Lecture Notes for

# Machine Learning in Python

[👨‍🏫, 👨‍💻, 🐍, 👨‍🔬]

Professor Eric Larson

## Feature Spaces + Wide and Deep Networks

# Lecture Agenda

- Logistics:
  - Grading Update
- Agenda:
  - Finish Keras Demo
  - Wide and Deep Networks
  - Wide and Deep Town Hall (if time)

# Class Overview, by topic

Table Data Visualization

Numpy, Pandas, Seaborn
Overviews with some in-depth discussion

Dimension Reduction and Image Processing

Scikit-learn, Scikit Image,
Intuition only, Some mathematics

Linear and Logistic Regression

Numpy, Recreate API for Scikit-learn
Detailed mathematics for simple optimization
intuition for advanced optimization

Neural Networks and Back Prop.

Numpy
Detailed mathematics for NN operations

Wide and Deep Networks

Convolutional Networks

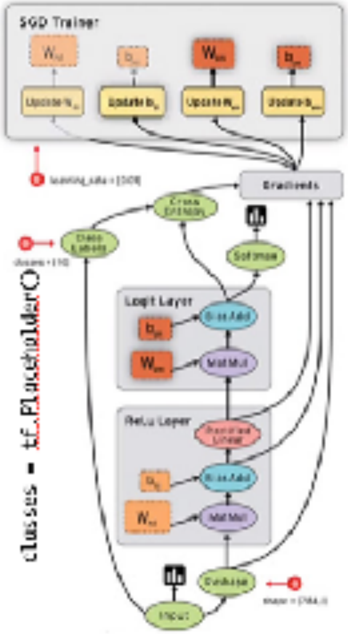
Recurrent Networks

Keras, Tensorflow
Intuition, Detailed implement.

Ethics in Language Models

ConceptNet
Case studies

# Last Time: Tensorflow and Keras



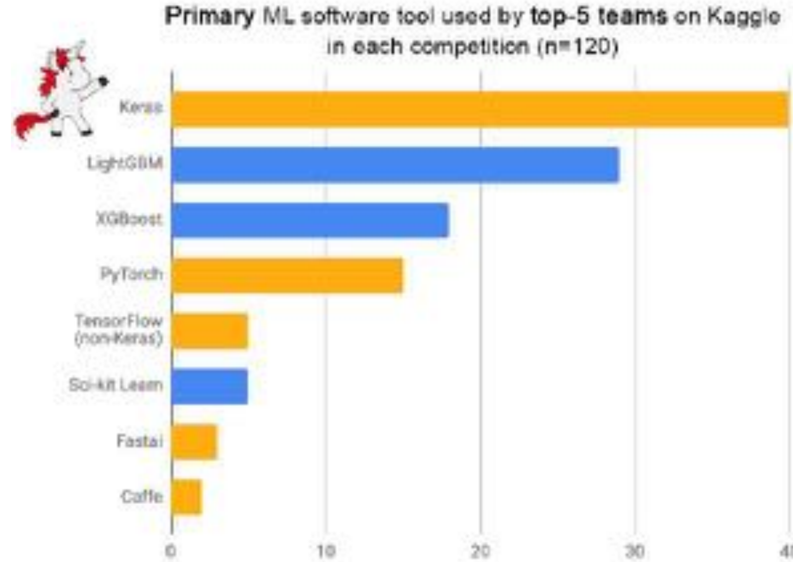

```
opt = tf.train.SGDOptimizer(learning_rate=0.01)
opt_operation = opt.minimize(loss)
```

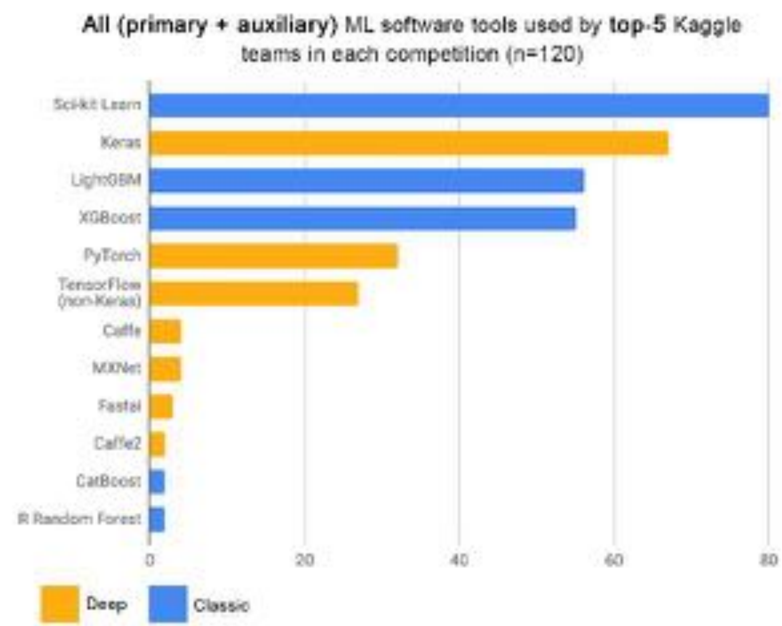
```
A_h1 = tf.relu( tf.matmul(Input,W_h1) + b_h1 )
A_sm = tf.matmul(A_h1,W_sm) + b_sm

y_pr = tf.softmax(A_sm)
loss = tf.sparse_softmax_cross_entropy_with_logits(
            classes, A_sm )
```

```
W_sm = tf.Variable(..)
b_sm = tf.Variable(..)
W_h1 = tf.Variable(..)
b_h1 = tf.Variable(..)
```

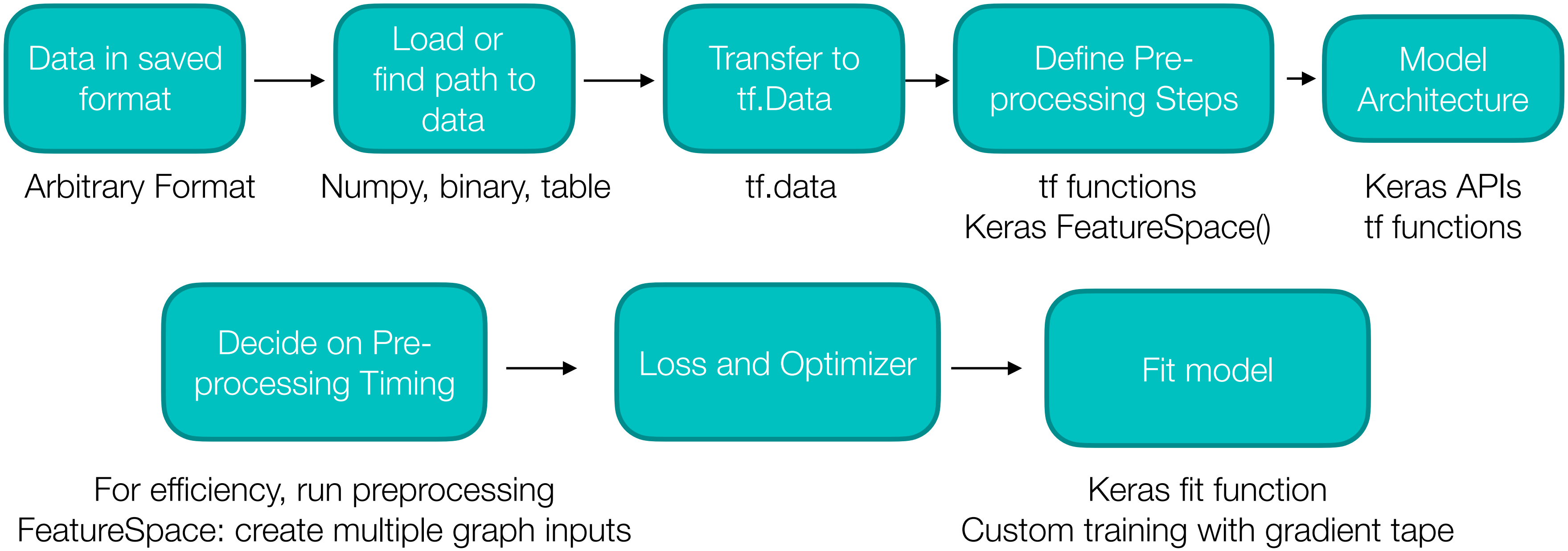
```
Input = tf.Placeholder() # size is 28x28
Input = tf.Reshape(Input, [784,1])
```

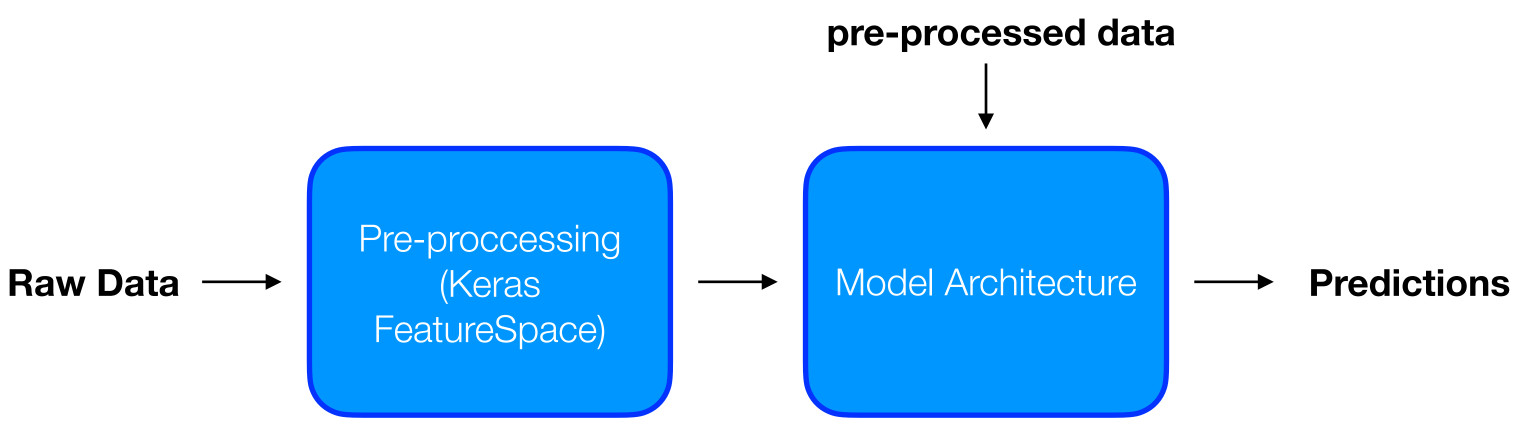
- **Keras Sequential API**
  - great for simple, feed forward models
- **Keras Functional API**
  - build models through series of nested functions
  - each "function" represents an operation in the NN



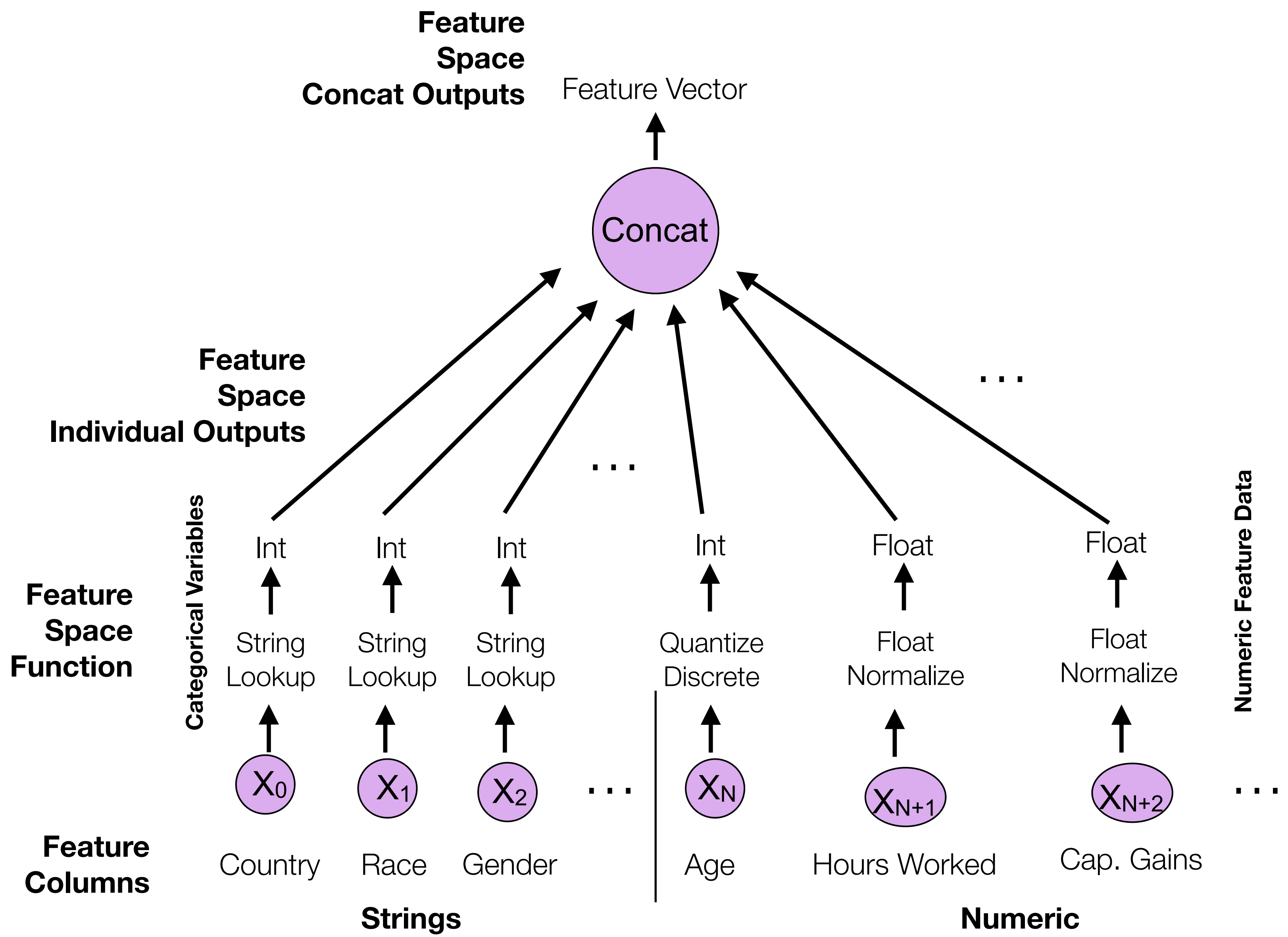



# Using Keras and Tensorflow



# Keras FeatureSpaces



# Demo

Setting up Feature Spaces

`10a. Keras Wide and Deep as TFData.ipynb`

# Categorical Feature Embeddings Review

- One hot encoded data can be "embedded" through a matrix multiplication (column select)

Trainable Matrix in Network

Reduced Dimensions

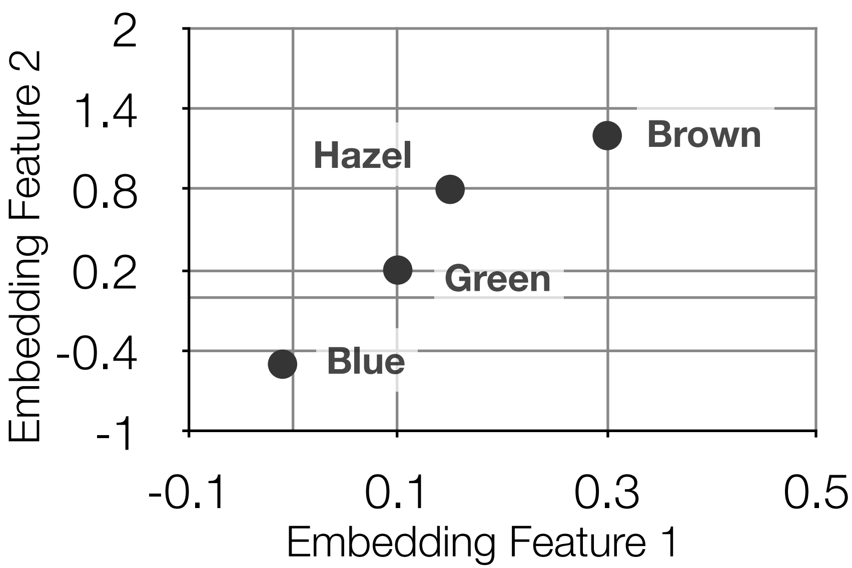
| | | | |
|---|---|---|---|
| 0.1 | 0.3 | -0.01 | 0.15 |
| 0.2 | 1.2 | -0.5 | 0.8 |

Num Categories

$\cdot$

**Eye Color**

$$\begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix} \begin{array}{l} \text{Green} \rightarrow 0 \\ \text{Brown} \rightarrow 1 \\ \text{Blue} \rightarrow 2 \\ \text{Hazel} \rightarrow 3 \end{array}$$



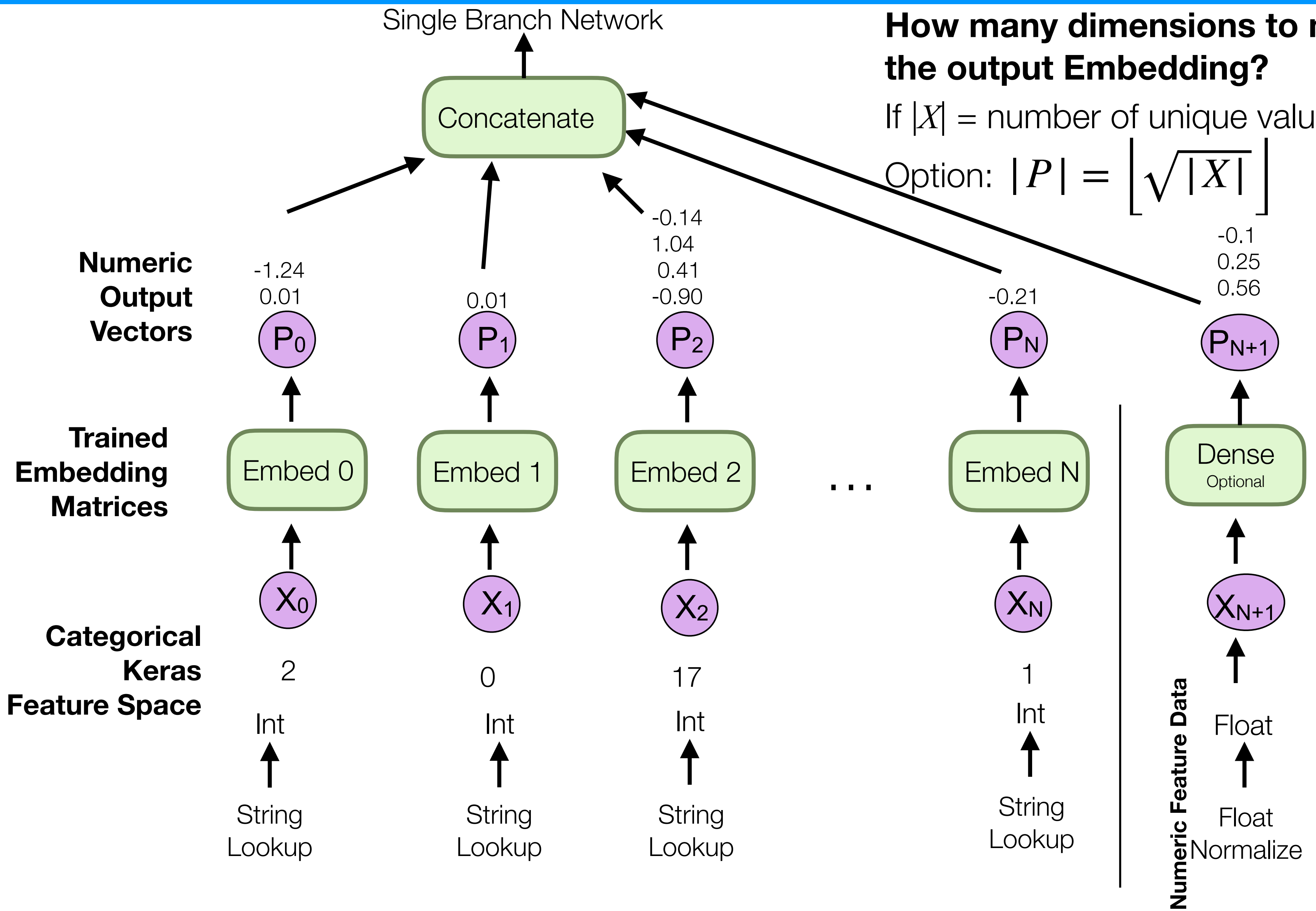

**Computationally**: there is no need to one hot encode eye color, we can just use the integer to index into column of **embedding matrix**

# Using Embeddings in Keras Review

**How many dimensions to make the output Embedding?**

If $|X|$ = number of unique values

Option: $|P| = \left\lfloor \sqrt{|X|} \right\rfloor$

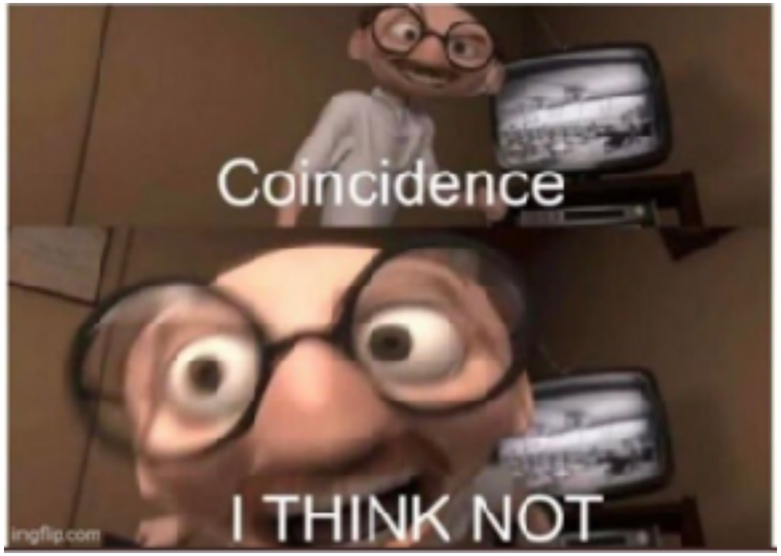


Adding Embedding Branches

`10a. Keras Wide and Deep as TFData.ipynb`

# Wide and Deep Networks

When $p < 0.05$



# Wide and Deep

## Wide & Deep Learning for Recommender Systems

Heng-Tze Cheng, Levent Koc, Jeremiah Harmsen, Tal Shaked, Tushar Chandra, Hrishi Aradhye, Glen Anderson, Greg Corrado, Wei Chai, Mustafa Ispir, Rohan Anil, Zakaria Haque, Lichan Hong, Vihan Jain, Xiaobing Liu, Hemal Shah

Google Inc.*

**ABSTRACT**

Generalized linear models with nonlinear feature transfor-

have never or rarely occurred in the past. Recommendations based on memorization are usually more topical and

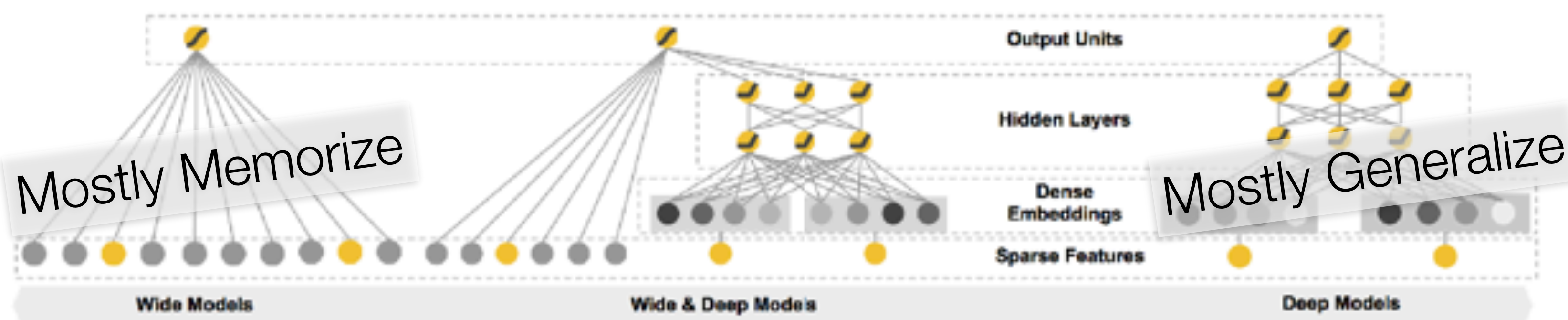
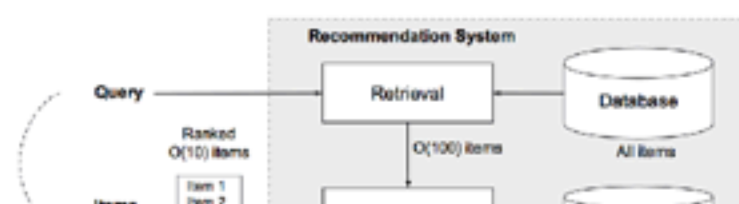



**Figure 1: The spectrum of Wide & Deep models.**

linear model with feature transformations for generic recommender systems with sparse inputs.

- The implementation and evaluation of the Wide & Deep recommender system productionized on Google



# Why wide and deep?

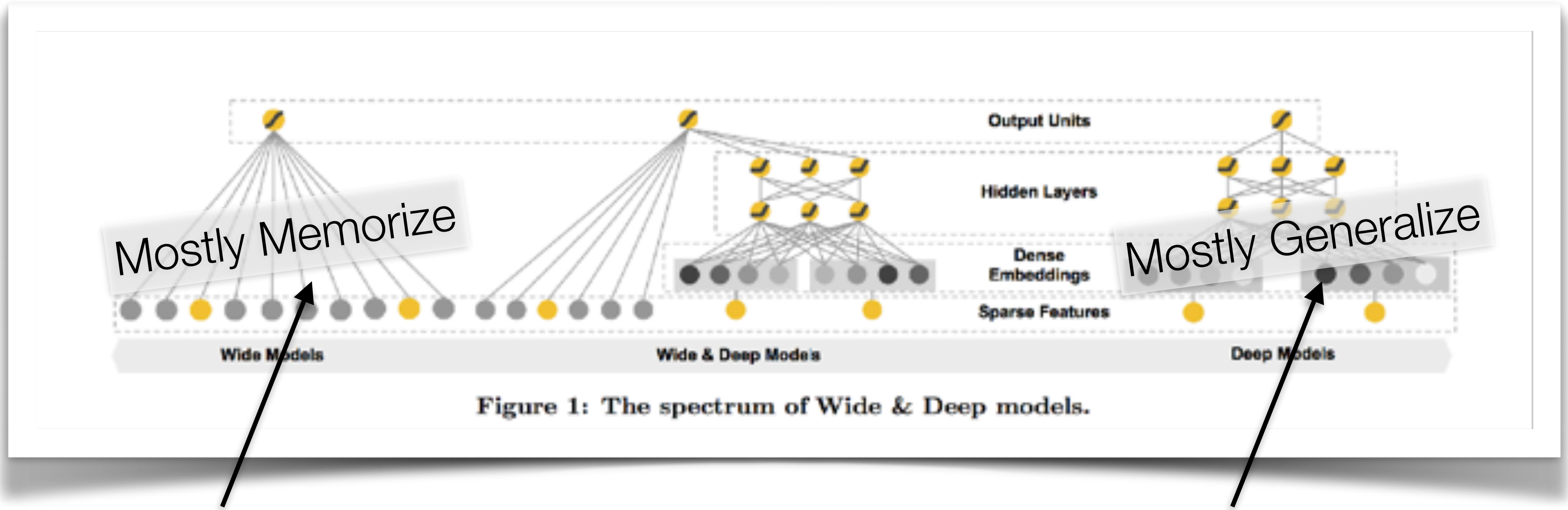


Figure 1: The spectrum of Wide & Deep models.

**But why memorize?**

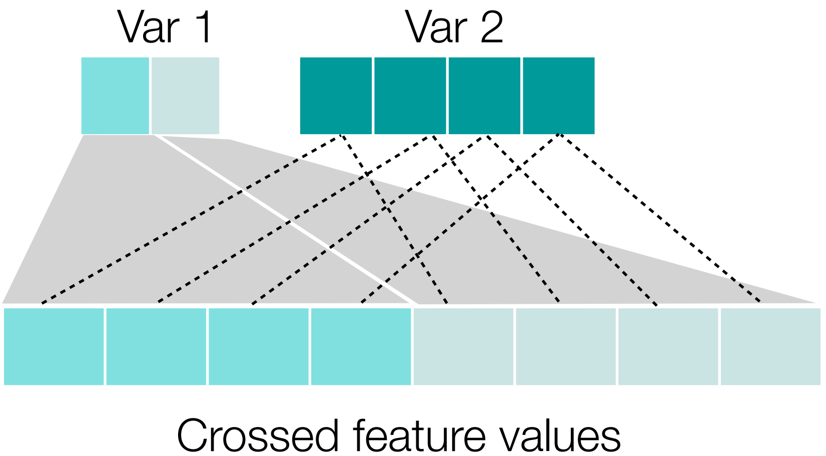
**Obvious!**

- Categorical values have combinations that repeat!
  - so memorizing these values is not necessarily a bad strategy
  - let's make memorizing easy on one network

# Wide networks (Memorize?)

- Wide refers to the expansion of features set
- Crossed feature columns of categorical features

- Movie Rating
  - G
  - PG
  - PG-13
  - R
  - Else
- Movie Genre
  - Action
  - Drama
  - Comedy
  - Horror
  - Else

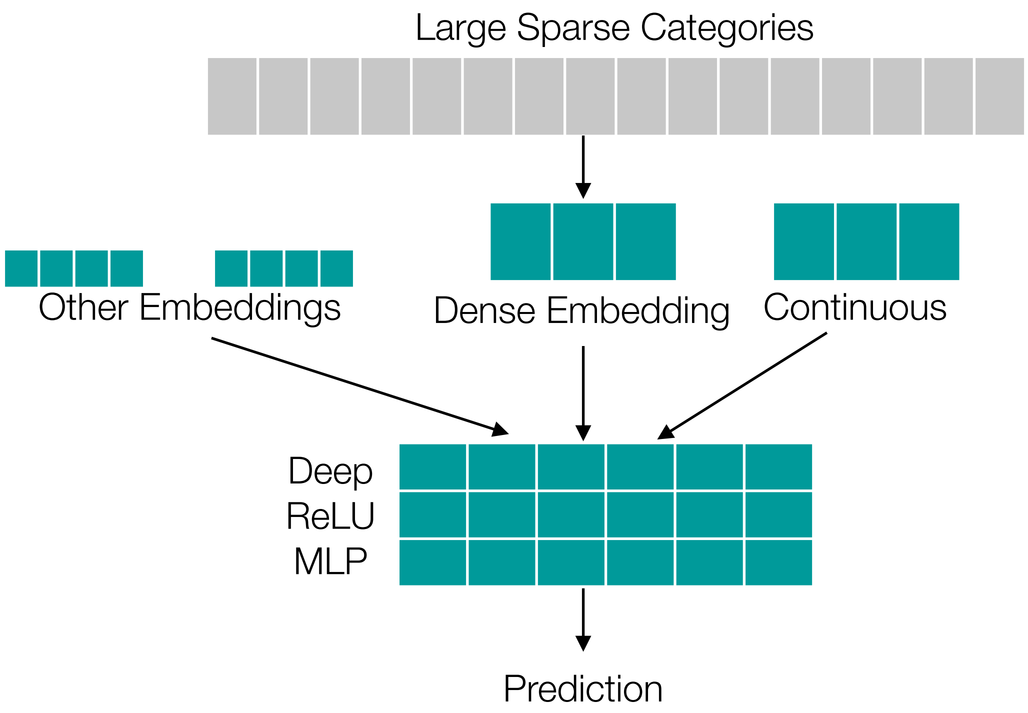



- Crossed feature “Rating-Genre”
  - G-Action, G-Drama, G-Comedy, G-Horror, G-else
  - PG-Action, PG-Drama, PG-Comedy, PG-Horror, G-else
  - and so on … one hot encoded

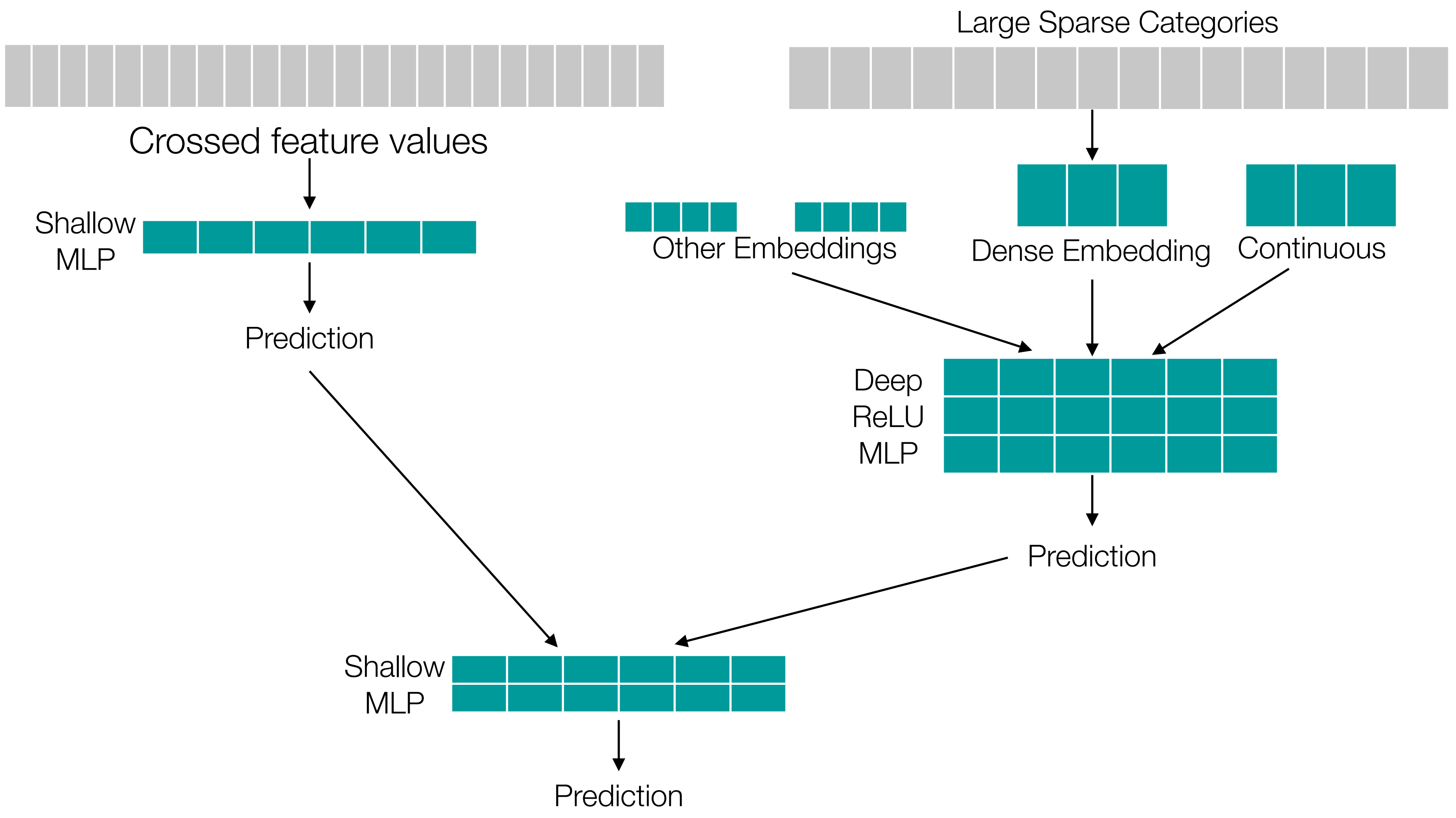
# Deep Features: What we have already done!

- Deep refers to increasingly narrow hidden layers
- Essentially the same as what we already did!

- Movie Actors
  - Armand Assante
  - Meryl Streep
  - Danny Trejo
  - Kevin Bacon
  - Audrey Hepburn
  - …
-



# Combining Memorization and Generalization



# Wide and Deep

**Demo**

Adding Wide Branches

`10a. Keras Wide and Deep as TFData.ipynb`

# Town Hall, Wide and Deep Networks


WHEN VISITING A NEW HOUSE, IT'S GOOD TO CHECK WHETHER THEY HAVE AN ALWAYS-ON DEVICE TRANSMITTING YOUR CONVERSATIONS SOMEWHERE.