Analysis of the *Creepy Crawly* Solitaire Game
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Introduction

Creepy Crawly is a solitaire card game invented by Solebon LLC, the developers of the "Solebon Solitaire - 50 Card Games" app for iPhone and iPad (http://www.solebon.com/). This analysis is my own work, and has not been authorized or approved by Solebon LLC. The screen shots included here are from an iPod Touch (5th Generation), which runs version 6.2 of the iPhone app.

Definitions and Rules

The initial *deal* consists of eight *column*s with five face-up cards each, one additional face-down *hidden card* above each of the eight columns, and (at the upper-left corner of Figure 1) a *stock* of four face-down cards. All of the cards, face-up or face-down, are in random order. For the sake of reference, we'll number the columns one through eight, from left to right.

Figure 1

The directional terms *top*, *bottom*, *high*, *low*, *up*, *down*, *over*, *under, above*, and *below* usually refer to positions within a column, and are defined so that the top (or highest) card in a column is the one physically next to the hidden card (if there still is one) in that column. If that seems counterintuitive, try thinking of the cards as not overlapping. (In some cases context will make it clear that card *denominations* are being compared, not column positions. For example, a four of spades is a lower denomination than a five of spaces.)

Two cards of a single suit, within a column, are said to be *in sequence* if the two cards are physically adjacent, and the card that is below the other (in column position) is the next lower denomination. In Figure 1, the seven and six of hearts happen to be in sequence, and so do the ten and nine of hearts. Likewise, any number of physically adjacent cards in a column are in sequence if each adjacent pair within those cards is in sequence.

The goal is to put each suit, one suit at a time, into a *complete-suit sequence*, from king down to ace, contiguously, within a single column, and with no card (of another suit) under the ace. In other words, the king does not have to be the top card in the column, but the ace must be the bottom card in the column. Once the complete-suit sequence is complete, or once the card(s) under the ace of an otherwise complete-suit sequence is/are moved away, that suit is automatically discarded. If all four complete-suit sequences are completed and discarded, the game is *won*; otherwise, the game is *lost* when the player quits. Some games are *unwinnable*, and at least

some of those cases are *provably unwinnable*, meaning that it can be shown that the initial deal (including the hidden cards and the stock) is such that it is impossible to win the game.

Notation

The four suits are S (spades), H (hearts), D (diamonds), and C (clubs). The variable S_m stands for any particular suit, where m = S, H, D, or C.

The thirteen card denominations are A (ace), 2, 3, . . . , 9, 10, J, Q, and K. The variable D_x stands for any particular card denomination, where x = 1, . . . , 13, and where D_1 = A (Ace), D_2 = 2 (Deuce or Two), . . . , D_{10} = 10, D_{11} = J (Jack), D_{12} = Q (Queen), and D_{13} = K (King).

So AC is the ace of clubs, 7D is the seven of diamonds, 10S is the ten of spaces, and QH is the queen of hearts. The variable D_xS_m stands for the card of denomination D_x and suit S_m. This is also referred to as the *value* of the card. D_8S_H is the same as 8H, the eight of hearts.

A *column segment* is a series $[D_xS_m, . . . , D_yS_n]$ of two or more contiguous cards within a particular column, where the first card, here shown as D_xS_m, is nearest the top of the column, and the last one, D_yS_n, is nearest the bottom of the column. For example, [3H, AC, 10C] is a column segment consisting of the three of hearts, with the ace of clubs under it, and the ten of clubs under the ace.

An *in-sequence pair* is a same-suit two-card column segment whose two cards are in sequence, i.e., $[D_xS_m, D_{x-1}S_m]$, e.g., [QS, JS].

An *open card* is a face-up card that is currently the lowest card in its column. Unless it's an ace, it's eligible to be the target of a move.

Three Types of Actions, Plus Undo

There are three types of *action* allowed, plus *undo*, which is not so much a part of the game as it is a recognition that there is a lot to be learned from trying different approaches to one deal.

Move: Transfer any face-up card D_xS_m, where a ≠ 13 (i.e., the card is not a king), along with any cards under it, from any column to the bottom of a *different* column whose bottom card is $D_{x+1}S_m$. For example, if there's a column whose bottom card is the eight of hearts (i.e., the eight of hearts is *open*), and the seven of hearts is face-up anywhere in any other column, the seven of hearts and any cards below it can be moved so that the seven of hearts is now under the eight of hearts. If a move removes all the face-up cards from a column, leaving only the hidden card, the hidden card is turned face-up and becomes the top (and for now, the only) card in that column. If a move removes all the cards from a column, and there is no hidden

card (because it has already been revealed in a previous action), the column is (for now) an *empty column*.

A move of one card can be written in the notation D_xS_m ➔ $D_{x+1}S_m$, meaning that card D_xS_m is moved to open card $D_{x+1}S_m$. A move of more than one card (a column segment) can be written $[D_xS_m, \ldots, D_yS_n]$ ➔ $D_{x+1}S_m$. For example, a move of the queen of clubs, with the three and seven of hearts under it, to the open king of clubs would be [QC, 3H, 7H] ➔ KC.

King Shift: Transfer any king, along with any cards under it, to any empty column. As in a move, if the king was the top card in its original column, then if only a hidden card is left, it is turned face-up; if there was no hidden card, the column is now empty.

Stock Deal: Deal the four cards in the stock to the bottoms of columns one through four (the left-most four columns). This action can be done only once in a game (except that it can be undone and redone with "undo", as described below). The four cards are dealt in random order, which is to say that the player has no control over which one goes to which of the four columns.

Undo (*not* an action *per se*): Reverse the latest action (move, king shift, or stock deal). If undo is used more than once consecutively, multiple actions are reversed, in reverse order. If a stock deal is reversed by using undo, and then eventually the stock deal is done again, the four cards are dealt in the same order as before. Undo is not necessarily allowed in every implementation of Creepy Crawly, but this analysis *assumes* its availability. Restarting the game is another option, but it will not be mentioned again, since it is the same as using undo repeatedly to go back to the initial deal.

Generalities, Observations, and Suppositions

A move always creates an in-sequence pair, i.e. $[D_xS_m, D_{x-1}S_m]$. Example: [7D, 6D]. As the game progresses, moves build longer and longer sequences of each suit.

An in-sequence pair, e.g., [7D, 6D], may or may not have been created by a move. But a two-card column segment that is *not* an in-sequence pair (i.e., if the two cards are different suits or they are not in sequence), then that segment has either existed from the original deal, or (less likely) it was accidentally created by the stock deal.

Undo provides the option of making decisions based on temporarily revealed information, specifically the value of one or more hidden cards, or the values and positions of the stock cards. A multiple undo could reverse the game back all the way to the initial deal if desired.

A king shift to an empty column in such as way that the king's original column becomes empty might seem pointless, but it can affect the game if (1) the stock has

not yet been dealt, and (2) at least one of the two columns involved in the king shift is one of the four left-most columns, i.e., those affected by dealing the stock. Undo makes it possible to make an informed decision about whether to do that. For example, suppose the only card in the left column is JC. When the stock is dealt, the new card in the left column is QC, which would now be below the JC. (This reverse sequence may or may not be a game-stopper, but it *is* awkward.) Now suppose the fifth column from the left is empty before the stock deal. Then, if undo is available, you could back up to before the stock deal and move the JC to the empty column. The stock deal will drop the QC into the left-most column, and the JC can be moved under it.

A major subgoal of play should be to reveal hidden cards, and to create empty columns (so that kings can be moved to them). Therefore, try to move cards at the tops of their columns.

If an empty column exists and more than one king is available to be shifted to it, prefer a king at the top of its column with a hidden card above it. This may be beneficial, depending on the value of the hidden card. Go ahead and shift the king, reveal the hidden card, and continue play for a while. If eventually another empty column is created, then shifting the king was probably a beneficial action. If on the other hand it seems like a dead end, undo all the actions until the king is in its previous position, and try something else.

No move can be made to a column whose lowest card is an ace. If play reaches a point where the stock has been dealt, no king shifts are available, and each of the non-empty columns has an ace as its lowest card, then no further actions can be made, at least not until undo is used to back up to a better position. The game may still be winnable, but only with undo.

Sometimes there are two alternative moves involving the same cards within a single suit. In Figure 2, note the 9S in column two and the [8S, 10S] in column six. Option 1 is to move the 9S to column six, resulting in [8S, 10S, 9S]. Option 2 is to move [8S, 10S] to column two, resulting in [9S, 8S, 10S]. Either way, the resulting three-card column segment is out of sequence. But which option is better? Well, either way, the key to eventually splitting up this spade threesome as a step toward getting all the spades into order is to move the 10S to a column whose bottom card is JS. The JS is currently in column eight, with [2H, 3H] under it. The only way to open up the JS is to move the 3H to 4H, and then move 2H to 3H. But 4H

Figure 2

is right above the 8S in column six! So if you do Option 1 for the spades, you wind up with [4H, 8S, 10S] in column six, and [JS, 2H, 3H] in column eight - and there's no way out of that! But Option 2 results in [9S, 8S, 10S] in column two, an open 4H in column six, and the [JS, 2H, 3H] still in column eight. From there it's easy to move 3H ➔ 4H, 2H ➔ 3H, [10S, 9S] ➔ JS, and 8S ➔ 9S. At the end of all that, the spades are in order ([JS, 10S, 9S, 8S]) and so are the hearts ([5H, 4H, 3H, 2H]).

Unwinnable Games

Many deals can be proven to be unwinnable. If a deal can be proven to be unwinnable, then there's no real point to continuing the game. But if unwinnability cannot be proven, then it may be worth continuing to try to win, even if it involves using undo.

Here are some examples of provably unwinnable games:

If at any point in the game, including the initial deal, one column contains a

Figure 3

column segment $[D_xS_m, D_{x-1}S_n]$ (where m and n are different suits), and another column contains a column segment $[D_xS_n, D_{x-1}S_m]$, then the game is

Figure 4

unwinnable. In the initial deal shown in Figure 3, [7S, 6H] appears in the third column, and [7H, 6S] in column 7. The only way to split the [7S, 6H] is to move 6H to an open 7H. But the only way to open up the 7H is to move 6S to an open 7S. At best, this deal will end up looking like Figure 4.

If at any point in the game, including the initial deal, one column contains a column segment $[D_xS_m, D_{y-1}S_m]$ (i.e., same suit), and another column contains a column segment $[D_yS_m, D_{x-1}S_m]$, then the game is unwinnable. Example: In Figure 5, column three contains [JC, 3C], and column four contains [4C, 10C]; the 3C cannot be moved to the 4C until the 10C is moved to the JC, and vice versa. (It's irrelevant that both pairs are at the tops of their respective columns.)

Figure 5

If, at any time after the stock deal, there is only one remaining hidden card, which can be shown by a process of elimination to be D_xS_m, and the top face-up card just below it is $D_{x-1}S_m$, then the game is unwinnable. By extension, if there are two, three, or four remaining hidden cards $D_xS_m, \ldots, D_yS_n$ (where x, y, etc. do not have to be different, and m, n, etc. do not have to be different), and the top face-up cards just below them are $D_{x-1}S_m, \ldots, D_{y-1}S_n$, (same suits, next lower denominations) then the game is unwinnable. For example, if there are two remaining hidden cards that must be 10C and 2H, and the two cards just below the two hidden cards are 9C and AH (in either order), the game is unwinnable; neither hidden card can be revealed until either the 9C or AH is moved, and neither of them can be moved until either the 10C or 2H is available.

There are many other combinations, of course. In Figure 6, you can deduce that the two hidden cards are 7C and 9S. (Of course, we don't know which hidden card has which value.) The cards just under the hidden cards are AC and 8S; so to reveal at least one of the hidden cards, either 2C or 9S must be open. The 9S is hidden, but what about 2C, in column one? To open up the 2C so it could accept a move, the 6C just below it must be moved to another column. But that would require the 7C, which is the other hidden card. Therefore, this game is probably unwinnable. Why "probably"? There is a slight chance that the game could be winnable. Remember that the [2C, 6C] column segment, because it is not an in-sequence pair, must have been present at the initial deal *unless* it was accidentally created by the stock deal. That can

Figure 6

be determined by using undo to go back before the stock deal. If the [2C, 6C] does not exist before the stock deal, then there is a slight chance that it can be avoided by arranging for the 2C to be in a different column when the stock is dealt.

In a similar way, a single suit can get itself knotted up so as to make the game unwinnable. In Figure 7, note the four consecutive diamonds in column two: [QD, 9D, JD, 10D]. A prerequisite for eventually getting these four cards into sequence is to move the [JD, 10D] (and any cards under them - here, the AC) to another column. But this requires an open QD in the target column. The QD shown here will never be open until the 9D is moved away, and that would require the 10D to be open in another column. Again, one hope is that either the [QD, 9D] or the [9D, JD] was accidentally created by the stock deal, and that it is possible to avoid it with the help of undo. But in this case, there's another, better hope. The [JD, 10D] column segment

is in sequence, and that means that it may have been created by a move - specifically, the move 10D ➔ JD. This can be determined by using undo until either you undo a 10D ➔ JD move, or you reach the initial deal and see that [JD, 10D] was there from the beginning. If the former, then just replay the rest of the game and avoid the 10D ➔ JD move. But if you get back to the initial deal and see that [QD, 9D, JD, 10D] was all there from the beginning, then there's no hope.

Often in the midst of a game, you may have a subgoal that looks difficult to achieve. In this case, try working backwards to determine the other actions that must precede it. In Figure 8, suppose you would like to help the diamonds along by moving [4D, 3D] ➔ 5D. The 5D is not yet open, but it will be if you can move the 6S. The 7S is not yet open, but it will be if you can move [3H, AD]. The 4H is not yet open, but moving the AS would solve that. The 2S is blocked by the AC, but that's easily fixed. Now you see that your subgoal can be reached by the following sequence of moves:

> AC ➔ 2C
> AS ➔ 2S
> [3H, AD] ➔ 4H
> 6S ➔ 7S
> [4D, 3D] ➔ 5D (QED)

Figure 7

Figure 8

Once you get the hang of it, these backwards chains are easy to see. And since each link in the chain implies what the next link must be (in either direction), you don't have to memorize the sequence to keep track of a chain of whatever length.

Conclusion

Let's close with an outline of a general strategy:

Begin the game by making moves in any order that seems good, but preferring those that reveal a hidden card or leave an empty column.

Hold off on king shifts and the stock deal until no moves are possible. (This isn't a hard-and-fast rule; it's just a guideline.)
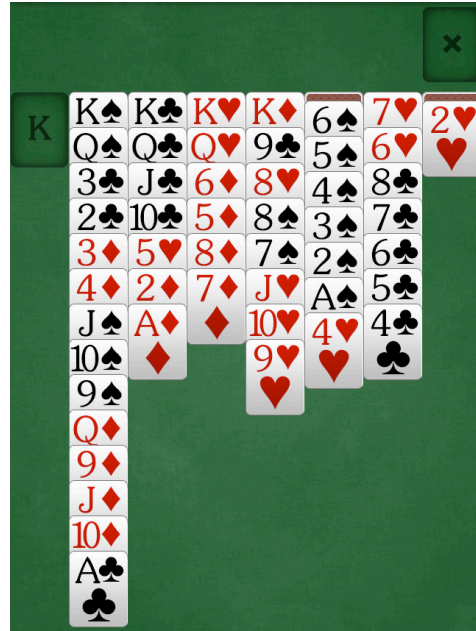
If you have at least one empty column when you run out of moves, do a king shift, preferring a king that is at the top of its column. If you have more kings than empty columns, try each king shift and see what it leads to. If one of them seems like a dead end, use undo to back out of it, then try shifting a different king.

After each king shift, pursue the available moves in any order that works well, until you run out of moves again. Then do the next king shift, if any, and proceed likewise.

When no moves or king shifts are available, then do the stock deal. Examine the results - specifically, the bottom two cards in each of the first four columns. If any of these pairs, created "accidentally" by the stock deal, seems particularly unfortunate (which doesn't actually occur very often), consider whether it could be fixed with undo. This is possible only if the column involved contains a king, and if there's a blank column available to shift it to.

After the stock deal, proceed as before. Make moves as long as you can, then see if any helpful king shifts are available.

If you manage to sequence all four suits, congratulations!

But if you come to a dead end, try to determine whether the deal is provably unwinnable. If it is, you've lost. But if another try seems worthwhile, back up to a point where you can try a different sequence of moves, perhaps all the way back to the initial deal. If you worked from the left the first time, try working from the right the second time; this is a simple approach to making moves in a different order.

If you ever reach a point where it seems that you're *almost* out of moves, take heart! A single move has the potential to bust the board wide open again.