Team Number: LLHS-1

School Name: Los Lunas High School

Area of Science: Mathematics

Project Title: What's Missing?

Problem Definition:

Missing pieces of data can simultaneously be both crucial and hard to find. How does a person go about finding one missing piece of information? Does a person go through all the records until he or she can finally piece together what's missing? Theoretically, yes, that is one method for finding it, and while it would be a time-consuming process, it should work.

However, what happens when there are two, three, or more missing pieces of information? How does one find the missing pieces then? One cannot go through all the records anymore because there are too many holes in it. Is it impossible then? The answer is no. The world is governed by patterns, patterns that when observed are tested, and when tested to be true are set as "theories" or perhaps even "laws" by which the world is governed. Therefore, if the world is governed by patterns, can we see a pattern in missing pieces of information? And using that pattern, is there an algorithm that will enable us to find our missing pieces of data?

Problem Solution:

The card game SET has many mathematical properties. The most notable is an algorithm that, when missing a card, will enable us to find what that missing card is based solely on the cards left over after playing the game. The game is comprised of 81 cards, each card having 4 different attributes (number, color, shading, and shape) with each attribute having 3 different variations. The variations are listed below:

- Number = 1, 2, or 3
- Color = Red, Green, or Purple
- Shading = Open (no shading/empty), Hashed, or Solid
- Shape = Oval, Diamond, or Squiggle

The object of the game is to create a "SET," a group of 3 cards in which each of the attribute's variations are either all the same or all different. For example, when looking at the color attribute, the variation has to be either all red, green, *or* purple (in other words all the same) or red, green, *and* purple (in other words all different). This is done for each of the attributes. The person who finds the most SETs wins. This is the regular version of the game.

However, there is a version called "End Game SET," where the only difference is that a card is taken out at the beginning of the game. After the card is taken out, the game is played normally.

At the end, there will be cards left over (the ones that did not pair with the other cards to create a SET), and using those cards, an algorithm can be used to find the missing card.

It works in this way:

1. Assign the variations of an attribute with a value of either 0, 1, or 2.
2. Add up the variations of all the cards.
3. Repeat steps 1 and 2 for each attribute.
4. Find the number that will cause the modulus 3 of the sum to equal zero.
5. Refer to the variation values to find the corresponding variation.

An example:

Let's say we have the following 5 cards left:

- 3 red open squiggles
- 1 green solid oval
- 3 green solid diamonds
- 3 green open ovals
- 3 red solid ovals

Following steps 1 and 2 for all the attributes we have the following assignment:

- Number: 1=0, 2=1, 3=2
- Color: Red=0, Green=1, Purple=2
- Shading: Open=0, Hashed=1, Solid=2
- Shape: Oval=0, Diamond=1, Squiggle=2

Now let's add all the variations of the attributes:

Number: 2 + 0 + 2 + 2 + 2 = 8

Color: 0 + 1 + 1 + 1 + 0 = 3

Shading: 0 + 2 + 2 + 0 + 2 = 6

Shape: 2 + 0 + 1 + 0 + 0 = 3

Now find the number that will cause the modulus 3 (the remainder after dividing by 3) of each of the above sums to equal zero. Those numbers in order of the above sums are: 1, 0, 0, 0.

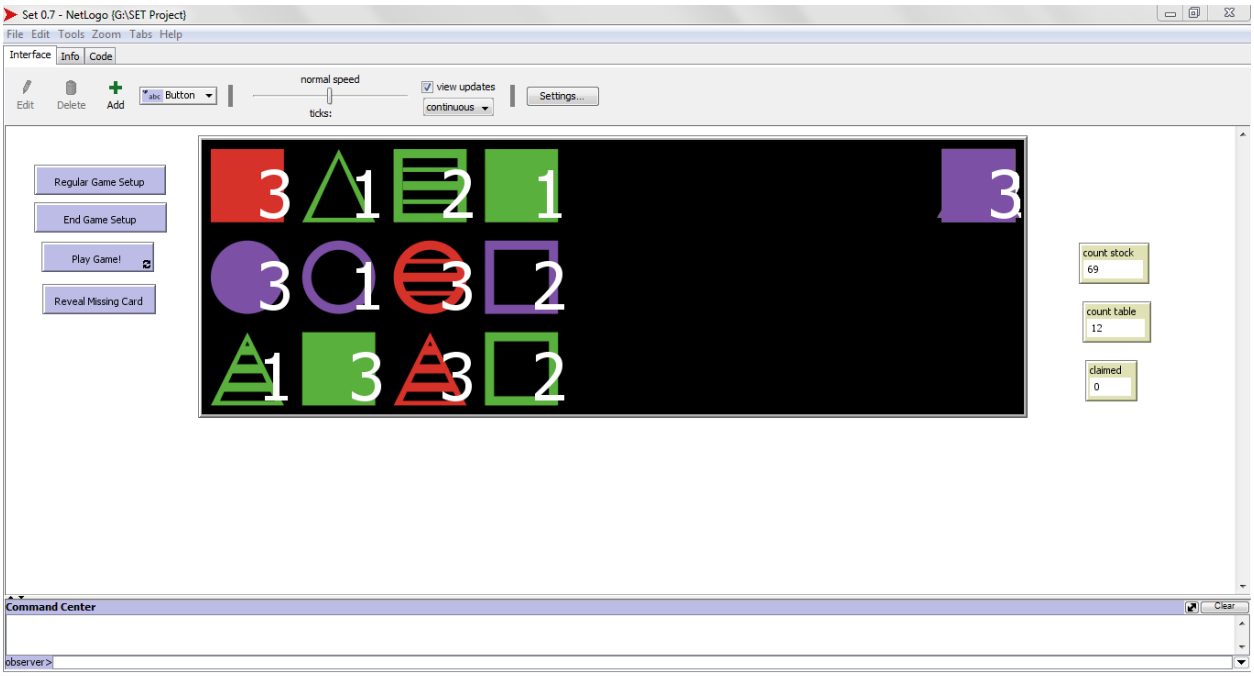
Now look at the corresponding values to find the variations: We will need 2 red open ovals.

We can use this algorithm to find one missing card.

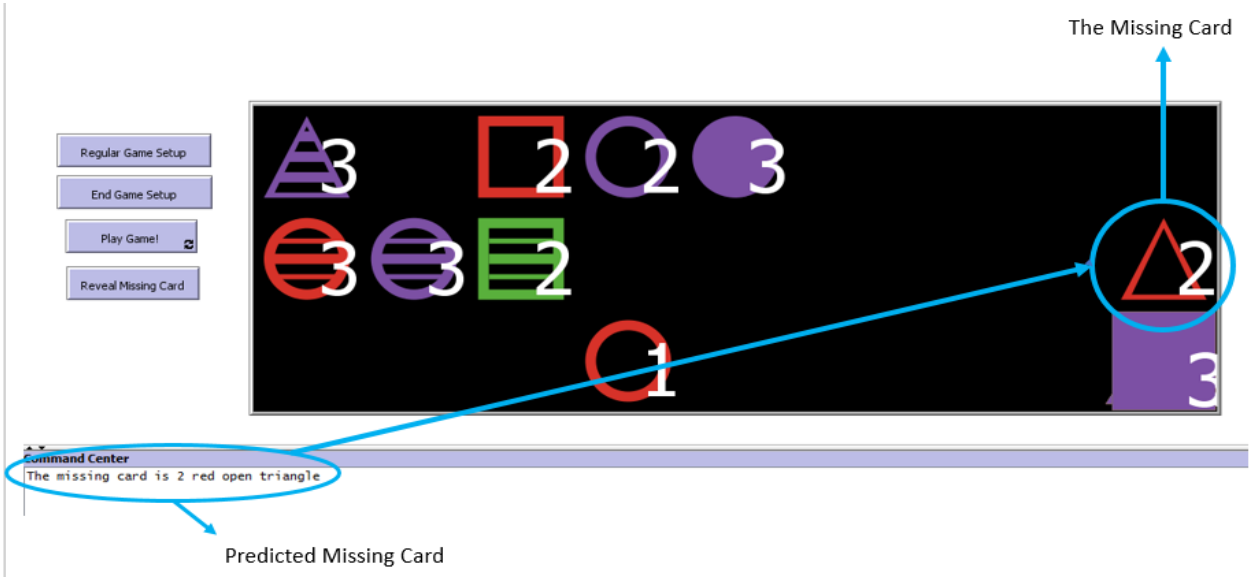
Progress to Date:

Presently, our team has done some research about the mathematical properties of the game SET. Using that research, we have created a working NetLogo version of the game SET. It plays both the regular and End Game versions.

Regular Setup and Game



End Game Version



Expected Results:

We expect to be able to create an algorithm that will find 2 or 3 missing cards/missing pieces of information. We then expect to be able to apply this to the real world in accounting or cybersecurity.

Team Members:

Jen Marie Phifer, Forest Good

Sponsoring Teacher: Anne Loveless