The integral part calculus plays in using the backpropagation algorithm for machine learning.

As part of Research Experience for Educators (RET) the primary mission of the project is to expose Advanced Placement Calculus high school students to the field of computer vision by providing them with a learning experience that both advances their knowledge in a specific calculus topic while simultaneously integrating concepts and tools typically encountered in the field of computer vision.

**Learning Goals:** The student will understand how calculus is used in the backpropagation process of machine learning in a neural network. The student will be able to recognize and apply the following AP Calculus topics: evaluate and derive a logistic function, interpret and apply the chain rule, demonstrate mathematical fluency, and analyze functions.

**Problem**

How is a car trained to be autonomous?

**Objective**

This project will focus on the concept of backpropagation as a means to adjust weights and biases while training a computer to learn how to recognize input images and video.

**Connection to AP Calculus**

The logistic function, sigmoid, and its limiting factor is a topic covered on the AP Exam. The activation function in our neural network model will be a logistic function. Students will evaluate it during a “forward pass” and find its derivative for use in the backpropagation.

**Conceptual Frameworks**

Machine Learning  
Neural Networks

**Independent Student Research**

Students will explore the following sites and any others they may find to gain some insight on machine learning and neural networks to answer the following questions.

What is machine learning?
What is a neural network?

**Classroom Activities**

1. Students will be given the transfer function, \( \sigma(x) = \frac{1}{1 + e^{-x}} \), and asked to work in pairs to verify that its derivative is \( \sigma'(x) = \sigma(x)(1 - \sigma(x)) \).

2. Students will be given inputs, weights, biases, and asked to find the output value, \( \hat{y} \), for the given neural network.

3. Students will be given the desired output value and asked to find the error using the squared error function.

4. Students will discuss with their partner what this error value means.

5. Students will be asked what can be done to minimize the error.

6. Students will find the change in error with respect to an outer layer weight and a hidden layer weight.

**List of figures:**

- Figure 1: [Link to Image]
- Figure 2: [Link to Image]
- Figure 3: [Link to Image]
- Figure 4: [Link to Image]
- Figure 5: [Link to Image]