REPORT-1

What is Machine Learning?

Arthur Samuel (1959):

Machine Learning: Field of study that gives computers the ability to learn without being explicitly programmed.

Tom Mitchell (1998) Well-posed Learning Problem: A computer program is said to learn from experience E with respect to some task T and some performance measure P, if its performance on T, as measured by P, improves with experience E.

Machine learning Algorithms –

1. Supervised Learning – When we are given a training dataset in which “right answers” are given for every parameter , we use supervised learning algorithms to develop models for predicting future “right answers”.

In Supervised learning there are two types of problems –

1. Regression - Predict continuous valued output.
2. Classification - Discrete valued output (0 or 1)

2. Unsupervised Learning 🡪 When we are given a training dataset in which the data is not labeled for anything and we have to find a pattern in the set automatically with trial and error we use unsupervised learning.

Examples are – Clustering , Cocktail party Problem algorithm (can be used to find or distinguish elements in a chaotic environment like in a audio clip different sounds can be distinguished ).

Linear Regression –

1. With one variable –

h(x) = **θ + θ1(x)**

We try to find the values of the theta(0) and theta(1) to get out model to predict the future values in a better way.

For this we have to check the accuracy of the function for our given dataset and try to maximize it. This is done using cost function , which we try to minimize to increase the accuracy.

Cost function for one variable linear regression –

J(theta(0),theta(1))=(1/2N)∑i=1 to n(h(x)i-y)^2

The graph for plotting the cost function for one variable linear regression is always a convex function graph (bowl shaped).

Gradient descent – It is a algorithm which we use to minimize the cost function. In this we first take arbitrary values of the coefficients and then update them simultaneously each iteration to get to their optimum value so that the cost function is minimum.

“Batch” Gradient Descent

“Batch”: 'Each 'step' of 'gradient descent' uses 'all the training' examples.

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c0jxD480HVfBmlSa9pGpeD/E1xo901xbhgv76DcrL/AHlZW6dq9Z/Y31nUPEn7KfwtvtWvrjVdQ1Twjpl7dXtzLi4urmS1V33f8CzVT9s79jXR/wBtn4Jah4F1zxN478L6RrCeXfyeF9TGn317CMt9neVldShPVWG1skH71a37KX7Nlh+yr8ENJ8C6b4p8ceLrDR4vKtNQ8U6sNR1Hyf4VEwVf3artVRjhVUUAcR8Q/wBhs+M/2htX+J/h34sfFD4c+JNe0iDQ9TTw5aaHcW9xDbu+35tQ0u6kVtzN9x1Xhfl717H4P0K60jw9DY3uqaxqtxaweR9tvvs/2i76fvv9HVR+i11VFAHO+Fvh3o/gnUNYvtN0+0sbvxBcfbNSeGP5rqbbt3t610VFFABVW90xbtt27bVqigAooooAp29gyTeZvbb1VN3y1coooAKKKKACiiigDj0+Geh6Z451DxNZ2Nra+ItXgt7e7v0gVrq8t7dsrbk/3fvf99e1dhRRQAV86/tIfsX6t+1PoOtaFqnxn+LXhfwn4os/sd14e0az8PLai32gN++m0u4nVm/2Zx/s7a+iqKAOd8HeDbfwX4T03SLWRZIdLsbawgD+luNqn9P0roqKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigApqJtQLS7hQ/3aUZX2AWiiimAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAGjRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAGjRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAGjRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAGjRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAGjRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAGjRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAGjRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAGjRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAGjRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAGjRWd9ok/vt+dH2iT++350AaNFZ32iT++350faJP77fnQBo0VnfaJP77fnR9ok/vt+dAH//2Q==)

Since the graph for cost function of one variable LR is convex function, it is guaranteed that the gradient descent algorithm will reach the global minimum of the function.

If we use gradient descent for more variables of other functions, we find that there is a chance that the gradient descent algorithm will stop at a local optimum value of the function instead of going towards the global minimum.

1. Multivariable Linear Regression –

*hθ*​(*x*)=*θ*0​+*θ*1​*x*1​+*θ*2​*x*2​+*θ*3​*x*3​+⋯+*θn*​*xn*​

*hθ*​(*x*)= *θ(Transpose)x*

*where θ is the matrix of all coefficients*

Diagram, text

Description automatically generated

Feature scaling involves dividing the input values by the range (i.e. the maximum value minus the minimum value) of the input variable, resulting in a new range of just 1.

Mean normalization involves subtracting the average value for an input variable from the values for that input variable resulting in a new average value for the input variable of just zero

**Polynomial Regression**

Our hypothesis function need not be linear (a straight line) if that does not fit the data well.

We can **change the behavior or curve** of our hypothesis function by making it a quadratic, cubic or square root function (or any other form).

For example, if our hypothesis function is

*hθ*​(*x*)=*θ*0​+*θ*1​*x*1

​ then we can create additional features based on *x*1​, to get the quadratic function

*hθ*​(*x*)=*θ*0​+*θ*1​*x*1​+*θ*2​*x*12​ or the cubic function *hθ*​(*x*)=*θ*0​+*θ*1​*x*1​+*θ*2​*x*12​+*θ*3​*x*13

One important thing to keep in mind is, if you choose your features this way then feature scaling becomes very important.

eg. if x\_1*x*1​ has range 1 - 1000 then range of x\_1^2*x*12​ becomes 1 - 1000000 and that of x\_1^3*x*13​ becomes 1 – 1000000000

# Normal Equation

Gradient descent gives one way of minimizing J. Let’s discuss a second way of doing so, this time performing the minimization explicitly and without resorting to an iterative algorithm. In the "Normal Equation" method, we will minimize J by explicitly taking its derivatives with respect to the θj ’s, and setting them to zero. This allows us to find the optimum theta without iteration. The normal equation formula is given below:

*θ*=(*XTX*)−1*XTy*

If X^TX is **noninvertible,** the common causes might be having :

* Redundant features, where two features are very closely related (i.e. they are linearly dependent)
* Too many features (e.g. m ≤ n). In this case, delete some features or use "regularization" (to be explained in a later lesson).

Solutions to the above problems include deleting a feature that is linearly dependent with another or deleting one or more features when there are too many features.

Logistic Regression –

We use this algorithm when the problem statement requires classification.

For instance, if we are trying to build a spam classifier for email, then *x*(*i*) may be some features of a piece of email, and y may be 1 if it is a piece of spam mail, and 0 otherwise. Hence, y∈{0,1}. 0 is also called the negative class, and 1 the positive class, and they are sometimes also denoted by the symbols “-” and “+.” Given x^{(i)}*x*(*i*), the corresponding y^{(i)}*y*(*i*) is also called the label for the training example.

0≤*hθ*​(*x*)≤1. This is accomplished by plugging theta^Tx *θTx* into the Logistic Function.

Diagram

Description automatically generated with medium confidence

*hθ*​(*x*) will give us the **probability** that our output is 1. For example, *hθ*​(*x*)=0.7 gives us a probability of 70% that our output is 1. Our probability that our prediction is 0 is just the complement of our probability that it is 1 (e.g. if probability that it is 1 is 70%, then the probability that it is 0 is 30%).

Text

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The **decision boundary** is the line that separates the area where y = 0 and where y = 1. It is created by our hypothesis function.

# Cost Function

We cannot use the same cost function that we use for linear regression because the Logistic Function will cause the output to be wavy, causing many local optima. In other words, it will not be a convex function.

Instead, our cost function for logistic regression looks like:

Text, letter

Description automatically generated

If our correct answer 'y' is 0, then the cost function will be 0 if our hypothesis function also outputs 0. If our hypothesis approaches 1, then the cost function will approach infinity.

If our correct answer 'y' is 1, then the cost function will be 0 if our hypothesis function outputs 1. If our hypothesis approaches 0, then the cost function will approach infinity.

Note that writing the cost function in this way guarantees that J(θ) is convex for logistic regression.

Chart

Description automatically generated

Chart

Description automatically generated

We can compress our cost function's two conditional cases into one case:

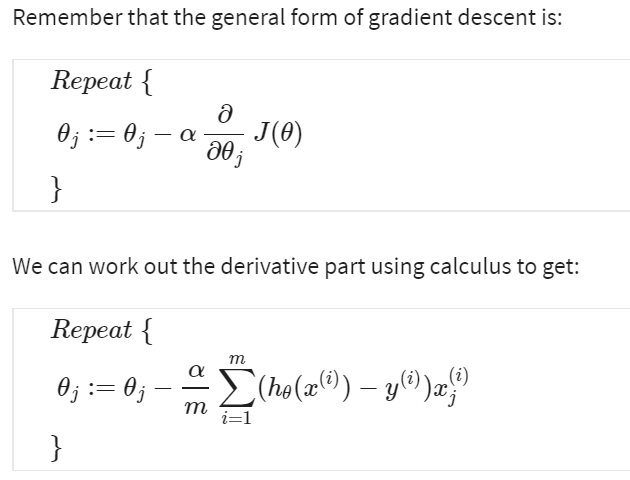
Cost(*hθ*​(*x*),*y*)=−*y*log(*hθ*​(*x*))−(1−*y*)log(1−*hθ*​(*x*))

Text

Description automatically generated

Gradient Descent –

This algorithm is identical to the one we used in linear regression. We still have to simultaneously update all values in theta.



# Multiclass Classification: One-vs-all

Now we will approach the classification of data when we have more than two categories. Instead of y = {0,1} we will expand our definition so that y = {0,1...n}.

Since y = {0,1...n}, we divide our problem into n+1 (+1 because the index starts at 0) binary classification problems; in each one, we predict the probability that 'y' is a member of one of our classes.

Train a logistic regression classifier h\_\theta(x)*hθ*​(*x*) for each class i to predict the probability that Py = i￼ ￼.

To make a prediction on a new x, pick the class ￼that maximizes h\_\theta (x) *hθ*​(*x*)

# The Problem of Overfitting

When the hypothesis fits the training data too much, we get a the situation of overfitting, which will lead to less accurate predictions on new dataset.

Underfitting, or high bias, is when the form of our hypothesis function h maps poorly to the trend of the data. It is usually caused by a function that is too simple or uses too few features. At the other extreme, overfitting, or high variance, is caused by a hypothesis function that fits the available data but does not generalize well to predict new data. It is usually caused by a complicated function that creates a lot of unnecessary curves and angles unrelated to the data.

This terminology is applied to both linear and logistic regression. There are two main options to address the issue of overfitting:

1) Reduce the number of features:

* Manually select which features to keep.
* Use a model selection algorithm (studied later in the course).

2) Regularization

* Keep all the features, but reduce the magnitude of parameters *θj*​.
* Regularization works well when we have a lot of slightly useful features.

If we have overfitting from our hypothesis function, we can reduce the weight that some of the terms in our function carry by increasing their cost.

Say we wanted to make the following function more quadratic:

*θ*0​+*θ*1​*x*+*θ*2​*x^*2+*θ*3​*x^*3+*θ*4​*x^*4

We'll want to eliminate the influence of \theta\_3x^3*θ*3​*x*3 and \theta\_4x^4*θ*4​*x*4 . Without actually getting rid of these features or changing the form of our hypothesis, we can instead modify our **cost function**:

​ *Min* 1/2m​∑*i*=1to*m*​(*hθ*​(*x*(*i*))−*y*(*i*))^2+1000⋅*θ*3^2​+1000⋅*θ*4^2​

We've added two extra terms at the end to inflate the cost of *θ*3​ and *θ*4​. Now, in order for the cost function to get close to zero, we will have to reduce the values of *θ*3​ and *θ*4​ to near zero. This will in turn greatly reduce the values of *θ*3​*x*3 and *θ*4​*x*4 in our hypothesis function. As a result, we see that the new hypothesis (depicted by the pink curve) looks like a quadratic function but fits the data better due to the extra small terms *θ*3​*x^*3 and *θ*4​*x^*4.

Text

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If lambda is chosen to be too large, it may smooth out the function too much and cause underfitting

# Regularized Linear Regression

Text, letter

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Graphical user interface, text, application, email

Description automatically generated

# Regularized Logistic Regression

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