University of Nevada
Reno

A Computer Analysis of Hit Frequency For a Complex Video Gaming Machine

A professional paper submitted in partial fulfillment
of the requirements for the degree of
Master of Science
with a major in Computer Science

by

Damien Charles Ennis

Dr. Frederick C. Harris, Jr., Advisor

May 2000

Abstract

The current generation slot machines is based on computer technology. Through the use of a random number generator and computer-generated displays it is possible to design machines that offer a greater variety of gaming alternatives and are more reliable to operate than mechanical slot machines. A requirement for marketing an electronic gaming machine is that the manufacturer be able to reliably predict the frequency of player hits for the machine. A simple mathematical model for the prediction of hit frequencies is not available. The only way to accurately predict the number of hits is to enumerate all possible outcomes and record which of those outcomes constitutes a hit. This paper describes an improved approach to the analysis of hit frequencies and the software that was developed to implement this approach. This approach improves on past methods of hit estimation and, although designed for a specific gaming machine, is readily adaptable to other machines.

Contents

List Of Figures

List Of Tables

1. Introduction

The current generation of slot machines is based on computer technology. Through the use of a random number generator and computer-generated displays, it is possible to design machines that offer a greater variety of gaming alternatives, are more interesting and exciting to players, and are more reliable to operate than older generations of mechanical slot machines. Instead of a three-reel machine with 20 symbols per reel, electronic slots can offer five or even more virtual reels, with each reel containing 60 or more symbols. Current technology supports the linking of electronic slots into networks to allow progressive jackpots based on the cumulative play of all of the machines in the network rather than a single machine.

PROM chips (programmable read-only memory) “contain the game instructions and a random number generator, which determines the outcome of the games,” although some newer machines employ a combination of PROM and hard disk storage, with game control functions in PROM and code for multimedia displays and sound effects on the hard disk [4]. Game control functions include random number generation, player win decoding, money handling, security, and accounting functions. Code is encrypted and machines must be certified by the gaming commission within the jurisdiction where they are installed [1].

A basic requirement for marketing new electronic slot machines is that the manufacturer be able to reliably predict the frequency of hits for each machine.

However, unlike rolling dice where the probable frequency of particular outcomes can be easily calculated, the accurate prediction of hit frequencies on an electronic gaming machine can be extremely difficult. The cause of this difficulty is that electronic gaming machines have multiple pay lines – anywhere from three to 25, or even more. In addition, these machines often incorporate the concept of "scatter pays." These are combinations of special symbols that, when displayed, result in a player hit even though they do not line up a single pay line. This combination is termed as a hit rather than a win in that the player may not have matched or exceeded his original bet.

With the additional opportunities associated with electronic slots has come increased complexity in establishing pay outs based on the probable frequency of player hits. With a three-reel, 20-symbol mechanical machine, the possible number of different outcomes equals 20^3 or 8,000. Such machines typically have a single pay line. With this relatively limited number of possible outcomes, it is relatively easy to perform an analysis that results in an entirely reliable tabulation of player hits. However, with electronic machines simulating more reels and larger numbers of symbols on each reel, having multiple pay lines, and allowing for scatter pays, the challenge of accurately predicting hit frequency becomes much more substantial. Determining this frequency for the five-reel, 60-stop machine that is the subject of this paper requires dealing with 60^5 or 777,600,000 possible outcomes.

A simple mathematical model for the analysis of hit frequencies is not available. The only way to accurately know the number of hits is to enumerate all possible outcomes and record which of those outcomes constitutes a hit. Accordingly, the purpose of this paper is to describe an improved approach to the analysis of actual hit frequencies and the software that was developed to implement this approach. The approach described in this paper improves on past methods of hit estimation and, although currently applied to a specific electronic machine, is readily adaptable to other machines.

The paper includes an example of the play structure of a traditional gaming system and a statement of the problem that was addressed. It also discusses alternative approaches and an overview of the implemented approach. Lastly, there is a brief discussion of findings and conclusions.

2. Sample Gaming System

To illustrate basic slot machine concepts, this section describes the reels, symbols, and payout table of an actual electromechanical slot machine – the Jennings "Little Duke" [2]. This three-reel, 10-stop machine has a single pay line offering a total percentage payout of 69.6. In contrast, payouts for contemporary video slots typically range between 82 and 98 percent [3].

The three reel strips of the Little Duke are shown in Table 1.

REEL STOP	REEL 1	Reel 2	Reel 3
Stop 1	Cherry	Cherry	Plum
Stop 2	Bar	Bar	Lemon
Stop 3	Cherry	Cherry	Orange
Stop 4	Orange	Orange	Lemon
Stop 5	Cherry	Cherry	Plum
Stop 6	Plum	Plum	Bar
Stop 7	Lemon	Cherry	Plum
Stop 8	Orange	Orange	Orange
Stop 9	Lemon	Cherry	Lemon
Stop 10	Bell	Bell	Bell

Table 1 – Reel Strips

Not only does the sequence of symbols vary from reel to reel but also the frequency of their occurrence, as is shown in Table 2.

SYMBOL	REEL 1	Reel 2	Reel 3	TOTAL
Lemons	2	0	3	5
Cherries	3	5	0	8
Oranges	2	2	2	6
Plums	1	1	3	5
Bells	1	1	1	3
Bars	1	1	1	3

Table 2 – Symbol Frequencies

A pay table translates specific three-symbol pay line combinations into actual payouts and thus specifies both the frequency of player hits and percentage payout. Because the Little Duke has a single payout line and obviously does not incorporate the concept of scatter hits, determination of hit frequency is a trivial problem. The actual pay table for the Little Duke is shown in Table 3.

HIT LINE	NUMBER OF WAYS	SINGLE HIT PAYOUT (COINS)	EXPECTED PAYOUT PER 1000 PLAYS
Bar–Bar–Bar	1	100	100
Bell–Bell–Bell	1	16	16
Bell–Bell-Bar	1	16	16
Plum–Plum–Plum	3	12	36
Plum–Plum–Bar	1	12	12
Orange–Orange–Orange	8	8	64
Orange–Orange–Bar	4	8	32
Cherry–Cherry–Cherry	0	0	0
Cherry–Cherry–Lemon	45	4	180
Cherry–Cherry–Bell	15	4	60
Cherry–Cherry–Any	90	2	180
HIT FREQUENCY	169	**TOTAL EXPECTED PAYOUT**	696

Table 3 – Pay Table

For a basic machine with a single hit line, such as the Little Duke, determination of hit frequency is simply a matter of identifying the number of symbol combinations that would result in a player hit. In this example, 169 combinations, order counting (out of the total of 1,000 possible combinations for a three-reel, 10-stop machine) result in some level of hit, ranging from a two-coin return for a combination of two CHERRIES and any other symbol except a BELL or LEMON to a 100-coin payout for a combination of three BARS. Thus, the player would receive the psychological reward of having coins dropped into the tray approximately 16.9 percent of the time and a return of approximately 69.6 percent of his investment.

Note that although it is the specification of the single hit payout for each winning combination that determines the total expected payout for the machine, the payout is not based entirely on the player's probability of success – unlike the majority of casino gambling alternatives. For example, the combinations of BAR–BAR–BAR, BELL–BELL–BELL, BELL-BELL-BAR, and PLUM–PLUM–BAR all have the same probability of success (1 occurrence per 1,000 plays), yet their associated payouts range from 12 to 100 coins.

3. Problem Background

The key problem in determining hit frequencies with a modern electronic gaming machine is simultaneity: a single play can result in multiple hits. For the purposes of this analysis, any time a player gets one or more hits as a result of a single play, that success must be counted in terms of hit frequency as a single hit. For example, on a five-line machine whether the player has a single hit or hits on all five lines, it still counts as one.

The objectives of this project were to develop a analytical approach and associated software for a five-reel, 60 stop macine that enumerates all possible reel combinations and evaluates how many of them are hits, assuming the maximum number of pay lines has been played. It must not count a simultaneous pay line and scatter hit as two separate hits, nor can it consider two or more pay lines hitting simultaneously as separate hits. The program must be able read in a standard file format and use the information within to initialize the analysis.

A final constraint was that the program must run within an acceptable maximum processing time on an Intel-based computer in a Windows environment. An acceptable processing time is considered to be 48 hours.

Past attempts at one manufacturer to measure hit frequencies were based on mathematical estimation. One equation employed was:

$HF_T = HF_L * \#\text{ of lines} + HF_S$

Where HF_T is the calculated hit frequency of the game, this is the complete and total hit frequency that can be associated with the game including: HF_L is the one-line hit frequency, and HF_S is the scatter hit frequency.

The problem with this equation is that it doesn't account for simultaneity at all. It counts every hit, even though multiple hits may occur on a single play. Thus, it substantially inflates the expected frequency of player success in terms of hits. In fact, this equation can result in an estimated frequency greater than 1.0 (or 100 percent). For example, a one-line hit frequency of 0.1 on a machine with 10 or more pay lines would result in an estimated hit frequency that exceeded 1.0.

An improved equation is:

$HF_T = 1 - (1 - HF_L)^{\#\text{ of lines}} + HF_S$

This equation is at least more realistic in estimating the impact on hit frequency of multiple pay lines, but it is still an estimation. This equation is based on the assumption that as the number of lines increases, the contribution associated with the first pay line's hit frequency is reduced. However, it still represents a rough approximation.

4. APPROACH

During the course of the project, three different approaches were investigated. The first two approaches were partially successful, in that they resulted in accurate calculations of hit frequencies, but neither satisfied the acceptable processing time requirement. The third approach proved to be entirely successful, with actual run times ranging from a low of 20 minutes to a high of approximately 17 hours. The difference in run time depended upon the number of reels and the number of stops per reel on the machine being analyzed.

The core algorithm remained relatively constant between the three versions. It is composed of several nested loops that represent the various reels of the slot machine, as is depicted in Figure 1 below. Within the center of these loops are the various pay-line assignments and evaluations.

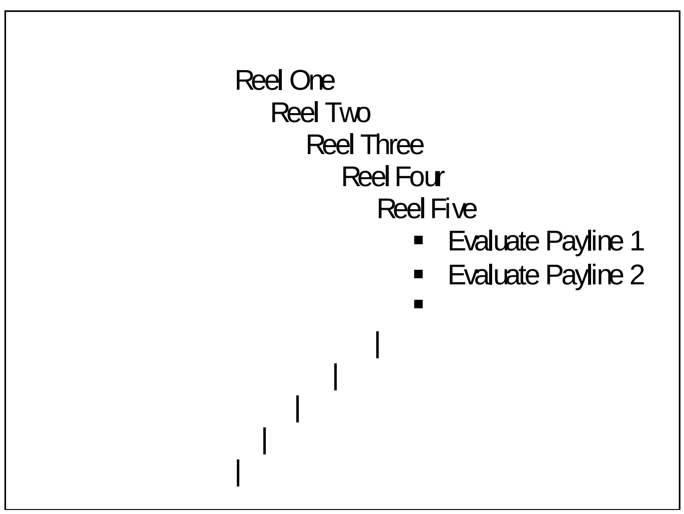

Figure 1 – Structure of Reel Spin Section

The actual processing steps are shown in Figure 2 and described below.

(1) Extraction of the data from input file – input file format specified elsewhere in this paper

(2) Initialization of global variables

  (2a) Transformation of symbol-based reel strips into integer-index form – this is done as the reels are read in and is based on the list of symbols as stated in the input file

  (2b) Creation of the symbol equivalence look-up table – these two additional loops are turned into overhead in the final approach, thus taking them out of the critical reel spin section

(3) Reel Spin Section

  (3a) Pay line creation – create a pay line based on location of symbols

  (3b) Pay line evaluation – evaluate the pay line vs. the table of paying combos

  (3c) Scatter evaluation – check current screen for scatter pays, this is also checked against the same table of paying combos

(4) Accumulation of statistical data – various summations and calculations

(5) Output of generated information – create a standard output file format

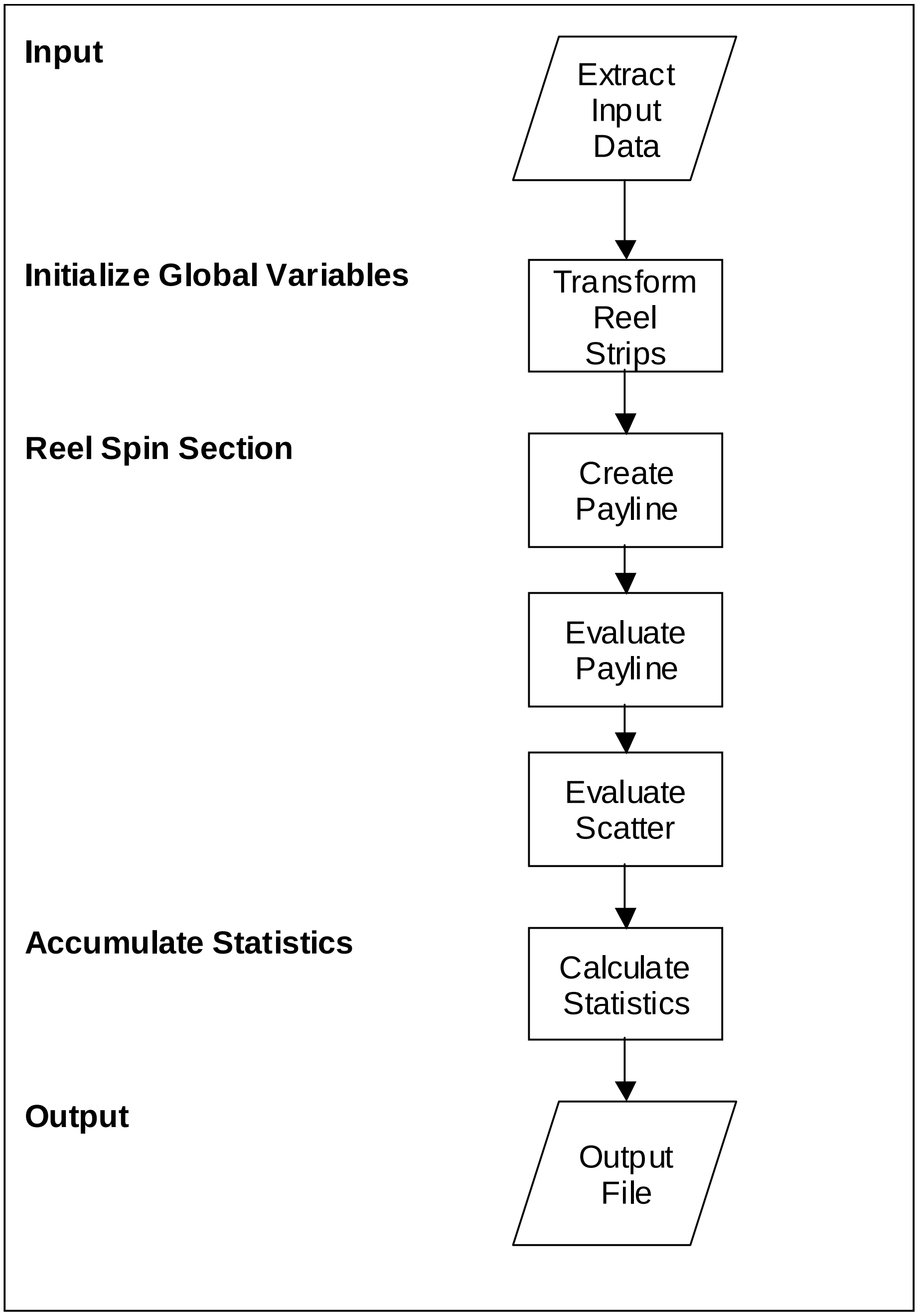

Figure 2 -- Processing Steps

The three approaches differed in the evaluation of special symbols, which is the most challenging aspect of the problem, in that the handling of the reel strips leaves very few options. Special symbols are defined in the game to stand for multiple regular symbols and are used within the pay combos. Every possible combination of symbols must be enumerated. There is no opportunity for short cuts. It is not possible to simulate actual reel spins. In order to meet operational parameters, processing and analysis of pay lines within the loops must be optimized, as demonstrated by the early unsuccessful attempts.

The initial approach was based on comparing special symbols against regular symbols during the reel spin analysis. The approach was structured around a table of two-character symbol values and required that the system process regular symbols against special symbols during the reel spins. In addition to the traverse of the paying combinations, two additional nested loops were necessary to evaluate each special symbol within the pay combos against the regular symbols contained within the pay lines. These loops added a very large number of loops to each analysis run. This approach resulted in unacceptable run times, to the extent that using available hardware the analysis would not return at all on non-trivial games. However, the system did appear to produce the correct results on small sample games. The unacceptable computational times were the result of additional nested loops within the already multi-nested reels spin.

The logic of the system was fine. The design was flawed within the problem constraints.

The second approach involved dealing with special symbols by enumerating all possible pay combinations. In other words, pay combinations containing special symbols were mapped into all possible equivalent non-special symbol combinations, thus removing the need to traverse an equivalence table during the reel spin section. A recursive function was created to expand the multidimensional array of paying combinations. The original array was filled with the paying combinations composed of special symbols as defined in a standard game. The function would populate a new array with all combinations of regular symbols generated from an equivalence table. With each paying combination composed of five special symbols, and with each special symbol being equivalent for up to 12 regular symbols, the size of the destination array became quite large. Although it reduced the number of nested loops within the reel spin section, it drastically increased the size of the pay combo traverse. This approach proved unworkable, in that it resulted in storage overflow.

The third and ultimately successful approach involved using an integer-based look-up table for special symbols. This approach is similar to the first in that special substitute symbols are stored in a table. It differs in that there is no necessity to loop to compare values within the table. Instead, the data is represented in such a way that the symbol directly indexes its location in the table. As the game's symbols are read in from the standard file they are immediately converted into an integer equivalent. Using the integer values, a special symbol look-up table is generated before the reel spin section. Within this function all symbols for the game are given an integer index. Using these indices a table of equivalence is created wherein the symbols themselves define their location within the table. Instead of increasing the number of nested loops, the special symbols are evaluated as overhead and calculated at the beginning of the program. This approach to managing special symbols, combined with the conversion of the reel strips from symbols to their associated index values in the table, allowed for acceptable run times and memory allocation.

The look-up table generation function is shown in Figure 3. It is important to note that all values in the array LU are previously initialized to zero.

```
// creates the I/0 look-up table for special symbols
int CreateLU(void)
{
	int i,j;

	for(i=0;i<numSym;i++)
	{
		for(j=0;j<numSym;j++)
		{
			if(i==j) LU[i][j]=1;
			else if(EquivCheck(i,j))
				LU[i][j]=1;
		}
	}



	return 1;
}
```

Figure 3 – Look-up Table Function

In all three attempts the bulk of the run time resulted from the five nested loops that enumerate all possible stops on the five reels. Similarities between the original algorithm and finally successful one allow for an informative comparison. Comparison of the first failed approach with the ultimately successful approach shows how critical handling the special symbol evaluation is. The run time of the final successful approach is approximately $O(n^{(\text{the \# of reels}+1)})$. Where n is the number of stops per reel. Here the additional plus one is from the traverse of the paying combo table during the reel spin. The run-time of the first failed attempt is approximately $O(n^{(\text{the \# of reels}+1+2)})$. The extra two in the exponent comes from the additional two loops needed to evaluate the special symbols when comparing pay lines versus paying combos within the reel spin section.

Software for the project was written using a standard C++ compiler and a combination of C and C++ syntax. The operating system was Windows 98. The software requires at least a Pentium II processor. Input to the program is a standardized file that has been generated by a separate, proprietary software module. The data included in the input file consists of:

- Number of reels
- Number of stops per reel
- Number of pay lines
- Number of non-scatter pay combinations
- Total number of pay combinations (including scatter)
- Symbols associated with the game
- Sequence of symbols for each reel strip
- Pay combinations and the pay out amount associated with each combination

Together, these data elements constitute the basic characteristics of a specific game machine. A sample input file is shown in figure 4.

```
5                                   // # OF REELS
42 42 42 42 42                      // STOPS R1 R2 ...
9                                   // PAY-LINES
3                                   // NON-SCATTER PAYS
4                                   // TOTAL PAYS

SC                                  // FIRST SCATTER SYMBOL

5                                   // # OF REGULAR SYMBOLS
9                                   // TOTAL SYMBOLS reg+spec+scat
R1 R2 S1 S2 SO -- RR SS SC          // ALL SYMBOLS

-- R1 R2 S1 S2 SO                   // SPECIAL SYMBOLS
RR R1 R2                               // where [n][0] is sub
SS S1 S2                               // and [n][>0] are what it stands for
SC SO

S1 SO R1 R2 S2                      // REELS
R1 S2 R2 S1 R2
S2 R2 R1 R2 R1
SO S1 S2 S2 R1

RR RR RR RR RR                      // PAY COMBOS
RR RR SS SS SS
SS SS SS SS SS
SC SC -- -- --

250                                 // PAY AMOUNTS
150                                 // matches combos exactly
100
2
```

Figure 4 – Sample Input File

5. Results And Conclusion

The software has successfully analyzed over a dozen games to date, with additional functionality being added to the program regularly. The analytical tool is becoming a standard within one of the major companies in the industry. Reliability of results was based partially on the calculation of payback. Payback is readily available from simple calculations. As the hit frequency analysis is running, a tabulation of each combo hit is taken. This number multiplied by each combo's value and then divided by the total number of outcomes produces the games payback. This was the main piece of data used to evaluate the accurateness of the hit frequency results for actual games. Preliminary correctness was ascertained by running the analysis on mini games, which could be calculated by hand. Since the analysis is in a complete traversal of the game space and not a random sample, the reliability of results is relatively inherent. Both a sample output file and the source code of the project are included as appendices.

The project supports three conclusions. The first conclusion is that the algorithm and software constitute a significant improvement over previous approaches. As noted in the paper, in the past, hit frequencies were simply estimated using equations that were significantly flawed – to the point that one of the approaches could erroneously report expected hit frequencies in excess of 100 percent. The new approach gives an exact measure of expected frequencies.

The second conclusion is that it is in fact possible to do a rigorous analysis of expected hit frequencies for a five-real, 60-stop game machine that allows for scatter pay on a standard Intel-based personal computer running Windows. Although the run times and resource requirements associated with the first two analytical methods that were tried (and ultimately abandoned) suggested that it might be necessary to employ a supercomputer to conduct a rigorous analysis, in the end the judicious use of an integer-based look-up table brought the task within reasonable limits.

The final conclusion is that the analytical successful approach should be readily adaptable to the analysis of other complex video gaming machines. And in fact the approach has been recently modified so that it can be used on two different categories of machine. All that is required is the modification of the truth table structure and the number and sequence of reel loops processed during the course of the analysis. In addition, the analytical approach is not limited to electronic versions of the more traditional slot machines. It can also be used to perform hit analysis of most reel spinning games and perhaps even more esoteric game machines being considered for future development by the gaming industry.

Appendix A – Glossary

Hit	A combination of symbols on the pay line that results in a win for the player.
Pay Line	The alignment of symbols in the display window of the slot machine that, if matching a pay category, produces a hit
Pay Table	The specification of the amount of winnings associated with each of Pay Line; winnings can range from the value of the coins entered by the player for that specific play to a multi-million dollar jackpot.
Reel	The strip of symbols that rotates when the slot machine is played (or, in the case of electronic slot machines, the simulation thereof).
Scatter Pay	A combination of symbols that result in a hit even though they do not appear on a pay line.
Special Symbols	Symbols used within pay combinations to represent multiple regular symbols. For example, "Any Bar" is a special symbol that represents any of the three different regular bar symbols, "1-bar." "2-bar," and "3-bar."
Stop	The specific points where the reel is stopped to reveal the Pay Line; a reel with 30 symbols would have 30 stops.

Appendix B – Source Code

```
Due to the fact that this code
is Proprietary, it is not
included in the published
version of this paper.
```

Appendix C –Output File

```
iGame true hit frequency analyzer     V1.2b
game data from : wofclassic.std

Number of reels : 5
Number of stops per reel : 60   60   60   60   60
Number of paylines : 9
Number of non-scatter pay-combos : 155
Total number of pay-combos : 181
The scatter symbol is : SC

Total number of symbols(regular+special+scatter) : 25
A list of all symbols ->
F1 F2 F3 F4 TR CA CR GP DI CS B1 B2 WF -- W1 W2 W3 W4 WT WA WR WG WD XS SC

The listing of the reels (symbol) ->
   F1   GP   F2   F2   F1
   TR   F1   B2   GP   TR
   F2   F4   F4   CA   F3
   B1   F3   CA   F4   B1
   F1   B1   B2   WF   TR
   CA   GP   CR   CR   CR
   B1   F2   F1   F1   CS
   TR   F1   TR   CS   F3
   CR   GP   F4   F2   DI
   F1   F2   GP   CA   GP
   CS   F1   B1   B1   F4
   F3   B1   CA   F2   GP
   DI   F3   DI   GP   WF
   B1   F1   B2   B1   F4
   F4   B2   F2   F1   DI
   F3   F4   CR   CA   B1
   WF   F3   B2   F4   F4
   F4   CA   F4   B1   F3
   F3   WF   TR   CA   CA
   B1   TR   CR   F1   F1
   F2   CS   B2   CR   DI
   F1   GP   CA   F4   WF
   DI   F1   CR   B1   F4
   F2   F2   B1   F2   CR
   F1   CR   F4   CA   B1
   B1   TR   TR   F3   TR
   F3   WF   CS   WF   F3
   F4   CA   F4   CR   B1
   WF   CR   GP   TR   CA
   F3   F1   B1   F4   DI
   F4   B2   F4   F1   CR
   B1   F1   CA   CR   B1
   F1   DI   B1   CS   TR
   CR   B2   TR   F1   F3
   GP   F2   GP   CR   WF
   B1   GP   B2   TR   F4
   F2   DI   CA   F1   CR
   CA   B1   F3   B1   B1
   F1   F2   B2   DI   F1
   B2   F3   CR   F1   TR
   DI   TR   F3   F3   CA
   F2   WF   B1   B1   F1
   B2   CR   DI   F2   B1
   CA   TR   F3   TR   TR
   F1   B2   B2   B1   CR
   F3   GP   DI   F3   CS
   GP   F3   F1   CR   TR
   F2   B1   WF   B1   DI
   CR   DI   F2   F4   B1
   TR   F2   GP   DI   F2
   F1   B2   F4   F3   CA
   GP   GP   B2   TR   F3
   CA   F4   CR   CR   B1
   F2   B1   TR   F3   F2
   F3   GP   CA   F4   F3
   DI   F2   B1   WF   B1
   F4   B2   DI   F3   CA
   GP   F3   F4   TR   F1
   F2   F4   CR   F4   B1
   DI   B1   DI   CR   F2
```

	R1	R2	R3	R4	R5
F1	9	7	2	7	5
F2	8	7	3	5	3
F3	7	6	3	6	7
F4	5	4	8	7	5
TR	3	4	5	5	7
CA	4	2	6	5	5
CR	3	3	7	8	5
GP	4	8	4	2	2
DI	5	3	5	2	5
CS	1	1	1	2	2
B1	7	6	6	8	11
B2	2	6	9	0	0
WF	2	3	1	3	3
Total :	60	60	60	60	60

Cycle : 777600000

One Line ->

Pay Combo					Hits	Pays	Total Pays
SC	SC	XS	XS	XS	1495908.0	2.0	2991816.000
XS	XS	XS	SC	SC	6666948.0	2.0	13333896.000
XS	XS	SC	XS	SC	3158028.0	2.0	6316056.000
XS	XS	SC	SC	XS	3158028.0	2.0	6316056.000
XS	SC	XS	XS	SC	3158028.0	2.0	6316056.000
XS	SC	XS	SC	XS	3158028.0	2.0	6316056.000
XS	SC	SC	XS	XS	1495908.0	2.0	2991816.000
SC	XS	XS	XS	SC	3158028.0	2.0	6316056.000
SC	XS	XS	SC	XS	3158028.0	2.0	6316056.000
SC	XS	SC	XS	XS	1495908.0	2.0	2991816.000
SC	SC	SC	XS	XS	78732.0	5.0	393660.000
XS	XS	SC	SC	SC	350892.0	5.0	1754460.000
XS	SC	XS	SC	SC	350892.0	5.0	1754460.000
XS	SC	SC	XS	SC	166212.0	5.0	831060.000
XS	SC	SC	SC	XS	166212.0	5.0	831060.000
SC	XS	XS	SC	SC	350892.0	5.0	1754460.000
SC	XS	SC	XS	SC	166212.0	5.0	831060.000
SC	XS	SC	SC	XS	166212.0	5.0	831060.000
SC	SC	XS	XS	SC	166212.0	5.0	831060.000
SC	SC	XS	SC	XS	166212.0	5.0	831060.000
SC	SC	SC	SC	XS	8748.0	20.0	174960.000
XS	SC	SC	SC	SC	18468.0	20.0	369360.000
SC	XS	SC	SC	SC	18468.0	20.0	369360.000
SC	SC	XS	SC	SC	18468.0	20.0	369360.000
SC	SC	SC	XS	SC	8748.0	20.0	174960.000
SC	SC	SC	SC	SC	972.0	400.0	388800.000
F2	F2	--	--	--	11289600.0	2.0	22579200.000
F1	F1	--	--	--	12927600.0	2.0	25855200.000
GP	GP	--	--	--	6336000.0	2.0	12672000.000
DI	DI	--	--	--	2916000.0	2.0	5832000.000
F2	WF	--	--	--	4838400.0	4.0	19353600.000
WF	F2	--	--	--	2822400.0	4.0	11289600.000
F1	WF	--	--	--	5540400.0	4.0	22161600.000
WF	F1	--	--	--	2872800.0	4.0	11491200.000
GP	WF	--	--	--	2376000.0	4.0	9504000.000
WF	GP	--	--	--	3168000.0	4.0	12672000.000
DI	WF	--	--	--	2916000.0	4.0	11664000.000
WF	DI	--	--	--	1166400.0	4.0	4665600.000
F1	F1	F1	--	--	378000.0	5.0	1890000.000
F4	F4	F4	--	--	480000.0	5.0	2400000.000
F3	F3	F3	--	--	385560.0	5.0	1927800.000
F2	F2	F2	--	--	524160.0	5.0	2620800.000
WF	W4	W4	--	--	192000.0	10.0	1920000.000
W4	WF	W4	--	--	360000.0	10.0	3600000.000
W4	W4	WF	--	--	129000.0	10.0	1290000.000
WF	W3	W3	--	--	110160.0	10.0	1101600.000
W3	WF	W3	--	--	192780.0	10.0	1927800.000
W3	W3	WF	--	--	229500.0	10.0	2295000.000
WF	W2	W2	--	--	131040.0	10.0	1310400.000
W2	WF	W2	--	--	224640.0	10.0	2246400.000
W2	W2	WF	--	--	293280.0	10.0	2932800.000
WF	W1	W1	--	--	84000.0	10.0	840000.000
W1	WF	W1	--	--	162000.0	10.0	1620000.000
W1	W1	WF	--	--	312000.0	10.0	3120000.000
WF	WF	--	--	--	636840.0	10.0	6368400.000
TR	TR	TR	--	--	187200.0	10.0	1872000.000
CA	CA	CA	--	--	149760.0	10.0	1497600.000

CR	CR	CR	--	--	185220.0	10.0	1852200.000
WF	WT	WT	--	--	124800.0	20.0	2496000.000
WT	WF	WT	--	--	234000.0	20.0	4680000.000
WT	WT	WF	--	--	90480.0	20.0	1809600.000
WF	WR	WR	--	--	123480.0	20.0	2469600.000
WR	WF	WR	--	--	308700.0	20.0	6174000.000
WR	WR	WF	--	--	70560.0	20.0	1411200.000
WF	WA	WA	--	--	74880.0	20.0	1497600.000
WA	WF	WA	--	--	336960.0	20.0	6739200.000
WA	WA	WF	--	--	74880.0	20.0	1497600.000
F4	F4	F4	F4	--	58240.0	25.0	1456000.000
F3	F3	F3	F3	--	37800.0	25.0	945000.000
F2	F2	F2	F2	--	45360.0	25.0	1134000.000
F1	F1	F1	F1	--	45864.0	25.0	1146600.000
GP	GP	GP	--	--	422400.0	25.0	10560000.000
DI	DI	DI	--	--	247500.0	25.0	6187500.000
WF	W4	W4	W4	--	23296.0	50.0	1164800.000
W4	WF	W4	W4	--	61152.0	50.0	3057600.000
W4	W4	WF	W4	--	15652.0	50.0	782600.000
W4	W4	W4	WF	--	67860.0	50.0	3393000.000
WF	W3	W3	W3	--	10800.0	50.0	540000.000
W3	WF	W3	W3	--	24300.0	50.0	1215000.000
W3	W3	WF	W3	--	22500.0	50.0	1125000.000
W3	W3	W3	WF	--	47700.0	50.0	2385000.000
WF	W2	W2	W2	--	11340.0	50.0	567000.000
W2	WF	W2	W2	--	24300.0	50.0	1215000.000
W2	W2	WF	W2	--	25380.0	50.0	1269000.000
W2	W2	W2	WF	--	63828.0	50.0	3191400.000
WF	W1	W1	W1	--	10192.0	50.0	509600.000
W1	WF	W1	W1	--	24024.0	50.0	1201200.000
W1	W1	WF	W1	--	37856.0	50.0	1892800.000
W1	W1	W1	WF	--	50544.0	50.0	2527200.000
WF	WG	WG	--	--	211200.0	50.0	10560000.000
WG	WF	WG	--	--	237600.0	50.0	11880000.000
WG	WG	WF	--	--	198000.0	50.0	9900000.000
WF	WD	WD	--	--	99000.0	50.0	4950000.000
WD	WF	WD	--	--	346500.0	50.0	17325000.000
WD	WD	WF	--	--	118800.0	50.0	5940000.000
B2	B2	B2	--	--	388800.0	79.8	31033623.312
B1	B1	B1	--	--	786240.0	88.6	69640594.733
TR	TR	TR	TR	--	15000.0	100.0	1500000.000
CA	CA	CA	CA	--	12480.0	100.0	1248000.000
CR	CR	CR	CR	--	26208.0	100.0	2620800.000
GP	GP	GP	GP	--	14080.0	100.0	1408000.000
DI	DI	DI	DI	--	7800.0	100.0	780000.000
F4	F4	F4	F4	F4	5600.0	100.0	560000.000
F3	F3	F3	F3	F3	5292.0	100.0	529200.000
F2	F2	F2	F2	F2	2520.0	100.0	252000.000
F1	F1	F1	F1	F1	4410.0	100.0	441000.000
WF	W4	W4	W4	W4	2240.0	200.0	448000.000
W4	WF	W4	W4	W4	5880.0	200.0	1176000.000
W4	W4	WF	W4	W4	1505.0	200.0	301000.000
W4	W4	W4	WF	W4	6525.0	200.0	1305000.000
W4	W4	W4	W4	WF	13050.0	200.0	2610000.000
WF	W3	W3	W3	W3	1512.0	200.0	302400.000
W3	WF	W3	W3	W3	3402.0	200.0	680400.000
W3	W3	WF	W3	W3	3150.0	200.0	630000.000
W3	W3	W3	WF	W3	6678.0	200.0	1335600.000
W3	W3	W3	W3	WF	8586.0	200.0	1717200.000
WF	W2	W2	W2	W2	630.0	200.0	126000.000
W2	WF	W2	W2	W2	1350.0	200.0	270000.000
W2	W2	WF	W2	W2	1410.0	200.0	282000.000
W2	W2	W2	WF	W2	3546.0	200.0	709200.000
W2	W2	W2	W2	WF	9456.0	200.0	1891200.000
WF	W1	W1	W1	W1	980.0	200.0	196000.000
W1	WF	W1	W1	W1	2310.0	200.0	462000.000
W1	W1	WF	W1	W1	3640.0	200.0	728000.000
W1	W1	W1	WF	W1	4860.0	200.0	972000.000
W1	W1	W1	W1	WF	9720.0	200.0	1944000.000
WF	WT	WT	WT	--	10000.0	200.0	2000000.000
WT	WF	WT	WT	--	18750.0	200.0	3750000.000
WT	WT	WF	WT	--	7250.0	200.0	1450000.000
WT	WT	WT	WF	--	30600.0	200.0	6120000.000
WF	WR	WR	WR	--	17472.0	200.0	3494400.000
WR	WF	WR	WR	--	43680.0	200.0	8736000.000
WR	WR	WF	WR	--	9984.0	200.0	1996800.000
WR	WR	WR	WF	--	36504.0	200.0	7300800.000
WF	WG	WG	WG	--	7040.0	200.0	1408000.000
WG	WF	WG	WG	--	7920.0	200.0	1584000.000
WG	WG	WF	WG	--	6600.0	200.0	1320000.000

WG	WG	WG	WF	--	53460.0	200.0	10692000.000
WF	WD	WD	WD	--	3120.0	200.0	624000.000
WD	WF	WD	WD	--	10920.0	200.0	2184000.000
WD	WD	WF	WD	--	3744.0	200.0	748800.000
WD	WD	WD	WF	--	38376.0	200.0	7675200.000
WF	WA	WA	WA	--	6240.0	200.0	1248000.000
WA	WF	WA	WA	--	28080.0	200.0	5616000.000
WA	WA	WF	WA	--	6240.0	200.0	1248000.000
WA	WA	WA	WF	--	31824.0	200.0	6364800.000
WF	WF	WF	--	--	19440.0	200.0	3888000.000
TR	TR	TR	TR	TR	2100.0	250.0	525000.000
CA	CA	CA	CA	CA	1200.0	250.0	300000.000
CR	CR	CR	CR	CR	2520.0	250.0	630000.000
B1	B1	B1	B1	--	98784.0	265.7	26249151.197
B1	B1	B1	B1	B1	22176.0	442.9	9821109.514
WF	WT	WT	WT	WT	1400.0	500.0	700000.000
WT	WF	WT	WT	WT	2625.0	500.0	1312500.000
WT	WT	WF	WT	WT	1225.0	500.0	612500.000
WT	WT	WT	WF	WT	4284.0	500.0	2142000.000
WT	WT	WT	WT	WF	4986.0	500.0	2493000.000
WF	WR	WR	WR	WR	1680.0	500.0	840000.000
WR	WF	WR	WR	WR	4200.0	500.0	2100000.000
WR	WR	WF	WR	WR	1200.0	500.0	600000.000
WR	WR	WR	WF	WR	3510.0	500.0	1755000.000
WR	WR	WR	WR	WF	7866.0	500.0	3933000.000
WF	WA	WA	WA	WA	600.0	500.0	300000.000
WA	WF	WA	WA	WA	2700.0	500.0	1350000.000
WA	WA	WF	WA	WA	750.0	500.0	375000.000
WA	WA	WA	WF	WA	3060.0	500.0	1530000.000
WA	WA	WA	WA	WF	4986.0	500.0	2493000.000
GP	GP	GP	GP	GP	512.0	500.0	256000.000
DI	DI	DI	DI	DI	750.0	500.0	375000.000
WF	WG	WG	WG	WG	256.0	1000.0	256000.000
WG	WF	WG	WG	WG	288.0	1000.0	288000.000
WG	WG	WF	WG	WG	264.0	1000.0	264000.000
WG	WG	WG	WF	WG	1944.0	1000.0	1944000.000
WG	WG	WG	WG	WF	4896.0	1000.0	4896000.000
WF	WD	WD	WD	WD	300.0	1000.0	300000.000
WD	WF	WD	WD	WD	1050.0	1000.0	1050000.000
WD	WD	WF	WD	WD	420.0	1000.0	420000.000
WD	WD	WD	WF	WD	3690.0	1000.0	3690000.000
WD	WD	WD	WD	WF	3726.0	1000.0	3726000.000
WF	WF	WF	WF	--	1026.0	1000.0	1026000.000
WF	WF	WF	WF	WF	54.0	99760.0	5387040.000
Totals :					102796992.000		715351098.755

Lines Played	True Hits	Total Pays	Hit Frequency	Payback
1	100677168	715351098.754	12.947	91.995
2	164078136	1430702197.463	21.101	91.995
3	226599444	2146053296.188	29.141	91.995
4	276593616	2861404395.090	35.570	91.995
5	320127876	3576755494.299	41.169	91.995
6	324472392	4292106593.233	41.727	91.995
7	328514292	5007457692.246	42.247	91.995
8	372320388	5722808790.469	47.881	91.995
9	411759288	6438159888.392	52.953	91.995
Max Line	411759288	6438159888.39230	52.95258	91.99474

Highest paying screen was ->

```
F4  CR  F1  WF  F3
WF  TR  WF  CR  WF
F3  WF  F2  F1  F4
```

Pay amount is 100000.00000

Starting time is Thu Mar 30 11:14:14 2000

Completed time is Fri Mar 31 07:02:40 2000

References

[1] S. Boelhouwer. Playing for keeps: developing casino games. In *Game Developer*, Vol. 7, Number 1 (January 2000), pages 44 – 50.

[2] D. Mead. S*lot Machine Reel Strips*. Mead Publishing Corporation. 1983. Page 33

[3] R.A. Epstein. The Theory of Gambling and Statistical Logic. Revised Edition. Academic Press. 1977.

[4] Thompson, Coutenay. Electronic age comes to slot machines. The Oregonian. January 23, 1998.