



Stroke Prediction

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Motivation and Objective

Stroke is the **second leading cause of death globally**, responsible for **~11%** of total deaths ¹. **Every 40 seconds**, someone in the US has a stroke. **Every 3.5 minutes**, someone dies of stroke.

Stroke has major negative impacts to society and economy. Understanding key factors leading to stroke can potentially help reduce risk factors and improve early diagnosis.

*Our **objective** is to predict a chance of stroke given health data to improve patient care.*

Data

Stroke Prediction Dataset

11 clinical features for predicting stroke events



Source: [kaggle](#)

The data contains 5110 observations with 12 attributes (including patient id and stroke: Yes/No)

Data Pre-Processing

Update Representation

- Fill n/a. Save ~200 BMI nulls with KNN
- One hot encode. Convert categorical data columns into sparse representations.

Balance

- **Stratify.** Ensure sufficient minority class representation across train, validation & test sets.
- **Balance.** Balance train data with SMOTE (Synthetic Minority Over-sampling Technique)

	age	gender	mpg_10	mpg_15	mpg_20	mpg_25	mpg_30	mpg_35	mpg_40	mpg_45	mpg_50	mpg_55	mpg_60	mpg_65	mpg_70	mpg_75	mpg_80	mpg_85	mpg_90	mpg_95	mpg_100	mpg_105	mpg_110	mpg_115	mpg_120	mpg_125	mpg_130	mpg_135	mpg_140	mpg_145	mpg_150	mpg_155	mpg_160	mpg_165	mpg_170	mpg_175	mpg_180	mpg_185	mpg_190	mpg_195	mpg_200	mpg_205	mpg_210	mpg_215	mpg_220	mpg_225	mpg_230	mpg_235	mpg_240	mpg_245	mpg_250	mpg_255	mpg_260	mpg_265	mpg_270	mpg_275	mpg_280	mpg_285	mpg_290	mpg_295	mpg_300	mpg_305	mpg_310	mpg_315	mpg_320	mpg_325	mpg_330	mpg_335	mpg_340	mpg_345	mpg_350	mpg_355	mpg_360	mpg_365	mpg_370	mpg_375	mpg_380	mpg_385	mpg_390	mpg_395	mpg_400	mpg_405	mpg_410	mpg_415	mpg_420	mpg_425	mpg_430	mpg_435	mpg_440	mpg_445	mpg_450	mpg_455	mpg_460	mpg_465	mpg_470	mpg_475	mpg_480	mpg_485	mpg_490	mpg_495	mpg_500	mpg_505	mpg_510	mpg_515	mpg_520	mpg_525	mpg_530	mpg_535	mpg_540	mpg_545	mpg_550	mpg_555	mpg_560	mpg_565	mpg_570	mpg_575	mpg_580	mpg_585	mpg_590	mpg_595	mpg_600	mpg_605	mpg_610	mpg_615	mpg_620	mpg_625	mpg_630	mpg_635	mpg_640	mpg_645	mpg_650	mpg_655	mpg_660	mpg_665	mpg_670	mpg_675	mpg_680	mpg_685	mpg_690	mpg_695	mpg_700	mpg_705	mpg_710	mpg_715	mpg_720	mpg_725	mpg_730	mpg_735	mpg_740	mpg_745	mpg_750	mpg_755	mpg_760	mpg_765	mpg_770	mpg_775	mpg_780	mpg_785	mpg_790	mpg_795	mpg_800	mpg_805	mpg_810	mpg_815	mpg_820	mpg_825	mpg_830	mpg_835	mpg_840	mpg_845	mpg_850	mpg_855	mpg_860	mpg_865	mpg_870	mpg_875	mpg_880	mpg_885	mpg_890	mpg_895	mpg_900	mpg_905	mpg_910	mpg_915	mpg_920	mpg_925	mpg_930	mpg_935	mpg_940	mpg_945	mpg_950	mpg_955	mpg_960	mpg_965	mpg_970	mpg_975	mpg_980	mpg_985	mpg_990	mpg_995	mpg_1000	mpg_1005	mpg_1010	mpg_1015	mpg_1020	mpg_1025	mpg_1030	mpg_1035	mpg_1040	mpg_1045	mpg_1050	mpg_1055	mpg_1060	mpg_1065	mpg_1070	mpg_1075	mpg_1080	mpg_1085	mpg_1090	mpg_1095	mpg_1100	mpg_1105	mpg_1110	mpg_1115	mpg_1120	mpg_1125	mpg_1130	mpg_1135	mpg_1140	mpg_1145	mpg_1150	mpg_1155	mpg_1160	mpg_1165	mpg_1170	mpg_1175	mpg_1180	mpg_1185	mpg_1190	mpg_1195	mpg_1200	mpg_1205	mpg_1210	mpg_1215	mpg_1220	mpg_1225	mpg_1230	mpg_1235	mpg_1240	mpg_1245	mpg_1250	mpg_1255	mpg_1260	mpg_1265	mpg_1270	mpg_1275	mpg_1280	mpg_1285	mpg_1290	mpg_1295	mpg_1300	mpg_1305	mpg_1310	mpg_1315	mpg_1320	mpg_1325	mpg_1330	mpg_1335	mpg_1340	mpg_1345	mpg_1350	mpg_1355	mpg_1360	mpg_1365	mpg_1370	mpg_1375	mpg_1380	mpg_1385	mpg_1390	mpg_1395	mpg_1400	mpg_1405	mpg_1410	mpg_1415	mpg_1420	mpg_1425	mpg_1430	mpg_1435	mpg_1440	mpg_1445	mpg_1450	mpg_1455	mpg_1460	mpg_1465	mpg_1470	mpg_1475	mpg_1480	mpg_1485	mpg_1490	mpg_1495	mpg_1500	mpg_1505	mpg_1510	mpg_1515	mpg_1520	mpg_1525	mpg_1530	mpg_1535	mpg_1540	mpg_1545	mpg_1550	mpg_1555	mpg_1560	mpg_1565	mpg_1570	mpg_1575	mpg_1580	mpg_1585	mpg_1590	mpg_1595	mpg_1600	mpg_1605	mpg_1610	mpg_1615	mpg_1620	mpg_1625	mpg_1630	mpg_1635	mpg_1640	mpg_1645	mpg_1650	mpg_1655	mpg_1660	mpg_1665	mpg_1670	mpg_1675	mpg_1680	mpg_1685	mpg_1690	mpg_1695	mpg_1700	mpg_1705	mpg_1710	mpg_1715	mpg_1720	mpg_1725	mpg_1730	mpg_1735	mpg_1740	mpg_1745	mpg_1750	mpg_1755	mpg_1760	mpg_1765	mpg_1770	mpg_1775	mpg_1780	mpg_1785	mpg_1790	mpg_1795	mpg_1800	mpg_1805	mpg_1810	mpg_1815	mpg_1820	mpg_1825	mpg_1830	mpg_1835	mpg_1840	mpg_1845	mpg_1850	mpg_1855	mpg_1860	mpg_1865	mpg_1870	mpg_1875	mpg_1880	mpg_1885	mpg_1890	mpg_1895	mpg_1900	mpg_1905	mpg_1910	mpg_1915	mpg_1920	mpg_1925	mpg_1930	mpg_1935	mpg_1940	mpg_1945	mpg_1950	mpg_1955	mpg_1960	mpg_1965	mpg_1970	mpg_1975	mpg_1980	mpg_1985	mpg_1990	mpg_1995	mpg_2000	mpg_2005	mpg_2010	mpg_2015	mpg_2020	mpg_2025	mpg_2030	mpg_2035	mpg_2040	mpg_2045	mpg_2050	mpg_2055	mpg_2060	mpg_2065	mpg_2070	mpg_2075	mpg_2080	mpg_2085	mpg_2090	mpg_2095	mpg_2100	mpg_2105	mpg_2110	mpg_2115	mpg_2120	mpg_2125	mpg_2130	mpg_2135	mpg_2140	mpg_2145	mpg_2150	mpg_2155	mpg_2160	mpg_2165	mpg_2170	mpg_2175	mpg_2180	mpg_2185	mpg_2190	mpg_2195	mpg_2200	mpg_2205	mpg_2210	mpg_2215	mpg_2220	mpg_2225	mpg_2230	mpg_2235	mpg_2240	mpg_2245	mpg_2250	mpg_2255	mpg_2260	mpg_2265	mpg_2270	mpg_2275	mpg_2280	mpg_2285	mpg_2290	mpg_2295	mpg_2300	mpg_2305	mpg_2310	mpg_2315	mpg_2320	mpg_2325	mpg_2330	mpg_2335	mpg_2340	mpg_2345	mpg_2350	mpg_2355	mpg_2360	mpg_2365	mpg_2370	mpg_2375	mpg_2380	mpg_2385	mpg_2390	mpg_2395	mpg_2400	mpg_2405	mpg_2410	mpg_2415	mpg_2420	mpg_2425	mpg_2430	mpg_2435	mpg_2440	mpg_2445	mpg_2450	mpg_2455	mpg_2460	mpg_2465	mpg_2470	mpg_2475	mpg_2480	mpg_2485	mpg_2490	mpg_2495	mpg_2500	mpg_2505	mpg_2510	mpg_2515	mpg_2520	mpg_2525	mpg_2530	mpg_2535	mpg_2540	mpg_2545	mpg_2550	mpg_2555	mpg_2560	mpg_2565	mpg_2570	mpg_2575	mpg_2580	mpg_2585	mpg_2590	mpg_2595	mpg_2600	mpg_2605	mpg_2610	mpg_2615	mpg_2620	mpg_2625	mpg_2630	mpg_2635	mpg_2640	mpg_2645	mpg_2650	mpg_2655	mpg_2660	mpg_2665	mpg_2670	mpg_2675	mpg_2680	mpg_2685	mpg_2690	mpg_2695	mpg_2700	mpg_2705	mpg_2710	mpg_2715	mpg_2720	mpg_2725	mpg_2730	mpg_2735	mpg_2740	mpg_2745	mpg_2750	mpg_2755	mpg_2760	mpg_2765	mpg_2770	mpg_2775	mpg_2780	mpg_2785	mpg_2790	mpg_2795	mpg_2800	mpg_2805	mpg_2810	mpg_2815	mpg_2820	mpg_2825	mpg_2830	mpg_2835	mpg_2840	mpg_2845	mpg_2850	mpg_2855	mpg_2860	mpg_2865	mpg_2870	mpg_2875	mpg_2880	mpg_2885	mpg_2890	mpg_2895	mpg_2900	mpg_2905	mpg_2910	mpg_2915	mpg_2920	mpg_2925	mpg_2930	mpg_2935	mpg_2940	mpg_2945	mpg_2950	mpg_2955	mpg_2960	mpg_2965	mpg_2970	mpg_2975	mpg_2980	mpg_2985	mpg_2990	mpg_2995	mpg_3000	mpg_3005	mpg_3010	mpg_3015	mpg_3020	mpg_3025	mpg_3030	mpg_3035	mpg_3040	mpg_3045	mpg_3050	mpg_3055	mpg_3060	mpg_3065	mpg_3070	mpg_3075	mpg_3080	mpg_3085	mpg_3090	mpg_3095	mpg_3100	mpg_3105	mpg_3110	mpg_3115	mpg_3120	mpg_3125	mpg_3130	mpg_3135	mpg_3140	mpg_3145	mpg_3150	mpg_3155	mpg_3160	mpg_3165	mpg_3170	mpg_3175	mpg_3180	mpg_3185	mpg_3190	mpg_3195	mpg_3200	mpg_3205	mpg_3210	mpg_3215	mpg_3220	mpg_3225	mpg_3230	mpg_3235	mpg_3240	mpg_3245	mpg_3250	mpg_3255	mpg_3260	mpg_3265	mpg_3270	mpg_3275	mpg_3280	mpg_3285	mpg_3290	mpg_3295	mpg_3300	mpg_3305	mpg_3310	mpg_3315	mpg_3320	mpg_3325	mpg_3330	mpg_3335	mpg_3340	mpg_3345	mpg_3350	mpg_3355	mpg_3360	mpg_3365	mpg_3370	mpg_3375	mpg_3380	mpg_3385	mpg_3390	mpg_3395	mpg_3400	mpg_3405	mpg_3410	mpg_3415	mpg_3420	mpg_3425	mpg_3430	mpg_3435	mpg_3440	mpg_3445	mpg_3450	mpg_3455	mpg_3460	mpg_3465	mpg_3470	mpg_3475	mpg_3480	mpg_3485	mpg_3490	mpg_3495	mpg_3500	mpg_3505	mpg_3510	mpg_3515	mpg_3520	mpg_3525	mpg_3530	mpg_3535	mpg_3540	mpg_3545	mpg_3550	mpg_3555	mpg_3560	mpg_3565	mpg_3570	mpg_3575	mpg_3580	mpg_3585	mpg_3590	mpg_3595	mpg_3600	mpg_3605	mpg_3610	mpg_3615	mpg_3620	mpg_3625	mpg_3630	mpg_3635	mpg_3640	mpg_3645	mpg_3650	mpg_3655	mpg_3660	mpg_3665	mpg_3670	mpg_3675	mpg_3680	mpg_3685	mpg_3690	mpg_3695	mpg_3700	mpg_3705	mpg_3710	mpg_3715	mpg_3720	mpg_3725	mpg_3730	mpg_3735	mpg_3740	mpg_3745	mpg_3750	mpg_3755	mpg_3760	mpg_3765	mpg_3770	mpg_3775	mpg_3780	mpg_3785	mpg_3790	mpg_3795	mpg_3800	mpg_3805	mpg_3810	mpg_3815	mpg_3820	mpg_3825	mpg_3830	mpg_3835	mpg_3840	mpg_3845	mpg_3850	mpg_3855	mpg_3860	mpg_3865	mpg_3870	mpg_3875	mpg_3880	mpg_3885	mpg_3890	mpg_3895	mpg_3900	mpg_3905	mpg_3910	mpg_3915	mpg_3920	mpg_3925	mpg_3930	mpg_3935	mpg_3940	mpg_3945	mpg_3950	mpg_3955	mpg_3960	mpg_3965	mpg_3970	mpg_3975	mpg_3980	mpg_3985	mpg_3990	mpg_3995	mpg_4000	mpg_4005	mpg_4010	mpg_4015	mpg_4020	mpg_4025	mpg_4030	mpg_4035	mpg_4040	mpg_4045	mpg_4050	mpg_4055	mpg_4060	mpg_4065	mpg_4070	mpg_4075	mpg_4080	mpg_4085	mpg_4090	mpg_4095	mpg_4100	mpg_4105	mpg_4110	mpg_4115	mpg_4120	mpg_4125	mpg_4130	mpg_4135	mpg_4140	mpg_4145	mpg_4150	mpg_4155	mpg_4160	mpg_4165	mpg_4170	mpg_4175	mpg_4180	mpg_4185	mpg_4190	mpg_4195	mpg_4200	mpg_4205	mpg_4210	mpg_4215	mpg_4220	mpg_4225	mpg_4230	mpg_4235	mpg_4240	mpg_4245	mpg_4250	mpg_4255	mpg_4260	mpg_4265	mpg_4270	mpg_4275	mpg_4280	mpg_4285	mpg_4290	mpg_4295	mpg_4300	mpg_4305	mpg_4310	mpg_4315	mpg_4320	mpg_4325	mpg_4330	mpg_4335	mpg_4340	mpg_4345	mpg_4350	mpg_4355	mpg_4360	mpg_4365	mpg_4370	mpg_4375	mpg_4380	mpg_4385	mpg_4390	mpg_4395	mpg_4400	mpg_4405	mpg_4410	mpg_4415	mpg_4420	mpg_4425	mpg_4430	mpg_4435	mpg_4440	mpg_4445	mpg_4450	mpg_4455	mpg_4460	mpg_4465	mpg_4470	mpg_4475	mpg_4480	mpg_4485	mpg_4490	mpg_4495	mpg_4500	mpg_4505	mpg_4510	mpg_4515	mpg_4520	mpg_4525	mpg_4530	mpg_4535	mpg_4540	mpg_4545	mpg_4550	mpg_4555	mpg_4560	mpg_4565	mpg_4570	mpg_4575	mpg_4580	mpg_4585	mpg_4590	mpg_4595	mpg_4600	mpg_4605	mpg_4610	mpg_4615	mpg_4620	mpg_4625	mpg_4630	mpg_4635	mpg_4640	mpg_4645	mpg_4650	mpg_4655	mpg_4660	mpg_4665	mpg_4670	mpg_4675	mpg_4680	mpg_4685	mpg_4690	mpg_4695	mpg_4700	mpg_4705	mpg_4710	mpg_4715	mpg_4720	mpg_4725	mpg_4730	mpg_4735	mpg_4740	mpg_4745	mpg_4750	mpg_4755	mpg_4760	mpg_4765	mpg_4770	mpg_4775	mpg_4780	mpg_4785	mpg_4790	mpg_4795	mpg_4800	mpg_4805	mpg_4810	mpg_4815	mpg_4820	mpg_4825	mpg_4830	mpg_4835	mpg_4840	mpg_4845	mpg_4850	mpg_4855	mpg_4860	mpg_4865	mpg_4870	mpg_4875	mpg_4880	mpg_4885	mpg_4890	mpg_4895	mpg_4900	mpg_4905	mpg_4910	mpg_4915	mpg_4920	mpg_4925	mpg_4930	mpg_4935	mpg_4940	mpg_4945	mpg_4950	mpg_4955	mpg_4960	mpg_4965	mpg_4970	mpg_4975	mpg_4980
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Modeling

Training and tuning of supervised ML options:

- Binary Logistic Regression
- Random Forest
- Deep Learning - Keras Sequential
- Deep Learning with Hyper Parameters (Optuna)



Modeling

Challenges Opportunities

Baseline (Logistic Regression)

Poor recall

Affordable, explainable, quick

Random Forest

Poor precision

Higher recall

Keras Sequential

Not explainable

Accuracy improvement

Keras Sequential w/ Optuna

Complex

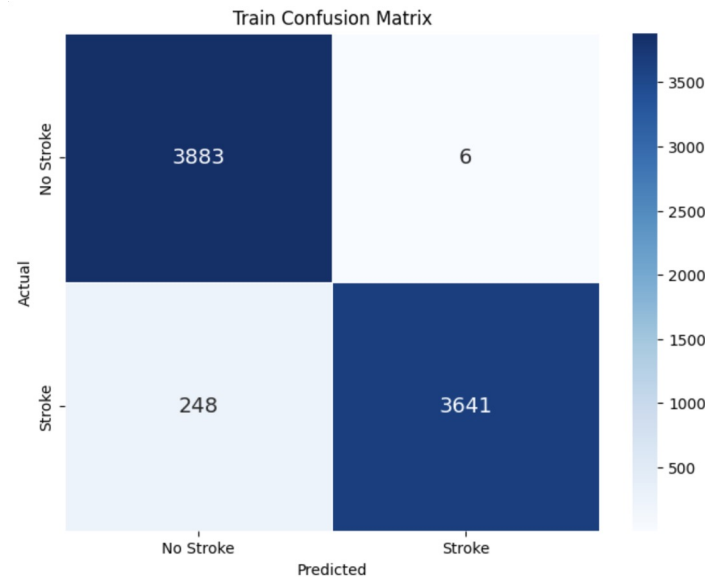
HP optimization

Binary Logistic Regression

The model is biased towards
missing actual stroke prediction

[Low False Positives at the cost of High False Negatives]

Validation Dataset	
Accuracy	0.95
Precision	0.73
Recall	0.53
F-1 score	0.55





Modeling

Challenges Opportunities

Baseline (Logistic Regression)

Poor recall



Affordable, explainable, quick

Random Forest

Poor precision



Higher recall

Keras Sequential

Not explainable



Accuracy improvement

Keras Sequential w/ Optuna

Complex



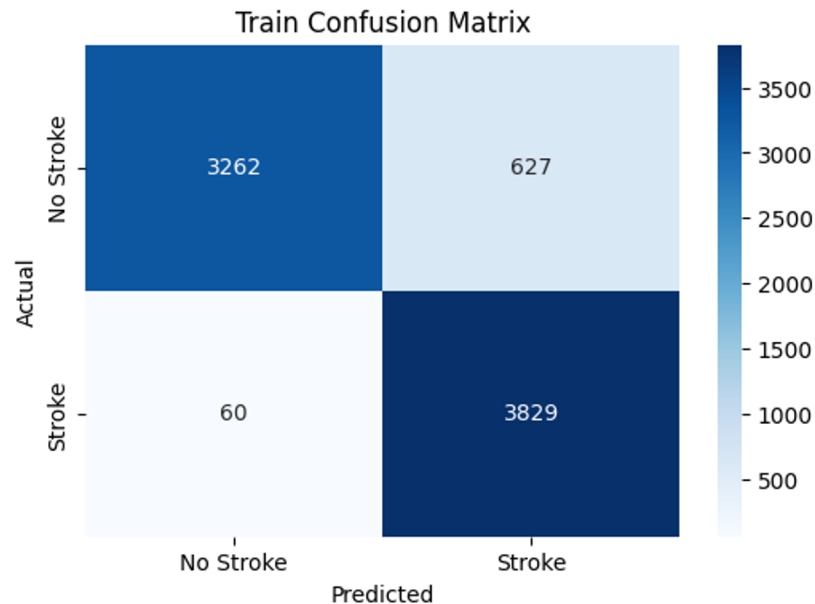
HP optimization

Random Forest

The model improved in predicting actual stroke prediction at the cost of predicting of no stroke

[Lower False Negatives at the cost of Higher False Positives]

Validation Dataset	
Accuracy	0.80
Precision	0.56
Recall	0.71
F-1 score	0.56





Modeling

Challenges Opportunities

Baseline (Logistic Regression)

Poor recall

Affordable, explainable, quick

Random Forest

Poor precision

Higher recall

Keras Sequential

Not explainable

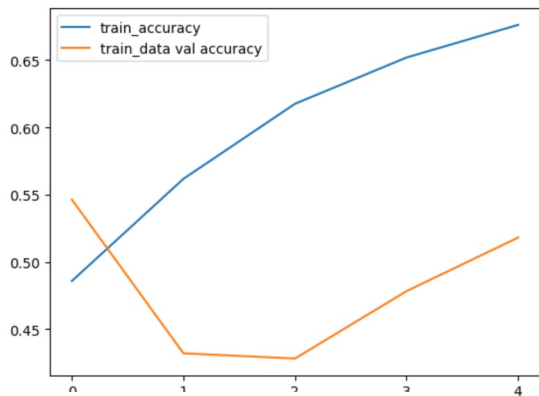
Accuracy improvement

Keras Sequential w/ Optuna

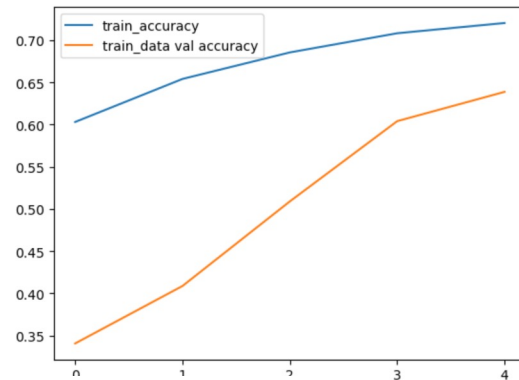
Complex

HP optimization

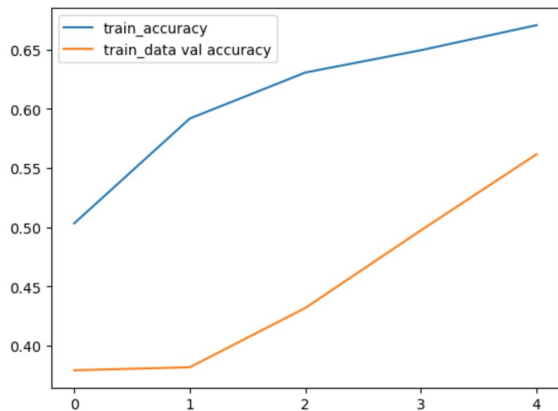
Deep Learning (improved accuracy experimentally)



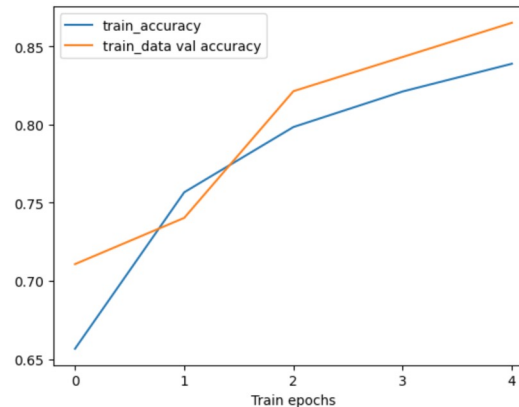
Hidden layers = None, actv = tanh, opt = SGD,
learning_rate=0.01, num_epochs=5



Hidden layers = 16 actv = relu, opt = SGD,
learning_rate=0.01, num_epochs=5



Hidden layers = 8, actv = relu, opt = SGD,
learning_rate=0.01, num_epochs=5

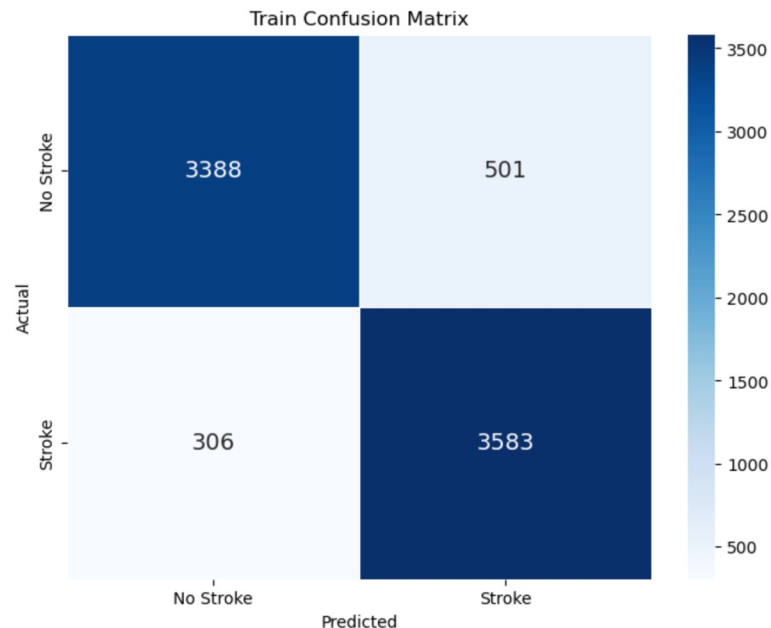


Hidden layers = 16, actv = tanh, opt = Adam,
learning_rate=0.01, num_epochs=5

Keras Sequential

Deep Learning improved the key metrics, over RF, on the training and validation datasets (especially *accuracy*, 0.90 on the training data)

Validation Dataset	
Accuracy	0.86
Precision	0.59
Recall	0.76
F-1 score	0.62





Modeling

Challenges Opportunities

Baseline (Logistic Regression)

Poor recall



Affordable, explainable, quick

Random Forest

Poor precision



Higher recall

Keras Sequential

Not explainable



Accuracy improvement

Keras Sequential (Optimized)

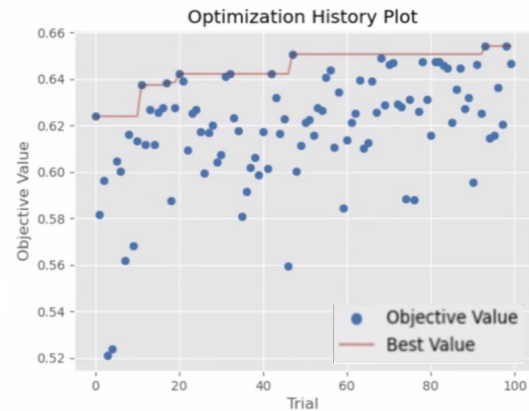
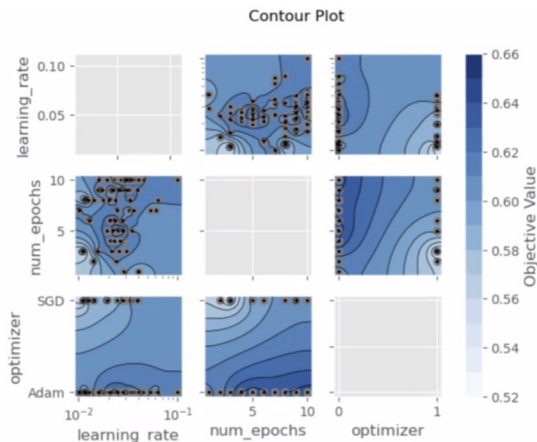
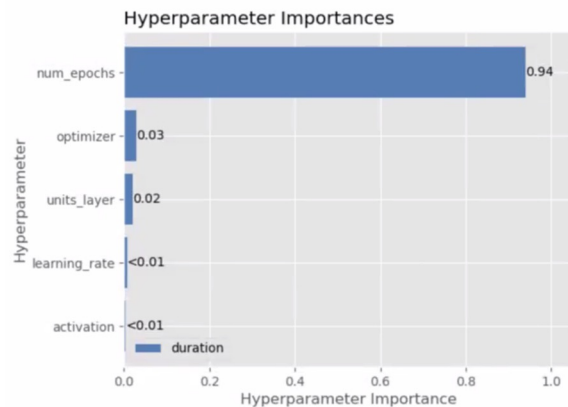
Complex



HP optimization

What is ptuna

Navigating and visualizing the Hyperparameter space



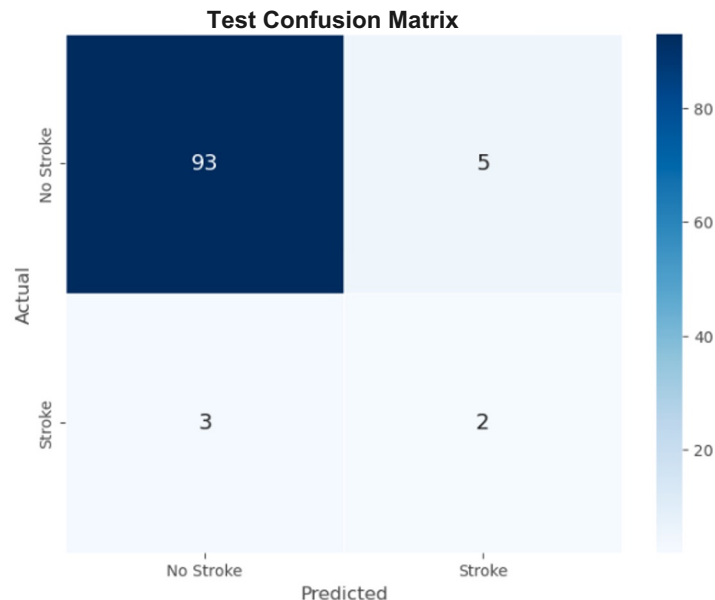
Keras Sequential (Optimized)

Improved model's accuracy, precision, recall and f-1 score, compared to other models.

Test Dataset	
Accuracy	0.92
Precision	0.63
Recall	0.67
F-1 score	0.65

Optuna Best Parameters

Hidden layers = 97, **actv** = tanh, **opt** = Adam,
learning_rate=0.025342599583490992, **num_epochs**=5






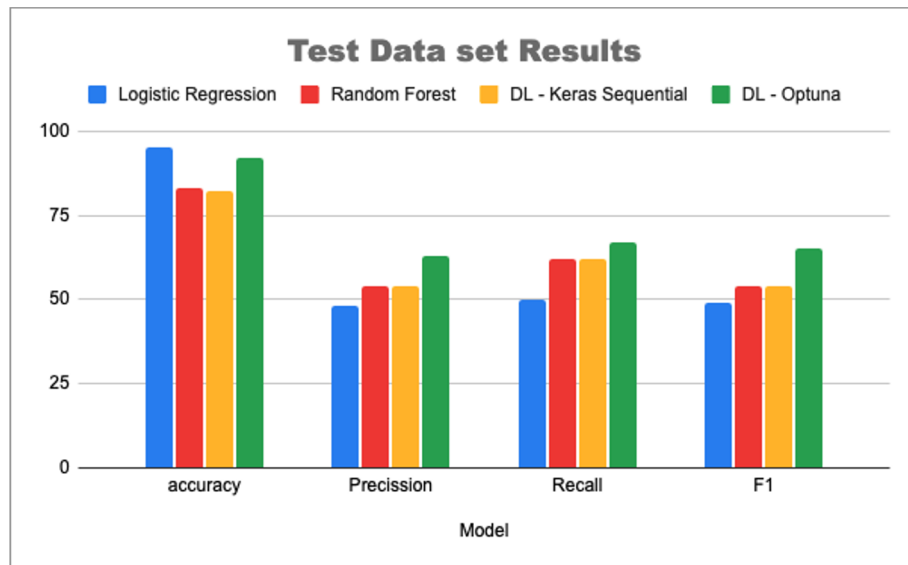
Conclusion

Models predicted stroke with at least over 80% accuracy.

Similar performance of **Random Forest** and **Keras Sequential** models across all metrics.

Logistic Regression model predicted stroke with 95% accuracy, at cost of all other metrics.

Keras Sequential model +  demonstrated the best performance.

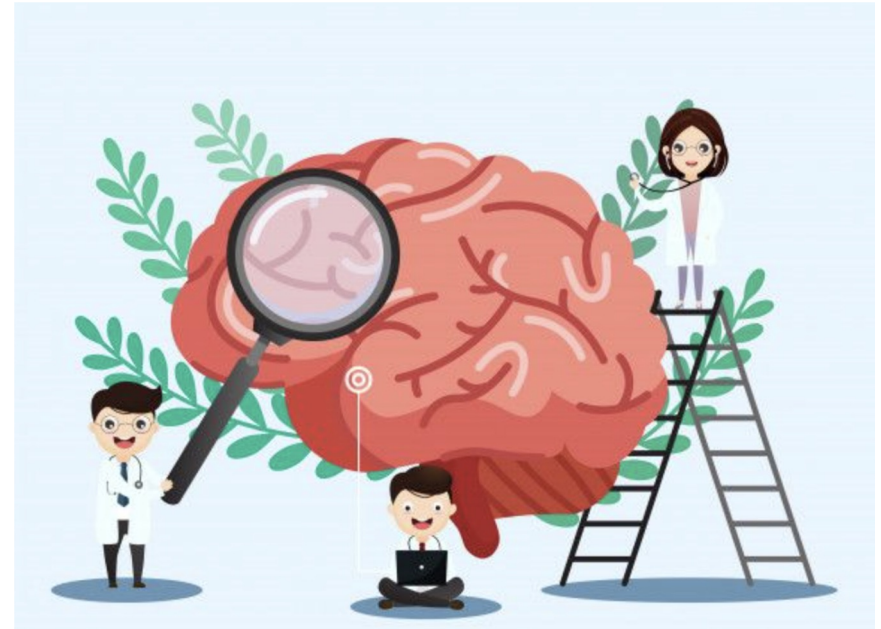


Conclusion

Average cost of hospitalization of patients with stroke per year, per patient in the United States is nearly **\$60,000**.

Preventative measures include:

- Keep Average Glucose Level in normal range
- Be active
- Eat healthy
- Keep BMI in normal range





Thank you!