**Characterization of Set Cards Using Image Processing**

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Visualization and Image Processing

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***Abstract****: The game SET involves cards with variations of four different features: shape, number, color, and shading. Computer vision is the study of programming computers to extract information from images. Different methods were developed to extract data of these features from images of Set cards. Shape was determined by measuring the ratio of the area of a single shape to the total area of the card. Shading was determined by measuring the ratio of the un-shaded parts of a shape to the total area of the shape. Number was determined by measuring the number of contiguous Sets of pixels in binary images of cards. Color was determined by analyzing the different red, green, and blue values of pixels. The program successfully extracted the characteristics of scanned and downloaded images of Set cards.*

**1.0 Introduction**

Computer vision is a field focused on programming computers to extract information from images. This fast growing field has increasing relevance as computers become more powerful. Current uses of computer vision include medical image processing and visual surveillance. In order for a computer or robot to accomplish these tasks involving pictures, it is necessary for them to be able to interpret related images.

 Pixels are the smallest parts of an image. Each pixel is made up of three different colors: red, green, and blue. Every pixel’s component colors have values denoting the intensity of the color at that point. Typically, 0 denotes that the color is not present, while 255 denotes that the color is present a full intensity. All three of these colors combined form the color of the pixel. When all of the pixels are considered together, a color image is formed. Computers read images by looking at individual pixels and the intensity values of the three colors at each pixel.

 Binary images are pictures that contain two colors: black and white. In a binary image, each pixel either has a value of 0 or 1. Binary images are easier to interpret because they have fewer possibilities for pixels. This allows operations like detecting the number of shapes simpler.

Computers use this pixel data to interpret and recognize shapes. Most methods of shape recognition involve programming a library of possible shapes into a computer. Observed shapes are then compared to shapes in the library, and a match can be found (Grimson, 1991). One method of comparing shapes is based on unique characteristics of the shapes including edges and intersections found within an object. Other methods involve extracting the different brightness values at points on the object (Belongie, Malik, Puzicha, 2002). Edge detection algorithms can also be used to find shapes and their colors (Parker, 1996).

 The game of SET involves cards that each have 4 characteristics: color, number, shape, and shading. Table 1 shows the different possibilities for each characteristic. A Set consists of three cards in which each feature is either the same on each card or is different on each card (How to Play Set®; Rules and Overview). The goal of SET is to identify Sets within groups of 12 cards.

Table 1: Possibilities for each characteristic on a SET card

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | **Color** | **Shape** | **Shading** |
| 1 | Red | Oval | Not Shaded |
| 2 | Green | Diamond | Partially Shaded |
| 3 | Purple | Squiggle | Fully Shaded |

Figure 1 shows some examples of Sets. In row one, all of the cards are red, ovals, and contain two shapes. In each card, the shading is different. In row two, all of the cards are partially shaded. In addition, each card has a different number of shapes, a different shape, and a unique color. In row three, each card has a different shape, number of shapes, color, and shading.

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

Figure 1: Sample Sets (How to Play Set®; Rules and Overview)

 This experiment investigated the possibility of using computers to determine the characteristics of Set cards. This experiment is important because it provides a basis for another method of computer image interpretation. While the methods used to determine the characteristics of Set cards currently work in limited contexts, they can be expanded and modified to meet different and more challenging needs.

**2.0 Methods**

Various image processing techniques were used to determine the characteristics of the Set card. The following sub-sections describe the techniques chosen in order to determine the four characteristics.

**2.1: Number Detection**

In order to determine the number of shapes on a card, the image of a Set card was converted into a binary image. The number of contiguous groups of pixels with the same values was counted. Since each shape was contiguous, the number of contiguous groups was equal to the number of shapes on the card. In order to account for noise in the background, all detected shapes were checked to ensure they contained at least 1000 pixels. For each detected object that had fewer than 1000 pixels, the number of shapes was decreased by 1.

**2.2: Determining Color**

Two different techniques were used to determine the color of the shapes on the card. Both techniques are described to show how different techniques can be used to find the same values of color.

One method made use of text images of the red and blue channels of the RGB Set card picture. All near-white values were excluded. The average of the remaining numbers in the text image was computed. A high average indicated strong presence of the color, while a low average indicated weak presence of the color. Different combinations of presence of red or blue in the image indicated the color of the shapes in the Set card.

 Another method used a script that looked at the red, green, and blue values of each pixel. Skipping near white pixels (where all three values were all above 0.7), the program found a pixel where only some combinations of the colors were strongly present (intensity above 0.6). The combinations of strongly present and weakly present colors suggested the color of the Set card.

 **2.3: Determining Shape**

In order to determine shape, the ratio of the number of pixels in one shape to the total area of the card was computed. Before this ratio was calculated, holes in the cards were filled. This had the effect of making all shapes appear fully shaded, thus eliminating the shading variable from these shape calculations. Table 2 shows the different ratios used to determine the shape present on the card.

Table 2: Ratios used in Shape Determination

|  |  |  |
| --- | --- | --- |
| Shape  | Lower Bound | Upper Bound |
| Diamond | 0.06 | 0.107 |
| Squiggle | 0.107 | 0.1325 |
| Oval | 0.1325 | 0.17 |

**2.4: Determining Shading**

 In order to determine shading, the number of near white pixels that were inside the shape was computed. This was done by measuring how many pixels were associated with a shape both before and after holes in the shape had been filled during shape detection. The difference between these two numbers was found, and a ratio between the number of pixels that had been filled in and the total area of the shape was then computed. Table 3 shows how the ratios were used to determine the shading.

Table 3: Ratios used in Shading Determination

|  |  |  |  |
| --- | --- | --- | --- |
| Shape | Shading | Lower Bound | Upper Bound |
| All Shapes | Completely Shaded | 0 | 0 |
| Diamond | Half Shaded | 0.01 | 0.68 |
| Not Shaded | 0.68 | none |
| Squiggle | Half Shaded | 0.01 | 0.71 |
| Not Shaded | 0.71 | none |
| Oval | Half Shaded | 0.01 | 0.75 |
| Not Shaded | 0.75 | none |

**2.5: Determining if Three Cards Form a Set**

 After the characteristics of a given card had been detected, a numerical descriptor was assigned that described which variation of the each detected aspect had been found. Each possibility was given a separate number. For example, if the color was red, a value of 1 was stored; if the color was green, a value of 2 was stored; if the color was purple, a value of 3 was stored. A similar process was repeated for number, shading, and shape. The 4 values were input into a separate matrix for each card. All 3 card matrices were added together to form a 4th matrix.

 In order for 3 cards to form a Set, each characteristic must be the same on all 3 cards or different on all 3 cards. Thus, if all characteristics had possible values of 1, 2, or 3, the possible sums could be 3 (1+1+1), 6 (2+2+2 or 1+2+3), or 9 (3+3+3). If only these values were present in the 4th matrix, the cards were said to be a Set. Otherwise, they were said to not be a Set.

**2.6: Testing the programs**

 In order to test different methods of determining the characteristics of Set cards for accuracy, different sample cards downloaded from the SET Game Company Homepage and scanned images of cards were submitted for analysis. The results were compared to actual characteristics of the cards.

**3.0: Results**

The program successfully interpreted 81/81 Set cards downloaded from the SET Enterprises website. 36/36 scanned images of Set cards were also interpreted successfully. The method to detect if three cards was or was not a Set was also successful in differentiating between the two in cases involving both downloaded and scanned Set cards. Figure 2 shows the sample output given by the developed methods. The interpreted card is shown on the right.



Figure 2: Sample Output of Set card Characteristic Recognition Methods

**4.0: Discussion**

The purpose of this investigation was to determine if it was possible for the characteristics of Set cards to be extracted on a computer. It is clear that this is indeed possible. Developed methods successfully interpreted pictures of cards that had been downloaded from the SET website and that had been scanned into the computer. Cards downloaded from the SET website were free of any background noise or color variation between the cards. Scanned images had both background noise and color variation. It is important that the methods were able to interpret both types of cards because it gives them more applicability; the programs used here worked successfully in a variety of contexts.

Future work should continue to expand the scope of this program and its methods. Currently, all cards tested and all developed methods focused on images with only the card and nothing else in them. In addition, the methods only work for one card at a time. Expanding the program to detect many cards within an image and interpret all of them would increase the uses of the program. Application of the methods used in this program to other problems should be pursued. The ability to pick out multiple Sets from a series of scanned cards could also be considered.

# 5.0: Works Cited

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