DavisSML Tensorflow Lab 1

Some content is taken from

- www.tensorflow.org (http://www.tensorflow.org)
- http://rail.eecs.berkeley.edu/deeprlcourse/ (http://rail.eecs.berkeley.edu/deeprlcourse/)

To install tensorflow use pip: `pip install tensorflow`

There are 2 exercises below. Do not use Keras or another high level API.

Tensors

In [1]:
```
import tensorflow as tf
import numpy as np
import matplotlib.pyplot as plt
```

- Tensorflow is based around tensor objects
- Tensors can be symbolic or actual data
- Eager execution actually creates the tensors, not just symbolically. Without it the Tensors would only be symbolic until a session is started.

In [2]:
```
tf.enable_eager_execution()
```

Several types of special tensors are

- tf.Variable : typically parameters in your model
- tf.constant : fixed values (gradients will not be calculated wrt them)
- tf.placeholder : a tensor waiting to be assigned a value; not compatible with eager execution
- tf.SparseTensor : a sparse tensor

In [3]:
```
# initialize these constants
a = tf.constant(1.0)
b = tf.constant(2.0)

# mathematical operations are defined on tensors
c = a + b

print(c)
```

```
tf.Tensor(3.0, shape=(), dtype=float32)
```

Above are scalars which are order 0 tensors, other types are below:

In [4]:
```
mammal = tf.Variable("Elephant", tf.string) # order 0
ignition = tf.Variable(451, tf.int16)
floating = tf.Variable(3.14159265359, tf.float64)
its_complicated = tf.Variable(12.3 - 4.85j, tf.complex64)
```

In [5]:
```
mammal.get_shape()
```

Out[5]:
```
TensorShape([])
```

Here are some order 1 tensors of various types:

In [6]:
```
mystr = tf.Variable(["Hello","World"], tf.string) #order 1
cool_numbers  = tf.Variable([3.14159, 2.71828], tf.float32)
first_primes = tf.Variable([2, 3, 5, 7, 11], tf.int32)
its_very_complicated = tf.Variable([12.3 - 4.85j, 7.5 - 6.23j], tf.complex64)
```

The shape of the tensor is like that of numpy arrays, they will tell you the order and dimensions.

In [7]:
```
its_complicated.get_shape(), its_very_complicated.get_shape(),first_primes.get_shape
```

Out[7]:
```
(TensorShape([]), TensorShape([Dimension(2)]), TensorShape([Dimension(5)]))
```

In [8]:
```
beta_init = np.random.uniform(0,1,(32,32,32))
betas = [tf.convert_to_tensor(beta_init[0,0,0], dtype=tf.float32),
         tf.convert_to_tensor(beta_init[:,0,0], dtype=tf.float32),
         tf.convert_to_tensor(beta_init[:,:,0], dtype=tf.float32), #order 2
         tf.convert_to_tensor(beta_init, dtype=tf.float32)]

[beta.get_shape() for beta in betas]
```

Out[8]:
```
[TensorShape([]),
 TensorShape([Dimension(32)]),
 TensorShape([Dimension(32), Dimension(32)]),
 TensorShape([Dimension(32), Dimension(32), Dimension(32)])]
```

Tensor operations input and output tensors, and will cast to a tensor if needed.

In [9]:
```
print(tf.square(5))
print(tf.reduce_sum([1, 2, 3]))
```

```
tf.Tensor(25, shape=(), dtype=int32)
tf.Tensor(6, shape=(), dtype=int32)
```

Even when in eager mode Tensors are different than arrays because

- they are immutable : the data cannot be modified without reassiging the variable
- they can live on GPUs as comfortably as CPUs

Why are they immutable?

You can assign slices to other variables:

In [10]:
```
X = tf.Variable([[1,2,3],[3,4,5]])
Y = X[:2,:2]
```

In [11]:
```
Y
```

Out[11]:
```
<tf.Tensor: id=96, shape=(2, 2), dtype=int32, numpy=
array([[1, 2],
       [3, 4]])>
```

In [12]:
```
X.assign([[2,2,3],[3,4,5]])
```

Out[12]:
```
<tf.Variable 'UnreadVariable' shape=(2, 3) dtype=int32, numpy=
array([[2, 2, 3],
       [3, 4, 5]])>
```

In [13]:
```
X, Y
```

Out[13]:
```
(<tf.Variable 'Variable:0' shape=(2, 3) dtype=int32, numpy=
 array([[2, 2, 3],
        [3, 4, 5]])>, <tf.Tensor: id=96, shape=(2, 2), dtype=int32, numpy=
 array([[1, 2],
        [3, 4]])>)
```

In [14]:
```
beta = tf.convert_to_tensor(beta_init, dtype=tf.float32)
beta.device
```

Out[14]:
```
'/job:localhost/replica:0/task:0/device:CPU:0'
```

Can use GPU if it is available, because many operations are then parallel, it can be much faster:

In [16]:
```
import time

def time_matmul(x):
  start = time.time()
  for loop in range(10):
    tf.matmul(x, x)

  result = time.time()-start

  print("10 loops: {:0.2f}ms".format(1000*result))


# Force execution on CPU
print("On CPU:")
with tf.device("CPU:0"):
  x = tf.random_uniform([2000, 2000])
  assert x.device.endswith("CPU:0")
  time_matmul(x)

# Force execution on GPU #0 if available
if tf.test.is_gpu_available():
  print("On GPU:")
  with tf.device("GPU:0"): # Or GPU:1 for the 2nd GPU, GPU:2 for the 3rd etc.
    x = tf.random_uniform([2000, 2000])
    assert x.device.endswith("GPU:0")
    time_matmul(x)
else:
  print('GPU unavailable')
```

```
On CPU:
10 loops: 844.74ms
On GPU:
10 loops: 1.00ms
```

Automatic differentiation

Typically automatic differentiation works behind the scenes in tensorflow, but with gradienttape you can actually interact with the gradients. When you start the gradienttape, it will start tracking the operations performed and thus can compute gradients.

In this case the resulting gradient is also a tensor:

In [17]:
```
## simple gradient

print("Running simple gradient ex.")

x = tf.ones((2, 2))

with tf.GradientTape() as t:
  t.watch(x)
  y = tf.reduce_sum(x)
  z = tf.multiply(y, y)

dz_dx = t.gradient(z, x)

print(dz_dx)
```

```
Running simple gradient ex.
tf.Tensor(
[[8. 8.]
 [8. 8.]], shape=(2, 2), dtype=float32)
```

Exercise 1. (5 pts) Below is incomplete code for logistic regression gradient computation. Fill in the necessary components.

In [32]:

```
## logistic regression gradient

print("Running log.reg. ex.")

n, p = 10,5
X_val = np.random.uniform(0,1,(n,p),)
beta_val = np.random.uniform(0,1,(p,1))
p_val = 1. / (1. + np.exp(-X_val @ beta_val))
y_val = 2*(np.random.uniform(0,1,(n)) < p_val) - 1

### Create X,y,beta tensors of the same shape from the above arrays
X = tf.convert_to_tensor(X_val, dtype=tf.float32)
y = tf.convert_to_tensor(y_val, dtype=tf.float32)
beta = tf.convert_to_tensor(beta_val, dtype=tf.float32)



with tf.GradientTape(persistent=True) as t:
    t.watch(beta)
    z = tf.tensordot(y, tf.matmul(X,beta),axes=1)
    w = tf.reduce_sum(-tf.log(1 + tf.exp(-z)))
    z2 = tf.matmul(y, tf.tensordot(X,beta,axes=1))
    w2 = tf.reduce_sum(-tf.log(1 + tf.exp(-z2)))
    ### create z an order 1, with shape [10], tensor of the (y X \beta) vector.
    ### Matrix multiply is tf.multiply, tf.tensordot is dot product

    ### create a tensor for the sum of - log likelihood (log(1 + exp(-z)))

# calculate the gradient of the loss and print it
grad1 = t.gradient(w, beta)
grad2 = t.gradient(w2, beta)
print(grad1)
print(grad2)
```

```
Running log.reg. ex.
tf.Tensor(
[[0.14849472]
 [0.30762616]
 [0.41728202]
 [0.90182316]
 [0.58966696]], shape=(5, 1), dtype=float32)
tf.Tensor(
[[0.14849472]
 [0.30762616]
 [0.41728202]
 [0.90182316]
 [0.58966696]], shape=(5, 1), dtype=float32)
```

I tried 2 menthods to calculate gradients. Both gave the same answer

Sessions

We will leave eager mode, to see how sessions work.

In [ ]:

```
import os
os._exit(00)
```

In [1]:

```
import tensorflow as tf
import numpy as np
import matplotlib.pyplot as plt
```

In [2]:
```python
def tf_reset_graph():
    try:
        sess.close()
    except:
        pass
    new_graph = tf.Graph()
    return new_graph, tf.Session(graph=new_graph)

def tf_reset_default():
    try:
        sess.close()
    except:
        pass
    tf.reset_default_graph()
    return tf.Session()
```

In [3]:
```python
tf_graph, sess = tf_reset_graph()
```

A computation graph contains

- tensors defined in with that graph as default
- operations that relate the tensors

The session is associated with a graph. Typically, you will be working with a single graph, so you do not have to explicitly associate the operations/tensors to a graph, and can rely on the default.

In [4]:
```python
# define your inputs
with tf_graph.as_default():
    a = tf.constant(1.0)
    b = tf.constant(2.0)

    # do some operations
    c = a + b

# get the result
sess.run(c)
```

Out[4]:
```
3.0
```

Notice that the session above is still open and needs to be closed. If you look at tf_reset, this is what happens in the try: statement.

With a session it makes sense to have placeholder tensors that can be fed data. You should think of this as taking the place of a constant, where the constant value is determined at run time.

In [5]:

```
tf_graph, sess = tf_reset_graph()

with tf_graph.as_default():
    # define your inputs
    a = tf.placeholder(dtype=tf.float32, shape=[1], name='a_placeholder')
    b = tf.placeholder(dtype=tf.float32, shape=[1], name='b_placeholder')

    # do some operations
    c = a + b

# get the result
c0_run = sess.run(c, feed_dict={a: [1.0], b: [2.0]})
c1_run = sess.run(c, feed_dict={a: [2.0], b: [4.0]})

print('c0 = {0}'.format(c0_run))
print('c1 = {0}'.format(c1_run))
```

```
c0 = [3.]
c1 = [6.]
```

You can allow the placeholder tensor to have variable dimensions by making the dimension input to be None.

In [6]:

```
sess = tf_reset_default()

# inputs
a = tf.placeholder(dtype=tf.float32, shape=[None], name='a_placeholder')
b = tf.placeholder(dtype=tf.float32, shape=[None], name='b_placeholder')

# do some operations
c = a + b

# get outputs
c0_run = sess.run(c, feed_dict={a: [1.0], b: [2.0]})
c1_run = sess.run(c, feed_dict={a: [1.0, 2.0], b: [2.0, 4.0]})

print(a)
print('a shape: {0}'.format(a.get_shape()))
print(b)
print('b shape: {0}'.format(b.get_shape()))
print('c0 = {0}'.format(c0_run))
print('c1 = {0}'.format(c1_run))
```

```
Tensor("a_placeholder:0", shape=(?,), dtype=float32)
a shape: (?,)
Tensor("b_placeholder:0", shape=(?,), dtype=float32)
b shape: (?,)
c0 = [3.]
c1 = [3. 6.]
```

Layers are operations that add variables to the default graph. They are used to make the code more concise and development easier. The following Dense layer will add a scalar coefficient and an intercept.

Optimizers are operations that build out the compute graph for a stochastic gradient descent algorithm. It will create the necessary tensors to make gradient steps, and can be standard SGD, RMSprop, Adam, etc.

In [7]:
```
sess = tf_reset_default()

## Silly data
x = tf.constant([[1], [2], [3], [4]], dtype=tf.float32)
y_true = tf.constant([[0], [-1], [-2], [-3]], dtype=tf.float32)

"""
This layer implements the operation: outputs = activation(inputs * coefficient + interce
Where activation is the activation function passed as the activation argument (if not No
kernel (coefficient) is a weights matrix created by the layer,
and bias (intercept) is a bias vector created by the layer (only if use_bias is True).

The layer is an operation with variables (to be seen)
"""
linear_model = tf.layers.Dense(units=1)


"""
Apply the linear_model operation to tensor x to produce tensor y_pred
"""
y_pred = linear_model(x)


"""
Losses are output scalar tensors and can accept weights, etc.
"""
loss = tf.losses.mean_squared_error(labels=y_true, predictions=y_pred)

"""
Can either use a scalar learning rate or tensor (I want to change mine so I use a tensor
"""
learning_rate = tf.placeholder(tf.float32, shape=[])


"""
train module contains optimizers such as AdaGrad and Adam
- contains methods: apply_gradients, compute_gradients, variables, minimize
- minimize returns an operation that minimizes the input (loss) tensor
"""
optimizer = tf.train.GradientDescentOptimizer(learning_rate)
train = optimizer.minimize(loss)

"""
You can initialize variables by hand or just use random starts like below
"""
init = tf.global_variables_initializer()


"""
TensorFlow uses the tf.Session class to represent a connection between the client progra

- the session should be closed to free up the device, or even better, use the with claus
- the run method will execute the subgraph in order to evaluate the tensor or run the op
"""

sess.run(init)

for i in range(100):
    lr = .5*(i+1)**-1.
    _, loss_value = sess.run((train, loss), feed_dict={learning_rate : lr})
    print(loss_value)
```

```
26.320143
1400.1321
```

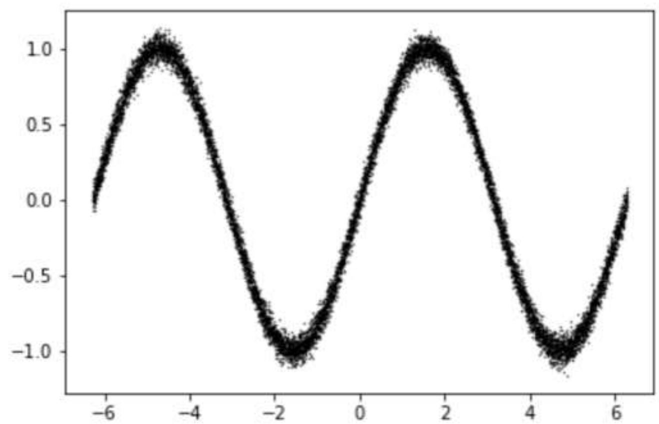
In [15]:
```
print(sess.run(y_pred))
print(sess.run(linear_model.weights))
```

```
[[-0.27734506]
 [-1.1343927 ]
 [-1.9914403 ]
 [-2.8484879 ]]
[array([[-0.8570476]], dtype=float32), array([0.57970256], dtype=float32)]
```

The following example from UC Berkeley CS294, trains a fully connected neural net (with 3 hidden layers) for a dataset (below) with scalar input.

In [16]:
```
# generate the data
inputs = np.linspace(-2*np.pi, 2*np.pi, 10000)[:, None]
outputs = np.sin(inputs) + 0.05 * np.random.normal(size=[len(inputs),1])

plt.scatter(inputs[:, 0], outputs[:, 0], s=0.1, color='k', marker='o')
```

Out[16]: <matplotlib.collections.PathCollection at 0x14cfff90ba8>



In [21]:

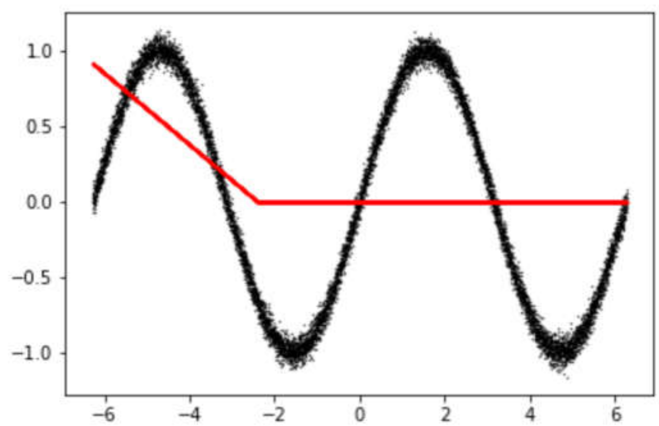
```
sess = tf_reset_default()

def create_model():
    # create inputs
    input_ph = tf.placeholder(dtype=tf.float32, shape=[None, 1])
    output_ph = tf.placeholder(dtype=tf.float32, shape=[None, 1])

    # create variables
    W0 = tf.get_variable(name='W0', shape=[1,3], initializer=tf.contrib.layers.xavier_in
    #W1 = tf.get_variable(name='W1', shape=[20, 20], initializer=tf.contrib.layers.xavie
    #W2 = tf.get_variable(name='W2', shape=[20, 1], initializer=tf.contrib.layers.xavier_

    b0 = tf.get_variable(name='b0', shape=[3], initializer=tf.constant_initializer
    #b1 = tf.get_variable(name='b1', shape=[20], initializer=tf.constant_initializer(0.)
    #b2 = tf.get_variable(name='b2', shape=[1], initializer=tf.constant_initializer(0.))

    weights = [W0]#[W0, W1, W2]
    biases = [b0]#[b0, b1, b2]
    activations = [tf.nn.relu]#[tf.nn.sigmoid, tf.nn.relu, tf.nn.sigmoid]

    # create computation graph
    layer = input_ph
    for W, b, activation in zip(weights, biases, activations):
        layer = tf.matmul(layer, W) + b
        if activation is not None:
            layer = activation(layer)
    output_pred = layer

    return input_ph, output_ph, output_pred

input_ph, output_ph, output_pred = create_model()

# create loss
mse = tf.reduce_mean(0.5 * tf.square(output_pred - output_ph))

# create optimizer
opt = tf.train.AdamOptimizer().minimize(mse)

# initialize variables
sess.run(tf.global_variables_initializer())
# create saver to save model variables
saver = tf.train.Saver()

# run training
batch_size = 32
for training_step in range(10000):
    # get a random subset of the training data
    indices = np.random.randint(low=0, high=len(inputs), size=batch_size)
    input_batch = inputs[indices]
    output_batch = outputs[indices]

    # run the optimizer and get the mse
    _, mse_run = sess.run([opt, mse], feed_dict={input_ph: input_batch, output_ph

    # print the mse every so often
    if training_step % 1000 == 0:
        print('{0:04d} mse: {1:.3f}'.format(training_step, mse_run))
        saver.save(sess, '/tmp/model.ckpt')
```

```
0000 mse: 2.115
1000 mse: 0.230
2000 mse: 0.238
3000 mse: 0.231
4000 mse: 0.214
5000 mse: 0.140
```

In [22]:
```
sess = tf_reset_default()

# create the model
input_ph, output_ph, output_pred = create_model()

# restore the saved model
saver = tf.train.Saver()
saver.restore(sess, "/tmp/model.ckpt")

output_pred_run = sess.run(output_pred, feed_dict={input_ph: inputs})

plt.scatter(inputs[:, 0], outputs[:, 0], c='k', marker='o', s=0.1)
plt.scatter(inputs[:, 0], output_pred_run[:, 0], c='r', marker='o', s=0.1)
```

```
INFO:tensorflow:Restoring parameters from /tmp/model.ckpt
```

Out[22]: <matplotlib.collections.PathCollection at 0x14d0076c0f0>



In [32]:
```
n = 10000
X = np.random.uniform(0,1,(n,2))
p = 1 / (1 + np.exp(-5*(X.sum(axis=1) - 2.* (X[:,0] * X[:,1] > .25) - .5)))
y = np.random.uniform(0,1,n) < p
```

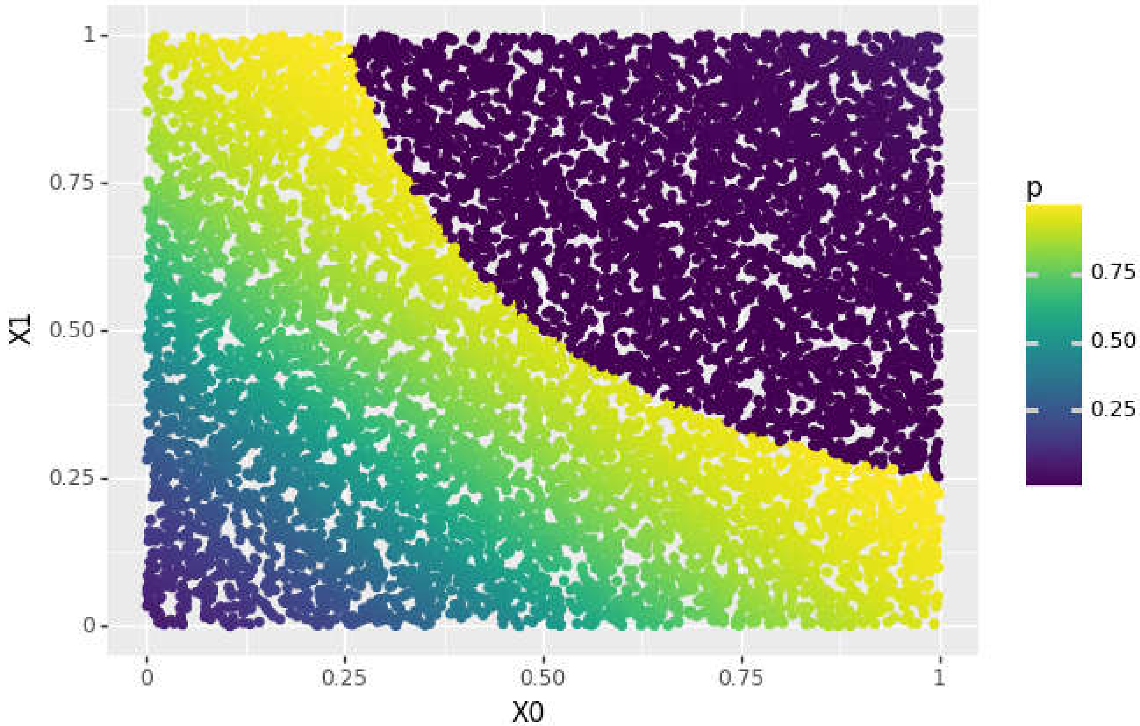
In [33]:
```
import plotnine as p9
import pandas as pd
```

In [34]:
```
XOR_data = pd.DataFrame(X,columns=['X0','X1'])
XOR_data['p'] = p
```

In [59]:
```
XOR_data.head()
inputs = np.array(XOR_data.iloc[:,0:2]).astype('float32')
outputs = np.array(XOR_data.iloc[:,2]).reshape((inputs.shape[0],1))
print(inputdata.shape,outputs.shape)
```

```
(10000, 2) (10000, 1)
```

In [42]:
```
p9.ggplot(XOR_data,p9.aes(x='X0',y='X1',color='p')) + p9.geom_point()
```



Out[42]: <ggplot: (-9223371947463327495)>

Exercise 2. (15 pts) Create a neural net with dense hidden layers (including intercepts for each hidden unit) and logistic loss function. Train it on the above dataset with 2 dimensional input using Adam and 32 minibatch size. You may want to increase the number of iterations until you see convergence. You can assess visually by plotting the predictions and comparing to the true probability.

1. Try ReLu activation as well as sigmoid activation for 1 hidden layer and 3 units.
2. Try ReLu activation with 2 hidden layers and 3 units each.
3. Try (2) but with any combination of ReLu and Sigmoid activation.

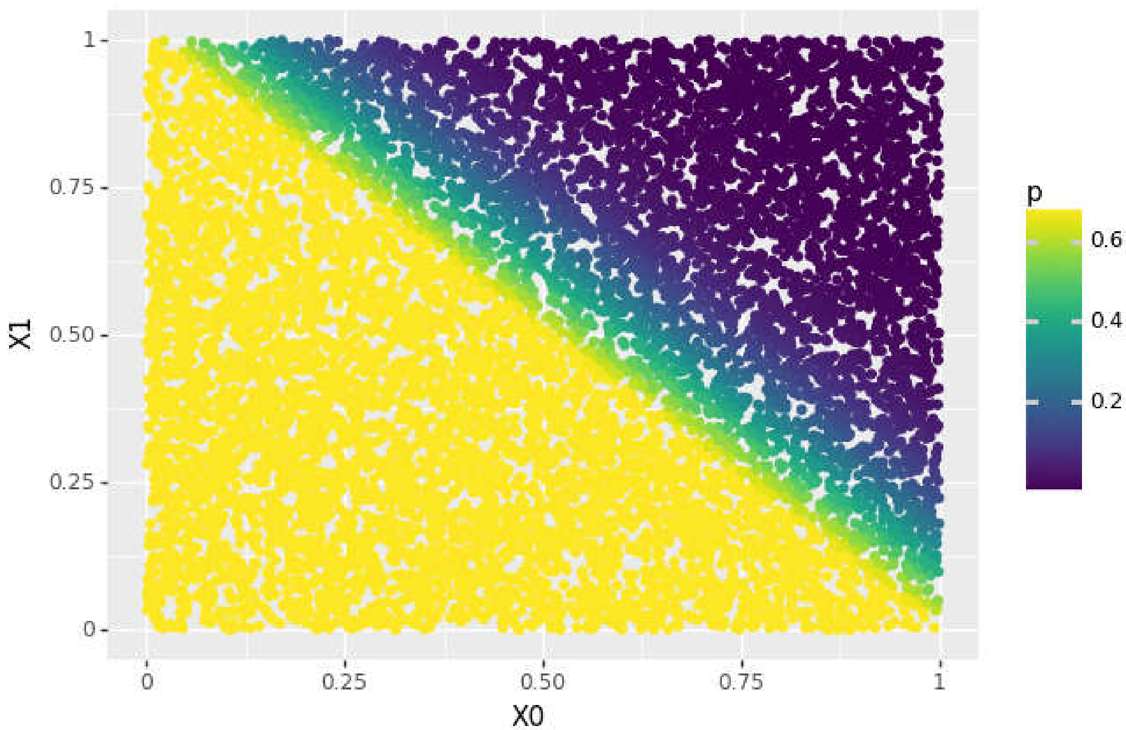
In [83]:

```
#1. Relu
sess = tf_reset_default()

def create_model():
    # create inputs
    input_ph = tf.placeholder(dtype=tf.float32, shape=[None, 2])
    output_ph = tf.placeholder(dtype=tf.float32, shape=[None,1])

    # create variables
    W0 = tf.get_variable(name='W0', shape=[2,3], initializer=tf.contrib.layers.xavier_in
    #W1 = tf.get_variable(name='W1', shape=[20, 20], initializer=tf.contrib.layers.xavie
    W1 = tf.get_variable(name='W1', shape=[3, 1], initializer=tf.contrib.layers.xavier_i

    b0 = tf.get_variable(name='b0', shape=[3], initializer=tf.constant_initializer
    #b1 = tf.get_variable(name='b1', shape=[20], initializer=tf.constant_initializer(0.)
    b1 = tf.get_variable(name='b1', shape=[1], initializer=tf.constant_initializer

    weights = [W0,W1]#[W0, W1, W2]
    biases = [b0,b1]#[b0, b1, b2]
    activations = [tf.nn.relu,tf.nn.sigmoid]#[tf.nn.sigmoid, tf.nn.relu, tf.nn.sigmoid]

    # create computation graph
    layer = input_ph
    print('input shape = ',input_ph.get_shape())
    for W, b, activation in zip(weights, biases, activations):
        layer = tf.matmul(layer, W) + b
        if activation is not None:
            layer = activation(layer)
    output_pred = layer
    print(output_ph, output_pred)
    return input_ph, output_ph, output_pred

input_ph, output_ph, output_pred = create_model()

# create loss
#product = tf.multiply(output_ph,output_pred)
#logloss = tf.reduce_sum(-tf.log(1 + tf.exp(-(product))))
#logloss = -tf.reduce_sum((tf.multiply(output_ph,tf.log(output_pred)) + tf.multiply((1 -
logloss = tf.losses.log_loss(output_ph,output_pred)

# create optimizer
opt = tf.train.AdamOptimizer().minimize(logloss)

# initialize variables
sess.run(tf.global_variables_initializer())
# create saver to save model variables
saver = tf.train.Saver()

# run training
batch_size = 32
for training_step in range(50000):
    #print('in the training')
    # get a random subset of the training data
    indices = np.random.randint(low=0, high=len(inputs), size=batch_size)
    input_batch = inputs[indices]
    output_batch = outputs[indices]

    # run the optimizer and get the mse
    _, logloss_run = sess.run([opt, logloss], feed_dict={input_ph: input_batch, output_p

    # print the mse every so often
    if training_step % 1000 == 0:
        print('{0:04d} logloss: {1:.3f}'.format(training_step, logloss_run))
        saver.save(sess, '/tmp/model.ckpt')
```

In [82]:

```
sess = tf_reset_default()

# create the model
input_ph, output_ph, output_pred = create_model()

# restore the saved model
saver = tf.train.Saver()
saver.restore(sess, "/tmp/model.ckpt")

output_pred_run = sess.run(output_pred, feed_dict={input_ph: inputs})

XOR_data_copy = XOR_data.copy()
XOR_data_copy.iloc[:,2] = output_pred_run
p9.ggplot(XOR_data_copy,p9.aes(x='X0',y='X1',color='p')) + p9.geom_point()
```

```
input shape =  (?, 2)
Tensor("Placeholder_1:0", shape=(?, 1), dtype=float32) Tensor("Sigmoid:0", shap
e=(?, 1), dtype=float32)
INFO:tensorflow:Restoring parameters from /tmp/model.ckpt
```



Out[82]: <ggplot: (-9223371947452406952)>

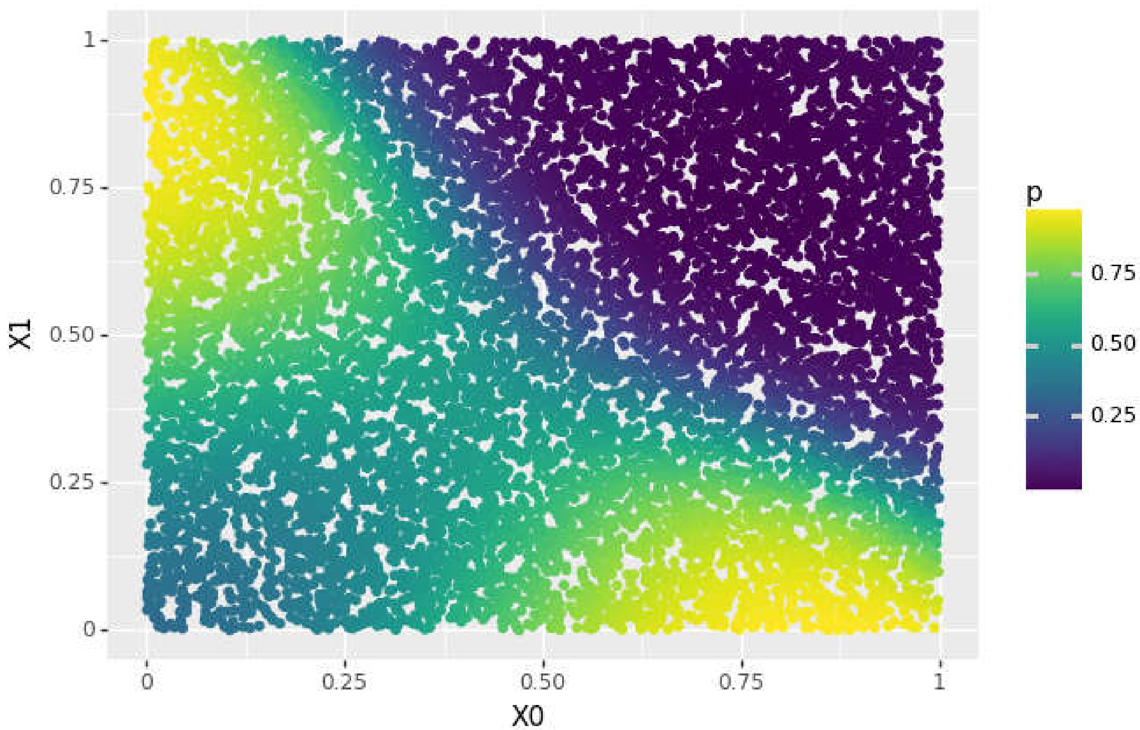
In [84]:

```
#1. Sigmoid
sess = tf_reset_default()

def create_model():
    # create inputs
    input_ph = tf.placeholder(dtype=tf.float32, shape=[None, 2])
    output_ph = tf.placeholder(dtype=tf.float32, shape=[None,1])

    # create variables
    W0 = tf.get_variable(name='W0', shape=[2,3], initializer=tf.contrib.layers.xavier_in
    #W1 = tf.get_variable(name='W1', shape=[20, 20], initializer=tf.contrib.layers.xavie
    W1 = tf.get_variable(name='W1', shape=[3, 1], initializer=tf.contrib.layers.xavier_i

    b0 = tf.get_variable(name='b0', shape=[3], initializer=tf.constant_initializer
    #b1 = tf.get_variable(name='b1', shape=[20], initializer=tf.constant_initializer(0.)
    b1 = tf.get_variable(name='b1', shape=[1], initializer=tf.constant_initializer

    weights = [W0,W1]#[W0, W1, W2]
    biases = [b0,b1]#[b0, b1, b2]
    activations = [tf.nn.sigmoid,tf.nn.sigmoid]#[tf.nn.sigmoid, tf.nn.relu, tf.nn.sigmoi

    # create computation graph
    layer = input_ph
    print('input shape = ',input_ph.get_shape())
    for W, b, activation in zip(weights, biases, activations):
        layer = tf.matmul(layer, W) + b
        if activation is not None:
            layer = activation(layer)
    output_pred = layer
    print(output_ph, output_pred)
    return input_ph, output_ph, output_pred

input_ph, output_ph, output_pred = create_model()

# create loss
#product = tf.multiply(output_ph,output_pred)
#logloss = tf.reduce_sum(-tf.log(1 + tf.exp(-(product))))
#logloss = -tf.reduce_sum((tf.multiply(output_ph,tf.log(output_pred)) + tf.multiply((1 -
logloss = tf.losses.log_loss(output_ph,output_pred)

# create optimizer
opt = tf.train.AdamOptimizer().minimize(logloss)

# initialize variables
sess.run(tf.global_variables_initializer())
# create saver to save model variables
saver = tf.train.Saver()

# run training
batch_size = 32
for training_step in range(50000):
    #print('in the training')
    # get a random subset of the training data
    indices = np.random.randint(low=0, high=len(inputs), size=batch_size)
    input_batch = inputs[indices]
    output_batch = outputs[indices]

    # run the optimizer and get the mse
    _, logloss_run = sess.run([opt, logloss], feed_dict={input_ph: input_batch, output_p

    # print the mse every so often
    if training_step % 1000 == 0:
        print('{0:04d} logloss: {1:.3f}'.format(training_step, logloss_run))
        saver.save(sess, '/tmp/model.ckpt')
```

In [85]:

```
sess = tf_reset_default()

# create the model
input_ph, output_ph, output_pred = create_model()

# restore the saved model
saver = tf.train.Saver()
saver.restore(sess, "/tmp/model.ckpt")

output_pred_run = sess.run(output_pred, feed_dict={input_ph: inputs})

XOR_data_copy = XOR_data.copy()
XOR_data_copy.iloc[:,2] = output_pred_run
p9.ggplot(XOR_data_copy,p9.aes(x='X0',y='X1',color='p')) + p9.geom_point()
```

```
input shape =  (?, 2)
Tensor("Placeholder_1:0", shape=(?, 1), dtype=float32) Tensor("Sigmoid_1:0", shap
e=(?, 1), dtype=float32)
INFO:tensorflow:Restoring parameters from /tmp/model.ckpt
```



Out[85]: <ggplot: (-9223371947451215100)>

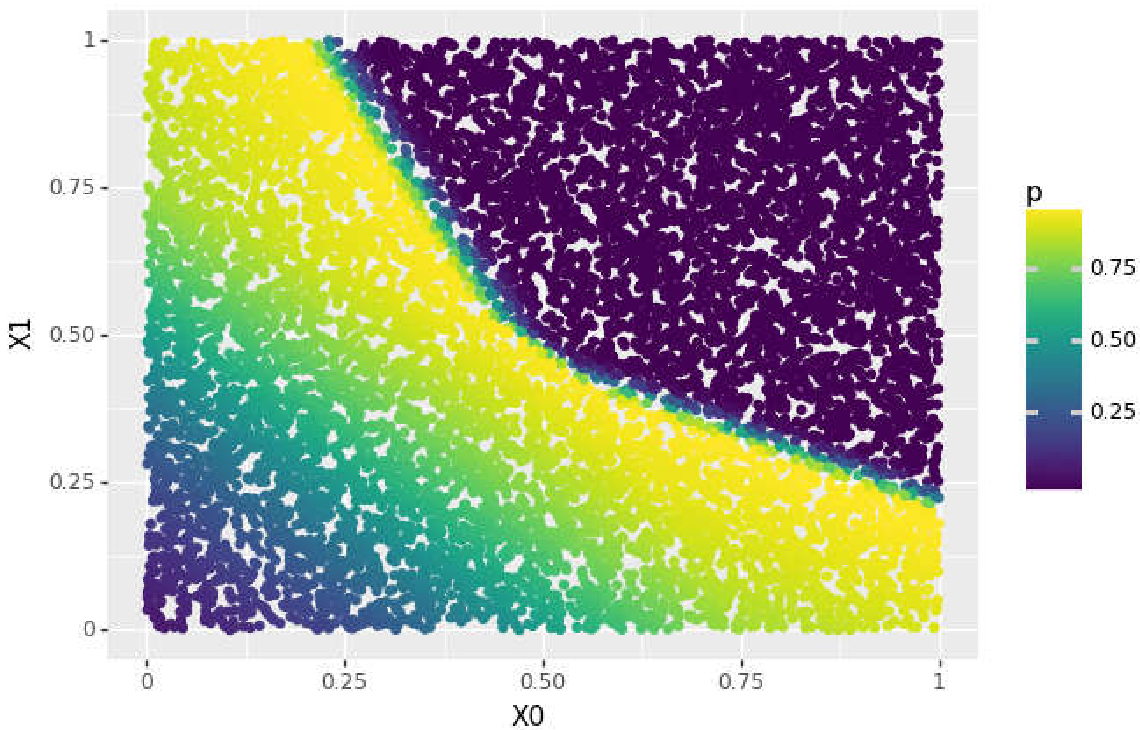
In [86]:

```
#2. Relu
sess = tf_reset_default()

def create_model():
    # create inputs
    input_ph = tf.placeholder(dtype=tf.float32, shape=[None, 2])
    output_ph = tf.placeholder(dtype=tf.float32, shape=[None,1])

    # create variables
    W0 = tf.get_variable(name='W0', shape=[2,3], initializer=tf.contrib.layers.xavier_in
    W1 = tf.get_variable(name='W1', shape=[3, 3], initializer=tf.contrib.layers.xavier_i
    W2 = tf.get_variable(name='W2', shape=[3, 1], initializer=tf.contrib.layers.xavier_i

    b0 = tf.get_variable(name='b0', shape=[3], initializer=tf.constant_initializer
    b1 = tf.get_variable(name='b1', shape=[3], initializer=tf.constant_initializer
    b2 = tf.get_variable(name='b2', shape=[1], initializer=tf.constant_initializer

    weights = [W0,W1,W2]#[W0, W1, W2]
    biases = [b0,b1,b2]#[b0, b1, b2]
    activations = [tf.nn.relu,tf.nn.relu,tf.nn.sigmoid]#[tf.nn.sigmoid, tf.nn.relu, tf.n

    # create computation graph
    layer = input_ph
    print('input shape = ',input_ph.get_shape())
    for W, b, activation in zip(weights, biases, activations):
        layer = tf.matmul(layer, W) + b
        if activation is not None:
            layer = activation(layer)
    output_pred = layer
    print(output_ph, output_pred)
    return input_ph, output_ph, output_pred

input_ph, output_ph, output_pred = create_model()

# create loss
#product = tf.multiply(output_ph,output_pred)
#logloss = tf.reduce_sum(-tf.log(1 + tf.exp(-(product))))
#logloss = -tf.reduce_sum((tf.multiply(output_ph,tf.log(output_pred)) + tf.multiply((1 -
logloss = tf.losses.log_loss(output_ph,output_pred)

# create optimizer
opt = tf.train.AdamOptimizer().minimize(logloss)

# initialize variables
sess.run(tf.global_variables_initializer())
# create saver to save model variables
saver = tf.train.Saver()

# run training
batch_size = 32
for training_step in range(50000):
    #print('in the training')
    # get a random subset of the training data
    indices = np.random.randint(low=0, high=len(inputs), size=batch_size)
    input_batch = inputs[indices]
    output_batch = outputs[indices]

    # run the optimizer and get the mse
    _, logloss_run = sess.run([opt, logloss], feed_dict={input_ph: input_batch, output_p

    # print the mse every so often
    if training_step % 1000 == 0:
        print('{0:04d} logloss: {1:.3f}'.format(training_step, logloss_run))
        saver.save(sess, '/tmp/model.ckpt')
```

In [87]:

```
sess = tf_reset_default()

# create the model
input_ph, output_ph, output_pred = create_model()

# restore the saved model
saver = tf.train.Saver()
saver.restore(sess, "/tmp/model.ckpt")

output_pred_run = sess.run(output_pred, feed_dict={input_ph: inputs})

XOR_data_copy = XOR_data.copy()
XOR_data_copy.iloc[:,2] = output_pred_run
p9.ggplot(XOR_data_copy,p9.aes(x='X0',y='X1',color='p')) + p9.geom_point()
```

```
input shape =  (?, 2)
Tensor("Placeholder_1:0", shape=(?, 1), dtype=float32) Tensor("Sigmoid:0", shap
e=(?, 1), dtype=float32)
INFO:tensorflow:Restoring parameters from /tmp/model.ckpt
```



Out[87]: <ggplot: (89402592008)>

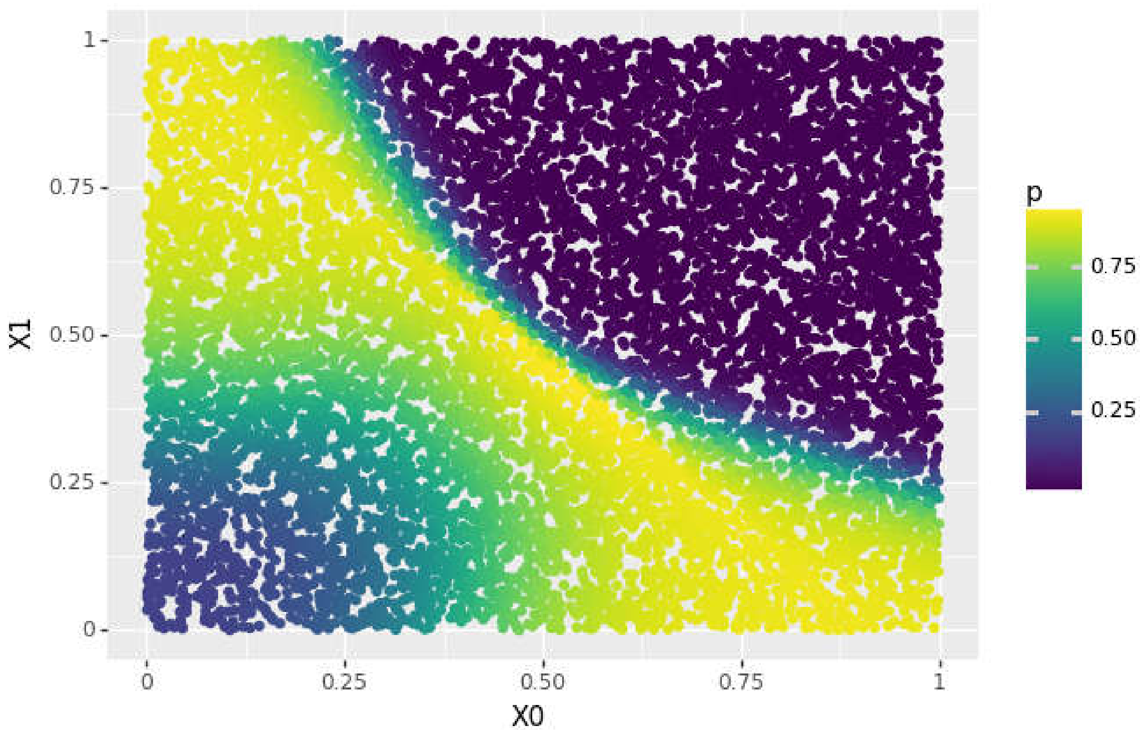
In [88]:

```
#3. Relu,Sigmoid
sess = tf_reset_default()

def create_model():
    # create inputs
    input_ph = tf.placeholder(dtype=tf.float32, shape=[None, 2])
    output_ph = tf.placeholder(dtype=tf.float32, shape=[None,1])

    # create variables
    W0 = tf.get_variable(name='W0', shape=[2,3], initializer=tf.contrib.layers.xavier_in
    W1 = tf.get_variable(name='W1', shape=[3, 3], initializer=tf.contrib.layers.xavier_i
    W2 = tf.get_variable(name='W2', shape=[3, 1], initializer=tf.contrib.layers.xavier_i

    b0 = tf.get_variable(name='b0', shape=[3], initializer=tf.constant_initializer
    b1 = tf.get_variable(name='b1', shape=[3], initializer=tf.constant_initializer
    b2 = tf.get_variable(name='b2', shape=[1], initializer=tf.constant_initializer

    weights = [W0,W1,W2]#[W0, W1, W2]
    biases = [b0,b1,b2]#[b0, b1, b2]
    activations = [tf.nn.relu,tf.nn.sigmoid,tf.nn.sigmoid]#[tf.nn.sigmoid, tf.nn.relu, t

    # create computation graph
    layer = input_ph
    print('input shape = ',input_ph.get_shape())
    for W, b, activation in zip(weights, biases, activations):
        layer = tf.matmul(layer, W) + b
        if activation is not None:
            layer = activation(layer)
    output_pred = layer
    print(output_ph, output_pred)
    return input_ph, output_ph, output_pred

input_ph, output_ph, output_pred = create_model()

# create loss
#product = tf.multiply(output_ph,output_pred)
#logloss = tf.reduce_sum(-tf.log(1 + tf.exp(-(product))))
#logloss = -tf.reduce_sum((tf.multiply(output_ph,tf.log(output_pred)) + tf.multiply((1 -
logloss = tf.losses.log_loss(output_ph,output_pred)

# create optimizer
opt = tf.train.AdamOptimizer().minimize(logloss)

# initialize variables
sess.run(tf.global_variables_initializer())
# create saver to save model variables
saver = tf.train.Saver()

# run training
batch_size = 32
for training_step in range(50000):
    #print('in the training')
    # get a random subset of the training data
    indices = np.random.randint(low=0, high=len(inputs), size=batch_size)
    input_batch = inputs[indices]
    output_batch = outputs[indices]

    # run the optimizer and get the mse
    _, logloss_run = sess.run([opt, logloss], feed_dict={input_ph: input_batch, output_p

    # print the mse every so often
    if training_step % 1000 == 0:
        print('{0:04d} logloss: {1:.3f}'.format(training_step, logloss_run))
        saver.save(sess, '/tmp/model.ckpt')
```

In [89]:

```
sess = tf_reset_default()

# create the model
input_ph, output_ph, output_pred = create_model()

# restore the saved model
saver = tf.train.Saver()
saver.restore(sess, "/tmp/model.ckpt")

output_pred_run = sess.run(output_pred, feed_dict={input_ph: inputs})

XOR_data_copy = XOR_data.copy()
XOR_data_copy.iloc[:,2] = output_pred_run
p9.ggplot(XOR_data_copy,p9.aes(x='X0',y='X1',color='p')) + p9.geom_point()
```

```
input shape =  (?, 2)
Tensor("Placeholder_1:0", shape=(?, 1), dtype=float32) Tensor("Sigmoid_1:0", shap
e=(?, 1), dtype=float32)
INFO:tensorflow:Restoring parameters from /tmp/model.ckpt
```



Out[89]: <ggplot: (-9223371947446081876)>