Using Genetic Algorithms to Estimate Tropical Cyclone Intensity

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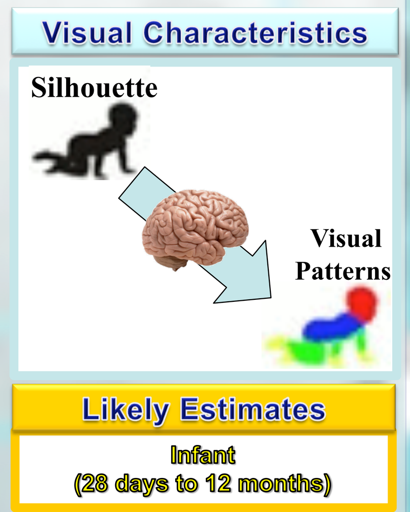
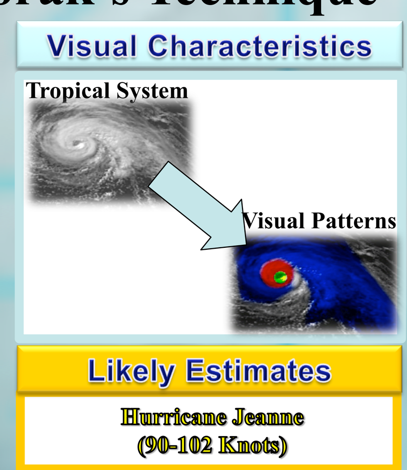
1. INTRODUCTION

Visual patterns help us make good estimates



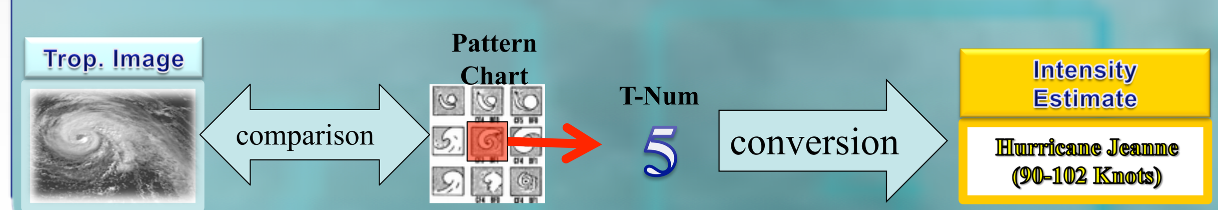
◆Examining the human silhouette to the right, you would most likely guess it to be an infant within the age range specified below. You're able to do this because your brain breaks down the image into recognizable visual patterns (highlighted in different colors) and compares it to past experiences in order to make an age estimate.

Tropical System Intensity and Dvorak's Technique



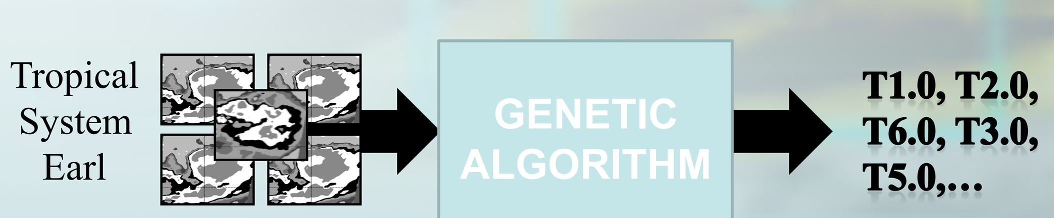
◆In a similar way, Vernon Dvorak realized in the 1970's that tropical systems also have unique visual patterns such as outer curving bands (in blue) or an eye (in green) that allow us to make good estimates about how intense they are (as measured in maximum sustained winds).

◆He devised an elaborate technique for comparing a tropical system's image to a chart of visual patterns to arrive at a tropical number (or T-Num) which could be converted to tropical system intensity as shown below.

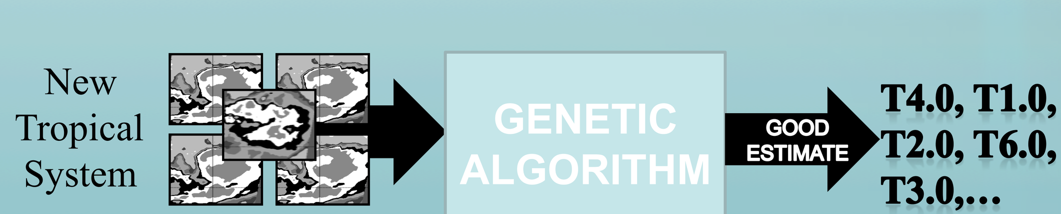


2. OBJECTIVE

- To use a genetic algorithm (GA) to teach a computer to learn for itself how to process the visual patterns of a tropical system and estimate its intensity through T-Nums (without the Dvorak Technique).



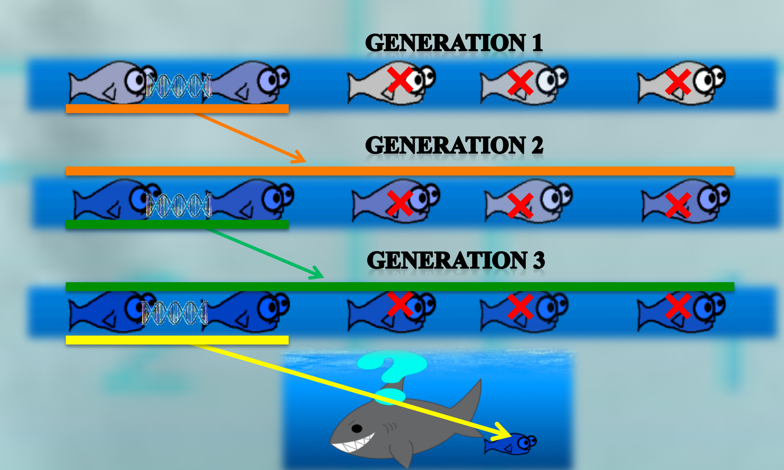
- In the training stage, 21 satellite images from Hurricane Earl (2010) are fed into the GA. The GA learns how to associate the patterns with T-Nums. Once the GA has learned, it should be able to process new satellite imagery to produce additional intensity estimates.



3. METHOD

(1) The genetic algorithm (GA) is based on biological evolution

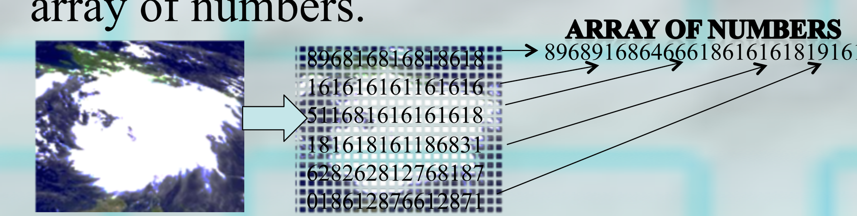
◆In the hypothetical illustration below, a population of a species of fish have members with a variety of color shades. The fish with bluer shades have a higher survival rate since it's harder for a predator (like a shark) to find them in a blue ocean. Because of this, bluer fish tend to pass their genes to later generations while lighter fish die off.



◆Over many generations, more of the blue genes get expressed until the fish blends in so well that sharks can't detect them. Nature "naturally selects" the fittest fish for its environment.

(2) The genes of this GA are a list of operators

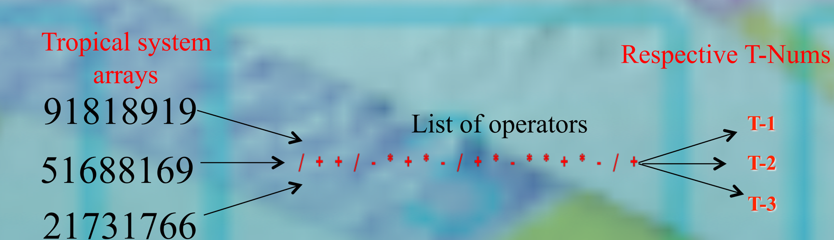
◆Every digital image is a grid of pixels, each which represents a number. By linking its rows together, we create a long array of numbers.



◆By placing random mathematical operators between these numbers we can get the computer to calculate values from each image. Our intention is for the calculated values to be as close as possible to that image's T-Num.

3/ 8+2+0/9.5+8+0*2.7/3+9*6.2*0*2+9*8.0/5+6 ≅ Tnum

◆In this research, our 'genes' are the list of operators. We want the genetic algorithm to evolve towards the list of operators that will correctly convert each tropical system's image's number list into its respective T-Num.

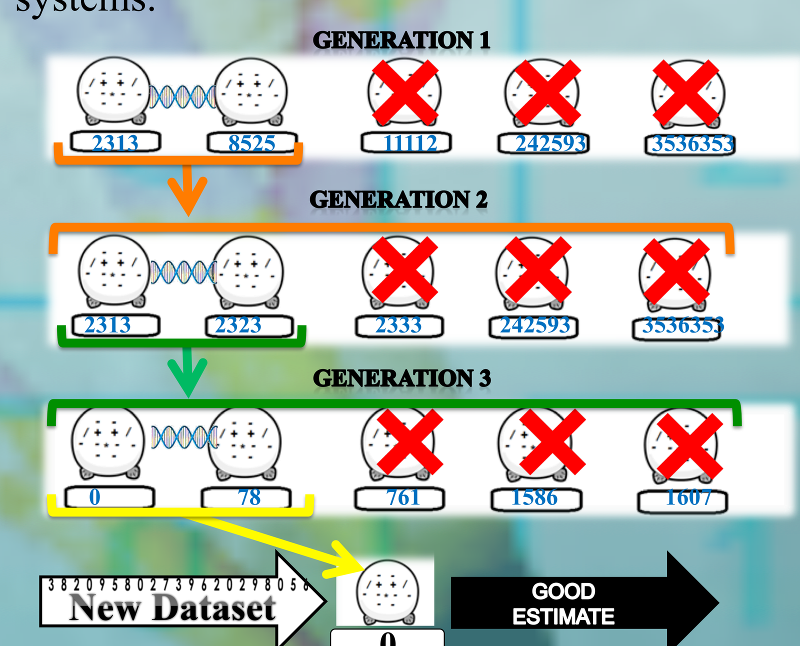


(3) Random solutions of the GA evolve to better solutions over time

◆To do this, we used a measure of how well or 'fit' our 'genes' performed by finding the difference between the value it generated and the actual T-Num we want to approach. The closer the fitness is to zero, the better the operator list approximates the true T-Num value.

FITNESS = |generated value –TNum|

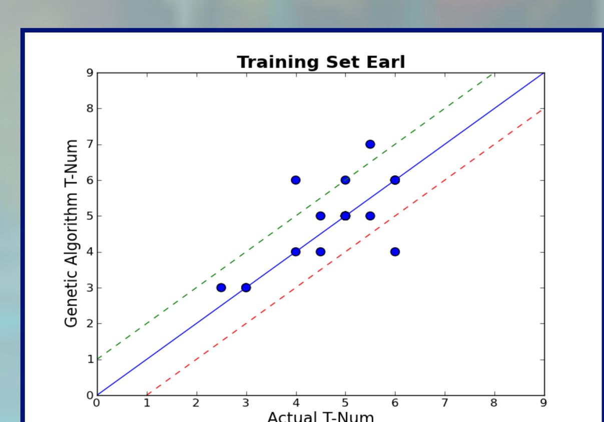
◆By initially creating a population of random genes or operator lists, we can artificially select the solutions with the best fitness and pass a random mix of their operators to the next generation. By repeating this process over several generations, we can produce a solution that will have a fitness close to zero. From this, will test its performances with other tropical systems.



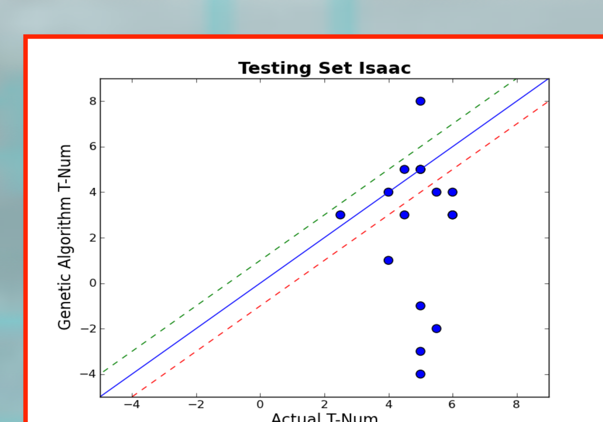
4. RESULTS and DISCUSSION

Trained Vs. Tested

◆After training the GA with Hurricane Earl, the GA evolved a solution with a fit close to zero. In testing the GA with the Hurricane Earl dataset, the fit is 0.4 with most values falling within ±1 T-Num from the actual values (as indicated by the area between the green and red dotted lines). When given a new dataset from Hurricane Isaac (2012), the GA's estimates are well outside of an acceptable error range.



No. of Images: 21
Initial Average Fitness: 4.29
Final Average Fitness: 0.4
Learning Time: Approx. 4 days
Execution Time: Less than 20 seconds
R-squared: 0.53



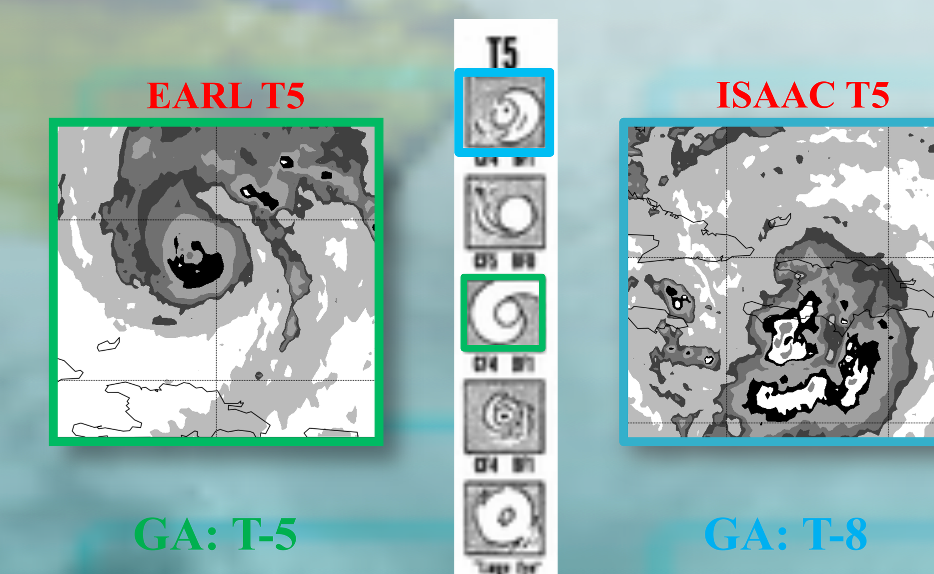
No. of Images: 18
Average Fitness: 3.4
Execution Time: Less than 20 seconds
R-squared: 0.04

Different Features

◆The reason we believe the GA performed well with Earl and not Isaac is most likely due to the differences in their visual patterns. During their development, Earl was a fairly organized system while Isaac was not. As shown in the chart of tropical system patterns below, the GA must have been trained to recognize only Earl's features (blue Xs). Since most of Isaac's patterns (red Xs) do not overlap with Earl's, the GA completely missed those images.

5. DISCUSSION (cont.)

- To support this claim further, take two images (one of Earl and Isaac) which both have a T-Num of 5. Since the GA was trained for Earl, it correctly recognized the visual pattern highlighted in green (notice its similarities to Earl), yet missed Isaac's visual pattern highlighted in blue (notice its similarities to Isaac).



6. FUTURE WORK

- To improve the GA, the GA must learn from a larger set of patterns. Instead of learning from one tropical cyclone, all storms from the last 5 years should be given to the GA so it understands the diversity of patterns associated with a particular storm intensity.

7. REFERENCES

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8. ACKNOWLEDGEMENTS

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