

Klondike Solitaire

CS 458

Due 11:59 pm, May XX, 2016

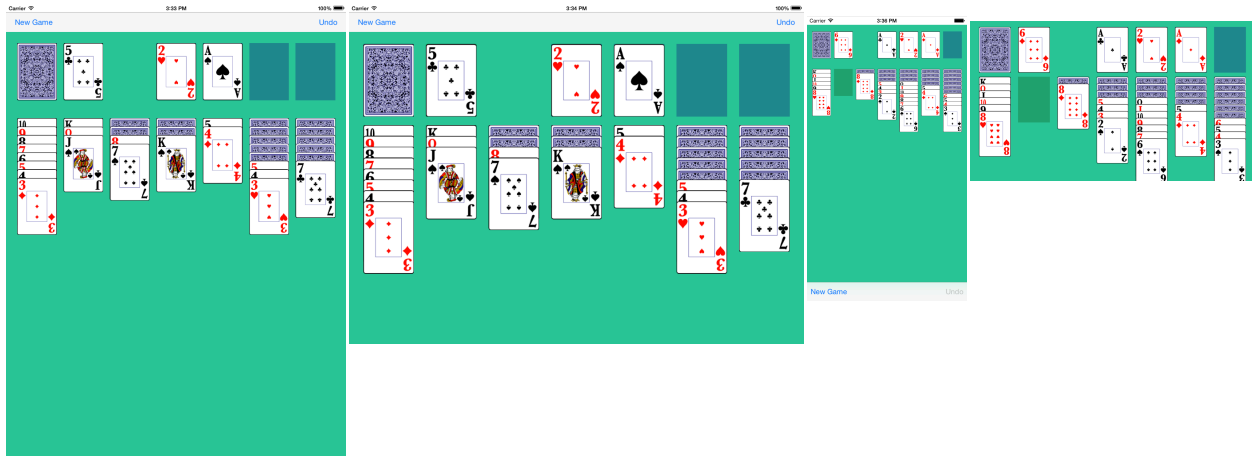


Figure 1: Klondike Solitaire Screenshots on iPad 2 and iPhone 6.

1 Introduction

This project describes an implementation of the popular *Klondike* solitaire card game for iOS. For a detailed description of how its played check out wikipedia:

[http://en.wikipedia.org/wiki/Klondike_\(solitaire\)](http://en.wikipedia.org/wiki/Klondike_(solitaire))

The game uses a standard 52-card deck of playing cards; Each card is either face-up or face-down on a card table as illustrated in Figure 1. Section 2 explains the terminology for the various regions of the card table. The MVC model elements represent a deck of (immutable) playing cards and a game engine that records the state of the game and dictates legal moves as described in Section 3. Section 4 describes how to represent playing cards and card table regions with Core Animation Layers. Most of the user interaction is handled by the `SolitaireView` class in the implementation described here. Other potential features are listed in Section 5.

2 Card table terminology and layout

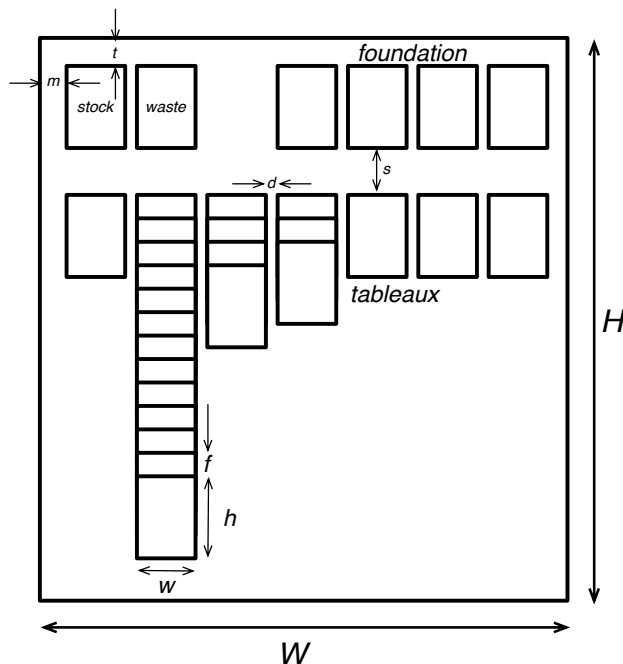


Figure 2: Layout of regions and cards.

There are thirteen regions that can hold stacks of cards as illustrated in Figure 2:

stock Holds cards (face down) not yet in play elsewhere. The user taps the top card to deal one or more cards (my app deals three) which are then flipped over and moved to the top of the waste.

waste Holds cards (face up) dealt from the stock. The user can move the top card onto one of the foundation or tableau stacks.

foundation One of four stacks that hold thirteen cards from ace to king all of the same suit. The goal is to get all 52 cards onto the foundation stacks.

tableau One of seven stacks that hold zero or more face down cards beneath a set of face up cards that alternate in color and descend in rank (ace is the lowest rank). A king may be placed on an empty tableau.

3 The Model

3.1 Cards

We represent a playing card by its suit and rank as listed in Figure 3. The `==` operator is overloaded for `Card`'s and we add a `hashCode` property so that `Card`'s can be `Hashable` (so we can use them as dictionary keys and them in `Set`'s.).

```

enum Suit : UInt8 {
    case SPADES = 0
    case CLUBS  = 1
    case DIAMONDS = 2
    case HEARTS = 3
}

let ACE    : UInt8 = 1
let JACK   : UInt8 = 11
let QUEEN  : UInt8 = 12
let KING   : UInt8 = 13

func ==(left: Card, right: Card) -> Bool {
    return left.suit == right.suit && left.rank == right.rank
}

struct Card : Hashable {
    let suit : Suit // .SPADES ... .HEARTS
    let rank : UInt8 // 1 ... 13

    var hashCode: Int {
        return Int(suit.rawValue*13 + rank - 1) // perfect hash to 0 ... 51
    }

    init(suit s : Suit, rank r : UInt8) {
        suit = s;
        rank = r
    }
    ...
}

```

Figure 3: We represent each playing card as an (immutable) **struct** that encodes the card's suit and rank. By conforming to the **Hashable** protocol we can use cards as dictionary keys.

3.2 Game Engine

The state of the game and behaviors are defined by a singleton object (stored in the App Delegate) that is an instance of the **Solitaire** class which has the following interface:

```

init() Create new Solitaire game model object.

func freshGame() Reshuffle and redeal cards to start a new game.

func gameWon() -> Bool All cards have successfully reached a foundation stack.

func isCardFaceUp(card : Card) -> Bool Is given card face up?

```

```

func fanBeginningWithCard(card : Card) -> [Card]? Array of face up cards found stacked
    on top of one of the tableau's.

func canDropCard(card : Card, onFoundation i : Int) -> Bool Can the given cards be
    legally dropped on the ith foundation?

func didDropCard(card : Card, onFoundation i : Int) The user did drop the given card on
    on the ith foundation.

func canDropCard(card : Card, onTableau i : Int) -> Bool; Can the given card be legally
    dropped on the ith tableau?

func didDropCard(card : Card, onTableau i : Int) The user did drop the card on the on
    the ith tableau.

func canDropFan(cards : [Card], onTableau i : Int) -> Bool Can the given stack of cards
    be legally dropped on the i tableau?

func didDropFan(cards : [Card], onTableau i : Int) A stack of cards has been dropped in
    the ith tableau.

func canFlipCard(card : Card) -> Bool Can user legally flip the card over?

func didFlipCard(card : Card) The user did flip the card over.

func canDealCard() -> Bool Can user move top card from stock to waste?

func didDealCard() Uses did move the top stack card to the waste.

func collectWasteCardsIntoStock() Move all waste cards back to the stock (they're all flipped
    over – order is maintained).

```

3.3 Internal representation

Internally we store the various card stacks in arrays and keep track of which cards are “face up” in a set:

```

class Solitaire {
    var stock : [Card]
    var waste : [Card]
    var foundation : [[Card]] // Array of 4 card stacks
    var tableau : [[Card]]    // Array of 7 card stacks

    private var faceUpCards : Set<Card>;
    ...
}
@end

```

4 The View Elements

4.1 Displaying Poker Cards

I represent each card visually using a custom `CALayer` subclass named `CardLayer` – each instance is permanently associated with exactly one of the model’s `Cards`:

```
class CardLayer: CALayer {
    let card : Card
    var faceUp : Bool {
        didSet {
            if faceUp != oldValue {
                let image = faceUp ? frontImage : CardLayer.backImage
                self.contents = image?.CGImage
            }
        }
    }
    let frontImage : UIImage
    static let backImage = UIImage(named: ...)

    init(card : Card) {
        self.card = card
        faceUp = true
        frontImage = imageForCard(card) // load associated image from main bundle
        super.init()
        self.contents = frontImage.CGImage
        self.contentsGravity = kCAGravityResizeAspect
    }
    ...
}
```

Each card image is stored in a `UIImage` instance (loaded from PNG’s stored the app’s bundle at launch time) whose `CGImage` property is used to set the `CardLayer`’s `contents` property. A single image is shared by all `CardLayer`’s to represent the backside of the card and a unique image is used when the card is face up. Using Core Animation layers has the advantage of being automatically animated as they change position and their stacking order is controlled by the `zPosition` property.

4.2 The Card Table View

Most of the UI interaction (*e.g.*, touching and dragging cards) is handled directly by my `SolitaireView` class ¹ which encapsulates the card table view elements and all the playing cards and has direct access to the model object (lazy loaded from the App Delegate). Internally I represent all the pertinent regions of the card table with a `CALayer` which are added (along with all 52 playing cards) as sublayer’s the view’s main layer. I use a dictionary to map a model `Card` to its associated `CardLayer`.

¹Perhaps it would be more appropriate for the view controller to handle much of this logic.

```

class SolitaireView: UIView {
    var stockLayer : CALayer!
    var wasteLayer : CALayer!
    var foundationLayers : [CALayer]! // four foundation layers
    var tableauLayers : [CALayer]!    // seven tableau layers

    var topZPosition : CGFloat = 0 // "highest" z-value of all card layers
    var cardToLayerDictionary : [Card : CardLayer]! // map card to it's layer

    var draggingCardLayer : CardLayer? = nil // card layer dragged (nil => no drag)
    var draggingFan : [Card]? = nil          // fan of cards dragged
    var touchStartPoint : CGPoint = CGPointZero
    var touchStartLayerPosition : CGPoint = CGPointZero

    lazy var solitaire : Solitaire! = { // reference to model in app delegate
        let appDelegate = UIApplication.sharedApplication().delegate as! AppDelegate
        return appDelegate.solitaire
    }()
    ...
}
@end

```

4.2.1 Initializing the View

An instance of my `SolitaireView`, which is stored in the StoryBoard, is further initialized after it has been deserialized from the StoryBoard. Each layer is created and added as a sublayer to the view's main layer. Each layer is given a name for future identification on user touches.

```

override func awakeFromNib() {
    self.layer.name = "background"

    stockLayer = CALayer()
    stockLayer.name = "stock"
    stockLayer.backgroundColor =
        UIColor(colorLiteralRed: 0.0, green: 0.5, blue: 0.0, alpha: 0.3).CGColor
    self.layer.addSublayer(stockLayer)

    ... create and add waste, foundation, and tableau sublayers ...

    let deck = Card.deck() // deck of poker cards
    cardToLayerDictionary = [:]
    for card in deck {
        let cardLayer = CardLayer(card: card)
        cardLayer.name = "card"
        self.layer.addSublayer(cardLayer)
        cardToLayerDictionary[card] = cardLayer
    }
}

```

```

    }
}

```

The actual positions and sizes of each layer is determined later as described in the next section.

4.2.2 Table Layout

The various sublayers are (re)arranged when the orientation of the app changes which triggers the view's `layoutSublayersOfLayer:` method. The view provides a method that determines the size and position of each layer based on the current view geometry:

```

-(void)layoutTableAndCards {
    const CGFloat width = self.frame.size.width;
    const CGFloat height = self.frame.size.height;
    const BOOL portrait = width < height;

    ... determine size and position of stock, waste, foundation
        and tableau layers ...

    if (self.solitaire != nil)
        [self layoutCards];
}

```

The size, position, and z-order of each card layer is computed in the method below. The cards in each tableau stack is fanned downwards.

```

-(void)layoutCards {
    CGFloat z = 1.0;    // card layer z-positions will be set to 1..52

    NSArray *stock = [solitaire stock];
    for (Card *card in stock) {
        CardLayer *cardLayer = [cardToLayerDictionary objectForKey:card];
        cardLayer.frame = stockLayer.frame;
        cardLayer.faceUp = [solitaire isCardFaceUp:card];
        cardLayer.zPosition = z++;
    }

    ... layout cards in waste and foundation stacks ...

    const CGFloat fanOffset = FAN_OFFSET*cardSize.height;
    for (int i = 0; i < 7; i++) {
        NSArray *tableau = [solitaire tableau:i];
        const CGPoint origin = tableauLayers[i].frame.origin;
        int j = 0;
        for (Card *card in tableau) {
            CardLayer *cardLayer = [cardToLayerDictionary objectForKey:card];
            cardLayer.frame = CGRectMake(origin.x, origin.y + j*fanOffset,

```

```

                                cardSize.width, cardSize.height);
    cardLayer.faceUp = [solitaire isCardFaceUp:card];
    cardLayer.zPosition = z++;
    j++;
}
}

    topZPosition = z; // remember "highest position"
}

```

4.2.3 Dragging and Tapping Cards

Most of the user interaction involves the user selecting a card (or stack of cards), dragging them to another location, and dropping them on a stack. Other gestures can trigger actions as well:

1. The user taps on the top card of the stock when wanting to “deal” another card;
2. A tap on the stock causes all the waste cards to be collected back into the stock;
3. A double tap provides a shortcut that automatically moves a top face-up card to a foundation stack (if legal).

Most actions begin on a user touch where we can use `CALayer`’s `hitTest:` method to determine which layer was touched:

```

-(void)touchesBegan:(NSSet *)touches withEvent:(UIEvent *)event {
    UITouch *touch = [touches anyObject];
    CGPoint touchPoint = [touch locationInView:self];
    CGPoint hitTestPoint = [self.layer convertPoint:touchPoint
                                                toLayer:self.layer.superlayer];
    CALayer *layer = [self.layer hitTest:hitTestPoint];

    if (layer == nil) return; // can this happen?

    if ([layer.name isEqual:@"card"]) {
        CardLayer *cardLayer = (CardLayer*) layer;
        Card *card = cardLayer.card;
        if ([self.solitaire isCardFaceUp:card]) {
            ...if tap count > 1 move to foundation if allowed...
            ...else initiate drag of card (or stack of cards) by setting
                draggingCardLayer, and (possibly) draggingFan...
        } else if ([self.solitaire canFlipCard:card]) {
            [cardLayer setFaceUp:YES];
            [self.solitaire didFlipCard:card];
        } else if ([[self.solitaire stock] lastObject] isEqual:card) {
            ...deal card(s) from stock to waste..
        }
    } else if ([layer.name isEqual:@"stock"]) {

```



```

        [self.solitaire collectWasteCardsIntoStock];
        ...flip and move waste card layers back to stock...
    }
}

```

The following method is used to drag or move a `CardLayer` (or a fanned stack of `CardLayer`'s). The instance variables `draggingCardLayer` and `draggingFan` are set in the `touchesBegan:withEvent:` method when the user selects a card (or stack of cards) to drag. While the user is dragging cards (*e.g.*, while processing a `touchesMoved:withEvent:` message) we want to disable animation, but otherwise we animate the change of position:

```

-(void)dragCardsToPosition:(CGPoint)position animate:(BOOL)animate {
    if (!animate) {
        [CATransaction begin];
        [CATransaction setValue:(id)kCFBooleanTrue
            forKey:kCATransactionDisableActions];
    }
    draggingCardLayer.position = position;
    if (draggingFan != nil) {
        const CGFloat off = FAN_OFFSET*draggingCardLayer.bounds.size.height;
        const int n = [draggingFan count];
        for (int i = 1; i < n; i++) {
            CardLayer *clayer =
                [cardToLayerDictionary objectForKey:[draggingFan objectAtIndex:i]];
            clayer.position = CGPointMake(position.x, position.y + i*off);
        }
    }
    if (!animate) {
        [CATransaction commit];
    }
}

```

For example, if the user drops a fan of cards in a bogus location, we can use this method to animate moving them back to their original position.

4.2.4 Dropping Card(s)

When a touch sequence ends we need to do the following:

1. Determine where the user is attempting to drop the card(s) by comparing the frame of the layer being dragged with all the frames of potential target layers (`CGRectIntersectsRect` is useful here).
2. Check to see if this is a valid drop (can't just drop them anywhere) and a legal drop (consult the model).
3. If the drop is okay, then the model needs to be informed of the change and the view needs to be updated accordingly.

4. If the drop is *not* okay, then the card(s) need to moved back

```
-(void)touchesEnded:(NSSet *)touches withEvent:(UIEvent *)event {
    if (draggingCardLayer) {
        if (dragging only one card) {
            ... determine where the user is trying to drop the card
            ... determine if this is a valid/legal drop
            ... if so, update model and view
            ... else put card back from whence it came
        } else { // fan of cards (can only drop on tableau stack)
            ... determine if valid/legal drop
            ... if so, update model and view
            ... else put cards back from whence they came
        }
        draggingCardLayer = nil;
    }
}
```

5 Other Bells and Whistles

5.1 Persistant Store

When the app enters the background, the state of the model should be saved in the app's sandbox. If the `Solitaire` class (and the `Card` class) conform to the `NSCoding` protocol, the archiving technique discussed in class works well. When the app is launched, check to see if the state of the previous run has been saved; If so, decode the archive, otherwise start a new (random) game.

5.2 Animating the deal

If you are dealing more than one card at a time when the use touches the card on the top of the stock, there should be a sequence of animations triggered for each card. Don't forget to update the layer's model layer before each animation so that the final resting place each dealt card persists!

5.3 Undo

Having one level of undo is a nice feature (more than this tempts the user to cheat). To accomplish this you need to record the appropriate set of actions that undo the most recent action. These actions can be stored in an instance of `NSInvocation` – this is actually a bit of work!

5.4 Party when the user wins!

The user should get some sort of visual “pay off” when (s)he wins. A cool card animation might be the ticket.

6 Finishing up

Polishing the final app and following the steps needed for submission to the iTune's store is worth practicing. This can easily be made into a universal app that operates in all orientations – the trick is making the cards just the right size and placing the tableaus so you can see up to $6 + 13$ cards fanned out (6 face-down cards plus king through ace).