a metaprobability for each of the higher order subsequences. This is then used in a simple decision rule to second-guess the basic algorithm.

The program operates on a sequence of up to 100 ones and zeros, typed in on-line. The computer provides its prediction and a running record of the cumulative percent correct after every one of its opponent's choices. At the end of the session, it provides a list of the sequences of hits (1) and misses (0) for the first-order algorithm and the syntely of the second-order metaprobability. Finally, it provides a 2 by 2 table of whether or not the second-order algorithm stayed with or reversed the first-order prediction, as a function of the hit or miss of the first-order prediction.

The program provides a choice of whether or not computer predictions use the second-guessing procedure. In either case, all of the summary output described above is provided.

The program also has an RS232C serial printer driver in Lines 5000-5070, needed for the LPRINT commands.

As a sample of the output, data for 10 sessions of predictions without second-guessing followed by 15 sessions with second-guessing yielded the bivariate tables shown in Table 1. The table shows that with no second-guessing in the algorithm, I outwitted the computer

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Table 1
Bivariate Tables Showing the Number of Trials Predicted Correctly and Incorrectly by the Computer, With and Without Second-Guessing

	First-Order Predictions			
	Without Second-Guessing		With Second-Guessing	
	Right	Wrong	Right	Wrong
Change	244	414	344	313
Stay	115	137	350	354
Total	359	551	694	667

60.3% of the time. However, secretly, the second-guessing algorithm was matching a very high proportion (58%) of the author's choices.

When the second-guessing algorithm was used for the computer's overt predictions, I managed a meager 51.4% victory over 15 sessions of 100 trials. Statistically speaking, this is no significant victory. In fact, my performance is not much better than if I had been matched against a random generator. Of course, the

major difference between this result and that against a random number generator is that I could have lost very badly by using a highly redundant and recurrent sequence of choices.

The computer listing is presented in the Appendix.

REFERENCES

- EPSTEIN, R. A. *The theory of gambling and statistical logic*. New York: Academic Press, 1967.
- FLAVELL, J. H. *Cognitive development*. Englewood Cliffs, N.J.: Prentice-Hall, 1977.
- PSOTKA, J. Syntely: Paradigm for an inductive psychology of memory, perception, and thinking. *Memory & Cognition*, 1977, 5, 553-560.
- SCHEIBE, K. E., & BLOOM, A. J. An empirical assault on the predictability of sequential binary choices. *Psychological Record*, 1979, 29, 487-500.
- SIMON, H. A. Problem solving and education. In D. T. Tuma & F. Reif (Eds.), *Problem solving and education*. Hillsdale, N.J.: Erlbaum, 1980.
- SLAK, S., HIRSCH, K. A., & SYRJA, K. V. Randomization of univariate and bivariate sequences and Baddeley's limited capacity hypothesis. *Journal of Psychology*, 1979, 103, 169-182.

APPENDIX

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1 GOSUB 5000
2 LPRINT"MEM MUST BE SET TO 32511"
10 LPRINT"COPYRIGHT JOSEPH PSOTKA 1436 FALLSMEAD WAY, ROCKVILLE,MD. 20854"
20 LPRINT"      (301) 762-8755      JUNE 14, 1980  "
30 LPRINT
40 LPRINT"THIS GAME TESTS YOUR PROBLEM SOLVING SKILLS. IT PROVIDES A VERY COMPLICATED PROBLEM THAT YOU MUST SOLVE. IN A SENSE, THE PROBLEM HAS NO SOLUTION. YOU MUST DO THE BEST YOU CAN."
50 LPRINT"BUT THERE IS NO SINGLE WAY TO GET THE BEST RESULTS."
60 LPRINT
70 LPRINT"YOUR TASK IS TO OUTSMART THE COMPUTER BY PREDICTING A SERIES OF ONES AND ZEROS. IN A SEQUENCE THE COMPUTER CANNOT GUESS."
80 LPRINT"HOWEVER, THE COMPUTER IS PROGRAMMED TO DISCOVER ORDER IN YOUR SEQUENCE S, AND TO TRY TO SECONDGUESS YOUR SERIES."
90 LPRINT"IF YOU COULD GUESS TRULY RANDOMLY, YOU AND THE COMPUTER WOULD TIE. IF YOU CAN DISCOVER THE COMPUTER'S SENSE OF ORDER, YOU CAN WIN."
110 LPRINT
120 LPRINT"THE COMPUTER TELLS YOU WHAT IT PREDICTED, AND GIVES YOU A RUNNING SCORE. IF THE PERCENT CORRECT IS LESS THAN .5, YOU ARE LOSING!"
130 LPRINT
140 LPRINT"THE FIRST TWO PREDICTIONS DO NOT COUNT. THEY ARE PRACTICE."
145 INPUT" IF YOU DON'T WANT SECONDGUESSING, HIT (0); OTHERWISE HIT (1):"E2
150 LPRINT
160 LPRINT"*****"
170 LPRINT
180 LPRINT"TRIAL    YOUR PREDICTION    COMPUTER'S PREDICTION    PERCENT CORRECT"
185 LPRINT"-----"
190 LPRINT
200 DIM S(100),R(100),P(100),D(2),B(100),E(100),F(100)
210 T=0:C=0
220 FOR Y=1 TO 100
230 FOR I=1 TO Y:P(I)=0:NEXT I
231 E(Y)=0
240 L=1:D(1)=0:D(2)=0:X=Y-1:Z=0:P=0
250 GOSUB 500
260 GOSUB 1040
270 GOSUB 1900
280 A=P(K)
290 FOR I=1 TO Y
291 IF P(I)>.5 THEN E(I)=E(I)+1
292 P(I)=0
293 NEXT I
300 L=1:D(1)=0:D(2)=0:P=1:Z=0
310 GOSUB 3000
315 GOSUB 3100
320 GOSUB 2000
325 PRINT
330 Y=Y+1:IF Y<101 THEN 230
340 GOSUB 2006
350 END
500 BS=INKEY$:IF BS="" THEN 500
505 B(Y)=ASC(B$)

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506 B(Y)=B(Y)-48
510 FOR I=1 TO Y: S(I)=B(I): NEXT I
520 LPRINT Y, B(Y),
530 RETURN
1040 IF Y>2 THEN 1130
1060 R(Y)=1
1065 LPRINT
1080 GOTO 330
1130 FOR J=1 TO X-1
1140 IF S(X) <> S(X-J) THEN 1300
1150 L=L+1
1160 NEXT J
1170 IF L <> X THEN 1300
1180 IF P=0 THEN 1220
1190 LET P(K)=1
1200 RETURN
1220 IF S(X)=S(Y) THEN 1250
1230 T=T+1: R(Y)=0: C=T/(X-1)
1240 LPRINT S(X), C*100
1250 IF S(X) <> S(Y) THEN 1270
1260 R(Y)=1
1270 GOTO 330
1300 IF S(X)=1 THEN 1500
1310 FOR K=L TO X-1
1320 IF S(X-K)=1 THEN 1400
1330 FOR I=1 TO X-1
1340 IF X-I-K=0 THEN 1370
1350 IF S(X-I) <> S(X-I-K) THEN 1370
1360 NEXT I
1370 LET D(S(X-K+1)+1) = D(S(X-K+1)+1) +1
1380 GOTO 1450
1400 FOR I=1 TO X-1
1410 IF X-I-K=0 THEN 1440
1420 IF S(X-I)=S(X-I-K) THEN 1440
1430 NEXT I
1440 D((1-S(X-K+1))+1)=D((1-S(X-K+1))+1) +1
1450 P(K)=D(S(Y)+1)/(D(S(Y)+1)+D((1-S(Y))+1))
1460 NEXT K
1470 GOTO 1650
1500 FOR K=L TO X-1
1510 IF S(X-K)=0 THEN 1580
1520 FOR I=1 TO X-1
1530 IF X-I-K=0 THEN 1560
1540 IF S(X-I) <> S(X-I-K) THEN 1560
1550 NEXT I
1560 D(S(X-K+1)+1) = D(S(X-K+1)+1) +1
1570 GOTO 1630
1580 FOR I=1 TO X-1
1590 IF X-I-K=0 THEN 1620
1600 IF S(X-I)=S(X-I-K) THEN 1620
1610 NEXT I
1620 D((1-S(X-K+1))+1) = D((1-S(X-K+1))+1) +1
1630 P(K)=D(S(Y)+1)/(D(S(Y)+1)+D((1-S(Y))+1))
1640 NEXT K
1650 K=K-1
1660 IF Y<10 THEN 1740
1670 FOR I=1 TO X
1680 IF S(I) <> S(Y) THEN 1710
1690 LET Z=Z+1
1710 NEXT I

1720 Z=Z/X:P(K)=(P(K)+Z)/2
1730 IF P(K)>.5 THEN PRINT "S": ELSE PRINT "D":
1740 RETURN
1900 IF P(K) > .5 THEN 1930
1910 R(Y)=0
1920 GOTO 1940
1930 R(Y)=1
1940 RETURN
2000 LPRINT P(K), C*100
2005 RETURN
2006 LPRINT "THANK YOU VERY MUCH. THAT
IS THE END!"
2008 LPRINT
2009 LPRINT " I RESPONSE FIRST CORRECTNESS SECOND P(
I)"
2010 FOR I= 1 TO Y-1
2020 LPRINT I, B(I), R(I), F(I), E(I)
2030 NEXT I
2040 A=0: B=0: C=0: D=0
2050 FOR I=10 TO Y-1
2060 IF R(I)=0 THEN 2080
2070 IF F(I)>.5 THEN C=C+1 ELSE A=A+1
2075 GOTO 2090
2080 IF F(I)>.5 THEN D=D+1 ELSE B=B+1
2090 NEXT I
2091 LPRINT "
RIGHT FIRST
WRONG"
2092 LPRINT ,A,B
2093 LPRINT " SECOND"
2094 LPRINT ,C,D
2095 END
3000 IF Y<10 THEN 3090
3010 FOR I=1 TO X
3020 S(I)=R(I)
3030 NEXT I
3040 S(Y)=1
3050 GOSUB 1040
3055 F(Y)=P(K)
3056 IF E2=0 THEN 3090
3060 IF P(K) > .5 THEN 3090
3070 P(K)=1-A
3080 GOTO 3095
3090 P(K)=A
3095 RETURN
3100 IF P(K) > .5 THEN 3140
3110 T=T+1
3120 P(K)=1-B(Y)
3130 GOTO 3150
3140 P(K)=B(Y)
3150 C=T/(X-1)
4000 RETURN
4444 END
5000 POKE 16421,2:POKE 16422,0:POKE 16423,127
5010 FOR X=32512 TO 32529
5020 READ Y
5030 POKE X,Y
5040 NEXT X
5050 RETURN
5060 DATA 219,234,203,119,40,250,121,211,235
5070 DATA 254,13,32,4,14,10,24,239,201

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